DOE/NASA/0002-79/1
NASA CR-159632

MOD-2 FAILURE MODE AND EFFECTS ANALYSIS

Robert Lynette and Robert Poore
Boeing Engineering and Construction Co.

July 1979

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lewis Research Center
Under Contract DEN 3-2

for
U.S. DEPARTMENT OF ENERGY
Energy Technology
Distributed Solar Technology Division

NOTICE

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Distributed Solar Technology Division
Washington, D.C. 20545
Under Interagency Agreement DE-AI01-79ET20485

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INTRODUCTION

The failure mode and effects analyses (FMEA) were performed during preliminary and detail design in order to identify all MOD-2 failure modes and to ensure that the resultant effects are: (1) acceptable from a safety standpoint and (2) fail safe or, if not fail safe, represent least cost solutions (i.e., result in the lowest cost of electricity). R

The FMEA's were completed by the cognizant designers and reviewed by system engineers and a reliability specialist. In general, fail safe design is employed wherever cost effective and a safe life design is employed for single thread structural items such as the rotor. The failure severity code used in the analysis is described in Table 1.

Completion of the FMEA's by the designers as an in-line part of the design process resulted in numerous design changes to either prevent serious failure modes or reduce their impact. The FMEA's contained herein reflect the detail design configuration. All major changes incorporated subsequent to the DDR R
will be evaluated relative to personnel safety and cost of electricity. R

Whenever applicable, failure frequency data has been included in the analyses. This data was used to quantify the probability of occurrences and hence the impact on the cost of electricity.

SUMMARY OF RESULTS

Over 860 failure modes were analyzed and numerous corrective actions were R
implemented to preclude costly failures. Special attention was directed at all potentially catastrophic failure modes; the results of this effort are summarized in Table 2.

Wherever practical, redundancy is used to preclude catastrophic failures. Safe life design is employed for items whose failure could cause serious damage, but could not be made redundant (e.g., blade fatigue cracks). The ability to control each rotor pitch control surface independent of the other precludes several potentially serious failure modes such as control linkage binding or bearing failures (the MOD-2 design provide for an orderly shutdown with just one control tip operative). The most probable, potentially catastrophic failure mode is the rapid progression of a fatigue crack in the blade. The MOD-2 design has incorporated a crack detection system which will R
cause an orderly WTS shutdown prior to suffering significant rotor damage.

The detailed FMEA sheets are contained in Appendix A, and relevant electrical/hydraulic schematics are included in Appendix B. Appendix C contains the results of a staff analysis of WTS emergency shutdowns. Appendix D contains an FMEA of the cable runs and both slip rings.

Summary of Revisions (Initial Analysis at PDR; this revision at DDR)

The purposes for this revision are: (1) to update the FMEA based on changes to the MOD-2 configuration that have occurred since the preliminary design review (PDR), (2) to add a new section that contains an analysis of the possible effect of electrical failures that have a potential for causing numerous secondary failures (e.g., a wire shorts and causes other wires in the same bundle to short to ground or to other wires) and (3) to add a new section that contains an analysis of the possible effects of contact-to-contact shorts of adjacent slip rings in the two slip ring assemblies. The latter two sections could not be completed at the PDR since cable runs and slip ring assignments had not yet been established.

The major configuration changes covered by this revision are:

1. Addition of ice detection and crack detection systems.
2. Changes in the gearbox lubrication system to take advantage of the pump redundancy.
3. Deletion of the delta pressure sensors in the yaw hydraulics system.
4. Changes in the yaw drag brake caliper to make the drag proportional to hydraulic pressure rather than depending upon a mechanical spring.

The following pages have been added:

iii - new page

Pages 273 through 295 Appendix D (new section)

The following pages have been revised:

i, ii, v (was page iv)

1, 2, 29, 46, 69.1, 72, 82, 98, 129, 148, 169, 262, 263, 266a, 267 & 268

TABLE 1, SAFETY AND FAILURE SEVERITY CATEGORY GUIDE

HAZARD CATEGORY	IMPACT						
	FUNCTION		REPAIR COST		TIME TO REPAIR		PERSONNEL INJURY
Minimal	None (1)	and	Under $1000	and	Under 2 Days	and	None
Marginal	None Critical (2)	and	Under $1,000	and	Under 2 Days	and	First Aid
Critical	Loss of Function (3)	or	Up to $10,000	or	Up to 10 Days	or	Hospital
Catastrophic	Loss of System (4)	or	Over $10,000	or	Over 10 Days	or	Fatal or Permanent Disable

Impact values include the dollar and human cost of an unplanned event (a realized hazard).

Hospitalization is a severity category; includes wound stitches, extensive burn treatment, broken bone setting and equivalents.

Permanent Disablement includes loss of limb, sight or other majority body function.

*With the exception of flying objects emanating from the WTS, personnel injury can only occur during period of preventative and corrective maintenance.

(1) Minor items that can be repaired with convenient.

(2) No loss of generating capability, but repair must be accomplished within 2 weeks to avoid shutdown.

(3) Causes WTS shutdown.

(4) Destruction of major element such as rotor or gear box.

TABLE 1, SAFETY AND FAILURE CATEGORY GUIDE

Table 2, Summary of Major Failures and Effects – MOD-2-107

Failure	Effect	Corrective action
Structural failures		
Rotor		
• Ice forms and is thrown off	Could injure public – remote possibility	Ice detection system added
• Blade fatigue cracks • Spar buckling • Fatigue crack at control tip spindle end thread or at tip-blade interface • Inboard joint-rotor to hub bolt or flange weld failure • Broken teeter trunnion or flange cracks • Buckling inboard sections or hub compression skins	Loss of part of rotor and possible secondary damage if allowed to progress	Crack detection system shuts down WTS prior to incurring serious damage Safe life design Fatigue tests Inspection schedule Mid-blade assembly buckling test
Drive		
• Broken low speed shaft • Broken quill shaft bulkhead joint	Loss of load	Emergency shutdown effected prior to reaching damaging overspeed Safe life design
• Teeter shaft or flange cracks	Possible extensive rotor damage	Strain gage correlation Safe life design
Tower		
• Failure of structure or foundation	Extensive damage	Safe life design
Control system failures		
• Signal to one tip incorrectly drives control surface to zero pitch • Control linkage to one tip jams	Emergency shutdown triggered by differential of tip position signals	None required, analysis verifies that one tip operative can safely stop rotor
• Control system signal to both pitch actuators incorrectly drives control surfaces to zero pitch	Emergency shutdown triggered by generator output power sensor	None required – shutdown occurs prior to damaging overspeed
• Power output sensor fails, calling for power increase when system is already at full power output	Damaging overspeed possible if load drops off prior to initiating shutdown	System changed to command shutdown prior to load dropping off Also, backup power sensor signal sent to controller
Electrical power failures		
• Synchronizer provides signal to close bus tie contactor too soon or too late (WTS not proper phase relationship or voltage to mate with bus)	High current transient causing high torque load on the generator that could cause mechanical damage to generator or drive train	Synchronizer is fully redundant and fail safe
• Loss of commercial power while WTS is at rated power	Rotor speed increases	None required – shutdown occurs prior to damaging overspeed

APPENDIX A

MOD-2 FAILURE MODES AND EFFECTS ANALYSIS - DETAILED WORKSHEETS

TABLE OF CONTENTS

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 1
ROTOR	SHELL STRUCTURE	FMEA NO 4.1.1

FUNCTION OF COMPONENT

CARRY SHEAR AND BENDING LOADS TO BLADE ATTACHMENT AT HUB

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1. FATIGUE CRACK IN TENSION SKIN WELD. CAUSES LOSS OF PORTION OF BLADE IF CRACK IS UNDECTECTED.	ALL
MAY CAUSE CHANGE IN BLADE STIFFNESS AND IN TURN INCREASE VIBRATION.	
2. ICE ACCUMULATIONS COULD SEPARATE FROM ROTOR AND STRIKE PEOPLE OR ANIMALS IF DETECTION SYSTEM FAILS	G

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	Cannot be accurately calculated					X	X*

FAILURE DETECTION METHODS

1. CRACK DETECTION SYSTEM.
2. ICE DETECTORS ON BLADES.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1 IT IS POSSIBLE TO AVOID THIS FAILURE MODE BY USE OF A CRACK DETECTION SYSTEM. (INCORPORATED INTO SYSTEM)

SAFE LIFE DESIGN OF THIS COMPONENT IS INTENDED TO AVOID THIS FAILURE MODE.

* IF NOT DETECTED

2. ICE DETECTORS ON BOTH BLADES PROVIDE REDUNDANCY. DETECTION CIRCUIT IS FAIL SAFE (I.E , OPEN OR SHORTED WIRE/CONNECTION RESULTS IN WTS SHUTDOWN).

NAME J. NOBLE   DATE 8/15/78

Rev. 10/25/78
3/8/79

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM-UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 2
ROTOR	SPARS	FMEA NO 4.1.2

FUNCTION OF COMPONENT

CARRY SHEAR LOADS TO BLADE ATTACHMENT AT HUB.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 FATIGUE CRACK ACROSS SPAR. CAUSES OVERSTRESSING OF SHELL STRUCTURE	ALL
2 BUCKLING OF SPARS BY HIGH RESIDUAL WELDING STRESSES CAUSES OVERSTRESSING OF SPAR TO SHELL WELDS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 ^{6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	Cannot be accurately calculated					X	X*
2		" " "	"			X	X*

FAILURE DETECTION METHODS

1 Crack Detection System

2 Not directly observable

3 Change in blade stiffness may be detected by an accelerometer as increased vibration

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

THESE FAILURE MODES WOULD NOT IMMEDIATELY AFFECT WTS OPERATION, BUT COULD LEAD TO CATASTROPHIC FAILURE OF THE BLADE SHELL STRUCTURE IN A FAIRLY SHORT TIME.

IT IS POSSIBLE TO AVOID MODE I BY USE OF A CRACK DETECTION SYSTEM. (INCORPORATED).

SAFE LIFE DESIGN OF THIS COMPONENT IS INTENDED TO AVOID THESE FAILURE MODES.

* IF NOT DETECTED

NAME J. NOBLE DATE 8/15/78

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3/8/79

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I - FEATHER

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MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 3
ROTOR ASSY.	INBD JOINT	FMEA NO 4.1.3

FUNCTION OF COMPONENT

ATTACHES ROTOR BLADE TO HUB

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 BOLT FAILURE DUE TO CORROSION, FATIGUE, OR INTERNAL DEFECT - LOSS OF BLADE CAUSES SEVERE ASYMMETRIC LOADING ON TEETER BEARING, DRIVE TRAIN, NACELLE & TOWER.	F, G, H
2. FLANGE WELD FAILURE DUE TO INCLUSION, FATIGUE CORROSION OR OVER-LOAD - LOSS OF BLADE CAUSES SEVERE ASYMMETRIC LOADING ON TEETER BEARING, DRIVE TRAIN, NACELLE & TOWER.	F, G, H

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1		Cannot be accurately calculated				X	X*
2		" "	"	"		X	X*

FAILURE DETECTION METHODS

1 VISUAL INSPECTION (BOLTS MISSING - CRACKS IN WELD)

2 CHANGE IN NATURAL FREQUENCY (OR STIFFNESS) OF ROTOR ASSY.

3 INCREASE IN VIBRATION

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1. INSPECTION OF FLANGE WELD & CONSERVATIVE LOCAL DESIGN
2. USE OF MANY, SMALL DIAMETER HIGH QUALITY BOLTS GIVES REDUNDANT LOAD PATH
3. APPLICATION AND MAINTENANCE OF GOOD CORROSION PROTECTION SYSTEM (INSIDE & OUTSIDE) SHOULD PREVENT ANY FAILURE CAUSED BY CORROSION (ALSO FAY SURFACE SEALANT)
4. LOW FATIGUE ALLOWABLES SHOULD PRECLUDE FAILURE DUE TO MOMENTARY OVERLOAD.
5. SAFE LIFE DESIGN OF THESE COMPONENTS IS INTENDED TO AVOID FATIGUE FAILURES. JOINT FATIGUE TEST TO ESTABLISH FATIGUE ALLOWABLES

* IF NOT DETECTED

NAME Al Falco DATE 8/16/78

OPERATING MODES

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A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D - TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G - OPERATE
H - TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 4
ROTOR	PIVOT SPINDLE	FMEA NO 4.1.4

FUNCTION OF COMPONENT

PROVIDE CONTROL AXIS AND STRUCTURAL RESTRAINT FOR CONTROL TIP.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 FATIGUE CRACK AT INBD. END THREAD. TIP WOULD FALL OFF CAUSING IMBALANCE & SHUTDOWN.	ALL
2 FATIGUE CRACK AT TIP-BLADE INTERFACE. TIP WOULD FALL OFF CAUSING IMBALANCE & SHUTDOWN.	ALL
3 OVERSPEED CAUSES BENDING OF SPINDLE. DISPLACED HINGELINE WOULD CAUSE IMBALANCE & SHUTDOWN.	ALL
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^{6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1		Cannot be	accurately ca	lculated			X
2		" "	"	"			X
3		" "	"	"		X	

FAILURE DETECTION METHODS

1 OBSERVABLE

2 OBSERVABLE

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

SAFE LIFE DESIGN OF THIS COMPONENT IS INTENDED TO AVOID THESE FAILURE MODES.

REDUNDANCY COULD BE ACHIEVED BY AN ADDITIONAL CLAMP OR SIMILAR DEVICE AROUND SPINDLE AND PUT INBOARD OF THE OUTBOARD BEARING.

NAME J. NOBLE DATE 8/15/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
HUB	HUB	PAGE 5 FMEA NO 4.2

FUNCTION OF COMPONENT

ATTACHES ROTOR BLADE TO TEETER BEARING

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 LIGHTNING STRIKE - LOCALIZED PAINT DAMAGE. FAY SEAL PROTECTED BY CONSIDERABLE METAL-METAL CONTACT	ALL
2 HAIL - OVERALL PAINT DAMAGE - MOST SEVERE ON LEADING EDGE	ALL
3 SNIPER - LOCALIZED PAINT DAMAGE	ALL
4 INTERNAL MOISTURE BUILDUP - ACCELERATES CORROSION LARGE AMOUNT COULD FREEZE AND CAUSE UNBALANCE	ALL

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	Frequency is site dependent			X			
2	Frequency is site dependent			X			
3	Frequency is site dependent			X			
4	Frequency is site dependent					X	

FAILURE DETECTION METHODS

1, 2 and 3: VISUAL FOR PAINT DAMAGE & RESULTING CORROSION

4 INTERNAL MOISTURE DETECTION SYSTEM

IF UNBALANCE DUE TO ICE IS LARGE ENOUGH TO CAUSE A PROBLEM IT WILL BE DETECTED BY BEARING VIB DETECTOR AND SHUTDOWN WTS.

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

4 MOISTURE BUILDUP IS MINIMIZED BY PROVIDING VENTS AT OUTBD. END AND ALLOWING CENTRIFUGAL FORCE TO FORCE THE WATER OUT. CORROSION CONTROL SYSTEM WILL MINIMIZE CORROSION.

1,2,3 NORMAL MAINTENANCE PAINTING SHOULD PREVENT ANY MAJOR DAMAGE DUE TO LOCALIZED PAINT REMOVAL.

1,2 WTS INSPECTION FOLLOWING EXTREME WEATHER CONDITIONS.

NAME AL FALCO DATE 8/6/78

OPERATING MODES Rev. 10/25/78

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 6
HUB	HUB	FMEA NO 4.2

FUNCTION OF COMPONENT

ATTACHES ROTOR BLADE TO TEETER BEARING

FAILURE MODES & EFFECTS	APPLICABLE OPERATING-MODES
1 INBD. OF STA. 60: HUB FAILURE FROM FATIGUE CRACK PROPAGATION RESULTING IN SEVERE DEFORMATIONS AND POSSIBLE INTERFERENCE WITH NACELLE OR TOWER	F, G, H
2 OUTBD OF STA 60: HUB FAILURE FROM FATIGUE CRACK PROPAGATION CAUSING LOSS OF BLADE RESULTING IN SEVERE ASYMMETRIC LOADING ON TEETER BEARING, NACELLE, DRIVE TRAIN & TOWER	F,G,H

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1		CANNOT BE ACCURATELY CALCULATED					X
2		" "	"				X

FAILURE DETECTION METHODS

1, 2 VISUAL INSPECTION

CHANGE IN FREQUENCY OF ROTOR ASSY.

INCREASE IN VIBRATION

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1,2 SAFE LIFE DESIGN IS INTENDED TO AVOID FATIGUE FAILURES

NAME AL FALCO | DATE 8/ 6/78

OPERATING MODES Rev. 10/25/78

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM-UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
HUB	HUB	PAGE 7 FMEA NO 4.2

FUNCTION OF COMPONENT

ATTACHES ROTOR BLADE TO TEETER BEARING

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
BUCKLING OF COMPRESSION SKINS DUE TO OVERLOAD (SEVERE SNOW, ICE &/OR HURRICANE LOADS) RESULTING IN COLLAPSEOF BLADE AND WTS SHUT-DOWN INITIATED BY VIBRATION DETECTION SYSTEM AFTER STARTUP.	A, F, G

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	CANNOT BE ACCURATELY CALCULATED						X
2							
3							
4							

FAILURE DETECTION METHODS

1 VIBRATION PICK-UP MOUNTED ON LOW SPEED SHAFT FRONT BEARING.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

ESTABLISHMENT OF CONSERVATIVE ENVIRONMENTAL OPERATING RANGE TO MINIMIZE RISK OF THIS FAILURE MODE.

NAME AL FALCO DATE 8/16/78

OPERATING MODES Rev. 10/25/78

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM-UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
PITCH CHANGE MECHANISM	ACTUATORS	PAGE 8 FMEA NO 4.3.1.1

FUNCTION OF COMPONENT

POSITION THE VARIABLE PITCH PORTION OF THE WIND TURBINE ROTOR BLADE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 INTERNAL LEAK - REDUCES RATE OF MOTION, ACTUATOR CREEPS UNDER LOAD, HEATS FLUID.	F, G, H
2 EXTERNAL LEAK DISSIPATES SYSTEM FLUID	F, G, H
3 JAMMED - UNABLE TO CONTROL BLADE PITCH ON ONE BLADE ONLY	F, G, H
4 ROD-END SEPARATION - UNABLE TO CONTROL BLADE PITCH, ONE BLADE ONLY	F, G, H

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1,2	.95	70	1.7		X	X *	
3	.04	70	41			X	
4	.01	70	164			X	

FAILURE DETECTION METHODS

1 POOR SPEED CONTROL, OVERHEAT WARNING, MANUAL TEST

2 VISUAL, LOW FLUID QUANTITY ALARM

3 FEEDBACK SIGNALS FROM 2 BLADES DISAGREE, UNABLE TO FEATHER OR UNFEATHER ONE BLADE.

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

SYSTEM WILL SHUT DOWN.

1. SUGGEST MANUAL TEST TO ALLOW MAINTENANCE PERSONNEL TO DETECT INTERNALLY LEAKY ACTUATOR. BY DISABLING FEEDBACK, ABSOLUTE RATE OF CHANGE DIFFERENCES CAN BE DETECTED AND ACTUATOR CAN BE REPLACED PRIOR TO FAILURE.

3,4 SINGLE BLADE FEATHERED WILL STOP THE ROTOR. FREE TIP (#4) WILL ALIGN ITSELF STREAMLINE TO THE WIND.

* IF UNDETECTED DURING INSPECTIONS.

NAME D. W. KING | DATE 8/9/78

OPERATING MODES Rev. 10/25/78

A - SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F - TRANSITION TO OPERATE
G - OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 9
PITCH CHANGE MECHANISM	RESERVOIR	FMEA NO 4.3.1.2

FUNCTION OF COMPONENT

CONTAINS A SUPPLY OF HYDRAULIC FLUID FOR THE PITCH CONTROL HYDRAULIC SYSTEM.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 BAFFLE JAMS AND TUMBLES - ▷	F,G,H, & I
2 ROTARY SEAL FAILS - AIR SLOWLY ENTERS HYDRAULIC SYSTEM, &/OR OIL LEAKS FROM BREATHER	F, G,H, & I
3 LIQUID LEVEL GAUGE FAILS - PRODUCES EMPTY INDICATION PRODUCES FALSE INDICATION - ▷	F,G,H, & I
4 EXTERNAL JOINTS LEAKS - EVENTUALLY PRODUCES LOW LEVEL ALARM SPREADS OIL IN AREA OF LOW SPEED SHAFT	F,G,H,&I

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	10	10	110			X	
2,4	100	20	5.7			X	
3	100	7	17			X	
4							

FAILURE DETECTION METHODS

1 LOW LEVEL ALARM & VISUAL DETECTION OF OIL IN BREATHER WTS SHUT DOWNS.

2,4 LOS SYSTEM PRESSURE &/OR OIL IN BREATHER WTS SHUTS DOWN

3 WTS SHUTS DOWN.

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

▷ LIQUID LEVEL INDICATOR PRODUCES INTERMITTENT LOW LEVEL ALARM, AIR ENTERS PUMP INLET, OIL ESCAPES FROM BREATHER.

▷ IF INDICATOR INCORRECTLY SHOWS A SATISFACTORY OIL LEVEL WHEN THE OIL LEVEL IS UNSATISFACTORY, THE OIL TEMPERATURE OR PRESSURE DETECTION SYSTEM WILL SHUT THE WTS DOWN.

DEVELOPMENTAL TESTS TO BE CONDUCTED TO VERIFY RESERVOIR PERFORMANCE.

NAME D. W KING DATE 7/20/8

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM-UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 10
PITCH CHANGE MECHANISM	ACCUMULATORS	FMEA NO 4.3.1.3

FUNCTION OF COMPONENT

1. STORE HYDRAULIC ENERGY FOR FEATHFRING
2. STORE ENERGY FOR SHORT TERM PEAK DEMANDS DURING NORMAL OPERATION

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 GAS LEAKS INTO HYDRAULIC SYSTEM - SPRING RATE OF SYSTEM REDUCED, EVENTUAL LOSS OF ACCUMULATOR CAPABILITY.	F, G, H, & I
2 GAS LEAKS EXTERNALLY - LOSS OF ACCUMULATOR CAPABILITY.	G, H, & I
3 OIL LEAKS EXTERNALLY - DISSIPATES OIL FROM SYSTEM	A, F, G, H, & I
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	30	42	9		X	X IF UNDETECTED	
2	20	42	14			X	
3	30	42	9		X	X IF UNDETECTED	
4							

FAILURE DETECTION METHODS

1. LOW ACCUMULATOR GAS PRESSURE WHEN HYDRAULICS DE-PRESSURIZED-DISABLES START-UP ABILITY.
2. GAS PRESSURE NOT EQUAL TO HYDRAULIC PRESSURE; SYSTEM SHUTS DOWN.
3. LOSS OF HYDRAULIC PRESSURE AND VISUAL INSPECTION
4.

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. W. KING | DATE 7/21/8

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
PITCH CHANGE MECHANISM	START-STOP VALVES	11 / 4.3.1.4.1

FUNCTION OF COMPONENT

APPLIES HYDRAULIC PRESSURE TO SERVO VALVES FOR NORMAL OPERATION

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 EITHER VALVE FAILS TO OPEN - UNABLE TO START TURBINE.	F
2 EITHER VALVE FAILS TO CLOSE - TURBINE SHUTS DOWN NORMALLY.	H
3 BOTH VALVES FAIL TO CLOSE - ▷	H
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	90	41	3.1			X	
2	10	41	278			X	
3	100	.003	$.5 \times 10^6$			X	

FAILURE DETECTION METHODS

1 UNABLE TO START TURBINE-ALL OTHER SYSTEMS OK.

2 PERIODIC CHECK FOR VALVE OPERATION.

3 UNABLE TO IMPLEMENT NORMAL SHUTDOWN, BUT NO PROBLEM.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

▷- TWO VALVES PROVIDED TO INCREASE RELIABILITY.

NAME D. W. KING DATE 7/21/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM-UP
C - WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G - OPERATE
H - TRANSITION TO FEATHER
I FEATHER

78 K 6162-001

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 12
PITCH CHANGE MECHANISM	SYSTEM RELIEF VALVE	FMEA NO 4.3.1.4.2

FUNCTION OF COMPONENT

RELIEVES PRESSURE IN EVENT PUMP COMPENSATOR FAILS

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 LEAKS INTERNALLY - UNABLE TO MAINTAIN SYSTEM PRESSURE, HEATS FLUID	E,F,G,H
2 LEAKS EXTERNALLY - DISSIPATES SYSTEM FLUID, MAKES A MESS	E,F,G,H
3 FAILS TO OPEN - SYSTEM MAY BE OVER PRESSUREIZED IF PUMP COMPENSATOR ALSO FAILS.	E,F,G.
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	40	17	66.6		X	X IF UNDETECTED	
2	40	17	66.6		X		
3	20	17	33.3		X ▷	X IF UNDETECTED	

FAILURE DETECTION METHODS

1 LOW PRESSURE ALARM, OR OVERHEAT ALARM

2 LOW FLUID QUANTITY ALARM

3 NO DETECTION METHOD EXCEPT BENCH TEST - CONSTITUTES DOUBLE FAILURE.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

▷ PROBABILITY OF DOUBLE FAILURE IS NEGLIGIBLE

NAME D. W. KING

DATE 8/9/78

OPERATING MODES

Rev. 10/25/78

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G - OPERATE
H - TRANSITION TO FEATHER
I - FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
PITCH CHANGE MECHANISM	TEETER BRAKE VALVE	PAGE 13 FMEA NO 4.3.1.4.3

FUNCTION OF COMPONENT

CONTROLS HYDRAULIC PRESSURE TO RELEASE TEETER BRAKE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 FAILS TO OPEN-TEETER BRAKE SLIPS, BRAKE LINING & PLATE WEARS.	G
2 FAILS TO CLOSE-TEETER BRAKE RELEASES TOO EARLY ON START-UP	F
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	90	21	6.2		X		
2	10	21	55.6		X		

FAILURE DETECTION METHODS

1 BRAKE SQUEAKS DURING NORMAL OPERATION, VISUAL INSPECTION

2 MANUAL INSPECTION.

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

HYDRAULIC PRESSURE SWITCH ADDED TO INDICATE BRAKE RELEASE STATUS.

NAME D. W. KING DATE

OPERATING MODES

Rev. 10/25/78

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F - TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 14
PITCH CHANGE MECHANISM	SERVO VALVE	FMEA NO 4.3.1.4.4

FUNCTION OF COMPONENT

CONTROLS PITCH CHANGE ACTUATOR

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 FAILS TO RESPOND TO COMMANDS - ONE BLADE TIP MOVES TO LIMIT OF MOTION.	F,G H
2 INTERNAL LEAKAGE - HEATS FLUID, REDUCES RATE OF PITCH CHANGE.	F,G H
3 JAMS - ONE BLADE TIP WILL NOT MOVE	F,G,H
4 EXTERNAL LEAKAGE - DEPLETES SUPPLY IF NOT DETECTED.	F,G,H

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	9	74	17.1			X	
2 , 4	90	74	1.7		X (4)	X (2)	
3	1	74	154			X	

FAILURE DETECTION METHODS

1 POSITION FEEDBACK FROM 2 BLADES DISAGREE

2 OVERHEAT WARNING

3 SAME AS 1 ABOVE. 4. FLUID LEVEL SENSOR.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

FOR 1, 2, 3, 4 EMERGENCY STOP IS INITIATED WHICH BY-PASSES SERVO VALVE.

NAME D. W. KING DATE 8/9/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B - TRANSITION TO WARM-UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 15
PITCH CHANGE MECHANISM	SHUTTLE VALVE	FMEA NO 4.3.1.4.5

FUNCTION OF COMPONENT

DISABLES SERVO VALVE & APPLIES BLADE FEATHERING PRESSURE UPON LOSS OF NORMAL HYDRAULIC SYSTEM PRESSURE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 FAILS TO SHUTTLE WHEN PRESSURIZED - UNABLE TO CONTROL ONE BLADE TIP, BYPASSES FLUID	F,G H
2 FAILS TO SHUTTLE WHEN DE-PRESSURIZED- UNABLE TO FEATHER ONE BLADE TIP	H,I
3 LEAKS	F,G,H,
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	10	27	41.7			X	
2	10	27	41.7		X		
3	90	27	4.6		X		

FAILURE DETECTION METHODS

1 UNABLE TO UN-FEATHER BLADE TIP ON START COMMAND
LOW PRESSURE ALARM, OVERTEMP ALARM

2 NO PRESSURE CHANGE IN FEATHERING ACCUMULATOR ON "FEATHER" COMMAND. SLOW FEATHERING OR NO FEATHERING.

3 INSPECTION DURING PREVENTATIVE MAINTENANCE PERIODS.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1,2. SHUTDOWN CAN BE ACCOMPLISHED BY FEATHERING ONE BLADE.

NAME D. W. King DATE 8/9/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H - TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 16
PITCH CHANGING MECHANISM	FITTINGS & HOSES	FMEA NO 4.3.1.5

FUNCTION OF COMPONENT

SUPPLIES PRESSURIZED HYDRAULIC FLUID TO CONTROL ACTUATORS AND FEATHER LATCHES

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 TUBING TOTALLY FAILS - LOSS OF PRESSURE: OIL WOULD SPILL INTO RACEWAY AND/OR BLADE SECTIONS.	F,G,H
2 HYDRAULIC FLUID LEAKS - OIL WOULD LEAK INTO RACEWAY: POSSIBLE OIL COATING ON ELECTRICAL COMPONENTS.	F,G,H
3 LINES CLOG - LOSS OF PRESSURE	F,G,H
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	20	29	20			X	
2	75	29	5.3		X	*	
3	5	29	80			X	

FAILURE DETECTION METHODS

1 LOW OIL PRESSURE, LOW OIL QUANTITY. SYSTEM WOULD GO INTO EMERGENCY STOP.

2 VISUAL AND OIL LEVEL INDICATOR

3 SLOW FEATHERING RESPONSE PICKED UP BY MICRO PROCESSOR.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1. SYSTEM WOULD GO INTO AUTOMATIC STOP (FEATHER LATCH WOULD LOCK) IF FAILURE OCCURED AT 1250-1260 STATION, COMPARTMENT W/ELECTRICAL & MECHANICAL COMPONENTS MAY BE COATED WITH OIL. ELECTRICAL COMPONENTS SHOULD BE RESISTANT TO OIL. FLUID TRAPS IN BLADE SHOULD ALSO BE AVOIDED, (DRAINS).
2. SMALL LEAKS COULD ENTER RACEWAY AREA: ELECTRICAL WIRING SHOULD BE OIL RESISTANT.
3. THIS FAILURE MODE IS NOT VERY LIKELY SINCE THE SYSTEM HAS TWO FILTERS.

* CRITICAL IF LEVEL OR PRESSURE SENSORS INITIATE SHUTDOWN PRIOR TO LEAK DETECTION BY MAINTENANCE PERSONNEL.

NAME JOSE A. BURRUEL DATE 7/26/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 17
PITCH CHANGE MECHANISM	FILTERS	FMEA NO 4.3.1.6

FUNCTION OF COMPONENT

REMOVES SOLID PARTICLES FROM HYDRAULIC FLUID.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 FAILS TO REMOVE PARTICLES - ▷	F, G H
2 LEAKS EXTERNALLY - DISSIPATES SYSTEM FLUID MAKES A MESS	F, G H
3 EXCESSIVE PRESSURE DROP - ▷ DUE TO FILTER CLOGGING	F, G, H
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	FILTER CLOGGED, SEE #3				X	X*	
2	100	14	8.3			X	
3	CANNOT BE ACCURATELY ESTIMATED				X	X*	

FAILURE DETECTION METHODS

1 PERIODIC FLUID SAMPLING & FILTER ELEMENT REPLACEMENT

2 LOW FLUID QUANTITY ALARM· VISUAL INSPECTION

3 DIFFERENTIAL PRESSURE SWITCHES. WTS WILL STOP IF EXCESSIVE PRESSURE DROP IS INDICATED.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

▷- INCREASES WEAR RATE OF PUMP, MAY CAUSE MALFUNCTION OF VALVES.

▷- INTERNAL BYPASS VALVE OPENS PRODUCING SAME EFFECT AS FAILURE MODE NO. 1; MAY ALSO REDUCE PITCH CHANGE RATES WHICH WOULD BE DETECTED BY THE MICROPROCESSOR.

* IF UNDETECTED BY MAINTENANCE PERSONNEL

NAME D. W. KING DATE 8/9/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G - OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM-UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
PITCH CHANGE MECHANISM	MOTOR-PUMP ASSY.	PAGE 18, FMEA NO 4.3.1.7&8

FUNCTION OF COMPONENT

PROVIDE HYDRAULIC POWER FOR OPERATION OF PITCH CHANGE MECHANISM

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 LOW HYDRAULIC OR NO PRESSURE - PRODUCES LOW PRESSURE ALARM WTS SHUTDOWN	F,G,H
2 LOW HYDRAULIC FLOW - REDUCES PITCH CHANGE RATES, MOMENTARY LOW PRESSURE ALARM - WTS SHUTDOWN	F,G,H
3 EXCESSIVE HYDRAULIC PRESSURE - OVERHEATS HYDRAULIC FLUID. - WTS SHUTDOWN	F,G,H
4 LEAKS - EXTERNAL	F G H

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	38	6.1			X	
2	20	38	15.2			X	
3	100	17	6.7			X	
4	30	38	10.0		X	X*	

FAILURE DETECTION METHODS

1 LOW PRESSURE ALARM - WTS SHUTDOWN

2 LOW PRESSURE ALARM - WTS SHUTDOWN

3 OVERHEAT ALARM - WTS SHUTDOWN

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

* IF UNDETECTED

NAME D. W. KING DATE 8/9/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D - TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I FEATHER

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MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM ROTOR - EPS	COMPONENT CONTROL CABLE TO TIP NO 1 ACTUATOR	PAGE 19 FMEA NO 4.3.1.10.1

FUNCTION OF COMPONENT

PROVIDE A PATH FOR THE FLOW OF COMMANDS AND OPERATIONAL DATA FROM THE TEETER BEARING FLEXIBLE CABLE ASSEMBLY TO THE TIP NO. 1 ACTUATOR

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Wire in cable is open circuited: No path for a specific command or data to or from Tip No. 1 actuator. Tip is not controllable.	F,G,H
2 Cable is partially short circuited: False commands may result or false data may be transmitted, Tip No. 1 does not position properly.	F,G,H
3 Cable is partially grounded / or high resistance. Loss of data or command function to Tip No. 1. Tip No. 1 does not position properly.	F,G,H
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	20	.04	14×10^3			X	
2	10	.04	28×10^3			X	
3	70	.04	4×10^3			X	

FAILURE DETECTION METHODS

1 - 3 Tip No. 1 data displayed on CRT terminal indicates that commands are not executed.

WTS SHUTS DOWN DUE TO DIFFERENTIAL IN THE TWO PITCH POSITION SIGNALS.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

Conservative mechanical design of cable will reduce occurrence of these failures.

Failsafe shutdown is initiated if tip control signals are not executed.

NAME G. TRUSK / H. Roth DATE 8/17/78

Rev. 10/3/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM-UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

78 K 6162-001

MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
ROTOR - EPS	CONTROL CABLE TO TIP NO 2 ACTUATOR	PAGE 20 FMEA NO 4.3.1.10.2

FUNCTION OF COMPONENT

PROVIDE A PATH FOR THE FLOW OF COMMANDS AND OPERATIONAL DATA FROM THE TEETER BEARING FLEXIBLE CABLE ASSEMBLY TO THE TIP NO. 2 ACTUATOR

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Wire in cable is open circuited: No path for a specific command or data to or from tip No. 2 actuator, tip is not controllable.	F,G,H
2 Cable is partially short circuited: False commands may result or false data may be transmitted, tip No. 2 does not position properly.	F,G,H
3 Cable is partially grounded/or high resistance. Loss of data or command function to tip No. 2 does not position properly.	F,G,H
4 In 1,2, and 3 WTS may shut down.	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	20	.04	14×10^3			X	
2	10	.04	28×10^3			X	
3	70	.04	4×10^3			X	

FAILURE DETECTION METHODS

1 - 3 Tip No. 2 data displayed on CRT terminal indicates that commands are not executed.

WTS shuts down due to differential of pitch position signals.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1-3 Conservative mechanical design of cable will reduce occurrence of these failures.

Failsafe shutdown initiated if tip control signals are not executed.

NAME G. TRUSK / H. Roth DATE 8/17/78

OPERATING MODES

Rev. 10/5/78
Rev. 10/25/78

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I - FEATHER

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MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM ROTOR - EPS

COMPONENT TIP NO. 1 BONDING STRAP

PAGE 21

FMEA NO 4.3.1.10.3

FUNCTION OF COMPONENT

PROVIDE A PATH FOR THE FLOW OF LIGHTNING CURRENT FROM THE VARIABLE PITCH TIP OF THE ROTOR TO THE FIXED PITCH PORTION OF THE BLADE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Bonding strap is open circuited.	ALL
2 Bonding strap has high resistance due to fraying.	ALL
3 Bonding strap has high resistance due to poor bond connection.	ALL
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	20	.2	2.8×10^3				*1
2	40	.2	1.4×10^3				*1
3	40	.2	1.4×10^3				*1

FAILURE DETECTION METHODS

1 - 3 Periodic inspection.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1 - 3 When lightning strikes the variable pitch tip of the rotor the resultant extremely high current will follow the path of least resistance to ground. If an infinite or high resistance path replaces the low resistance bond path the current will possibly flow through the tip pitch bearing or hydraulic lines causing local overheating, pitting or welding of parts. Redundant bonding straps will be used to preclude this failure mode. Straps will be designed to minimize strap fatigue failures.

*1 Physical damage could be fatal at a manned site due to falling parts, or molten metal. Probability of site being manned in a thunder storm and also having failure of both straps is negligible. O&M manual will specify that no one is allowed in nacelle during lightning storms.

NAME G. TRUSK / H. Roth

DATE 8/17/78

REV. 10/5/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 22
ROTOR - EPS	TIP NO. 2 BONDING STRAP	FMEA NO 4.3.1.10.4

FUNCTION OF COMPONENT

PROVIDE A PATH FOR THE FLOW OF LIGHTNING CURRENT FROM THE VARIABLE PITCH TIP OF THE ROTOR TO THE FIXED PITCH PORTION OF THE BLADE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Bonding strap is open circuited.	ALL
2 Bonding strap has high resistance due to fraying.	ALL
3 Bonding strap has high resistance sue to poor bond connection.	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ. %	COMPONENT FAILURE RATE x 10^6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	20	.2	2.8×10^3				1*
2	40	.2	1.4×10^3				1*
3	40	.2	1.4×10^3				1*

FAILURE DETECTION METHODS

1 - 3 Periodic inspection.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1-3 When lightning strikes the variable pitch tip of the rotor the resultant extremely high current will follow the path of least resistance to ground. If an infinite or high resistance path replaces the low resistance bond path the current will possibly flow through the tip pitch bearing or hydraulic lines causing local heating, pitting, or welding of parts.

Redundant bonding straps will be used to preclude this failure mode, straps will be designed to minimize strap fatigue failures.

* See page 21 for safety note.

NAME G. TRUSK / H. Roth DATE 8/17/78

Rev. 10/5/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 23
ROTOR	FEATHER LOCK MECHANISM	FMEA NO 4.3.2

FUNCTION OF COMPONENT

TO HOLD BLADE TIP IN THE FEATHERED POSITION

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 MECHANISM FAILS TO LOCK	A,B,C,D,E,F,H,I
2 MECHANISM FAILS TO UNLOCK	F,G
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	10	2.3	500			X	
2	90	2.3	55.6			X	

FAILURE DETECTION METHODS

1 TIP POSITION INDICATOR SHOWS MOVEMENT AND PITCH LOCK STATUS INDICATES UNLOCKED.

2 TIP DOES NOT RESPOND TO COMMAND - START-UP NOT POSSIBLE.

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1. SINCE ONLY ONE TIP IS REQUIRED TO STOP WTS, A FAILURE TO LOCK WILL NOT PREVENT A WTS SHUTDOWN.

2. FAILING TO UNLOCK IS A FAIL-SAFE FEATURE. WTS WILL BE INSPECTED FOR FAILURE CAUSE.

NAME M. A. HOYT DATE 8/15/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 24
ROTOR	FASTENERS, ROD ENDS	FMEA NO 4.3.2

FUNCTION OF COMPONENT

ATTACHEMENT OF ACTUATOR TO BLADE AND TIP.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 ROD END BEARINGS WEAR EXCESSIVELY.	G
2 ROD END BREAKS	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	98	6.8	17		X		
2	2	6.8	833			X	

FAILURE DETECTION METHODS

1 INSPECTION, TIP POSITION INDICATOR.

2 INSPECTION, TIP POSITION INDICATOR.

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1. EXCESSIVE WEAR WILL BE INDICATED BY TIP POSITION MOVEMENT AT A FIXED COMMAND.

2. SINCE TIPS ARE CONTROLLLED INDEPENDENTLY, FAILURE OF ONE TIP ROD END WILL NOT PREVENT AN EMERGENCY SHUT DOWN BY THE OTHER TIP.

NAME MAURIE HOYT DATE 8/15/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D - TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I - FEATHER

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MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
DRIVE TRAIN	SHAFT (PART OF LOW SPEED SHAFT & BEARINGS)	PAGE 25 FMEA NO 5.1.1

FUNCTION OF COMPONENT

TO TRANSMIT TORQUE FROM ROTOR TO THE QUILL SHAFT AND REACT ROTOR MOMENT (FROM OVERHUNG WEIGHT).

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 BROKEN TEETER SHAFT OR SHAFT FLANGE JOINT - ROTOR COULD FALL OFF	G
2 BROKEN QUILL SHAFT BULKHEAD JOINT - WOULD ALLOW ROTOR TO FREEWHEEL	G
3 DEFORMED SHAFT STRUCTURE - COULD CAUSE IMBALANCE AND BEARING FAILURE	G
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	5	1.1	2000				X
2	5	1.1	2000				X
3	90	1.1	111				X

FAILURE DETECTION METHODS

1 LOSS OF ROTOR CAUSES LOSS OF GENERATOR LOAD, INITIATES (ELECTRICAL) EMERGENCY SHUTDOWN AS UTILITY TRIES TO DRIVE GENERATOR

2 LOSS OF GENERATOR RESULTS IN ACTIONS ABOVE (1) PLUS OVERSPEED OF ROTOR TRIGGERS FEATHERING OF BLADES AND SUBSEQUENT APPLICATIONS OF ROTOR BRAKE.

3 VIBRATIONS & INCREASED TEMPERATURE SENSED AT BEARINGS WOULD INITIATE EMERG. SHUTDOWN.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1. SAFE LIFE DESIGN

   INCIPIENT FAILURE DETECTION DEVICES NOT PRACTICAL.

2. EMERGENCY SHUTDOWN PROCEDURE PREVENTS ROTOR OVERSPEED IN EXCESS OF DESIGN LIMITS.

3. NONE REQUIRED.

NAME ROLF LUTH DATE 8/7/8

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
DRIVE TRAIN	RADIAL BEARING (FLUID)	PAGE 26 FMEA NO 5.1.2

FUNCTION OF COMPONENT

TO SUPPORT LOW SPEED SHAFT BY DECREASING RUNNING FRICTIONS AND TO REACT ROTOR MOMENT (FROM OVERTURNING) ROTOR WEIGHT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 BEARING FAILURE WHILE IN MOTION - CAUSES HIGH VIBRATION AND OVER-TEMPERATURE.	F, G, H
2 BEARING FAILURE WHILE PARKED - INCREASED BREAKAWAY MOMENT LEADING TO FM (1) WHEN BROKEN LOOSE	ALL
3 DETERIORATED BEARING - INCREASED FRICTION AND TEMPERATURE	ALL
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	10	10.3	111			X	
2	Cannot be accurately estimated					X	
3	90	10.3	12.3			X	

FAILURE DETECTION METHODS

1 TEMPERATURE AND VIBRATIONS SENSORS WOULD INITIATE EMERGENCY SHUTDOWN.

2 THERE IS NO-INSTRUMENTATIONS THAT SENSES EXCESSIVE BREAKAWAY TORQUE, HOWEVER, ONCE IN MOTION FAILURE WOULD BE DETECTED PER FM(1) ABOVE

3 EXCESSIVE TEMPERATURE INITIATES EMERGENCY SHUTDOWN.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

2. System will be designed to allow lubrication of bearing if stationary for extended periods.

NAME ROLF LUTH DATE 8/7/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 27
DRIVE TRAIN	TEETER BEARING	FMEA NO 5.1.3

FUNCTION OF COMPONENT

ACCOMODATES TEETER MOTION, TRANSMITS ROTOR TORQUE TO LOW SPEED SHAFT, SUPPORTS WEIGHT OF ROTOR, REACTS ROTOR DRAG LOAD

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHEAR FAILURE OF ELASTOMER - 1 2	ALL
2 FAILURE OF BOND BETWEEN ELEASTOMER & METAL PARTS 1 2 3	ALL
3 DETERIORATION OF ELASTOMER DUE TO OIL, OZONE, OR LIGHTNING - PRIMARILY SURFACE EFFECTS, BUT MAY SHORTEN LIFE.	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ. %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	33	22.8	15			X	
2	33	22.8	15			X	
3	33	22.8	15			X	

FAILURE DETECTION METHODS

1 VISUAL

2 VISUAL

3 VISUAL

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1 MAY ALLOW EXCESSIVE DISPLACEMENT OF ROTOR DUE TO DEAD WEIGHT AND DRAG LOADS RESULTING IN INCREASED VIBRATION

2 FAILURE PROGRESSES VERY SLOWLY AND IS VISUALLY DETECTABLE. IF FAILURE IS FIRST DETECTED AT 35% OF LIFE, BEARING WILL PROBABLY COMPLETE 100% OF LIFE CYCLES SATISFACTORILY.

3 CORROSION OF METAL PARTS MAY ACCELERATE BOND FAILURE.

PERIODIC INSPECTIONS REQUIRED.

NAME D. W. KING — DATE 7/19/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H - TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 28
DRIVE TRAIN	RADIAL/THRUST BEARING	FMEA NO 5.1.4

FUNCTION OF COMPONENT

SUPPORT LOW SPEED SHAFT BY DECREASING RUNNING FRICTIONS AND TO REACT ROTOR MOMENT (FROM OVERHUNG ROTOR WEIGHT) AND ROTOR THRUST

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 BEARING FAILURE WHILE IN MOTION CAUSES HIGH VIBRATIONS AND TEMPERATURE AND COULD CAUSE FAILURE OF RADIAL BEARING AND GEARBOX BY & FAILURE TO REACH THRUST.	F, G, H, I
2. BEARING FAILURE WHILE PARKED - INCREASED BREAK-AWAY MOMENT LEADING & TO FM (1) ABOVE WHEN BROKEN LOOSE.	ALL
3. DETERIORATED BEARING - INCREASED FRICTION, TEMPERATURE AND VIBRATION	ALL
4 CORROSION WHILE STATIONARY OVER EXTENDED PERIODS DUE TO OIL DRAINING OFF BEARING SURFACES	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ RER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	55	10.3	20.2			X	
2 , 4		INCLUDED IN 1 AND 3				X	
3	45	10.3	24.7		X		

FAILURE DETECTION METHODS

TEMPERATURE AND VIBRATIONS SENSORS WOULD INITIATE EMERGENCY SHUTDOWN. THERE IS NO INSTRUMENTATIONS THAT SENSES EXCESSIVE BREAKAWAY TORQUE, HOWEVER, ONCE IN MOTION FAILURE WOULD
2 BE DETECTED PER FM ABOVE.

3 EXCESSIVE TEMPERATURE INITIATES EMERGENCY SHUTDOWN.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

SYSTEM WILL BE DESIGNED TO ALLOW LUBRICATION OF BEARING IF STATIONARY FOR EXTENDED PERIODS.

NAME R. LUTH DATE 8/7/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F - TRANSITION TO OPERATE	I FEATHER

MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 29 FMEA NO.
DRIVE TRAIN	TEETER STOP	5.1.5

FUNCTION OF COMPONENT

RESTRAIN TEETERING MOTION OF THE ROTOR WHEN THE TURBINE IS SHUT DOWN. LIMITS TEETER ANGLE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 BRAKE FAILS TO RELEASE - BRAKE LINING & PLATE WILL WEAR OUT DUE TO SLIPPAGE.	G
2 BRAKE FAILS TO APPLY OR IS WORN OUT -ROTOR BANGS ON MOTION LIMIT STOPS	A,B,C,D,E,F,H,I
3 MOTION STOP BUMPERS FAIL - EXCESSIVE TEETER ANGLE, MAY CONTACT TOWER	A,B,C,D,E,F,H,I
4 LEAKS	G

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	20	22.8	25			X	
2	4	22.8	125			X	
3	1	22.8	500			X	
4	75		6.7		X		

FAILURE DETECTION METHODS

1-4 VISUAL INSPECTION

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1. BRAKE WILL SLIP AND EVENTUALLY WEAR OUT. NO MAJOR DAMAGE RESULTS.

2. REQUIRES PERIODIC INSPECTION & REPLACEMENT OF WORN BRAKE LINING.

3,4 REQUIRES PERIODIC INSPECTION.

NAME D. W. KING DATE 7/18/78

3/8/79

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 30
DRIVE TRAIN - EPS	SLIP RINGS	FMEA NO 5.1.6.1

FUNCTION OF COMPONENT

PROVIDES THE ROTATING PORTION OF THE PATH FOR THE FLOW OF ELECTRICAL POWER AND SIGNALS BETWEEN THE NACELLE AND THE DRIVE TRAIN

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SLIP RING FAILURES RESULT IN LOSS OF POWER AND/OR SIGNALS. ALL POWER AND SIGNAL LINES ARE ADDRESSED UNDER THEIR RESPECTIVE	ALL
2 SUBSYSTEMS.	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY ▷			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
ALL	100	37.6	3				

FAILURE DETECTION METHODS

1 ▷

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

SEE INDIVIDUAL CABLES FOR FAILURE EFFECTS AND DETECTION METHODS

▷

NAME	G. TRUSK	DATE	8/17/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 31
DRIVE TRAIN - EPS	SLIP RING JUNCTION BOX	FMEA NO 5.1.6.2

FUNCTION OF COMPONENT

PROVIDES A PROTECTED ELECTRICAL JUNCTION POINT FOR THE WIRES COMING OUT OF THE SLIP RINGS AND THE CABLES DISTRIBUTING POWER AND SIGNALS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuited conductor within junction box. Loss of associated function.	ALL
2 Short circuited conductors within junction box. Loss of associated functions, erratic operation, or loss of meaningful data.	ALL
3 Conductor grounded within junction box. Loss of associated function.	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY *			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.1	200				
2	25	1.1	400				
3	25	1.1	400				

FAILURE DETECTION METHODS

1 - 3 *

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

* See individual cables for failure effects and detection methods for each signal and power line.

NAME G. TRUSK / H. Roth DATE 8/17/78

OPERATING MODES

Rev. 10/5/78

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H - TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 32
DRIVE TRAIN - EPS	POWER CABLE TO HYDRAULIC SYSTEM	FMEA NO 5.1.6.3.1

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF ACCESSORY POWER ON THE LOW SPEED SHAFT FROM THE SLIP RING JUNCTION BOX TO THE PITCH CONTROL HYDRAULIC SYSTEM.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Conductor is open circuited. Hydraulic pump motors may operate at reduced capacity. WTS may shutdown.	F,G,H
2 Conductor is short circuited. Hydraulic pump motors may operate at reduced capacity. WTS may shutdown.	F,G,H
3 Conductor is grounded. Hydraulic pump motors may operate at reduced capacity. WTS may shutdown.	F,G,H
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500			1*	
2	25	.15	>3000			1*	
3	25	.15	>3000			1*	

FAILURE DETECTION METHODS

1 - 3 WTS may shutdown if hydraulic accumulator pressure cannot be maintained.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1 - 3 Periodic review of CRT data should reveal that pitch accumulator pressure has been low.

1* Pump motors can run on 2 of the 3 phases; however, motor temperature will increase and capacity will be reduced.

NAME G. TRUSK /H. Roth DATE 8/17/78

Rev. 10/5/78

OPERATING MODES

A SHUTDOWN	D - TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 33
DRIVE TRAIN - EPS	CONTROL CABLE TO THE HYDRAULIC SYSTEM	FMEA NO 5.1.6.3.2

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF COMMANDS AND OPERATIONAL DATA ON THE LOW SPEED SHAFT FROM THE SLIP RING JUNCTION BOX TO THE ROTOR PITCH CONTROL HYDRAULIC SYSTEM.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 A control or data wire is open circuited. Control function cannot be accomplished. WTS will shutdown.	F,G,H
2 A control or data wire is shorted to another wire. Incorrect commands or data present. WTS will shutdown.	F,G,H
3 A control of data wire is grounded Control function cannot be accomplished. WTS will shutdown.	F,G,H
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500			1	
2	25	.15	>2000			1	
3	25	.15	>3000			1	

FAILURE DETECTION METHODS

1 - 3 WTS shutsdown due to differential pitch signals.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

NAME G. TRUSK / H. Roth DATE 8/17/78

OPERATING MODES REV. 10/5/78

A - SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 34
DRIVE TRAIN - EPS	ROTOR ACTUATOR CONTROL CABLE	FMEA NO 5.1.6.3.3

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF COMMANDS AND OPERATIONAL DATA ON THE LOW SPEED SHAFT FROM THE SLIP RING JUNCTION BOX TO THE ROTOR JUNCTION BOX.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 A control or data wire is open circuited. Control function cannot be accomplished. WTS will shutdown.	ALL
2 A control or data wire is shorted to another wire, incorrect commands or data present. WTS will shutdown.	ALL
3 A control or data wire is grounded. Control function cannot be accomplished. WTS will shutdown.	ALL
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500			1	
2	25	.15	>3000			1	
3	25	.15	>3000			1	

FAILURE DETECTION METHODS

1 - 3 WTS shutsdown due to differential pitch position signals.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

NAME G. TRUSK / H. Roth DATE 8/17/78

REV. 10/5/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F - TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 35
DRIVE TRAIN-EPS	FLEX CABLE ACROSS TEETER BEARING	FMEA NO 5.1.6.3.4

FUNCTION OF COMPONENT

PROVIDES A PATH ACROSS THE TEETER BEARING FOR THE FLOW OF COMMANDS AND OPERATIONAL DATA FROM THE ROTOR JUNCTION BOX TO THE ROTOR.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 A control or data wire is open circuited. Control function cannot be accomplished. WTS will shutdown.	ALL
2 A control or data wire is shorted to another wire. Incorrect commands or data present. WTS will shutdown.	ALL
3 A control or data wire is grounded. Control function cannot by accomplished. WTS will shutdown.	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1,2,3	100	11.41	10			X	

FAILURE DETECTION METHODS

1 WTS shutsdown due to differential pitch position signals.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

NAME G. TRUSK DATE 8/17/78

OPERATING MODES REV. 10/5/78

A SHUTDOWN
B - TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 36
DRIVE TRAIN - EPS	TEETER BEARING BONDING STRAP	FMEA NO 5.1.6.3.5

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF LIGHTNING CURRENT AROUND THE TEETER BEARING FROM THE ROTOR TO THE DRIVE TRAIN.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Bonding strap is open circuited.	ALL
2 Bonding strap has high resistance due to fraying.	ALL
3 Bonding strap has high resistance due to poor bond connection.	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^{6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	5	1.1	2000			1*	
2	50	1.1	200			1*	
3	45	1.1	222			1*	

FAILURE DETECTION METHODS

1 - 3 Periodic Inspection

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1-3 When lightning strikes a rotor blade the resultant extremely high current will follow the path of least resistance to ground. If an infinite or high resistance path replaces the low resistance bond path the current will possibly flow through the teeter bearing resulting in erratic operation and WTS shutsdown. Redundant bonding straps will be used to preclude this failure mode. Straps will be designed to minimize strap fatigue failures. Straps will be inspected periodically. Probability of both straps failing is negligible.

1* Rotor will operate with the teeter mechanism inoperative.

NAME G. TRUSK / H. Roth DATE 8/17/78

OPERATING MODES

Rev. 10/5/78

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 37
DRIVE TRAIN - EPS	ROTOR JUNCTION BOX	FMEA NO 5.1.6.4

FUNCTION OF COMPONENT

PROVIDES A PROTECTED ELECTRICAL JUNCTION POINT FOR THE RIGID CABLE COMING OUT THE SLIP RING JUNCTION BOX AND THE FLEXIBLE CABLE GOING AROUND THE TEETER BEARING.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuited conductor within junction box. Loss of associated function.	ALL
2 Short circuited conductors within junction box. Loss of associated functions, erratic operation, or loss of meaningful data.	ALL
3 Conductor grounded within junction box. Loss of associated function.	ALL
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	5	44			X	
2	25	5	88			X	
3	25	5	88			X	

FAILURE DETECTION METHODS

1 WTS shutdown. See individual signal and power lines.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

See individual signal wires for impacts.

NAME G. TRUSK / H. Roth DATE 8/17/78

Rev. 10/6/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM-UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 38
DRIVE TRAIN	QUILL SHAFT	FMEA NO 5.2.1

FUNCTION OF COMPONENT

TO TRANSMIT ROTOR TORQUE FROM THE LOWSPEED SHAFT TO THE GEAR BOX AND TO LIMIT TORSIONAL ROSONANCE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHAFT FAILURE - WOULD ALLOW ROTOR TO FREE WHEEL	F,G,H
2	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	100	3.4	33.3				X*
2							
3							
4							

FAILURE DETECTION METHODS

1 LOSS OF GENERATOR LOAD INITIATES (ELECTRICAL) EMERGENCY SHUTDOWN DUE TO SUDDEN DROP IN POWER OUTPUT. AS BACKUP TO THIS SHUTDOWN PROCEDURE, THE OVERSPEED SWITCH ON THE LOW SPEED SHAFT INITIATES SHUTDOWN.

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

STRUCTURAL AND FATIGUE ANALYSIS ACCOMPLISHED TO CONFIRM ADEQUATE SAFETY MARGIN IN DESIGN. WTS WILL NOT EXCEED DESIGN OVERSPEED LIMITS UNDER THESE CONDITIONS.

* DESIGNATED CATISTROPHIC DUE TO HIGH COST OF REPLACING THE QUILL SHAFT.

NAME ROLF LUTH

DATE 8/7/8

Rev. 11/27/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM-UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 39
DRIVE TRAIN	QUILL SHAFT COUPLING	FMEA NO 5.2.2

FUNCTION OF COMPONENT

TO TRANSMIT TORQUE FROM LOW SPEED SHAFT TO GEAR BOX AND TO ACCOMMODATE SHAFT MISALIGNMENT

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 COUPLING STRUCTURAL FAILURE - WOULD PERMIT ROTOR TO FREEWHEEL	F,G,H
2 COUPLING INCIPIENT FAILURE OR DAMAGE DUE TO OVERLOAD.	F,G,H
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	10	13.7	137			X	
2	90	13.7	9.3		X 1		
3							
4							

FAILURE DETECTION METHODS

1 BREAK IN LOAD PATH CAUSES LOSS OF GENERATOR LOAD WHICH INITIATES EMERGENCY SHUT DOWN AS UTILITY TRIES TO DRIVE GENERATOR.

2 INEFFICIENT JOINTS CAN CAUSE UNDETECTABLE TEMP. RISE - ~~ULTIMATE FAILURE DETECTED PER~~ FM(1) ABOVE

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1 IF DETECTED BY INSPECTION PRIOR TO FAILURE MODE 1 OCCURRING.

ROTOR OVERSPEED IS WITHIN DESIGN LIMITS.

NAME ROLF LUTH DATE 8/7/8

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G - OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 40
DRIVE TRAIN	GEARBOX MOUNTING INSTALLATION	FMEA NO 5.3.1

FUNCTION OF COMPONENT

TO ATTACH G/B TO NACELLE BASE PLANE TO MAINTAIN DRIVE TRAIN ALIGNMENT AND TO REACT LOADS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 ATTACHMENT BOLTS WORKING LOOSE, CAUSING LOSS OF ALIGNMENT	G,H
2 ATTACHMENT BOLT FAILURE CAUSING MAJOR FAILURE OF DRIVE TRAIN	G,H
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	100	1.1	104		1	X	
2			2				X
3							
4							

FAILURE DETECTION METHODS

1 MISALIGNMENT WOULD BE DETECTED BY BEARING TEMPERATURE AND VIBRATIONS SENSORS AND
2 SYSTEM WOULD SHUT DOWN. (2) ATTACHMENT BOLT FAILURE WOULD BE SENSED AS ABOVE,
3 HOWEVER, LACK OF DETECTION COULD BE CATASTROPHIC.
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1 MARGINAL IF DETECTED DURING INSPECTION PRIOR TO EXCESSIVE VIBRATION CAUSING SHUTDOWN.

2 REQUIRES DOUBLE FAILURE - NEGLIGIBLE PROBABILITY.

NAME ROLF LUTH	DATE 8/7/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM-UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I - FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
DRIVE TRAIN	GEARS AND SHAFTS	PAGE 41 FMEA NO 5.3.2

FUNCTION OF COMPONENT

TO TRANSFER ROTOR TORQUE AND INCREASE RPM (FROM 17.5 RPM TO 1800 RPM)

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 LOSS OF LOAD PATH DUE TO CHIPPED GEAR OR SHEARED SHAFT - WOULD ALLOW ROTOR TO FREE WHEEL.	F,G,H
2 DAMAGED GEAR TEETH - COULD EVENTUALLY LEAD TO FM(1) ABOVE	F,G,H
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	5	3.4	667				X
2	95	3.4	35			X	
3							
4							

FAILURE DETECTION METHODS

1 LOSS OF GENERATOR LOAD DUE TO BROKEN LOAD PATH WILL INITIATE (TECHNICAL) EMERGENCY SHUTDOWN AS UTILITY TRIES TO DRIVE GENERATOR. (2) DAMAGED GEAR TEETH SHOULD BE INDICATED BY CHIP DETECTOR IN SUMP WHICH SHUTS DOWN SYSTEM. ROTOR OVERSPEED WILL ALSO INITIATE SHUTDOWN, VIA RPM SENSOR.

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Rotor overspeed will be within design limits

NAME ROLF LUTH DATE 8/7/8

OPERATING MODES Rev. 10/25/78

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G - OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 42
DRIVE TRAIN	GEAR BOX BEARINGS	FMEA NO 5.3.3

FUNCTION OF COMPONENT

TO ALIGN GEAR TRAIN COMPONENTS AND REDUCE GEAR/SHAFT FRICTION

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 BEARING FAILURE WHILE RUNNING - RESULTANT MISALIGNMENT OF GEARS	F,G,H
2 BEARING DETERIORATIONS - INCREASE IN TEMPERATURE AND NOISE LEVELS	All
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	10	11.4	100				X
2	90	11.4	11.1			X	
3							
4							

FAILURE DETECTION METHODS

1 1, 2 OIL TEMPERATURE AND VIBRATION SENSORS CAUSE SYSTEM SHUTDOWN.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

TEMPERATURE AND VIBRATION SENSORS WILL PICK UP IMPENDING FAILURE PRIOR TO SERIOUS STRUCTURAL DAMAGE.

NAME R. LUTH DATE 8/7/78

OPERATING MODES

Rev. 10/25/78

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I - FEATHER

MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 43
DRIVE TRAIN	HIGH SPEED SHAFT	FMEA NO 5.4.1

FUNCTION OF COMPONENT

TO TRANSMIT TORQUE FROM GEARBOX TO GENERATOR

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 BROKEN SHAFT - WOULD ALLOW ROTOR TO FREE WHEEL	F,G,H
2	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
	100	3.4	33.3			X	

FAILURE DETECTION METHODS

1 LOSS OF GENERATOR LOAD WOULD SHUT DOWN GENERATOR AND FEATHER BLADES. SHUTDOWN INITIATED THROUGH OVERSPEED SENSORS.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

ROTOR OVERSPEED PRIOR TO SHUTDOWN WOULD BE WITHIN DESIGN UNITS.

NAME R. LUTH DATE 8/7/78

OPERATING MODES

Rev. 10/25/78

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 44
DRIVE TRAIN	HIGH SPEED SHAFT COUPLING	FMEA NO 5.4.2

FUNCTION OF COMPONENT

TO TRANSMIT TORQUE FROM GEAR BOX TO GENERATOR AND TO ACCOMODATE SHAFT MISALIGNMENT

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 COUPLING STRUCTURAL FAILURE - WOULD PERMIT ROTOR TO FREE WHEEL	
2. COUPLING INCIPIENT FAILURE OR DAMAGE DUE TO OVERLOAD/OVERFLEX - - INCREASE IN TEMPERATURE AND DECREASE IN EFFICIENCY.	F,G,H
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ. %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	5	13.7	167			X	
2	95	13.7	8.8			X	

FAILURE DETECTION METHODS

1 BREAK IN LOAD PATH CAUSES LOSS OF GENERATOR LOAD WHICH INITIATES EMERGENCY SHUT DOWN

2 OF GENERATOR AND THE FEATHERING OF THE BLADES.

3 INEFFICIENT JOINTS CAN CAUSE UNDETECTED TEMPERATURE RISE - ULTIMATE FAILURE DETECTED PER FM(1) ABOVE.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

INSPECTION OF WTS @ 2-MONTH INTERVALS SHOULD DETECT INCIPIENT FAILURES.

NAME ROLF LUTH DATE 8/7/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H - TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM
DRIVE TRAIN

COMPONENT
ROTOR BRAKE

PAGE 45
FMEA NO 5.5

FUNCTION OF COMPONENT
TO POSITION AND HOLD ROTOR

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 HYDRAULIC/ELECTRIC FAILURE WOULD CAUSE BRAKE TO CLOSE WHICH WOULD BURN IT OUT AT FULL TORQUE.	F, G, H
2 FAILURE OF BRAKE TO OPERATE WOULD PERMIT BLADE TO STOP AT ANY ANGLE AND WOULD PRECLUDE HOLDING ROTOR IN SELECTED POSITION.	A, B,C,D,E,H,I

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1.	95	18.3	6.6			X	
2.	5	18.3	125		X		

FAILURE DETECTION METHODS

1. WTS SHUTDOWN UPON LOSS OF HYDRAULIC PRESSURE SENSED.
2. VISUAL INSPECTION

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

MOD-2 DESIGN INCORPORATES CAPABILITY TO MANUALLY TURN ROTOR AND LOCK LOW SPEED SHAFT IN DESIRED POSITION.

NAME ROLF LUTH DATE 8/7/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C - WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
DRIVE TRAIN	GEARBOX LUBRICATION	PAGE 46 FMEA NO 5.6.1

FUNCTION OF COMPONENT

PROVIDE LUBRICATION, AND REMOVE HEAT FROM THE GEARBOX BEARINGS AND GEARS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 LUBRICANT PUMP FAILURE - AUXILIARY PUMP IS STARTED -	F,G,H
2 SEAL FAILURE - LOSS OF FLUID - LOSS OF GEARBOX IF UNDETECTED	F, G, H
3 HEATER FAILURE - WTS WILL NOT START - LOW FLUID TEMPERATURE	F. G, H
4 BLOCKED FILTER - PRESSURE DIFFERENTIAL ACROSS FILTER TRIPS BYPASS VALVE, WTS SHUTDOWN AFTER TIME DELAY.	F,G,H,

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	100	20	6 ▷2		X ▷1		
2	100	10	12 ▷2		X ▷1		
3	100	5	30			X	
4		Not Applicable				X	

FAILURE DETECTION METHODS

1 VISUAL INSPECTION

2. WTS SHUTDOWN

3. WTS DOES NOT START

4. WTS SHUTDOWN

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

▷1 THE GEARBOX LUBE SYSTEM IS REDUNDANT. IF A PUMP FAILURE DOES NOT RESULT IN THE STARTING OF THE AUXILIARY PUMP THE WTS WILL SHUT DOWN.

▷2 PUMP AND SEALS ARE REDUNDANT. THIS FAILURE RATE IS FOR A SINGLE PUMP. PROBABILITY OF BOTH PUMPS FAILING BEFORE THE FIRST ONE IS REPAIRED IS NEGLIGIBLE.

NAME ROLF LUTH | DATE 10/20/78
Rev. 10/25/78
3/8/79

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 47
DRIVE TRAIN	ROTOR BEARING LUBRICATION	FMEA NO 5.6.2

FUNCTION OF COMPONENT

PROVIDE LUBRICATION FOR ROTOR BEARINGS

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SEAL FAILURE - LOSS OF LUBRICANT - POSSIBLE FLUID CONTAMINATION	F, G, H
2 CONTAMINATED FLUID - EXCESSIVE WEAR ON MOVING PARTS	F, G, H
3 OIL IS COLD - TOO THICK FOR PROPER LUBRICATION -	F, G, H
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	100	10	12			X 1	
2		Cannot be accurately estimated			X		
3		Negligible if oil changed			X		
4							

FAILURE DETECTION METHODS

1 BEARING OVERHEATS - WTS SHUTS DOWN - VISUAL INSPECTION

2 INSPECTION - VISUAL

3 NONE

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1. IF NOT DETECTED PRIOR TO WTS SHUTDOWN

FLUID WILL BE CHANGED AT SIX MONTH INTERVALS TO MINIMIZE CONTAMINATION AND ADJUST TO SEASONAL CHANGES.

NAME ROLF LUTH DATE 10/20/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I - FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 48
DRIVE TRAIN	GENERATOR LUBRICATION	FMEA NO 5.6.3

FUNCTION OF COMPONENT

PROVIDES LUBRICATION TO THE SLEEVE BEARINGS SUPPORTING THE GENERATOR ROTOR AT EACH END OF THE GENERATOR FRAME.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 LOSS OF OIL: LOSS OF LUBRICATION CAPABILITY	F,G
2 DIRTY OIL: EXCESSIVE WEAR ON MOVING PARTS	F,G
3 OIL TOO THICK (COLD)	F
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	100	10	11.4			X 1	
2		Negligible	with Preventative Maint.		X		
3	100	1	114			X	
4							

FAILURE DETECTION METHODS

1 WTS SHUTDOWN WHEN BEARING OVER TEMPERATURE IS PRESENT.

2 NONE, UNLESS OVERTEMP OCCURS

3 WTS IS SHUTDOWN

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1 IF UNDETECTED BY INSPECTION PRIOR TO WTS SHUTDOWN.

1. When oil level drops below oil ring, lubrication of the bearing begins to deteriorate until insufficient lubrication is possible. The bearings are excessively worn and temperature rises until bearing overtemperature protection initiates WTS shutdown. On-site review of stored data will identify the source of trouble. Check oil-level sight gauge at each end of generator housing for low level or presence of oil on floor. Inspect and replace bearing if necessary.
2. Periodic maintenance should detect this condition.
3. Generator space heaters will keep the oil warm. See also FMED 6.8.3.11.

NAME H. ROTH DATE 10/20/8

OPERATING MODES Rev. 10/25/78

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM-UP	E STANDBY	H TRANSITION TO FEATHER
C WARM-UP	F TRANSITION TO OPERATE	I FEATHER

MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 49
DRIVE TRAIN ASSEMBLY - EPS	GENERATOR	FMEA NO 5.7

FUNCTION OF COMPONENT

CONVERTS SHAFT TORQUE AT 1800 RPM INTO ELECTRICAL POWER

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 ELECTRICAL WINDING FAIL TO OPEN. CAUSES LOSS OF ELECTRICAL POWER OUTPUT AND WTS SHUTDOWN	F, G
2 ELECTRICAL WINDING FAIL SHORTED OR GROUNDED: CAUSES LOSS OF ELECTRICAL POWER OUTPUT AND WTS SHUTDOWN	F, G
3 GENERATOR OVERHEATS. CAUSES GENERATOR CIRCUIT BREAKER TO OPEN WHICH CAUSES WTS TO SHUT DOWN.	F, G
4 GENERATOR MECHANICAL FAILURE: CAUSES ABNORMAL POWER GENERATION WHICH OPENS GENERATOR CIRCUIT BREAKER WHICH CAUSES SHUTDOWN.	F, G

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ. %	COMPONENT FAILURE RATE x 10 ^{6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1,2,3,4	100	10.3	11.1			X	

FAILURE DETECTION METHODS

1 POWER PROTECTIVE RELAYS SEE SECTION 6.8

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

GENERATOR HAS MULTIPLE PROTECTIVE DEVICES SENSING CURRENT, VOLTAGE AND TEMPERATURE. EACH INITIATES WTS SHUTDOWN UPON WARNING SIGNAL.

NAME G. TRUSK DATE 8/17/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 50
NACELLE	PRIMARY TRUSS STRUCT.	FMEA NO 6.1.1.

FUNCTION OF COMPONENT

PRIMARY TRUSS THAT SUPPORTS ROTOR SHAFT GEARBOX
GENERATOR SECONDARY STRUCTURE MISC. EQUIPMENT.
TRANSFERS LOAD TO YAW BEARING SUPPORT STRUCTURE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 CRACK IN WELD OR TRUSS MEMBERS INITIATES COLLAPSE OF NACELLE	ALL
2 CORROSION OF WELD OR MEMBER INITIATES COLLAPSE OF NACELLE	ALL
3 EXCESSIVE NACELLE DEFLECTION LONG TERM DAMAGE TO BEARINGS AND/OR COUPLING	F, G, H.
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1,2,3	100	11.4	10		X		

FAILURE DETECTION METHODS

1 HIGH LEVEL OF INITIAL INSPECTION OF WELDS AND STRUCTURE.

2 MORE FREQUENT INSPECTION INTERVAL

3 ALIGNMENT CHECK PERIODICALLY.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

WELD CRACKING FAILURE CAN BE REDUCED BY MORE EXTENSIVE INITIAL INSPECTION OF WELDS.
PERIODIC INSPECTION OF CRITICAL WELDS SHOULD DETECT CRACK BEFORE TOTAL MEMBER FAILURE.
MULTIPLE LOAD PATHS OF TRUSS STRUCTURE MAY ALLOW MORE EXTENDED INSPECTION INTERVAL.
CORROSION MAY BE PREVENTED BY FREQUENT PAINT TOUCHING-UP AND INSPECTION AND REPAIR ON CRITICAL MEMBERS.

NAME K. HERNLEY   DATE 8-16-78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H - TRANSITION TO FEATHER
C WARM-UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE	SECONDARY SUPPORT STRUCT.	PAGE 51 FMEA NO 6.1.2

FUNCTION OF COMPONENT

SUPPORTS ENCLOSURE AND WALKWAYS AROUND GENERATOR BAY

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 CRACKS IN WELDS ENCLOSURE DAMAGE -	ALL
2 CORROSION DAMAGE ENCLOSURE DAMAGE	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1,2	100	11.4	10		X		

FAILURE DETECTION METHODS

1 HIGH LEVEL OF INITIAL WELD INSPECTION

2 FREQUENT INSPECTION

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

WELD CRACKING CAN BE REDUCED BY MORE COSTLY INITIAL INSPECTION OR ENCLOSURE ISOLATION BY ELASTOMERIC MOUNTS. FREQUENT VISUAL INSPECTION WOULD DETECT FAILURES OF MEMBERS. MULTIPLE LOAD PATHS DECREASE PROBABILITY OF UNDETECTED FAILURE

NAME K. HERNLEY DATE 8-16-78

OPERATING MODES Rev. 10/25/78

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D - TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 52
NACELLE	YAW BEARING SUPPORT STRUCTURE	FMEA NO 6.1.3

FUNCTION OF COMPONENT

TRANSFERS LOADS FROM NACELLE TO YAW BEARING

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 CRACKS IN WELDS - NACELLE DISPLACEMENT	ALL
2 CORROSION OF WELD OR MEMBER - NACELLE DISPLACEMENT	ALL
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	Included in 6.1.1				X 1	X	
2					X 1	X	

FAILURE DETECTION METHODS

1

2 FREQUENT INSPECTION

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

WELD CRACKING CAN BE REDUCED BY HIGH LEVEL OF INITIAL INSPECTION.

FREQUENT INSPECTION OF CRITICAL WELDS MAY DETECT CRACK BEFORE FAILURE.

MULTIPLE WELDS & GUSSETS INCREASE TIME TO FAILURE

1 IF DETECTED EARLY

NAME K. HERNLEY DATE 8/16/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM UP
C - WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 53
NACELLE	FWD BEARING SUPPORT	FMEA NO 6.1.4

FUNCTION OF COMPONENT

TRANSFERS RADIAL LOAD FROM LIVE-SHAFT TO NACELLE TRUSS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 WELD FAILURE RESULTS IN ROTOR DISPLACEMENT	All
2 WILL DAMAGE/DESTROY BOTH SHAFT BEARINGS, LIVE SHAFT, AND COUPLING.	All
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1& 2		Included in 6.1.1				X	X*

FAILURE DETECTION METHODS

1 HIGH LEVEL INITIAL INSPECTION

2 FREQUENT INSPECTION

3 INCREASING VIBRATION SENSED BY #1 VIBRATION MONITOR RESULTING IN WTS SHUTDOWN.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

THE BEARING SUPPORT TO TRUSS WELD IS MOST VULNERABLE. ADDITIONAL WELD AREA & HIGH FACTOR OF SAFETY REDUCES POSSIBILITY OF CATASTROPHIC FAILURE. FREQUENT INSPECTION AND MAINTENANCE OF PROTECTIVE PAINT ELIMINATES CORROSIVE DAMAGE. REDUNDANT SUPPORT DESIGN REDUCES POSSIBILITY OF SUDDEN COLLAPSE.

* IF UNDETECTED

NAME K. HERNLEY | DATE 8/16/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I - FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE	AFT BEARING SUPPORT	PAGE 54 FMEA NO 6.1.5

FUNCTION OF COMPONENT

TRANSFERS RADIAL & THRUST LOADS FROM LIVE SHAFT TO NACELLE TRUSS

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 WELD FAILURE LIVE SHAFT LIFTS & JAMS DRIVE TRAIN	F, G, H
2	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	Included in 6.1.1					X	

FAILURE DETECTION METHODS

1 HIGH LEVEL OF INITIAL INSPECTION

FREQUENT INSPECTION BY MAINTENANCE PERSONNEL

#2 VIBRATION SENSOR INITIATES WTS SHUTDOWN

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

THE BEARING SUPPORT TO TRUSS WELD IS MOST VULNERABLE. THERE ARE MULTIPLE LOAD PATHS, REDUNDANT STRUCTURE, AND HIGHER FACTORS OF SAFETY TO MINIMIZE PROBABILITY OF CATASTROPHIC FAILURE.

MAINTENANCE OF PAINT ELIMINATES CORROSIVE DAMAGE.

NAME K. HERNLEY DATE 8/16/78

OPERATING MODES

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A - SHUTDOWN
B - TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 55
NACELLE	ENCLOSURE	FMEA NO 6.1.6

FUNCTION OF COMPONENT

PROVIDES ADEQUATE ENVIRONMENTAL CONDITIONS FOR THE MAINTENANCE PERSONNEL & EQUIPMENT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SKIN OR STRINGER CRACKS AT FASTENERS LEAKS - EVENTUAL PARTIAL SKIN LOSS	All
2 CORROSION OF FASTENERS LEAKS - EVENTUAL PARTIAL SKIN LOSS	All
3 CORROSION OF SKIN OR STRINGERS RESULTING IN LEAKS	All
4 DAMAGE DUE TO LIGHTNING STRIKE AND/OR HAIL	All

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1-4	Included in 6.1.1			X			

FAILURE DETECTION METHODS

1-3 FREQUENT INSPECTION

4 GROUNDING OF STRUCTURE TO PROVIDE LIGHTNING PATH.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

MAINTENANCE OF PAINT AND CORRODED FASTENER REPLACEMENT WILL REDUCE CORROSIVE DAMAGE. CORRUGATED SKINS REDUCE NUMBER OF FASTENERS PERHAPS PERMITTING MORE COSTLY CORROSION RESISTANT FASTENERS.

NAME K. HERNLEY DATE 8/16/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM-UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 56
YAW DRIVE SYSTEM	BRAKE DISC	FMEA NO 6.3.1

FUNCTION OF COMPONENT
SUPPORTS YAW BEARING AND PROVIDES CLAMPING SURFACE FOR BRAKE CALIPERS

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 CRACKS, OR BREAKS - COULD CAUSE BRAKE FAILURE AND/OR YAW BEARING FAILURE	ALL
2 BRAKE SURFACE WARPING, PITTING, OR GALLING - CAUSING ERRATIC BRAKING	ALL
3 DIRT OR LUBRICANT ON DISC - ERRATIC OR CHATTERING BRAKES	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	33	4.6	75.8		X		X 1
2	33	4.6	75.8		X		
3	33	4.6	75.8		X		

FAILURE DETECTION METHODS

1 VISUAL INSPECTION OF DISC

2 ERRATIC BRAKING

3 SLOW OR ERRATIC YAW MOTION

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)
LOW ALLOWABLES WILL MINIMIZE POTENTIAL FAILURES.

1 IF UNDETECTED TO POINT OF YAW BEARING FAILURE

NAME J. W. ACKER DATE 8/7/78
Rev. 10/25/78

OPERATING MODES

A - SHUTDOWN	D TRANSITION TO STANDBY	G - OPERATE
B TRANSITION TO WARM UP	E STANDBY	H - TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
YAW DRIVE SYSTEM	BEARING, GEAR, PINIONS	PAGE 57 FMEA NO 6.3.2

FUNCTION OF COMPONENT

THE BEARING SUPPORTS THE NACELLE AND PERMITS IT TO YAW. THE GEAR (PART OF THE BEARING) AND PINION TRANSMIT YAW DRIVE TORQUE FROM THE DRIVE GEAR BOX TO THE YAW BEARING.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 BEARING STRUCTURAL FAILURE - COULD CAUSE WTS TO BECOME INOPERABLE.	F, G, H
2 GALLING, BRINELLING, FRETTING - COULD CAUSE YAW MOTION TO BE ERRATIC, SLOW, OR COMPLETELY STOPPED	F, G, H
3 GEAR FAILURE COULD CAUSE LOSS OF YAW ROTATION.	F, G, H
4 PINION FAILURE - WOULD CAUSE LOSS OF YAW DRIVE	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE × 10^6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1,2,3,4	100	1.1	100			X	

FAILURE DETECTION METHODS

1 VISUAL INSPECTION.

2 OBSERVATION OF ERRATIC YAW MOTION, OR LACK OF MOTION

3 EXCESS OR UNUSUAL NOISE.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

EXERCISE OF YAW SYSTEM TO MINIMIZE BRINELLING

BEARING GEAR AND PINION SHOULD BE DESIGNED WITH A "WEAK LINK" TO MINIMIZE DAMAGE TO EXPENSIVE COMPONENTS

NAME J. W. ACKER DATE 8/7/78

OPERATING MODES

Rev. 10/25/78
Rev. 11/27/78

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 58
YAW DRIVE SYSTEM	GEAR BOX	FMEA NO 6.3.3

FUNCTION OF COMPONENT

THE GEAR BOX PROVIDES TWO STAGES OF GEAR REDUCTION PERMITTING A HIGHER SPEED HYDRAULIC MOTOR TO DRIVE THE LOWER SPEED DRIVE PINION (AND LOW SPEED GEAR)

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 OIL SEAL FAILURE - LOSS OF LUBRICANT AND SUBSEQUENT GEAR BOX FAILURE	F,G,H
2 GEAR BOX SEIZES OR JAMS - WTS WILL NOT YAW: IN EXTREME WINDS COULD CAUSE STRUCTURAL FAILURE	F,G,H
3 GEAR BOX FAILS TO TRANSMIT TORQUE - WTS WILL NOT YAW OR COMMAND	ALL
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	85	14.8	9			X	
2	10	14.8	154			X	
3	5	14.8	308			X	

FAILURE DETECTION METHODS

BI-MONTHLY INSPECTION

2. WTS FAILURE TO YAW ON COMMAND

3. ERRATIC YAW MOTION

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

NAME J. W. ACKER

DATE 8/7/78
Rev. 10/25/78

OPERATING MODES

A - SHUTDOWN
B - TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 59
YAW DRIVE SYSTEM	HYDRAULIC MOTOR	FMEA NO 6.3.4

FUNCTION OF COMPONENT

THE HYDRAULIC MOTOR SUPPLIES THE PRIME POWER TO THE YAW DRIVE GEAR TRAIN, ON COMMAND, TO CAUSE THE WTS TO YAW. -

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 FLUID LEAKS EXTERNALLY - SYSTEM MAY LOSE PRESS. (FLUID) & FAIL TO OPERATE:	F, G, H
2 MOTOR FAILS TO OPERATE - SYSTEM WILL NOT YAW ON COMMAND	F, G, H
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	85	13.7	9.8		X	1 X	
2	15	13.7	55.6			X	

FAILURE DETECTION METHODS

1 LEAKS - VISUAL, RESERVOIR LEVEL DEPLETION, LOW HYD. PRESSURE, LOW TORQUES.

2 FAILURE TO YAW - WTS WILL NOT ASSUME COMMANDED POSITION

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1 CRITICAL IF UNDETECTED LEADING TO GEARBOX FAILURE.

NAME J. W. ACKER

DATE 8/8/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 60
YAW DRIVE SYSTEM	HYDRAULIC PUMP & MOTOR	FMEA NO 6.3.5

FUNCTION OF COMPONENT

SUPPLIES HYDRAULIC FLUID AT CONTROLLED 2000 PSI PRESSURE, ON DEMAND, TO OPERATE YAW HYDRAULIC MOTOR, YAW BRAKE CALIPERS, AND ROTOR BRAKE CALIPERS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 PUMP LEAKS EXTERNALLY - SYSTEM MAY BE DEPLETED, THEN FAIL TO OPERATE	F,G,H
2 PUMP FAILS TO MAINTAIN PRESSURE - SYSTEM MAY NOT FUNCTION PROPERLY (NO BRAKE RELEASE, SLOW YAW)	F,G,H
3 PUMP FAILS - RESULTING LOSS OF PRESSURE WOULD PROHIBIT BRAKE RELEASE OR YAW MOTION	F,G,H
4 MOTOR FAILS - SAME AS #3	F,G,H

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	33	3.4	101		X		
2	10	3.4	34			X	
3,4	57	3.4	58.5			X	

FAILURE DETECTION METHODS

1-4 WTS Shutdown (low pressure sensor)

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

NAME J. W. Acker DATE 8/8/78

OPERATING MODES

Rev. 10/25/78

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F - TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I - FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 61
YAW DRIVE SYSTEM	RESERVOIR	FMEA NO 6.3.6

FUNCTION OF COMPONENT

CONTAINS A SUPPLY OF HYDRAULIC FLUID FOR THE YAW HYDRAULIC SYSTEM

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 EXTERNAL LEAK - EVENTUALLY PRODUCES A LOW LEVEL ALARM, SPREADS OIL IN NACELLE, SHUTS DOWN SYSTEM	F, G, H
2 LIQUID LEVEL GAGE FAILS - PRODUCES FALSE HIGH OR LOW READINGS	F, G, H
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE × 10^6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	90	6.8	18.5		X - ▷		
2	10	6.8	68	X			

FAILURE DETECTION METHODS

1 VISUAL INSPECTION OF RESERVOIR, SPILLED OIL IN NACELLE

2 LOW SYSTEM PRESSURE OR LEVEL OR SYSTEM INOPERATIVE

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

▷ IF DETECTED BY INSPECTION PRIOR TO CRITICAL FAILURE

NAME J. W. ACKER DATE 8/8/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G - OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM-UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 62
YAW DRIVE SYSTEM	HEAT EXCHANGER	FMEA NO 6.3.6.2

FUNCTION OF COMPONENT

COOLS HYDRAULIC FLUID TO LIMIT MAXIMUM TEMPERATURE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 LEAKS FLUID, DEPLETES RESERVOIR, WTS SHUTS DOWN. WON'T YAW, WON'T RELEASE ROTOR BRAKE	F, G, H
2 THERMOSTAT FAILS, SYSTEM OVERHEATS, WTS SHUTS DOWN.	F, G, H
3 FAN FAILS, SYSTEM OVERHEATS, WTS SHUTS DOWN.	F, G, H
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	20	2.3	250		X	X ▷	
2	40	2.3	125			X	
3	40	2.3	125			X	

FAILURE DETECTION METHODS

1 OVERTEMPERATURE SIGNAL

2 LEAKING OIL IN NACELLE - VISUAL/LOW PRESS. SIGNAL

3 HYDRAULIC SYSTEM FAILURE - OVERTEMP SIGNAL

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

▷ CRITICAL IF NOT DETECTED PRIOR TO SHUTDOWN.

NAME J. W. ACKER DATE 8/8/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G - OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
YAW DRIVE SYSTEM	ACCUMULATORS (2)	PAGE 63 FMEA NO 6.3.6.3

FUNCTION OF COMPONENT

STORE ENERGY TO MAINAIN RELEASED ROTOR BRAKE IF SYSTEM FAILS.
REDUCE PUMP RIPPLE, DAMPEN HYDRAULIC SYSTEM PULSATIONS

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 GAS LEAKS-LOSS OF ACCUMULATOR CAPABILITY, RESULTING IN LOSS OF ABOVE FUNCTIONS	F, G, H
2 OIL LEAKS-LOSS OF ACCUMULATOR CAPABILITY, LOSS OF ABOVE FUNCTIONS POSSIBLE SYSTEM FAILURE	F, G, H
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	27.4	8.3			X	
2	50	27.4	8.3		X	X ▷	
3							
4							

FAILURE DETECTION METHODS

1 MONITOR GAS PRESSURES IN ACCUMULATORS
2 VISUAL INSPECTION FOR OIL LEAKS
MONITOR SYSTEM PRESSURE, RESERVOIR LEVEL

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1 If Undetected

NAME J. W. ACKER DATE 8/8/78

Rev. 10/25/78

OPERATING MODES

A - SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 64
YAW DRIVE SYSTEM	RELIEF VALVES (3)	FMEA NO 6.3.6.4

FUNCTION OF COMPONENT
TO PREVENT OVERPRESSURE OF THE HYDRAULIC SYSTEM IN THE EVENT OF A PUMP PRESSURE COMPENSATOR FAILURE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 LEAKS EXTERNALLY - MAY DEPLETE RESERVOIR AND CAUSE SYSTEM FAILURE	
2 LEAKS INTERNALLY - SYSTEM PRESSURE WOULD BE LOW, MAY NOT OPERATE YAW OR BRAKE ACTUATORS	F, G, H
3 FAILS TO OPEN AT PRESET PRESSURE, COULD CAUSE HYDRAULIC COMPONENT OVERPRESSURE IF PUMP COMPENSATOR FAILS	F, G, H
4	F, G, H

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	70	51.3	3.2			X	
2	20	51.3	11.1			X	
3	10	51.3	22.2		X	X ▷	

FAILURE DETECTION METHODS

1 VISUAL INSPECTION, WTS shutdown

2 PERIODIC TESTING FOR PRESSURE SETTING - LOW PRESSURE, WTS SHUTDOWN

3 SIGNAL SHUTS DOWN WTS.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

▷ CRITICAL IF PRESSURE LOSS SUFFICIENT TO INITIATE SHUTDOWN.

NAME J. W. ACKER | DATE 8/8/78

OPERATING MODES | Rev. 10/25/78

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 65
YAW DRIVE SYSTEM	SOLENOID VALVES (2)	FMEA NO 6.3.6.5

FUNCTION OF COMPONENT

TO RELEASE ROTOR BRAKE AND/OR YAW BRAKE, ON COMMAND

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 VALVE FAILS TO OPERATE - ROTOR BRAKE, OR YAW BRAKE WILL NOT RELEASE- WTS CANNOT START	F, G, H
2 VALVE FAILS TO DEACTIVATE - ROTOR BRAKE OR YAW BRAKE WILL NOT APPLY UNTIL PRESSURE IS RELEASED BY FLUID BLEEDING BACK THROUGH 3 SYSTEM, OR YAW CONTROL VALVE IS SHUTTLED.	A, B, C, D, E, I
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	95	27.4	4.4			X	
2	5	27.4	87.8			X	

FAILURE DETECTION METHODS

PERIODIC CHECK FOR VALVE OPERATION

2 BRAKE(S) FAIL TO RELEASE OR APPLY (WHEN SYSTEM IS OTHERWISE OK).

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

NAME J. W. ACKER   DATE 8/8/78

Rev. 10/25/78
Rev. 11/27/78

OPERATING MODES

A - SHUTDOWN
B - TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 66
YAW DRIVE SYSTEM	MOTOR CONTROL VALVE	FMEA NO 6.3.6.6

FUNCTION OF COMPONENT

CONTROLS YAW MOTION BY CONTROLLING FLOW AND DIRECTION OF FLOW OF HYDRAULIC FLUID TO YAW DRIVE MOTOR.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 LEAKS INTERNALLY - COULD CAUSE UNCONTROLLED, ERRATIC YAW MOTION	ALL
2 FAILS TO OPEN - WTS WILL NOT YAW ON COMMAND	F, G, H
3 FAILS TO CLOSE - WTS WILL NOT STOP. YAW BRAKE WILL NOT APPLY ON COMMAND	F, G, E, H, I
4 LEAKS EXTERNALLY - COULD DEPLETE SYSTEM FLUID, CAUSE OPERATIONAL FAILURE IF UNDETECTED	F, G, H

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	30	18.3	20.8		X		
2	10	18.3	62.6			X	
3	20	18.3	31.3		X		
4	40	18.3	15.6		X		

FAILURE DETECTION METHODS

1,2 ERRATIC MOTION IN YAW, DOES NOT FOLLOW COMMAND - MICROPROCESSOR SHUTS WTS DOWN.

4. VISUAL INSPECTION: LOSS OF PRESSURE SENSED; LOSS OF LEVEL SENSED.

3 WTS WILL SHUT DOWN IF YAW MOTOR MOVES NACELLE TO WRONG POSITION.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

NAME J. W. ACKER

DATE 8/9/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G - OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 67
YAW DRIVE SYSTEM	FITTINGS, TUBES, HOSES - YAW SYSTEM	FMEA NO 6.3.6.7

FUNCTION OF COMPONENT

SUPPLIES PRESSURIZED HYDRAULIC FLUID TO YAW HYDRAULIC MOTORS

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 RUPTURE - LOSS OF SYSTEM PRESSURE & FLUID - SYSTEMS WOULD FAIL TO OPERATE.	F, G, H
2. LEAKAGE	F, G, H
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	10	37.6	30.3			X	
2	90	37.6	3.4		▷ X	▷ X	

FAILURE DETECTION METHODS

VISUAL INSPECTION OF SYSTEM

LOW PRESSURE OR RESERVOIR LEVEL INDICATION RESULTING IN SHUTDOWN.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

▷ DEPENDS ON SEVERITY OF LEAK. LOSS OF PRESSURE INITIATES SHUTDOWN. MINOR LEAKS MAY BE DETECTED BY VISUAL INSPECTION.

NAME J. W. ACKER DATE 8/9/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F - TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
YAW DRIVE SYSTEM	FITTINGS, TUBES, HOSES, YAW BRAKE	PAGE 68 FMEA NO 6.3.6.8

FUNCTION OF COMPONENT

SUPPLIES PRESSURIZED HYDRAULIC FLUID TO YAW BRAKE CALIPERS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 RUPTURE - LOSS OF SYSTEM PRESSURE & FLUID SYSTEMS WOULD FAIL TO OPERATE	F, G, H
2 LEAK - LOSS OF SYSTEM PRESSURE & FLUID SYSTEMS WOULD FAIL TO OPERATE.	F, G, H
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	10	3.4	333			X	
2	90	3.4	37		x ▷	X	

FAILURE DETECTION METHODS

VISUAL INSPECTION

LOW PRESSURE OR RESERVOIR LEVEL RESULTING IN SHUTDOWN

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

▷

DEPENDS ON SEVERITY OF LEAK. LOSS OF PRESSURE INITIATES SHUTDOWN. MINOR LEAKS MAY BE DETECTED BY VISUAL INSPECTION.

NAME J. W. ACKER | DATE 8 /78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G - OPERATE
B TRANSITION TO WARM UP	E STANDBY	H - TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
YAW DRIVE SYSTEM	FITTINGS, TUBES, HOSES, ROTOR BRAKE	PAGE 69 FMEA NO 6.3.6.9

FUNCTION OF COMPONENT

SUPPLIES PRESSURIZED HYDRAULIC FLUID TO ROTOR BRAKE CALIPER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 RUPTURE - LOSS OF SYSTEM PRESSURE & FLUID, SYSTEM FAILS TO OPERATE	F, G, H
2 LEAKS - LOSS OF SYSTEM PRESSURE & FLUID, SYSTEM FAILS TO OPERATE	F, G, H
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	10	3.4	333			X	
2	90	3.4	37		1 X	X	

FAILURE DETECTION METHODS

VISUAL INSPECTION

LOW PRESSURE & RESERVOIR LEVEL RESULTING IN SHUTDOWN

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1 DEPENDS ON SEVERITY OF LEAK. LOSS OF PRESSURE INITIATES SHUTDOWN.

NAME J. W. ACKER DATE 8/8/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H - TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
YAW DRIVE SYSTEM	HIGH PRESSURE AND LOW PRESSURE/FILTERS	PAGE 69.1 FMEA NO 6.3.6.10,11

FUNCTION OF COMPONENT

THE FILTERS REMOVE CONTAMINANTS FROM THE YAW DRIVE SYSTEM HYDRAULIC FLUID.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 EXTERNAL LEAKS - COULD DEPLETE HYDRAULIC SYSTEM FLUID, CAUSING SYSTEM FAILURE.	F, G, H
2 PLUGGED FILTER - COULD RESULT IN CONTAMINATION AS FILTERS ARE BY-PASSED.	F, G, H
3	
4	

R

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	100	1	100		X	X ▷	
2		Not applicable				X	
3							
4							

FAILURE DETECTION METHODS

1 VISUAL - LOOK FOR EXTERNAL LEAKS

2 RESERVOIR OIL LEVEL INDICATOR WOULD INDICATE GROSS LEAK.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

▷ IF NOT DETECTED BY INSPECTION PRIOR TO SYSTEM SHUTDOWN.

2. FILTERS WILL BE CHANGED AT REGULAR MAINTENANCE INTERVALS.

NAME J. W. ACKER DATE 10/23/8

Rev. 10/25/78
3/8/79

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I - FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
YAW DRIVE SYSTEM	CHECK VALVES (4)	PAGE 69.2 FMEA NO 6.3.6.12

FUNCTION OF COMPONENT

CHECK VALVES ARE USED TO PREVENT FLUID FROM FLOWING IN A REVERSE DIRECTION IN FLUID LINES.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 FAILURE TO CHECK IN ROTOR BRAKE LINE - NO EFFECT UNLESS SOLENOID VALVE LEAKS ALSO. THEN ROTOR BRAKE WOULD CLAMP ON.	F, G, H
2 FAILURE TO CHECK IN YAW BRAKE LINE - NO EFFECT.	F, G, H
3 FAILURE TO CHECK IN PUMP OUTLET LINE - FLUID MAY BLEED BACK INTO PUMP ON SYSTEM SHUT-DOWN.	F, G, H
4 FAILURE TO CHECK IN PUMP CASE DRIVE LINE - PUMP CASE COULD BE PRESSURIZED IF SYSTEM RETURN PRESSURE WAS EXCESSIVE.	F, G, H

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	100	3	33		X		
2	100	3	33	X			
3	100	3	33	X			
4	100	3	33		X		

FAILURE DETECTION METHODS

1-4 SYSTEM FUNCTIONAL TEST, OR REMOVE AND TEST COMPONENT.

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NONE OF THESE FAILURES ARE CATASTROPHIC. MOST WOULD TAKE A DOUBLE FAILURE TO DO ANYTHING. THESE VALVES ARE IN THE SYSTEM AS A "BACK UP" ONLY.

NAME J. W. ACKER DATE 10/23/8

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
YAW DRIVE SYSTEM	NEEDLE VALVE	PAGE 69.3 FMEA NO 6.3.6.13

FUNCTION OF COMPONENT

THE NEEDLE VALVE IS USED TO ISOLATE THE SYSTEM PRESSURE GAGE SO IT MAY BE SERVICED OR CALIBRATED.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 EXTERNAL LEAK - COULD DEPLETE SYSTEM HYDRAULIC FLUID AND RESULT IN WTS SHUTDOWN.	F, G, H
2 FAILURE TO CLOSE OFF COMPLETELY - WOULD PRECLUDE DEAD-WEIGHT TESTING THE GAGE BECAUSE OF INTERNAL LEAK.	A
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	75	4.4	33			X ▷1	
2	25	4.4	100	X			
3							
4							

FAILURE DETECTION METHODS

1 EXTERNAL LEAK - VISUAL INSPECTION, OF RESERVOIR LEVEL INDICATOR

2 FAILURE TO CLOSE - WOULD BE OBVIOUS TO MAN CHECKING OR SERVICING GAGE.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

▷1 If undetected by visual inspection prior to WTS shutdown.

NAME J. W. ACKER DATE 10/23/8

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 70
YAW DRIVE SYSTEM	WEATHER SHIELD	FMEA NO 6.3.7

FUNCTION OF COMPONENT

SHIELDS YAW DRIVE SYSTEM BEARING, BRAKE CALIPERS, AND DISC FROM THE WEATHER

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 FAILURE OF THE WEATHER SHIELD WOULD HAVE ONLY LONG TERM DELETERIOUS EFFECTS ON YAW COMPONENTS	ALL
2 FAILURE DUE TO EXTREME WINDS, LIGHTNING STRIKE, AND/OR HAIL.	
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE × 10^6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1		Negligible		X			
2		Site dependent		X			

FAILURE DETECTION METHODS

1-2 VISUAL INSPECTION AT REGULAR INTERVALS & AFTER SEVERE WEATHER CONDITIONS.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

NAME J. W. ACKER DATE 8/8/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F - TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 71
YAW DRIVE SYSTEM	MISCELLANEOUS FASTENERS	FMEA NO 6.3.8

FUNCTION OF COMPONENT

FASTENERS HOLD BEARING AND HYDRAULIC COMPONENTS IN PLACE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 FAILURE OF ANY ONE FASTENER HAS NO EFFECT ON OPERATION OF WTS BECAUSE OF REDUNDANCY.	ALL
2	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1		Negligible		X			

FAILURE DETECTION METHODS

1 VISUAL INSPECTION ON REGULAR SCHEDULE.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

NAME J. W. ACKER

DATE 8/8/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 72
YAW DRIVE SYSTEM	BRAKE CALIPERS	FMEA NO 6 3.9

FUNCTION OF COMPONENT

1. CALIPERS ARE SPRING LOADED TO CLAMP ON DISC TO PROHIBIT YAW MOTION.
2. WHEN HYDRAULIC PRESSURE IS APPLIED, 6 of 7 BRAKES, RELEASE, PERMITTING YAW MOTION (7th BRAKE MAINTAINS DRAG ON DISC FOR DAMPING PURPOSES).

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 MECHANICAL OR SPRING FAILURE - BRAKE WOULD RELEASE, REDUCING YAW HOLDING OR DRAG TORQUE. ▷1	ALL
2 HYDRAULIC FAILURE - BRAKE WOULD NOT RELEASE, PROHIBITING OR INHIBITING YAW MOTION	E, G, L
3 BRAKE PAD FAILURE - YAW BRAKE TORQUE MAY NOT BE ADEQUATE FOR HURRICANE WINDS	A, E, I
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1		Negligible -	6 units for	holding yaw	position	▷2 X	
2			See 6 3.6.8			X	
3	100	Negligible -	6 Units for	holding yaw	position	▷2	X

FAILURE DETECTION METHODS

1 VISUAL INSPECTION - ALL MODES OF FAILURE

2 ERRATIC MOTION OR EXCESSIVE NOISE/LACK OF YAW MOTION ON COMMAND. WTS SHUTS DOWN

3 (LOW HYDRAULIC PRESSURE OR LEVEL SIGNAL).

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

▷1 REDUCING HOLDING TORQUE MAY ALLOW WTS TO WEATHERVANE. LOSS OF DRAG TORQUE MAY CAUSE YAW MOTION TO BE ERRATIC.

▷2 PROBABILITY OF FAILURE OF SPRING OR OTHER MECHANICAL ITEM ON THE SINGLE DRAG BRAKE IS APPROXIMATELY ONCE EVERY 10 YEARS AND WOULD BE DETECTED AT 2 MONTH INSPECTION PERIOD. PAD WEAR WILL BE CHECKED EVERY 2 MONTHS.

NAME J W. ACKER DATE 8/8/78

Rev. 10/25/78
Rev 11/27/78
3/8/79

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE
ENVIRONMENTAL CONTROL SYSTEM	COOLING EQUIPMENT	73
		FMEA NO 6.5.1

FUNCTION OF COMPONENT

FANS EXHAUST HOT AIR FROM NACELLE, DRAW AMBIENT AIR INTO NACELLE TO MAINTAIN LESS THAN 10% NACELLE SUPERHEAT ON WARM DAYS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 FAN OR MOTOR FAILS - NACELLE OVERHEATS - WTS shuts down if overheat affects components.	F, G, H
2	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	100	1.1	100		X	▷1	

FAILURE DETECTION METHODS

1 NACELLE TEMPERATURE SENSOR(S) INDICATE OVERTEMPERATURE

NACELLE OPERATING COMPONENTS INDICATE OVERTEMPERATURE

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

▷1 IF COMPONENTS OVERHEAT SUFFICIENTLY TO CAUSE WTS SHUTDOWN.

THE USE OF A NACELLE OVERTEMPERATURE SIGNAL DIRECTLY SHUTTING THE WTS DOWN IS CURRENTLY BEING CONSIDERED

NAME J. W. ACKER | DATE 8/7/78

Rev. 10/25/78
Rev. 11/27/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H - TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 74
ENVIRONMENTAL CONTROL SYSTEM	HEATING EQUIPMENT	FMEA NO 6.5.2

FUNCTION OF COMPONENT

TBD - THERE IS, AT THIS WRITING, NO KNOWN REQUIREMENT TO HEAT THE NACELLE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1	
2	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV

FAILURE DETECTION METHODS

1

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

NAME J. W. ACKER

DATE - 8/8/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	HIGH VOLTAGE POWER CABLE TO THE GENERATOR ACCESSORY UNIT	PAGE 74.1 FMEA NO 6.6.1.1.

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF HIGH VOLTAGE GENERATOR OUTPUT CURRENT FROM THE GENERATOR TO THE GENERATOR ACCESSORY UNIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: One or more high voltage power phases go to zero; GCB* and BTC* open, WTS shuts down.	G
2 Short circuit: Possible phase-to-phase or phase-to-neut fault; GCB and BTC open, WTS shuts down.	G
3 Grounded conductor: Massive fault on one conductor; GCB and BTC open, WTS shuts down.	G
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.6	142			X	
2	25	1.6	284			X	
3	25	1.6	284			X	
4							

FAILURE DETECTION METHODS

1 - 3. Power output from WTS indicates zero; BTC and GCB position indicate "open".

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1. Differential current protection relay will cause the GCB to open, or as a backup, the differential current protection will cause the BTC to open within milliseconds.
2. Generator or bus tie unit differential current protection or generator over-current protection circuits will cause the GCB and BTC to open within milliseconds.
3. Same as #2 plus the ground current relay will cause the GCB to open within milliseconds.

*GCB - Generator circuit breaker

*BTC - Bus tie contactor

NAME H. Roth

DATE 9/27/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	HIGH VOLTAGE POWER CABLES	PAGE 75 FMEA NO 6. 6.1

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF HIGH VOLTAGE GENERATOR OUTPUT CURRENT FROM THE GENERATOR ACCESSORY UNIT TO THE CABLE TRANSITION MECHANISM.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: One or more phases go to zero voltage; GCB* and BTC* open, WTS shuts down	G
2 Short circuit: possible phase-to-phase fault; GCB and BTC open, WTS shuts down	G
3 Grounded conductor· Massive fault on one conductor, GCB and BTC open, WTS shuts down.	G
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 ^{6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.6	142			X	
2	25	1.6	284			X	
3	25	1.6	284			X	

FAILURE DETECTION METHODS

1 - 3. Power output from WTS indicates zero; BTC and GCB position indicate "open."

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1. Differential current protection relay will cause the GCB to open, or as a backup, the differential protection circuit will cause the BTC to open within milliseconds.
2. Generator or bus tie contractor unit (BTCU) differential current protection or generator over-current protection circuits will cause the GCB and BTC to open within milliseconds.
3. Same as #2 plus the ground current relay will cause the GCB to open within milliseconds.

*GCB - Generator circuit breaker

BTC - Bus tie contractor

NAME G. Trusk/ H. ROTH DATE 8/17/78

Rev. 9/26/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B - TRANSITION TO WARM-UP	E STANDBY	H TRANSITION TO FEATHER
C WARM-UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE
NACELLE - EPS	MAIN 480 VOLT FEEDERS	76 FMEA NO 6.6.2.1

FUNCTION OF COMPONENT

PROVIDE A PATH FOR THE FLOW OF 480 VOLT ACCESSORY POWER FROM THE CABLE TRANSITION MECHANISM TO THE GENERATOR ACCESSORY UNIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: Limited excitation power available to generator loss of some single phase 480 V loads.	All
2 Short circuit: Same effect as open circuit, after appropriate protective device clearing.	All
3 Grounded conductor: Same effect as open circuit after appropriate protective device clearing.	All
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500			X	
2	25	.15	>3000			X	
3	25	.15	>3000			X	

FAILURE DETECTION METHODS

1-3. WTS will shutdown via Failsafe system.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

An uninteruptable power supply provides 40VDC power to protection devices and critical loads.

NAME H. ROTH G. Trusk DATE 8/17/78

Rev. 9/26/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 77
NACELLE - EPS	AC POWER CABLE TO THE CONTROL SYS	FMEA NO 6.6.2.2

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF ACCESSORY POWER FOR OPERATION OF THE CONTROL SYSTEM. CABLE RUNS FROM THE CB PANEL IN THE GENERATOR ACCESSORY UNIT TO THE NACELLE CONTROL UNIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Cable is open circuited. Computer becomes inoperative. WTS shuts down.	All
2 Cable is shorted to ground. Computer becomes inoperative. WTS shuts down.	All
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	75	.15	>1000			X	
2	25	.15	>3000			X	

FAILURE DETECTION METHODS

1 & 2. Power output from WTS indicates zero.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1 & 2. WTS shut down will be initiated via the failsafe shutdown system.

NAME G. Trusk / H. ROTH

DATE 8/17/78
Rev. 9/26/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	DC(UNINTERRUPTABLE) POWER CABLE TO THE CONTROL SYSTEM	PAGE 78 FMEA NO 6.6.2.3

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF UNINTERRUPTABLE DC FOR OPERATION OF THE CONTROL SYSTEM. CABLE RUNS FROM THE GENERATOR ACCESSORY UNIT TO THE NACELLE CONTROL UNIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Cable is open circuit: WTS shuts down	All
2 Cable is short to ground: WTS shuts down	All
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	75	.15	>1000			X	
2	25	.15	>3000			X	

FAILURE DETECTION METHODS

1 & 2. Power output from WTS indicates zero.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1 & 2. WTS shut down will be initiated via the failsafe shutdown system.

NAME G. TRUSK/ H. ROTH DATE 8/17/78

Rev. 9/26/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	POWER CABLE TO THE YAW DRIVE SYS	PAGE 79 FMEA NO 6. 6. 2.4

FUNCTION OF COMPONENT

PROVIDE A PATH FOR THE FLOW OF ACCESSORY POWER FOR OPERATION OF THE YAW DRIVE SYSTEM. CABLE RUNS FROM THE CIRCUIT BREAKER PANEL IN THE GENERATOR ACCESSORY UNIT TO THE YAW DRIVE SYSTEM.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Cable is open circuited. WTS shuts down	F, G, H
2 Cable is shorted to ground, protective circuitry clears, WTS shuts down	F, G, H
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	75	.15	>1000			X	
2	25	.15	>3000			X	

FAILURE DETECTION METHODS

1 & 2. Power output from WTS indicates zero.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

Yaw drive hydraulic pump motor does not run or develop sufficient power to maintain yaw accumulator pressure. Excessive difference between nacelle position indicator and wind sensors initiates shutdown.

NAME G. TRUSK/ H. ROTH

DATE 8/17/78
~~Rev. 9/26/78~~
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F - TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 80
NACELLE - EPS	POWER CABLE TO THE PITCH CONTROL SYSTEM	FMEA NO 6.6.2.5

FUNCTION OF COMPONENT

PROVIDE A PATH FOR THE FLOW OF ACCESSORY POWER FOR OPERATION OF THE PITCH CONTROL SYSTEM. CABLE RUNS FROM THE CIRCUIT BREAKER PANEL IN THE GENERATOR ACCESSORY UNIT TO THE LOW SPEED SHAFT SLIP RING ASSEMBLY.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Cable is open circuited (one or more conductors). WTS shuts down	F, G, H
2 Cable is short circuited to ground (one or more phase conductors). WTS shuts down	F, G, H
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	75	.15	>1000			X	
2	25	.15	>3000			X	

FAILURE DETECTION METHODS

1 Power output from WTS indicates zero

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

Pitch drive hydraulic pump motor does not run or develope sufficient power to maintain pitch accumulator pressure Loss of pressure causes controls to shut WTS down. Verify power cable continuity, repair as required.

NAME G. TRUSK / H. ROTH

DATE 8/17/78

Rev. 9/26/78
Rev. 10/25/78

OPERATING MODES

- A SHUTDOWN
- B TRANSITION TO WARM UP
- C - WARM UP
- D TRANSITION TO STANDBY
- E STANDBY
- F TRANSITION TO OPERATE
- G OPERATE
- H TRANSITION TO FEATHER
- I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	POWER CABLE TO GEARBOX OIL HEATERS	PAGE 81 FMEA NO 6.6.2.6

FUNCTION OF COMPONENT

PROVIDE A PATH FOR THE FLOW OF ACCESSORY POWER FOR OPERATION OF THE LUBE OIL HEATERS IN THE GEARBOX. CABLE RUNS FROM THE CIRCUIT BREAKER PANEL IN THE GENERATOR ACCESSORY UNIT TO THE GEAR BOX ASSEMBLY.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Cable open circuited (one or more conductors). If gearbox oil temp is low WTS will not enter "operate" mode	D, E, F, G, H
2 Cable is short circuited to ground (one or more phase conductors). Protective circuitry clears If gearbox oil temp is low WTS will not enter "operate" mode.	D, E, F, G, H
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	75	.15	>1000			1*	
2	25	.15	>3000			1*	

FAILURE DETECTION METHODS

1 Power output from WTS indicates zero.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

If gearbox oil temperature is low, verify continuity of gearbox heaters and power cable. Repair as required.

* If WTS has been operating, and/or air temp. is high enough to keep oil vescosity low failure will be "minimal."

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OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	POWER CABLE TO THE LUBRICATION SYSTEM	PAGE 82 FMEA NO 6 6.2.7

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF ACCESSORY POWER FOR OPERATION OF THE LUBRICATION SYSTEM. CABLE RUNS FROM THE CIRCUIT BREAKER PANEL IN THE GENERATOR ACCESSORY UNIT TO THE LUBE SYSTEM.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Cable is open circuited (one or more conductors). Lube system has redundant wiring and pumps.	All
2 Cable is short circuited to ground (one or more conductors). Protective circuitry clears. Lube system has redundant pump.	All
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	75	.15	>1000			X	--
2	25	.15	>3000			X	

FAILURE DETECTION METHODS

1 Failure of one pump results in operation of backup pump. Periodic maintenance detects this change.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

If both pumps fail loss of oil pressure results in WTS shutdown.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 83
NACELLE - EPS	POWER CABLE TO THE ENVIRONMENT CONTROL SYSTEM	FMEA NO 6.6.2.8

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF ACCESSORY POWER FOR OPERATION OF THE ENVIRONMENTAL CONTROL SYSTEM. CABLE RUNS FROM THE CIRCUIT BREAKER PANEL IN THE GENERATOR ACCESSORY UNIT TO THE ENVIRONMENTAL CONTROL SYSTEM.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Cable is open circuited (one or more conductors). ECS is inoperative. Nacelle temperatures may exceed allow limit	All
2 Cable is shorted to ground (one or more conductors). Protective devices clear. Nacelle temperaturs may exceed allowable limits.	All
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1 & 2	100	.15	>760	X		X*	

FAILURE DETECTION METHODS

1

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

Will be inspected at 2 month intervals.

* WTS will shut down if temperature falls or rises to unacceptable limits (control system will become inoperative resulting in shutdown).

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OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G - OPERATE
H TRANSITION TO FEATHER
I - FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	POWER CABLE TO THE ELECTRICAL FACILITIES EQUIPMENT	PAGE 84 FMEA NO 6.6.2.9

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF ACCESSORY POWER FOR THE OPERATION OF THE ELECTRICAL FACILITIES LOCATED IN OR ON THE NACELLE. CABLE RUNS FROM THE CIRCUIT BREAKER PANEL IN THE GENERATOR ACCESSORY UNIT TO LIGHTS, CONVENIENCE OUTLETS AND AIRCRAFT WARNING LTS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Cable is open circuited (one or more conductors). Affected function is inoperative (lights or portable equipment).	All
2 Cable is short circuited to ground (one or more conductors). Protective devices clear.	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1 & 2	100	.15	>760	X			

FAILURE DETECTION METHODS

1 Function (lights or portable equipment) is inoperative.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

Replace fuse/reset appropriate circuit breaker, repair as required

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OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F - TRANSITION TO OPERATE
G - OPERATE
H - TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 85
NACELLE - EPS	UNINTERRUPTABLE POWER FEEDERS	FMEA NO 6.6.2.10

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF UNINTERRUPTABLE POWER (DC) FROM THE CABLE TRANSITION MECHANISM TO THE GENERATOR ACCESSORY UNIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Cable is open-circuited. Emergency WTS shut down.	F, G, H
2 Cable is short circuited to ground. Protective devices clear, emergency WTS shut down.	F, G, H
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 ^{6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	75	.15	>1000			X	
2	25	.15	>3000			X	

FAILURE DETECTION METHODS

1 & 2. Power output from WTS indicates zero.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

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OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM UP
C - WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 86
NACELLE - EPS	GENERATOR CONTROL CABLE	FMEA NO 6.6.3.1.

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF GENERATOR EXCITATION CURRENT AND GENERATOR WINDING TEMPERATURE SIGNALS BETWEEN THE GENERATOR AND THE GENERATOR ACCESSORY UNIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 A conductor in cable is open circuited. Temperature data lost and/or generator excitation lost. WTS will shut down.	F, G, H
2 One or more conductors in cable are short circuited. Same effect as #1. WTS shuts down.	F, G, H
3 A conductor in cable is shorted to ground same effect as #1. WTS shuts down.	F, G, H
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500			X	
2	25	.15	>3000			X	
3	25	.15	>3000			X	
4							

FAILURE DETECTION METHODS

1 For temperature - no remote display. For excitation - GCB and BTC tripped, power from WTS indicates zero.

3 & 2 GCB and BTC tripped, power from WTS indicates zero.

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	CONTROL CABLE TO THE GENERATOR ACCESSORY UNIT	PAGE 87 FMEA NO 6.6.3.2

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF COMMANDS AND OPERATIONAL DATA BETWEEN THE NACELLE CONTROL UNIT AND THE GENERATOR ACCESSORY UNIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 A conductor in cable is open-circuit. WTS shuts down.	F, G, H
2 Two or more conductors in cable are shorted together. WTS shuts down.	F, G, H
3 A conductor with a control function is short-circuited to ground WTS shuts down	F, G, H
4 A conductor carrying operational data is short-circuited to ground. WTS shuts down	F, G, H

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	> 1500			X	
2	25	.15	> 3000			X	
3,4	25	.15	> 3000			X	

FAILURE DETECTION METHODS

1-4 Power output from WTS indicates zero, BTE is tripped.

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1-4. Either the generator field enable signal will not enable the field current relay, inhibiting excitation of the generator or a zero power signal generator output will prevent closing the BTC or cause it to trip.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 88
NACELLE - EPS	CONTROL CABLE TO THE ROTOR	FMEA NO 6.6.3.3

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF CONTROL SIGNALS AND OPERATIONAL DATA BETWEEN THE NACELLE CONTROL UNIT AND THE LOW SPEED SHAFT SLIP RING ASSEMBLY.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 A conductor in the cable is open-circuited. Loss of associated command function or data. *	F, G, H
2 Two or more conductors are shorted together. Loss of associated command function or erroneous data. *	F, G, H
3 A conductor in the cable is short-circuited to ground. Loss of associated command function or erroneous data: *	F, G, H
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^6$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500			X	
2	25	.15	>2000			X	
3	25	.15	>3000			X	

FAILURE DETECTION METHODS

1 - 3 None until WTS shuts down or fails to deliver power.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

See FMEA sheets 7.7.13 through 7.7.26
Failsafe system initiates shutdown if necessary.

* WTS may be shutdown or control function may be locked out or improper commands are issued which ultimately would lead to WTS shutdown.

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Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 89
NACELLE - EPS	CONTROL CABLE	FMEA NO 6.6.3.4

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF CONTROL SYSTEM OPERATIONAL DATA BETWEEN THE NACELLE CONTROL UNIT AND THE NACELLE MOUNTED WIND SENSOR.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 A conductor in cable is open-circuited. Wind data is lost from one sensor. WTS shuts down	E, F, G, H, I
2 A conductor in cable is short circuited to another conductor. Wind data is lost from one sensor. WTS shuts down.	E, F, G, H, I
3 A conductor in cable is shorted to ground. Wind data is lost from one sensor. WTS shuts down.	E, F, G, H, I
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 ^{6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500			X	
2	25	.15	>3000			X	
3	25	.25	>3000			X	

FAILURE DETECTION METHODS

1 NCU detects wind sensor difference between two sensors.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

Data from one wind sensor does not agree with data from the other wind sensor which causes the WTS to be shut down in the lockout mode.

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OPERATING MODES

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A SHUTDOWN
B TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	CONTROL CABLE TO THE TOWER	PAGE 90 FMEA NO 6.6.3.5

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF CONTROL SYSTEM COMMANDS AND OPERATIONAL DATA BETWEEN THE NACELLE CONTROL UNIT AND THE TOWER SLIP RING

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Wire in cable is open circuited. WTS may shut down, fail to connect WTS to utility, or not shut down when required.	ALL
2 Wire in cable is short circuited to ground. Same effect as No. 1	ALL
3 Wires in cable are shorted together. Same effect as No. 1	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	1400		X*	X*	
2	25	.15	2800		X*	X*	
3	25	.15	2800		X*	X*	
4							

FAILURE DETECTION METHODS

1-3 Loss of manual control; WTS shutdown if critical systems involved.

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

* Manual command "auto/shutdown" or status signals originating at the base may not be received by control equipment in the nacelle. Commands originating in the nacelle may not be received at the base (i.e., "synchronizer enable" or "utility bus tie disconnect"). If failure occurs while WTS is in the operate mode and "utility bus tie disconnect" command cannot be sent via the control system, the EPS "directional power" relay will trip the BTC when power reverses due to low or no wind; generator in the nacelle is protected from damage by protection devices located in, and controlled by, circuits within the nacelle.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 91
NACELLE - EPS	CONTROL CABLE TO THE GEAR BOX	FMEA NO 6.6.3.6

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF STATUS AND PERFORMANCE INFORMATION FROM THE GEARBOX TO THE NACELLE CONTROL UNIT

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Wire in cable is open circuited: WTS may shut down.	F, G, H
2 Wire in cable is shorted to ground: WTS may shut down.	F, G, H
3 Wires in cable are short circuited: WTS may shut down.	F, G, H
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE × 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	1400			X	
2	25	.15	2800			X	
3	25	.15	2800			X	
4							

FAILURE DETECTION METHODS *

1-3 If WTS shuts down, power output indicated is zero.

2 1-3

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1&2 WTS shuts down due to interpretation that data indicates rotor at zero speed, excessive vibration or excessive low speed bearing temperature.

2 WTS shuts down due to interpretation that data indicates rotor speed is excessive. If fault is on vibration or bearing temperature circuits, redundant signals are provided to maintain data integrity.

* See FMEA 7.7.7 through 7.7.12

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F - TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	CONTROL CABLE TO THE LUBRICATION SYSTEM	PAGE 92 FMEA NO 6.6.3.7

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF COMMANDS AND OPERATIONAL DATA BETWEEN THE NACELLE CONTROL UNIT AND THE LUBRICATION SYSTEM.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Wire in cable is open circuited: WTS may shut down. Oil pump may not be turned on or off, but redundant path provided.	F, G, H
2 Wire in cable is short circuited to ground: same effect as No. 1, additionally, data cannot be monitored.	F, G, H
3 Wires in cable are short circuited: WTS may shut down	F, G, H
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY *			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	1400		X*	X *	
2	25	.15	2800		X*	X *	
3	25	.15	2800		X*	X *	
4							

FAILURE DETECTION METHODS *

1

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Pump on/off commands may not be obeyed if command wires are faulted.

If status wires are faulted, WTS may shut down because data erroneously is interpreted to mean one of the following: excessive particles in lub oil, oil overtemperature, oil filter restricted or oil level is low. Oil pump may be erroneously commanded on or off.

* Depends upon which wire(s) faulty for details. See FMEA 7.7.2.8.- 7.7.3.5.

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OPERATING MODES

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A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	CONTROL CABLE TO THE YAW DRIVE SYSTEM	PAGE 92.1 FMEA NO 6.6.3.8

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF COMMANDS AND OPERATIONAL DATA BETWEEN THE NACELLE CONTROL UNIT AND THE YAW DRIVE SYSTEM CONTROLS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Wire in cable is open circuited: WTS shuts down or hydraulic pump cannot be turned on or off.	F, G, H
2 Wire in cable is short circuited to ground: same effect as #1 plus nacelle may yaw left or right.	F, G, H
3 Wires in cable are short circuited: no data monitored on shorted wires or hydraulic motor cannot be turned on or off or nacelle may yaw right or left.	F, G, H
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.1	200			X	
2	25	1.1	400			X	
3	25	1.1	400			X	
4							

FAILURE DETECTION METHODS

1-3 WTS shuts down. Manned substation receives alarm. On site data review will identify problem circuit, inspection is required to pinpoint specific problem.

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

See FMEAs 7.7.50 through 7.7.62.

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OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	SLIP RING BRUSH ASSEMBLY (DRIVE TRAIN)	PAGE 93 FMEA NO 6.6.4

FUNCTION OF COMPONENT

PROVIDES THE STATIONARY PORTION OF THE PATH FOR THE FLOW OF ELECTRICAL POWER AND SIGNALS BETWEEN THE NACELLE AND THE DRIVE TRAIN. ALSO PROVIDES A PROTECTED ELECTRICAL JUNCTION FOR INCOMING NACELLE CABLES

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 A brush fails to make contact with slip ring: loss of data or command function	ALL
2 High impedance contact between brush and slip ring: same effect as No. 1.	ALL
3 Conductive path between brushes	ALL
4 Conductive path between brush and structure or case	ALL

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	98	37.6	3.0 ▷			X	
2	1	37.6	303 ▷			X	
3	1	37.6	303 ▷			X	
4							

FAILURE DETECTION METHODS

1 -4 Inspection and continuity tests

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

See FMEA sheets 7.7.13 through 7.7.26 and 6.6.3.3

▷ Total for all signals

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 94
NACELLE - EPS	GENERATOR CIRCUIT BREAKER (GCB)	FMEA NO 6.8.1

FUNCTION OF COMPONENT

PROVIDES A MEANS TO OPEN THE HIGH VOLTAGE POWER OUTPUT LINES FROM THE GENERATOR.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Breaker contacts cannot be closed, WTS cannot enter operate mode.	E, F
2 Breaker contacts cannot be opened, generator may carry excessive fault currents. 2	F, G, H
3 Breaker contacts have high resistance. Excessive voltage drop causes heating of breaker	F, G, H
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	25	2.3	200			X	
2	25	2.3	200			X	
3	50	2.3	100	X			
4							

FAILURE DETECTION METHODS

1 Generator circuit breaker position indicator indicates open

2 Generator circuit breaker position indicator indicates closed, zero power output.

3 None-on-site; inspection may reveal higher temps or lower voltage than normal.

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1-3 Generator circuit breakers are in commercial use and should be very dependable.

2 Bus tie contactor unit has fuses that backup the GCB and protect the generator.

NAME G. TRUSK/H. ROTH | DATE 8/18/78

OPERATING MODES

Rev 10/12/78
Rev 10/25/78

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 95
NACELLE - EPS	VOLTAGE REGULATOR	FMEA NO 6.8.2.1

FUNCTION OF COMPONENT

ROVIDES AND CONTROLS DC POWER TO THE GENERATOR EXCITER

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Output voltage is zero: GCB & BTC trip. WTS shuts down.	F, G, H
2 Output voltage too low: GCB & BTC trip. WTS shuts down	F, G, H
3 Output voltage too high: GCB & BTC trip. WTS shuts down.	F, G, H
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	11.4	20			X	
2	25	11.4	40			X	
3	25	11.4	40			X	

FAILURE DETECTION METHODS

1, 2, 3 Power output from WTS indicates zero.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1. Prior to BTC closure: BTC will not close since power output from generator is zero. After BTC closure: Loss of excitation protection trips GCB.

2. Prior to BTC closure: Output voltage is high, synchronizer inhibits BTC closure. After BTC closure: Power factor becomes more leading, either power factor or overcurrent protection trips the GCB.

NAME G. TRUSK / H. Roth | DATE 8/17/78

REV. 10/9/78
REV. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELL EPS	POWER FACTOR CONTROLER (PFC)	PAGE 96 FMEA NO 6.8.2.2

FUNCTION OF COMPONENT

PROVIDES A FEEDBACK CONTROL SIGNAL TO THE VOLTAGE REGULATOR TO MAINTAIN A CONSTANT OUTPUT POWER FACTOR FROM THE GENERATOR.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 THE PFC DOES NOT PROVIDE CONTROL SIGNALS TO THE VOLTAGE REGULATOR (VR): POWER FACTOR IS NOT CONTROLLED, SEE 1.	G
2 THE PFC PROVIDES TOO HIGH A SIGNAL TO THE VR: PF IS LESS THAN DESIRED, SEE 1	G
3 THE PFC PROVIDES TOO SMALL A SIGNAL TO THE VR: PF IS GREATER THAN DESIRED, SEE 1.	G
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE - FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1,2,3,	100	22.8	5		X	2	

FAILURE DETECTION METHODS

1 -3 NO DETECTION OF FAILURE UNTIL CERTAIN ELECTRICAL PARAMETERS SUCH AS

~~2~~ DIFFERENTIAL CURRENT OR OVER-CURRENT ARE EXCEEDED.

~~3~~

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1-3 UNDER NORMAL WIND CONDITIONS NO PROBLEMS ARE ENCOUNTERED, THE VR PROVIDES SUFFICIENT CONTROL; HOWEVER, IF HIGH WIND GUSTS ARE PRESENT THE GENERATOR MAY SLIP A POLE AND EITHER DIFFERENTIAL CURRENT OR OVER-CURRENT PROTECTION CIRCUITS WILL INITIATE WTS SHUT DOWN. IF A POLE IS NOT SLIPPED THERE WILL BE KNOWLEDGE THAT PF IS EXCESSIVE.

2&3 IF PF IS OUT-OF-TOLERANCE, IT IS NOT DETECTED AND MAXIMUM REAL POWER IS NOT AVAILABLE FROM THE WTS.

1 UNDER GUSTY WIND CONDITIONS THE GENERATOR PULL-OUT TORQUE MAY BE EXCEEDED CAUSING THE GENERATOR TO SLIP A POLE WITH ATTENDANT VERY HIGH UNBALANCED PHASE CURRENTS, WTS MAY SHUT DOWN. 2 WTS SHUTS DOWN IF CURRENTS EXCEED CERTAIN LIMITS.

NAME G. TRUSK/H. ROTH DATE 8/17/78

Rev. 9/8/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 97
NACELLE - EPS	FIELD CURRENT RELAY	FMEA NO 6.8.2.3

FUNCTION OF COMPONENT

ROVIDES A DIRECT MEANS OF ENABLING AND DISABLING THE GENERATOR EXCITATION.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 FCR fails closed; excitation current cannot be removed from the generator field windings	G
2 FCR fails open, generator cannot be excited	F, G, H
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	20	3.4	168	X			
2	80	3.4	42			X	

FAILURE DETECTION METHODS

1 Generator output power present, BTC* indicates open.

2 Generator power indicates zero power, BTC* indicates open.

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

* Bus Tie Contractor

**Generator Circuit Breaker

NAME H. ROTH/G. TRUSK DATE 8/17/78

Rev. 9/25/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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SUBSYSTEM	COMPONENT	PAGE 98
NACELLE - EPS	OVER VOLTAGE RELAY	FMEA NO 6.8.3.1

FUNCTION OF COMPONENT

MONITORS THE GENERATOR OUTPUT VOLTAGE AND PROVIDES A SIGNAL TO THE CONTROL SYSTEM INITIATING SHUTDOWN WHEN THE GENERATOR VOLTAGE EXCEEDS A PRESET LIMIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Over voltage relay fails open. No effect.	F, G, H
2 Over voltage relay fails closed. WTS shutsdown.	F, G, H
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	80	3.4	42	X			
2	20	3.4	168			X	

FAILURE DETECTION METHODS

1 None

2 GCB and BTC position indicates open

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

Voltage while on line controlled by utility buss. If over excitation occurs while on line, over temp sensors will initiate shutdown.

DELETED - FUNCTION PERFORMED WITHIN SYNCHRONIZER

NAME H. ROTH/G. TRUSK DATE 8/17/78

Rev. 9/25/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B - TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 99
NACELLE - EPS	UNDER FREQUENCY RELAY	FMEA NO 6.8.3.2

FUNCTION OF COMPONENT

MONITORS THE GENERATOR OUTPUT VOLTAGE AND PROVIDES A SIGNAL TO TRIP THE GENERATOR CIRCUIT BREAKER WHEN THE GENERATOR POWER OUTPUT FREQUENCY FALLS BELOW A PRESET LIMIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Under frequency relay fails open. No effect.	F, G, H
2 Under frequency relay fails closed. GCB trips and WTS shuts down.	F, G, H
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	80	3.4	42	X			
2	20	3.4	168			X	

FAILURE DETECTION METHODS

1 None

2 GCB and BTC position indicates open.

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1. Under frequency caused by low rpm; if off-line rpm sensor results in redundant system. If on-line, utility buss controls frequency, any fluctions would be due to loss of utility power, initiating shutdown.

NAME H. ROTH G. TRUSK

DATE 8/17/78
~~Rev. 9/25/78~~
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 100
NACELLE - EPS	OVERCURRENT RELAY	FMEA NO 6.8.3.3

FUNCTION OF COMPONENT

MONITORS THE GENERATOR OUTPUT CURRENT AND PROVIDES A SIGNAL TO TRIP THE GENERATOR CIRCUIT BREAKER WHEN THE GENERATOR OUTPUT CURRENT EXCEEDS A PRESET LIMIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Overcurrent relay fails open: No effect	G
2 Overcurrent relay fails closed. GCB trips and WTS shuts down.	G
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE × 10[6] PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	80	3.4	42	X			
2	20	3.4	168			X	

FAILURE DETECTION METHODS

1 None

2 GCB and BTC position indicates open

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1. No overcurrent protection available to the generator; however, if overcurrent results from a fault condition, ground current sensing or differential current sensing will cause the GCB to open.

NAME H. ROTH/ G. TRUSK

DATE 8/17/78

rev. 9/25/78
rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE
NACELLE-EPS	REVERSE POWER RELAY	101 FMEA NO 6.8.3.4

FUNCTION OF COMPONENT

MONITORS THE GENERATOR OUTPUT POWER AND PROVIDES A SIGNAL TO TRIP THE GENERATOR CIRCUIT BREAKER WHEN THE GENERATOR OUTPUT POWER FALLS TO A LEVEL WHERE THE POWER FLOW MAY REVERSE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 RELAY FAILS OPEN: GENERATOR MAY ACT AS A MOTOR IF A REAL REVERSAL OF POWER OCCURS.	G
2 RELAY FAILS CLOSED: GCB TRIPS AND WTS SHUTS DOWN	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	80	3.4	42	X			
2	20	3.4	168			X	
3							
4							

FAILURE DETECTION METHODS

1 GENERATOR POWER INDICATION INDICATES NEGATIVE POWER IS GENERATED.

2 GENERATOR POWER INDICATION INDICATES ZERO POWER IS GENERATED; GCB AND BTC POSITION

~~3~~ INDICATES "OPEN"

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME G. TRUSK/H. ROTH

DATE 8/17/78
Rev. 9/8/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 102
NACELLE - EPS	GROUND CURRENT RELAY	FMEA NO 6.8.3.5

FUNCTION OF COMPONENT

MONITORS THE GENERATOR OUTPUT CURRENT FLOW IN THE NEUTRAL LINE TO GROUND AND PROVIDES A SIGNAL TO TRIP THE GENERATOR CIRCUIT BREAKER WHEN THE CURRENT FLOW RISES TO A PRESENT LEVEL TO INDICATE AN ELECTRICAL FAULT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 GCR fails open. No effect	G
2 GCR fails closed. WTS shuts down.	G
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 ^{6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	80	3.4	42	X			
2	20	3.4	168			X	

FAILURE DETECTION METHODS

1 None - Requires periodic check

2 GCB and BTC position indicates open

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

2. OPR or OCR will probably initiate shutdown, over temp. sensors would initiate shutdown if fault continued.

NAME G. TRUSK / H ROTH

DATE 8/17/78
Rev. 9/25/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 103
NACELLE - EPS	DIFFERENTIAL PROTECTION RELAY	FMEA NO 6.8.3.6

FUNCTION OF COMPONENT

MONITORS THE DIFFERENTIAL CURRENT FLOW IN THE VARIOUS BRANCHS OF THE GENERATOR STATOR WINDING AND PROVIDES A SIGNAL TO TRIP THE GENERATOR CIRCUIT BREAKER WHEN THE DIFFERENTIAL CURRENT EXCEEDS A PRESET LIMIT TO INDICATE A FAULT WITHIN THE DIFFERENTIAL PROTECTION ZONE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 DPR fails open, no effect	G
2 DPR fails closed, WTS shuts down	G
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	80	3.4	42	X			
2	20	3.4	168			X	

FAILURE DETECTION METHODS

1 None - Requires periodic checks

2 Generator power indiction indicates zero power; GCB and BTC position indicates "open".

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

NAME H. ROTH/ G. TRUSK DATE 8/17/78 Rev. 9/25/78 Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	GENERATOR WINDING OVER TEMPERATURE RELAY (OTR)	PAGE 103.1 FMEA NO 6.8.3.7

CTION OF COMPONENT

' THE TEMPERATURE SIGNAL OF EACH GENERATOR FIELD WINDING AND PROVIDES A SIGNAL TO THE CONTROL SYSTEM INITIATING A SHUTDOWN WHEN ANY WINDING EXCEEDS A PRESET LIMIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Relay fails open: Generator may operate with overheated windings resulting in eventual destruction of interwiding insulation and massive internal fault currents	G
2. Relay fails closed: WTS shuts down	G
3	
4	

FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10^6 PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	80	3.4	42				1*
2	20	3.4	168			X	

DETECTION METHODS

1 & 2. GCB & BTBS open, power output from WTS indicates zero.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1. Excessive winding temperatures are caused by either internal or external faults that should be sensed by over-current, differential current or ground current protective curcuits that trip the GCB and cause WTS shut-down. Once the generator is shut-down via the OTR the control system will prevent re-enabling the generator exitation until the winding temperature is within acceptable limits.

1* only if backup protection devises fail (i.e., Over-current, differential current, or ground fault) (Less than .1% chance per 30 years).

NAME H. ROTH DATE 9/27/78

OPERATING MODES

A SHUTDOWN
B - TRANSITION TO WARM UP
C WARM UP
D - TRANSITION TO STANDBY
E STANDBY
F - TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 103.2
NACELLE - EPS	GENERATOR BEARING OVERTEMPERATURE RELAY	FMEA NO 6.8.3.8

FUNCTION OF COMPONENT

Provides a signal to the control system to shutdown the WTS if a bearing over-temperature signal is received from the temperature sensors.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Relay fails open: Generator may operate with overheated bearings resulting in eventual destruction of the bearing. 1*	G
2 Relay fails closed: WTS shuts down.	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	80	3.4	42				1*
2	20	3.4	168			X	
3							
4							

FAILURE DETECTION METHODS

1 None remotely, until WTS shutdown.
2 BTC open, power output from WTS indicates zero.
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

The most probable cause for an overheated bearing is loss of lubricant. Control system has redundant inputs to effect normal shutdown or failsafe shutdown in the event of generator bearing overheat.

1* Bearing may seize and cause significant damage to the structure. This would require two relays to fail, due to redundant system. Probability of joint failure is less than .1% in 30 years.

NAME H. ROTH DATE 9/27/78

OPERATING MODES Rev 10/25/78

A SHUTDOWN
B TRANSITION TO WARM UP
C - WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	LOSS OF EXCITATION RELAY	PAGE 103.3 FMEA NO 6.8.3.9

FUNCTION OF COMPONENT

Provides a means to trip the generator circuit breaker when excitation power to the generator field is lost.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: Relay does not operate	F.G.
2 Relay does not issue GCB trip signal	F.G.
3 Relay issues GCB trip signal prematurely	F.G.
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	80	3.4	42			X	
2	10	3.4	333			X	
3	10	3.4	333			X	
4							

FAILURE DETECTION METHODS

1- 3 WTS Shut Down

2 X

3 X

4 X

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1 & 2 Damage may occur to the generator if excitation is lost and GCB is not tripped in a timely manner. Other protection devices will trip the BTC to remove the generator from the system.

NAME H. ROTH DATE 10-18-78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G - OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 103.4
NACELLE - EPS	POWER FACTOR RELAY	FMEA NO 6.8.3.10

FUNCTION OF COMPONENT

Provides a means to signal the control system to shut down if the power factor exceeds preset limits.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Relay does not operate: Power factor may exceed tolerable level causing generator heating.	G
2 Relay operates prematurely: Frequent unnecessary shut downs.	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	80	3.4	42			X	
2	20	3.4	167			X	
3							
4							

FAILURE DETECTION METHODS

1 WTS Shut Down When Generator Overtemperature Limits Are Exceeded.

2 WTS Shut Down

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME H. Roth DATE 10-18-78

Rev 10-25-78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C - WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G - OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	
NACELLE - EPS	GENERATOR BEARING UNDERTEMPERATURE RELAY	PAGE 103.5 FMEA NO 6.8.3.11

FUNCTION OF COMPONENT

PROVIDES A SIGNAL TO THE CONTROL SYSTEM FOR INHIBITING START-UP OF THE WTS WHEN THE GENERATOR BEARING TEMPERATURE IS TOO LOW.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Relay contacts stuck open: WTS rotor will not rotate or WTS will shut down.	F, G, H
2 Relay contacts remain closed: Generator may be rotated without lubrication. (Double failure)	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	80	3.4	42			X	
2	20	3.4	167	X			
3							
4							

FAILURE DETECTION METHODS

1 WTS will not start.

2 If damage is severe, eventual bearing over-temperature shutdown during "operate" mode.

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

2. Normally not detectable since relay contacts should be closed under conditions where maintenance personnel are at station. If relay is suspect, conduct operability test replace if required. This relay is a backup for the generator heater. If the heater fails, the relay protects the generator.

NAME H. Roth DATE 10-19-78

Rev 10-25-78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 104
NACELLE - EPS	POTENTIAL TRANSFORMER (PT)	FMEA NO 6.8.4.1

FUNCTION OF COMPONENT

PROVIDES A 0-115 VOLT SIGNAL PROPORTIONAL TO THE 0-4160 VOLT OUTPUT OF THE GENERATOR. THIS SIGNAL IS USED BY THE GENERATOR PROTECTIVE RELAYS AND THE GENERATOR INSTRUMENTATION TRANSDUCERS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Transformer is open-circuited, no effect	G
2 Transformer has short-circuited windings	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 ^{6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	25	1.1	400			X	
2	75	1.1	133			X	

FAILURE DETECTION METHODS

1 WTS shutdown

2 WTS shutdown 1*

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

Potential transformers are utilized for many functions· 1) Controls, 2) Voltage regulation, 3) Indication devices, 4) Over-voltage protection, 5) Watt-hour meters, 6) Watt-meter, and 7) Synchronizer circuits.

1* If PT is in a control circuit the WTS will shut down due to over-excitation

NAME G. TRUSK / H ROTH | DATE 8/17/78
Rev. 9/25/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C - WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE
NACELLE - FPS	CURRENT TRANSFORMER (CT)	105 FMEA NO. 6.8.4.2

FUNCTION OF COMPONENT

PROVIDES A 0-5 AMP ANALOG SIGNAL PROPORTIONAL TO THE 0-433 AMP GENERATOR OUTPUT LINE CURRENT. THIS SIGNAL IS USED BY THE GENERATOR PROTECTIVE RELAYS AND THE GENERATOR INSTRUMENTATION TRANSDUCERS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit in the current transformer secondary winding: no output from CT	G
2 Short circuit between individual turns of the current transformer: lower output from CT	G
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	25	1.1	400			X	
2	75	1.1	133			X	

FAILURE DETECTION METHODS

1 WTS shutdown

2 WTS shutdown

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

Current transformers are utilized for many functions: 1) Controls, 2) Voltage regulation, 3) Indication devices, 4) Over-current protection, 5) Watt-hour meters, 6) Watt-meter, 7) Ground fault protection, and 8) Differential protection circuits.

NAME G TRUSK/ H. ROTH DATE 8/18/78

Rev. 9/25/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I FEATHER

78 K-6162-001

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 106
NACELLE - EPS	VOLTAGE TRANSDUCER	FMEA NO 6.8.5.1

FUNCTION OF COMPONENT

PROVIDES A 0-1 MA OUTPUT ANALOG SIGNAL FROM THE 0-115 VOLT OUTPUT OF A POTENTIAL TRANSFORMER THIS SIGNAL IS PROVIDED TO THE CONTROL SUBSYSTEM AND TO A VOLTMETER DISPLAY.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit in the voltage transducer. No output from transducer.	G
2 Short circuit between individual turns of the voltage transducer. No or incorrect output from transducer.	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE $\times 10^{6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	25	1.1	400	X			
2	75	1.1	133	X			

FAILURE DETECTION METHODS

1 & 2. None. Voltage signal is for data purposes only.

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

1 & 2. Independant over voltage protection in provided.

NAME G. TRUSK/ H. ROTH

DATE 8/17/78
Rev. 9/25/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B - TRANSITION TO WARM-UP	E STANDBY	H TRANSITION TO FEATHER
C - WARM UP	F TRANSITION TO OPERATE	I - FEATHER

78-K-6162-001

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	CURRENT TRANSDUCER	PAGE 107 FMEA NO 6.8.5.2

FUNCTION OF COMPONENT

PROVIDES A 0-1 MA OUTPUT ANALOG SIGNAL FROM THE 0-5 AMP OUTPUT OF A CURRENT TRANSFORMER. THIS SIGNAL IS PROVIDED TO AN AMMETER DISPLAY.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: control system or ammeter sense zero current.	G
2 Short circuited: same as #1.	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	75	1.1	133	X			
2	25	1.1	400	X			
3							
4							

FAILURE DETECTION METHODS

1 -2 Zero current displayed at WTS site. No remote detection available.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Approximate current can be derived from displayed or stored real power data.

NAME G. TRUSK/H. ROTH DATE 8/17/78
REV 10/13/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 108
NACELLE - EPS	REAL POWER TRANSDUCER	FMEA NO 6.8.5.3

FUNCTION OF COMPONENT

PROVIDES A 0-1 MA OUTPUT ANALOG SIGNAL OF GENERATOR KW OUTPUT BASED ON INPUTS FROM POTENTIAL AND CURRENT TRANSFORMERS. THIS SIGNAL IS PROVIDED TO THE CONTROL SYSTEM AND TO A KW METER DISPLAY.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Output high: WTS shuts down.	G
2 Output low: WTS shuts down.	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	100	1.1	100			X	
2	100	1.1	100			X	
3							
4							

FAILURE DETECTION METHODS

1&2 WTS shuts down, zero power output, BTC indicates open.

~~2~~

~~3~~

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1. Real power signal is high. System operates at reduced power levels. Detected by comparison with other units in farm.
2. Real power is low. Control system uses real power data to set the rotor blade pitch. WTS shutdown will be initiated when generator protection sensors approach overstress limits.

NAME G. TRUSK/H. ROTH

DATE 8/17/78
REV 10/13/78
REV 10/25/78
REV 11/2/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	REACTIVE POWER TRANSDUCER	PAGE 109 FMEA NO 6.8.5.4

FUNCTION OF COMPONENT

PROVIDES A 0-1 MA OUTPUT ANALOG SIGNAL OF GENERATOR KVAR OUTPUT BASED ON INPUTS FROM POTENTIAL AND CURRENT TRANSFORMERS. THIS SIGNAL IS PROVIDED TO A KVAR METER DISPLAY.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Output high: incorrect on-site displays.	G
2 Output low: incorrect on-site displays.	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.1	200	X			
2	50	1.1	200	X			
3							
4							

FAILURE DETECTION METHODS

1-2 No remote detection available. KVAR meter display is not compatible with

~~2~~ voltage, current, power factor and KW meter displays.

~~3~~

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

KVAR's can be derived from other data displayed at site: voltage, current, power factor and real power.

NAME G. TRUSK/H. ROTH DATE 8/17/78

REV 10/13/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM-UP	E STANDBY	H TRANSITION TO FEATHER
C WARM-UP	F TRANSITION TO OPERATE	I - FEATHER

78 K 6162-001 REV 1

MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 109.1
NACELLE - EPS	GENERATOR TEMPERATURE TRANSDUCER	FMEA NO 6.8.5.5

CTION OF COMPONENT

ROVIDES A VARIABLE RESISTANCE PROPORTIONAL TO TEMPERATURE OF THE GENERATOR WINDINGS AND SUPPLIES THIS DATA TO THE GENERATOR WINDING OVER TEMPERATURE RELAY.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Transducer is open-circuit: Over temperature relay is activated.	G
2 Transducer is short-circuited: Over temperature relay is activated.	G
3 Transducer is shorted to ground: Over temperature relay may or may not be activated.	G
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	COMPONENT FAILURE RATE x 10 6 PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	10	1.1	1000			X	
2	80	1.1	125			X	
	10	1.1	1000			X	

JRE DETECTION METHODS

1-3 GCB is open, BTC is open, power output from WTS is zero. (WTS shutdown initiated prior to detaching generator output from the line.)

2

3

DISCUSSION AND CORRECTIVE ACTION (IF APPLICABLE)

NAME H. ROTH DATE 9/28/78

REV 10/25/78

OPERATING MODES

A SHUTDOWN	D - TRANSITION TO STANDBY	G - OPERATE
B - TRANSITION TO WARM-UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F - TRANSITION TO OPERATE	I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	ACCESSORY POWER TRANSFORMER	PAGE 110 FMEA NO 6.8.6

FUNCTION OF COMPONENT

TRANSFORMS 480 VOLTS TO 115/230 VOLTS TO PROVIDE ELECTRICAL POWER TO ACCESSORIES MOUNTED IN THE NACELLE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: WTS cannot start up or shut down via normal control system procedure.	B, C, D, E, F,G,H
2 Short circuit: Same as No. 1	B, C, D, E, F,G,H
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.1	200			X	
2	50	1.1	200			X	
3							
4							

FAILURE DETECTION METHODS

1-2 Zero power output indicated at manned substation

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1-2 Loss of nacelle 115/230 Vac incapacitates the control system. Generation system protection will function from uninterruptable power supply. Shutdown via this mode will not result in rotor overspeed beyond design limits.

NAME G. TRUSK/H. ROTH DATE 8/17/78

Rev 10/13/78
Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	480 VOLT CIRCUIT BREAKER PANEL	PAGE 111 FMEA NO 6.8.7.1

FUNCTION OF COMPONENT

PROVIDES FOR THE DISTRIBUTION AND PROTECTION OF 480 VOLT ACCESSORY POWER WITHIN THE NACELLE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: WTS cannot start up or will go to emergency shutdown.	ALL
2 Short circuit: same as No. 1	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	75	1.1	133			X	
2	25	1.1	400			X	
3							
4							

FAILURE DETECTION METHODS

1-2 Zero power output indicated at manned substation.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Battery will discharge if maintenance is not effected.

NAME G. TRUSK/H. ROTH

DATE 8/17/78
Rev 10/13/78
Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 112
NACELLE - EPS	115/230 VOLT CIRCUIT BREAKER PANEL	FMEA NO 6.8.7.2

FUNCTION OF COMPONENT

PROVIDES FOR THE DISTRIBUTION AND PROTECTION OF 115/230 VOLT ACCESSORY POWER WITHIN THE NACELLE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Individual circuit breakers open prematurely or fail to close.	ALL
2 Individual circuit breakers fail to trip when required	ALL
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.1	200	X		1*	
2	50	1.1	200	X		1*	
3							
4							

FAILURE DETECTION METHODS

1 See FMEA sheets for individual items.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1* Critical if faulty breaker affects critical control systems, otherwise minimal.

NAME B. TRUSK/H. ROTH | DATE 7/17/78

Rev 10/13/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C - WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	4.16 KV BUSES	PAGE 114 FMEA NO 6.8.8.1

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF 4.16 KV POWER WITHIN THE GENERATOR ACCESSORY UNIT

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Buses are short circuited: WTS shuts down	G
2 A bus is open circuited: WTS shuts down	G
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	25	2.3	66.7			X	
2	75	2.3	200			X	
3							
4							

FAILURE DETECTION METHODS

1 WTS is shut down.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1 & 2 Differential protection or ground protection will trip the generator circuit breaker.

NAME G. TRUSK/H. ROTH DATE 8/17/78

REV 10/13/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 115
NACELLE - EPS	480 VOLT CIRCUITS	FMEA NO 6.8.8.2

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF 480 VOLT POWER WITHIN THE GENERATOR ACCESSORY UNIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 A circuit is open circuited:	All
2 A circuit is shorted to ground: protective circuit breaker trips	All
3 Two circuits are shorted:	All
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.1	200				
2	25	1.1	400				
3	25	1.1	400				
4							

FAILURE DETECTION METHODS

1

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

See FMEA sheets for individual items receiving 480 volt power.

NAME G. TRUSK/H. ROTH DATE 8/17/78

REV 10/13/78

REV 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	115/230 VOLT CIRCUITS	PAGE 116 FMEA NO 6.8.8.3

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF 115/230 VOLT WITHIN THE GENERATOR ACCESSORY UNIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 A circuit is open circuit:	All
2 A circuit is shorted to ground: protective circuit breaker trips	All
3 Two circuits are shorted:	All
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY *			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.1	200				
2	25	1.1	400				
3	25	1.1	400				
4							

FAILURE DETECTION METHODS

1

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

* See FMEA sheets for individual items receiving 115/230 volt power

NAME G. TRUSK/H. ROTH   DATE 8/17/78
REV 10/13/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE	D.C. CIRCUITS	PAGE 117 FMEA NO 6.8.8.4

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF UNINTERRUPTIBLE DC POWER WITHIN THE GENERATOR ACCESS OXRY UNIT (GAU).

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit in individual circuit: loss of individual function	All
2 Short to ground on individual circuit: same as #1	All
3 Open circuit to the GAU: loss of generator protective functions, aircraft warning lights and WTS shuts down.	All
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	75	1.1	133	*		X	
2	75	1.1	133	*		X	
3	25	1.1	400			X	
4							

FAILURE DETECTION METHODS

1 & 2 Not remotely detectable.

2

3 WTS shuts down

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

See FMEA sheets for individual functions:

Generator protective devices (6.8.1, 6.8.3.1 through 6.8.3.8)

Aircraft warning lights (6.9.3)

Control system (memory and fail-safe shutdown circuits 7.7.4 and 7.7.6)

* Failure severity critical if WTS shuts down via fail-safe shutdown circuits.

NAME G. TRUSK/H. ROTH

DATE 8/17/78
REV 10/13/78
REV 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
NACELLE - EPS	CONTROL CIRCUITS	PAGE 118 FMEA NO 6.8.8.5

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF COMMAND, CONTROL AND INSTRUMENTATION SIGNALS WITHIN THE GENERATOR ACCESSORY UNIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Individual path is open circuited	F, G, H
2 Individual path is shorted to ground	F, G, H
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY *			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	75	2.3	66.7				
2	25	2.3	200				
3							
4							

FAILURE DETECTION METHODS

1
2
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

* See FMEA sheets for individual functions and failure severity (6.8.1 through 6.8.5.5).

NAME G. TRUSK/H. ROTH DATE 8/17/78

REV 10/13/78
REV 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 119
NACELLE - EPS	LIGHTING EQUIPMENT	FMEA NO 6.9.1

FUNCTION OF COMPONENT

PROVIDES ILLUMINATION OF NACELLE INTERIOR AREAS USED FOR MAINTENANCE AND REPAIR WHEN THE NACELLE IS OCCUPIED.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Individual circuit breakers supplying lighting circuits trip: respective lights extinguish.	A
2 Lamps burned out	A
3 115/230 V power failure: all lights go out	A
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	57	4	X			
2	40	57	5	X			
3	10	57	20	X			
4							

FAILURE DETECTION METHODS

1 Lights fail to illuminate or extinguish. No remote detection.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME G. TRUSK/H. ROTH — DATE 8/17/78

Rev 10/13/78
Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C - WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 120
NACELLE - EPS	CONVENIENCE OUTLETS	FMEA NO 6.9.2

FUNCTION OF COMPONENT

MAKES ACCESSORY POWER AVAILABLE FOR TEMPORARY USE WITHIN THE NACELLE FOR ASSEMBLY MAINTENANCE AND REPAIR TASKS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Individual circuit breakers supplying convenient outlets trip: No power available at outlet.	A
2 Open circuit to specific outlet: No power available at outlet.	A
3 115/230 V power failure: No power available at any nacelle convenience outlet	A
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	11.4	20	X			
2	25	11.4	40	X			
3	25	11.4	40	X			
4							

FAILURE DETECTION METHODS

1-3 Portable equipment fails to function

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME B. TRUSK/H. ROTH DATE 8/17/78

OPERATING MODES

Rev 10/13/78
Rev 10/25/78

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 121
NACELLE - EPS	AIRCRAFT WARNING LIGHTS	FMEA NO 6.9.3

FUNCTION OF COMPONENT

COMPLIES WITH FAA REQUIREMENTS TO PROVIDE VISUAL WARNING OF OBSTRUCTION TO LOW FLYING AIRCRAFT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Circuit breaker is tripped: high-intensity flashing white obstruction (HIFWO) lights are extinguished.	All
2 Wire to individual (one of three) high-intensity flashing white obstruction lights is open circuit: one HIFWO is extinguished.	All
3 Lamp malfunctions (burns out): individual HIFWO light is extinguished.	All
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	2	1140	5	X			
2	1	1140	10	X			
3	97	1140	.1	X			
4							

FAILURE DETECTION METHODS

1 -3 Alarm at manned substation. Visual observance at site.

~~2~~

~~3~~

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME G. TRUSK/H. ROTH

DATE 8/17/78
REV 10/13/78
REV 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	
TOWER SUBASSEMBLY	TOWER STRUCTURE	PAGE 122 FMEA NO 7.1.1

FUNCTION OF COMPONENT

THE TOWER STRUCTURE SUPPORTS AND PROVIDES MOUNTING PROVISIONS FOR THE YAW DRIVE SYSTEM, ELECTRICAL CABLES AND NACELLE ACCESS DEVICE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Structural failure to tower due to overload	All modes
2	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	negligible						X
2							
3							
4							

FAILURE DETECTION METHODS

1 Inspect tower if overload condition occurs.
2
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

The tower structure will be safe life designed, and no failures are anticipated unless loads greater than the design limit loads occur. Structural analysis will be performed using the MOD-2 WTS structural design criteria.

NAME J. SHULTZ DATE 8-14-78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 123
TOWER SUBASSEMBLY	NACELLE ACCESS DEVICE	FMEA NO 7.1 2

FUNCTION OF COMPONENT

THE NACELLE ACCESS DEVICE PROVIDES TRANSPORTATION FOR TWO PERSONS/AND OR MAINTENANCE EQUIPMENT BETWEEN THE GROUND AND THE TOP OF THE TOWER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Power lifting device malfunctions	Maintenance
2 Power lifting device cable brakes	Maintenance
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	99	1.1	101	X			
2	1	1.1	10,000	X			
3							
4							

FAILURE DETECTION METHODS

1 Periodic maintenance and inspections

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Use ladder backup system if lift malfunctions and repair lift.

Replace damaged cables and fittings.- Plan to use lift with 2 cables.

NAME J. SHULTZ DATE 8-14-78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER SUBASSEMBLY	LADDER	PAGE 124 FMEA NO 7.1.3

FUNCTION OF COMPONENT

THE LADDER PROVIDES A MEANS OF ENTERING AND EGRESSING THE NACELLE FROM THE POWER LIFT PLATFORM AND PROVIDES AN ALTERNATE SYSTEM IF THE POWER LIFT MALFUNCTIONS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Structural failure due to overload. failure.	maintenance
2	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1		Negligible		X			
2							
3							
4							

FAILURE DETECTION METHODS

1 Periodic visual inspections

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

No failure anticipated - ladder and attachments will be safe life designed - structural analysis will be performed using the MOD-2 WTS structural design criteria.

NAME J. SHULTZ DATE 8-14-78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 125
TOWER SUBASSEMBLY	TOWER FOUNDATION	FMEA NO 7.1.4

FUNCTION OF COMPONENT

The TOWER FOUNDATION SUPPORTS AND PROVIDES MOUNTING PROVISIONS FOR THE TOWER STRUCTURE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Structural failure of concrete foundation due to overload.	All modes
2 Structural failure of attachment bolts due to overload or corrosion.	All modes
3 Differential settlement of foundation due to overload resulting in excessive system tilt.	All modes
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1		Negligible				X	
2		Negligible				X	
3		Negligible				X	
4							

FAILURE DETECTION METHODS

1 Perioduc visual inspections

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

No failures anticipated unless loads greater than the design limit loads occur. Structural analysis will be performed using the MOD-2 WTS structural design criteria. Corrosion prevention finishes will be used and maintenance performed when required.

NAME J. SHULTZ DATE 8-14-78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM-UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD 2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 126
TOWER - EPS	TOWER-HIGH VOLTAGE CABLE	FMEA NO 7 2 1 1

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF HIGH VOLTAGE GENERATOR OUTPUT CURRENT FROM THE CABLE TRANSITION MECHANISM TO THE HIGH VOLTAGE JUNCTION BOX AT THE FOOT OF THE TOWER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 OPEN CIRCUIT: ONE OR MORE PHASES GO TO ZERO VOLTAGE; GCB OPENS, BTC (BUSTIE CONTACTOR) OPENS, WTS SHUTS DOWN.	G
2 SHORT CIRCUIT: POSSIBLE PHASE-TO-PHASE FAULT; GCB OPENS, BTC OPENS, WTS SHUTS DOWN.	G
3 GROUNDED CONDUCTOR MASSIVE FAULT ON ONE CONDUCTOR; GCB OPENS, BTC OPENS, WTS SHUTS DOWN.	G
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.8	286			X	
2	25	.8	578			X	
3	25	.8	578			X	
4							

FAILURE DETECTION METHODS

1 GENERATOR POWER INDICATION INDICATES ZERO POWER; BTC POSITION INDICATES "OPEN".

2 -3 GENERATOR POWER INDICATION INDICATES ZERO POWER; GCB AND BTC POSITION INDICATES BOTH ARE "OPEN".

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1 DIFFERENTIAL CURRENT PROTECTION RELAY WILL CAUSE THE GCB TO OPEN OR AS A BACKUP, THE DIFFERENTIAL CURRENT PROTECTION CIRCUIT WILL CAUSE THE BTC TO OPEN.

2 GENERATOR OR BTCU DIFFERENTIAL CURRENT PROTECTION OR GENERATOR OVER-CURRENT PROTECTION CIRCUITS WILL CAUSE THE GCB AND BTC TO OPEN

3 SAME AS 2 PLUS THE GROUND CURRENT RELAY WILL CAUSE THE GCB TO OPEN.

NAME G TRUSK/H. ROTH DATE 8/17/78

Rev. 9/8/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 127
TOWER - EPS	TOWER TO BTBU HIGH VOLTAGE CABLE	FMEA NO 7.2.1.2

FUNCTION OF COMPONENT

PROVIDES AN UNDERGROUND PATH FOR THE FLOW OF HIGH VOLTAGE GENERATOR CURRENT FROM THE JUNCTION BOX INSIDE THE FOOT OF THE TOWER TO THE BUS TIE BREAKER UNIT LOCATED OUTSIDE AND AWAY FROM THE TOWER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: one or more high voltage power phases go to zero volts: BTC opens, WTS shuts down	G
2 Short circuit: possible phase-to-phase or phase-to-neutral fault; BTC opens, WTS shuts down	G
3 Grounded conductor: massive fault on one high voltage conductor BTC opens, WTS shuts down	G
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.4	571			X	
2	25	.4	1143			X	
3	25	.4	1143			X	
4							

FAILURE DETECTION METHODS

1-3 WTS shut down

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1-3 Tower zone differential current protection relay will cause the BTC to open. As a backup: generator over-current or ground protection relay may trip the GCB; fused manual disconnect may fuse open.

NAME G. TRUSK/H. ROTH DATE 8/17/78

Rev 10/13/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	BTBU TO TRANSFORMER HIGH VOLTAGE CABLE	PAGE 128 FMEA NO 7.2.1.3

FUNCTION OF COMPONENT

PROVIDES AN UNDERGROUND PATH FOR THE FLOW OF HIGH VOLTAGE GENERATOR OUTPUT CURRENT FROM THE BUS TIE BREAKER UNIT TO THE INPUT SIDE OF THE POWER OUTPUT TRANSFORMER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: one or more high voltage power phases go to zero volts: BTC opens, WTS shuts down, accessory power is distributed at other than 3-phase.	G
2 Short circuit: possible phase-to-phase or phase-to-neutral fault; BTC opens, WTS shuts down, accessory power is distributed at other than 3-phase.	G
3 Grounded conductor: Massive fault on one high voltage conductor BTC opens, WTS shuts down, accessory power is distributed at other than 3 phase.	G
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.4	570			X	
2	25	.4	1140			X	
3	25	.4	1140			X	
4							

FAILURE DETECTION METHODS

1-3 WTS shut down

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1-3 For generator protection see FMEA 7.2.1.2

1-3 For accessory power utilization equipment protection (TBA) see also FMEA 7.2.2.1

NAME G. TRUSK/H. ROTH DATE 8/28/78

Rev 10/13/78
Rev. 10/25/78

OPERATING MODES

A - SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 129
TOWER - EPS	~~AERIAL~~ HIGH VOLTAGE CABLE	FMEA NO 7.2.1.4

FUNCTION OF COMPONENT

PROVIDES A PATH VIA ~~AERIAL~~ underground CONDUCTORS FOR THE FLOW OF GENERATOR POWER FROM THE OUTPUT SIDE OF THE POWER TRANSFORMER TO THE BLADE SIDE OF THE FUZED MANUAL DISCONNECT SWITCH.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Conductor open circuit: one or more high voltage power phases go to zero volts: BTC opens, WTS shuts down, accessory power is distributed at other than 3-phase.	G
2 Conductor short circuit: possible phase-to-phase or phase-to-neutral fault: BTC opens, WTS shuts down, accessory power is distributed at other than 3-phase.	G
3 Grounded Conductor: massive fault on one high voltage conductor BTC opens, WTS shuts down; accessory power is distributed at other than 3-phase.	G
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.4	571			X	
2	25	.4	1143			X	
3	25	.4	1143			X	
4							

FAILURE DETECTION METHODS

1-3 WTS shuts down

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1-3 For generator protection, see FMEA 7.2.1.2

1-3 For accessory power utilization equipment protection (TBA) see FMEA 7.2.2.1.

NAME G. TRUSK/H. ROTH DATE 8/17/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

Revision: 10/16/78
Rev. 10/25/78

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	ACCESSORY POWER FEEDER TO THE TOWER JUNCTION BOX	PAGE 130 FMEA NO 7.2.2.1

FUNCTION OF COMPONENT

PROVIDE AN UNDERGROUND PATH FOR THE FLOW OF NECESSARY POWER FROM THE BUS TIE BREAKER UNIT TO THE ACCESSORY POWER JUNCTION BOX AT THE BASE OF THE TOWER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: accessory power is distributed at other than 3-phase.	F, G, H
2 Short circuit: fused manual disconnect may fuse and accessory power distributed at other than 3-phase.	F, G, H
3 Grounded conductor: fused manual disconnect fuses and accessory power distributed at other than 3-phase.	F, G, H
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.13	1800			X	
2	25	.13	3600			X	
3	25	.13	3600			X	
4							

FAILURE DETECTION METHODS

1-3 WTS shut down.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

If power phase faulted is supplying the control system, WTS will go into emergency shutdown; if one of the other two phases, the WTS will probably shut down.

NAME G. TRUSK/H. ROTH DATE 8/17/78

REV 10/16/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE
TOWER - EPS	ACCESSORY POWER FEEDER TO THE NACELLE	131 FMEA NO 7.2.2.2

FUNCTION OF COMPONENT

PROVIDE A PATH FOR THE FLOW OF NACELLE ACCESSORY POWER FROM THE JUNCTION BOX AT THE BASE OF THE TOWER TO THE CABLE TRANSITION MECHANISM AT THE YAW BEARING.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open Circuit	F,G,H
2 Short Circuit	F,G,H
3 Grounded Conductor	F,G,H
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500			X	
2	25	.15	>3000			X	
3	25	.15	>3000			X	
4							

FAILURE DETECTION METHODS

1-3 WTS shutdown.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Same as FMEA 7.2.2.1

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DATE 8/17/78

Rev. 10/16/78

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	ACCESSORY POWER CABLE TO THE TOWER CONTROL UNIT	PAGE 132 FMEA NO 7.2.2.3

FUNCTION OF COMPONENT

PROVIDE AN UNDERGROUND PATH FOR THE FLOW OF ACCESSORY POWER FROM THE BUS TIE CIRCUIT BREAKER UNIT TO THE CONTROL SYSTEM'S TOWER CONTROL UNIT LOCATED INSIDE THE BASE OF THE TOWER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: loss of capability to communicate with nacelle control system.	Maintenance
2 Short circuit: Same as #1	Maintenance
3 Grounded Conductor. Same as #1	Maintenance
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.13	1800	X			
2	25	.13	3600	X			
3	25	.13	3600	X			
4							

FAILURE DETECTION METHODS

1 -3 None remotely

2 1-3 On Site: Inability to manually operate the WTS

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME G. TRUSK/H. ROTH DATE 8/17/8

OPERATING MODES

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A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	ACCESSORY POWER CABLE TO THE LIFT SYSTEM	PAGE 133 FMEA NO 7.2.2.4

FUNCTION OF COMPONENT

PROVIDE AN UNDERGROUND PATH FOR THE FLOW OF ACCESSORY POWER FROM THE BUS TIE BREAKER UNIT TO THE LIFT SYSTEM LOCATED IN THE BASE OF THE TOWER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open Circuit: Elevator will not operate	Maintenance
2 Short Circuit: Elevator protective circuit breaker trips, elevator will not operate	Maintenance
3 Grounded Conductor: Elevator protective circuit breaker trips, elevator will not operate	Maintenance
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500	X			
2	25	.15	>3000	X			
3	25	.15	>3000	X			
4							

FAILURE DETECTION METHODS

1-3 On-site elevator does not operate, associated circuit breaker is tripped

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Emergency egress from the lift is via a ladder with safety rail

NAME G. TRUSK/H. ROTH DATE 8/17/78

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Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	ACCESSORY POWER FEEDER TO TOWER ELECTRICAL FACILITIES	PAGE 134 FMEA NO 7.2.2.5

FUNCTION OF COMPONENT

PROVIDE A PATH FOR THE FLOW OF ACCESSORY POWER FROM THE BUS TIE BREAKER UNIT TO THE ELECTRICAL FACILITIES LOCATED AT THE FOOT OF THE TOWER

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open Circuit· lights or utility outlets not functional	Maintenance
2 Short Circuit· protective circuit breaker trips and lights or utility outlets not functional	Maintenance
3 Grounded Conductor, Proctective circuit breaker trips and lights or utility outlets not functional	Maintenance
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500	X			
2	25	.15	>3000	X			
3	25	.15	>3000	X			
4							

FAILURE DETECTION METHODS

1-3 None remotely

1-3 On Site: Lights out or electrical outlets not functionin g

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

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OPERATING MODES

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Rev. 10/25/78

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE
TOWER - EPS	ACCESSORY POWER CABLE TO THE POWER OUTPUT TRANSFORMER	135 FMEA NO 7.2.2.6

FUNCTION OF COMPONENT

PROVIDE AN UNDERGROUND PART FOR THE FLOW OF ACCESSORY POWER FROM THE BUS TIE BREAKER TO THE HIGH VOLTAGE POWER OUTPUT TRANSFORMER

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open Circuit: WTS shuts down, accessory power distributed at less than 3-phase.	All
2 Short Circuit: Same as #1, fused manual switch for accessory power may be fused open.	All
3 Grounded Conductor: Same as #2	All
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500			X	
2	25	.15	>3000			X	
3	25	.15	>3000			X	
4							

FAILURE DETECTION METHODS

1 WTS Shut Down

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1-3 Differential protection will trip the BTC if WTS in "Operate" mode.

NAME G. TRUSK/H. ROTH DATE 8/17/78

Rev 10/16/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F - TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	UNINTERRUPTABLE POWER FEEDER TO THE TOWER JUNCTION BOX	PAGE 136 FMEA NO 7.2.2.7

FUNCTION OF COMPONENT

PROVIDE AN UNDERGROUND PATH FOR THE FLOW OF UNINTERRUPTABLE (DC) POWER FROM THE BUS TIE BREAKER TO THE JUNCTION BOX LOCATED INSIDE THE BASE OF THE TOWER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open Circuit: No power to operate protection devices in BTCU.	F, G
2 Short Circuit: Same as #1	F, G
3 Conductor Grounded: Same As #1	F, G
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500			*	
2	25	.15	>3000			*	
3	25	.15	>3000			*	
4							

FAILURE DETECTION METHODS

1

1-3 WTS shutdown.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Conservative and redundant design of cable run & careful fabrication techniques should minimize the probability of this failure mode. If the following faults occur WTS will non shut down: Utility transformer low oil or overtemperature, reverse power or differential protection.

Utility transformer is protected against explosion and fire. Fused manual disconnect may fuse open under certain fault conditions.

NAME G. TRUSK/H. ROTH DATE 8/17/78

Rev. 10/16/78
Rev. 10/25/78
Rev. 11/27/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	UNINTERRUPTABLE POWER CABLE TO THE TOWER CONTROL UNIT	PAGE 137 FMEA NO 7.2.2.8

FUNCTION OF COMPONENT

PROVIDE AN UNDERGROUND PATH FOR THE FLOW OF UNINTERRUPTABLE POWER FROM THE BUS TIE BREAKER UNIT TO THE CONTROL SYSTEMS TOWER CONTROL UNIT MOUNTED INSIDE THE BASE OF THE TOWER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit. Loss of stored data	Maintenance
2 Short circuit· Same as #1	Maintenance
3 Conductor Grounded Same as #1	Maintenance
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.13	1800	X			
2	25	.13	3600	X			
3	25	.13	3600	X			
4							

FAILURE DETECTION METHODS

1 - 3 Remotely, None

~~1~~ 2 1-3*

~~1~~ 3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Data stored in memory is lost, maintenance personnel are not able to use on-site stored data for trouble identification. Trouble shooting procedures are adequate to isolate and identify source of malfunctions.

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Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE
TOWER - EPS	UNINTERRUPTABLE POWER FEEDER TO THE NACELLE	138
		FMEA NO 7.2.2.9

FUNCTION OF COMPONENT
PROVIDE A PATH FOR THE FLOW OF NACELLE UNINTERRUPTABLE (DC) POWER FROM THE JUNCTION BOX LOCATED INSIDE THE BASE OF THE TOWER TO THE CABLE TRANSITION MECHANISM AT THE YAW BEARING.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open Circuit	All
2 Short Circuit: Same as #1	All
3 Conductor Grounded	All
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY *			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE × 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500			X	
2	25	.15	>3000			X	
3	25	.15	>3000			X	
4							

FAILURE DETECTION METHODS

1-3 WTS shutdown.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Same as FMEA's 6.6.2.3 & 6.6.2.10

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE
TOWER EPS	CONTROL CABLE TO THE NACELLE	139 FMEA NO 7.2.3.1

FUNCTION OF COMPONENT

PROVIDE A PATH FOR THE FLOW OF CONTROL SYSTEM COMMANDS AND DATA FROM THE TOWER CONTROL UNIT INSIDE THE BASE OF THE TOWER TO THE CABLE TRANSITION MECHANISM AT THE YAW BEARING.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Wire is open circuit	All
2 Wires short circuited	All
3 Wire shorted to ground	All
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.15	>1500			X	
2	25	.15	>3000			X	
3	25	.15	>3000			X	
4							

FAILURE DETECTION METHODS

1 -3 WTS shutdown.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Same as FMEA 6.6.3.5

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	CONTROL CABLE TO THE BTB UNIT	PAGE 140 FMEA NO 7.2.3.2

FUNCTION OF COMPONENT

PROVIDE AN UNDERGROUND PATH FOR THE FLOW OF CONTROL SYSTEM COMMANDS AND DATA FROM THE TOWER CONTROL UNIT LOCATED INSIDE THE BASE OF THE TOWER TO THE BUS TIE BREAKER UNIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: BTB does not trip on WTS shutdown command, synchronizer cannot be enabled, utility bus tie or power status is not available.	F.G.
2 Short circuit: same as #1	F.G.
3 Grounded conductor: Same as #1	F.G.
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	.6	400	X			
2	25	.6	800	X			
3	25	.6	800	X			
4							

FAILURE DETECTION METHODS

1-3 None remotely

~~2~~ 1-3 On-site· Review of stored data

~~3~~

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Protective devices in the EPS will trip the BTC as a result of reverse power if WTS is shut down.

Also see FMEA 7.7.41 through 7.7.44

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OPERATING MODES

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A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	CABLE TRANSITION MECHANISM	PAGE 141 FMEA NO 7.3.

FUNCTION OF COMPONENT

PROVIDE A MEANS OF TRANSFERRING POWER AND SIGNAL ELECTRICAL CIRCUITS FROM THE NACELLE TO TOWER AROUND THE YAW BEARING THUS ALLOWING THE NACELLE TO ROTATE IN RELATION TO THE TOWER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuits or high impedance	ALL
2 Conductive path between brushes	
3 Conductive path to case	
4	

FAILURE FREQUENCY				FAILURE SEVERITY ▷			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	98	37.6	3.1 ▷				
2	1	37.6	303 ▷				
3	1	37.6	303 ▷				
4							

FAILURE DETECTION METHODS ▷

1

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

▷ Total for all signals

▷ See FMEA's 6.6.1.1, 6.6.1.2, 6.6.2.1 through 6.6.2.10 for failure severity and fault detection methods.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 142
TOWER - EPS	ELECTRICAL PATH ACROSS YAW BEARING	FMEA NO 7.4.1

FUNCTION OF COMPONENT

PROVIDE A PATH FOR THE FLOW OF LIGHTNING CURRENT THROUGH THE YAW BEARING.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 High resistance.	All
2	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	100	1.1	100	X			
2							
3							
4							

FAILURE DETECTION METHODS

1 Inspection
2
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Yaw bearing is massive and offers a very low resistance path to high currents resulting during lightning strokes.

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REV 10/17/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 143
TOWER - EPS	GENERATOR LIGHTING ARRESTORS	FMEA NO 7.4.2

FUNCTION OF COMPONENT

PROVIDE A LOW IMPEDANCE PATH FOR THE FLOW OF LIGHTNING INDUCED CURRENT FROM THE GENERATOR WINDINGS TO THE STRUCTURAL GROUND PATH OF THE SYSTEM. (THESE ARRESTORS ARE IN THE GENERATOR TERMINAL BOX).

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: No protection against lightning surge currents.	All
2	
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	100	1.1	100			X	
2							
3							
4							

FAILURE DETECTION METHODS

1 WTS shutdown

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

If lightning surge currents reach the generator winding, because the arrestor is open circuit, insulation damage can occur leading to an internal fault. Backup protection is provided by differential protection and ground current protection. Careful attention to lightning arrestor installation should be sufficient to preclude this failure mode.

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OPERATING MODES

A - SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM-UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	TRANSFORMER LIGHTNING ARRESTORS	PAGE 144 FMEA NO 7.4.3

FUNCTION OF COMPONENT

PROTECT THE TRANSFORMER WINDINGS BY PROVIDING A LOW IMPEDANCE PATH TO EARTH GROUND FOR LIGHTNING INDUCED CURRENT. (THESE ARRESTORS ARE LOCATED IN THE TRANSFORMER TERMINAL BOX).

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit. No protection against lightning surge currents.	All
2	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	100	1.1	100			X	
2							
3							
4							

FAILURE DETECTION METHODS

1 WTS Shut down

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

If lightning surge currents reach the transformer windings, because the arrestor is open circuit, insulation damage or flashover can occur leading to an internal fault. Backup protection is provided by differential protection.

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Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 145
TOWER - EPS	EARTH GRID	FMEA NO 7.4.4

FUNCTION OF COMPONENT

PROVIDE A SATISFACTORY ELECTRICAL CONNECTION WITH THE EARTH TO PROVIDE A CURRENT PATH FOR LIGHTNING AND ELECTRICAL FAULT CURRENTS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit possible: erratic relay operation, possible high potential between structures and earth.	All
2 High resistance circuit: same as #1.	All
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	25	1.1	400 ▷2			X	▷1
2	75	1.1	133 ▷2			X	▷1
3							
4							

FAILURE DETECTION METHODS

1 -2 None remotely.

? 1-2 On-site: erratic relay operation.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

During faults or lightning, lethal potential differences can occur between equipment and earth when the earth connection is either open circuited or has a high resistance. During normal operation protective relays may operate inadvertently to result in WTS shutdown and possible shock hazards to personnel may exist due to unbalanced loads. Special precautions will be taken to assure that grounds are properly installed and that earth/ground resistance is at safe levels.

▷1 If site is occupied- O&M Manual will prohibit maintenance during storms.

▷2 Without periodic inspections. With periodic inspections, frequency is over 100,000 years between failure.

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OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 146
TOWER - EPS	CONNECTION TO EARTH GRID	FMEA NO 7.4.5

FUNCTION OF COMPONENT

PROVIDE A PATH FOR THE FLOW OF LIGHTNING INDUCED CURRENTS AND ELECTRICAL FAULT CURRENTS IN THE WTS STRUCTURE TO THE EARTH GRID TO ALLOW THEIR SAFE DISSIPATION.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Same as FMEA 7.4.4	All
2	
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	100	1 1	100				
2							
3							
4							

FAILURE DETECTION METHODS

1

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Same as FMEA 7.4.4.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	BTBU ENCLOSURE	PAGE 147 FMEA NO 7.6.1.1

FUNCTION OF COMPONENT

PROVIDE A WEATHERPROOF HOUSING, A MOUNTING BASE AND A MEANS OF CONVENIENT ACCESS TO ALL THE EQUIPMENT AND WIRING PACKAGED WITHIN THE BUS TIE BREAKER UNIT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Enclosure leaks water or sand/dust into enclosure.	ALL
2	
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1		Negligible		X			
2							
3							
4							

FAILURE DETECTION METHODS

1 Inspection
2
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Proper positioning of parts to minimize water entering live circuits by baffling, channeling and drip proofing as well as close detail to weather-proofing or enclosure and drainage will preclude electrical failures due to water and particulate damage.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 148
TOWER -EPS	BUS TIE CONTACTOR (BTC)	FMEA NO 7.6.1.2

FUNCTION OF COMPONENT

PROVIDE A REMOTELY OPERATED, HIGH VOLTAGE, HIGH CURRENT, ELECTRICAL SWITCH TO PERMIT THE FREQUENT CONNECTING AND DISCONNECTING OF THE WTS ELECTRICAL POWER OUTPUT TO THE UTILITY TRANSMISSION LINE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 BTC FAILS OPEN· WTS CANNOT BE CONNECTED TO THE UTILITY TRANSMISSION LINE.	F,G,H
2 BTC FAILS CLOSED: GCB WILL OPEN, WTS SHUTS DOWN.	F,G,H
3 BTC HAS INTERNAL SHORT: POSSIBLE PHASE-TO-PHASE FAULT; GCB OPENS, BTC OPENS (IF POSSIBLE), WTS SHUTS DOWN.	F,G,H
4 BTC HAS INTERNAL FAULT TO GROUND: MASSIVE FAULT OF A PHASE CONDUCTOR: GCB OPENS, BTC OPENS (IF POSSIBLE), WTS SHUTS DOWN.	F,G,H

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	20	2.28	100			X	
2	30	2.28	167			X	
3	30	2.28	167			X	
4	20	2.28	100			X	

FAILURE DETECTION METHODS

1 GENERATOR POWER INDICATION INDICATES ZERO POWER, BTC INDICATES OPEN.

2 NOT DEFECTABLE UNTIL A DISCONNECT SIGNAL IS SENT AND NOT OBEYED.

3 & 4 GENERATOR POWER INDICATION INDICATES ZERO POWER, BTC AND GCB INDICATE OPEN.

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1-4 REPLACE THE BTC; THE BTC IS COMMERCIALLY AVAILABLE AND IN EXTENSIVE USE BY THE UTILITIES AND SHOULD BE VERY DEPENDABLE.

2 PROTECTIVE CIRCUITS TRIP THE GCB IF THE BTC HAS NOT OPENED AFTER IT SHOULD.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 149
TOWER - EPS	SYNCHRONIZER	FMEA NO 7.6.1.3.1

FUNCTION OF COMPONENT

DETERMINE WHEN VOLTAGE AMPLITUDES AND PHASE RELATIONSHIPS OF THE GENERATOR OUTPUT AND THE UTILITY TRANSMISSION LINE ARE WITHIN ACCEPTABLE, PRESET LIMITS AND PROVIDE A SIGNAL TO CLOSE THE BUS TIE CONTACTOR.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 FAILS TO OPERATE: WTS IS NOT CONNECTED TO UTILITY TRANSMISSION LINES.	F,G,H
2 OPERATES TO SYNC TOO EARLY: MECHANICAL DAMAGE POSSIBLE.	F,G,H
3 OPERATES TO SYNC TOO LATE: MECHANICAL DAMAGE POSSIBLE.	F,G,H
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1-3	100	▷				X	
2							
3							
4							

FAILURE DETECTION METHODS

1 GENERATOR POWER INDICATOR INDICATES ZERO POWER, BTC INDICATES OPEN.

2 &3 IN EXTREME OUT-OF-SYNC BTC CLOSURE, MECHANICAL DAMAGE MAY OCCUR TO THE GENERATOR OR

3 DRIVE TRAIN.

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

▷ Synchronizer is redundant, failure of one circuit results in disabling synchronizer. Resultant failure rate is negligible.

* FAILURE SEVERITY MAY BE CATASTROPHIC IF MECHANICAL FAILURE RESULTS.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE
TOWER - EPS	DIFFERENTIAL PROTECTION RELAY	150 FMEA NO 7.6.1.3.2

FUNCTION OF COMPONENT

MONITORS THE DIFFERENTIAL CURRENT FLOW IN THE WTS POWER OUTPUT CIRCUIT ZONE FROM THE CABLE TRANSITION MECHANISM TO THE FUSED MANUAL DISCONNECT SWITCH AND PROVIDES A SIGNAL TO OPEN THE BUS TIE CONTACTOR WHEN THE DIFFERENTIAL CURRENT EXCEEDS A PRESET LIMIT THUS INDICATING AN ELECTRICAL FAULT WITHIN THE PROTECTED ZONE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit in sensing wires: BTC trips or cannot be closed.	G
2 Trip setting is too low: BTC will trip too often on unbalanced loads or transients.	G
3 Trip setting too high: fault currents may continue to flow.	G
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	21	11.1			X	
2	25	21	22.2			X	
3	25	21	22.2			X	
4							

FAILURE DETECTION METHODS

1 WTS shut down

2 WTS shut down

3 WTS shut down

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1. Differential protection senses differential current in open phase. Trouble-shooting procedures will reveal source of trouble, repair as necessary.

2. Reset trip setting or replace differential protection relay in BTCU.

3. GCB will trip on overcurrent. Troubleshoot reset trip setting or replace differential protection relay as necessary.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	GENERATOR VOLTMETER	PAGE 151 FMEA NO 7.6.1.4.1

FUNCTION OF COMPONENT

PROVIDES A CONTINUOUS VISUAL DISPLAY OF THE MAGNITUDE OF THE OUTPUT VOLTAGE OF THE GENERATOR FOR USE DURING ACCEPTANCE TESTING, TROUBLE SHOOTING AND MAINTENANCE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Does not indicate: no effect	Maintenance
2 Indicates high or low: no effect	Maintenance
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1, 2	100	1.1	100	X			
2							
3							
4							

FAILURE DETECTION METHODS

1 Visual inspection
2 Visual inspection
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

See also FMEA 7.6.1.4.9

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OPERATING MODES

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A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 152
TOWER - EPS	UTILITY VOLTMETER	FMEA NO 7.6.1.4.2

FUNCTION OF COMPONENT

PROVIDES A CONTINUAL VISUAL DISPLAY OF THE MAGNITUDE OF THE UTILITY VOLTAGE AT ITS INTERFACE WITH THE WTS FOR USE DURING ACCEPTANCE TESTING, TROUBLE SHOOTING AND MAINTENANCE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Does not indicate: no effect	All
2 Indicates high or low: no effect	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1, 2	100	1.1	100	X			
2							
3							
4							

FAILURE DETECTION METHODS

1- 2 Visual Inspection

2 Periodic Calibration Check

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 153
TOWER - EPS	GENERATOR AMMETER	FMEA NO 7.6.1 4.3

FUNCTION OF COMPONENT

PROVIDES A CONTINUOUS VISUAL DISPLAY OF THE CURRENT FLOWING OUT OF THE GENERATOR

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Meter does not indicate: no direct reading of generator output current	G
2 Meter indicates high or low: incorrect generator output current data.	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1 ,2	100	1.1	100	X			
2							
3							
4							

FAILURE DETECTION METHODS

1 - 2	Visual and calculations
2	Periodic calibration check
3	
4	

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME G. TRUSK/H. ROTH DATE 8/17/8

OPERATING MODES

Rev. 8/18/8
Rev. 10/25/78

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 154
TOWER - EPS	LINE AMMETER	FMEA NO 7 6.1.4.4

FUNCTION OF COMPONENT

PROVIDES A CONTINUOUS VISUAL DISPLAY OF THE CURRENT FLOWING IN THE LINE BETWEEN THE WTS AND THE UTILITY

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Meter does not indicate: No direct reading of line current	All
2 Meter indicates high or low: incorrect line current data	All
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1, 2	100	1.1	100	X			
2							
3							
4							

FAILURE DETECTION METHODS

1 - 2 Visual and calculations

2 Periodic Calibration Check

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME G. TRUSK/H. ROTH DATE 8/17/8

Rev 10/18/78
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 155
TOWER - EPS	GENERATOR KW METER	FMEA NO 7.6.1.4.5

FUNCTION OF COMPONENT

PROVIDES A CONTINUOUS DISPLAY OF THE KW (POWER) BEING DELIVERED BY THE GENERATOR.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Meter does not indicate: No direct reading of power delivered by generator.	G
2 Meter indicates high or low: incorrect generator output power reading	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1,2	100	1.1	100	X			
2							
3							
4							

FAILURE DETECTION METHODS

1 - 2 Visual and calculations

2 Periodic calibration check

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME G TRUSK / H. ROTH DATE 8/17/8

OPERATING MODES

Rev. 10/18/8
Rev. 10/25/78

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 156
TOWER - EPS	GENERATOR POWER FACTOR METER	FMEA NO 7.6.1.4.6

FUNCTION OF COMPONENT

PROVIDES A CONTINUOUS DISPLAY OF THE POWER FACTOR OF CURRENT BEING DELIVERED BY THE GENERATOR.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Meter does not indicate: no direct reading of power factor delivered by the generator.	G
2 Meter indicates high or low: incorrect power factor data.	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1,2	100	1.1	100	X			
2							
3							
4							

FAILURE DETECTION METHODS

1 -2 Visual and calculations

2 Periodic Calibration Check

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME G. TRUSK/H. ROTH DATE 8/17/8

Rev. 10/18/8
Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 157
TOWER - EPS	GENERATOR KILOWATT- HOUR METER	FMEA NO 7.6.1.4.7

FUNCTION OF COMPONENT

PROVIDES A CONTINUOUS VISUAL DISPLAY OF THE ACCUMULATED KILOWATT-HOURS DELIVERED BY THE GENERATOR

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Meter does not operate: meter readings are incorrect.	G
2 Meter indicates high or low: meter readings are incorrect.	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE, x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1,2	100	1.1	100	X			
2							
3							
4							

FAILURE DETECTION METHODS

1 -2 Periodic reasonableness check.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME H. ROTH/G. TRUSK — DATE 8/17/8

Rev. 10/18/8

Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 158
TOWER - EPS	LINE KILOWATT - HOUR METER	FMEA NO 7 6.1.4.8

FUNCTION OF COMPONENT

PROVIDES A CONTINUOUS VISUAL DISPLAY OF THE ACCUMULATED KILOWATT - HOURS DELIVERED BY THE WTS TO THE UTILITY

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Meter does not operate: Meter readings are incorrect	All
2 Meter indicates high or low: incorrect power used/delivered displayed on meter	All
3	
4	-

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1,2	100	1.1	100	X			
2							
3							
4							

FAILURE DETECTION METHODS

1 -2 Visual inspection, periodic calibration checks.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME G. TRUSK/H. ROTH DATE 8/17/8

OPERATING MODES

Rev. 10/18/8
Rev. 10/23/78

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	POTENTIAL TRANSFORMER	PAGE 159 FMEA NO 7.6.1.4.9

FUNCTION OF COMPONENT

PROVIDES A 0-115 VOLT SIGNAL PROPORTIONAL TO THE 0-4160 VOLT LEVEL EXISTING AT THE POINT OF CONNECTION. THIS SIGNAL IS USED BY THE SYNCHRONIZER, VOLTMETER AND THE VOLTAGE TRANSDUCER

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Secondary or primary winding is open circuited: No output	F,G,H
2 Secondary or primary windings or short circuited	F,G,H
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	20	1.1	500			X	
2	80	1.1	125			X	
3							
4							

FAILURE DETECTION METHODS

1 WTS Shutdown

2 WTS shutdown.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Failures of potential transformers associated with control or protective relaying will result in WTS shutdown:

Voltage Transducer (voltage regulator)	See FMEA 6.8.2.1
Underfrequency Protection	See FMEA 6.8.3.2
Overvoltage Protection	See FMEA 6.8.3.1
Synchronizer	See FMEA 7.6.1.3.1
Synchronization Check	See FMEA 7.6.1.3.1
Power Factor Protection	See FMEA 6.8.3.10
Power Factor Control	See FMEA 6.8.2.2

For Metering Errors See FMEAS: 7.6.1.4.1, 7.6.1.4.2, 7.6.1.4.5 through 7.6.1.4.8

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE
TOWER - EPS	CURRENT TRANSFORMER	160 FMEA NO 7.6.1.4.10

FUNCTION OF COMPONENT

PROVIDES A 0-5 AMP SIGNAL PROPORTIONAL TO THE 0-433 AMP CURRENT IN THE LINE TO WHICH IT IS ATTACHED. THIS SIGNAL IS USED BY THE DIFFERENTIAL PROTECTION RELAY, AMMETER AND THE CURRENT TRANSDUCER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SECONDARY WINDING FAILS OPEN CIRCUIT: NO OUTPUT SIGNAL.	F,G,H
2 SHORT BETWEEN SECONDARY WINDINGS: INCORRECT TURNS RATIO.	F,G,H
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	20	1.1	500			X	
2	80	1.1	125			X	
3							
4							

FAILURE DETECTION METHODS

1 WTS Shutdown
2 WTS shutdown
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Failuresof current transformers associated with control or protective relaying will result in WTS shutdown.

Reverse Power Protection	See FMEA	6.8.3.4
Differential Protection	See FMEA	6.8.3.6 & 7.6.1.3.2
Power Factor Controller	See FMEA	6.8.2.2
Loss of Excitation Protection	See FMEA	6.8.3.9
Time Over-Current Protection	See FMEA	6.8.3.3
Ground Fault Protection	See FMEA	6.8.3.5

For Metering Errors See FMEAS: 7.6.1.4.3 through 7.6.1.4.8

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Rev. 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 161
TOWER - EPS	GENERATOR TOTAL RUNNING HOURS	FMEA NO 7.6.1.4.11

FUNCTION OF COMPONENT

PROVIDES A CONTINUOUS VISUAL DISPLAY OF THE TOTAL ACCUMULATED HOURS OF OPERATION OF THE GENERATOR

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Does not run or quits running: No direct display of correct generator running time.	G
2 Accumulate time too fast or slow: incorrect display of generator running time.	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1-2	100	6.8	16.7	X			
2							
3							
4							

FAILURE DETECTION METHODS

1-2 Visual and calculations.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Check wiring continuity to potential transformer, repair if needed; replace clock if required.

NAME G. TRUSK / H. ROTH

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 162
TOWER - EPS	BTC OPERATING CYCLES	FMEA NO 7.6.1.4.12

FUNCTION OF COMPONENT

PROVIDES A CONTINUOUS VISUAL DISPLAY OF THE NUMBER OF OPERATING CYCLES ON THE BUS TIE BREAKER. THIS IS MANDATORY DATA REQUIRED FOR BTC PREVENTATIVE MAINTENANCE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Does not register count: operating cycle data for the BTC is incorrect	F,H
2 Misses cycle counts. Operating cycle data for the BTC is incorrect.	F,H
3	
4	

FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1 &2	100	6.8	16.7	X			
2							
3							
4							

FAILURE DETECTION METHODS

1 & 2 Visual

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Operating cycle data is used for maintenance purposes, maximum time interval to BTC contact inspection and refurbishment will also be used.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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163 – 166 Missing

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 167
TOWER - EPS	4.16 kV TO 480 VOLT TRANSFORMER	FMEA NO 7.6.1.5.1

FUNCTION OF COMPONENT

PROVIDES ALL OF THE ACCESSORY POWER USED IN THE WTS

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit in primary or secondary windings: No output or non 3-phase output.	ALL
2 Internal short circuit: input fuzed manual switch fuses open, No output.	ALL
3 Internal ground fault: input fuzed manual switch, fuses open, no output.	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.1	200			X	
2	25	1.1	400			X	
3	25	1.1	400			X	
4							

FAILURE DETECTION METHODS

1-3 WTS is shut down.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

No accessory power available for housekeeping and maintenance functions

See also FMEAS 6.8.6, 6.8.7.1 and 6.8.7.2, 6.8.8.2-6.8.8.4, 6.9.1-6.9.3, 7.2.2.1-7.2.2.9, 7.6.1.6.2, 7.6.1.7.3-7.6.1.7.5

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE
TOWER - EPS	TRANSFORMER 480 VOLT TO 115/230 VOLT	168 FMEA NO 7.6.1.5.2

FUNCTION OF COMPONENT

PROVIDES ALL OF THE 115/230 VOLT ACCESSORY POWER USED IN THE TOWER BELOW THE CABLE TRANSITION MECHANISM.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 No output due to no input: no power for tower and base lights, convenience outlets, housekeeping and maintenance functions.	Maintenance
2 No output due to internal fault: circuit breaker trips, then same as #1.	Maintenance
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	-	-	-	X			
2	100	1.1	100	X			
3							
4							

FAILURE DETECTION METHODS

1-2 None, remotely

~~2~~1-2 On-site: no lights, stored data or convenience outlet power for trouble-shooting/repair equipment.

~~3~~

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Portable source of power required to effect troubleshooting/repair operations. Reset circuit breaker or replace transformer as required.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	BATTERY	PAGE 169 FMEA NO 7.6.1.6.1

FUNCTION OF COMPONENT

PROVIDES UNINTERRUPTIBLE POWER (DC) WHEN POWER FROM OTHER SOURCES IS NOT AVAILABLE. SUPPLIES THE ELECTRICAL POWER SYSTEM PROTECTIVE RELAYS AND PORTIONS OF THE CONTROL SYSTEM.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Discharged: WTS shuts down	All
2 Overcharged/Overheated. DC output voltage too high	All
3 Under temperature: DC output voltage is too low would result in WTS shut down.	All
4 Battery Internal Fault: Same as FM 1 if many cells are shorted WTS shutdown if open circuited.	

R

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1,4	70	11.4	14.3			X	
2	29	11.4	34.5	X			
3	1	11.4	1000			X	
4							

FAILURE DETECTION METHODS

1 WTS shuts down. On-site trouble shooting

2 On-site inspection of data.

3 None until needed, then emergency shut down

4 Same as FM 1

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Loss of battery supply 48V power results in WTS failsafe shutdown. Battery monitoring circuit detects open battery line. R

See also FMEA's 6.6.2.10, 6.8.8.4, 7.6.1.6.2 and 7.6.1.76

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 170
TOWER -EPS	BATTERY CHARGER	FMEA NO 7.6 1.6.2

FUNCTION OF COMPONENT

WHEN ENERGIZED, MAINTAINS THE BATTERY IN A STATE OF FULL CHARGE AND SUPPLIES UNINTERRUPT ABLE POWER (DC).

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Output remains high (not regulating properly): Battery overcharges DC voltage is high.	All
2 Output low (not regulating properly)· DC voltage is low and battery is undercharged.	All
3 No output. battery will be discharged, WTS will shut down.	All
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	25	2.3	200	X			
2	25	2.3	200			X	
3	50	2.3	100			X	
4							

FAILURE DETECTION METHODS

1 None - Requires on-site check

2 None - requires on-site check (if very low, WTS may shut down).

3 WTS shutdown (after battery discharges)

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Periodic inspection

See also FMEA 7.6.1.6.1

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 171
TOWER - EPS	BATTERY HEATER	FMEA NO 7.6.1.6.3

FUNCTION OF COMPONENT

MAINTAINS THE BATTERY TEMPERATURE AT OR ABOVE THE MINIMUM ACCEPTABLE LIMIT WHICH IN TURN MAINTAINS THE BATTERY OUTPUT VOLTAGE. HEATER IS ENERGIZED BY THE ACCESSORY POWER SYSTEM.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Heater is open circuit: Battery may be too cold. (See FMEA 7.6.1.6.1)	All
2 Heater thermostat is short circuited or stuck shut: battery may overheat and fail.*	All
3 No accessory power available: Same as #1	All
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	2.3	100	X			
2	25	2.3	200			X	
3	25	2.3	200	X			
4							

FAILURE DETECTION METHODS

1 & 3 None until battery power is needed.

2 None until battery is destroyed or maintenance personnel inspect.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1 & 3 Redundant heaters are provided.

2 Periodic inspection of battery electrolyte level and case temperature is necessary.

See also FMEA 7.6.1.6.2

* Pressure relief is provided to prevent dangerous pressure buildup.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 172
TOWER - EPS	HIGH VOLTAGE INPUT BUS	FMEA NO 7.6.1.7.1

FUNCTION OF COMPONENT

PROVIDES A POINT OF CONNECTION FOR THE INCOMING HIGH VOLTAGE POWER CABLES AND A PATH FOR POWER FLOW TO THE GENERATOR SIDE OF THE BUS TIE BREAKER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: WTS will not enter operate mode or will shut down	F, G
2 Short circuit. Same as #1	F, G
3 Grounded conductor: Same as #1	F, G
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.1	200			X	
2	25	1.1	400			X	
3	25	1.1	400			X	
4							

FAILURE DETECTION METHODS

1-3 WTS is shut down.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Protective relays prevent BTC from closing or trip the BTC.

NAME G. TRUSK/H. ROTH DATE 8/17/8

Rev. 10/17/8

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 173
TOWER - EPS	HIGH VOLTAGE OUTPUT BUS	FMEA NO 7.6.1.7.2

FUNCTION OF COMPONENT

PROVIDES A POINT OF CONNECTION FOR THE OUTGOING HIGH VOLTAGE POWER CABLES AND A PATH FOR POWER FLOW TO THE UTILITY SIDE OF THE BUS TIE BREAKER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: WTS will not enter operate mode or will shut down.	F,G
2 Short circuit: same as #1	F,G
3 Grounded conductor: same as #1	F,G
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.1	200			X	
2	25	1.1	400			X	
3	25	1.1	400			X	
4							

FAILURE DETECTION METHODS

1-3 WTS is shut down.

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1-3 Control system will not permit "operate" mode if utility power is sensed as not present or diff. prot. will trip BTC.

See also FMEA 7.2.1.1 through 7.2.2.9.

NAME G. TRUSK/H. ROTH

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OPERATING MODES

A - SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	480 VOLT ACCESSORY POWER CIRCUIT BREAKER PANEL	PAGE 174 FMEA NO 7.6.1.7.3

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF 480 VOLT ACCESSORY POWER WITHIN THE BUS TIE BREAKER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: Loss of individual 480V load function.	ALL
2 Short circuit. circuit breaker trips then same as No. 1	ALL
3 Conductor grounded: Same as No. 2	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY *			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.1	200				
2	25	1.1	400				
3	25	1.1	400				
4							

FAILURE DETECTION METHODS

1 -3 None, remotely

2 1-3 Onsite: loss of individual function

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

See FMEA 7.2.2.1 through 7.2.2.9, 6.8.7.1

NAME H. ROTH/G. TRUSK

DATE 8/17/78
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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C - WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	115/230 VOLT ACCESSORY POWER CIRCUIT BREAKER PANEL	PAGE 175 FMEA NO 7.6.1.7.4

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF 115/230 VOLT ACCESSORY POWER WITHIN THE BUS TIE BREAKER

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: loss of individual 115/230 V load function if feeder to tower.	All
2 Short circuit: circuit breaker trips, then same as #1.	All
3 Grounded conductor: same as #2.	All
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY *			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.1	200				
2	25	1.1	400				
3	25	1.1	400				
4							

FAILURE DETECTION METHODS

1 - 3 None, remotely

~~2~~ 1-3 On-site: loss of individual function

~~3~~

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

*See individual FMEA sheets.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
TOWER - EPS	UNINTERRUPTABLE POWER CIRCUIT	PAGE 176 FMEA NO 7.6.1.7.5

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF UNINTERRUPTABLE POWER WITHIN THE BUS TIE BREAKER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: power not available for operating protective relays in BTCU or to tower/nacelle	ALL
2 Short circuit: same as No. 1	ALL
3 Grounded conductor same as No. 1	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	1.1	200			X	
2	25	1.1	400			X	
3	25	1.1	400			X	
4							

FAILURE DETECTION METHODS

1 -3 WTS shuts down

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

See FMEA's 6.8.8.4, 7.2.2.8, 7.2.2.9.

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DATE 8/17/78
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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 177
TOWER - EPS	CONTROL CIRCUIT	FMEA NO 7.6.1.7.6

FUNCTION OF COMPONENT

PROVIDES A PATH FOR THE FLOW OF CONTROL SYSTEM COMMANDS AND DATA WITHIN THE BUS TIE BREAKER.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: associated relay will not function, loss of circuit protection; loss of status data.	F.G.
2 Short circuit: Same as No. 1, or relay functions inadvertently causing WTS shutdown.	F.G.
3 Grounded conductor: same as No. 1	F.G.
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	50	2.3	100			X	
2	25	2.3	200			X	
3	25	2.3	200			X	
4							

FAILURE DETECTION METHODS

1-3 WTS shutdown

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Generator protective circuits will trip the GCB if failure in BTCU jeopardizes the generator.

See also FMEA 7.2.3.2.

NAME G. TRUSK/H. ROTH DATE 8/17/78

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 178
TOWER - EPS	POWER OUTPUT TRANSFORMER	FMEA NO 7.6.2

FUNCTION OF COMPONENT

MATCHES THE OUTPUT VOLTAGE OF THE WTS GENERATION SYSTEM WITH THE VOLTAGE OF THE INTERFACING UTILITY POWER TRANSMISSION LINE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuited winding: WTS shuts down	G
2 Short circuited windings: WTS shuts down, fused manual disconnect switch fuses open.	G
3 Winding shorted to ground. same as #2	G
4 Oil overheated· WTS shuts down	G

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1 -3	90	1.1	111.1			X	
~~2~~ 4	10	1.1	1000			X	
3							
4							

FAILURE DETECTION METHODS

1 -4 WTS shuts down

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

Also FMEA 7.2.1.4.

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 179
TOWER - EPS	FUSED MANUAL DISCONNECT SWITCH	FMEA NO 7.6.3

FUNCTION OF COMPONENT

PROVIDES A MEANS OF TOTALLY ELECTRICALLY ISOLATING THE WTS FROM THE UTILITY AND PROVIDES A FAIL-SAFE VISUAL INDICATION THAT THE CIRCUIT IS OPEN.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 Open circuit: WTS shuts down or cannot start up.	All
2 Stuck shut: cannot disconnect WTS from utility.	All
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1	90	.7	185			X	
2	10	.7	1666	X			
3							
4							

FAILURE DETECTION METHODS

1 WTS shut down.

2 Requires manual check.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

If switch cannot be closed or if it fuses open, WTS will either shut down or will not transition to operate.

If switch is stuck shut, WTS cannot be disconnected from utility but fused protection is still available. Bus tie contactor and generator circuit breakers continue to function.

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OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

CONTROL SUBSYSTEM - FAILURE FREQUENCY

Based on the analysis contained in sheets 180-257, there are no catastrophic failure modes that can be caused by a control system failure. Trade studies completed during conceptual design concluded that a single thread system was most cost effective; therefore, no effort has been made to compute failure frequencies for individual signal lines. The cumulative failure rate for the entire control system is three failures per year.

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 180
CONTROL SUB SYSTEM (NCV)	POWER FAIL RESTART CKT	FMEA NO. 7.7.1

FUNCTION OF COMPONENT

ORDERLY SHUT DOWN & RESTART OF COMPUTER DURING POWER INTERRUPTION.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 INTERRUPT LINE SHORTS POWER FAIL INTERRUPT ACTIVATES-EMERGENCY SHUT DOWN ACTIVATED.	ALL
2 INTERRUPT LINE OPENS-POWER FAIL DOES NOT OPERATE ON POWER INTERRUPT.	ALL
3 PF STATUS FAILS HIGH-CAUSES INITIALIZATION ON POWER FAIL INTERRUPT	ALL
4 PF STATUS FAILS LOW-CAUSES POWER FAIL EMERGENCY SHUT DOWN ON START UP.	B-C

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1,4						X	
2,3				X			
3							
4							

FAILURE DETECTION METHODS

1 SYSTEM WILL NOT RESTART; POWER INDICATION MANUAL CONTROL BOX BLINKS.

2 ERATIC OPERATION

3 ERATIC OPERATION

4 SYSTEM WILL NOT START

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME J. HUTTON DATE 8/11/78

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	CPU, PROM & DATA BUS	PAGE 181 FMEA NO 7.7.2

FUNCTION OF COMPONENT

STORES AND OPERATES COMPUTER PROGRAM.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 CPU FAILURE-CONTROL OUTPUTS ARE NOT UP-DATED OR GO TO "0"	ALL
2 PROM OR DATA BUS FAILURES-ERATIC COMPUTER OPERATION RESULTS SAME AS OTHER CONTROL SYSTEM FMEA-GENERALLY SAME AS CPU FAILURE	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE × 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CRT AND SYSTEM DOES NOT RESPOND TO CHANGES & FAIL SAFE SYSTEM SHUTS DOWN WTS WHEN

~~2~~ UNSAFE CONDITIONS ARISE.

~~3~~ 2. SEE 1 ABOVE.

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME J. HUTTON DATE 8/11/78 Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 182
CONTROL SUB SYSTEM (NCV)	INTERRUPT LOGIC	FMEA NO 7.7.3

FUNCTION OF COMPONENT

PROVIDES CYCLING & SEQUENCING OF COMPUTER FUNCTIONS

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 1/10 SEC INT PULSE FAILS-COMPUTER STOPS UPDATING DATA INPUTS & CONTROL OUTPUTS	ALL
2 1/10 SEC INT PULSE CDT PARTIAL FAILURE SHORTENING CONTROL CYCLE.	ALL
3 IAB INTERRUPTS FAIL-ANALOG DATA INPUT STOPS	ALL
4 SIO INTERRUPTS FAIL-CRT SERVICING STOPS	ALL

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3						X	
4				X			

FAILURE DETECTION METHODS

1 CRT & SYSTEM DOES NOT RESPOND TO CHANGES

2 FAULT FLAG SHOWS INCOMPLETE CONTROL CYCLE.

3 FAULT FLAG SHOWS INCOMPLETE CONTROL CYCLE.

4 CRT DOES NOT RESPOND TO CHANGES.

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME J. HUTTON DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM (NCV)	SERIAL I/O CKTS.	PAGE 184 FMEA NO 7.7.5

FUNCTION OF COMPONENT

PROVIDES INTERFACE BETWEEN COMPUTER AND CRT TERMINALS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 INTERMITTENT FAULTS AND NOISE-CRT DISPLAY WILL BE INCORRECT-CONTROL WILL BE INCORRECT.	ALL
2 HARD FAILURE-CRT DISPLAY AND CONTROL INOPERATIVE.	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2				X			
3							
4							

FAILURE DETECTION METHODS

1 DISPLAY ERRATIC

2 DISPLAY DOES NOT WORK

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME J. HUTTON

DATE 8/11/78

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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM (NCV)	FAIL SAFE SYSTEM	PAGE 185 FMEA NO 7.7.6

FUNCTION OF COMPONENT

PROVIDES REDUNDANT SHUT DOWN CAPABILITY IN THE EVENT OF PRIMARY CONTROL SYSTEM FAILURES.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 RELAY COILS, ALL CONTACTS OPEN, ALL WIRES OPEN EXCEPT MANUAL RESET-CAUSES SYSTEM SHUT DOWN	B-H
2 CONTACTS SHORTED-REDUNDANT SHUT DOWN CAPABILITY IS LOST	B-H
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2				X			
3							
4							

FAILURE DETECTION METHODS

1 FAIL SAFE TRIP ON

2 FAIL SAFE DOES NOT TRIP WHEN PRIMARY CONTROL SENSES FAILURE.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

PRIMARY SYSTEM STILL RESPONDS TO FAULTS.

NAME J. HUTTON DATE 8/11/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 186
CONTROL SUB SYSTEM	RPM SIGNAL	FMEA NO 7.7.7

FUNCTION OF COMPONENT

PROVIDES RPM DATA FOR THE CONTROL SYSTEM FROM THE LOW SPEED SHAFT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT TO GROUND; CONTROL WILL INDICATE "O" RPM RESULTING IN WTS SHUT DOWN	ALL, EXCEPT STANDBY
2 SHORT CIRCUIT TO VOLTAGE; CONTROL WILL INDICATE MAX RPM RESULTING IN WTS SHUT DOWN.	ALL
3 OPEN CIRCUIT; CONTROL INDICATES "O" RPM RESULTING IN WTS SHUT DOWN	ALL, EXCEPT STANDBY
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3						X	
4							

FAILURE DETECTION METHODS

1 CONTROL WILL BE IN LOCKOUT MODE

2 CONTROL WILL BE IN LOCKOUT MODE

3 CONTROL WILL BE IN LOCKOUT MODE

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

FAIL SAFE ALSO MONITORS HIGH RPM.

NAME R.K. HILDAHL DATE 8/11/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM-UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 187
CONTROL SUB SYSTEM	#1 VIBRATION SIGNAL	FMEA NO 7.7.8

FUNCTION OF COMPONENT

PROVIDES ALARM SIGNAL FOR EXCESSIVE VIBRATION MONITORED ON LOW SPEED SHAFT FRONT BEARING.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT, PRIMARY CONTROL WILL NOT MONITOR. REDUNDANTLY SENSORED BY FAIL SAFE SYSTEM.	ALL
2 OPEN CIRCUIT, PRIMARY CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION

2 CONTROL WILL BE IN LOCKOUT MODE.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

FAIL SAFE SYSTEM PROVIDES REDUNDANCY

NAME R. K. HILDAHL　　DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F - TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 188
CONTROL SUB SYSTEM	#2 VIBRATION SIGNAL	FMEA NO 7.7.9

FUNCTION OF COMPONENT

PROVIDES ALARM SIGNAL FOR EXCESSIVE VIBRATION MONITORED ON LOW SPEED SHAFT REAR (NEAR GEAR BOX) BEARING.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; PRIMARY CONTROL WILL NOT MONITOR REDUNDANT SENSORED BY FAIL SAFE SYSTEM.	ALL
2 OPEN CIRCUIT; PRIMARY CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION

2 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

FAIL SAFE SYSTEM PROVIDES REDUNDANCY.

NAME R.K. HILDAHL   DATE 8/11/78
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OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	BEARING OVERTEMPERATURE #1	PAGE 189 FMEA NO 7.7 10

FUNCTION OF COMPONENT

PROVIDES ALARM SIGNAL FOR LOW SPEED SHAFT FRONT BEARING OVER TEMPERATURE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; PRIMARY CONTROL WILL NOT MONITOR	ALL
2 OPEN CIRCUIT, PRIMARY CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION

2 CONTROL WILL BE IN LOCKOUT MODE.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

FAIL SAFE SYSTEM PROVIDES REDUNDANCY

NAME R. K. HILDAHL DATE 8/11/78 Rev 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM-UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	BEARING OVERTEMPERATURE # 2	PAGE 190 FMEA NO 7.7.11

FUNCTION OF COMPONENT

PROVIDES OVER TEMPERATURE ALARM SIGNAL FOR LOW SPEED SHAFT REAR (NEAR GEAR BOX) BEARING.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; PRIMARY CONTROL WILL NOT MONITOR	ALL
2 OPEN CIRCUIT; PRIMARY CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION

2 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

1. FAIL SAFE SYSTEM PROVIDES REDUNDANCY

NAME R. K. HILDAHL | DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 192
CONTROL SUB SYSTEM	TEETER BRAKE UNLOCK COMMAND SIGNAL	FMEA NO 7.7.13

FUNCTION OF COMPONENT

PROVIDES COMMAND TO UNLOCK TEETER BRAKE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT COMMAND TEETER BRAKE TO UNLOCK.	ALL
2 OPEN CIRCUIT; CONTROL WILL NOT COMMAND TEETER BRAKE TO UNLOCK	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION

2 REQUIRES INSPECTION

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME R. K. HILDAHL DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	EMERGENCY ACCUMULATOR COMMAND SIGNAL	PAGE 193 FMEA NO 7.7.14

FUNCTION OF COMPONENT

COMMANDS EMERGENCY ACCUMULATOR TO FEATHER ROTOR BLADES & SIGNALS FAIL SAFE CKT THAT CONTROL SYSTEM HAS SHUT DOWN SYSTEM

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL ACTIVATE EMERGENCY ACCUMULATOR.	ALL
2 OPEN CIRCUIT; CONTROL WILL ACTIVATE EMERGENCY ACCUMULATOR.	ALL
3 SHORT TO VOLTAGE: CONTROL WILL NOT ACTIVATE EMERGENCY ACCUMULATOR	ALL
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3						X	
4							

FAILURE DETECTION METHODS

1 CONTROL IN LOCKOUT MODE.

2 CONTROL IN LOCKOUT MODE.

3 FAIL SAFE DETECTS INVALID SEQUENCE

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

FAIL SAFE SYSTEM PROVIDES REDUNDANCY.

NAME R. K. HILDAHL DATE 8/11/78

Rev 11/1/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	PITCH HYD PUMP ON COMMAND SIGNAL	PAGE 194 FMEA NO 7.7.15

FUNCTION OF COMPONENT

PROVIDES COMMAND TO START HYDRAULIC PUMP.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT COMMAND PUMP ON AND CONTROL WILL MAINTAIN WTS SHUT DOWN	ALL
2 OPEN CIRCUIT; CONTROL WILL NOT COMMAND PUMP ON, AND CONTROL WILL MAINTAIN WTS SHUT DOWN	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO.	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL BE IN LOCKOUT MODE

2 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME R. K. HILDAHL   DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	PITCH HYD PUMP OFF SIGNAL	PAGE 195 FMEA NO 7.7.16

FUNCTION OF COMPONENT

PROVIDES COMMAND TO TURN OFF HYDRAULIC PUMP.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT COMMAND PUMP OFF	ALL
2 OPEN CIRCUIT; CONTROL WILL NOT COMMAND PUMP OFF	ALL
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1					X		
2					X		
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL BE IN LOCKOUT, HYD. PUMP RUNNING

2 CONTROL WILL BE IN LOCKOUT, HYD. PUMP RUNNING.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME R. K. HILDAHL DATE 8/11/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G - OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT #1	PAGE 196
CONTROL SUB SYSTEM	PITCH SERVO COMMAND SIGNAL	FMEA NO 7.7.17

FUNCTION OF COMPONENT

PROVIDES COMMANDS TO TIP ACTUATOR THAT CONTROLS BLADE TIP #1

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT COMMAND ACUATOR, CONTROL SYSTEM WILL SHUT DOWN WTS	ALL
2 OPEN CIRCUIT; CONTROL WILL NOT COMMAND ACTUATOR; CONTROL SYSTEM WILL SHUTDOWN WTS	ALL
3 INCORRECT SIGNAL COMMANDING FULL POWER	
4 INCORRECT SIGNAL COMMANDING FEATHER POSITION	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3						X	
4						X	

FAILURE DETECTION METHODS

1 CONTROL WILL BE IN LOCKOUT MODE

2 CONTROL WILL BE IN LOCKOUT MODE

3 WTS SHUTDOWN

4 WTS SHUTDOWN

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME R. K. HILDAHL DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G - OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	#2 PITCH SERVO COMMAND SIGNAL	PAGE 197 FMEA NO 7.7.18

FUNCTION OF COMPONENT

PROVIDES COMMANDS TO TIP ACTUATOR THAT CONTROLS BLADE TIP #2

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT COMMAND ACTUATOR; CONTROL SYSTEM WILL SHUT DOWN WTS	ALL
2 OPEN CIRCUIT; CONTROL WILL NOT COMMAND ACTUATOR. CONTROL SYSTEM WILL SHUT DOWN WTS	ALL
3 INCORRECT SIGNAL COMMANDING FULL POWER	
4 INCORRECT SIGNAL COMMANDING FEATHER POSITION	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3						X	
4						X	

FAILURE DETECTION METHODS

1 CONTROL WILL BE IN LOCKOUT MODE

2 CONTROL WILL BE IN LOCKOUT MODE

3 WTS SHUTDOWN

4 WTS SHUTDOWN

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME R. K. HILDAHL

DATE 8/11/78
Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	#1 BLADE PITCH POSITION SIGNAL	PAGE 198 FMEA NO 7.7.19

FUNCTION OF COMPONENT

PROVIDES POSITION STATUS FOR ONE TIP BLADE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 ONE OR MORE SHORT CIRCUITS; CONTROL WILL NOT POSITION TIPS TOGETHER; WTS WILL SHUT DOWN	ALL
2 ONE OR MORE OPEN CIRCUITS; CONTROL WILL NOT POSITION TIPS TOGETHER; WTS WILL SHUT DOWN	ALL
3 COMBINATION OF SHORT & OPEN CIRCUITS; CONTROL WILL NOT POSITION TIPS TOGETHER, WTS WILL SHUT DOWN	ALL
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3						X	
4							

FAILURE DETECTION METHODS CONTROL TESTS POSITION IN STANDBY MODE.

1 BLADE TIPS NOT POSITIONED THE SAME, POSSIBLE CONTROL IN LOCKOUT MODE

2 SAME AS 1.

3 SAME AS 1.

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

SHUT DOWN WILL OCCUR WHEN THE POSITION FEEDBACK FROM EACH TIP DIFFERS.

NAME R. K. HILDAHL DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	#2 BLADE PITCH POSITION SIGNAL	PAGE 199 FMEA NO 7.7.20

FUNCTION OF COMPONENT

PROVIDES POSITION STATUS FOR ONE TIP BLADE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 ONE OR MORE SHORT CIRCUITS; CONTROL WILL NOT POSITION TIPS TOGETHER, WTS WILL SHUT DOWN	ALL
2 ONE OR MORE OPEN CIRCUITS; CONTROL WILL NOT POSITION TIPS TOGETHER, WTS WILL SHUT DOWN	ALL
3 COMBINATION OF SHORT AND OPEN CIRCUITS; CONTROL WILL NOT POSITION TIPS TOGETHER; WTS WILL SHUT DOWN	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3						X	
4							

FAILURE DETECTION METHODS CONTROL TESTS POSITION IN STANDBY MODE.

1 BLADE TIPS NOT POSITIONED THE SAME, POSSIBLE CONTROL IN LOCKOUT MODE.

2 SAME AS 1.

3 SAME AS 1.

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME R. K. HILDAHL DATE 8/11/78 Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 200
CONTROL SUB SYSTEM	BLADE LOCKED #1 SIGNAL	FMEA NO 7.7.21

FUNCTION OF COMPONENT

PROVIDES STATUS SIGNAL FOR BLADE #1 LOCK

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTOL WILL NOT MONITOR BLADE LOCK	ALL
2 OPEN CIRCUIT; CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION

2 CONTROL WILL BE IN LOCKOUT MODE.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME R. K. HILDAHL DATE 8/11/78

OPERATING MODES Rev 10/25/78

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	PITCH HYD FILTER CLOGGED SIGNAL	PAGE 201 FMEA NO 7.7.22

FUNCTION OF COMPONENT

PROVIDES STATUS SIGNAL FOR FILTER #1, 2 AND 3

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT MONITOR	ALL
2 OPEN CIRCUIT; CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION
2 CONTROL WILL BE IN LOCKOUT
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME R K HILDAHL

DATE 8/11/78
Rev 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 202
CONTROL SUB SYSTEM	BLADE LOCKED #2 SIGNAL	FMEA NO 7.7.23

FUNCTION OF COMPONENT

PROVIDES STATUS SIGNAL FOR BLADE #2 LOCK.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORTED CONTACT: CONTROL WILL NOT MONITOR BLADE LOCK.	ALL
2 OPEN CIRCUIT: CONTROL WILL SHUT DOWN WTS.	ALL
3 SHORT CIRCUIT: CONTROL WILL SHUTDOWN WTS.	ALL
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ. %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3						X	
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION.

2 CONTROL WILL BE IN LOCKOUT MODE.

3 CONTROL WILL BE IN LOCKOUT MODE.

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. Kenkman DATE 11/1/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 203
CONTROL SUB SYSTEM	PITCH HYD OIL TEMP HIGH SIGNAL	FMEA NO 7.7.24

FUNCTION OF COMPONENT

PROVIDES INDICATION OF PITCH HYD OIL TEMP. WHEN HIGH

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT MONITOR	ALL
2 OPEN CIRCUIT; CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION

2 CONTROL WILL BE IN LOCKOUT MODE.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME R. K. HILDAHL | DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	PITCH HYD OIL PRESSURE LOW SIGNAL	PAGE 204 FMEA NO 7.7.25

FUNCTION OF COMPONENT

PROVIDE STATUS SIGNAL FOR PITCH OIL PRESSURE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT MONITOR	ALL
2 OPEN CIRCUIT; CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 SIGNAL TESTED IN STANDBY MODE & CONTROL WILL END UP IN LOCKOUT MODE

2 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME R. K. HILDAHL

DATE 8/11/78
Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 205
CONTROL SUB SYSTEM	PITCH ACCUMULATORS PRECHARGE LOW	FMEA NO 7.7.26

FUNCTION OF COMPONENT

PROVIDES STATUS SIGNAL FOR THE EMERGENCY AND OPERATIONAL ACCUMULATOR PRECHARGES.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT MONITOR	ALL
2 OPEN CIRCUIT; CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL TEST DURING STANDBY AND WILL GO INTO LOCKOUT MODE

2 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

FAIL SAFE SYSTEM PROVIDES REDUNDANCY

NAME R. K. HILDAHL DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 206
CONTROL SUB SYSTEM	PITCH HYD OIL LEVEL LOW SIGNAL	FMEA NO 7.7.27

FUNCTION OF COMPONENT

WARNS CONTROL SYSTEM ON LOW OIL LEVEL

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT MONITOR	ALL
2 OPEN CIRCUIT; CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION

2 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME R. K. HILDAHL DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H - TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	
CONTROL SUB SYSTEM	GEAR BOX OIL TEMP. HIGH SIGNAL	PAGE 207 FMEA NO 7.7.28

FUNCTION OF COMPONENT

PROVIDES ALARM SIGNAL FOR GEAR BOX OIL TEMPERATURE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT MONITOR	ALL
2 OPEN CIRCUIT; CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE × 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQUIRES PERIODIC INSPECTION

2 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 208
CONTROL SUB SYSTEM	GEAR BOX OIL PRESSURE LOW SIGNAL	FMEA NO 7.7.29

FUNCTION OF COMPONENT

PROVIDES ALARM SIGNAL FOR LOW OIL PRESSURE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT MONITOR THIS SIGNAL IF WTS IS OPERATING-WILL NOT START IF IN STANDBY	ALL
2 OPEN CIRCUIT; CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL GO INTO LOCK OUT MODE
2 CONTROL WILL BE IN LOCK OUT MODE
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

FAIL SAFE SYSTEM PROVIDES REDUNDANCY

NAME D. KENKMAN DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 209
CONTROL SUB SYSTEM	GEAR BOX OIL LEVEL LOW SIGNAL	FMEA NO 7.7 30

FUNCTION OF COMPONENT

PROVIDES ALARM SIGNAL FOR LOW OIL LEVEL

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT MONITOR THIS SENSOR	ALL
2 OPEN CIRCUIT, CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQRUIRES PERIODIC INSPECTION
2 CONTROL WILL BE IN LOCKOUT MODE
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/11/78
Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 210
CONTROL SUB SYSTEM	GEAR BOX OIL TEMP. LOW	FMEA NO 7.7.31

FUNCTION OF COMPONENT

PROVIDES ALARM SIGNAL IF OIL TEMP. IS TOO LOW TO OPERATE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT MONITOR THIS SENSOR	ALL
2 OPEN CIRCUIT; CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQUIRES PERIODIC INSPECTION

2 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN

DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	GEAR BOX OIL FLOW LOW SIGNAL	PAGE 211 FMEA NO 7.7.32

FUNCTION OF COMPONENT

PROVIDES ALARM SIGNAL FOR LOW OIL FLOW

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT MONITOR THIS SENSOR	ALL
2 OPEN CIRCUIT, CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL TEST DURING STANDBY MODE & GO INTO LOCKOUT MODE
2 CONTROL WILL BE IN LOCK OUT MODE
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME DON KENKMAN — DATE 8/11/78 Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	GEAR BOX OIL PUMP ON COMMAND	PAGE 213 FMEA NO 7.7.34

FUNCTION OF COMPONENT

PROVIDES SIGNAL TO START GEAR BOX OIL PUMP

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT TURN OIL PUMP ON	ALL
2 OPEN CIRCUIT; CONTROL WILL NOT TURN OIL PUMP ON	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL GO INTO LOCKOUT MODE

2 CONTROL WILL GO INTO LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN

DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 214
CONTROL SUB SYSTEM	GEAR BOX OIL PUMP OFF COMMAND	FMEA NO 7.7.35

FUNCTION OF COMPONENT

PROVIDES SIGNAL TO TURN OFF GEAR BOX OIL PUMP

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL NOT TURN PUMP OFF	ALL
2 OPEN CIRCUIT; CONTROL WILL NOT TURN PUMP OFF	ALL
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL BE IN LOCKOUT MODE

2 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	ROTOR BRAKE COMMAND SIGNAL	PAGE 215 FMEA NO 7.7.36

FUNCTION OF COMPONENT

PROVIDES SIGNAL TO ACTIVATE WTS ROTOR

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT, BRAKES WILL BE APPLIED	ALL
2 OPEN CIRCUIT; BRAKES WILL BE APPLIED	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL BE IN LOCKOUT MODE

2 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

ALSO MONITORED AND CONTROLLED BY FAIL SAFE SYSTEM

NAME D. KENKMAN

DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	ROTOR BRAKE UNLOCKED SIGNAL	PAGE 217 FMEA NO 7.7.38

FUNCTION OF COMPONENT

INDICATES POSITION OF ROTOR BRAKE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL ACT AS THOUGH BRAKE IS IN LOCKED POSITION AND WTS WILL GO INTO LOCKOUT	E
2 OPEN CIRCUIT-CONTROL WILL ACT AS THOUGH BRAKE IS IN UNLOCKED POSITION	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL GO INTO LOCKOUT MODE

2 CONTROL WILL GO INTO LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/11/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 218
CONTROL SUB SIGNAL	GENERATOR FIELD ENABLE SIGNAL	FMEA NO 7.7.29

FUNCTION OF COMPONENT

ENABLES THE GENERATOR TO PRODUCE POWER

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; GENERATOR WILL NOT OUPUT POWER AND THE WTS WILL GO INTO LOCKOUT	G
2 OPEN CIRCUIT; GENERATOR WILL NOT GENERATE OUTPUT POWER AND THE WTA WILL GO INTO LOCKOUT	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL GO INTO LOCKOUT MODE

2 CONTROL WILL GO INTO LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/11/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 219
CONTROL SUB SYSTEM	GENERATOR OUTPUT SIGNAL	FMEA NO 7.7.40

FUNCTION OF COMPONENT

PROVIDES ANALOG SIGNAL TO CONTROL SYSTEM PROPORTIONAL TO GENERATOR OUTPUT

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL RECEIVE NO OUTPUT OR LOW AND SHUTS WTS DOWN	
2 OPEN CIRCUIT; CONTROL WILL RECEIVE NO OUTPUT AND SHUT WTS DOWN	
3 HIGH RESISTANCE; OUTPUT SIGNAL WILL BE IN ERROR AND ACTUAL OUTPUT WILL BE EITHER HIGHER OR LOWER THAN EXPECTED	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3				X			
4							

FAILURE DETECTION METHODS

1 CONTROL WILL GO INTO LOCKOUT MODE

2 CONTROL WILL GO INTO LOCKOUT MODE

3 MAY REQUIRED PERIODIC INSPECTION

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/11/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 220
CONTROL SUB SYSTEM	UTILITY POWER STATUS SIGNAL	FMEA NO 7.7.41

FUNCTION OF COMPONENT

PROVIDES UTILITY POWER STATUS TO CONTROL SYSTEM

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL LOSE MONITORING CAPABILITY	ALL
2 OPEN CIRCUIT; CONTROL WILL SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 INSPECTION REQUIRED
2 WTS WILL NOT START-IN LOCKOUT MODE
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN   DATE 8/10/78
Rev 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H - TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	BUS TIE CONTACTOR OPEN SIGNAL	PAGE 221 FMEA NO 7.7.42

FUNCTION OF COMPONENT

PROVIDES STATUS OF THE UTILITY BUS TIE BREAKER

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL WILL LOSE MONITORING CAPABILITY IF OPERATING	ALL
2 OPEN CIRCUIT; WTS WILL BE SHUT DOWN	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL GO INTO LOCKOUT MODE AFTER SHUT DOWN

2 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/10/78
Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 222
CONTROL SUB SYSTEM	SYNC ENABLE SIGNAL	FMEA NO 7.7.43

FUNCTION OF COMPONENT

ENABLES THE AUTO SYNCHRONIZER TO SYNCHRONIZE THE WTS TO THE UTILITY NETWORK

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRTUIT; WILL PREVENT ENABLE	ALL
2 OPEN CIRCUIT WILL PREVENT ENABLE	F
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL BE IN LOCKOUT MODE

2 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME DONALD KENKMAN DATE 8/10/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	BUS TIE DISCONNECT COMMAND SIGNAL	PAGE 223 FMEA NO 7.7.44

FUNCTION OF COMPONENT

COMMANDS THE GENERATOR SYSTEM TO DISCONNECT THE GENERATOR OUTPUT FROM THE UTILITY PWR LINE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; CONTROL SYSTEM WILL NOT CONTROL DISCONNECT; PWR SYSTEM(GENERATOR) WILL CONTROL	B THRU I
2 OPEN CIRCUIT; DISCONNECT WILL OCCUR AND WTS WILL SHUT DOWN	ALL
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 SYSTEM WILL NOT RECONNECT AND WILL REVERT TO LOCKOUT MODE

2 SYNCHRONIZATION WILL NOT OCCUR AND WTS WILL REVERT TO LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN

DATE 8/10/78
Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 224
CONTROL SUB SYSTEM	REMOTE RS 232 SIGNAL	FMEA NO 7.7.45

FUNCTION OF COMPONENT

PROVIDES REMOTE CONTROL/MONITOR CAPABILITY FOR THE WTS

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; TERMINAL WILL NOT OPERATE WTS IN MANUAL MODE; NOR DISPLAY DATA	MANUAL
2 OPEN CIRCUIT-SAME AS ABOVE	MANUAL
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2				X			
3							
4							

FAILURE DETECTION METHODS

1 INSPECTION

2 INSPECTION

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME DON KENKMAN | DATE 8/11/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	LOCAL RS 232 SIGNAL	PAGE 225 FMEA NO 7.7.46

FUNCTION OF COMPONENT

PROVIDES MANUAL CONTROL/MONITOR CAPABILITY AT THE WTS SITE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT; TERMINAL WILL NOT OPERATE WTS IN MANUAL MODE NOR DISPLAY DATA	
2 OPEN CIRCUIT; SAME AS 1, ABOVE	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2				X			
3							
4							

FAILURE DETECTION METHODS

1 INSPECTION

2 INSPECTION

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN

DATE 8/14/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 226
CONTROL SUB SYSTEM	GROUND INTRUSION SIGNAL	FMEA NO 7.7.47

FUNCTION OF COMPONENT

PROVIDES AN ALARM SIGNAL FOR GROUND INTRUSION

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORTED CONTACTS-CONTROL WILL NOT MONITOR	ALL
2 OPEN CIRCUIT-CONTROL WILL SHUT DOWN WTS	ALL
3 SHORT TO GROUND-SAME AS 2	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3						X	
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION

2/3 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME DON KENKMAN DATE 8/10/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 228
CONTROL SUB SYSTEM	NCU TEMP. LOW SIGNAL	FMEA NO 7.7.49

FUNCTION OF COMPONENT

PROVIDES ALARM SIGNAL WHEN UNDER TEMP. OCCURS IN THE NACELLE CONTROL UNIT. CONTROL SYSTEM WILL WAIT FOR LOSS OF SIGNAL PRIOR TO SYSTEM RESET.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORTED CONTACTS-CONTROL WILL NOT MONITOR	ALL
2 OPEN CIRCUIT-CONTROL WILL SHUT DOWN WTS	ALL
3 SHORT TO GROUND-SAME AS 2	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3						X	
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION

2 /3 CONTROL WILL BE IN WAIT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN — DATE 8/10/78

Rev 10/25/78
Rev 11/27/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	YAW ACCUM PRECHARGE LOW SIGNAL	PAGE 229 FMEA NO 7.7.50

FUNCTION OF COMPONENT

PROVIDES ALARM SIGNAL FOR LOW ACCUMULATOR PRECHARGE PRESSURE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORTED CONTACT; CONTROL WILL NOT MONITOR WHILE WTS IS OPERATING-IF IN STANDBY-WTS WILL NOT START	ALL
2 OPEN CIRCUIT; CONTROL WILL SHUT DOWN WTS	ALL
3 SHORT TO GROUND-SAME AS 2	-
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3						X	
4							

FAILURE DETECTION METHODS

1 CONTROL WILL MONITOR IN STANDBY MODE FOR "NO" PRESSURE AND GO INTO LOCKOUT MODE

2 /3 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/10/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 230
CONTROL SUB SYSTEM	YAW OIL LEVEL LOW SIGNAL	FMEA NO 7.7.51

FUNCTION OF COMPONENT

PROVIDES ALARM SIGNAL FOR LOW HYD OIL LEVEL

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORTED CONTACTS: CONTROL WILL NOT MONITOR	ALL
2 OPEN CIRCUIT; CONTROL WILL SHUT DOWN WTS	ALL
3 SHORT TO GROUND-SAME AS 2	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3						X	
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION

2 /3 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/9/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 231
CONTROL SUB SYSTEM	YAW OIL PRESS LOW SIGNAL	FMEA NO 7.7.52

FUNCTION OF COMPONENT

PROVIDES ALARM SIGNAL FOR LOW HID. OIL PRESSURE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORTED CONTACTS; CONTROL WILL NOT MONITOR WHILE WTS IS OPERATING-IF IN STANDBY-WTS WILL NOT START	ALL
2 OPEN CIRCUIT, CONTROL WILL SHUT DOWN WTS DUE TO THE ALARM	ALL
3 SHORT TO GROUND-SAME AS 2	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3						X	
4							

FAILURE DETECTION METHODS

1 CONTROL WILL MONITOR IN STANDBY MODE FOR "NO" PRESSURE & GO INTO LOCKOUT MODE

2 /3 CONTROL WILL BE IN LOCKOUT MODE.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/9/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G - OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	YAW OIL TEMP. HIGH SIGNAL	PAGE 234 FMEA NO 7 7.54

FUNCTION OF COMPONENT

PROVIDES AN ALARM SIGNAL WHEN THE YAW OIL TEMP. BECOMES EXCESSIVE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORTED CONTACT; CONTROL WILL NOT MONITOR TEMP. SENSOR	ALL
2 OPEN CIRCUIT; CONTROL WILL SHOT DOWN DUE TO AN ALARM	ALL
3 SHORT TO GROUND-SAME AS 2	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3						X	
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION

2 /3 CONTROL WILL BE IN LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/9/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	YAW OIL PUMP ON SIGNAL	PAGE 235 FMEA NO 7.7.56

FUNCTION OF COMPONENT

PROVIDES SIGNAL TO TURN ON THE YAW SYSTEMS OIL PUMP

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT WILL PREVENT PUMP TURN ON	ALL
2 OPEN CIRCUIT WILL PREVENT PUMP TURN ON	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 NACELLE WILL NOT YAW AND CONTROL WILL END UP IN LOCKOUT MODE

2 SAME AS #1

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/9/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	YAW OIL PUMP OFF SIGNAL	PAGE 236 FMEA NO 7.7.57

FUNCTION OF COMPONENT

PROVIDES SIGNAL TO TURN OFF THE YAW SYSTEM OIL PUMP

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT WILL PREVENT PUMP TURN OFF	ALL
2 OPEN CIRCUIT WILL PREVENT PUMP TURN OFF	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL END UP IN LOCKOUT MODE, PUMP RUNNING

2 SAME AS #1

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/9/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I - FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	YAW LEFT COMMAND SIGNAL	PAGE 237 FMEA NO 7.7 58

FUNCTION OF COMPONENT

COMMANDS THE YAW SYSTEM TO MOVE THE NACELLE IN A LEFT DIRECTION

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT CAUSES NACELLE TO TRAVEL LEFT IF PRESSURE IS UP	ALL
2 OPEN CIRCUIT; NACELLE WILL NOT MOVE LEFT AND WHEN REQUIRED, WTS WOULD BE SHUT DOWN	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL END UP ON LOCKOUT MODE

2 SAME AS #1

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/9/78

OPERATING MODES Rev 10/25/78

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

78 K 6162-001 REV 1

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	YAW RIGHT COMMAND SIGNAL	PAGE 238 FMEA NO 7.7.59

FUNCTION OF COMPONENT

COMMANDS THE YAW SYSTEM TO MOVE THE NACELLE IN A RIGHT DIRECTION

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT CAUSES NACELLE TO TRAVEL RIGHT IF PRESSURE IS UP	ALL
2 OPEN CIRCUIT; NACELLE WILL NOT MOVE RIGHT	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL END UP IN LOCKOUT MODE
2 SAME AS #1
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/9/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C - WARM UP
D TRANSITION TO STANDBY
E STANDBY
F - TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	FAIL SAFE YAW HYD. PUMP OFF COMMAND SIGNAL	PAGE 240 FMEA NO 7.7.61

FUNCTION OF COMPONENT

TURNS OFF YAW HYD. POWER DURING A FAIL SAFE SHUT DOWN.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT PREVENTS F/S SYSTEM FROM TURNING HYD PUMP OFF.	G
2 OPEN CIRCUIT: CAUSING FAIL SAFE SYSTEM TO TURN HYD PUMP OFF.	G
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 INSPECTION REQUIRED

2 WTS IN SHUTDOWN MODE FROM PRESSURE FAILURE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. Kenkman DATE 11/1/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G - OPERATE
B TRANSITION TO WARM-UP	E. STANDBY	H - TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 241
CONTROL SYSTEM	NCU TEMPERATURE LOW SIGNAL	FMEA NO 7.7.6.2.

FUNCTION OF COMPONENT

PROVIDES INHIBIT TO CONTROL ELECTRONICS DURING LOW TEMP. CONDITIONS THROUGH INTERRUP CONTROL.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT: CONTROL WILL NOT MONITOR.	
2 OPEN CIRCUIT: INTERRUPT WILL OCCUR AND CONTROL WILL SHUT DOWN	
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION.

2 CONTROL SYSTEM WILL BE INHIBITED.

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

FAIL SAFE SYSTEM IS NOT TEMPERATURE DEPENDANT AND WILL CONTROL DANGEROUS CONDITIONS.

NAME D. Kenkman DATE 11/1/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 242
CONTROL SUB SYSTEM	#1 WIND SPEED SIGNAL	FMEA NO 7.7.63

FUNCTION OF COMPONENT

PROVIDES WIND SPEED DATA FROM #1 SENSOR

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT	ALL
2 OPEN CIRCUIT	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 WIND SPEED WILL NOT AGREE WITH #2 SENSOR AND WTS WILL BE SHUT DOWN IN LOCKOUT MODE

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME DON KENKMAN DATE 8/9/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 243
CONTROL SUB SYSTEM	#2 WIND SPEED SIGNAL	FMEA NO 7.7.64

FUNCTION OF COMPONENT

PROVIDES WIND SPEED DATA FROM #2 SENSOR

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT	ALL
2 OPEN CIRCUIT	ALL
3 INCORRECT SIGNAL (RESULTING FROM ICING, ETC.)	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 WIND SPEED WILL NOT AGREE WITH #1 SENSOR AND WTS WILL BE SHUT DOWN IN LOCKOUT MODE

2

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME DON KENKMAN DATE 8/9/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 244
CONTROL SUB SYSTEM	#1 WIND DIRECTION SIGNAL	FMEA NO 7.7.65

FUNCTION OF COMPONENT

PROVIDES WIND DIRECTION DATA FROM #1 SENSOR

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT	ALL
2 OPEN CIRCUIT	ALL
3 INCORRECT SIGNAL (RESULTING FROM ICING, ETC.)	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 WIND DIRECTION WILL NOT AGREE WITH #2 SENSOR AND WTS WILL BE SHUT DOWN IN LOCKOUT
2 MODE
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME DON KENKMAN DATE 8/9/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 245
CONTROL SUB SYSTEM	#2 WIND DIRECTION SIGNAL	FMEA NO 7.7.66

FUNCTION OF COMPONENT

PROVIDES WIND DIRECTION DATA FROM #2 SENSOR

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT	ALL
2 OPEN CIRCUIT	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 WIND DIRECTION WILL NOT AGREE WITH #1 SENSOR AND WTS WILL BE SHUT DOWN IN LOCKOUT MODE
2
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME DON KENKMAN DATE 8/9/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE
CONTROL SUB SYSTEM	FAIL SAFE GENERATOR BEARING OVERTEMPERATURE	246 FMEA NO 7.7 67

FUNCTION OF COMPONENT

PROVIDES ALARM FOR GENERATOR BEARING OVERTEMPERATURE.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT - CONTROL WILL SHUT DOWN WTS.	ALL
2 OPEN CIRCUIT - WILL SHUT WTS DOWN.	ALL
3 SHORTED CONTACT - WILL NOT MONITOR.	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3				X			
4							

FAILURE DETECTION METHODS

1 WTS WILL BE IN LOCKOUT MODE.

2 WTS WILL BE IN LOCKOUT MODE.

3 REQUIRES INSPECTION.

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

REDUNDANT TO CONTROL SIGNAL.

NAME D. Kenkman   DATE 11/1/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 247
CONTROL SUB SYSTEM	FAIL SAFE ENABLE SIGNAL	FMEA NO 7.7.68

FUNCTION OF COMPONENT

PROVIDES SIGNAL TO CONTROL SYSTEM THAT FAIL SAFE SYSTEM IS OPERATING IN A READY TO OPERATE CONDITION

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT CAUSING CONTROL SYSTEM TO BELIEVE THAT FAIL SAFE SYSTEM IS OPERATING AND CLEAR	ALL
2 OPEN CIRCUIT CAUSING CONTROL TO SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 INSPECTION REQUIRED

2 WTS WILL NOT START & GOES INTO LOCKOUT MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. KENKMAN DATE 8/9/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G - OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	FAIL SAFE EMERGENCY ACC. PRESSURE LOW SIGNAL	PAGE 248 FMEA NO 7.7.69

FUNCTION OF COMPONENT

PROVIDE A SIGNAL TO THE FAIL SAFE SYSTEM INDICATING THE STATUS OF THE PITCH EMERGENCY ACCUMULATORS ARE WITHIN LIMITS.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT CAUSING FAIL SAFE TO NOT MONITOR	ALL
2 OPEN CIRCUIT CAUSING FAIL SAFE TO SHUT DOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 REQUIRES INSPECTION
2 WTS WILL GO INTO FAIL SAFE SHUT DOWN MODE
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

REDUNDANT TO CPU CONTROL SYSTEM WILL STILL SHUT DOWN IF THE ACCUMULATORS ARE OUTSIDE OF LIMITS.

NAME D. KENKMAN | DATE 8/9/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G - OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM UP	F TRANSITION TO OPERATE	I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	FAIL SAFE PITCH ACCUM SIGNAL	PAGE 249 FMEA NO 7.7.70

FUNCTION OF COMPONENT

ACTIVATES THE EMERGENCY PITCH ACCUMULATOR TO FEATHER THE BLADES

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 OPEN CIRCUIT CAUSING BLADES TO FEATHER	ALL
2 SHORT CIRCUIT CAUSING BLADES TO FEATHER	ALL
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR	MEAN TIME BETWEEN FAILURE (YEARS)	MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3							
4							

FAILURE DETECTION METHODS

1 WTS WILL SHUT DOWN IN FAIL SAFE SHUT DOWN MODE

2 WTS WILL SHUT DOWN IN FAIL SAFE SHUT DOWN MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

REDENDANT TO CPU CONTROL

NAME D. KENKMAN DATE 8/9/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	FAIL SAFE PITCH HYD. PUMP OFF COMMAND SIGNAL	PAGE 250 FMEA NO 7.7.71

FUNCTION OF COMPONENT

TURNS OFF THE PITCH HYDRAULIC POWER DURING A FAIL SAFE EMERGENCY SHUT DOWN

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT CAUSING FAIL SAFE SYSTEM TO TURN OFF HYDRAULICS.	ALL
2 OPEN CIRCUIT CAUSING FAIL SAFE TO TURN PITCH HYDRAULICS-OFF & STAY OFF	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 WTS WILL BE IN SHUTDOWN MODE

2 WTS WILL BE SHUT DOWN IN FAIL SAFE SHUT DOWN MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

REDUNDANT TO CPU CONTROL

NAME D. KENKMAN DATE 8/9/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	FAIL SAFE BEARING TEMP. #1 AND #2 SIGNAL	PAGE 251 FMEA NO 7.7.72

FUNCTION OF COMPONENT

ALARMS THE FAIL SAFE SYSTEM WHEN EXCESSIVE BEARING TEMPERATURE IS PRESENT IN THE LOW SPEED SHAFT.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT CAUSING FAIL SAFE TO NOT MONITOR SENSOR	ALL
2 OPEN CIRCUIT CAUSING FAIL SAFE TO SHUT WTS DOWN OR STAY DISABLED	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 MANUAL INSPECTION REQUIRED

2 WTS WILL BE SHUT DOWN IN FAIL SAFE SHUT DOWN MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

REDUNDANT TO CPU CONTROL SO THAT EXCESSIVE BEARING TEMPERATURES WILL BE DETECTED

NAME D. KENKMAN DATE 8/8/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM-UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE / FMEA NO
CONTROL SUB SYSTEM	FAIL SAFE VIBRATION #1 AND #2 SIGNAL	PAGE 252 FMEA NO 7.7.73

FUNCTION OF COMPONENT

ALARMS FAIL SAFE SYSTEM ON EXCESSIVE SYSTEM VIBRATION FOR QUICK SHUT DOWN

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT CAUSING FAIL SAFE TO NOT MONITOR SENSOR	ALL
2 OPEN CIRCUIT CAUSING FAIL SAFE TO SHUT WTS DOWN OR STAY DISABLED	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE x 10^{-6} PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 MANUAL INSPECTION IS REQUIRED

2 WTS WILL BE STOPPED IN FAIL SAFE SHUT DOWN MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

REDUNDANT TO CPU CONTROL SO THAT SYSTEM WILL STILL DETECT VIBRATION

NAME D. KENKMAN DATE 8/8/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM-UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 253
CONTROL SUB SYSTEM	FAIL SAFE GEAR BOX OIL PRESSURE SIGNAL	FMEA NO 7.7.74

FUNCTION OF COMPONENT

ALARMS FAIL SAFE SYSTEM ON LOW GEAR BOX PRESSURE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT CAUSING FAIL SAFE SYSTEM TO NOT MONITOR SENSOR	ALL
2 OPEN CIRCUIT CAUSING FAIL SAFE SYSTEM TO SHUT WTS DOWN OR STAY DISABLED	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2						X	
3							
4							

FAILURE DETECTION METHODS

1 INSPECTION REQUIRED

2 WTS WILL BE STOPPED IN FAIL SAFE SHUT DOWN MODE

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

REDUNDANT TO CPU CONTROL, SO LOW PRESSURE WILL STILL BE DETECTED

NAME D. KENKMAN | DATE 8/8/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H - TRANSITION TO FEATHER
I FEATHER

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MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 254
CONTROL SUB-SYSTEM	FAIL SAFE GEAR BOX TEMP. HIGH SIGNAL	FMEA NO. 7.7.75

FUNCTION OF COMPONENT

ACTIVATES FAIL SAFE SYSTEM WHEN GEAR BOX OIL TEMPERATURE IS HIGH

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT CAUSING FAIL SAFE TO ACTIVATE AND SHUT DOWN WTS	ALL
2 OPEN CIRCUIT CAUSING FAIL SAFE TO ACTIVATE AND SHUTDOWN WTS	ALL
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2				X			
3							
4							

FAILURE DETECTION METHODS

1 WTS WILL BE STOPPED IN FAIL SAFE SHUT DOWN MODE

2 INSPECTION WILL BE REQUIRED

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

REDUNDANT TO CPU CONTROL.

NAME D. KENKMAN DATE 8/9/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 256
CONTROL SUB SYSTEM	FAIL SAFE ROTOR BRAKE COMMAND SIGNAL	FMEA NO 7.7.7.7

FUNCTION OF COMPONENT

APPLIES BRAKE COMMAND SIGNAL TO ACTIVATE ROTOR BRAKE

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SIGNAL SHORTS CLOSED & BRAKE WILL BE ENERGIZED	ALL
2 SIGNAL OPEN CIRCUIT & BRAKE WILL BE ENERGIZED	ALL
3 INTERMITTENT-BRAKE WILL BE APPLIED AT RANDOM CAUSING EXCESSIVE HEAT OR PREVENT WTS FROM REACHING RPM	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2						X	
3				X			
4							

FAILURE DETECTION METHODS

1 WTS WILL SHUT DOWN & ROTOR WILL NOT TURN

2 WTS WILL SHUT DOWN AND ROTOR WILL NOT TURN

3 BRAKES WILL BECOME OVER TEMP. & SENSOR WILL SHUT DOWN WTS OR CONTROL WILL MONITOR & SHUT DOWN WTS IN LOCKOUT MODE

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

REDUNDANT TO CPU CONTROL

NAME DON KENKMAN | DATE 8/8/78

Rev 10/25/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 257
CONTROL SUB SYSTEM	FAIL SAFE OVER SPEED	FMEA NO 7.7.78

FUNCTION OF COMPONENT

PROVIDES AN ALARM SIGNAL FOR ROTOR OVER SPEED

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 OPEN CIRCUIT-FAIL SAFE SHUTS DOWN SYSTEM	B THRU I
2 SHORT CIRCUIT-FAIL SAFE WILL NOT MONITOR	G
3	
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1						X	
2				X			
3							
4							

FAILURE DETECTION METHODS

1 CONTROL WILL BE IN FAIL SAFE LOCKOUT

2 INSPECTION REQUIRED

3

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

REDUNDANT TO CPU CONTROL

NAME R. E. HUTTON DATE 8/14/78

OPERATING MODES

A SHUTDOWN
B TRANSITION TO WARM UP
C WARM UP
D TRANSITION TO STANDBY
E STANDBY
F TRANSITION TO OPERATE
G OPERATE
H TRANSITION TO FEATHER
I FEATHER

MOD-2 Failure Mode and Effects Analysis

SUBSYSTEM	COMPONENT	PAGE 258
CONTROL SUB SYSTEM	TEST VAN READY SIGNAL	FMEA NO 7.7.79

FUNCTION OF COMPONENT

PROVIDES CAPABILITY FOR TEST VAN TO SHUT DOWN WTS DURING ALARMS OCCURING UNDER SPECIAL TEST CONDITIONS MONITORED BY THE TEST VAN.

FAILURE MODES & EFFECTS	APPLICABLE OPERATING MODES
1 SHORT CIRCUIT: TO GROUND: CONTROL WILL SHUT DOWN WTS.	ALL
2 OPEN CIRCUIT: CONTROL WILL SHUT DOWN WTS.	ALL
3 SHORTED CONTACTS: CONTROL WILL NOT MONITOR TEST VAN READY.	ALL
4	

FAILURE FREQUENCY			MEAN TIME BETWEEN FAILURE (YEARS)	FAILURE SEVERITY			
FAILURE MODE NO	FAILURE MODE FREQ %	FAILURE RATE $\times 10^{-6}$ PER HOUR		MINIMAL I	MARGINAL II	CRITICAL III	CATASTROPHIC IV
1				X			
2				X			
3				X			
4							

FAILURE DETECTION METHODS

1 WTS WILL GO INTO LOCKOUT MODE.

2 WTS WILL GO INTO LOCKOUT MODE.

3 REQUIRES INSPECTION.

4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

NAME D. Kenkman DATE 11/1/78

OPERATING MODES

A SHUTDOWN	D TRANSITION TO STANDBY	G OPERATE
B TRANSITION TO WARM UP	E STANDBY	H TRANSITION TO FEATHER
C WARM-UP	F TRANSITION TO OPERATE	I - FEATHER

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APPENDIX B

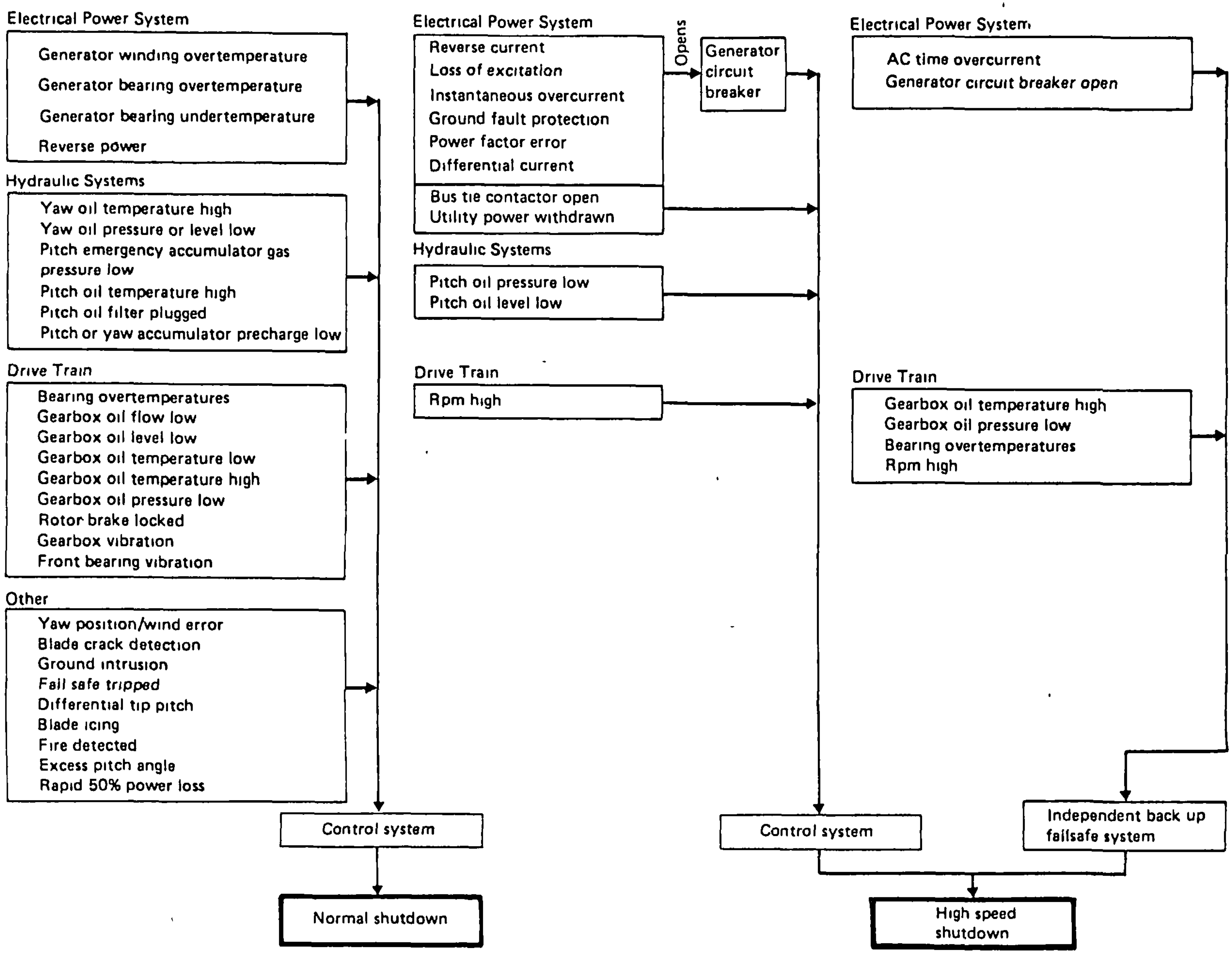


Figure 1, MOD-2 Safety System

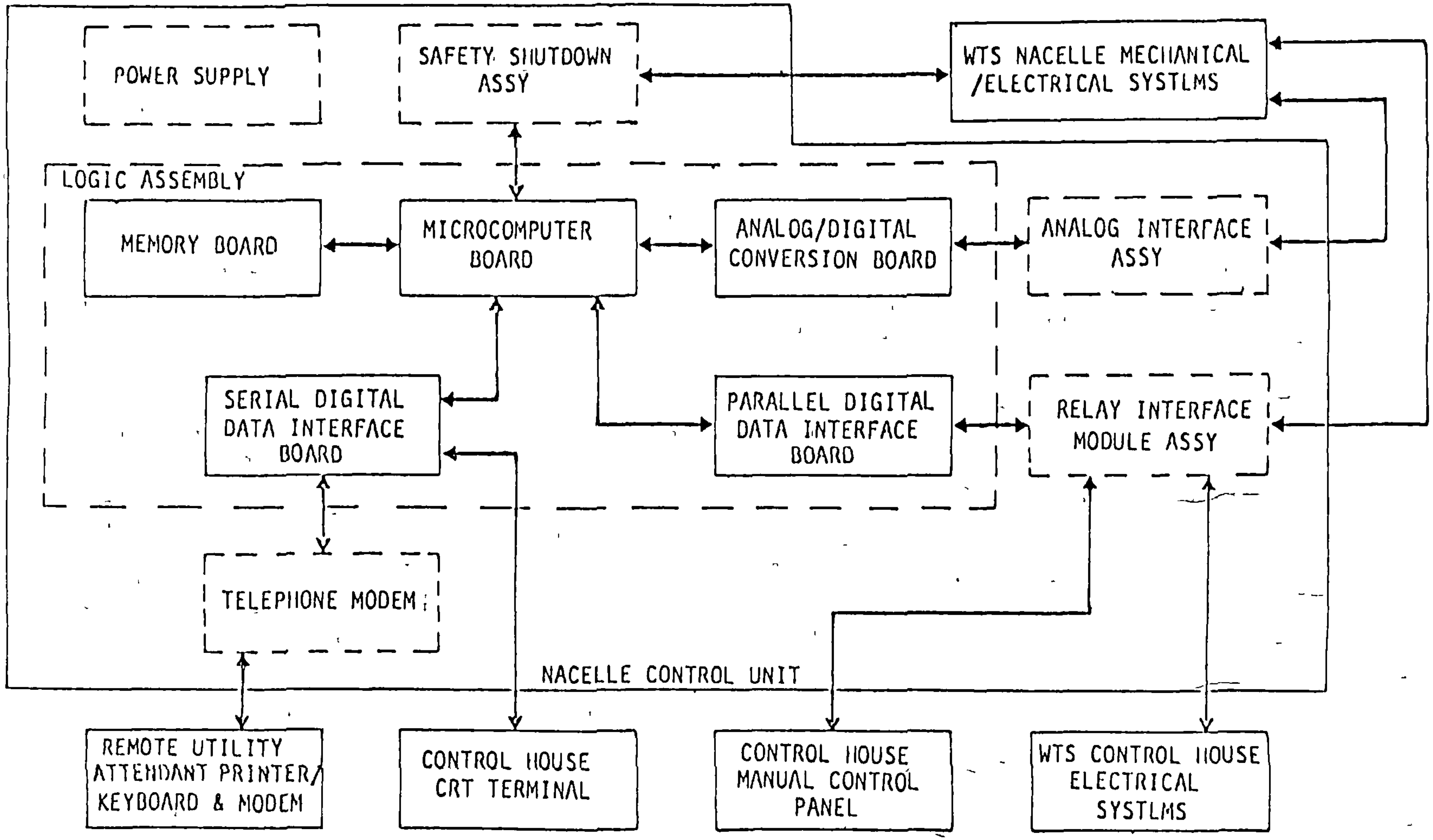


FIGURE 2, CONTROL SYSTEM BLOCK DIAGRAM

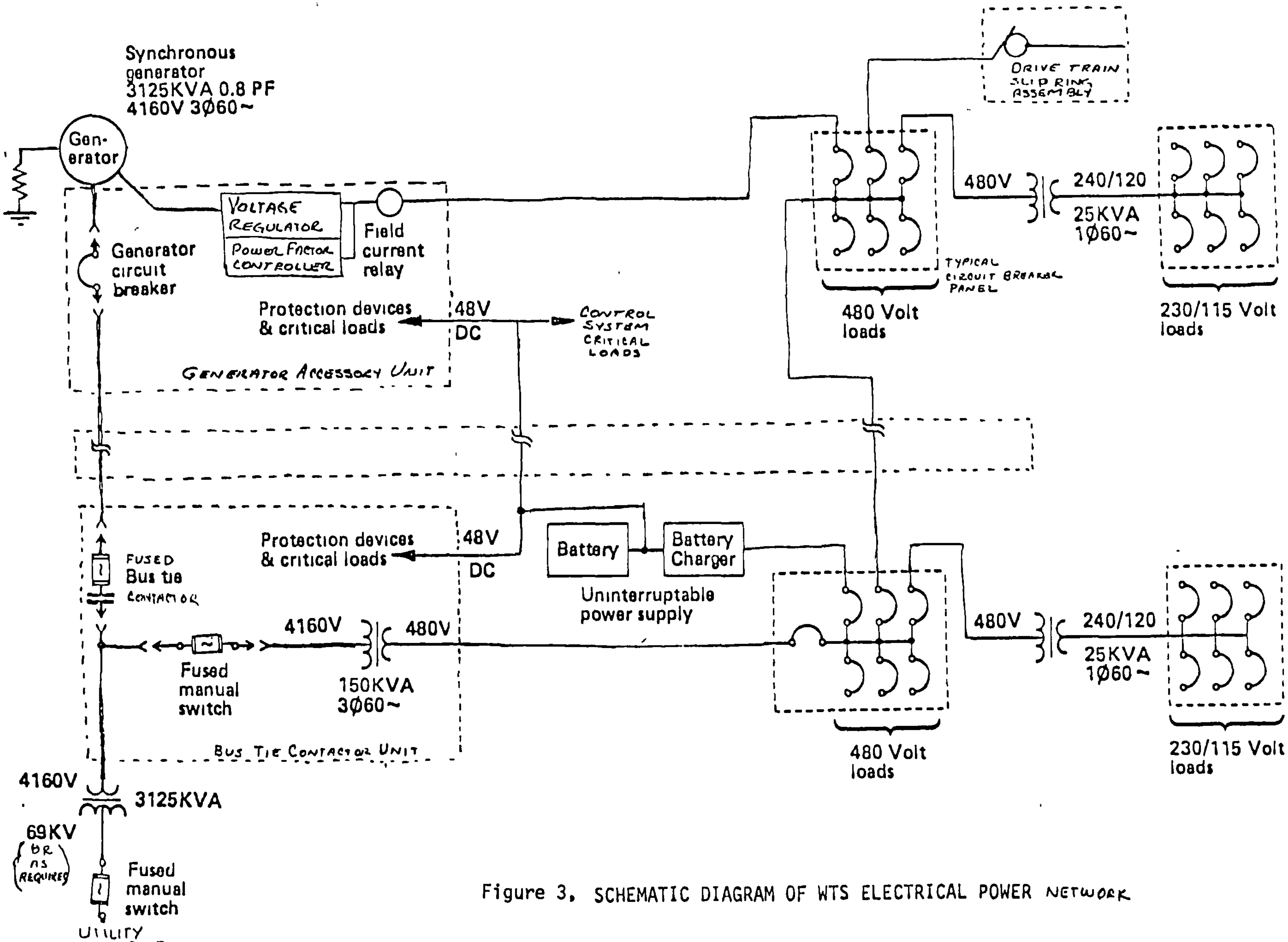
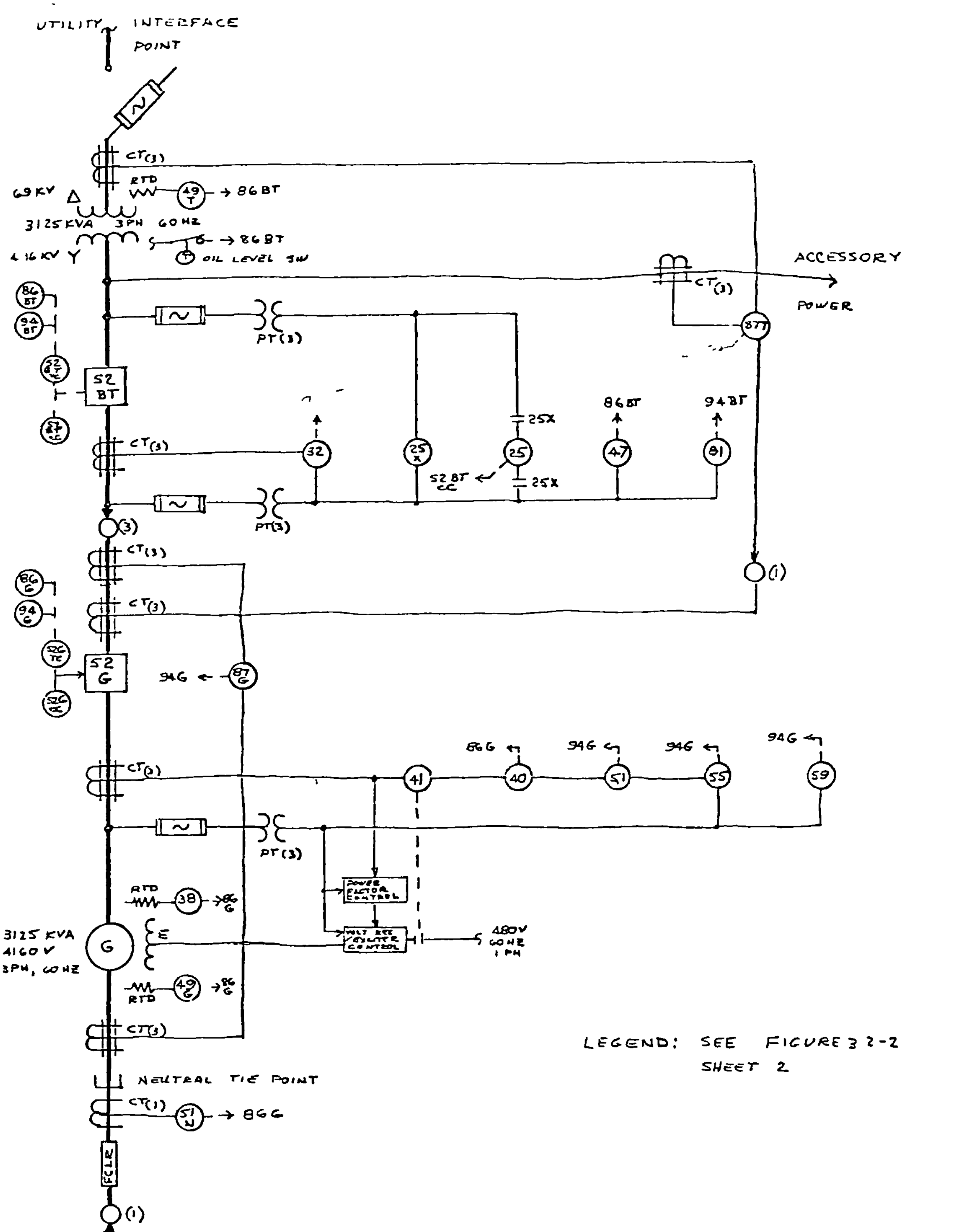


Figure 3. SCHEMATIC DIAGRAM OF WTS ELECTRICAL POWER NETWORK



LEGEND: SEE FIGURE 3.2-2
SHEET 2

Figure 3, SCHEMATIC DIAGRAM OF WTS ELECTRICAL PROTECTION
(SHEET 1 OF 2) (Con't)

LEGEND:

25 SYNCHRONIZING RELAY

25X SYNCHRONIZATION CHECK RELAY

32 DIRECTIONAL POWER RELAY

38 GENERATOR BEARING OVER TEMPERATURE RELAY

40 LOSS OF EXCITATION RELAY

41 FIELD CURRENT RELAY

47 PHASE SEQUENCE RELAY

49 THERMAL RELAY

51 AC TIME OVERCURRENT RELAY

52G GENERATOR CIRCUIT BREAKER

52BT BUS TIE CONTACTOR

55 POWER FACTOR RELAY

59 OVER VOLTAGE RELAY

51N GROUND PROTECTION RELAY

81 UNDER FREQUENCY RELAY

86 - LOCKING OUT RELAY

87 DIFFERENTIAL PROTECTIVE RELAY

94 TRIPPING RELAY

$\boxed{FC\ LR}$ FAULT CURRENT LIMITING RESISTOR

(X) SUBSCRIPT = QUANTITY USED

→○ SLIP RING (ARROW DENOTES BRUSH)

$\boxed{\sim}$ FUSED MANUAL DISCONNECT DEVICE

BT BUS TIE
CC CLOSE COIL
CT CURRENT TRANSFORMER
E EXCITER
G GENERATOR
PT POTENTIAL TRANSFORMER
RTD RESISTANCE TEMPERATURE DEVICE
T TRANSFORMER
TC TRIP COIL

Figure 3, SCHEMATIC DIAGRAM OF WTS' ELECTRICAL PROTECTION (SHEET 2 OF 2) (Con't)

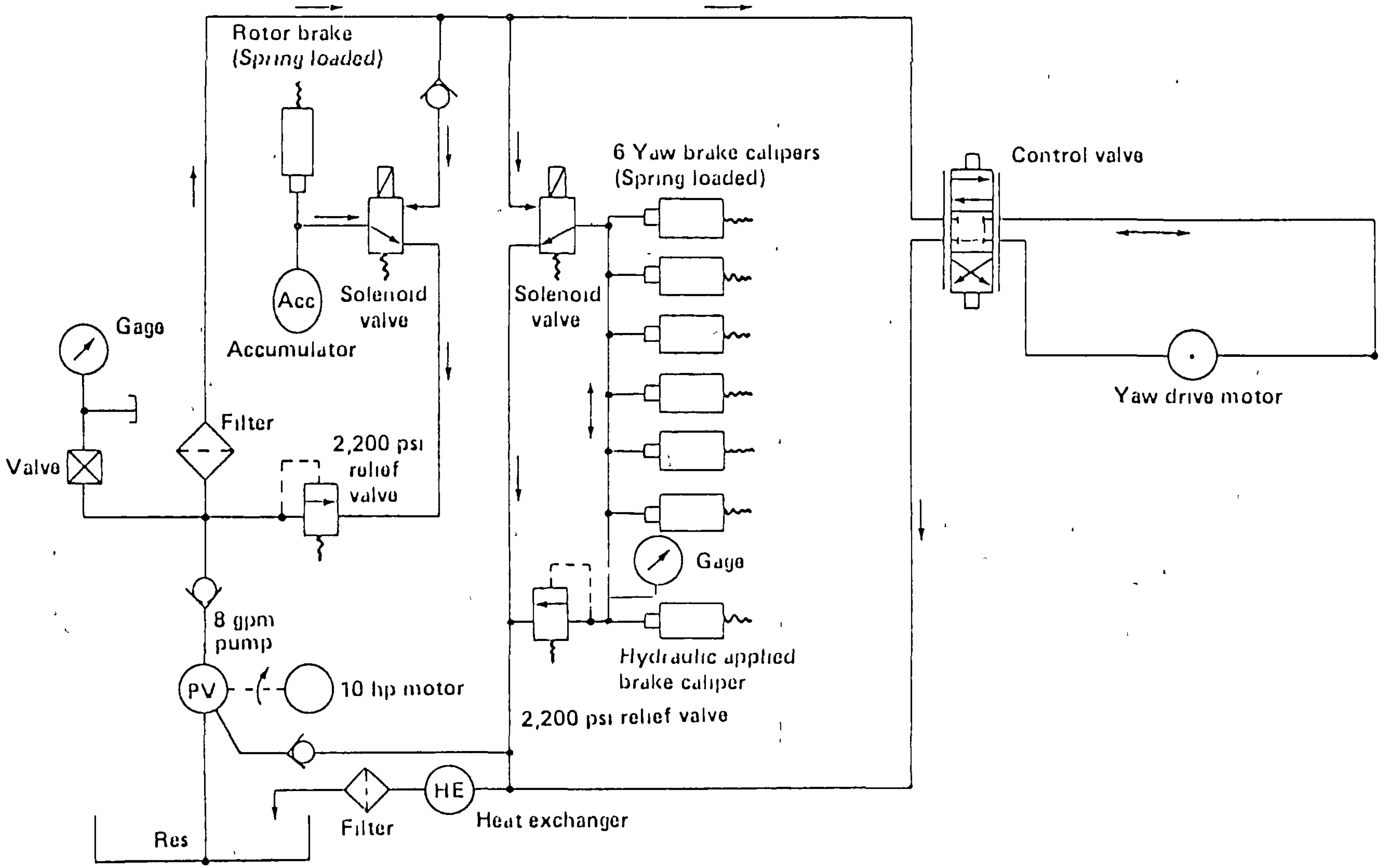
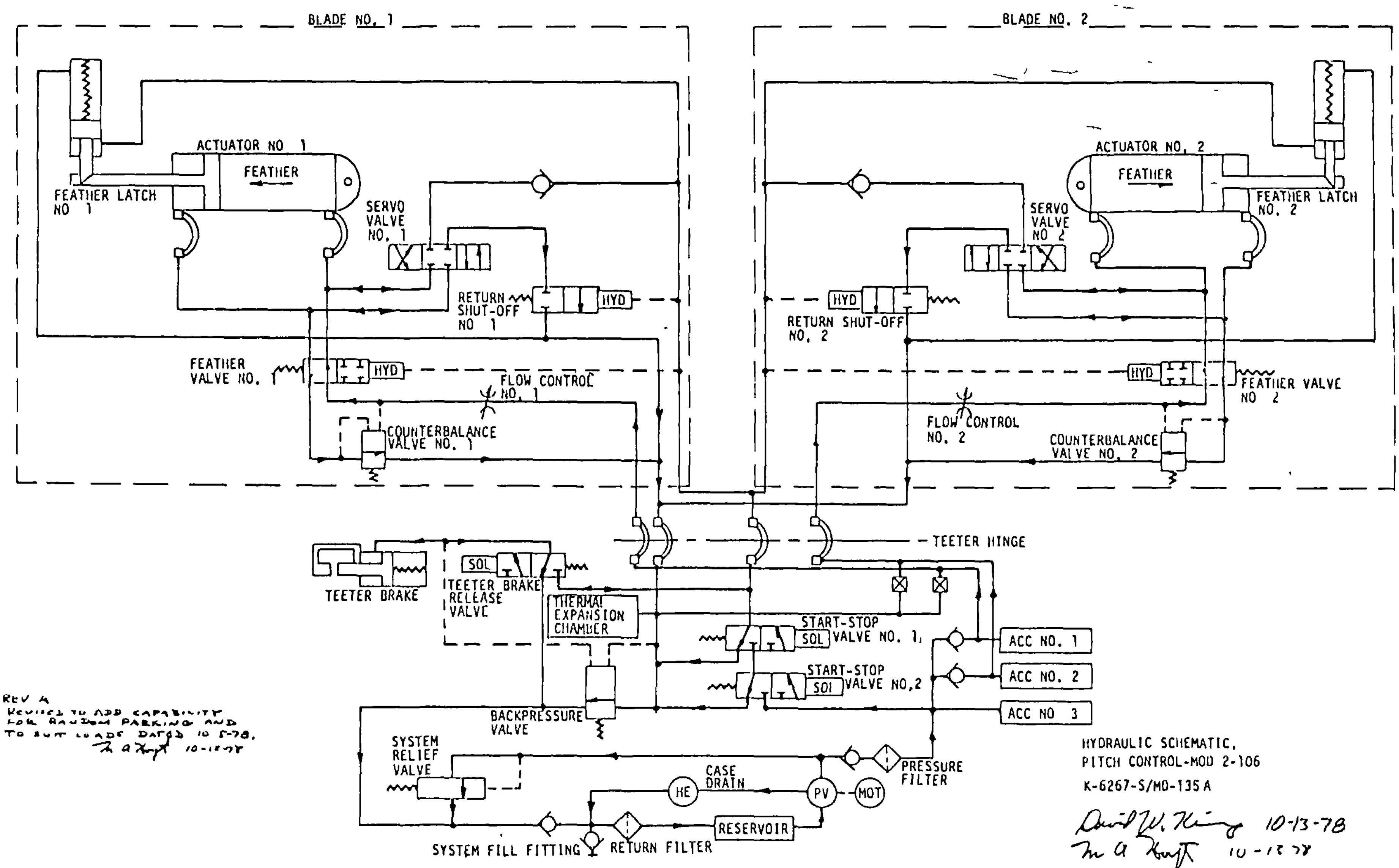


FIGURE 5, HYDRAULIC SCHEMATIC, YAW SYSTEM R



REV A
Revised to add capability for random parking and to suit loads dated 10-5-78.
10-13-78

FIGURE 4, HYDRAULIC SCHEMATIC - PITCH R

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APPENDIX C

MEMO K-6265-SS-487, DATED 18 October, 1978, MOD-2 FAILURE MODE AND EFFECTS ANALYSIS

October 18, 1978
K-6265-SS-487

To: W. Wiesner

cc: G. Davison
R. Douglas
J. Erickson
W. Engle
H. Davis

Subject: MOD-2 Failure Mode and Effects Analysis

Reference: K-6266-RL-177, Same Subject, Sept. 14, 1978

The shut down analysis requested in the subject reference has been performed as part of a more comprehensive study on emergency shutdown conditions. The following shutdown analyses were performed:

Condition	Description	Shutdown Procedure
#1	Normal shutdown	Feather at 1^{o} per second, drop load at 125 kw
#2	Emergency shutdown	Feather at 4^{o} per second for 6 seconds and 1^{o} per second thereafter, drop load at 125 kw
#3	Drop load, emergency shutdown	Drop load, feather at 4^{o} per second for 6 second and 1^{o} per second thereafter
#4	Control system malfunction Emergency shutdown	Power exceeds 2X rated, drop load, feather at 4^{o} per second for 6 seconds and 1^{o} per second thereafter
#5	One tip jams Emergency shutdown	One tip jams, feather other tip at 6^{o} per second for 8 seconds and 1^{o} per second thereafter, drop load at 125 kw
#6	Lose one tip Emergency shutdown	Lose one tip, feather other tip at 6^{o} per second for 8 seconds and 1^{o} per second thereafter, drop load at 125 kw.

The maximum rotor overspeeds resulting from the shutdown condition are presented below.

SHUT DOWN CONDITION	MAX ROTOR SPEED (RPM) 45 MPH	28 MPH
#1	17.530	17.529
#2	17.516	17.515
#3	18.536	19.771
#4	20.016 [1]	[2]
#5	17.519	[3]
#6	17.526	[3]

[1] 1.5 gust required to drop load

[2] Unable to drop load with 1.5 gust

[3] Have not run these cases but rotor speed should not be much different than condition 5 or 6 for 45 mph since load is not disconnected.

Shutdown condition #4 and #5 correspond most closely to the conditions requested in the reference memo. The worst overspeeds result when the load is dropped before initiation of the shutdown procedure (Conditions #3 and #4). The max overspeed, however, does not exceed 15 percent. Under the other shutdown condition, the load is not dropped until the aerodynamic torques are small resulting in negligible overspeeds.

Prepared by: S.A. Shipley
S. A. Shipley

Approved by: J. S. Andrews
J. S. Andrews

APPENDIX D

CABLE RUNS AND SLIP RING ANALYSES

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
Crack Detection-Power Cable to Motor	*Crack detection system*	Phase-to-phase short or short to ground	Crack detection system disabled. "No flow"switches activate resulting in WTS shutdown.
Crack Detection - wires to no flow and flow sensor switches	Crack detection system	Wires short to each other	Switches disabled such that crack would go unnoticed. No serious problem since upon first WTS shutdown NCU would detect a fault and inhibit restart.
Ice detector signal cable	Ice detection system	Wires short together.	Wires short together-causes WTS shutdown. Wires open-detector inoperative-Detector on other blade still operative. Short to ground-damages NCU I/O module when detector activates. Damage not significant
Control system - 48 VDC power supply cable and 208/120 VAC power supply	Control system (NCU)	Power line shorts to ground or to negative wire, or an AC short occurs.	Circuit breaker opens resulting in WTS shutdown. No secondary damage. *(Shutdown initiated by removing power to pitch control accumulators resulting in blade tips feathering)*

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
Tip Control Cables to each Tip (from low speed shaft)	Rotor - Pitch Control	Worst Case - Short in Cable such that tip is driven hard over.	WTS shuts down via microprocessor command. Tip still under control stops WTS. No significant damage to WTS (Microprocessor detects rapid change in power output and large difference in tip positions).
Power cable to pitch hydraulic motor	Pitch control and teeter brake	Worst case is loss of power to pump motor and subsequent loss of hydraulic pressure	WTS shuts down upon detection on loss of pressure. No damage to WTS.
Pitch hydraulic pump on cable	Pitch control and teeter brake	Short - wire to wire; short to ground	Both failures result in pump shut down and WTS shut down.
Pitch and teeter brake status signals and solenoid command signals	Pitch control and teeter brake	Short such that 115 VAC is applied to all or some lines.	Possible combinations: 1. Start-stop solenoids disabled-WTS shuts down (115 VAC short to ground) 2. Teeter brake disabled, 115 VAC line shorts to ground, WTS shuts down 3. Sensors by-passed. NCU thinks all status signals are o.k. Lack of detection of second fault possible until WTS has a normal shut down. Then it will detect fault and not restart. Probability of shorting to all related sensors is negligible.

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
Generator to Generator Accessory Unit - Power Cable	Electrical Power	Short to ground, wire-to-wire shorts	Differential current protection relay causes generator circuit breaker to open in both cases.
Generator to Generator Accessory Unit - Sensor Outputs	Electrical Power	Short to ground, wire-to-wire shorts	Sensor signals are at 110 VAC and a short to ground will result in WTS shutdown via I/O module opening. Wire-to-wire shorts would disable sensor, and therefore must be checked during preventative maintenance. A short to the exciter will result in abnormal generator output which will be detected by the G.A.U. resulting in WTS shutdown.
D.C. power panel to Generator Accessory Unit	Electrical Power, Controls	Short to ground.	Opens circuit breaker resulting in WTS shutdown.

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
Oil Reservoir to Gearbox	Drive Train	Short to ground or wire-to-wire short.	Short to ground opens I/O or circuit breaker and WTS shuts down. Wire-to-wire short could render "oil pressure low" or "oil temp high" sensors inoperative, but these signals are redundant.
Environmental Control - All Cables	Environmental Control	Short to ground or phase to phase short	Circuit breaker opens disabling fans. Not detected by N.C.U. May cause failure in N.C.U. which could result in erroneous signals to pitch, yaw or electrical controls. Similar to a random N.C.U. failure. Fail safe system shuts down WTS (see FMEA controls for analyses of each N.C.U. control line).

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
Fire Detector Cable	Fire detection and extinguishing system	Wire-to-wire short resulting in the detector being ineffective.	Fire would not be detected until second detector picked up smoke. Integrity of wiring checked during preventative maintenance. Emergency egress for personnel provided.
460 VAC cable from power distribution box to yaw drive system; 120 VAC single phase	Yaw drive system	Short - phase-to-phase or to ground	Circuit breaker opens rendering yaw drive system inoperative and resulting in WTS shut down as NCU detects that yaw drive system is inoperative.
Yaw drive signal and status lines	Yaw drive system	Both status and command signals are 110 VAC, so wire-to-wire shorts are very unlikely. A short from any wire to ground possible.	Shorts to ground result in I/O or circuit breaker opening and WTS shutdown. Wire-to-wire short renders command lines or status lines inoperative. Inoperative command line results in WTS shutdown via NCU. Status signals have back-up (i.e., yaw oil pressure low results in unresponsive yaw system which is detected by NCU).

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
Generator Accessory Unit Outputs to NCU	Power output circuits including generator	Short to ground on any single wire. Since all wires but one in this cable are at 110 VAC, the probability of a wire-to-wire short is very small, but long term insulation creep could result in this failure mode. The remaining wire is the power transducer.	Short to ground results in circuit breaker opening and WTS shutdown via pitch accumulators firing and driving blades to feather position. Results of a wire-to-wire short is to render the status signal inoperative since sensor output would be bypassed. Can be detected by periodic wrap-around check during preventative maintenance; second failure required before any problem exists. Shorts to the power transducer result in immediate WTS shutdown via NCU.
Cables to wind sensors	Yaw system, control system at start-up	Wire-to wire-short or short to ground	Cables from both sensors are separated so that a failure within one cable causes a disparity in signals resulting in WTS shutdown.

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
NCU to Drive Train	Drive Train	Wire to wire short applies 110 VAC to other 110 VAC lines or to 5 VDC failsafe lines.	Short of 110 VAC to other 110 VAC lines would bypass protection sensors (bearing overtemp. #1 and #2). Highly unlikely and detectable by checking during preventative maintenance. Short to 5 VDC lines (overspeed and RPM sensors) would result in shutdown via N.C.U.
460 VAC power distribution to gearbox controls	Drive train - controls	Phase to Phase short or short to ground	Circuit breaker fails and WTS shuts down.
NCU to Drive Train Oil Reservoir	Drive Train	Short to ground or wire-to-wire short.	Short to ground results in circuit breaker opening and WTS shutdown (all wires are 110 VAC). Wire-to-wire short could disable "oil pressure low" line, but it is redundant and is therefore not a problem.

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
208/120 volt Power Distribution Panel - Housekeeping Circuits and EPS	Aircraft Warning Lights, Generator Protection Circuits	Short to ground, wire-to-wire short	All shorts to ground open circuit breakers. Wire-to-wire shorts would open circuit breaker if different phases short together or if 208 volt line shorts to 120 volt line. Other wire-to-wire shorts have no impact
460 VAC Power Distribution Panel - Housekeeping Circuits	Generator Heaters, Housekeeping, 208/120 VAC supply	Short to ground, wire-to-wire short	Same as 208/120 volt cable above
NCU to Yaw Slip Rings	CRT, Ground Intrusion System, Telephone Line, WTS status indicators, Bus Tie Contactor	Short to ground, wire-to-wire short	CRT, telephone and status indicators not critical functions and no significant damage occurs. Control wire to Bus Tie Contactor shorts to ground or open circuit causes Bus Tie Contactor to open resulting in WTS shtdown. Bus Tie Contactor status lines shorts or opens results in WTS shutdown. Short or open sync. enable line inhibits WTS start-up.

LOW SPEED SHAFT

SLIP RING ANALYSIS

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

LOW SPEED SHAFT SLIP RING ANALYSIS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
<u>LOW SPEED SHAFT</u> <u>SLIP RINGS</u> Rings 1-10	Power Circuits - 460 VAC and 28 volts DC	Ring to adjacent ring short	All of these shorts result in a circuit breaker opening and loss of pitch hydraulic pressure or pitch control. WTS shuts down via hydraulic pressure low or erroneous pitch position feedback signal
#11	Command return (ground)	Short to #10 (280 DC) Short to #12 (110 VAC)	Same as above. Fires emergency accumulator resulting in safe WTS shutdown
#12	Accumulator inhibit command	Short to #13 (110 VAC)	Would prevent firing emergency accumulator on one side, but second accumulator would fire and safely shutdown the WTS.

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
LOW SPEED SHAFT SLIP RINGS (Con't) #13	Teeter brake unlock command	Short to #14 (110 VAC)	110 VAC would remain on fail-safe emergency accumulator status line when shutdown. No impact.
Failsafe Emergency Accumulator Low #14	Highspeed shutdown	Short to #15 (110 VAC)	Short would give false signal indicating that emergency accumulator pressure to fail-safe system was normal when it could be failed. NCU signal is redundant with with this function and would shut down WTS. Failsafe wiring should be checked every 2 months.
Failsafe Emergency Accumulator Return #15	Highspeed shutdown	Short to #16 (110 VAC)	Same as #14 above.

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
Status signal line #16	Pitch Control	Short to #17 (110 VAC)	Would not provide oil low information. Pressure low and/or temperature high would result in shutdown.
Pitch Hydraulic Oil Level Low #17	Pitch Control	Short to #18 (110 VAC)	Same as #16 above
Pitch Hydraulic Oil Filter Clogged #18	Pitch Control	Short to #19 (110 VAC)	Would not provide oil filter clogged information. Filter would be by-passed by relief valve.
Pitch Hydraulic Pressure Low #19	Pitch Control	Short to #20 (110 VAC)	Would not provide pressure low information. Would be detected by fail-safe system and WTS would shut down.
Pitch Hydraulic Oil Temperature High #20	Pitch Control	Short to #21 (110 VAC)	Would not provide oil temperature high information. If WTS performance suffered, the control system would detect it. No major damage would occur if undetected.

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
Pitch Hydraulic Accumulator Precharge Pressure Low #21	Pitch Control	Short to #22 (110 VAC)	Would not provide status. Backed up by fail safe system
Pitch emergency accumulator gas pressure low #22	Pitch Control	Short to #23 (110 VAC)	Would not provide gas pressure low signal. Fail-safe system backs up this detector. (See #14)
Crack detection status signal #23	Crack detection	Short to #24 (110 VAC)	Would not provide crack detection capability.
Crack detection status signal return #24	Crack detection	Short to #25 (110 VAC)	Same as #23 above
Emergency Accum. Inhibit Command #25	Pitch Control	Short to #26 (spare) Short to #24 (110 VAC)	No impact Same as number 12.
#26	Spare	- - - - - - -	- - - - - -

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
Low Speed Shaft Slip Rings 27-34	Ice Detection	Shorts to adjacent slip rings	Would render one side of rotor ice detection inoperative. Signals to each detector separated so both sides would not fail. Test signals checks circuit integrity.
#35 - 36	Spares		
Servo valve, Tip #1 #37-41 Position sensor, Tip #1, #42-46 Servo Valve, Tip #2, #44-51 Position sensor, Tip #2, 52-56	Pitch control	Slip ring to slip ring short	WTS would shut down since the NCU would detect an error between the two blade tip posit-tions. Worse case would be loss of a servo amp in the NCU.
#57	Spare		
#58 - 72	Test Instrumentation	Slip ring-to-slip ring shorts	Not a part of the in-line WTS functions - would not inhibit normal or high speed shut downs.

YAW SLIP RING ANALYSIS

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
<u>YAW SLIP RINGS</u> Ground - #1 & #6 Primary Power out - #2-4 Neutral - #5	Electrical power	Ring-to-ring short	Short would probably vaporize. If not, instantaneous over-current and/or ground fault relays would trip the generator circuit breaker and open the bus tie contactor. As a back-up, the BTC is fused.
480 volts A.C. #7-9	All systems that utilize 480 and 240/120 VAC. (Controls, electrical)	Ring-to-ring short	Minor shorts (a wire strand) would vaporize. A major short would trip the 480 VAC circuit breaker(s) resulting in WTS shutdown.
48 VDC lines #10-13	Control system	Ring-to-ring short	Loss of 48 VDC to controls would result in shutdown. The uninterruptable power to the BTC would be maintained since there is a fuse between the battery output and the slip rings, but the wire to the BTC is on the battery side of the fuse.

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
<u>YAW SLIP RINGS</u> Fault current Limiting device (FCLD) #14	Electrical power	Short to #15 (low level current is on #15 - differential CT).	Would create imbalance which would trigger differential CT.
Differential CT ØA #15	Electrical Power	Short to #16 (FCLD)	Same as #14 above
Fault current Limiting device #16	Electrical power	Short to #17 (low level current)	Same as #14 above
Differential CT ØB, ØC and Common #17, 18, 19	Electrical power	Ring-to-ring shorts 17-18, 18-19 Short #19 - #20	Same as #14 above
Sync. Enable Relay #20	Electrical Power	Short to #21 (BTC Tripping relay - 110 VAC when closed).	No impact on sync. enable relay since it already has 110 VAC applied. No impact on the BTC relay since it too has 110 VAC applied when rotating. During shutdown, both #20 and #21 have "0" volts applied, so no impact from a short.

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
YAW SLIP RINGS BTC Tripping Relay - #21	Electrical Power	Short to ring #22	Would short I/O module and disconnect BTC resulting in WTS shutdown.
Command return #22 (from BTC and sync. enable relay.)	Electrical Power	Short to #23	None, #23 is a spare
Spares - #23 and #24	-	-	-
Generator Circuit Breaker (GCB) Closed indicator return #25	Electrical Power	Short to #26 (Generator field current meter)	Would apply 48 VDC to the Generator Field Current meter. Could cause 48 VDC circuit breaker to open, shutting down the WTS. No serious consequences if current draw is insufficient to trip the breaker.

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
YAW SLIP RINGS Generator Field Current Meter (+) #26	Electrical Power	Short to #27 (48 VDC)	Same as #25 above.
Generator Circuit Breaker Closed Indicator	Electrical Power	Short to #28 (current meter)	Same as #25 above.
Generator Field Current Meter (-) #28	Electrical Power	Short to #29 (110 VAC)	Would cause ammeter to act eratic. No WTS operational consequence.
BTC Tripped #29	Electrical Power	Short to #30 (110 VAC)	Would incorrectly indicate that the BTC was closed when it was opened. NCU will detect and lock out the WTS.
Utility Power Present #30	Electrical Power	Short to #31 (110 VAC)	Would indicate that utility power was present when it wasn't. NCU would not have AC power so could not start up. If the short occurred during operation and subsequently, power was lost, the WTS would shift from 60 HZ frequently and shut down.

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
YAW SLIP RINGS 110 VAC for BTC signals (Ident. #90 and 91 Slip ring #31)	Electrical power	Short to #32 (110 VAC)	None. #32 is the instrumentation van signal that is either at "0" or 110 VAC. In operational use, this line will be 110 VAC.
Instrumentation Van Not Ready Signal #32	Instrumentation	Short to #33 (48 VDC ground return)	Would destroy 110 VAC test signal I/O in NCU. No operational impact.
D.C. Return for 48 VDC signals #33	Manual control panel indicators	Short to #34 (48 VDC)	Same as #32 above.
Auto Mode Indicator #34	Manual control panel indicators	Short to #35 (48 VDC or 0)	Could erroneously indicate that the control system was in auto mode. Would be obvious fault since the manual mode light would also be on.
C/S Enabled Indicator #35	Manual control panel indicators	Short to #36 (48 VDC or 0)	Could erroneously indicate that the WTS was shut down. Indicatorswould be in conflict and failure obvious.
Shut Down Indicator #36	Manual control panel indicators	Short to #37 (48 VDC or 0)	Could erroneously indicate that the WTS was in manual mode. Failure would be obvious.

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
YAW SLIP RINGS Manual mode indicator #37	Manual control panel.	Short to #38 (110 VAC or "0")	Would put 48 VDC onto 110 VAC line if in manual mode. Could damage NCU I/O Module, but would not result in secondary damage.
Shutdown Switch #38	Manual control of WTS	Short to #39 (110 VAC)	Both lines are at 110 VAC or one is at 0. Shutdown would occur if short happens while running.
120 VAC supply #39	Manual control panel	Short to #40 (48 VDC)	Could damage NCU I/O module. No secondary damage. Failure would be obvious since several functions on the panel would be disabled.
Emergency Stop #40 & 41	Manual control panel	Short to #41 and/or 42	By-passes switch and stops WTS. Short to #42 could damage NCU I/O. No other damage.
Ground Intrusion Switch #42 and 43	Ground Intrusion	Short to #43 or #44	Would erroneously indicate a ground intrusion. Short to #44 no problem. (#44 is a spare)

FAILURE MODE AND EFFECTS ANALYSIS -- CABLE RUNS

CABLE RUN	SYSTEMS AFFECTED	FAILURE MODE(S)	EFFECTS
YAW SLIP RINGS #44 - 51	None - Spares	----	---
Remote telephone lines #52 - 56	Communications to remote utility control console	Ring-to-ring shorts. All circuits are low level TTL.	Loss of communications with site. No damage to WTS.
Local CRT #57 - 61	Local CRT signals	Ring-to-ring shorts. Circuits are low level TTL.	Loss of information to local CRT. No damage to WTS.
#62 - 120	Test Signals - used during initial test only. Disabled prior to turnover.	-----	-----

1 Report No NASA CR-159632	2 Government Accession No	3 Recipient's Catalog No
4 Title and Subtitle MOD-2 FAILURE MODE AND EFFECTS ANALYSIS		5 Report Date July 1979
		6 Performing Organization Code
7 Author(s) Robert Lynette and Robert Poore		8 Performing Organization Report No
		10 Work Unit No
9 Performing Organization Name and Address Boeing Engineering & Construction Co Boeing Company Seattle, Washington		11 Contract or Grant No DEN 3-2
		13 Type of Report and Period Covered Technical Memorandum
12 Sponsoring Agency Name and Address U S Department of Energy Distributed Solar Technology Division Washington, D.C. 20545		14 Sponsoring Agency Code Report No. DOE/NASA/0002-79/1

15 Supplementary Notes

Final report. Prepared under Interagency Agreement DE-AI01-79ET20485. Project Manager, James P. Couch, Wind Energy Project Office, NASA Lewis Research Center, Cleveland, Ohio 44135.

16 Abstract

The report contains the results of a failure mode and effects analysis of the Mod-2 wind turbine. This work was performed by the Boeing Engineering and Construction Company, a Division of the Boeing Company, as a part of contract DEN 3-2 to design and build three 300 foot diameter, 2500 kWe, wind turbines.

17 Key Words (Suggested by Author(s))	18 Distribution Statement
Wind turbine generator Mod-2 WTG FMEA Failure modes	Unclassified - unlimited STAR Category 44 DOE Category UC-60

19 Security Classif (of this report)	20 Security Classif (of this page)	21 No of Pages	22 Price*
Unclassified	Unclassified		

* For sale by the National Technical Information Service Springfield Virginia 22161

☆ U S GOVERNMENT PRINTING OFFICE 1979 — 657-060/5351