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84AEPD004

Mod-5A Wind Turbine Generator Program Design Report

Volume IV—Drawings and Specifications
Book 1

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General Electric Company
(Advanced Energy Programs Department)

August 1984

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lewis Research Center
Under Contract DEN 3-153

for
U.S. DEPARTMENT OF ENERGY
Conservation and Renewable Energy
Division of Wind Energy Technology

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Washington, D.C. 20545
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Volume I, Executive Summary

Volume I contains an overview of the MOD-5A Program. These topics are covered:

- Objectives of the MOD-5A Program
- Description of the Final Design (Model 304.2)
- Cost of Energy
- Power Output
- Trade-Off Studies
- Development Tests
- Analyses of Loads and Dynamics
- Manufacturing and Quality Assurance and Safety Plans

Volume II, Conceptual and Preliminary Design

These sections comprise Volume II, which is divided into two books, as follows:

Book 1
- 1.0 Summary
- 2.0 Introduction
- 3.0 Design Requirements
- 4.0 Conceptual Design Studies
- 5.0 Design, Development, and Optimization
- 6.0 System Dynamics Analysis
- 7.0 System Loads Analysis

Book 2
- 8.0 Development Tests
- 9.0 Design Criteria
- Appendix A System Specification
- Appendix B Design Load Tables

Volume III, Final Design and System Description

These sections comprise Volume III, which is divided into two books, as follows:

Book 1
- 1.0 Summary
- 2.0 Introduction
- 3.0 System Description - Model 304.2
- 4.0 Rotor Subsystem
- 5.0 Drivetrain Subsystem
- 6.0 Nacelle Subsystem
- 7.0 Tower and Foundation Subsystems

Volume IV, Drawings and Specifications

This volume contains the numbered drawings and specifications for the final design of the MOD-5A wind turbine. The volume is divided into five books, as follows:

Book 1 47A380002 through 47A380030

Book 2 47A380031 through 47A380068

Book 3 47A380074 through 47A380126

Book 4 47A380128 through 47A387125

Book 5 47D381002 through 47D387130

Volume IV of the MOD-5A Wind Turbine Generator Program Design Report contains the drawings and specifications for the baseline configuration in ascending drawing number order. Due to binding limitations, this volume is presented in multiple books.

Each book contains a full breakdown parts listing, as well as "where-used" list. The first and last drawing number in each part is noted below to indicate in which part of Volume IV to locate a particular drawing.

Volume IV	First Drawing
Part 1	47A380002 through 47A380030
Part 2	47A380031 through 47A380068
Part 3	47A380074 through 47A380126
Part 4	47A380128 through 47A387125
Part 5	47D381002 through 47D387130

NOTES: Part numbers preceded by "**" or not starting with "47-" are either standard hardware, vendor numbers, or unissued drawings. These numbers appear on the parts lists, but are not included in the volume.

DRAWINGS AND SPECIFICATIONS

WTG - MOD 5A

DRAWING LIST

(NUMERICAL SEQUENCE)

IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47A380024	INSTL CABLING REQT				X		0000		EA	47E382304G1		X	001867
47A380030	SPEC,SYST DISP PNL				X		0000		EA	47E387112G1		X	001849
47A380046	CONT ELEK CAB SPEC				X		0000		EA	47E387062G1		X	000564
47A380052	ELECTRICAL FAB. STD				X	5	0000		EA	47D387083G1		X	000663
47A380052	ELECTRICAL FAB. STD				X	5	0000		EA	47D387089G1		X	001561
47A380052	ELECTRICAL FAB. STD				X	5	0000		EA	47D387113G1		X	001774
47A380052	ELECTRICAL FAB. STD				X	5	0000		EA	47D387121G1		X	000877
47A380052	ELECTRICAL FAB. STD				X	5	0000		EA	47D387130G1		X	000914
47A380052	ELECTRICAL FAB. STD				X	5	0000		EA	47E387027G1		X	001370
47A380052	ELECTRICAL FAB. STD				X	5	0000		EA	47E387037G1		X	000701
47A380052	ELECTRICAL FAB. STD				X	5	0000		EA	47E387062G1		X	000561
47A380052	ELECTRICAL FAB. STD				X	5	0000		EA	47E387072G1		X	000777
47A380052	ELECTRICAL FAB. STD				X	5	0000		EA	47E387084G1		X	001811
47A380052	ELECTRICAL FAB. STD				X	5	0000		EA	47E387085G1		X	001636
47A380052	ELECTRICAL FAB. STD				X	5	0000		EA	47E387091G1		X	001513
47A380052	ELECTRICAL FAB. STD				X	5	0000		EA	47E387095G1		X	000638
												00.000	
47A380067	CONT SYST U.P.S.SPEC				M		0000		EA	47E387081G1	01.000	01.000	001318
47A380068	30-KVA XFMR SPEC				M		0000		EA	47E387081G1	01.000	01.000	001316
47A380069P31	NAMEPLATE,IDENT (J1)				*		0000		EA	47E387027G1	01.000	01.000	001345
47A380069P31	NAMEPLATE,IDENT (J1)				*		0000		EA	47E387084G1	01.000	01.000	001822
47A380069P31	NAMEPLATE,IDENT (J1)				*		0000		EA	47E387085G1	01.000	01.000	001646
47A380069P31	NAMEPLATE,IDENT (J1)				*		0000		EA	47E387091G1	01.000	01.000	001524
												04.000	
47A380069P32	NAMEPLATE,IDENT (J2)				*		0000		EA	47E387084G1	01.000	01.000	001823
47A380069P32	NAMEPLATE,IDENT (J2)				*		0000		EA	47E387085G1	01.000	01.000	001647
47A380069P32	NAMEPLATE,IDENT (J2)				*		0000		EA	47E387091G1	01.000	01.000	001525
												03.000	
47A380069P33	NAMEPLATE,IDENT (J3)				B		0000		EA	47E387084G1	01.000	01.000	001824
47A380069P33	NAMEPLATE,IDENT (J3)				B		0000		EA	47E387091G1	01.000	01.000	001526
												02.000	
47A380069P52	NAMEPLATE, IDENT (TB*				*		0000		EA	47E387072G1	01.000	01.000	000782
47A380069P71	NAMEPLATE,IDENT(GND)				*		0000		EA	47E387027G1	01.000	01.000	001346
47A380070P3	NPL, AN/REV STATUS				*		0000		EA	47E387027G1	01.000	01.000	001348
47A380070P3	NPL, AN/REV STATUS				*		0000		EA	47E387062G1	01.000	01.000	000560
47A380070P3	NPL, AN/REV STATUS				*		0000		EA	47E387072G1	01.000	01.000	000677
47A380070P3	NPL, AN/REV STATUS				*		0000		EA	47E387084G1	01.000	01.000	001825
47A380070P3	NPL, AN/REV STATUS				*		0000		EA	47E387085G1	01.000	01.000	001648

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47A380070P3	NPL, AN/REV STATUS				*		0000		EA	47E387091G1	01.000	01.000	001527
47A380070P3	NPL, AN/REV STATUS				*		0000		EA	47E387095G1	01.000	01.000	000640
												07.000	
47A380071PAR	SLEEVING, SHRINK				*		0000		FT	47D387121G1	AR		000881
47A380071PAR	SLEEVING, SHRINK				*		0000		FT	47D387130G1	AR		000920
47A380071PAR	SLEEVING, SHRINK				*		0000		FT	47E387027G1	AR		001366
47A380071PAR	SLEEVING, SHRINK				*		0000		FT	47E387062G1	AR		000954
47A380071PAR	SLEEVING, SHRINK				*		0000		FT	47E387072G1	AR		000784
47A380071PAR	SLEEVING, SHRINK				*		0000		FT	47E387084G1	AR		001818
47A380071PAR	SLEEVING, SHRINK				*		0000		FT	47E387085G1	AR		001642
47A380071PAR	SLEEVING, SHRINK				*		0000		FT	47E387091G1	AR		001520
47A380071PAR	SLEEVING, SHRINK				*		0000		FT	47E387095G1	AR		000643
												00.000	
47A380094	7500KVA VAR SP GEN				X		0000		EA	47E387081G1	X		001864
47A380102	FINISH				X		0000		PT	47C387096G1	X		000827
47A380102	FINISH				X		0000		PT	47E387084G1	X		001847
												00.000	
47A380102P1	FINISH				M		0000		QT	47D387121G1	AR		000878
47A380102P1	FINISH				M		0000		QT	47D387130G1	AR		000917
												00.000	
47D381002P1	BEARING, YAW				M		0000		EA	47E382133G1	01.000	01.000	000025
47D381003P1	ACTUATOR,HYDRAULIC				M		0000		EA	47E382165G1	04.000	04.000	000032
47D381010P1	BRAKE ASSY				M		0000		EA	47E382165G1	08.000	08.000	000031
47D381010P2	BRAKE ASSY				M		0000		EA	47E382603G1	02.000	04.000	000218
47D381010P2	BRAKE ASSY				M		0000		EA	47E382603G2	02.000	04.000	000246
												08.000	
47E381017	YAW SR ELECT INTFC				X		0000		EA	47E382594G1	X		000109
47D381013	ELEC INTERFACE				X		0000		EA	47E382599G1	X		001236
47D381019P1	SLIP RNG UN YAW AXIS				M		0000		EA	47E382594G1	01.000	01.000	000108
47D381020P1	ROTOR SLIPRING UNIT				M		0000		EA	47E382599G1	01.000	01.000	001237
47D381024P1	ROTARY POSITION SR				M		0000		EA	47E382599G1	01.000	01.000	001252
47C381030P1	HINGE, TRAP DOOR				*		0000		EA	47D382430G1	01.000	02.000	000397
47C381030P1	HINGE, TRAP DOOR				*		0000		EA	47D382430G2	01.000	02.000	000405
47C381030P1	HINGE, TRAP DOOR				*		0000		EA	47D382474G1	01.000	01.000	000414
47C381030P1	HINGE, TRAP DOOR				*		0000		EA	47D382474G2	01.000	01.000	000422
												06.000	

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47C381036P1	BOLT,FATIGUE RATED				B		0000		EA	47E382363G1	14.000	14.000	000350
47C381036P10	BOLT,FATIGUE RATED				B		0000		EA	47E382363G1	12.000	12.000	000327
47C381036P10	BOLT,FATIGUE RATED				B		0000		EA	47E382496G1	08.000	08.000	001270
47C381036P10	BOLT,FATIGUE RATED				B		0000		EA	47E382608G1	60.000	60.000	001291
												80.000	
47C381036P14	BOLT,FATIGUE RATED				B		0000		EA	47E382602G1	16.000	16.000	000167
47C381036P14	BOLT,FATIGUE RATED				B		0000		EA	47E382603G1	12.000	24.000	000238
47C381036P14	BOLT,FATIGUE RATED				B		0000		EA	47E382603G2	12.000	24.000	000265
												64.000	
47C381036P15	BOLT,FATIGUE RATED				B		0000		EA	47E382165G1	36.000	36.000	000045
47C381036P16	BOLT,FATIGUE RATED				B		0000		EA	47E382165G1	12.000	12.000	000046
47C381036P2	BOLT,FATIGUE RATED				B		0000		EA	47E382363G1	32.000	32.000	000324
47C381036P2	BOLT,FATIGUE RATED				B		0000		EA	47E382602G1	20.000	20.000	000174
												52.000	
47C381036P20	BOLT, FATIGUE RATED				B		0000		EA	47D382598G1	08.000	08.000	000548
47C381036P20	BOLT, FATIGUE RATED				B		0000		EA	47E382363G1	88.000	88.000	000326
47C381036P20	BOLT, FATIGUE RATED				B		0000		EA	47E382597G1	120.000	120.000	000537
												216.000	
47C381036P21	BOLT				B		0000		EA	47E382608G1	08.000	08.000	001295
47C381036P22	BOLT,FATIGUE RATED				B		0000		EA	47D382598G1	08.000	08.000	000549
47C381036P24	BOLT,FATIGUE RATED				B		0000		EA	47D382598G1	08.000	08.000	000547
47C381036P24	BOLT,FATIGUE RATED				B		0000		EA	47E382441G1	36.000	36.000	000196
												44.000	
47C381036P25	BOLT,FATIGUE RATED				B		0000		EA	47E382363G1	36.000	36.000	000328
47C381036P26	BOLT,FATIGUE RATED				B		0000		EA	47E382363G1	12.000	12.000	000348
47C381036P26	BOLT,FATIGUE RATED				B		0000		EA	47E382607G1	96.000	96.000	001279
												108.000	
47C381036P3	BOLT,FATIGUE RATED				B		0000		EA	47E382496G1	84.000	84.000	001268
47C381036P32	BOLT				M		0000		EA	47E382133G1	144.000	144.000	000026
47C381036P4	BOLT,FATIGUE RATED				M		0000		EA	47E382306G1	20.000	20.000	000310
47C381036P40	BOLT, STRUCT. 2-12				M		0000		EA	47E382306G1	24.000	24.000	000307
47C381036P5	BOLT,FATIGUE RATED				B		0000		EA	47E382495G1	24.000	48.000	001267

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47C381036P50	BOLT				B		0000		EA	47E382553G1	36.000	36.000	000366
47C381036P6	BOLT,FATIGUE RATED				B		0000		EA	47E382363G1	60.000	60.000	000325
47C381036P6	BOLT,FATIGUE RATED				B		0000		EA	47E382602G1	20.000	20.000	000170
												80.000	
47A381037P1	LACING TAPE				*		0000		FT	47D387121G1	AR		000880
47A381037P1	LACING TAPE				*		0000		FT	47D387130G1	AR		000919
47A381037P1	LACING TAPE				*		0000		FT	47E387062G1	AR		000853
47A381037P1	LACING TAPE				*		0000		FT	47E387072G1	AR		000773
47A381037P1	LACING TAPE				*		0000		FT	47E387084G1	AR		001820
47A381037P1	LACING TAPE				*		0000		FT	47E387085G1	AR		001644
47A381037P1	LACING TAPE				*		0000		FT	47E387091G1	AR		001522
47A381037P1	LACING TAPE				*		0000		FT	47E387095G1	AR		000642
												00.000	
47A381038P3	TAPE,LACING				*		0000		FT	47E387027G1	AR		001367
47C381039P1	EXPANSION JOINT				M		0000		EA	47E382570G1	02.000	02.000	000519
47C381039P2	EXPANSION JOINT				M		0000		EA	47E382570G1	01.000	01.000	000520
47D381040P1	HEAT EXCHANGER				M		0000		EA	47E387062G1	02.000	02.000	000555
47A381043PAR	SLEEVING, VINYL				*		0000		FT	47E387062G1	AR		000955
47A381043PAR	SLEEVING, VINYL				*		0000		FT	47E387072G1	AR		000774
47A381043PAR	SLEEVING, VINYL				*		0000		FT	47E387095G1	AR		000629
												00.000	
47A381044PAR	SLEEVING,TEFLON				*		0000		FT	47D387089G1	AR		001383
47A381044PAR	SLEEVING,TEFLON				*		0000		FT	47D387121G1	AR		000868
47A381044PAR	SLEEVING,TEFLON				*		0000		FT	47D387130G1	AR		000921
47A381044PAR	SLEEVING,TEFLON				*		0000		FT	47E387084G1	AR		001819
47A381044PAR	SLEEVING,TEFLON				*		0000		FT	47E387085G1	AR		001643
47A381044PAR	SLEEVING,TEFLON				*		0000		FT	47E387091G1	AR		001521
												00.000	
47A381044P5	SLEEVING				B		0000		FT	47D387113G1	AR		001469
47A381045PAR	CLAMP,LOOP-CUSHIONED				M		0000		EA	47E387062G1	AR		000579
47A381045P3	CLAMP,CABLE (.187 DI*				*		0000		EA	47E387072G1	02.000	02.000	000743
47A381045P5	CABLE CLAMP				B		0000		EA	47E387084G1	03.000	03.000	001817
47A381045P5	CABLE CLAMP				B		0000		EA	47E387085G1	03.000	03.000	001641
47A381045P5	CABLE CLAMP				B		0000		EA	47E387091G1	03.000	03.000	001519
												09.000	
47A381045P6	CLAMP,CABLE (.375 DI*				*		0000		EA	47E387072G1	04.000	04.000	000744

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47E381046P1	GEARBOX ENVELOPE				B		0000		EA	47E382553G1	01.000	01.000	000364
47B381059P4	CONNECTOR CUTOUT COV*				*		0000		EA	47E387072G1	03.000	03.000	000680
47D381060P1	VIDEO MONITOR				M		0000		EA	47E387112G1	01.000	01.000	001327
47C381066P1	HOSE ASSY				M		0000		EA	47J382330G1	04.000	04.000	001126
47C381066P2	HOSE ASSY				M		0000		EA	47J382330G1	06.000	06.000	001125
47A381067P1	CTL PROCESSING UNIT				M		0000		EA	47E387095G1	01.000	01.000	000594
47A381067P10	120 VAC TRK OUT MDL				M		0000		EA	47E387062G1	47.000	47.000	000570
47A381067P11	12-BIT A/D CONVERTER				M		0000		EA	47E387095G1	02.000	02.000	000603
47A381067P12	12-BIT SS ANLG INPUT				M		0000		EA	47E387095G1	03.000	03.000	000604
47A381067P13	12-BIT ANALOG OUTPUT				M		0000		EA	47E387095G1	02.000	02.000	000605
47A381067P14	WATCHDOG TIMER				M		0000		EA	47E387095G1	01.000	01.000	000601
47A381067P15	ERROR DETECTOR				M		0000		EA	47E387095G1	01.000	01.000	000600
47A381067P16	POWER SUPPLY				M		0000		EA	47E387095G1	01.000	01.000	000591
47A381067P17	CHASSIS INTERFACE				M		0000		EA	47E387095G1	01.000	01.000	000595
47A381067P18	CHASSIS				M		0000		EA	47E387095G1	02.000	02.000	000592
47A381067P2	ARITH. PROCESSING				M		0000		EA	47E387095G1	01.000	01.000	000599
47A381067P20	FILLER BLANK				M		0000		EA	47E387095G1	15.000	15.000	000602
47A381067P23	CABLE, I/O TRACK				M		0000		EA	47E387062G1	01.000	01.000	000575
47A381067P3	16K EXECUTIVE MEMORY				M		0000		EA	47E387095G1	01.000	01.000	000596
47A381067P31	TERMINATOR PLUG				M		0000		EA	47E387062G1	01.000	01.000	000571
47A381067P4	12K PROM, 4K RAM MEM				M		0000		EA	47E387095G1	01.000	01.000	000598
47A381067P5	16K RAM MEMORY				M		0000		EA	47E387095G1	01.000	01.000	000597
47A381067P6	TTY & EIA INTFC MDL				M		0000		EA	47E387095G1	03.000	03.000	000606
47A381067P7	I/O SYS DRIVER MDL				M		0000		EA	47E387095G1	01.000	01.000	000607
47A381067P8	I/O TRACK				M		0000		EA	47E387062G1	08.000	08.000	000568

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47A381067P9	120 VAC TRK INP MDL				M		.0000		EA	47E387062G1	81.000	81.000	000569
47C381072P1	CLAMP UNIT				M		0000		EA	47J382330G1	04.000	04.000	001138
47C381072P2	CLAMP UNIT				M		0000		EA	47J382330G1	52.000	52.000	001137
47C381072P3	CLAMP UNIT				M		0000		EA	47C382336G1	01.000	38.000	001133
47C381072P3	CLAMP UNIT				M		0000		EA	47C382336G2	01.000	08.000	001136
47C381072P3	CLAMP UNIT				M		0000		EA	47C382336G3	01.000	06.000	001186
												52.000	
47B381074P1	HOSE ASSY				M		0000		EA	47J382313G1	02.000	02.000	000086
47C381075P1	HOSE ASSY				M		0000		EA	47J382313G1	04.000	04.000	000084
47C381075P2	HOSE ASSY				M		0000		EA	47J382313G1	04.000	04.000	000085
47D381078P1	HIGH SPEED SFT ASSY				B		0000		EA	47D382589G1	01.000	01.000	000372
47D381080P1	TPR RLR BRG,SPDL/AFT				M		0000	80657	EA	47E382441G1	01.000	01.000	000178
47D381081P1	TPR RLR BRG,SPDL/FWD				M		0000	80657	EA	47E382441G1	01.000	01.000	000179
47D381082P1	COUPLING HUB, FWD				*		0000		EA	47D382435G1	01.000	01.000	000210
47D381082P2	TORQUE PLATE				M		0000		EA	47E382441G1	01.000	01.000	000195
47C381083P1	COUPLING HUB, AFT				*		0000		EA	47D382435G1	01.000	01.000	000211
47C381084P1	VALVE,THERMO,AMOT				M		0000		EA	47E382579G1	01.000	01.000	000477
47C381086P1	VALVE,RELIEF,4-IN				M		.0000		EA	47E382579G1	01.000	01.000	000478
47C381087P1	NUT				M		0000		EA	47E382306G1	20.000	20.000	000311
47C381087P1	NUT				M		0000		EA	47E382610G1	28.000	56.000	001028
												76.000	
47C381087P10	LOCKNUT				B		0000		EA	47E382363G1	124.000	124.000	000331
47C381087P10	LOCKNUT				B		0000		EA	47E382608G1	08.000	08.000	001296
												132.000	
47C381087P13	NUT, FATIGUE RATED				B		0000		EA	47E382133G1	144.000	144.000	000027
47C381087P13	NUT, FATIGUE RATED				B		0000		EA	47E382597G1	120.000	120.000	000538
												264.000	
47C381087P18	NUT 2-12				M		0000		EA	47E382306G1	24.000	24.000	000308
47C381087P2	LOCKNUT				B		0000		EA	47E382363G1	92.000	92.000	000329
47C381087P2	LOCKNUT				B		.0000		EA	47E382602G1	40.000	40.000	000173
												132.000	

IDENTIFICATION NO.	NOMENCLATURE	--- ECN --- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47C381087P22	LOCKNUT				B		0000		EA	47E382553G1	36.000	36.000	000368
47C381087P5	NUT				B		0000		EA	47E382441G1	360.000	360.000	000200
47C381087P5	NUT				B		0000		EA	47E382603G1	12.000	24.000	000239
47C381087P5	NUT				B		0000		EA	47E382603G2	12.000	24.000	000266
												408.000	
47C381087P6	LOCKNUT				B		0000		EA	47E382363G1	12.000	12.000	000330
47C381087P6	LOCKNUT				B		0000		EA	47E382608G1	60.000	60.000	001292
												72.000	
47C381087P9	NUT				B		0000		EA	47D382598G1	24.000	24.000	000546
47C381087P9	NUT				B		0000		EA	47E382363G1	12.000	12.000	000349
47C381087P9	NUT				B		0000		EA	47E382441G1	36.000	36.000	000198
47C381087P9	NUT				B		0000		EA	47E382607G1	96.000	96.000	001280
												168.000	
47C381088P1	WASHER,1.00 DIA				M		0000		EA	47E382306G1	20.000	20.000	000319
47C381088P1	WASHER,1.00 DIA				M		0000		EA	47E382363G1	92.000	92.000	000332
47C381088P1	WASHER,1.00 DIA				M		0000		EA	47E382496G1	84.000	84.000	001269
47C381088P1	WASHER,1.00 DIA				M		0000		EA	47E382602G1	40.000	40.000	000171
47C381088P1	WASHER,1.00 DIA				M		0000		EA	47E382610G1	28.000	56.000	001029
												292.000	
47C381088P10	WASHER,1.50 DIA				B		0000		EA	47D382598G1	24.000	24.000	000552
47C381088P10	WASHER,1.50 DIA				B		0000		EA	47E382363G1	136.000	136.000	000346
47C381088P10	WASHER,1.50 DIA				B		0000		EA	47E382607G1	96.000	96.000	001282
47C381088P10	WASHER,1.50 DIA				B		0000		EA	47E382608G1	68.000	68.000	001298
												324.000	
47C381088P13	WASHER, HARDENED STL				B		0000		EA	47E382133G1	144.000	144.000	000028
47C381088P13	WASHER, HARDENED STL				B		0000		EA	47E382597G1	120.000	120.000	000540
												264.000	
47C381088P14	WASHER, HARDENED STL				B		0000		EA	47E382133G1	144.000	144.000	000029
47C381088P14	WASHER, HARDENED STL				B		0000		EA	47E382597G1	120.000	120.000	000539
												264.000	
47C381088P17	WASHER 2.00				M		0000		EA	47E382306G1	24.000	24.000	000318
47C381088P18	WASHER 2.00				B		0000		EA	47E382306G1	24.000	24.000	000309
47C381088P2	WASHER,1.00 DIA				M		0000		EA	47E382306G1	20.000	20.000	000312
47C381088P2	WASHER,1.00 DIA				M		0000		EA	47E382363G1	105.000	105.000	000345
47C381088P2	WASHER,1.00 DIA				M		0000		EA	47E382602G1	40.000	40.000	000172
												165.000	
47C381088P21	WASHER				B		0000		EA	47E382553G1	36.000	36.000	000367

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IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47C381088P22	WASHER				B		0000		EA	47E382553G1	36.000	36.000	000369
47C381088P5	WASHER,1.25 DIA				B		0000		EA	47E382363G1	12.000	12.000	000333
47C381088P5	WASHER,1.25 DIA				B		0000		EA	47E382441G1	240.000	240.000	000201
47C381088P5	WASHER,1.25 DIA				B		0000		EA	47E382496G1	08.000	08.000	001271
47C381088P5	WASHER,1.25 DIA				B		0000		EA	47E382602G1	16.000	16.000	000168
												276.000	
47C381088P6	WASHER,1.25 DIA				B		0000		EA	47E382363G1	12.000	12.000	000347
47C381088P6	WASHER,1.25 DIA				B		0000		EA	47E382603G1	24.000	48.000	000242
47C381088P6	WASHER,1.25 DIA				B		0000		EA	47E382603G2	24.000	48.000	000270
												108.000	
47C381088P9	WASHER,1.50 DIA				M		0000		EA	47D382598G1	24.000	24.000	000545
47C381088P9	WASHER,1.50 DIA				M		0000		EA	47E382363G1	136.000	136.000	000334
47C381088P9	WASHER,1.50 DIA				M		0000		EA	47E382441G1	72.000	72.000	000197
47C381088P9	WASHER,1.50 DIA				M		0000		EA	47E382607G1	96.000	96.000	001281
47C381088P9	WASHER,1.50 DIA				M		0000		EA	47E382608G1	68.000	68.000	001293
												396.000	
47E381089P1	TRAILING EDGE INSTL				M		0000		EA	47E382590G1	02.000	02.000	001008
47E381089P2	TRAILING EDGE INSTL				M		0000		EA	47E382590G1	02.000	02.000	001009
47E381089P3	TRAILING EDGE INSTL				M		0000		EA	47E382590G1	02.000	02.000	001010
47J381090P1	INNER BLADE SECTION				M		0000		EA	47E382590G1	02.000	02.000	001006
47D381091P1	ICE DETECTOR				M		0000		EA	47E382469G1	02.000	04.000	001071
47E381093P1	BGR THRUST TEETER				M		0000		EA	47E382605G1	02.000	02.000	001198
47J381097P1	OUTER BLADE SECTION				M		0000		EA	47E382590G1	02.000	02.000	001007
47B381099PAR	WIRE,AWG 30,SLDRLESS				B		0000		FT	47D387113G1	AR		001776
47B381099PAR	WIRE,AWG 30,SLDRLESS				B		0000		FT	47E387037G1	AR		000698
												00.000	
47E381100P1	CABINET				M		0000		EA	47E387062G1	01.000	01.000	000554
47D381101P1	SHRINK DISC				M		0000		EA	47E382605G1	02.000	02.000	001200
47C381102P1	ROTOR SEAL FWD				M		0000	03668	EA	47E382441G1	02.000	02.000	000189
47C381103P1	ROTOR SEAL AFT				M		0000	03668	EA	47E382441G1	02.000	02.000	000190
47C381104P1	STUD				M		0000		EA	47E382441G1	120.000	120.000	000192
47C381104P2	STUD				M		0000		EA	47E382441G1	120.000	120.000	000193

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47E381105G1	BOLSTER ASSY				M		0000		EA	47E382590G1	01.000	01.000	000985
47B381106P1	"O" RING SEAL, AFT				M		0000		EA	47E382441G1	01.000	01.000	000181
47E381107P1	TROLLEY ASSY				M		0000		EA	47E382165G1	02.000	02.000	000034
47B381108P1	SENSOR, ROTOR SPEED				M		0000	81692	EA	47E382498G1	02.000	02.000	001276
47B381109P1	WSHR, BELLEVILLE SPR				B		0000	92830	EA	47E382441G1	120.000	120.000	000199
47C381110P1	SEAL, FWD, COUPLING				M		0000		EA	47E382601G1	04.000	04.000	000214
47C381111P1	BELLOWS JOINT				M		0000		EA	47E382599G1	01.000	01.000	001238
47E381112G1	FOUNDATION REQT				M		0000		EA	47E382297G1	01.000	01.000	000006
47E381112P1	FOUNDATION ASSEMBLY				M		0000		EA	47E381112G1	01.000	01.000	000007
47E381112P10	#11 REINFORCING ROD				M		0000		FT	47E381112G1	AR		000016
47E381112P3	NUT				B		0000		EA	47E381112G1	192.000	192.000	000009
47E381112P5	RECT. WIREWAY				M		0000		EA	47E381112G1	03.000	03.000	000011
47E381112P6	CONDUIT SECTION				M		0000		EA	47E381112G1	01.000	01.000	000012
47E381112P7	CONDUIT SECTION				M		0000		EA	47E381112G1	02.000	02.000	000013
47E381112P8	CONDUIT SECTION				M		0000		EA	47E381112G1	01.000	01.000	000014
47E381112P9	#09 REINFORCING ROD				M		0000		FT	47E381112G1	AR		000015
47E381113P1	FAIRING ENVELOPE				B		0000		EA	47D382606G1	01.000	01.000	000378
47D381114P1	BRG,RADIAL-TEETER				M		0000		EA	47E382583G1	01.000	02.000	001195
47C381115P1	ACTUATOR				B		0000		EA	47E382610G1	06.000	12.000	001025
47D382000	TOWER GEOMETRY/DIAG				X		0000		EA	47E382304G1	X		001873
47C382020	LUBRICATION SCHEM				X		0000		EA	47E382570G1	X		000535
47E382045	GEOMETRY ENVELOPE				X		0000		EA	47E382304G1	X		001307
47E382050P1	YAW HSG STRUCT,UPPER				M		0000		EA	47E382133G1	01.000	01.000	000023
47B382131P1	ENCLOSURE, DOOR				*		0000		EA	47D382430G1	01.000	02.000	000396
47B382131P1	ENCLOSURE, DOOR				*		0000		EA	47D382430G2	01.000	02.000	000404
47B382131P1	ENCLOSURE, DOOR				*		0000		EA	47D382474G1	01.000	01.000	000413

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IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47B382131P1	ENCLOSURE, DOOR				*		0000		EA	47D382474G2	01.000	01.000 06.000	000421
47E382133G1	YAW STRUCTURE ASSY				M		0000		EA	47D382593G1	01.000	01.000	000022
47E382165G1	YAW DRIVE INSTL				M		0000		EA	47D382593G1	01.000	01.000	000030
47C382181P1	TRACK MTG BRACKET				M		0000		EA	47E382165G1	04.000	04.000	000033
47C382181P2	TRACK, MTG BRACKET				M		0000		EA	47E382165G1	02.000	02.000	000063
47D382192P1	BRAKE MTG PLATE				M		0000		EA	47E382165G1	02.000	02.000	000041
47B382193P1	PIN, CLEVIS - BRAKE				M		0000		EA	47E382165G1	04.000	04.000	000044
47B382196P1	SPACER, CLEVIS BLOCK				M		0000		EA	47E382165G1	04.000	04.000	000061
47B382196P2	SPCR,ACTUATOR CLEVIS				M		0000		EA	47E382165G1	08.000	08.000	000062
47D382198P1	CLEVIS BLOCK				M		0000		EA	47E382165G1	02.000	02.000	000042
47D382198P2	CLEVIS BLOCK				M		0000		EA	47E382165G1	02.000	02.000	000064
47B382200P1	RETAINER, PIN				M		0000		EA	47E382165G1	04.000	04.000	000043
47E382219P1	YAW HSG STRUCT,LOWER				M		0000		EA	47E382133G1	01.000	01.000	000024
47C382234P1	GASKET				M		0000		EA	47E387062G1	02.000	02.000	000565
47B382248P1	AIR BAF, RIGHT SIDE				M		0000		EA	47E387062G1	01.000	01.000	000573
47B382248P2	AIR BAF, LEFT SIDE				M		0000		EA	47E387062G1	01.000	01.000	000574
47E382264P1	SIDE SUPPORT,WLDMT				M		0000		EA	47E382363G1	01.000	01.000	000361
47E382265P1	SIDE SUPPORT				M		0000		EA	47E382363G1	01.000	01.000	000320
47E382265P2	SIDE SUPPORT				M		0000		EA	47E382363G1	01.000	01.000	000321
47E382271P1	ROTOR ADAPTER,WLDMT				M		0000		EA	47E382363G1	01.000	01.000	000362
47E382272P1	ROTOR ADAPTER STRL				M		0000		EA	47E382363G1	01.000	01.000	000323
47D382274	NACELLE GEOMETRY				X		0000		EA	47E382304G1	X		001874
47B382277P1	DRIP TROUGH				M		0000		EA	47E382165G1	02.000	02.000	000069
47B382277P2	DRIP TROUGH				M		0000		EA	47E382165G1	02.000	02.000	000070

IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47C382278P1	MANIFOLD FITTING				M		0000		EA	47E382165G1	02.000	02.000	000065
47A382285	PROFILE COORDINATES				X		0000		EA	47E382590G1	X		001228
47J382287P1	CENTER BLADE SECT				M		0000		EA	47E382590G1	01.000	01.000	000984
47D382288	GENERAL SITE LCTN				X		0000		EA	47E382304G1	X		001870
47D382296P1	LOW SPEED SHAFT				*		0000		EA	47D382435G1	01.000	01.000	000209
47E382297G1	TWR/FOUNDATION INSTL				M		0000		EA	47D382356G1	01.000	01.000	000003
47E382297P7	GROUT				M		0000		LB	47E382297G1	AR		000020
47D382298	SITE PLAN-1ST UNIT				X		0000		EA	47E382304G1	X		001871
47E382301P1	BOLSTER				M		0000		EA	47E381105G1	02.000	02.000	000986
47E382303P1	TWR/ FDN PLATF REQT				M		0000		EA	47E382297G1	01.000	01.000	000017
47E382304G1	WTG ASSY, MOD-5A	1			M		0000		EA			01.000	000001
47E382306G1	BED PL.,MACH.&DRILL.	01			M		0000		EA	47E382363G1	01.000	01.000	000304
47J382313G1	HYDR PIPING, YAW DR				M		0000		EA	47D382593G1	01.000	01.000	000075
47E382314	HYDRAULIC SYS SCHEM				X		0000		EA	47J382313G1	X		000105
47J382330G1	BLADE HYDRAULIC INST				M		0000		EA	47E382590G1	01.000	01.000	001122
47J382330P1	TUBING HYDRAULIC				M		0000		FT	47J382330G1	720.000	720.000	001123
47J382330P2	TUBING HYDRAULIC				M		0000		FT	47J382330G1	480.000	480.000	001124
47E382333P1	SPINDLE SHAFT				M		0000		EA	47E382441G1	01.000	01.000	000177
47E382334P1	TIP,BLADE				M		0000		EA	47E382582G1	02.000	04.000	001053
47C382335P1	TUBE ADAPTER				M		0000		EA	47J382330G1	04.000	04.000	001140
47C382335P2	TUBE ADAPTER				M		0000		EA	47J382330G1	06.000	06.000	001139
47C382336G1	BRKT,CLAMP MODIFIED				M		0000		EA	47J382330G1	38.000	38.000	001131
47C382336G2	BRKT,CLAMP MODIFIED				M		0000		EA	47J382330G1	08.000	08.000	001134
47C382336G3	BRKT,CLAMP				M		0000		EA	47J382330G1	06.000	06.000	001184
47C382336P1	BRACKET,ANGLE				M		0000		EA	47C382336G1	02.000	76.000	001132

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47C382336P1	BRACKET,ANGLE				M		0000		EA	47C382336G2	02.000	16.000	001135
47C382336P1	BRACKET,ANGLE				M		0000		EA	47C382336G3	02.000	12.000	001185
												104.000	
47C382337P1	ADAPTER,TUBE				M		0000		EA	47J382330G1	12.000	12.000	001145
47B382338P1	STUD,MOUNTING				M		0000		EA	47J382330G1	10.000	10.000	001142
47C382349P1	SLEEVE,SPLIT				M		0000		EA	47J382330G1	150.000	150.000	001149
47C382349P2	SLEEVE,SPLIT				M		0000		EA	47J382330G1	100.000	100.000	001150
47C382350P1	TEETER SPRT OUTER				M		0000		EA	47C382551G2	01.000	04.000	001000
47C382351P1	TEETER SPRT INNER				M		0000		EA	47C382551G1	01.000	04.000	000996
47D382352G1	TEETER ARM ASSY				M		0000		EA	47E382605G1	04.000	04.000	001204
47D382352P1	TEETER ARM				M		0000		EA	47D382352G1	01.000	04.000	001205
47D382352P2	RETAINING RING				M		0000		EA	47D382352G1	01.000	04.000	001206
47C382353P1	TEETER SUPPORT PIN				M		0000		EA	47E382605G1	04.000	04.000	001210
47E382355P1	TWR STRUCTURE ASSY				M		0000		EA	47E382297G1	01.000	01.000	000004
47D382356G1	TOWER ASSY, WTG				M		0000		EA	47E382304G1	01.000	01.000	000002
47E382357G1	BRACKET,INBOARD				M		0000		EA	47J382330G1	02.000	02.000	001127
47E382357P1	BRACKET				M		0000		EA	47E382357G1	01.000	02.000	001128
47D382358P1	BRKT,OUTBOARD				M		0000		EA	47J382330G1	02.000	02.000	001130
47C382359P1	PLATE				M	M	0000		EA	47J382330G1	04.000	04.000	001165
47C382360G1	SUPPORT,HOSE				M		0000		EA	47J382330G1	02.000	02.000	001160
47C382360P1	PLATE				M		0000		EA	47C382360G1	01.000	02.000	001161
47C382360P2	PAD				M		0000		EA	47C382360G1	01.000	02.000	001162
47D382361G1	BASE,HOSE SUPPORT				M		0000		EA	47J382330G1	02.000	02.000	001155
47D382361P1	PLATE				M		0000		EA	47D382361G1	01.000	02.000	001156
47D382361P2	PAD				M		0000		EA	47D382361G1	01.000	02.000	001157
47E382363G1	NACELLE STRUCT ASSY	1			M		0000		EA	47E382597G1	01.000	01.000	000303

IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47D382372P1	RTR BRG RETAINER,FWD				M		0000		EA	47E382441G1	01.000	01.000	000184
47B382373P1	SPACER				M		0000		EA	47J382330G1	08.000	08.000	001166
47B382373P2	SPACER				M		0000		EA	47J382330G1	08.000	08.000	001167
47B382373P3	SPACER				M		0000		EA	47J382330G1	08.000	08.000	001168
47C382390P1	PLUG, SHAFT TEETER				M		0000		EA	47D382397G1	02.000	02.000	000992
47B382396P1	SHIM,BRG				M		0000		EA	47E382605G1	02.000	02.000	001199
47B382396P1	SHIM,BRG				X		0000		EA	47E382608G1	X	02.000	001290
47D382397G1	TEETER PVT SFT ASSY				M		0000		EA	47D382550G1	01.000	01.000	000990
47D382397P1	TEETER PIVOT SHAFT				M		0000		EA	47D382397G1	01.000	01.000	000991
47B382398P1	SPACER				M		0000		EA	47E382413G1	AR		001082
47C382399P1	BLOCK,BALLAST				M		0000		EA	47E382413G1	96.000	96.000	001080
47E382400G1	LIGHTING PROT INSTL				M		0000		EA	47E382590G1	02.000	02.000	001106
47E382400P3	LIGHTING STRIP				M		0000		FT	47E382400G1	AR		001109
47E382400P4	SPLICE PLATE				M		0000		EA	47E382400G1	16.000	32.000	001110
47E382400P6	SHIM				M		0000		EA	47E382400G1	02.000	04.000	001112
47B382401P1	STUD				M		0000		EA	47E382413G1	32.000	32.000	001081
47E382403P1	INSERT,BOLSTER				M		0000		EA	47C382552G1	01.000	02.000	001004
47D382406	GEOMETRY DWG				X		0000		EA	47E382590G1	X		001225
47E382407P1	LOW SP BK SPRT BRKT				M		0000		EA	47E382495G1	01.000	02.000	001255
47E382413G1	BALLAST INSTL				M		0000		EA	47E382590G1	01.000	01.000	001079
47B382419P1	WASHER				B		0000		EA	47E382165G1	96.000	96.000	000050
47B382420P1	JAM NUT				B		0000		EA	47E382165G1	04.000	04.000	000056
47E382429P1	BED PL. STRUCT. WELD				M		0000		EA	47E382306G1	01.000	01.000	000305
47D382430G1	TRAP DR. BEDPL / TWR				M		0000		EA	47E382472G1	02.000	02.000	000389
47D382430G2	TRAP DR. BEDPL / TWR				M		0000		EA	47E382472G1	02.000	02.000	000398

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47D382430P1	COVER				M		0000		EA	47D382430G1	01.000	02.000	000390
47D382430P1	COVER				M		0000		EA	47D382430G2	01.000	02.000	000399
												04.000	
47D382430P2	ANGLE				M		0000		EA	47D382430G1	02.000	04.000	000391
47D382430P2	ANGLE				M		0000		EA	47D382430G2	02.000	04.000	000400
												08.000	
47D382430P3	ANGLE				M		0000		EA	47D382430G1	02.000	04.000	000392
47D382430P3	ANGLE				M		0000		EA	47D382430G2	02.000	04.000	000401
												08.000	
47D382430P4	RIB				M		0000		EA	47D382430G1	02.000	04.000	000393
47D382430P4	RIB				M		0000		EA	47D382430G2	02.000	04.000	000402
												08.000	
47D382430P5	PLATE				M		0000		EA	47D382430G1	01.000	02.000	000394
47D382430P6	BAR				M		0000		EA	47D382430G1	01.000	02.000	000395
47D382430P6	BAR				M		0000		EA	47D382430G2	01.000	02.000	000403
												04.000	
47D382435G1	LOW SPEED SHAFT ASSY				*		0000		EA	47E382601G1	01.000	01.000	000208
47C382436P1	SEAL RTNR, COUPLING				M		0000		EA	47E382601G1	02.000	02.000	000212
47C382437P1	SEAL PL, FWD CPLG				M		0000		EA	47E382601G1	06.000	06.000	000213
47E382440	SCHEM ROTOR HYDR SYS				X		0000		EA	47E382590G1	X		001227
47E382441G1	YOKE / SPINDLE ASSY				M		0000		EA	47E382601G1	01.000	01.000	000159
47E382450P1	GEARBOX MTG. STRUCT.				M		0000		EA	47E382306G1	01.000	01.000	000306
47B382454P1	ANTI-ROTATION PIN				M		0000		EA	47E382441G1	02.000	02.000	000183
47D382455P1	DISC, RTR SPEED SNSR				M		0000		EA	47E382441G1	01.000	01.000	000191
47D382456P1	RTR SEAL RTNR, AFT				M		0000		EA	47E382441G1	01.000	01.000	000182
47D382457P1	LOW SPEED BRAKE DISC				M		0000		EA	47E382441G1	01.000	01.000	000185
47C382458P1	RETAINER, AFT				M		0000		EA	47E382441G1	06.000	06.000	000180
47E382460	BLADE TOLERANCE DWG				X		0000		EA	47E382590G1	X		001226
47D382461P1	LOW SPEED BRAKE				M		0000		EA	47E382495G1	04.000	08.000	001256
47C382463G1	RING, MOUNTING				M		0000		EA	47C382464G1	02.000	08.000	001067

IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47C382463P1	RING, MOUNTING				M		0000		EA	47C382463G1	02.000	08.000	001068
47C382464G1	RING & HOUSING ASSY				M		0000		EA	47E382469G1	02.000	04.000	001066
47C382464G1	RING & HOUSING ASSY				M		0000		EA	47E382469G2	02.000	04.000	001097
												08.000	
47D382465P1	FRAME,TRAP DOOR				M		0000		EA	47E382472G1	02.000	02.000	000423
47B382467P1	RETAINER				M		0000		EA	47E382469G1	02.000	04.000	001072
47B382467P2	RETAINER / COVER				M		0000		EA	47E382469G1	02.000	04.000	001075
47B382467P2	RETAINER / COVER				M		0000		EA	47E382469G2	02.000	04.000	001103
												08.000	
47B382468P1	GASKET				M		0000		EA	47E382469G1	02.000	04.000	001073
47E382469G1	ICE DETECTOR INSTL				M		0000		EA	47E382590G1	02.000	02.000	001065
47E382469G2	ICE DETECTOR INSTL				M		0000		EA	47E382590G1	02.000	02.000	001096
47B382470P1	GASKET, COVER				M		0000		EA	47E382469G1	02.000	04.000	001078
47B382470P1	GASKET, COVER				M		0000		EA	47E382469G2	02.000	04.000	001105
												08.000	
47E382472G1	LAD & FALSE FL INSTL				M		0000		EA	47E382597G1	01.000	01.000	000388
47E382472P11	SEALING STRIP				M		0000		EA	47E382472G1	AR		000429
47E382472P8	ROOF SCUTTLE				B		0000		EA	47E382472G1	01.000	01.000	000426
47D382474G1	TRAP DR,BEDPL / LUBE				M		0000		EA	47E382472G1	01.000	01.000	000406
47D382474G2	TRAP DR,BEDPL / LUBE				M		0000		EA	47E382472G1	01.000	01.000	000415
47D382474P1	COVER				M		0000		EA	47D382474G1	01.000	01.000	00040[illegible]
47D382474P1	COVER				M		0000		EA	47D382474G2	01.000	01.000	00041[illegible]
												02.000	
47D382474P2	ANGLE				M		0000		EA	47D382474G1	02.000	02.000	00040[illegible]
47D382474P2	ANGLE				M		0000		EA	47D382474G2	02.000	02.000	00041[illegible]
												04.000	
47D382474P3	ANGLE				M		0000		EA	47D382474G1	02.000	02.000	00040[illegible]
47D382474P3	ANGLE				M		0000		EA	47D382474G2	02.000	02.000	0004[illegible]
												04.000	
47D382474P4	RIB				M		0000		EA	47D382474G1	02.000	02.000	000410
47D382474P4	RIB				M		0000		EA	47D382474G2	02.000	02.000	000419
												04.000	

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IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47D382474P5	PLATE				M		0000		EA	47D382474G1	01.000	01.000	000411
47D382474P6	BAR				M		0000		EA	47D382474G1	01.000	01.000	000412
47D382474P6	BAR				M		0000		EA	47D382474G2	01.000	01.000	000420
												02.000	
47C382475P1	MOUNTING BLOCK				M		0000		EA	47E382472G1	02.000	02.000	000424
47B382480P1	BRACKET, SENSOR				M		0000		EA	47E382498G1	02.000	02.000	001275
47C382485P1	LIFTING,BRKT				M		0000		EA	47D382598G1	02.000	02.000	000543
47E382486P1	SIDE SUPPORT				M		0000		EA	47E382599G1	01.000	01.000	001235
47E382488P1	PRE-LOAD FIXTURE				M		0000		EA	47E382605G1	02.000	02.000	001213
47E382491G1	AIR DUCT UNIT				M		0000		EA	47E387062G1	02.000	02.000	000556
47D382492P1	NUT PLATE				M		0000		EA	47E382495G1	01.000	02.000	001259
47D382492P2	NUT PLATE				M		0000		EA	47E382495G1	02.000	04.000	001258
47D382492P3	NUT PLATE				M		0000		EA	47E382495G1	01.000	02.000	001260
47D382492P4	NUT PLATE				M		0000		EA	47E382495G1	02.000	04.000	001257
47D382493P1	NUT PLATE				M		0000		EA	47E382495G1	02.000	04.000	001262
47D382493P2	NUT PLATE				M		0000		EA	47E382495G1	01.000	02.000	001263
47D382493P3	NUT PLATE				M		0000		EA	47E382495G1	02.000	04.000	001261
47B382494P1	NUT PLATE				M		0000		EA	47E382495G1	08.000	16.000	001264
47E382495G1	LOW SP BK SPRT ASSY				M		0000		EA	47E382496G1	02.000	02.000	001254
47E382496G1	LOW SPEED BRAKE INST				M		0000		EA	47E382607G1	01.000	01.000	001253
47E382498G1	RTR SPEED SNSR INSTL				M		0000		EA	47E382607G1	01.000	01.[illegible]	[illegible]01274
47C382499P1	TOWER ACCESS DOOR				M		0000		EA	47E382297G1	01.000	01.000	000005
47D382550G1	SFT,TEETER BRG ASSY				M		0000		EA	47E381105G1	01.000	01.000	000987
47D382550P1	CLOTH,FIBERGLASS				M		0000		FT	47D382550G1	AR		000988
47D382550P2	ADHESIVE				M		0000		OZ	47D382550G1	AR		000989
47C382551G1	TEETER RESTR ASSY				M		0000		EA	47E381105G1	04.000	04.000	000993

IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	ECN PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47C382551G2	TEETEER RESTR ASSY				M		0000		EA	47E381105G1	04.000	04.000	000997
47C382551P1	CLOTH, FIBERGLASS				M		0000		FT	47C382551G1	AR		000994
47C382551P1	CLOTH, FIBERGLASS				M		0000		FT	47C382551G2	AR		000998
												00.000	
47C382551P2	ADHESIVE, EPOXY				M		0000		OZ	47C382551G1	AR		000995
47C382551P2	ADHESIVE, EPOXY				M		0000		OZ	47C382551G2	AR		000999
												00.000	
47C382552G1	BOLSTER INSR ASSY				M		0000		EA	47E381105G1	02.000	02.000	001001
47C382552P1	CLOTH,FIBERGLASS				M		0000		FT	47C382552G1	AR		001002
47C382552P2	ADHESIVE				M		0000		OZ	47C382552G1	AR		001003
47E382553G1	GEARBOX INSTALLATION				M		0000		EA	47E382597G1	01.000	01.000	000363
47D382554P1	FLOORING, BEDPLATE				M		0000		EA	47E382306G1	01.000	01.000	000313
47D382555P1	LIFTING BRKT				M		0000		EA	47D382598G1	02.000	02.000	000544
47E382556G1	GEARBOX/CLG PLATFORM				M		0000		EA	47E382579G1	01.000	01.000	000444
47E382556P1	ANGLE,4 X 4 X 3/8				M		0000		EA	47E382556G1	04.000	04.000	000445
47E382556P10	SIDE PLATE 4.0 HT				M		0000		EA	47E382556G1	02.000	02.000	000454
47E382556P11	ANGLE,3 X 3 X 3/8				M		0000		EA	47E382556G1	04.000	04.000	000455
47E382556P12	ANGLE,3 X 3 X 3/8				M		0000		EA	47E382556G1	04.000	04.000	000456
47E382556P13	ANGLE,3 X 3 X 3/8				M		0000		EA	47E382556G1	02.000	02.000	000457
47E382556P14	ANGLE,3 X 3 X 3/8				M		0000		EA	47E382556G1	02.000	02.000	000458
47E382556P2	CHANNEL,8-20 LB				M		0000		EA	47E382556G1	02.000	02.000	000446
47E382556P3	CHANNEL,6-16.3 LB				M		0000		EA	47E382556G1	04.000	04.000	000447
47E382556P4	ANGLE,3X3-7.2 LB				M		0000		EA	47E382556G1	04.000	04.000	000448
47E382556P5	CHANNEL,8-20 LB				M		0000		EA	47E382556G1	04.000	04.000	000449
47E382556P6	9-IN X 2 1/2 DP DECK				M		0000		EA	47E382556G1	14.000	14.000	000450
47E382556P7	6-IN X 2 1/2 DP DECK				M		0000		EA	47E382556G1	01.000	01.000	000451
47E382556P8	9-IN X 2 1/2 DP DECK				M		0000		EA	47E382556G1	01.000	01.000	000452

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47E382556P9	END PLATE 4.0 HT				M		0000		EA	47E382556G1	02.000	02.000	000453
47C382557P1	ROTOR BRG SHIM				M		0000		EA	47E382441G1	04.000	04.000	000186
47B382558P1	INSERT, BRAKE DISC				M		0000		EA	47E382441G1	120.000	120.000	000187
47C382559P1	RTR SEAL RTNR, FWD				M		0000		EA	47E382441G1	01.000	01.000	000188
47C382560P1	PLUG, TORQUE PLATE				M		0000		EA	47E382441G1	02.000	02.000	000194
47D382563G1	TORQUE PLATE ASSY				M		0000		EA	47E382165G1	04.000	04.000	000035
47D382563P1	TORQUE PLATE				M		0000		EA	47D382563G1	01.000	04.000	000036
47B382564P1	BEARING ANGLE				M		0000		EA	47D382563G1	02.000	08.000	000037
47E382570G1	LUBE PLATFORM INSTL				M		0000		EA	47E382597G1	01.000	01.000	000442
47E382570P10	PIPE ASSY				M		0000		EA	47E382570G1	01.000	01.000	000513
47E382570P11	PIPE ASSY				M		0000		EA	47E382570G1	01.000	01.000	000514
47E382570P12	PIPE ASSY				M		0000		EA	47E382570G1	01.000	01.000	000515
47E382570P13	PIPE ASSY				M		0000		EA	47E382570G1	01.000	01.000	000516
47E382570P4	PIPE ASSY				M		0000		EA	47E382570G1	01.000	01.000	000507
47E382570P5	PIPE ASSY				M		0000		EA	47E382570G1	01.000	01.000	000508
47E382570P6	PIPE ASSY				M		0000		EA	47E382570G1	01.000	01.000	000509
47E382570P7	PIPE ASSY				M		0000		EA	47E382570G1	01.000	01.000	000510
47E382570P8	PIPE ASSY				M		0000		EA	47E382570G1	01.000	01.000	000511
47E382570P9	PIPE ASSY				M		0000		EA	47E382570G1	01.000	01.000	000512
47E382571	LIFT REQT, TWR CMPNT				X		0000		EA	47D382356G1	X		000157
47D382572P1	SPACER,ADAPTER				M		0000		EA	47E382363G1	01.000	01.000	000338
47D382572P2	SPACER,ADAPTER				M		0000		EA	47E382363G1	01.000	01.000	000339
47D382572P3	SPACER,ADAPTER				M		0000		EA	47E382363G1	01.000	01.000	000340
47D382572P4	SPACER,ADAPTER				M		0000		EA	47E382363G1	01.000	01.000	000341
47D382572P5	SPACER,SIDE SUPPORT				M		0000		EA	47E382363G1	04.000	04.000	000342

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47D382572P6	SPACER,SIDE SUPPORT				M		0000		EA	47E382363G1	02.000	02.000	000343
47D382572P7	SPACER,SIDE SUPPORT				M		0000		EA	47E382363G1	02.000	02.000	000344
47D382574P1	TOP,STRL,FWD,WLDMT				M		0000		EA	47E382363G1	01.000	01.000	000360
47D382575P1	TOP STRUCTURE FWD				M		0000		EA	47E382363G1	01.000	01.000	000336
47D382576P1	TOP,STRL,AFT,WLDMT				M		0000		EA	47E382363G1	01.000	01.000	000359
47D382577P1	TOP STRUCTURE,AFT				M		0000		EA	47E382363G1	01.000	01.000	000322
47E382578P1	CRANE,MOUNTING STRL				M		0000		EA	47E382363G1	01.000	01.000	000337
47E382579G1	COOLING PLATFORM ASM				M		0000		EA	47E382570G1	01.000	01.000	000443
47E382579P16	PIPE,SCHED 40,5-IN				M		0000		FT	47E382579G1	07.000	07.000	000483
47E382579P18	PIPE,SCHED 40				M		0000		FT	47E382579G1	90.000	90.000	000485
47E382579P24	PIPE,SCHED 40,3IN				M		0000		FT	47E382579G1	05.000	05.000	000491
47B382580P1	SEAL,TOP STRUCTURE				M		0000		EA	47E382363G1	01.000	01.000	000351
47B382580P2	SEAL,TOP STRUCTURE				M		0000		EA	47E382363G1	01.000	01.000	000353
47B382580P3	SEAL,TOP STRUCTURE				M		0000		EA	47E382363G1	02.000	02.000	000354
47E382581P1	HUB, BRG - TEETER				M		0000		EA	47E382583G1	01.000	02.000	001196
47E382582G1	BLADE TIP ATCH ASSY				M		0000		EA	47E382590G1	02.000	02.000	001051
47E382582P10	ADHESIVE,EPOXY				B		0000		PT	47E382582G1	AR		001061
47E382582P11	GLASSFIBER CLOTH				B		0000		FT	47E382582G1	AR		001062
47E382583G1	TEETER HUB/BRG ASSY				M		0000		EA	47E382605G1	02.000	02.000	001194
47E382583P3	DOWEL PIN				M		0000		EA	47E382583G1	03.000	06.000	001197
47C382584G1	MOT/PUMP/CLR PLATF				M		0000		EA	47E382579G1	01.000	01.000	000464
47C382584P1	PLATE,BASE				M		0000		EA	47C382584G1	01.000	01.000	000465
47C382584P2	BEAM,4 W 13#				M		0000		EA	47C382584G1	02.000	02.000	000466
47C382584P3	BEAM,6 W 9#				M		0000		EA	47C382584G1	02.000	02.000	000467
47B382585P1	ANCHOR STUD				M		0000		EA	47E381112G1	96.000	96.000	000008

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47B382586P1	ANCHOR PLATE				M		0000		EA	47E381112G1	48.000	48.000	000010
47D382587P1	FLOATING MT BRACKET				M		0000		EA	47E382592G1	04.000	04.000	000152
47D382588P1	CROSS SPRT TOP STRL				M		0000		EA	47E382363G1	01.000	01.000	000352
47D382589G1	GEN & HS SFT INSTL				M		0000		EA	47E382597G1	01.000	01.000	000370
47E382590G1	ROTOR BLADE ASSY				M		0000		EA	47E382304G1	01.000	01.000	000983
47E382590P12	FIBERGLASS,CLOTH				B		0000		EA	47E382590G1	AR		001095
47E382590P23	ADHESIVE,EPOXY				B		0000		PT	47E382590G1	AR		001191
47D382591P1	STRUCTURE FRAME UNIT				M		0000		EA	47E382592G1	04.000	04.000	000149
47E382592G1	PERS ELEV/SUPT INSTL				M		0000		EA	47D382356G1	01.000	01.000	000146
47E382592P5	ANGLE SECTION				M		0000		EA	47E382592G1	20.000	20.000	000151
47D382593G1	YAW S/S ASSY				M		0000		EA	47D382356G1	01.000	01.000	000021
47E382594G1	YAW SLIP RING INSTL				M		0000		EA	47D382593G1	01.000	01.000	000107
47E382595G1	TWR PLATFORM INSTL				M		0000		EA	47D382356G1	01.000	01.000	000127
47D382596G1	AUX CRANE INSTL				M		0000		EA	47E382597G1	01.000	01.000	000373
47E382597G1	NACELLE OVERALL ASSY	1			M		0000		EA	47E382304G1	01.000	01.000	000302
47E382597G1	NACELLE OVERALL ASSY	1			X		0000		EA	47E382607G1	X		001230
												01.000	
47D382598G1	LFT BRACKETS INSTL				M		0000		EA	47E382597G1	01.000	01.000	000542
47D382598P8	SPACER,STA 227.5				M		0000		EA	47D382598G1	04.000	04.000	000550
47D382598P9	SPACER,STA 227.5				M		0000		EA	47D382598G1	02.000	02.000	000551
47E382599G1	SLIP RING INST				M		0000		EA	47E382607G1	01.000	01.000	001232
47E382599P10	CONDUIT 1.50 DIA				M		0000		EA	47E382599G1	06.000	06.000	001242
47E382599P19	ANGLES				M		0000		EA	47E382599G1	02.000	02.000	001251
47E382599P9	CONDUIT 2.00 DIA				M		0000		EA	47E382599G1	03.000	03.000	001241
47E382600P1	YOKE STRL,WELDMENT				M		0000		EA	47E382602G1	01.000	01.000	000161
47E382601G1	YOKE ASSY				M		0000		EA	47E382304G1	01.000	01.000	000158

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47E382601G1	YOKE ASSY				X		0000		EA	47E382607G1	X	01.000	001231
47E382601P27	GREASE				B		0000		LB	47E382601G1	AR		000300
47E382602G1	MACHINING ASSY, YOKE				M		0000		EA	47E382441G1	01.000	01.000	000160
47E382602P16	YOKE BRG CAP MACH				X		0000		EA	47E382602G1	X		000176
47E382602P2	YOKE BRG CAP				M		0000		EA	47E382605G1	02.000	02.000	001193
47E382602P3	BRACKET				M		0000		EA	47E382602G1	06.000	06.000	000163
47E382602P4	BRACKET				M		0000		EA	47E382602G1	01.000	01.000	000164
47E382602P5	BRACKET				M		0000		EA	47E382602G1	01.000	01.000	000165
47E382603G1	TEETER RSTR BK ASSY				M		0000		EA	47E382601G1	02.000	02.000	000215
47E382603G2	TEETER RSTR BK ASSY				M		0000		EA	47E382601G1	02.000	02.000	000243
47D382604G1	SHAFT ALIGNMENT FTG				M		0000		EA	47E382601G1	04.000	04.000	000288
47D382604P1	SHOE				M		0000		EA	47D382604G1	01.000	04.000	000289
47D382604P2	ADJUSTING SCREW				M		0000		EA	47D382604G1	01.000	04.000	000290
47D382604P3	BRACKET				M		0000		EA	47D382604G1	01.000	04.000	000291
47D382604P4	PIN,6.00-LG X.50 DIA				M		0000		EA	47D382604G1	02.000	08.000	000292
47D382604P9	PAD,NYLON				M		0000		EA	47D382604G1	02.000	08.000	000297
47E382605G1	TEETER BRG/RSTR INST				M		0000		EA	47E382590G1	01.000	01.000	001192
47E382605P19	PIN				M		0000		EA	47E382605G1	04.000	04.000	001219
47D382606G1	FAIRING INSTALLATION				M		0000		EA	47E382597G1	01.000	01.000	000377
47D382606P2	SEALING STRIP				M		0000		EA	47D382606G1	AR		000379
47D382606P3	ADHESIVE(SEE NOTE 4)				B		0000		EA	47D382606G1	AR		000380
47E382607G1	YOKE / NACELLE INSTL				M		0000		EA	47E382304G1	01.000	01.000	001229
47E382608G1	ROTOR BLADE INSTL				M		0000		EA	47E382304G1	01.000	01.000	001289
47D382609P1	YOKE BRG CAP,WLDMT				M		0000		EA	47E382602G1	02.000	02.000	000162

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IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47E382610G1	AILERON INSTALLATION				M		0000		EA	47E382590G1	02.000	02.000	001011
47A387005	I&C SIGNAL LIST				X		0000		EA	47E382304G1	X		001869
47D387009P1	GROUNDING XFMR				M		0000		EA	47E387060G1	01.000	01.000	000964
47D387010P1	CURRENT XFMR				M		0000		EA	47E387060G1	06.000	06.000	000966
47D387011P1	POTENTIAL XFMR				M		0000		EA	47E387060G1	03.000	03.000	000967
47C387013P1	GROUNDING RESISTOR				M		0000		EA	47E387060G1	02.000	02.000	000965
47E387014	SCHEM,NACELLE,GEN				X		0000		EA	47E382304G1	X		001872
47E387018	POWER DISTBR SCHEM				X		0000		EA	47E387081G1	X		001859
47D387022	SCHEMATIC				X		0000		EA	47D387121G1	X		000876
47E387027G1	ASSY,WTG CONTROL PAN*				*		0000		EA	47E387112G1	01.000	01.000	001328
47D387028P1	PANEL,FRONT,WTG CONT*				*		0000		EA	47E387027G1	01.000	01.000	001329
47D387029P1	CONNECTOR PANEL, WTG*				*		0000		EA	47E387027G1	01.000	01.000	001330
47D387030	SCHEMATIC DIAGRAM EL*				X	5	0000		EA	47E387027G1	X		001369
47D387032G1	GEAR BOX SIGNAL COND*				*		0000		EA	47E387072G1	01.000	01.000	000683
47D387034G1	WIND SIGNAL CONDITIO*				*		0000		EA	47E387072G1	01.000	01.000	000684
47E387037G1	ASSY,SYN SIG COND BD				*		0000		EA	47E387072G1	02.000	02.000	000685
47D387038	SCHEMATIC				X		0000		EA	47E387037G1	X		000702
47A387039	WIRE LIST				X		0000		EA	47E387037G1	X		000687
47D387040G1	POWER SIGNAL CONDITI*				*		0000		EA	47E387072G1	01.000	01.000	000681
47D387043G1	SYNCRO TO CURRENT CO*				*		0000		EA	47E387072G1	02.000	02.000	000682
47E387060G1	HIGH VOLTAGE CG ASSY				M		0000		EA	47E382597G1	01.000	01.000	000962
47E387061	SCHEMATIC				X		0000		EA	47E387072G1	X		000778
47E387062G1	CONT ELEK CAB, (CEC)				M		0000		EA	47E382597G1	01.000	01.000	000553
47D387063P1	PANEL				M		0000		EA	47D387121G1	01.000	01.000	000857
47D387063P2	MOUNTING CHASIS				M		0000		EA	47D387121G1	01.000	01.000	000858

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47E387064	SCHEMATIC				X		0000		EA	47E387062G1	X		000562
47E387064	SCHEMATIC				X		0000		EA	47E387095G1	X		000637
												00.000	
47E387065G1	PANEL, RIGHT SIDE				*		0000		EA	47E387062G1	01.000	01.000	000816
47E387065P1	PANEL,RIGHT SIDE				*		0000		EA	47E387065G1	01.000	01.000	000817
47E387069G1	HIGH V CG DRILL ASSY				M		0000		EA	47E387060G1	01.000	01.000	000963
47D387070G1	CENTER PANEL				*		0000		EA	47E387062G1	01.000	01.000	000582
47D387070P1	PANEL				*		0000		EA	47D387070G1	01.000	01.000	000583
47D387070P2	SPACER STRIP				*		0000		EA	47D387070G1	02.000	02.000	000584
47E387072G1	I&C SIG CONDITIONER				*		0000		EA	47E387062G1	01.000	01.000	000645
47D387073P1	PANEL,FRONT				*		0000		EA	47E387072G1	01.000	01.000	000646
47D387074P1	PANEL,RIGHT SIDE				*		0000		EA	47E387072G1	01.000	01.000	000647
47D387074P2	PANEL,LEFT SIDE				*		0000		EA	47E387072G1	01.000	01.000	000648
47C387075P1	PANEL,REAR				*		0000		EA	47E387072G1	01.000	01.000	000649
47B387076G1	MTG. BRACKET,CIRCUIT*				*		0000		EA	47E387072G1	02.000	02.000	000664
47B387076G2	MTG. BRACKET,CIRCUIT*				*		0000		EA	47E387072G1	02.000	02.000	000668
47B387076P1	BRACKET				*		0000		EA	47B387076G1	01.000	02.000	000665
47B387076P2	BRACKET				*		0000		EA	47B387076G2	01.000	02.000	000669
47B387078P1	SUPPORT ANGLE,CABLE				*		0000		EA	47E387072G1	01.000	01.000	000678
47B387079P1	MTG. BRACKET				*		0000		EA	47E387072G1	02.000	02.000	000679
47E387081G1	ELEC EQUIP BUILDING				M		0000		EA	47E382304G1	01.000	01.000	001308
47B387082P1	SHIELD				*		0000		EA	47E387072G1	01.000	01.000	000748
47B387082P1	SHIELD				*		0000		EA	47E387095G1	01.000	01.000	000611
												02.000	
47D387083G1	ASSY, MOTHER BD-SIGN*				*		0000		EA	47E387072G1	01.000	01.000	000651
47D387083P4	TERMINAL BLOCK				*		0000		EA	47D387083G1	01.000	01.000	000655
47D387083P5	TERMINAL BLOCK				*		0000		EA	47D387083G1	01.000	01.000	000656

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47E387084G1	ASSY, STATUS PANEL				M		0000		EA	47E387112G1	01.000	01.000	001666
47E387084P2	PANEL, SIDE				B		0000		EA	47E387084G1	02.000	02.000	001668
47E387085G1	ASSY, UTILITY PANEL				M		0000		EA	47E387112G1	01.000	01.000	001544
47E387085P2	PANEL, SIDE				M		0000		EA	47E387085G1	02.000	02.000	001546
47B387086P1	ANGLE				*		0000		EA	47D387083G1	02.000	02.000	000653
47D387087G1	ASSY, COLOR CODED FL*				*		0000		EA	47E387072G1	07.000	07.000	000738
47A387088	WIRE LIST				X		0000		EA	47E387072G1	X		000770
47D387089G1	ASSY,MTR SIG CONDTNR				M		0000		EA	47E387084G1	05.000	05.000	001675
47D387089G1	ASSY,MTR SIG CONDTNR				M		0000		EA	47E387085G1	03.000	03.000	001553
47D387089G1	ASSY,MTR SIG CONDTNR				M		0000		EA	47E387091G1	03.000	03.000	001380
												11.000	
47E387090P1	DRILL & TRIM				*		0000		EA	47D387083G1	01.000	01.000	000652
47E387091G1	ASSY,GENERATOR PANEL				M		0000		EA	47E387112G1	01.000	01.000	001371
47E387091P2	PANEL, SIDE				B		0000		EA	47E387091G1	01.000	01.000	001373
47D387092	SCHEMATIC				X		0000		EA	47D387089G1	X		001682
47E387093G1	WIND TRANSLATOR				M		0000		EA	47E387062G1	01.000	01.000	000800
47E387095G1	CONTROLLER ASSY				M		0000		EA	47E387062G1	01.000	01.000	000589
47E387095P42	BUSHING, STRAIN RLF				M		0000		EA	47E387095G1	01.000	01.000	000631
47E387095P43	BUSHING, STRAIN RLF				M		0000		EA	47E387095G1	08.000	08.000	000632
47E387095P47	PLUG, SNAP OUT				M		0000		EA	47E387095G1	03.000	03.000	000636
47C387096G1	MTG BRACKET ASSY				M		0000		EA	47E387062G1	02.000	02.000	000824
47C387096P1	MTG BRACKET				M		0000		EA	47C387096G1	01.000	02.000	000825
47E387097	SCHEMATIC				X		0000		EA	47E387085G1	X		001637
47E387098P1	PANEL, FRONT				M		0000		EA	47E387085G1	01.000	01.000	001545
47C387099P1	PANEL, REAR				M		0000		EA	47E387085G1	01.000	01.000	001547
47D387100	SCHEMATIC				X		0000		EA	47D387113G1	X		001772

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47E387101	SCHEMATIC				X		0000		EA	47E387084G1	X		001812
47E387103	SCHEMATIC				X		0000		EA	47E387091G1	X		001514
47E387104P1	PANEL, FRONT				B		0000		EA	47E387084G1	01.000	01.000	001667
47E387105P1	PANEL, FRONT				B		0000		EA	47E387091G1	01.000	01.000	001372
47D387106P1	PANEL, REAR				B		0000		EA	47E387084G1	01.000	01.000	001669
47D387106P1	PANEL, REAR				B		0000		EA	47E387091G1	01.000	01.000	001374
												02.000	
47D387107P1	SGL CD FR.,MODIFIED				B		0000		EA	47E387084G1	01.000	01.000	001671
47D387107P1	SGL CD FR.,MODIFIED				B		0000		EA	47E387091G1	01.000	01.000	001376
												02.000	
47D387108P1	BRACKET, CARD FRAME				B		0000		EA	47E387084G1	01.000	01.000	001672
47D387108P1	BRACKET, CARD FRAME				B		0000		EA	47E387091G1	01.000	01.000	001377
												02.000	
47D387109G1	FRONT PANEL				M		0000		EA	47E387060G1	01.000	01.000	000971
47D387110P1	BUS BAR				M		0000		EA	47E387060G1	01.000	01.000	000969
47E387112G1	SYS DISPLAY PNL ASSY				M		0000		EA	47E387081G1	01.000	01.000	001326
47D387113G1	SECURITY ALARM BOARD				M		0000		EA	47E387084G1	01.000	01.000	001763
47D387113G1	SECURITY ALARM BOARD				M		0000		EA	47E387091G1	01.000	01.000	001464
												02.000	
47E387114	CONTROL SYSTEM SCHEM				X		0000		EA	47E382304G1	X		001865
47E387115P1	MOUNTING FRAME				M		0000		EA	47E387095G1	01.000	01.000	000590
47E387116P1	DRILL & TRIM				M		0000		EA	47D387089G1	03.000	11.000	001381
47D387121G1	ESD ELECT ASSY				M		0000		EA	47E387062G1	01.000	01.000	000856
47D387122	SCHEMATIC				X		0000		EA	47D387130G1	X		000903
47A387124	WIRE LIST				X		0000		EA	47E387095G1	X		000630
47A387125	WIRE LIST				X		0000		EA	47D387121G1	X		000869
47A387128	WIRE LIST				X		0000		EA	47D387130G1	X		000902
47D387129P1	PANEL				M		0000		EA	47D387130G1	01.000	01.000	000883
47D387129P2	MOUNTING CHASSIS				M		0000		EA	47D387130G1	01.000	01.000	000884

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IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
47D387130G1	"G" SWITCH TEST ELEK				M		0000		EA	47E387062G1	01.000	01.000	000882
47D387132G1	ICE DETECTOR ELEK				M		0000		EA	47E387062G1	01.000	01.000	000922
4HP	PLUG				B		0000	97576	EA	47J382313G1	03.000	03.000	000099
4PN-SS	NIPPLE, PIPE				B		0000	97576	EA	47J382313G1	03.000	03.000	000079
4PT-SS	TEE, PIPE				B		0000	97576	EA	47J382313G1	03.000	03.000	000081
41F2R0	RESISTOR, 2 OHM				M		0000	03615	EA	47D387130G1	01.000	01.000	000897
4156-14-1	TERMINAL				M		0000	17117	EA	47D387130G1	08.000	08.000	000886
427D-SIZE-4	ELBOW,LONG				B		0000	14959	EA	47E382570G1	06.000	06.000	000505
427D-SIZE-5	ELBOW,LONG				B		0000	14959	EA	47E382570G1	03.000	03.000	000506
44A0111-16-9	WIRE, AWG #16				B	5	0000	06090	FT	47E387027G1	AR		001364
44A0111-16-9	WIRE, AWG #16				B	5	0000	06090	FT	47E387062G1	AR		000957
44A0111-16-9	WIRE, AWG #16				B	5	0000	06090	FT	47E387072G1	AR		000775
												00.000	
44A0111-20-9	WIRE, AWG #20				B	5	0000	06090	FT	47D387121G1	AR		000874
44A0111-20-9	WIRE, AWG #20				B	5	0000	06090	FT	47D387130G1	AR		000915
44A0111-20-9	WIRE, AWG #20				B	5	0000	06090	FT	47E387062G1	AR		000958
												00.000	
44A0111-22-9	WIRE, #22 AWG				B	5	0000	06090	FT	47E387072G1	AR		000783
44A0111-24-9	WIRE, AWG 24				B	5	0000	06090	FT	47E387084G1	AR		001816
44A0111-24-9	WIRE, AWG 24				B	5	0000	06090	FT	47E387085G1	AR		001640
44A0111-24-9	WIRE, AWG 24				B	5	0000	06090	FT	47E387091G1	AR		001518
												00.000	
44A0811-12-9	WIRE, AWG #12				B	5	0000	06090	FT	47E387062G1	AR		000956
4538K1	TFE SEALER, TEFLON				B		0000	39428	EA	47J382313G1	01.000	01.000	000076
4697-1032-SS-20	HEX M & F STANDOFF				M		0000	55566	EA	47E387062G1	12.000	12.000	000934
47-61-201-10	CAPTIVE SCREW				M		0000	94222	EA	47D387121G1	04.000	04.000	000861
47-61-201-10	CAPTIVE SCREW				M		0000	94222	EA	47D387130G1	04.000	04.000	000885
												08.000	
53451-1	RELAY				B	7	0000	18342	EA	47D387089G1	09.000	33.000	001595
5596A-8	TERMINAL BOARD				*		0000	75382	EA	47E387072G1	01.000	01.000	000750

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WTG - MOD 5A

TOP DOWN

BREAK DOWN

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM CROSS REF
00	47E382304G1	WTG ASSY, MOD-5A	1			M		0000	EA		1.00	-	000001
01	47D382356G1	TOWER ASSY, WTG				M		0000	EA	1.00	1.00	1-00	000002
02	47E382297G1	TWR/FOUNDATION INSTL				M		0000	EA	1.00	1.00	1-00	000003
03	47E382355P1	TWR STRUCTURE ASSY				M		0000	EA	1.00	1.00	1-00	000004
03	47C382499P1	TOWER ACCESS DOOR				M		0000	EA	1.00	1.00	2-00	000005
03	47E381112G1	FOUNDATION REQT				M		0000	EA	1.00	1.00	3-00	000006
04	47E381112P1	FOUNDATION ASSEMBLY				M		0000	EA	1.00	1.00	1-00	000007
04	47B382585P1	ANCHOR STUD				M		0000	EA	96.00	96.00	2-00	000008
04	47E381112P3	NUT				B		0000	EA	192.00	192.00	3-00	000009
04	47B382586P1	ANCHOR PLATE				M		0000	EA	48.00	48.00	4-00	000010
04	47E381112P5	RECT. WIREWAY				M		0000	EA	3.00	3.00	5-00	000011
04	47E381112P6	CONDUIT SECTION				M		0000	EA	1.00	1.00	6-00	000012
04	47E381112P7	CONDUIT SECTION				M		0000	EA	2.00	2.00	7-00	000013
04	47E381112P8	CONDUIT SECTION				M		0000	EA	1.00	1.00	8-00	000014
04	47E381112P9	#09 REINFORCING ROD				M		0000	FT	AR		9-00	000015
04	47E381112P10	#11 REINFORCING ROD				M		0000	FT	AR		10-00	000016
03	47E382303P1	TWR/ FDN PLATF REQT				M		0000	EA	1.00	1.00	4-00	000017
03	N214P58B	NUT 2 1/2 DIA.				B		0000	EA	96.00	96.00	5-00	000018
03	N402P58B	WASHER				B		0000	EA	96.00	96.00	6-00	000019
03	47E382297P7	GROUT				M		0000	LB	AR		7-00	000020
02	47D382593G1	YAW S/S ASSY				M		0000	EA	1.00	1.00	2-00	000021
03	47E382133G1	YAW STRUCTURE ASSY				M		0000	EA	1.00	1.00	1-00	000022
04	47E382050P1	YAW HSG STRUCT,UPPER				M		0000	EA	1.00	1.00	1-00	000023
04	47E382219P1	YAW HSG STRUCT,LOWER				M		0000	EA	1.00	1.00	2-00	000024
04	47D381002P1	BEARING, YAW				M		0000	EA	1.00	1.00	3-00	000025
04	47C381036P32	BOLT				M		0000	EA	144.00	144.00	4-00	000026
04	47C381087P13	NUT, FATIGUE RATED				B		0000	EA	144.00	144.00	5-00	000027
04	47C381088P13	WASHER, HARDENED STL				B		0000	EA	144.00	144.00	6-00	000028
04	47C381088P14	WASHER, HARDENED STL				B		0000	EA	144.00	144.00	7-00	000029
03	47E382165G1	YAW DRIVE INSTL				M		0000	EA	1.00	1.00	2-00	000030
04	47D381010P1	BRAKE ASSY				M		0000	EA	8.00	8.00	1-00	000031
04	47D381003P1	ACTUATOR,HYDRAULIC				M		0000	EA	4.00	4.00	2-00	000032
04	47C382181P1	TRACK MTG BRACKET				M		0000	EA	4.00	4.00	3-00	000033
04	47E381107P1	TROLLEY ASSY				M		0000	EA	2.00	2.00	4-00	000034
04	47D382563G1	TORQUE PLATE ASSY				M		0000	EA	4.00	4.00	5-00	000035
05	47D382563P1	TORQUE PLATE				M		0000	EA	1.00	4.00	1-00	000036
05	47B382564P1	BEARING ANGLE				M		0000	EA	2.00	8.00	2-00	000037
05	N23P25012B	SCREW,CAP				B		0000	EA	6.00	24.00	3-00	000038

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	ECN PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
05	N400P13B	WASHER,PLAIN				B		0000	EA	6.00	24.00	4-00		000039
05	N406P43B	LOCKWASHER				B		0000	EA	6.00	24.00	5-06		000040
04	47D382192P1	BRAKE MTG PLATE				M		0000	EA	2.00	2.00	6-00		000041
04	47D382198P1	CLEVIS BLOCK				M		0000	EA	2.00	2.00	7-00		000042
04	47B382200P1	RETAINER, PIN				M		0000	EA	4.00	4.00	8-00		000043
04	47B382193P1	PIN, CLEVIS - BRAKE				M		0000	EA	4.00	4.00	9-00		000044
04	47C381036P15	BOLT,FATIGUE RATED				B		0000	EA	36.00	36.00	10-00		000045
04	47C381036P16	BOLT,FATIGUE RATED				B		0000	EA	12.00	12.00	11-00		000046
04	N733P33112B	SCREW,12 POINT				B		0000	EA	12.00	12.00	12-00		000047
04	BLFR-22	SPHERICAL BEARING				B		0000	EA	4.00	4.00	13-00	81376	000048
04	DREM-20-080	ROD END BEARING				B		0000	EA	4.00	4.00	14-00	81376	000049
04	47B382419P1	WASHER				B		0000	EA	96.00	96.00	15-00		000050
04	N727P33040B	CAPSCREW				B		0000	EA	24.00	24.00	16-00		000051
04	N265P33B	LOCKNUT				B		0000	EA	32.00	32.00	17-00		000052
04	N265P34B	LOCKNUT				B		0000	EA	12.00	12.00	18-00		000053
04	N214P34B	HEX NUT				B		0000	EA	12.00	12.00	19-00		000054
04	N266P43B	LOCKNUT				B		0000	EA	48.00	48.00	20-00		000055
04	47B382420P1	JAM NUT				B		0000	EA	4.00	4.00	21-00		000056
04	N402AP17B	PLAIN WASHER, NARROW				B		0000	EA	64.00	64.00	22-00		000057
04	N402AP48B	PLAIN WASHER, REG.				B		0000	EA	24.00	24.00	23-00		000058
04	**47E382165-24	BOLT				B		0000	EA	24.00	24.00	24-00		000059
04	N228P21016B	CAPSCREW				B		0000	EA	16.00	16.00	26-00		000060
04	47B382196P1	SPACER, CLEVIS BLOCK				M		0000	EA	4.00	4.00	27-00		000061
04	47B382196P2	SPCR,ACTUATOR CLEVIS.				M		0000	EA	8.00	8.00	28-00		000062
04	47C382181P2	TRACK, MTG BRACKET				M		0000	EA	2.00	2.00	29-00		000063
04	47D382198P2	CLEVIS BLOCK				M		0000	EA	2.00	2.00	30-00		000064
04	47C382278P1	MANIFOLD FITTING				M		0000	EA	2.00	2.00	31-00		000065
04	N22P25036B	CAPSCREW				B		0000	EA	8.00	8.00	32-00		000066
04	N402AP13B	PLAIN WASHER, NARROW				B		0000	EA	8.00	8.00	33-00		000067
04	N405P43B	LOCKWASHER - MEDIUM				B	5	0000	EA	8.00	8.00	34-00		000068
04	47B382277P1	DRIP TROUGH				M		0000	EA	2.00	2.00	35-00		000069
04	47B382277P2	DRIP TROUGH				M		0000	EA	2.00	2.00	36-00		000070
04	A100-4	TUBE FTG, MALE CONN.				B		0000	EA	4.00	4.00	37-00	97576	000071
04	A400-4	TUBE FTG, MALE ELBOW				B		0000	EA	16.00	16.00	38-00	97576	000072
04	700-4	TUBE FTG, TEE UNION				B		0000	EA	8.00	8.00	39-00	97576	000073
04	B7A17B	.250 O.D X .035 WALL				M		0000	FT	20.00	20.00	40-00		000074
03	47J382313G1	HYDR PIPING, YAW DR				M		0000	EA	1.00	1.00	3-00		000075
04	4538K1	TFE SEALER, TEFLON				B		0000	EA	1.00	1.00	1-00	39428	000076
04	**47J382313-2	ACCUMULATOR & V PKG				M		0000	EA	1.00	1.00	2-00		000077
04	**47J382313-3	YAW POWER UNIT				M		0000	EA	1.00	1.00	3-00		000078
04	4PN-SS	NIPPLE, PIPE				B		0000	EA	3.00	3.00	4-00	97576	000079
04	3043T18	"U" BOLT & NUTS				B	5	0000	EA	6.00	6.00	5-00	39428	000080
04	4PT-SS	TEE, PIPE				B		0000	EA	3.00	3.00	6-00	97576	000081
04	B7A17B-.035	TUBING, .250 OD				B		0000	FT	4.00	4.00	7-00		000082
04	B7A17B-.065	TUBING, .500 OD				B		0000	FT	200.00	200.00	8-00		000083
04	47C381075P1	HOSE ASSY				M		0000	EA	4.00	4.00	9-00		000084

ORIGINAL PAGE IS OF POOR QUALITY

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	47C381075P2	HOSE ASSY				M		0000	EA	4.00	4.00	10-00		000085
04	47B381074P1	HOSE ASSY				M		0000	EA	2.00	2.00	11-00		000086
04	C9612-3	PRESSURE, SWITCH				B		0000	EA	3.00	3.00	12-00	89326	000087
04	HP36GT	VALVE, .50 NPT				B		0000	EA	3.00	3.00	13-00	01029	000088
04	22617-8	O-RING				B		0000	EA	10.00	10.00	14-00	01276	000089
04	980-8-8SS	CONNECTOR, BULKHEAD				B		0000	EA	2.00	2.00	15-00	97576	000090
04	100-8-4SS	CONNECTOR, MALE				B		0000	EA	3.00	3.00	16-00	97576	000091
04	100-8-8SS	CONNECTOR, MALE				B		0000	EA	3.00	3.00	17-00	97576	000092
04	8TFNSS	NIPPLF				B		0000	EA	8.00	8.00	18-00	97576	000093
04	A400-8SS	ELBOW, MALE				B		0000	EA	8.00	8.00	19-00	97576	000094
04	A600-8SS	TEE BRANCH, MALE				B		0000	EA	3.00	3.00	20-00	97576	000095
04	140-8-4SS	ADAPTER, REDUCER				B		0000	EA	4.00	4.00	21-00	97576	000096
04	700-8SS	TEE, UNION				B		0000	EA	16.00	16.00	22-00	97576	000097
04	100C-8SS	TUBE CAP				B		0000	EA	4.00	4.00	23-00	97576	000098
04	4HP	PLUG				B		0000	EA	3.00	3.00	24-00	97576	000099
04	100025	CLAMP ASSY				B		0000	EA	5.00	5.00	25-00	55017	000100
04	100050	CLAMP ASSY				B		0000	EA	103.00	103.00	26-00	55017	000101
04	8PRC-SS	CONNECTOR, REDUCING				B		0000	EA	3.00	3.00	27-00	97576	000102
04	300H1-15CG-04-K	PRESSURE TRANSDUCER				B		0000	EA	3.00	3.00	28-00	89326	000103
04	N405P41B	LOCK WASHER				B	5	0000	EA	12.00	12.00	29-00		000104
04	47E382314	HYDRAULIC SYS SCHEM				X		0000	EA	X		30-00		000105
03	**47D382593-4	GREASE SHIELD INSTL				M		0000	EA	1.00	1.00	4-00		000106
03	47E382594G1	YAW SLIP RING INSTL				M		0000	EA	1.00	1.00	5-00		000107
04	47D381019P1	SLIP RNG UN YAW AXIS				M		0000	EA	1.00	1.00	1-00		000108
04	47E381017	YAW SR ELECT INTFC				X		0000	EA	X		2-00		000109
04	**47E382594-3	CROSS BEAM				M		0000	EA	2.00	2.00	3-00		000110
04	**47E382594-4	MOUNTING BRACKET				M		0000	EA	1.00	1.00	4-00		000111
04	**47E382594-5	SUPPORT ANGLE				M		0000	EA	4.00	4.00	5-00		000112
04	**47E382594-6	YAW ELEC&INSTR INSTL				M		0000	EA	1.00	1.00	6-00		000113
04	N22P35052B	HEX HD BOLT				B		0000	EA	24.00	24.00	7-00		000114
04	N22AP35040B	HEX HD BOLT				B		0000	EA	12.00	12.00	8-00		000115
04	N265P35B	LOCK NUT, 3/4 DIA.				*		0000	EA	24.00	24.00	9-00		000116
04	N402P18B	WASHER, 3/4 DIA.				B		0000	EA	36.00	36.00	10-00		000117
04	N22P39068B	HEX HD BOLT				B		0000	EA	8.00	8.00	11-00		000118
04	N265P39B	LOCK NUT - 1 DIA.				B	5	0000	EA	8.00	8.00	12-00		000119
04	N402P20B	WASHER				B		0000	EA	8.00	8.00	13-00		000120
04	MS20995C20	LOCK WIRE				B	5	0000	FT	AR		14-00		000121
04	650LR-HAB350	POWER DISTR CONN				B		0000	EA	14.00	14.00	15-00	11117	000122
04	600BE	EXTENDER				B		0000	EA	6.00	6.00	16-00	11117	000123
04	**47E382594-17	DRAG LINK				M		0000	EA	2.00	2.00	17-00		000124
03	**47D382593-6	BRG, AUTO LUBE INSTL				M		0000	EA	1.00	1.00	6-00		000125
02	**47D382356-3	ELEC WIRE WAY INSTL				M		0000	EA	1.00	1.00	3-00		000126
02	47E382595G1	TWR PLATFORM INSTL				M		0000	EA	1.00	1.00	4-00		000127
03	**47E382595-1	LOWER PLATFORM ASSY				M		0000	EA	1.00	1.00	1-00		000128

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LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM CROSS REF
03	**47E382595-2	MID PLATFORM ASSY				M		0000	EA	1.00	1.00	2-00	000129
03	**47E382595-3	UPR (YAW) PLATF ASSY				M		0000	EA	1.00	1.00	3-00	000130
03	**47E382595-4	STAIRWAY ASSY				M		0000	EA	1.00	1.00	4-00	000131
03	**47E382595-5	PRIMARY LADDER ASSY				M		0000	EA	1.00	1.00	5-00	000132
03	**47E382595-6	ALTN LADDER ASSY				M		0000	EA	1.00	1.00	6-00	000133
03	**47E382595-7	GUARDRAIL ASSY				M		0000	EA	1.00	1.00	7-00	000134
03	**47E382595-8	HGR CABLE ASSY - UPR				M		0000	EA	12.00	12.00	8-00	000135
03	**47E382595-9	HGR CABLE ASSY - LWR				M		0000	EA	6.00	6.00	9-00	000136
03	**47E382595-10	ACCESS COVER HATCH				M		0000	EA	1.00	1.00	10-00	000137
03	**47E382595-11	HGR CLEVIS FITTING				M		0000	EA	12.00	12.00	11-00	000138
03	**47E382595-12	BEARING PADS				M		0000	EA	12.00	12.00	12-00	000135
03	N22P35036B	BLT,HEX HD, 3/4 DIA.				B		0000	EA	36.00	36.00	13-00	000140
03	N264P35B	LOCKNUT, 3/4 DIA.				B		0000	EA	36.00	36.00	14-00	000141
03	N402P18B	WASHER, 3/4 DIA.				B		0000	EA	36.00	36.00	15-00	000142
02	**47D382356-5	TWR INSTM INSTL				M		0000	EA	1.00	1.00	5-00	000143
02	**47D382356-6	TOWER MARKINGS				M		0000	EA	1.00	1.00	6-00	000144
02	**47D382356-7	GND WIRE WAY INSTL				M		0000	EA	1.00	1.00	7-00	000145
02	47E382592G1	PERS ELEV/SUPT INSTL				M		0000	EA	1.00	1.00	8-00	000146
03	**47E382592-1	LWR G TWR SECT ASSY				M		0000	EA	1.00	1.00	1-00	000147
03	**47E382592-2	UPR G TWR SECT ASSY				M		0000	EA	1.00	1.00	2-00	000148
03	47D382591P1	STRUCTURE FRAME UNIT				M		0000	EA	4.00	4.00	3-00	000149
03	15AS650	PERS ELEVATOR UNIT				M		0000	EA	1.00	1.00	4-00	000150
03	47E382592P5	ANGLE SECTION				M		0000	EA	20.00	20.00	5-00	000151
03	47D382587P1	FLOATING MT BRACKET				M		0000	EA	4.00	4.00	6-00	000152
03	N14P35060B	HEX HD BOLT,3/4 DIA.				B		0000	EA	16.00	16.00	7-00	000153
03	N265P35B	LOCK NUT, 3/4 DIA.				*		0000	EA	16.00	16.00	8-00	000154
03	N402P18B	WASHER, 3/4 DIA.				B		0000	EA	16.00	16.00	9-00	000155
03	PB34-414	PARA BLT,CONC ANCHOR				B		0000	EA	16.00	16.00	10-00	000156
02	47E382571	LIFT REQT, TWR CMPNT				X		0000	EA	X		9-00	000157
01	47E382601G1	YOKE ASSY				M		0000	EA	1.00	1.00	2-00	000158
02	47E382441G1	YOKE / SPINDLE ASSY				M		0000	EA	1.00	1.00	1-00	000159
03	47E382602G1	MACHINING ASSY, YOKE				M		0000	EA	1.00	1.00	1-00	000160
04	47E382600P1	YOKE STRL,WELDMENT				M		0000	EA	1.00	1.00	1-00	000161
04	47D382609P1	YOKE BRG CAP,WLDMT				M		0000	EA	2.00	2.00	2-00	000162
04	47E382602P3	BRACKET				M		0000	EA	6.00	6.00	3-00	000163
04	47E382602P4	BRACKET				M		0000	EA	1.00	1.00	4-00	000164
04	47E382602P5	BRACKET				M		0000	EA	1.00	1.00	5-00	000165
04	N500P12464C	PIN,TAPERED DOWEL#13				M		0000	EA	8.00	8.00	6-00	000166
04	47C381036P14	BOLT,FATIGUE RATED				B		0000	EA	16.00	16.00	7-00	000167
04	47C381088P5	WASHER,1.25 DIA				B		0000	EA	16.00	16.00	8-00	000168
04	N405P52B	LOCK WASHER				M		0000	EA	16.00	16.00	9-00	000169
04	47C381036P6	BOLT,FATIGUE RATED				B		0000	EA	20.00	20.00	10-00	000170

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	47C381088P1	WASHER,1.00 DIA				M		0000	EA	40.00	40.00	11-00		000171
04	47C381088P2	WASHER,1.00 DIA				M		0000	EA	40.00	40.00	12-00		000172
04	47C381087P2	LOCKNUT				B		0000	EA	40.00	40.00	13-00		000173
04	47C381036P2	BOLT,FATIGUE RATED				B		0000	EA	20.00	20.00	14-00		000174
04	CHOCKFAST-ORANGE	GROUTING				B		0000	EA	AR		15-00	20420	000175
04	47E382602P16	YOKE BRG CAP MACH				X		0000	EA	X		16-00		000176
03	47E382333P1	SPINDLE SHAFT				M		0000	EA	1.00	1.00	2-00		000177
03	47D381080P1	TPR RLR BRG,SPDL/AFT				M		0000	EA	1.00	1.00	3-00	80657	000178
03	47D381081P1	TPR RLR BRG,SPDL/FWD				M		0000	EA	1.00	1.00	4-00	80657	000179
03	47C382458P1	RETAINER, AFT				M		0000	EA	6.00	6.00	5-00		000180
03	47B381106P1	"O" RING SEAL, AFT				M		0000	EA	1.00	1.00	6-00		000181
03	47D382456P1	RTR SEAL RTNR, AFT				M		0000	EA	1.00	1.00	7-00		000182
03	47B382454P1	ANTI-ROTATION PIN				M		0000	EA	2.00	2.00	8-00		000183
03	47D382372P1	RTR BRG RETAINER,FWD				M		0000	EA	1.00	1.00	9-00		000184
03	47D382457P1	LOW SPEED BRAKE DISC				M		0000	EA	1.00	1.00	10-00		000185
03	47C382557P1	ROTOR BRG SHIM				M		0000	EA	4.00	4.00	11-00		000186
03	47B382558P1	INSERT, BRAKE DISC				M		0000	EA	120.00	120.00	12-00		000187
03	47C382559P1	RTR SEAL RTNR, FWD				M		0000	EA	1.00	1.00	13-00		000188
03	47C381102P1	ROTOR SEAL FWD				M		0000	EA	2.00	2.00	14-00	03668	000189
03	47C381103P1	ROTOR SEAL AFT				M		0000	EA	2.00	2.00	15-00	03668	000190
03	47D382455P1	DISC, RTR SPEED SNSR				M		0000	EA	1.00	1.00	16-00		000191
03	47C381104P1	STUD				M		0000	EA	120.00	120.00	17-00		000192
03	47C381104P2	STUD				M		0000	EA	120.00	120.00	18-00		000193
03	47C382560P1	PLUG, TORQUE PLATE				M		0000	EA	2.00	2.00	19-00		000194
03	47D381082P2	TORQUE PLATE				M		0000	EA	1.00	1.00	20-00		000195
03	47C381036P24	BOLT,FATIGUE RATED				B		0000	EA	36.00	36.00	21-00		000196
03	47C381088P9	WASHER,1.50 DIA				M		0000	EA	72.00	72.00	22-00		000197
03	47C381087P9	NUT				B		0000	EA	36.00	36.00	23-00		000198
03	47B381109P1	WSHR, BELLEVILLE SPR				B		0000	EA	120.00	120.00	24-00	92830	000199
03	47C381087P5	NUT				B		0000	EA	360.00	360.00	25-00		000200
03	47C381088P5	WASHER,1.25 DIA				B		0000	EA	240.00	240.00	26-00		000201
03	N2800P2	FITTING, LUBE				B		0000	EA	4.00	4.00	27-00		000202
03	N733P25016B	SCREW, TWELVE-POINT				B		0000	EA	78.00	78.00	28-00		000203
03	N405P43B	LOCKWASHER - MEDIUM				B	5	0000	EA	78.00	78.00	29-00		000204
03	N5700P6053B	PLUG, PIPE				B		0000	EA	4.00	4.00	30-00		000205
03	N733P29024B	SCREW, TWELVE-POINT				B		0000	EA	36.00	36.00	31-00		000206
03	N405P45B	WASHER, LOCK				B	5	0000	EA	36.00	36.00	32-00		000207
02	47D382435G1	LOW SPEED SHAFT ASSY				*		0000	EA	1.00	1.00	2-00		000208
03	47D382296P1	LOW SPEED SHAFT				*		0000	EA	1.00	1.00	1-00		000209
03	47D381082P1	COUPLING HUB, FWD				*		0000	EA	1.00	1.00	2-00		000210
03	47C381083P1	COUPLING HUB, AFT				*		0000	EA	1.00	1.00	3-00		000211
02	47C382436P1	SEAL RTNR, COUPLING				M		0000	EA	2.00	2.00	3-00		000212
02	47C382437P1	SEAL PL, FWD CPLG				M		0000	EA	6.00	6.00	4-00		000213
02	47C381110P1	SEAL, FWD, COUPLING				M		0000	EA	4.00	4.00	5-00		000214
02	47E382603G1	TEETER RSTR BK ASSY				M		0000	EA	2.00	2.00	6-00		000215

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LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	ECN PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
03	**47E382603-1	HOUSING WALL,LH				M		0000	EA	1.00	2.00	1-00		000216
03	**47E382603-2	HOUSING WALL,RH				M		0000	EA	1.00	2.00	2-00		000217
03	47D381010P2	BRAKE ASSY				M		0000	EA	2.00	4.00	3-00		000218
03	**47E382603-4	HOUSING COVER				M		0000	EA	1.00	2.00	4-00		000219
03	**47E382603-5	TEETER ARM				M		0000	EA	1.00	2.00	5-00		000220
03	**47E382603-6	HOUSING COVER				M		0000	EA	2.00	4.00	6-00		000221
03	**47E382603-7	OUTBD BELLOWS COVER				M		0000	EA	1.00	2.00	7-00		000222
03	**47E382603-8	INBD BELLOWS COVER				M		0000	EA	1.00	2.00	8-00		000223
03	**47E382603-9	ROLLER GUIDE ASSY				M		0000	EA	1.00	2.00	9-00		000224
03	**47E382603-10	BRKT ASSY,LIMIT SW				M		0000	EA	1.00	2.00	10-00		000225
03	**47E382603-11	BRKT,MTG,LIMIT SW				M		0000	EA	1.00	2.00	11-00		000226
03	CR115GM101	SWITCH,LIMIT				B		0000	EA	1.00	2.00	12-00	02295	000227
03	N14P21012B	SCREW,CAP,HEX HD				B		0000	EA	4.00	8.00	13-00		000228
03	N405P111B	LOCKWASHER				B		0000	EA	4.00	8.00	14-00		000229
03	N14P25016B	SCREW,HEX HD				B		0000	EA	34.00	68.00	15-00		000230
03	N405P113B	LOCKWASHER				B		0000	EA	34.00	68.00	16-00		000231
03	N14P29016B	SCREW HEX HD				B		0000	EA	2.00	4.00	17-00		000232
03	N405P115B	LOCKWASHER				B		0000	EA	2.00	4.00	18-00		000233
03	N14P35032B	SCREW,HEX HD				B		0000	EA	4.00	8.00	19-00		000234
03	N405P118B	LOCKWASHER				B		0000	EA	4.00	8.00	20-00		000235
03	N14P39048B	SCREW,HEX HD				B		0000	EA	10.00	20.00	21-00		000236
03	N266P39B	LOCKNUT				B		0000	EA	10.00	20.00	22-00		000237
03	47C381036P14	BOLT,FATIGUE RATED				B		0000	EA	12.00	24.00	23-00		000238
03	47C381087P5	NUT				B		0000	EA	12.00	24.00	24-00		000239
03	**47E382603-25	HYDR FLUID LINE ASSY				M		0000	EA	1.00	2.00	25-00		000240
03	271	LOCKTITE				B		0000	EA	AR		26-00	05972	000241
03	47C381088P6	WASHER,1.25 DIA				B		0000	EA	24.00	48.00	28-00		000242
02	47E382603G2	TEETER,RSTR BK ASSY				M		0000	EA	2.00	2.00	7-00		000243
03	**47E382603-1	HOUSING WALL,LH				M		0000	EA	1.00	2.00	1-00		000244
03	**47E382603-2	HOUSING WALL,RH				M		0000	EA	1.00	2.00	2-00		000245
03	47D381010P2	BRAKE ASSY				M		0000	EA	2.00	4.00	3-00		000246
03	**47E382603-4	HOUSING COVER				M		0000	EA	1.00	2.00	4-00		000247
03	**47E382603-5	TEETER ARM				M		0000	EA	1.00	2.00	5-00		000248
03	**47E382603-6	HOUSING COVER				M		0000	EA	2.00	4.00	6-00		000249
03	**47E382603-7	OUTBD BELLOWS COVER				M		0000	EA	1.00	2.00	7-00		000250
03	**47E382603-8	INBD BELLOWS COVER				M		0000	EA	1.00	2.00	8-00		000251
03	**47E382603-9	ROLLER GUIDE ASSY				M		0000	EA	1.00	2.00	9-00		000252
03	**47E382603-11	BRKT,MTG,LIMIT SW				M		0000	EA	1.00	2.00	11-00		000253
03	CR115GM101	SWITCH,LIMIT				B		0000	EA	1.00	2.00	12-00	02295	000254
03	N14P21012B	SCREW,CAP,HEX HD				B		0000	EA	4.00	8.00	13-00		000255
03	N405P111B	LOCKWASHER				B		0000	EA	4.00	8.00	14-00		000256
03	N14P25016B	SCREW,HEX HD				B		0000	EA	34.00	68.00	15-00		000257
03	N405P113B	LOCKWASHER				B		0000	EA	34.00	68.00	16-00		000258
03	N14P29016B	SCREW HEX HD				B		0000	EA	2.00	4.00	17-00		000259
03	N405P115B	LOCKWASHER				B		0000	EA	2.00	4.00	18-00		000260
03	N14P35032B	SCREW,HEX HD				B		0000	EA	4.00	8.00	19-00		000261

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
03	N405P118B	LOCKWASHER				B		0000	EA	4.00	8.00	20-00		000262
03	N14P39046B	SCREW,HEX HD				B		0000	EA	10.00	20.00	21-00		000263
03	N266P39B	LOCKNUT				B		0000	EA	10.00	20.00	22-00		000264
03	47C381036P14	BOLT,FATIGUE RATED				B		0000	EA	12.00	24.00	23-00		000265
03	47C381087P5	NUT				B		0000	EA	12.00	24.00	24-00		000266
03	**47E382603-25	HYDR FLUID LINE ASSY				M		0000	EA	1.00	2.00	25-00		000267
03	271	LOCKTITE				B		0000	EA	AR		26-00	05972	000268
03	**47E382603-27	BRKT ASSY,LIMIT SW				M		0000	EA	1.00	2.00	27-00		000269
03	47C381088P6	WASHER,1.25 DIA				B		0000	EA	24.00	48.00	28-00		000270
02	**47E382601-8	DRAG LINK				M		0000	EA	4.00	4.00	8-00		000271
02	**47E382601-9	CLAMP RING				M		0000	EA	1.00	1.00	9-00		000272
02	**47E382601-10	RTR BLADE HYD ASSY				M		0000	EA	1.00	1.00	10-00		000273
02	**47E382601-11	RTR BLADE ELECT ASSY				M		0000	EA	1.00	1.00	11-00		000274
02	N22BP29020B	BOLT, SLFLKG				B		0000	EA	48.00	48.00	12-00		000275
02	N22BP25016B	BOLT, SLFLKG				B		0000	EA	72.00	72.00	13-00		000276
02	N402P15B	WASHER				B		0000	EA	48.00	48.00	14-00		000277
02	N402P13B	WASHER				B		0000	EA	72.00	72.00	15-00		000278
02	N22P39048B	BOLT, HEX HD				B		0000	EA	12.00	12.00	16-00		000279
02	N402P20B	WASHER				B		0000	EA	20.00	20.00	17-00		000280
02	N22P39052B	BOLT, HEX HD				B		0000	EA	8.00	8.00	18-00		000281
02	N214P39B	NUT				B		0000	EA	8.00	8.00	19-00		000282
02	N22P45112B	BOLT, HEX HD				B		0000	EA	32.00	32.00	20-00		000283
02	N402P22B	WASHER				B		0000	EA	32.00	32.00	21-00		000284
02	N264P45B	LOCKNUT				B		0000	EA	32.00	32.00	22-00		000285
02	TA-30	PHILLYBOND ADHESIVE				B		0000	GA	AR		23-00	20420	000286
02	**47E382601-24	MTG BRACKET				B		0000	EA	4.00	4.00	24-00		000287
02	47D382604G1	SHAFT ALIGNMENT FTG				M		0000	EA	4.00	4.00	25-00		000288
03	47D382604P1	SHOE				M		0000	EA	1.00	4.00	1-00		000289
03	47D382604P2	ADJUSTING SCREW				M		0000	EA	1.00	4.00	2-00		000290
03	47D382604P3	BRACKET				M		0000	EA	1.00	4.00	3-00		000291
03	47D382604P4	PIN,6.00-LG X.50 DIA				M		0000	EA	2.00	8.00	4-00		000292
03	N504P2264	COTTER PIN				B		0000	EA	1.00	4.00	5-00		000293
03	N504P2224	COTTER PIN				B		0000	EA	1.00	4.00	6-00		000294
03	N402P20B	WASHER				B		0000	EA	1.00	4.00	7-00		000295
03	N402P81B	WASHER,FLAT				B		0000	EA	1.00	4.00	8-00		000296
03	47D382604P9	PAD,NYLON				M		0000	EA	2.00	8.00	9-00		000297
03	A15B60B1	ADH,ECCOBOND 281				B		0000	EA	AR		10-00		000298
02	**47E382601-26	HYD PIPING INSTL				M		0000	EA	1.00	1.00	26-00		000299
02	47E382601P27	GREASE				B		0000	LB	AR		27-00		000300
02	**47E382601-28	BLADE BUMPER ASSY				M		0000	EA	2.00	2.00	28-00		000301
01	47E382597G1	NACELLE OVERALL ASSY	1			M		0000	EA	1.00	1.00	3-00		000302
02	47E382363G1	NACELLE STRUCT ASSY	1			M		0000	EA	1.00	1.00	1-00		000303
03	47E382306G1	BED PL.,MACH.&DRILL.	01			M		0000	EA	1.00	1.00	1-00		000304

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	47E382429P1	BED PL. STRUCT. WELD				M		0000	EA	1.00	1.00	1-00		000305
04	47E382450P1	GEARBOX MTG. STRUCT.				M		0000	EA	1.00	1.00	2-00		000306
04	47C381036P40	BOLT, STRUCT. 2-12				M		0000	EA	24.00	24.00	3-00		000307
04	47C381087P18	NUT 2-12				M		0000	EA	24.00	24.00	4-00		000308
04	47C381088P18	WASHER 2.00				B		0000	EA	24.00	24.00	5-00		000309
04	47C381036P4	BOLT,FATIGUE RATED				M		0000	EA	20.00	20.00	6-00		000310
04	47C381087P1	NUT				M		0000	EA	20.00	20.00	7-00		000311
04	47C381088P2	WASHER,1.00 DIA				M		0000	EA	20.00	20.00	8-00		000312
04	47D382554P1	FLOORING, BEDPLATE				M		0000	EA	1.00	1.00	9-00		000313
04	N733P35040B	BOLT, STRUCT. .75-10				M		0000	EA	36.00	36.00	10-00		000314
04	N272P35	LOCKNUT .75-10				M		0000	EA	36.00	36.00	11-00		000315
04	N402P48B	WASHER .75				*		0000	EA	36.00	36.00	12-00		000316
04	A15F6C18	RTV SILICONE SEALANT				M		0000	OZ	AR		13-00		000317
04	47C381088P17	WASHER 2.00				M		0000	EA	24.00	24.00	14-00		000318
04	47C381088P1	WASHER,1.00 DIA				M		0000	EA	20.00	20.00	15-00		000319
03	47E382265P1	SIDE SUPPORT				M		0000	EA	1.00	1.00	2-00		000320
03	47E382265P2	SIDE SUPPORT				M		0000	EA	1.00	1.00	3-00		000321
03	47D382577P1	TOP STRUCTURE,AFT				M		0000	EA	1.00	1.00	4-00		000322
03	47E382272P1	ROTOR ADAPTER STRL				M		0000	EA	1.00	1.00	5-00		000323
03	47C381036P2	BOLT,FATIGUE RATED				B		0000	EA	32.00	32.00	6-00		000324
03	47C381036P6	BOLT,FATIGUE RATED				B		0000	EA	60.00	60.00	7-00		000325
03	47C381036P20	BOLT, FATIGUE RATED				B		0000	EA	88.00	88.00	8-00		000326
03	47C381036P10	BOLT,FATIGUE RATED				B		0000	EA	12.00	12.00	9-00		000327
03	47C381036P25	BOLT,FATIGUE RATED				B		0000	EA	36.00	36.00	10-00		000328
03	47C381087P2	LOCKNUT				B		0000	EA	92.00	92.00	11-00		000329
03	47C381087P6	LOCKNUT				B		0000	EA	12.00	12.00	12-00		000330
03	47C381087P10	LOCKNUT				B		0000	EA	124.00	124.00	13-00		000331
03	47C381088P1	WASHER,1.00 DIA				M		0000	EA	92.00	92.00	14-00		000332
03	47C381088P5	WASHER,1.25 DIA				B		0000	EA	12.00	12.00	15-00		000333
03	47C381088P9	WASHER,1.50 DIA				M		0000	EA	136.00	136.00	16-00		000334
03	90681A487	PIN,TAPER				B		0000	EA	6.00	6.00	17-00	39428	000335
03	47D382575P1	TOP STRUCTURE FWD				M		0000	EA	1.00	1.00	18-00		000336
03	47E382578P1	CRANE,MOUNTING STRL				M		0000	EA	1.00	1.00	19-00		000337
03	47D382572P1	SPACER,ADAPTER				M		0000	EA	1.00	1.00	20-00		000338
03	47D382572P2	SPACER,ADAPTER				M		0000	EA	1.00	1.00	21-00		000339
03	47D382572P3	SPACER,ADAPTER				M		0000	EA	1.00	1.00	22-00		000340
03	47D382572P4	SPACER,ADAPTER				M		0000	EA	1.00	1.00	23-00		000341
03	47D382572P5	SPACER,SIDE SUPPORT				M		0000	EA	4.00	4.00	24-00		000342
03	47D382572P6	SPACER,SIDE SUPPORT				M		0000	EA	2.00	2.00	25-00		000343
03	47D382572P7	SPACER,SIDE SUPPORT				M		0000	EA	2.00	2.00	26-00		000344
03	47C381088P2	WASHER,1.00 DIA				M		0000	EA	105.00	105.00	27-00		000345
03	47C381088P10	WASHER,1.50 DIA				B		0000	EA	136.00	136.00	28-00		000346
03	47C381088P6	WASHER,1.25 DIA				B		0000	EA	12.00	12.00	29-00		000347
03	47C381036P26	BOLT,FATIGUE RATED				B		0000	EA	12.00	12.00	30-00		000348
03	47C381087P9	NUT				B		0000	EA	12.00	12.00	31-00		000349
03	47C381036P1	BOLT,FATIGUE RATED				B		0000	EA	14.00	14.00	32-00		000350
03	47B382580P1	SEAL,TOP STRUCTURE				M		0000	EA	1.00	1.00	33-00		000351

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
03	47D382588P1	CROSS SPRT TOP STRL				M		0000	EA	1.00	1.00	34-00		000352
03	47B382580P2	SEAL,TOP STRUCTURE				M		0000	EA	1.00	1.00	35-00		000353
03	47B382580P3	SEAL,TOP STRUCTURE				M		0000	EA	2.00	2.00	36-00		000354
03	N733P35040B	BOLT, STRUCT. .75-10				M		0000	EA	20.00	20.00	37-00		000355
03	N733P35064B	BOLT,STRL				B		0000	EA	8.00	8.00	38-00		000356
03	N402P18B	WASHER, 3/4 DIA.				B		0000	EA	56.00	56.00	39-00		000357
03	N272P35	LOCKNUT .75-10				M		0000	EA	28.00	28.00	40-00		000358
03	47D382576P1	TOP,STRL,AFT,WLDMT				M		0000	EA	1.00	1.00	41-00		000359
03	47D382574P1	TOP,STRL,FWD,WLDMT				M		0000	EA	1.00	1.00	42-00		000360
03	47E382264P1	SIDE SUPPORT,WLDMT				M		0000	EA	1.00	1.00	43-00		000361
03	47E382271P1	ROTOR ADAPTER,WLDMT				M		0000	EA	1.00	1.00	44-00		000362
02	47E382553G1	GEARBOX INSTALLATION				M		0000	EA	1.00	1.00	2-00		000363
03	47E381046P1	GEARBOX ENVELOPE				B		0000	EA	1.00	1.00	1-00		000364
03	NUMBER-14	TAPER PIN 6.00 LG				B		0000	EA	4.00	4.00	2-00	76054	000365
03	47C381036P50	BOLT				B		0000	EA	36.00	36.00	3-00		000366
03	47C381088P21	WASHER				B		0000	EA	36.00	36.00	4-00		000367
03	47C381087P22	LOCKNUT				B		0000	EA	36.00	36.00	5-00		000368
03	47C381088P22	WASHER				B		0000	EA	36.00	36.00	6-00		000369
02	47D382589G1	GEN & HS SFT INSTL				M		0000	EA	1.00	1.00	3-00		000370
03	**47D382589-1	GENERATOR				B		0000	EA	1.00	1.00	1-00		000371
03	47D381078P1	HIGH SPEED SFT ASSY				B		0000	EA	1.00	1.00	2-00		000372
02	47D382596G1	AUX CRANE INSTL				M		0000	EA	1.00	1.00	4-00		000373
03	P20-10-30-20	CRANE				B		0000	EA	1.00	1.00	1-00	58811	000374
03	N405P49B	LOCKWASHER				B		0000	EA	36.00	36.00	2-00		000375
03	N22P36064B	BOLT				B		0000	EA	36.00	36.00	3-00		000376
02	47D382606G1	FAIRING INSTALLATION				M		0000	EA	1.00	1.00	5-00		000377
03	47E381113P1	FAIRING ENVELOPE				B		0000	EA	1.00	1.00	1-00		000378
03	47D382606P2	SEALING STRIP				M		0000	EA	AR		2-00		000379
03	47D382606P3	ADHESIVE(SEE NOTE 4)				B		0000	EA	AR		3-00		000380
03	BN360-813-3	BLIND NUT ASSY				B	5	0000	EA	56.00	56.00	4-00	73197	000381
03	N24P29048C	SCREW,HEX HD				B		0000	EA	48.00	48.00	5-00		000382
03	N405P15C	WASHER,LOCK				B	5	0000	EA	56.00	56.00	6-00		000383
03	N402P15C	WASHER 1/2 DIA				B	5	0000	EA	56.00	56.00	7-00		000384
03	N24P29024C	SCREW,HEX HD				B		0000	EA	8.00	8.00	8-00		000385
03	**47D382606-9	WINT SENSOR MAST				M		0000	EA	2.00	2.00	9-00		000386
02	**47E382597-6	ELECT EQUIP INSTL				M		0000	EA	1.00	1.00	6-00		000387
02	47E382472G1	LAD & FALSE FL INSTL				M		0000	EA	1.00	1.00	7-00		000388
03	47D382430G1	TRAP DR, BEDPL / TWR				M		0000	EA	2.00	2.00	1-00		000389
04	47D382430P1	COVER				M		0000	EA	1.00	2.00	1-00		000390

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LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	47D382430P2	ANGLE				M		0000	EA	2.00	4.00	2-00		000391
04	47D382430P3	ANGLE				M		0000	EA	2.00	4.00	3-00		000392
04	47D382430P4	RIB				M		0000	EA	2.00	4.00	4-00		000393
04	47D382430P5	PLATE				M		0000	EA	1.00	2.00	5-00		000394
04	47D382430P6	BAR				M		0000	EA	1.00	2.00	6-00		000395
04	47B382131P1	ENCLOSURE, DOOR				*		0000	EA	1.00	2.00	7-00		000396
04	47C381030P1	HINGE, TRAP DOOR				*		0000	EA	1.00	2.00	8-00		000397
03	47D382430G2	TRAP DR, BEDPL / TWR				M		0000	EA	2.00	2.00	2-00		000398
04	47D382430P1	COVER				M		0000	EA	1.00	2.00	1-00		000399
04	47D382430P2	ANGLE				M		0000	EA	2.00	4.00	2-00		000400
04	47D382430P3	ANGLE				M		0000	EA	2.00	4.00	3-00		000401
04	47D382430P4	RIB				M		0000	EA	2.00	4.00	4-00		000402
04	47D382430P6	BAR				M		0000	EA	1.00	2.00	6-00		000403
04	47B382131P1	ENCLOSURE, DOOR				*		0000	EA	1.00	2.00	7-00		000404
04	47C381030P1	HINGE, TRAP DOOR				*		0000	EA	1.00	2.00	8-00		000405
03	47D382474G1	TRAP DR,BEDPL / LUBE				M		0000	EA	1.00	1.00	3-00		000406
04	47D382474P1	COVER				M		0000	EA	1.00	1.00	1-00		000407
04	47D382474P2	ANGLE				M		0000	EA	2.00	2.00	2-00		000408
04	47D382474P3	ANGLE				M		0000	EA	2.00	2.00	3-00		000409
04	47D382474P4	RIB				M		0000	EA	2.00	2.00	4-00		000410
04	47D382474P5	PLATE				M		0000	EA	1.00	1.00	5-00		000411
04	47D382474P6	BAR				M		0000	EA	1.00	1.00	6-00		000412
04	47B382131P1	ENCLOSURE, DOOR				*		0000	EA	1.00	1.00	7-00		000413
04	47C381030P1	HINGE, TRAP DOOR				*		0000	EA	1.00	1.00	8-00		000414
03	47D382474G2	TRAP DR,BEDPL / LUBE				M		0000	EA	1.00	1.00	4-00		000415
04	47D382474P1	COVER				M		0000	EA	1.00	1.00	1-00		000416
04	47D382474P2	ANGLE				M		0000	EA	2.00	2.00	2-00		000417
04	47D382474P3	ANGLE				M		0000	EA	2.00	2.00	3-00		000418
04	47D382474P4	RIB				M		0000	EA	2.00	2.00	4-00		000419
04	47D382474P6	BAR				M		0000	EA	1.00	1.00	6-00		000420
04	47B382131P1	ENCLOSURE, DOOR				*		0000	EA	1.00	1.00	7-00		000421
04	47C381030P1	HINGE, TRAP DOOR				*		0000	EA	1.00	1.00	8-00		000422
03	47D382465P1	FRAME,TRAP DOOR				M		0000	EA	2.00	2.00	5-00		000423
03	47C382475P1	MOUNTING BLOCK				M		0000	EA	2.00	2.00	6-00		000424
03	**47E382472-7	FALSE FLOOR				M		0000	EA	1.00	1.00	7-00		000425
03	47E382472P8	ROOF SCUTTLE				B		0000	EA	1.00	1.00	8-00		000426
03	**47E382472-9	LADDER,ROOF				M		0000	EA	1.00	1.00	9-00		000427
03	**47E382472-10	LADDER,TOWER				M		0000	EA	2.00	2.00	10-00		000428
03	47E382472P11	SEALING STRIP				M		0000	EA	AR		11-00		000429
03	N727P29016B	BOLT,STRUCTURAL				B		0000	EA	32.00	32.00	12-00		000430
03	N402P45B	WASHER				B		0000	EA	72.00	72.00	13-00		000431
03	N265P29B	NUT,SELF-LOCKING .50*				*		0000	EA	112.00	112.00	14-00		000432

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
03	N727P29036B	BOLT,STRUCTURAL				B		0000	EA	48.00	48.00	15-00		000433
03	91151A033	WASHER,BEVEL				B		0000	EA	40.00	40.00	16-00	39428	000434
03	N727P29052B	BOLT,STRUCTURAL				B		0000	EA	28.00	28.00	17-00		000435
03	**47E382472-18	BRACKET,LADDER				M		0000	EA	8.00	8.00	18-00		000436
03	**47E382472-19	BRACKET,LADDER				M		0000	EA	1.00	1.00	19-00		000437
03	**47E382472-20	BRACKET,LADDER				M		0000	EA	1.00	1.00	20-00		000438
03	**47E382472-21	BRACKET,LADDER				M		0000	EA	2.00	2.00	21-00		000439
03	N727P29028B	BOLT,STRUCTURAL				B		0000	EA	24.00	24.00	22-00		000440
03	A15F6C18	RTV SILICONE SEALANT				M		0000	OZ	AR		23-00		000441
02	47E382570G1	LUBE PLATFORM INSTL				M		0000	EA	1.00	1.00	8-00		000442
03	47E382579G1	COOLING PLATFORM ASM				M		0000	EA	1.00	1.00	1-00		000443
04	47E382556G1	GEARBOX/CLG PLATFORM				M		0000	EA	1.00	1.00	1-00		000444
05	47E382556P1	ANGLE,4 X 4 X 3/8				M		0000	EA	4.00	4.00	1-00		000445
05	47E382556P2	CHANNEL,8-20 LB				M		0000	EA	2.00	2.00	2-00		000446
05	47E382556P3	CHANNEL,6-16.3 LB				M		0000	EA	4.00	4.00	3-00		000447
05	47E382556P4	ANGLE,3X3-7.2 LB				M		0000	EA	4.00	4.00	4-00		000448
05	47E382556P5	CHANNEL,8-20 LB				M		0000	EA	4.00	4.00	5-00		000449
05	47E382556P6	9-IN X 2 1/2 DP DECK				M		0000	EA	14.00	14.00	6-00		000450
05	47E382556P7	6-IN X 2 1/2 DP DECK				M		0000	EA	1.00	1.00	7-00		000451
05	47E382556P8	9-IN X 2 1/2 DP DECK				M		0000	EA	1.00	1.00	8-00		000452
05	47E382556P9	END PLATE 4.0 HT				M		0000	EA	2.00	2.00	9-00		000453
05	47E382556P10	SIDE PLATE 4.0 HT				M		0000	EA	2.00	2.00	10-00		000454
05	47E382556P11	ANGLE,3 X 3 X 3/8				M		0000	EA	4.00	4.00	11-00		000455
05	47E382556P12	ANGLE,3 X 3 X 3/8				M		0000	EA	4.00	4.00	12-00		000456
05	47E382556P13	ANGLE,3 X 3 X 3/8				M		0000	EA	2.00	2.00	13-00		000457
05	47E382556P14	ANGLE,3 X 3 X 3/8				M		0000	EA	2.00	2.00	14-00		000458
05	N22P28024B	SCREW,HEX HD,1/2-13				B		0000	EA	130.00	130.00	15-00		000459
05	N405P15B	LOCKWASHER				B		0000	EA	130.00	130.00	16-00		000460
05	N214FP29B	NUT,HEX,1/2-13				B		0000	EA	130.00	130.00	17-00		000461
05	1-700	CRIMPING TOOL				B		0000	EA	1.00	1.00	18-00	09098	000462
05	1-600	J-BOLT/NUT/WASHER				B		0000	EA	12.00	12.00	19-00	09098	000463
04	47C382584G1	MOT/PUMP/CLR PLATF				M		0000	EA	1.00	1.00	2-00		000464
05	47C382584P1	PLATE,BASE				M		0000	EA	1.00	1.00	1-00		000465
05	47C382584P2	BEAM,4 W 13#				M		0000	EA	2.00	2.00	2-00		000466
05	47C382584P3	BEAM,6 W 9#				M		0000	EA	2.00	2.00	3-00		000467
05	N22P33020B	SCREW,HEX HD				B		0000	EA	16.00	16.00	4-00		000468
05	N405P77B	LOCKWASHER				B		0000	EA	16.00	16.00	5-00		000469
04	350-SERIES-3DC	PUMP				B		0000	EA	1.00	1.00	3-00	59180	000470
04	326T-FRAME	MOTOR,TEFC				B		0000	EA	1.00	1.00	4-00		000471
04	N620B-SERIES-N600	COUPLING				B		0000	EA	1.00	1.00	5-00	89040	000472
04	OCS-2000D	OIL COOLER				B		0000	EA	3.00	3.00	6-00	67049	000473
04	89281/2F	CHECKVALVE,SWG,125LB				B		0000	EA	1.00	1.00	7-00	63686	000474

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	MODEL-400-D	FILTER,DUPLEX,4-IN				B		0000	EA	1.00	1.00	8-00	61424	000475
04	**47E382579-9	BASE,FILTER SUPPORT				M		0000	EA	1.00	1.00	9-00		000476
04	47C381084P1	VALVE,THERMO,AMOT				M		0000	EA	1.00	1.00	10-00		000477
04	47C381086P1	VALVE,RELIEF,4-IN				M		0000	EA	1.00	1.00	11-00		000478
04	FIG-258-32IN-LONG	SADDLE SUPPORT,4 IN				B		0000	EA	2.00	2.00	12-00	92959	000479
04	FIG-258-12.5IN-LONG	SADDLE SUPPORT,4 IN				B		0000	EA	1.00	1.00	13-00	92959	000480
04	FIG-277	PIPE ROLL & PLATE				B		0000	EA	1.00	1.00	14-00	92959	000481
04	105E-SIZE-4	TEE,FLANGED,250 LB				B		0000	EA	1.00	1.00	15-00	40475	000482
04	47E382579P16	PIPE,SCHED 40,5-IN				M		0000	FT	7.00	7.00	16-00		000483
04	290E-SIZE-5	FLANGE,SLIP-ON 300LB				B		0000	EA	2.00	2.00	17-00	40475	000484
04	47E382579P18	PIPE,SCHED 40				M		0000	FT	90.00	90.00	18-00		000485
04	290E-SIZE-4	FLANGE,SLIP-ON,300LB				B		0000	EA	12.00	12.00	19-00	40475	000486
04	264E-SIZE-4	TEE,STRAIGHT,300LB				B		0000	EA	4.00	4.00	20-00	40475	000487
04	264E-SIZE-4-X-3	TEE,REDUCING,300LB				B		0000	EA	3.00	3.00	21-00	40475	000488
04	260E-SIZE-4	ELBOW,STRAIGHT,300LB				B		0000	EA	10.00	10.00	22-00	40475	000489
04	1981/2E	UNION-3IN,300LB				B		0000	EA	6.00	6.00	23-00	40475	000490
04	47E382579P24	PIPE,SCHED 40,3IN				M		0000	FT	5.00	5.00	24-00		000491
04	FIG-268E-SIZE-3	ELBOW,STREET,300LB				B		0000	EA	6.00	6.00	25-00	40475	000492
04	260E-SIZE-4-X-3	ELBOW,REDUCING,300LB				B		0000	EA	3.00	3.00	26-00	40475	000493
04	N22P35056B	SCREW,HEX HD				B		0000	EA	120.00	120.00	27-00		000494
04	N405P48B	LOCKWASHER				B		0000	EA	120.00	120.00	28-00		000495
04	N214P35B	NUT				B		0000	EA	120.00	120.00	29-00		000496
04	N22P33036B	SCREW,HEX HD				B		0000	EA	8.00	8.00	30-00		000497
04	N405P47B	LOCKWASHER				B		0000	EA	50.00	50.00	31-00		000498
04	N214P33B	NUT				B		0000	EA	50.00	50.00	32-00		000499
04	N22P33032B	SCREW,HEX HD				B		0000	EA	10.00	10.00	33-00		000500
04	N402AP17B	PLAIN WASHER, NARROW				B		0000	EA	50.00	50.00	34-00		000501
04	N22P33020B	SCREW,HEX HD				B		0000	EA	40.00	40.00	35-00		000502
04	N22P29018B	SCREW,HEX HD				B		0000	EA	8.00	8.00	36-00		000503
04	N405P45B	WASHER, LOCK				B	5	0000	EA	8.00	8.00	37-00		000504
03	427D-SIZE-4	ELBOW,LONG				B		0000	EA	6.00	6.00	2-00	14959	000505
03	427D-SIZE-5	ELBOW,LONG				B		0000	EA	3.00	3.00	3-00	14959	000506
03	47E382570P4	PIPE ASSY				M		0000	EA	1.00	1.00	4-00		000507
03	47E382570P5	PIPE ASSY				M		0000	EA	1.00	1.00	5-00		000508
03	47E382570P6	PIPE ASSY				M		0000	EA	1.00	1.00	6-00		000509
03	47E382570P7	PIPE ASSY				M		0000	EA	1.00	1.00	7-00		000510
03	47E382570P8	PIPE ASSY				M		0000	EA	1.00	1.00	8-00		000511
03	47E382570P9	PIPE ASSY				M		0000	EA	1.00	1.00	9-00		000512
03	47E382570P10	PIPE ASSY				M		0000	EA	1.00	1.00	10-00		000513
03	47E382570P11	PIPE ASSY				M		0000	EA	1.00	1.00	11-00		000514
03	47E382570P12	PIPE ASSY				M		0000	EA	1.00	1.00	12-00		000515
03	47E382570P13	PIPE ASSY				M		0000	EA	1.00	1.00	13-00		000516
03	294E-SIZE-4	FLANGE,SLIP ON				B		0000	EA	14.00	14.00	14-00	14959	000517
03	294E-SIZE-5	FLANGE,SLIP ON				B		0000	EA	6.00	6.00	15-00	14959	000518
03	47C381039P1	EXPANSION JOINT				M		0000	EA	2.00	2.00	16-00		000519
03	47C381039P2	EXPANSION JOINT				M		0000	EA	1.00	1.00	17-00		000520
03	FIG-88-SIZE-4	U-BOLT				B		0000	EA	2.00	2.00	18-00	96723	000521
03	FIG-88-SIZE-5	U-BOLT				B		0000	EA	1.00	1.00	19-00	96723	000522

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
03	91151A031	WASHER,BEVEL				B		0000	EA	4.00	4.00	20-00	39428	000523
03	91151A33	WASHER,BEVEL				B		0000	EA	2.00	2.00	21-00	39428	000524
03	FIG-9-SIZE-5	HANGER,PEAR				B		0000	EA	1.00	1.00	22-00	96723	000525
03	FIG-500-5/8-DIA	ROD,THREADED				B		0000	EA	1.00	1.00	23-00	96723	000526
03	N214P33B	NUT				B		0000	EA	2.00	2.00	24-00		000527
03	N727P35056B	BOLT,STRUCTURAL				B		0000	EA	200.00	200.00	25-00		000528
03	N405P48B	LOCKWASHER				B		0000	EA	200.00	200.00	26-00		000529
03	N214P35B	NUT				B		0000	EA	200.00	200.00	27-00		000530
03	N727P35048B	BOLT,STRUCTURAL				B		0000	EA	32.00	32.00	28-00		000531
03	N402P48B	WASHER .75				*		0000	EA	32.00	32.00	29-00		000532
03	N265P35B	LOCK NUT, 3/4 DIA.				*		0000	EA	32.00	32.00	30-00		000533
03	91151A036	WASHER,BEVEL				B		0000	EA	32.00	32.00	31-00	39428	000534
03	47C382020	LUBRICATION SCHEM				X		0000	EA	X		32-00		000535
02	**47E382597-9	ELECT WW & CND INSTL				M		0000	EA	1.00	1.00	9-00		000536
02	47C381036P20	BOLT, FATIGUE RATED				B		0000	EA	120.00	120.00	10-00		000537
02	47C381087P13	NUT, FATIGUE RATED				B		0000	EA	120.00	120.00	11-00		000538
02	47C381088P14	WASHER, HARDENED STL				B		0000	EA	120.00	120.00	12-00		000539
02	47C381088P13	WASHER, HARDENED STL				B		0000	EA	120.00	120.00	13-00		000540
02	A15F6C18	RTV SILICONE SEALANT				M		0000	OZ	AR		14-00		000541
02	47D382598G1	LFT BRACKETS INSTL				M		0000	EA	1.00	1.00	15-00		000542
03	47C382485P1	LIFTING,BRKT				M		0000	EA	2.00	2.00	1-00		000543
03	47D382555P1	LIFTING BRKT				M		0000	EA	2.00	2.00	2-00		000544
03	47C381088P9	WASHER,1.50 DIA				M		0000	EA	24.00	24.00	3-00		000545
03	47C381087P9	NUT				B		0000	EA	24.00	24.00	4-00		000546
03	47C381036P24	BOLT,FATIGUE RATED				B		0000	EA	8.00	8.00	5-00		000547
03	47C381036P20	BOLT, FATIGUE RATED				B		0000	EA	8.00	8.00	6-00		000548
03	47C381036P22	BOLT,FATIGUE RATED				B		0000	EA	8.00	8.00	7-00		000549
03	47D382598P8	SPACER,STA 227.5				M		0000	EA	4.00	4.00	8-00		000550
03	47D382598P9	SPACER,STA 227.5				M		0000	EA	2.00	2.00	9-00		000551
03	47C381088P10	WASHER,1.50 DIA				B		0000	EA	24.00	24.00	10-00		000552
02	47E387062G1	CONT ELEK CAB, (CEC)				M		0000	EA	1.00	1.00	16-00		000553
03	47E381100P1	CABINET				M		0000	EA	1.00	1.00	1-00		000554
03	47D381040P1	HEAT EXCHANGER				M		0000	EA	2.00	2.00	2-00		000555
03	47E382491G1	AIR DUCT UNIT				M		0000	EA	2.00	2.00	3-00		000556
03	NP136931-A1	SIGNATURE STRIP				B	5	0000	EA	1.00	1.00	4-00		000557
03	N530P405G	SCR,DR RD HD,#4 X.31				B		0000	EA	4.00	4.00	5-00		000558
03	NP-206417	NAMEPLATE				B	5	0000	EA	1.00	1.00	6-00		000559
03	47A380070P3	NPL, AN/REV STATUS				*		0000	EA	1.00	1.00	7-00		000560
03	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		8-00		000561
03	47E387064	SCHEMATIC				X		0000	EA	X		9-00		000562
03	**47E387062-10	WIRE LIST				X		0000	EA	X		10-00		000563
03	47A380046	CONT ELEK CAB SPEC				X		0000	EA	X		11-00		000564
03	47C382234P1	GASKET				M		0000	EA	2.00	2.00	12-00		000565
03	**47E387062-13	PANEL, REAR RIGHT				M		0000	EA	1.00	1.00	13-00		000566
03	**47E387062-14	PANEL, REAR LEFT				M		0000	EA	1.00	1.00	14-00		000567

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OF POOR QUALITY

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
03	47A381067P8	I/O TRACK				M		0000	EA	8.00	8.00	15-00		000568
03	47A381067P9	120 VAC TRK INP MDL				M		0000	EA	81.00	81.00	16-00		000569
03	47A381067P10	120 VAC TRK OUT MDL				M		0000	EA	47.00	47.00	17-00		000570
03	47A381067P31	TERMINATOR PLUG				M		0000	EA	1.00	1.00	18-00		000571
03	**47E387062-19	CABLE ASSY				M		0000	EA	3.00	3.00	19-00		000572
03	47B382248P1	AIR BAF, RIGHT SIDE				M		0000	EA	1.00	1.00	20-00		000573
03	47B382248P2	AIR BAF, LEFT SIDE				M		0000	EA	1.00	1.00	21-00		000574
03	47A381067P23	CABLE, I/O TRACK				M		0000	EA	1.00	1.00	22-00		000575
03	**47E387062-23	CABLE CLAMP SUPPORT				M		0000	EA	1.00	1.00	23-00		000576
03	**47E387062-24	CABLE CLAMP SUPPORT				M		0000	EA	1.00	1.00	24-00		000577
03	**47E387062-25	CABLE CLAMP SUPPORT				M		0000	EA	1.00	1.00	25-00		000578
03	47A381045PAR	CLAMP,LOOP-CUSHIONED				M		0000	EA	AR		26-00		000579
03	A-72FSCPS	CENTER PANEL SUPPORT				M		0000	EA	2.00	2.00	27-00	00843	000580
03	A-72RP24F5	RELAY RACK ANGLE				M		0000	EA	1.00	1.00	28-00	00843	000581
03	47D387070G1	CENTER PANEL				*		0000	EA	1.00	1.00	29-00		000582
04	47D387070P1	PANEL				*		0000	EA	1.00	1.00	1-00		000583
04	47D387070P2	SPACER STRIP				*		0000	EA	2.00	2.00	2-00		000584
04	SS-024-3-ZI	SELF CLINCHING FASTE*				*		0000	EA	29.00	29.00	3-00	46384	000585
04	S-832-3-ZI	SELF CLINCHING FASTE*				*		0000	EA	6.00	6.00	4-00	46384	000586
04	S-632-3-ZI	SELF CLINCHING FASTE*				B	5	0000	EA	28.00	28.00	5-00	46384	000587
03	**47E387062-30	CABLE RETAINER				M		0000	EA	1.00	1.00	30-00		000588
03	47E387095G1	CONTROLLER ASSY				M		0000	EA	1.00	1.00	31-00		000589
04	47E387115P1	MOUNTING FRAME				M		0000	EA	1.00	1.00	1-00		000590
04	47A381067P16	POWER SUPPLY				M		0000	EA	1.00	1.00	2-00		000591
04	47A381067P18	CHASSIS				M		0000	EA	2.00	2.00	3-00		000592
04	SS00-30	HDL,RND 30 SET-OFF				B		0000	EA	2.00	2.00	4-00	08730	000593
04	47A381067P1	CTL PROCESSING UNIT				M		0000	EA	1.00	1.00	5-00		000594
04	47A381067P17	CHASSIS INTERFACE				M		0000	EA	1.00	1.00	6-00		000595
04	47A381067P3	16K EXECUTIVE MEMORY				M		0000	EA	1.00	1.00	7-00		000596
04	47A381067P5	16K RAM MEMORY				M		0000	EA	1.00	1.00	8-00		000597
04	47A381067P4	12K PROM, 4K RAM MEM				M		0000	EA	1.00	1.00	9-00		000598
04	47A381067P2	ARITH. PROCESSING				M		0000	EA	1.00	1.00	10-00		000599
04	47A381067P15	ERROR DETECTOR				M		0000	EA	1.00	1.00	11-00		000600
04	47A381067P14	WATCHDOG TIMER				M		0000	EA	1.00	1.00	12-00		000601
04	47A381067P20	FILLER BLANK				M		0000	EA	15.00	15.00	13-00		000602
04	47A381067P11	12-BIT A/D CONVERTER				M		0000	EA	2.00	2.00	14-00		000603
04	47A381067P12	12-BIT SS ANLG INPUT				M		0000	EA	3.00	3.00	15-00		000604
04	47A381067P13	12-BIT ANALOG OUTPUT				M		0000	EA	2.00	2.00	16-00		000605
04	47A381067P6	TTY & EIA INTFC MDL				M		0000	EA	3.00	3.00	17-00		000606
04	47A381067P7	I/O SYS DRIVER MDL				M		0000	EA	1.00	1.00	18-00		000607
04	3596A-3	TERMINAL BOARD				*		0000	EA	1.00	1.00	19-00	75382	000608
04	MS3596A-XP-3-38C	MARKER STRIP				*		0000	EA	1.00	1.00	20-00	75382	000609
04	9083	SPACER, THREADED				*		0000	EA	2.00	2.00	21-00	83330	000610
04	47B387082P1	SHIELD				*		0000	EA	1.00	1.00	22-00		000611
04	24205	COMPOUND, (LOCKTITE)				*		0000	OZ	AR		23-00	05972	000612
04	74755	PRIMER				*		0000	OZ	AR		24-00	05972	000613

LVL.	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	PC	TY	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	N153P13024	SCREW, PAN HD, #6-32				*		0000	EA	2.00	2.00	25-00		000614
04	N415P13	WASHER, LOCK, #6				*		0000	EA	4.00	4.00	26-00		000615
04	N400P37	WASHER, FL. #6				*		0000	EA	2.00	2.00	27-00		000616
04	N226P13	NUT, PLAIN HEX, #6-32				*		0000	EA	2.00	2.00	28-00		000617
04	N416P13	WSHR,LOCK, INTL T #6				*		0000	EA	2.00	2.00	29-00		000618
04	SFSW-10F-CP-GD2NA	PAN-L-SCREW, #10-32				B		0000	EA	12.00	12.00	30-00		000619
04	N153P16006	SCR, PH, #10-32				*		0000	EA	4.00	4.00	31-00		000620
04	N415P19	WASHER, LOCK, #10				*		0000	EA	4.00	4.00	32-00		000621
04	DC-37P	CONNECTOR				B		0000	EA	4.00	4.00	33-00	71468	000622
04	3341-1L	JACK SOCKET KIT				*		0000	EA	4.00	4.00	34-00	52760	000623
04	CP700-51	CONN HOUSING KIT				B		0000	EA	9.00	9.00	35-00	19006	000624
04	9158	CABLE, 5TP				B		0000	FT	AR		36-00	07903	000625
04	9160	CABLE, 8TP				B		0000	FT	AR		37-00	07903	000626
04	8741	CABLE, 2TP				B		0000	FT	AR		38-00	07907	000627
04	8740	CABLE, 1TP				B		0000	FT	AR		39-00	07907	000628
04	47A381043PAR	SLEEVING, VINYL				*		0000	FT	AR		40-00		000629
04	47A387124	WIRE LIST				X		0000	EA	X		41-00		000630
04	47E387095P42	BUSHING, STRAIN RLF				M		0000	EA	1.00	1.00	42-00		000631
04	47E387095P43	BUSHING, STRAIN RLF				M		0000	EA	8.00	8.00	43-00		000632
04	AML31EBA4AC	SWITCH, PUSH BUTTON				B		0000	EA	1.00	1.00	44-00	91929	000633
04	AML76F10T01P	SWITCH GUARD				B	5	0000	EA	1.00	1.00	45-00	91929	000634
04	**47E387095-46	LENS (RESET)				M		0000	EA	1.00	1.00	46-00		000635
04	47E387095P47	PLUG, SNAP OUT				M		0000	EA	3.00	3.00	47-00		000636
04	47E387064	SCHEMATIC				X		0000	EA	X		48-00		000637
04	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		49-00		000638
04	NP-206417	NAMEPLATE				B	5	0000	EA	1.00	1.00	50-00		000639
04	47A380070P3	NPL, AN/REV STATUS				*		0000	EA	1.00	1.00	51-00		000640
04	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		52-00		000641
04	47A381037P1	LACING TAPE				*		0000	FT	AR		53-00		000642
04	47A380071PAR	SLEEVING, SHRINK				*		0000	FT	AR		54-00		000643
03	**47E387062-32	TACHOMETER PANEL				M		0000	EA	1.00	1.00	32-00		000644
03	47E387072G1	I&C SIG CONDITIONER				*		0000	EA	1.00	1.00	33-00		000645
04	47D387073P1	PANEL,FRONT				*		0000	EA	1.00	1.00	1-00		000646
04	47D387074P1	PANEL,RIGHT SIDE				*		0000	EA	1.00	1.00	2-00		000647
04	47D387074P2	PANEL,LEFT SIDE				*		0000	EA	1.00	1.00	3-00		000648
04	47C387075P1	PANEL,REAR				*		0000	EA	1.00	1.00	4-00		000649
04	FCA4	HANDLE				B	5	0000	EA	2.00	2.00	5-00	08730	000650
04	47D387083G1	ASSY, MOTHER BD-SIGN*				*		0000	EA	1.00	1.00	6-00		000651
05	47E387090P1	DRILL & TRIM				*		0000	EA	1.00	1.00	1-00		000652
05	47B387086P1	ANGLE				*		0000	EA	2.00	2.00	2-00		000653
05	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		3-00		000654
05	47D387083P4	TERMINAL BLOCK				*		0000	EA	1.00	1.00	4-00		000655
05	47D387083P5	TERMINAL BLOCK				*		0000	EA	1.00	1.00	5-00		000656
05	RC36-8542-5	RECEPTACLE				*		0000	EA	10.00	10.00	6-00	57856	000657
05	3432-4205	HEADER				*		0000	EA	10.00	10.00	7-00	52760	000658
05	N153P9010	SCREW,PAN HD #4-40X5*				*		0000	EA	20.00	20.00	8-00		000659

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
05	N415P11	WASHER, LOCK, #4				*		0000	EA	20.00	20.00	9-00		000660
05	N226P9	NUT, HEX, #4-40				*		0000	EA	20.00	20.00	10-00		000661
05	AD34BS	RIVET				*		0000	EA	9.00	9.00	11-00	7707	000662
05	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		12-00		000663
04	47B387076G1	MTG. BRACKET,CIRCUIT*				*		0000	EA	2.00	2.00	7-00		000664
05	47B387076P1	BRACKET				*		0000	EA	1.00	2.00	1-00		000665
05	CLSS-032-3ZI	SELF CLINCHING FASTE*				*		0000	EA	1.00	2.00	3-00	46384	000666
05	CLS-832-3ZI	SELF CLINCHING FASTE*				*		0000	EA	2.00	4.00	4-00	46384	000667
04	47B387076G2	MTG. BRACKET,CIRCUIT*				*		0000	EA	2.00	2.00	8-00		000668
05	47B387076P2	BRACKET				*		0000	EA	1.00	2.00	2-00		000669
05	CLSS-032-3ZI	SELF CLINCHING FASTE*				*		0000	EA	1.00	2.00	3-00	46384	000670
05	CLS-832-3ZI	SELF CLINCHING FASTE*				*		0000	EA	2.00	4.00	4-00	46384	000671
04	HE215	POWER SUPPLY				B	5	0000	EA	1.00	1.00	9-00	18655	000672
04	PM345	POWER SUPPLY				*		0000	EA	1.00	1.00	10-00	18655	000673
04	RGR17-.250	GUIDE RAIL,CARD				*		0000	EA	4.00	4.00	11-00	57856	000674
04	051-64-002-41	GUIDE				B	5	0000	EA	20.00	20.00	12-00	57856	000675
04	NP-206417	NAMEPLATE				B	5	0000	EA	1.00	1.00	13-00		000676
04	47A380070P3	NPL, AN/REV STATUS				*		0000	EA	1.00	1.00	14-00		000677
04	47B387078P1	SUPPORT ANGLE,CABLE				*		0000	EA	1.00	1.00	15-00		000678
04	47B387079P1	MTG. BRACKET				*		0000	EA	2.00	2.00	16-00		000679
04	47B381059P4	CONNECTOR CUTOUT COV*				*		0000	EA	3.00	3.00	17-00		000680
04	47D387040G1	POWER SIGNAL CONDITI*				*		0000	EA	1.00	1.00	18-00		000681
04	47D387043G1	SYNCRO TO CURRENT CO*				*		0000	EA	2.00	2.00	19-00		000682
04	47D387032G1	GEAR BOX SIGNAL COND*				*		0000	EA	1.00	1.00	20-00		000683
04	47D387034G1	WIND SIGNAL CONDITIO*				*		0000	EA	1.00	1.00	21-00		000684
04	47E387037G1	ASSY,SYN SIG COND BD				*		0000	EA	2.00	2.00	22-00		000685
05	BB03-0501	BOARD				B		0000	EA	1.00	2.00	1-00	57856	000686
05	47A387039	WIRE LIST				X		0000	EA	X		2-00		000687
05	IC-308-WGG	SOCKET, 8-PIN				B		0000	EA	6.00	12.00	3-00	55322	000688
05	SC-1W3-GG	SOCKET				B		0000	EA	16.00	32.00	4-00	55322	000689
05	SC-1W1-GG-1	TERMINAL				B		0000	EA	15.00	30.00	5-00	55322	000690
05	DSS-C4	SWITCH COVER				M		0000	EA	1.00	2.00	6-00	95146	000691
05	AP-616-G-E	ADAPTER PLUG				M		0000	EA	2.00	4.00	7-00	55322	000692
05	BB248	TERMINAL				B		0000	EA	21.00	42.00	8-00	57856	000693
05	T-1S5-G	TERMINAL				B		0000	EA	6.00	12.00	9-00	55322	000694
05	N153P9006	SCR,PNH 4-40 X.375LG				B		0000	EA	2.00	4.00	10-00		000695
05	N400P35	WASHER,FLAT, NO. 4				*		0000	EA	2.00	4.00	11-00		000696
05	N415P11	WASHER, LOCK, #4				*		0000	EA	2.00	4.00	12-00		000697
05	47B381099PAR	WIRE,AWG 30,SLDRLESS				B		0000	FT	AR		13-00		000698
05	T-1S1-G	TERMINAL				B		0000	EA	21.00	42.00	14-00	55322	000699
05	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		15-00		000700
05	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		16-00		000701
05	47D387038	SCHEMATIC				X		0000	EA	X		17-00		000702

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
05	AWG-26-TYPE-S	BUS WIRE / QQ-W-343				B		0000	FT	AR		18-00		000703
05	CK06BX104K	CAPACITOR, .1 MFD				B	5	0000	EA	1.00	2.00	C1 -00	95275	000704
05	CK06BX104K	CAPACITOR, .1 MFD				B	5	0000	EA	1.00	2.00	C2 -00	95275	000705
05	150D106X9035R2	CAPACITOR, 10 MFD				B	5	0000	EA	1.00	2.00	C3 -00	56289	000706
05	CK06BX104K	CAPACITOR, .1 MFD				B	5	0000	EA	1.00	2.00	C4 -00	95275	000707
05	CK06BX104K	CAPACITOR, .1 MFD				B	5	0000	EA	1.00	2.00	C5 -00	95275	000708
05	RNC55H4530FS	RESISTOR, 453 OHMS				B		0000	EA	1.00	2.00	R1 -00		000709
05	RNC55H1102FS	RESISTOR, 11 K				B	5	0000	EA	1.00	2.00	R10 -00		000710
05	RNC55H1102FS	RESISTOR, 11 K				B	5	0000	EA	1.00	2.00	R11 -00		000711
05	3009P-1-202	POTENTIOMETER, 2 K				B		0000	EA	1.00	2.00	R12 -00	32997	000712
05	RNC55H9091FS	RESISTOR, 9.09 K				B	5	0000	EA	1.00	2.00	R13 -00		000713
05	RNC55H1001FS	RESISTOR				B	5	0000	EA	1.00	2.00	R14 -00		000714
05	3009P-1-202	POTENTIOMETER, 2 K				B		0000	EA	1.00	2.00	R15 -00	32997	000715
05	RNC55H1912FS	RESISTOR, 19.1 K				B	5	0000	EA	1.00	2.00	R16 -00		000716
05	3009P-1-501	POTENTIOMTR 500 OHMS				B		0000	EA	1.00	2.00	R17 -00	32997	000717
05	3009P-1-501	POTENTIOMTR 500 OHMS				B		0000	EA	1.00	2.00	R18 -00	32997	000718
05	3009P-1-501	POTENTIOMTR 500 OHMS				B		0000	EA	1.00	2.00	R19 -00	32997	000719
05	3009P-1-102	POTENTIOMETER, 1 K				B	7	0000	EA	1.00	2.00	R2 -00	32997	000720
05	3009P-1-501	POTENTIOMTR 500 OHMS				B		0000	EA	1.00	2.00	R20 -00	32997	000721
05	RNC55H1003FS	RESISTOR, 100 K				B	5	0000	EA	1.00	2.00	R3 -00		000722
05	RNC55H1271FS	RESISTOR, 1.27 K				B		0000	EA	1.00	2.00	R4 -00		000723
05	RNC55H1003FS	RESISTOR, 100 K				B	5	0000	EA	1.00	2.00	R5 -00		000724
05	RNC55H1003FS	RESISTOR, 100 K				B	5	0000	EA	1.00	2.00	R6 -00		000725
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	2.00	R7 -00		000726
05	RNC55H1333FS	RESISTOR, 133 K				B		0000	EA	1.00	2.00	R8 -00		000727
05	RNC55H3922FS	RESISTOR, 39.2 K				B	5	0000	EA	1.00	2.00	R9 -00		000728
05	DSS-4	SWITCH				B		0000	EA	1.00	2.00	S1 -00	95146	000729
05	SA810-C-96-0	SYN TO DC CONVERTER				M		0000	EA	1.00	2.00	U1 -00	14352	000730
05	TL087CP	OPERATIONAL AMPL				M		0000	EA	1.00	2.00	U2 -00	01295	000731
05	TL087CP	OPERATIONAL AMPL				M		0000	EA	1.00	2.00	U3 -00	01295	000732
05	TL087CP	OPERATIONAL AMPL				M		0000	EA	1.00	2.00	U4 -00	01295	000733
05	TL087CP	OPERATIONAL AMPL				M		0000	EA	1.00	2.00	U5 -00	01295	000734
05	2B20B	VOLT TO CUR CONV				M		0000	EA	1.00	2.00	U6 -00	24355	000735
05	2B20B	VOLT TO CUR CONV				M		0000	EA	1.00	2.00	U7 -00	24355	000736
05	TL087CP	OPERATIONAL AMPL				M		0000	EA	1.00	2.00	U8 -00	01295	000737
04	47D387087G1	ASSY, COLOR CODED FL*				*		0000	EA	7.00	7.00	23-00		000738
05	3502-1000	CONNECTOR				*		0000	EA	1.00	7.00	1-00	75037	000739
05	3417-7040	CONNECTOR				B	5	0000	EA	1.00	7.00	2-00	75037	000740
05	3302-37	CABLE 12" LG				*		0000	EA	1.00	7.00	3-00	75037	000741
04	3341-1L	JACK SOCKET KIT				*		0000	EA	7.00	7.00	24-00	52760	000742
04	47A381045P3	CLAMP,CABLE (.187 DI*				*		0000	EA	2.00	2.00	25-00		000743
04	47A381045P6	CLAMP,CABLE (.375 DI*				*		0000	EA	4.00	4.00	26-00		000744
04	3596A-3	TERMINAL BOARD				*		0000	EA	1.00	1.00	27-00	75382	000745
04	MS3596A-XP-3-38C	MARKER STRIP				*		0000	EA	1.00	1.00	28-00	75382	000746
04	9083	SPACER, THREADED				*		0000	EA	2.00	2.00	29-00	83330	000747
04	47B387082P1	SHIELD				*		0000	EA	1.00	1.00	30-00		000748

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	24205	COMPOUND, (LOCKTITE)				*		0000	OZ	AR		31-00	05972	000749
04	5596A-8	TERMINAL BOARD				*		0000	EA	1.00	1.00	32-00	75382	000750
04	N153P15010	SCR, PH, #8-32				*		0000	EA	4.00	4.00	33-00		000751
04	N415P16	WASHER, LOCK, #8				*		0000	EA	30.00	30.00	34-00		000752
04	N678P15008	SCREW, FLAT HD				B	5	0000	EA	2.00	2.00	35-00		000753
04	N226P15	NUT, HEX, #8-32				B	5	0000	EA	6.00	6.00	36-00		000754
04	N153P16010	SCREW,PAN HD #10-32X*				*		0000	EA	4.00	4.00	37-00		000755
04	N415P19	WASHER, LOCK, #10				*		0000	EA	20.00	20.00	38-00		000756
04	N226P16	NUT, HEX, #10-32				*		0000	EA	16.00	16.00	39-00		000757
04	N153P15005	SCREW,PAN HD #8-32X5*				*		0000	EA	12.00	12.00	40-00		000758
04	N153P9003	SCREW,PAN HD #4-40X3*				*		0000	EA	4.00	4.00	41-00		000759
04	N415P11	WASHER, LOCK, #4				*		0000	EA	6.00	6.00	42-00		000760
04	N153P16007	SCREW, PAN HD				*		0000	EA	8.00	8.00	43-00		000761
04	N153P15005	SCREW,PAN HD #8-32X5*				*		0000	EA	4.00	4.00	44-00		000762
04	N153P13024	SCREW, PAN HD, #6-32				*		0000	EA	2.00	2.00	45-00		000763
04	N415P13	WASHER, LOCK, #6				*		0000	EA	6.00	6.00	46-00		000764
04	N400P37	WASHER, FL. #6				*		0000	EA	2.00	2.00	47-00		000765
04	N226P13	NUT,PLAIN HEX, #6-32				*		0000	EA	2.00	2.00	48-00		000766
04	N153P16005	SCREW,PAN HD #10-32X*				*		0000	EA	6.00	6.00	49-00		000767
04	N153P9012	SCREW,PAN HD #4-40X3*				*		0000	EA	2.00	2.00	50-00		000768
04	N226P9	NUT, HEX, #4-40				*		0000	EA	2.00	2.00	51-00		000769
04	47A387088	WIRE LIST				X		0000	EA	X		52-00		000770
04	L108P12012	SCREW,PAN HD.M4X12				*		0000	EA	8.00	8.00	53-00		000771
04	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		54-00		000772
04	47A381037P1	LACING TAPE				*		0000	FT	AR		55-00		000773
04	47A381043PAR	SLEEVING, VINYL				*		0000	FT	AR		56-00		000774
04	44A0111-16-9	WIRE, AWG #16				B	5	0000	FT	AR		57-00	06090	000775
04	N400P39	WASHER, FLAT, #10				*		0000	EA	2.00	2.00	58-00		000776
04	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		59-00		000777
04	47E387061	SCHEMATIC				X		0000	EA	X		60-00		000778
04	N416P13	WSHR,LOCK, INTL T #6				*		0000	EA	1.00	1.00	61-00		000779
04	74755	PRIMER				*		0000	OZ	AR		62-00	05972	000780
04	MS5596-XP-8-8C	MARKER STRIP				*		0000	EA	1.00	1.00	63-00	75382	000781
04	47A380069P52	NAMEPLATE, IDENT (TB*				*		0000	EA	1.00	1.00	64-00		000782
04	44A0111-22-9	WIRE, #22 AWG				B	5	0000	FT	AR		65-00	06090	000783
04	47A380071PAR	SLEEVING, SHRINK				*		0000	FT	AR		66-00		000784
04	1488-6	SOLDER LUG				*		0000	EA	2.00	2.00	67-00	83330	000785
04	18RA-6	TERMINAL, LUG				*		0000	EA	8.00	8.00	68-00	59730	000786
04	18RA-6FLX	TERMINAL LUG, CRIMP				B	5	0000	EA	8.00	8.00	69-00	56501	000787
04	18RA-10	TERMINAL LUG, RING (*				*		0000	EA	4.00	4.00	70-00	56501	000788
04	30B-010	WIRE WRAP WIRE (1")				*		0000	FT	AR		71-00	8666	000789
04	30W-020	WIRE WRAP WIRE (2")				*		0000	FT	AR		72-00	8666	000790
04	30Y-030	WIRE WRAP WIRE (3")				*		0000	FT	AR		73-00	8666	000791
04	30R-040	WIRE WRAP WIRE (4")				*		0000	FT	AR		74-00	8666	000792
04	30BLK-050	WIRE WRAP WIRE (5")				*		0000	FT	AR		75-00	8666	000793
04	30B-060	WIRE WRAP WIRE (6")				*		0000	FT	AR		76-00	8666	000794
04	30W-070	WIRE WRAP WIRE (7")				*		0000	FT	AR		77-00	8666	000795
04	30Y-080	WIRE WRAP WIRE (8")				*		0000	FT	AR		78-00	8666	000796
04	30R-090	WIRE WRAP WIRE (9")				*		0000	FT	AR		79-00	8666	000797

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	30BLK-100	WIRE WRAP WIRE,(10")				*		0000	FT	AR		80-00	8666	000798
04	WB-16	WIRE WRAP WIRE, ROLL				*		0000	FT	AR		81-00	8666	000799
03	47E387093G1	WIND TRANSLATOR				M		0000	EA	1.00	1.00	34-00		000800
03	**47E387062-35	SPCR, CABLE RETAINER				M		0000	EA	1.00	1.00	35-00		000801
03	**47E387062-36	WIRE DUCT				M		0000	EA	2.00	2.00	36-00		000802
03	**47E387062-37	WIRE DUCT COVER				M		0000	EA	2.00	2.00	37-00		000803
03	722140	TERMINAL STRIP				M		0000	EA	8.00	8.00	38-00	52458	000804
03	**47E387062-39	MARKER STRIP				M		0000	EA	8.00	8.00	39-00		000805
03	**47E387062-40	CABLE ASSY, W1				M		0000	EA	1.00	1.00	40-00		000806
03	**47E387062-41	CABLE ASSY, W2				M		0000	EA	1.00	1.00	41-00		000807
03	**47E387062-42	CABLE ASSY, W3				M		0000	EA	1.00	1.00	42-00		000808
03	**47E387062-43	CABLE ASSY, W4				M		0000	EA	1.00	1.00	43-00		000809
03	**47E387062-44	CABLE ASSY, W5				M		0000	EA	1.00	1.00	44-00		000810
03	**47E387062-45	CABLE ASSY, W6				M		0000	EA	1.00	1.00	45-00		000811
03	**47E387062-46	CABLE ASSY, W7				M		0000	EA	1.00	1.00	46-00		000812
03	**47E387062-47	CABLE ASSY, W8				M		0000	EA	1.00	1.00	47-00		000813
03	**47E387062-48	CABLE ASSY, W9				M		0000	EA	1.00	1.00	48-00		000814
03	**47E387062-49	CABLE ASSY, W10				M		0000	EA	1.00	1.00	49-00		000815
03	47E387065G1	PANEL, RIGHT SIDE				*		0000	EA	1.00	1.00	50-00		000816
04	47E387065P1	PANEL,RIGHT SIDE				*		0000	EA	1.00	1.00	1-00		000817
04	S-0420-2-ZI	SELF CLINCHING FASTE*				*		0000	EA	12.00	12.00	2-00	46384	000818
04	SS-024-3-ZI	SELF CLINCHING FASTE*				*		0000	EA	45.00	45.00	3-00	46384	000819
04	S-832-3-ZI	SELF CLINCHING FASTE*				*		0000	EA	2.00	2.00	4-00	46384	000820
04	S-632-3-ZI	SELF CLINCHING FASTE*				B	5	0000	EA	6.00	6.00	5-00	46384	000821
03	**47E387062-51	WIRE DUCT				M		0000	EA	1.00	1.00	51-00		000822
03	**47E387062-52	WIRE DUCT COVER				M		0000	EA	1.00	1.00	52-00		000823
03	47C387096G1	MTG BRACKET ASSY				M		0000	EA	2.00	2.00	53-00		000824
04	47C387096P1	MTG BRACKET				M		0000	EA	1.00	2.00	1-00		000825
04	CLS-632-3	SELF CLINCHING FSTNR				B		0000	EA	8.00	16.00	2-00	46384	000826
04	47A380102	FINISH				X		0000	PT	X		3-00		000827
03	**47E387062-54	BLANK PANEL				M		0000	EA	1.00	1.00	54-00		000828
03	N30AP16010	SCR, HEX HD, #10-32				B		0000	EA	151.00	151.00	55-00		000829
03	N415P19	WASHER, LOCK, #10				*		0000	EA	187.00	187.00	56-00		000830
03	N226P16	NUT, HEX, #10-32				*		0000	EA	103.00	103.00	57-00		000831
03	N30AP21010	SCR, HEX HD, #1/4-20				B		0000	EA	37.00	37.00	58-00		000832
03	N415P25	WASHER, LOCK, (1/4)				B		0000	EA	37.00	37.00	59-00		000833
03	N400P39	WASHER, FLAT, #10				*		0000	EA	60.00	60.00	60-00		000834
03	SFSW10F16CP-G02NA	SCR, PANEL, #10-32				B		0000	EA	12.00	12.00	61-00	12324	000835
03	SFSW10F8CP-G02NA	SCR, PANEL, #10-32				B	5	0000	EA	12.00	12.00	62-00	12324	000836
03	N678P15016	SCR, FLAT HD, #8-32				B		0000	EA	9.00	9.00	63-00		000837
03	N415P16	WASHER, LOCK, #8				*		0000	EA	19.00	19.00	64-00		000838
03	N226P15	NUT, HEX, #8-32				B	5	0000	EA	9.00	9.00	65-00		000839
03	N153P9014	SCR, PH, #4-40				B		0000	EA	32.00	32.00	66-00		000840
03	N415P11	WASHER, LOCK, #4				*		0000	EA	32.00	32.00	67-00		000841

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
03	N226P9	NUT, HEX, #4-40				*		0000	EA	32.00	32.00	68-00		000842
03	N334P1502	RIVET,DOMED HD,BLIND				B		0000	EA	50.00	50.00	69-00		000843
03	N30AP16007	SCR, HEX HD, #10-32				B		0000	EA	30.00	30.00	70-00		000844
03	A-PS1420CM	CLAMPING NUT				B		0000	EA	9.00	9.00	71-00	00843	000845
03	N153P16006	SCR, PH, #10-32				*		0000	EA	18.00	18.00	72-00		000846
03	N153P15010	SCR, PH, #8-32				*		0000	EA	6.00	6.00	73-00		000847
03	N153P13016	SCR, PH, #6-32				B		0000	EA	13.00	13.00	74-00		000848
03	N415P13	WASHER, LOCK, #6				*		0000	EA	29.00	29.00	75-00		000849
03	N153P15006	SCR, PH, #8-32				*		0000	EA	4.00	4.00	76-00		000850
03	N153P13004	SCR, PH, #6-32				*		0000	EA	16.00	16.00	77-00		000851
03	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		78-00		000852
03	47A381037P1	LACING TAPE				*		0000	FT	AR		79-00		000853
03	**47E387062-80	BRKT,PWR SUPPLY SPRT				M		0000	EA	8.00	8.00	80-00		000854
03	7022AD	RELAY				B		0000	EA	1.00	1.00	81-00	72962	000855
03	47D387121G1	ESD ELECT ASSY				M		0000	EA	1.00	1.00	82-00		000856
04	47D387063P1	PANEL				M		0000	EA	1.00	1.00	1-00		000857
04	47D387063P2	MOUNTING CHASIS				M		0000	EA	1.00	1.00	2-00		000858
04	KHU17A11-120	RELAY				B	5	0000	EA	6.00	6.00	3-00	77342	000859
04	KHU17D11-28	RELAY				B		0000	EA	1.00	1.00	4-00	77342	000860
04	47-61-201-10	CAPTIVE SCREW				M		0000	EA	4.00	4.00	5-00	94222	000861
04	N678P13007	SCR,FLH 6-32 X .44LG				M		0000	EA	4.00	4.00	6-00		000862
04	N415P13	WASHER, LOCK, #6				*		0000	EA	6.00	6.00	7-00		000863
04	N226P13	NUT,PLAIN HEX, #6-32				*		0000	EA	4.00	4.00	8-00		000864
04	N226P7	NUT, HEX 3-48				M		0000	EA	7.00	7.00	9-00		000865
04	N415P9	WASHER,LOCK, EXT T #3				M		0000	EA	7.00	7.00	10-00		000866
04	IN4005	DIODE				B		0000	EA	1.00	1.00	11-00		000867
04	47A381044PAR	SLEEVING,TEFLON				*		0000	FT	AR		12-00		000868
04	47A387125	WIRE LIST				X		0000	EA	X		13-00		000869
04	MRA20PJ	CONNECTOR				M		0000	EA	1.00	1.00	14-00	79376	000870
04	6STV-15	TERMINAL STRIP				M		0000	EA	1.00	1.00	15-00	53337	000871
04	TCG-15	COVER, TERM STRIP				M		0000	EA	1.00	1.00	16-00	53337	000872
04	N195P1306	SCR,PNH 6-20 X .375LG				M		0000	EA	2.00	2.00	17-00		000873
04	44A0111-20-9	WIRE, AWG #20				B	5	0000	FT	AR		18-00	06090	000874
04	AWG-20-TYPE-S	WIRE, BUS/QQ-W-343				B		0000	FT	AR		19-00		000875
04	47D387022	SCHEMATIC				X		0000	EA	X		20-00		000876
04	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		21-00		000877
04	47A380102P1	FINISH				M		0000	QT	AR		22-00		000878
04	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		23-00		000879
04	47A381037P1	LACING TAPE				*		0000	FT	AR		24-00		000880
04	47A380071PAR	SLEEVING, SHRINK				*		0000	FT	AR		25-00		000881
03	47D387130G1	"G" SWITCH TEST ELEK				M		0000	EA	1.00	1.00	83-00		000882
04	47D387129P1	PANEL				M		0000	EA	1.00	1.00	1-00		000883
04	47D387129P2	MOUNTING CHASSIS				M		0000	EA	1.00	1.00	2-00		000884
04	47-61-201-10	CAPTIVE SCREW				M		0000	EA	4.00	4.00	3-00	94222	000885
04	4156-14-1	TERMINAL				M		0000	EA	8.00	8.00	4-00	17117	000886
04	KHU17A17-120	RELAY				M		0000	EA	6.00	6.00	5-00	77342	000887

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	MJ1000	TRANSISTOR				B	5	0000	EA	1.00	1.00	6-00	04713	000888
04	177-3-62	INSULATOR				B	5	0000	EA	1.00	1.00	7-00	05820	000889
04	MD-3452-G	SOCKET,TO-3				B	5	0000	EA	1.00	1.00	8-00	06770	000890
04	120-2	GREASE,THERMAL				B	5	0000	OZ	AR		9-00	05820	000891
04	LM10CH	OPERATIONAL AMPLIFIER				B	7	0000	EA	1.00	1.00	10-00	27014	000892
04	6140-188-1	SOCKET, 8 PIN				M		0000	EA	1.00	1.00	11-00	17117	000893
04	3059J-1-102M	POTENTIOMETER				M		0000	EA	2.00	2.00	12-00	32997	000894
04	WBR1000-50	CAPACITOR				B	5	0000	EA	1.00	1.00	13-00	14655	000895
04	150D105X9035A2	CAPACITOR				B	5	0000	EA	1.00	1.00	14-00	56289	000896
04	41F2R0	RESISTOR, 2 OHM				M		0000	EA	1.00	1.00	15-00	03615	000897
04	RN65C1004F	RESISTOR, 1M OHM				B	5	0000	EA	1.00	1.00	16-00		000898
04	MRA20PJ	CONNECTOR				M		0000	EA	1.00	1.00	17-00	79376	000899
04	6STV-10	TERMINAL STRIP				M		0000	EA	1.00	1.00	18-00	53337	000900
04	TC6-10	COVER, TERM. STRIP				M		0000	EA	1.00	1.00	19-00	53337	000901
04	47A387128	WIRE LIST				X		0000	EA	X		20-00		000902
04	47D387122	SCHEMATIC				X		0000	EA	X		21-00		000903
04	N678P13007	SCR,FLH 6-32 X .44LG				M		0000	EA	4.00	4.00	22-00		000904
04	N415P13	WASHER, LOCK, #6				*		0000	EA	8.00	8.00	23-00		000905
04	N226P13	NUT,PLAIN HEX, #6-32				*		0000	EA	4.00	4.00	24-00		000906
04	N226P7	NUT, HEX 3-48				M		0000	EA	6.00	6.00	25-00		000907
04	N415P9	WASHER,LOCK, EXT T #3				M		0000	EA	6.00	6.00	26-00		000908
04	N195P1306	SCR,PNH 6-20 X .375LG				M		0000	EA	2.00	2.00	27-00		000909
04	N153P13010	SCREW,PAN HD. #6-32				M		0000	EA	2.00	2.00	28-00		000910
04	N678P9008	SCREW,FLAT HD. #4-40				M		0000	EA	1.00	1.00	29-00		000911
04	N415P11	WASHER, LOCK, #4				*		0000	EA	1.00	1.00	30-00		000912
04	N226P9	NUT, HEX, #4-40				*		0000	EA	1.00	1.00	31-00		000913
04	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		32-00		000914
04	44A0111-20-9	WIRE, AWG #20				B	5	0000	FT	AR		33-00	06090	000915
04	AWG-20-TYPE-S	WIRE, BUS/QQ-W-343				B		0000	FT	AR		34-00		000916
04	47A380102P1	FINISH				M		0000	QT	AR		35-00		000917
04	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		36-00		000918
04	47A381037P1	LACING TAPE				*		0000	FT	AR		37-00		000919
04	47A380071PAR	SLEEVING, SHRINK				*		0000	FT	AR		38-00		000920
04	47A381044PAR	SLEEVING,TEFLON				*		0000	FT	AR		39-00		000921
03	47D387132G1	ICE DETECTOR ELEK				M		0000	EA	1.00	1.00	84-00		000922
03	MRA20SJH1	CONNECTOR				B		0000	EA	3.00	3.00	85-00	79376	000923
03	**47E387062-86	WIRE DUCT				M		0000	EA	4.00	4.00	86-00		000924
03	**47E387062-87	WIRE DUCT COVER				M		0000	EA	4.00	4.00	87-00		000925
03	**47E387062-88	CIRCUIT BKR PANEL				M		0000	EA	1.00	1.00	88-00		000926
03	112-220-101	CIRCUIT BKR (20A)				B		0000	EA	2.00	2.00	89-00	77342	000927
03	112-215-101	CIRCUIT BKR (15A)				B		0000	EA	7.00	7.00	90-00	77342	000928
03	112-210-101	CIRCUIT BKR (10A)				*		0000	EA	7.00	7.00	91-00	77342	000929
03	112-205-101	CIRCUIT BKR (5A)				B		0000	EA	2.00	2.00	92-00	77342	000930
03	1422552	POWER BLOCK (2 CKT)				M		0000	EA	1.00	1.00	93-00	26405	000931
03	1423552	POWER BLOCK (3 CKT)				M		0000	EA	1.00	1.00	94-00	26405	000932
03	**47E387062-95	SAFETY SHIELD				M		0000	EA	1.00	1.00	95-00		000933
03	4697-1032-SS-20	HEX M & F STANDOFF				M		0000	EA	12.00	12.00	96-00	55566	000934
03	24205	COMPOUND, (LOCKTITE)				*		0000	OZ	AR		97-00	05972	000935

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LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
03	74755	PRIMER				*		0000	OZ	AR		98-00	05972	000936
03	**47E387062-99	SPACER				M		0000	EA	13.00	13.00	99-00		000937
03	**47E387062-100	SUPPORT,(04-04-42-8)				M		0000	EA	13.00	13.00	100-00		000938
03	**47E387062-101	BUS BAR				M		0000	EA	1.00	1.00	101-00		000939
03	**47E387062-102	BUS BAR				M		0000	EA	1.00	1.00	102-00		000940
03	**47E387062-103	BUS BAR				M		0000	EA	1.00	1.00	103-00		000941
03	**47E387062-104	BUS BAR				M		0000	EA	1.00	1.00	104-00		000942
03	**47E387062-105	CONNECTION				M		0000	EA	130.00	130.00	105-00		000943
03	**47E387062-106	CONNECTION				M		0000	EA	62.00	62.00	106-00		000944
03	**47E387062-107	CONNECTION				M		0000	EA	4.00	4.00	107-00		000945
03	**47E387062-108	CONNECTION				M		0000	EA	1.00	1.00	108-00		000946
03	**47E387062-109	MARKERS (1 THRU 120)				M		0000	EA	1.00	1.00	109-00		000947
03	**47E387062-110	MARKERS (1 THRU 14)				M		0000	EA	1.00	1.00	110-00		000948
03	**47E387062-111	MARKERS (1 THRU 63)				M		0000	EA	1.00	1.00	111-00		000949
03	FD15-50	PWR SUPPLY,+/- 15VDC				M		0000	EA	1.00	1.00	112-00	14749	000950
03	B24N75	PWR SUPPLY, (24 VDC)				M		0000	EA	1.00	1.00	113-00	14749	000951
03	B28N70	PWR SUPPLY, (28 VDC)				M		0000	EA	1.00	1.00	114-00	14749	000952
03	B35FT40	PWR SUPPLY, (35 VDC)				M		0000	EA	1.00	1.00	115-00	14749	000953
03	47A380071PAR	SLEEVING, SHRINK				*		0000	FT	AR		116-00		000954
03	47A381043PAR	SLEEVING, VINYL				*		0000	FT	AR		117-00		000955
03	44A0811-12-9	WIRE, AWG #12				B	5	0000	FT	AR		118-00	06090	000956
03	44A0111-16-9	WIRE, AWG #16				B	5	0000	FT	AR		119-00	06090	000957
03	44A0111-20-9	WIRE, AWG #20				B	5	0000	FT	AR		120-00	06090	000958
03	18RA-6FLX	TERMINAL LUG, CRIMP				B	5	0000	EA	AR		121-00	56501	000959
03	10RC-10FLX	TERMINAL LUG, CRIMP				B		0000	EA	AR		122-00	56501	000960
03	**47E387062-123	BRKT, WIRING SUPPORT				M		0000	EA	1.00	1.00	123-00		000961
02	47E387060G1	HIGH VOLTAGE CG ASSY				M		0000	EA	1.00	1.00	17-00		000962
03	47E387069G1	HIGH V CG DRILL ASSY				M		0000	EA	1.00	1.00	1-00		000963
03	47D387009P1	GROUNDING XFMR				M		0000	EA	1.00	1.00	2-00		000964
03	47C387013P1	GROUNDING RESISTOR				M		0000	EA	2.00	2.00	3-00		000965
03	47D387010P1	CURRENT XFMR				M		0000	EA	6.00	6.00	4-00		000966
03	47D387011P1	POTENTIAL XFMR				M		0000	EA	3.00	3.00	5-00		000967
03	N24P25016	BOLT, HEX HEAD				B		0000	EA	12.00	12.00	6-00		000968
03	47D387110P1	BUS BAR				M		0000	EA	1.00	1.00	7-00		000969
03	N673P35	EYE BOLT				B		0000	EA	2.00	2.00	8-00		000970
03	47D387109G1	FRONT PANEL				M		0000	EA	1.00	1.00	9-00		000971
03	N227P25	NUT, HEX				B		0000	EA	12.00	12.00	10-00		000972
03	N415P75	WASHER, LOCK				B		0000	EA	2.00	2.00	11-00		000973
03	N227P35	NUT, HEX				B		0000	EA	2.00	2.00	12-00		000974
03	N415P37	WASHER, LOCK				B		0000	EA	36.00	36.00	13-00		000975
03	N24P25008	BOLT, HEX HD				B		0000	EA	24.00	24.00	14-00		000976
03	N24P29020	BOLT, HEX HD				B		0000	EA	36.00	36.00	15-00		000977
03	N415P50	WASHER, LOCK				B		0000	EA	36.00	36.00	16-00		000978
03	N227P29	NUT, HEX				B		0000	EA	36.00	36.00	17-00		000979
03	N27P21022	BOLT, HEX HD, SLOTTED				B		0000	EA	10.00	10.00	18-00		000980
03	N415P25	WASHER, LOCK, (1/4)				B		0000	EA	10.00	10.00	19-00		000981
03	N400P41	WASHER, FLAT				B	5	0000	EA	10.00	10.00	20-00		000982

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM CROSS REF
01	47E382590G1	ROTOR BLADE ASSY				M		0000	EA	1.00	1.00	4-00	000983
02	47J382287P1	CENTER BLADE SECT				M		0000	EA	1.00	1.00	1-00	000984
02	47E381105G1	BOLSTER ASSY				M		0000	EA	1.00	1.00	2-00	000985
03	47E382301P1	BOLSTER				M		0000	EA	2.00	2.00	1-00	000986
03	47D382550G1	SFT,TEETER BRG ASSY				M		0000	EA	1.00	1.00	2-00	000987
04	47D382550P1	CLOTH,FIBERGLASS				M		0000	FT	AR		1-00	000988
04	47D382550P2	ADHESIVE				M		0000	OZ	AR		2-00	000989
04	47D382397G1	TEETER PVT SFT ASSY				M		0000	EA	1.00	1.00	3-00	000990
05	47D382397P1	TEETER PIVOT SHAFT				M		0000	EA	1.00	1.00	1-00	000991
05	47C382390P1	PLUG, SHAFT TEETER				M		0000	EA	2.00	2.00	2-00	000992
03	47C382551G1	TEETER RESTR ASSY				M		0000	EA	4.00	4.00	3-00	000993
04	47C382551P1	CLOTH, FIBERGLASS				M		0000	FT	AR		1-00	000994
04	47C382551P2	ADHESIVE, EPOXY				M		0000	OZ	AR		2-00	000995
04	47C382351P1	TEETER SPRT INNER				M		0000	EA	1.00	4.00	3-00	000996
03	47C382551G2	TEETEER RESTR ASSY				M		0000	EA	4.00	4.00	4-00	000997
04	47C382551P1	CLOTH, FIBERGLASS				M		0000	FT	AR		1-00	000998
04	47C382551P2	ADHESIVE, EPOXY				M		0000	OZ	AR		2-00	000999
04	47C382350P1	TEETER SPRT OUTER				M		0000	EA	1.00	4.00	4-00	001000
03	47C382552G1	BOLSTER INSR ASSY				M		0000	EA	2.00	2.00	5-00	001001
04	47C382552P1	CLOTH,FIBERGLASS				M		0000	FT	AR		1-00	001002
04	47C382552P2	ADHESIVE				M		0000	OZ	AR		2-00	001003
04	47E382403P1	INSERT,BOLSTER				M		0000	EA	1.00	2.00	3-00	001004
03	**47E381105-6	EPOXY,THICKENED				B		0000	EA	AR		6-00	001005
02	47J381090P1	INNER BLADE SECTION				M		0000	EA	2.00	2.00	3-00	001006
02	47J381097P1	OUTER BLADE SECTION				M		0000	EA	2.00	2.00	4-00	001007
02	47E381089P1	TRAILING EDGE INSTL				M		0000	EA	2.00	2.00	5-00	001008
02	47E381089P2	TRAILING EDGE INSTL				M		0000	EA	2.00	2.00	6-00	001009
02	47E381089P3	TRAILING EDGE INSTL				M		0000	EA	2.00	2.00	7-00	001010
02	47E382610G1	AILERON INSTALLATION				M		0000	EA	2.00	2.00	8-00	001011
03	**47E382610-1	AIL SECT,INDB DRIVE				M		0000	EA	2.00	4.00	1-00	001012
03	**47E382610-2	AIL SECT,INBD TRAIL				M		0000	EA	2.00	4.00	2-00	001013
03	**47E382610-3	AIL SECT,CENTER DR				M		0000	EA	2.00	4.00	3-00	001014
03	**47E382610-4	AIL SECT,CENTER TR				M		0000	EA	2.00	4.00	4-00	001015
03	**47E382610-5	AIL SECT,OUTBD DRIVE				M		0000	EA	2.00	4.00	5-00	001016
03	**47E382610-6	AIL SECT,OUTBD TRAIL				M		0000	EA	2.00	4.00	6-00	001017

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
03	**47E382610-7	HINGE FITTING,INBD				M		0000	EA	2.00	4.00	7-00		001018
03	**47E382610-8	HINGE FITTING,INBD				M		0000	EA	2.00	4.00	8-00		001019
03	**47E382610-9	HINGE FITTING,CENTER				M		0000	EA	2.00	4.00	9-00		001020
03	**47E382610-10	HINGE FITTING,CENTER				M		0000	EA	2.00	4.00	10-00		001021
03	**47E382610-11	HINGE FITTING,OUTBD				M		0000	EA	2.00	4.00	11-00		001022
03	**47E382610-12	HINGE FITTING,OUTBD				M		0000	EA	2.00	4.00	12-00		001023
03	**47E382610-13	HINGE FITTING,TIP				M		0000	EA	2.00	4.00	13-00		001024
03	47C381115P1	ACTUATOR				B		0000	EA	6.00	12.00	14-00		001025
03	MXJRR-10AS	ROD END,MALE				B		0000	EA	6.00	12.00	15-00	73143	001026
03	FXJRR-10AS	ROD END,FEMALE				M		0000	EA	6.00	12.00	16-00	73143	001027
03	47C381087P1	NUT				M		0000	EA	28.00	56.00	17-00		001028
03	47C381088P1	WASHER,1.00 DIA				M		0000	EA	28.00	56.00	18-00		001029
03	**47E382610-19	PIN,SPECIAL				M		0000	EA	6.00	12.00	19-00		001030
03	N900P62C	RING,RETAINING				B		0000	EA	12.00	24.00	20-00		001031
03	N402P17C	WASHER,SHIM				B		0000	EA	6.00	12.00	21-00		001032
03	**47E382610-22	STUD,SPECIAL				M		0000	EA	6.00	12.00	22-00		001033
03	**47E382610-23	PIN,HOLLOW SPECIAL				M		0000	EA	6.00	12.00	23-00		001034
03	**47E382610-24	SPACER SLEEVE				M		0000	EA	12.00	24.00	24-00		001035
03	**47E382610-25	SPACER SLEEVE				M		0000	EA	6.00	12.00	25-00		001036
03	**47E382610-26	WASHER,SHIM				M		0000	EA	18.00	36.00	26-00		001037
03	**47E382610-27	WASHER,SPECIAL				M		0000	EA	24.00	48.00	27-00		001038
03	N271P35	NUT				B		0000	EA	24.00	48.00	28-00		001039
03	**47E382610-29	SHOULDER PIN				M		0000	EA	12.00	24.00	29-00		001040
03	**47E382610-30	SPACER SLEEVE				M		0000	EA	24.00	48.00	30-00		001041
03	**47E382610-31	PIN				M		0000	EA	6.00	12.00	31-00		001042
03	N900P75C	RING,RETAINING				B		0000	EA	12.00	24.00	32-00		001043
03	N402P18C	WASHER 3/4"DIA				B	5	0000	EA	12.00	24.00	33-00		001044
03	MODEL-RC	SHOCK ABSORBER				B		0000	EA	8.00	16.00	34-00	94389	001045
03	**47E382610-35	ACTUATOR ARM,ADJ				M		0000	EA	8.00	16.00	35-00		001046
03	N94P75024	SCREW,SHOULDER				B		0000	EA	8.00	16.00	36-00		001047
03	N264P33B	LOCKNUT				B		0000	EA	40.00	80.00	37-00		001048
03	N402P17B	WASHER				B		0000	EA	40.00	80.00	38-00		001049
03	N22P33036B	SCREW,HEX HD				B		0000	EA	32.00	64.00	39-00		001050
02	47E382582G1	BLADE TIP ATCH ASSY				M		0000	EA	2.00	2.00	9-00		001051
03	**47E382582-1	ATCH STRIP-NOSE SECT				M		0000	EA	2.00	4.00	1-00		001052
03	47E382334P1	TIP,BLADE				M		0000	EA	2.00	4.00	2-00		001053
03	D170-RF-6-6-5	INSERT,DELRIN				B		0000	EA	10.00	20.00	3-00		001054
03	N50P24020C	SCREW,HEX HD				B		0000	EA	10.00	20.00	4-00		001055
03	N400P43	WASHER,FLAT				B		0000	EA	10.00	20.00	5-00		001056
03	**47E382582-6	ATCH STRIP-UPPER FWD				M		0000	EA	2.00	4.00	6-00		001057
03	**47E382582-7	ATCH STRIP-UPPER AFT				M		0000	EA	2.00	4.00	7-00		001058
03	**47E382582-8	ATCH STRIP-LOWER FWD				M		0000	EA	2.00	4.00	8-00		001059
03	**47E382582-9	ATCH STRIP-LOWER AFT				M		0000	EA	2.00	4.00	9-00		001060
03	47E382582P10	ADHESIVE,EPOXY				B		0000	PT	AR		10-00		001061
03	47E382582P11	GLASSFIBER CLOTH				B		0000	FT	AR		11-00		001062
03	A15F7A1	SILICONE POTTING RTV				B		0000	PT	AR		12-00		001063
03	N197P2440	SCERW,WOOD,FLAT HD				B		0000	EA	AR		13-00		001064

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
02	47E382469G1	ICE DETECTOR INSTL				M		0000	EA	2.00	2.00	10-00		001065
03	47C382464G1	RING & HOUSING ASSY				M		0000	EA	2.00	4.00	1-00		001066
04	47C382463G1	RING, MOUNTING				M		0000	EA	1.00	4.00	1-00		001067
05	47C382463P1	RING, MOUNTING				M		0000	EA	1.00	4.00	1-00		001068
05	TLC-4C-0500W	INSERT, COIL THREAD				B		0000	EA	5.00	20.00	2-00	26390	001069
04	ZTR-64D	CAN, HOUSING				M		0000	EA	1.00	4.00	2-00	19178	001070
03	47D381091P1	ICE DETECTOR				M		0000	EA	2.00	4.00	2-00		001071
03	47B382467P1	RETAINER				M		0000	EA	2.00	4.00	3-00		001072
03	47B382468P1	GASKET				M		0000	EA	2.00	4.00	4-00		001073
03	**47E382469-5	EPOXY, ASBESTOS				B		0000	QT	AR		5-00		001074
03	47B382467P2	RETAINER / COVER				M		0000	EA	2.00	4.00	6-00		001075
03	N678P21010	SCREW, 100 DEG CSK				B		0000	EA	10.00	20.00	7-00		001076
03	N678P9006	SCREW, 100 DEG CSK				B		0000	EA	10.00	20.00	8-00		001077
03	47B382470P1	GASKET, COVER				M		0000	EA	'2.00	4.00	9-00		001078
02	47E382413G1	BALLAST INSTL				M		0000	EA	1.00	1.00	11-00		001079
03	47C382399P1	BLOCK,BALLAST				M		0000	EA	96.00	96.00	1-00		001080
03	47B382401P1	STUD				M		0000	EA	32.00	32.00	2-00		001081
03	47B382398P1	SPACER				M		0000	EA	AR		3-00		001082
03	N214DP44B	NUT				B		0000	EA	64.00	64.00	4-00		001083
03	**47E382413-5	WASHER				M		0000	EA	64.00	64.00	5-00		001084
03	**47E382413-6	HOUSING,BALLAST				M		0000	EA	2.00	2.00	6-00		001085
03	**47E382413-7	PLATE,RETAINER				M		0000	EA	2.00	2.00	7-00		001086
03	**47E382413-8	STEM,THREADED				M		0000	EA	2.00	2.00	8-00		001087
03	**47E382413-9	NUT				M		0000	EA	2.00	2.00	9-00		001088
03	**47E382413-10	WASHER				M		0000	EA	2.00	2.00	10-00		001089
03	**47E382413-11	SCREW,HEX HD				M		0000	EA	24.00	24.00	11-00		001090
03	**47E382413-12	PLATE,KEEPER				M		0000	EA	2.00	2.00	12-00		001091
03	**47E382413-13	SCREW,HEX HD				M		0000	EA	8.00	8.00	13-00		001092
03	**47E382413-14	INSERT				M		0000	EA	8.00	8.00	14-00		001093
03	**47E382413-15	INSERT				M		0000	EA	16.00	16.00	15-00		001094
02	47E382590P12	FIBERGLASS,CLOTH				B		0000	EA	AR		12-00		001095
02	47E382469G2	ICE DETECTOR INSTL				M		0000	EA	2.00	2.00	13-00		001096
03	47C382464G1	RING & HOUSING ASSY				M		0000	EA	2.00	4.00	1-00		001097
04	47C382463G1	RING, MOUNTING				M		0000	EA	1.00	4.00	1-00		001098
05	47C382463P1	RING, MOUNTING				M		0000	EA	1.00	4.00	1-00		001099
05	TLC-4C-0500W	INSERT, COIL THREAD				B		0000	EA	5.00	20.00	2-00	26390	001100
04	ZTR-64D	CAN, HOUSING				M		0000	EA	1.00	4.00	2-00	19178	001101

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LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
03	**47E382469-5	EPOXY, ASBESTOS				B		0000	QT	AR		5-00		001102
03	47B382467P2	RETAINER / COVER				M		0000	EA	2.00	4.00	6-00		001103
03	N678P21010	SCREW, 100 DEG CSK				B		0000	EA	10.00	20.00	7-00		001104
03	47B382470P1	GASKET, COVER				M		0000	EA	2.00	4.00	9-00		001105
02	47E382400G1	LIGHTING PROT INSTL				M		0000	EA	2.00	2.00	14-00		001106
03	**47E382400-1	GROUND STRAP, BRAIDED				M		0000	EA	6.00	12.00	1-00		001107
03	N46P20B	SCREW, STEEL CAP				B		0000	EA	6.00	12.00	2-00		001108
03	47E382400P3	LIGHTING STRIP				M		0000	FT	AR		3-00		001109
03	47E382400P4	SPLICE PLATE				M		0000	EA	16.00	32.00	4-00		001110
03	**47E382400-5	EPOXT, WEST SYSTEM				B		0000	PT	AR		5-00		001111
03	47E382400P6	SHIM				M		0000	EA	2.00	4.00	6-00		001112
03	N197P816	SCREW, WOOD				B		0000	EA	32.00	64.00	7-00		001113
03	72-08116	EPOXY, CONDUCTIVE				B		0000	PT	AR		8-00	07700	001114
03	72-00005	CAULKING, CONDUCTIVE				B		0000	PT	AR		9-00	07700	001115
03	**47E382400-10	R.T.V, TEFLON				B		0000	PT	AR		10-00		001116
03	**47E382400-11	JOINT COMPOUND, ELEC				B		0000	PT	AR		11-00	09922	001117
03	47A380009	DES. REQMTS, ROTOR BL				X		0000	EA	X		12-00		001118
02	**47E382590-15	BUMPER INSTL				M		0000	EA	1.00	1.00	15-00		001119
02	**47E382590-16	TETHER RETENN INSTL				M		0000	EA	2.00	2.00	16-00		001120
02	**47E382590-17	ELEC INSTM INSTL				M		0000	EA	1.00	1.00	17-00		001121
02	47J382330G1	BLADE HYDRAULIC INST				M		0000	EA	1.00	1.00	18-00		001122
03	47J382330P1	TUBING HYDRAULIC				M		0000	FT	720.00	720.00	1-00		001123
03	47J382330P2	TUBING HYDRAULIC				M		0000	FT	480.00	480.00	2-00		001124
03	47C381066P2	HOSE ASSY				M		0000	EA	6.00	6.00	3-00		001125
03	47C381066P1	HOSE ASSY				M		0000	EA	4.00	4.00	4-00		001126
03	47E382357G1	BRACKET, INBOARD				M		0000	EA	2.00	2.00	5-00		001127
04	47E382357P1	BRACKET				M		0000	EA	1.00	2.00	1-00		001128
04	N926P225	INSERT, COIL THD				B		0000	EA	5.00	10.00	2-00		001129
03	47D382358P1	BRKT, OUTBOARD				M		0000	EA	2.00	2.00	6-00		001130
03	47C382336G1	BRKT, CLAMP MODIFIED				M		0000	EA	38.00	38.00	7-00		001131
04	47C382336P1	BRACKET, ANGLE				M		0000	EA	2.00	76.00	1-00		001132
04	47C381072P3	CLAMP UNIT				M		0000	EA	1.00	38.00	2-00		001133
03	47C382336G2	BRKT, CLAMP MODIFIED				M		0000	EA	8.00	8.00	8-00		001134
04	47C382336P1	BRACKET, ANGLE				M		0000	EA	2.00	16.00	1-00		001135
04	47C381072P3	CLAMP UNIT				M		0000	EA	1.00	8.00	2-00		001136
03	47C381072P2	CLAMP UNIT				M		0000	EA	52.00	52.00	9-00		001137
03	47C381072P1	CLAMP UNIT				M		0000	EA	4.00	4.00	10-00		001138
03	47C382335P2	TUBE ADAPTER				M		0000	EA	6.00	6.00	11-00		001139

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
03	47C382335P1	TUBE ADAPTER				M		0000	EA	4.00	4.00	12-00		001140
03	C-MA-32	ADAPTER,MOUNTING				B		0000	EA	8.00	8.00	13-00	30780	001141
03	47B382338P1	STUD,MOUNTING				M		0000	EA	10.00	10.00	14-00		001142
03	C-SN-32	NUT,STACKING				B	5	0000	EA	332.00	332.00	15-00	30780	001143
03	C-TA-32	ADAPTER,THREADED				B	5	0000	EA	166.00	166.00	16-00	30780	001144
03	47C382337P1	ADAPTER,TUBE				M		0000	EA	12.00	12.00	17-00		001145
03	100-8-F8SS	ADAPTER,TUBE				B		0000	EA	8.00	8.00	18-00	97576	001146
03	900-14SS	UNION,BULKHEAD				B		0000	EA	6.00	6.00	19-00	97576	001147
03	900-8SS	UNION,BULKHEAD				B		0000	EA	4.00	4.00	20-00	97576	001148
03	47C382349P1	SLEEVE,SPLIT				M		0000	EA	150.00	150.00	21-00		001149
03	47C382349P2	SLEEVE,SPLIT				M		0000	EA	100.00	100.00	22-00		001150
03	C-SB-32-16	BUSHING,SPLIT				B	5	0000	EA	150.00	150.00	23-00	30780	001151
03	C-SB-32-14	BUSHING,SPLIT				B		0000	EA	6.00	6.00	24-00	30780	001152
03	C-SB-32-10	BUSHING,SPLIT				B		0000	EA	100.00	100.00	25-00	30780	001153
03	C-SB-32-8	BUSHING,SPLIT				B	5	0000	EA	4.00	4.00	26-00	30780	001154
03	47D382361G1	BASE,HOSE SUPPORT				M		0000	EA	2.00	2.00	27-00		001155
04	47D382361P1	PLATE				M		0000	EA	1.00	2.00	1-00		001156
04	47D382361P2	PAD				M		0000	EA	1.00	2.00	2-00		001157
04	N926P225	INSERT,COIL THD				B		0000	EA	4.00	8.00	3-00		001158
04	**47D382361-4	ADHESIVE				B		0000	PT	AR		4-00		001159
03	47C382360G1	SUPPORT,HOSE				M		0000	EA	2.00	2.00	28-00		001160
04	47C382360P1	PLATE				M		0000	EA	1.00	2.00	1-00		001161
04	47C382360P2	PAD				M		0000	EA	1.00	2.00	2-00		001162
04	N926P225	INSERT,COIL THD				B		0000	EA	2.00	4.00	3-00		001163
04	**47C382360-4	ADHESIVE				B		0000	PT	AR		4-00		001164
03	47C382359P1	PLATE				M	M	0000	EA	4.00	4.00	29-00		001165
03	47B382373P1	SPACER				M		0000	EA	8.00	8.00	30-00		001166
03	47B382373P2	SPACER				M		0000	EA	8.00	8.00	31-00		001167
03	47B382373P3	SPACER				M		0000	EA	8.00	8.00	32-00		001168
03	C-B-32	BOLT,.375-16 1.00 LG				B	5	0000	EA	322.00	322.00	33-00	30780	001169
03	C-N-32	NUT,.375-16				B	5	0000	EA	8.00	8.00	34-00	30780	001170
03	C-LW-32	LOCKWASHER				B	5	0000	EA	330.00	330.00	35-00	30780	001171
03	N727P29024B	BOLT,.500-13 1.50 LG				B		0000	EA	16.00	16.00	36-00		001172
03	N405P45B	WASHER, LOCK				B	5	0000	EA	16.00	16.00	37-00		001173
03	N405P43B	LOCKWASHER - MEDIUM				B	5	0000	EA	248.00	248.00	38-00		001174
03	N22P25012B	BOLT,.375-16 .75 LG				B		0000	EA	104.00	104.00	39-00		001175
03	N22P25020B	BOLT 3/8-16 X 1-1/4"*				B	5	0000	EA	28.00	28.00	40-00		001176
03	N22P25038B	BOLT,.375-16 2.38 LG				B		0000	EA	4.00	4.00	41-00		001177
03	N22P25042B	BOLT,.375-16 2.88 LG				B		0000	EA	4.00	4.00	42-00		001178
03	N22P25074B	BOLT,.375-16 4.62 LG				B		0000	EA	4.00	4.00	43-00		001179
03	**47J382330-44	SLEEVING				M		0000	EA	4.00	4.00	44-00		001180
03	**47J382330-45	SLEEVING,SHRINK				M		0000	EA	8.00	8.00	45-00		001181
03	N22P25034B	BOLT,.375-16 2.12 LG				B		0000	EA	8.00	8.00	46-00		001182
03	**47J382330-47	BRAZING ALLOY				B		0000	EA	AR		47-00		001183
03	47C382336G3	BRKT,CLAMP				M		0000	EA	6.00	6.00	48-00		001184

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	47C382336P1	BRACKET,ANGLE				M		0000	EA	2.00	12.00	1-00		001185
04	47C381072P3	CLAMP UNIT				M		0000	EA	1.00	6.00	2-00		001186
02	47D382406	GEOMETRY DWG				X		0000	EA	X		19-00		001187
02	47E382460	BLADE TOLERANCE DWG				X		0000	EA	X		20-00		001188
02	**47E382590-21	CONNECTING PLATE				M		0000	EA	2.00	2.00	21-00		001189
02	**47E382590-22	CONNECTING PLATE				M		0000	EA	2.00	2.00	22-00		001190
02	47E382590P23	ADHESIVE,EPOXY				B		0000	PT	AR		23-00		001191
02	47E382605G1	TEETER BRG/RSTR INST				M		0000	EA	1.00	1.00	24-00		001192
03	47E382602P2	YOKE BRG CAP				M		0000	EA	2.00	2.00	1-00		001193
03	47E382583G1	TEETER HUB/BRG ASSY				M		0000	EA	2.00	2.00	2-00		001194
04	47D381114P1	BRG,RADIAL-TEETER				M		0000	EA	1.00	2.00	1-00		001195
04	47E382581P1	HUB, BRG - TEETER				M		0000	EA	1.00	2.00	2-00		001196
04	47E382583P3	DOWEL PIN				M		0000	EA	3.00	6.00	3-00		001197
03	47E381093P1	BGR THRUST TEETER				M		0000	EA	2.00	2.00	3-00		001198
03	47B382396P1	SHIM,BRG				M		0000	EA	2.00	2.00	4-00		001199
03	47D381101P1	SHRINK DISC				M		0000	EA	2.00	2.00	5-00		001200
03	N060	LOCKNUT,TYPE SD				B		0000	EA	2.00	2.00	6-00	80648	001201
03	P60	LOCK PLATE				B		0000	EA	2.00	2.00	7-00	80648	001202
03	V1120E	SEAL-VEE RING				B		0000	EA	2.00	2.00	8-00		001203
03	47D382352G1	TEETER ARM ASSY				M		0000	EA	4.00	4.00	9-00		001204
04	47D382352P1	TEETER ARM				M		0000	EA	1.00	4.00	1-00		001205
04	47D382352P2	RETAINING RING				M		0000	EA	1.00	4.00	2-00		001206
04	GE160TG3AS-2RS	MONO BEARING				B		0000	EA	1.00	4.00	3-00	52676	001207
04	N22BP21014B	BOLT,LOCK				B		0000	EA	8.00	32.00	4-00		001208
04	N402P11B	WASHER, NARROW				B	5	0000	EA	8.00	32.00	5-00		001209
03	47C382353P1	TEETER SUPPORT PIN				M		0000	EA	4.00	4.00	10-00		001210
03	N22BP82080B	BOLT,LOCK				B		0000	EA	36.00	36.00	11-00		001211
03	N402P20B	WASHER				B		0000	EA	36.00	36.00	12-00		001212
03	47E382488P1	PRE-LOAD FIXTURE				M		0000	EA	2.00	2.00	13-00		001213
03	**47E382605-14	PRE-LOAD COLLAR				M		0000	EA	2.00	2.00	14-00		001214
03	**47E382605-15	LOADING STUD				M		0000	EA	6.00	6.00	15-00		001215
03	**47E382605-16	HYDR EXTENDER				M		0000	EA	2.00	2.00	16-00		001216
03	N22BP29020B	BOLT, SLFLKG				B		0000	EA	24.00	24.00	17-00		001217
03	N402P15B	WASHER				B		0000	EA	24.00	24.00	18-00		001218
03	47E382605P19	PIN				M		0000	EA	4.00	4.00	19-00		001219
02	N197P2048	SCREW,WOOD				B		0000	EA	AR		25-00		001220
02	**47E382590-26	BUTT WEDGE-REAR SPAR				M		0000	EA	2.00	2.00	26-00		001221
02	**47E382590-27	JOINT WEDGE-UPPER				M		0000	EA	2.00	2.00	27-00		001222
02	**47E382590-28	JOINT WEDGE-LOWER				M		0000	EA	2.00	2.00	28-00		001223
02	47A380009	DES. REQMTS,ROTOR BL				X		0000	EA	X		29-00		001224
02	47D382406	GEOMETRY DWG				X		0000	EA	X		30-00		001225

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	PC	TY	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM CROSS REF
02	47E382460	BLADE TOLERANCE DWG				X		0000	EA	X		31-00	001226
02	47E382440	SCHEM ROTOR HYDR SYS				X		0000	EA	X		32-00	001227
02	47A382285	PROFILE COORDINATES				X		0000	EA	X		33-00	001228
01	47E382607G1	YOKE / NACELLE INSTL				M		0000	EA	1.00	1.00	5-00	001229
02	47E382597G1	NACELLE OVERALL ASSY	1			X		0000	EA	X		1-00	001230
02	47E382601G1	YOKE ASSY				X		0000	EA	X		2-00	001231
02	47E382599G1	SLIP RING INST				M		0000	EA	1.00	1.00	3-00	001232
03	**47E382599-1	SUPPORT TUBE				M		0000	EA	1.00	1.00	1-00	001233
03	**47E382599-2	SUPPORT PADS				M		0000	EA	2.00	2.00	2-00	001234
03	47E382486P1	SIDE SUPPORT				M		0000	EA	1.00	1.00	3-00	001235
03	47D381018	ELEC INTERFACE				X		0000	EA	X		4-00	001236
03	47D381020P1	ROTOR SLIPRING UNIT				M		0000	EA	1.00	1.00	5-00	001237
03	47C381111P1	BELLOWS JOINT				M		0000	EA	1.00	1.00	6-00	001238
03	**47E382599-7	CONDUIT TIE BLOCK				M		0000	EA	3.00	3.00	7-00	001239
03	**47E382599-8	CONDUIT SPACER PAD				M		0000	EA	6.00	6.00	8-00	001240
03	47E382599P9	CONDUIT 2.00 DIA				M		0000	EA	3.00	3.00	9-00	001241
03	47E382599P10	CONDUIT 1.50 DIA				M		0000	EA	6.00	6.00	10-00	001242
03	**47E382599-11	JUNCTION BOX				M		0000	EA	1.00	1.00	11-00	001243
03	**47E382599-12	SEALING COLLAR				M		0000	EA	1.00	1.00	12-00	001244
03	A15B36	ADHESIVE,EPOXY				B		0000	OZ	AR		13-00	001245
03	B12B33	ADHESIVE,AL TAPE				B		0000	FT	AR		14-00	001246
03	N22BP29016B	BOLT,LOCK				B		0000	EA	12.00	12.00	15-00	001247
03	N402P15B	WASHER				B		0000	EA	16.00	16.00	16-00	001248
03	N22P29032B	BOLT				B		0000	EA	4.00	4.00	17-00	001249
03	N264P29B	NUT 1/2				B	5	0000	EA	4.00	4.00	18-00	001250
03	47E382599P19	ANGLES				M		0000	EA	2.00	2.00	19-00	001251
03	47D381024P1	ROTARY POSITION SR				M		0000	EA	1.00	1.00	20-00	001252
02	47E382496G1	LOW SPEED BRAKE INST				M		0000	EA	1.00	1.00	4-00	001253
03	47E382495G1	LOW SP BK SPRT ASSY				M		0000	EA	2.00	2.00	1-00	001254
04	47E382407P1	LOW SP BK SPRT BRKT				M		0000	EA	1.00	2.00	1-00	001255
04	47D382461P1	LOW SPEED BRAKE				M		0000	EA	4.00	8.00	2-00	001256
04	47D382492P4	NUT PLATE				M		0000	EA	2.00	4.00	3-00	001257
04	47D382492P2	NUT PLATE				M		0000	EA	2.00	4.00	4-00	001258
04	47D382492P1	NUT PLATE				M		0000	EA	1.00	2.00	5-00	001259
04	47D382492P3	NUT PLATE				M		0000	EA	1.00	2.00	6-00	001260
04	47D382493P3	NUT PLATE				M		0000	EA	2.00	4.00	7-00	001261
04	47D382493P1	NUT PLATE				M		0000	EA	2.00	4.00	8-00	001262
04	47D382493P2	NUT PLATE				M		0000	EA	1.00	2.00	9-00	001263
04	47B382494P1	NUT PLATE				M		0000	EA	8.00	16.00	10-00	001264
04	N46P22032B	SCREW, FLAT HD				B		0000	EA	38.00	76.00	11-00	001265
04	N402AP20B	WASHER				B		0000	EA	24.00	48.00	12-00	001266
04	47C381036P5	BOLT,FATIGUE RATED				B		0000	EA	24.00	48.00	13-00	001267
03	47C381036P3	BOLT,FATIGUE RATED				B		0000	EA	84.00	84.00	2-00	001268

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LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
03	47C381088P1	WASHER,1.00 DIA				M		0000	EA	84.00	84.00	3-00		001269
03	47C381036P10	BOLT,FATIGUE RATED				B		0000	EA	8.00	8.00	4-00		001270
03	47C381088P5	WASHER,1.25 DIA				B		0000	EA	8.00	8.00	5-00		001271
03	81341EB-30	EYE BOLT				B		0000	EA	2.00	2.00	6-00		001272
03	A15F6C18	RTV SILICONE SEALANT				M		0000	OZ	AR		7-00		001273
02	47E382498G1	RTR SPEED SNSR INSTL				M		0000	EA	1.00	1.00	5-00		001274
03	47B382480P1	BRACKET, SENSOR				M		0000	EA	2.00	2.00	1-00		001275
03	47B381108P1	SENSOR, ROTOR SPEED				M		0000	EA	2.00	2.00	2-00	81692	001276
03	N733P25016B	SCREW, TWELVE-POINT				B		0000	EA	4.00	4.00	3-00		001277
03	N405P43B	LOCKWASHER - MEDIUM				B	5	0000	EA	4.00	4.00	4-00		001278
02	47C381036P26	BOLT,FATIGUE RATED				B		0000	EA	96.00	96.00	6-00		001279
02	47C381087P9	NUT				B		0000	EA	96.00	96.00	7-00		001280
02	47C381088P9	WASHER,1.50 DIA				M		0000	EA	96.00	96.00	8-00		001281
02	47C381088P10	WASHER,1.50 DIA				B		0000	EA	96.00	96.00	9-00		001282
02	**47E382607-10	SEAL,STATOR HALVES				M		0000	EA	2.00	2.00	10-00		001283
02	**47E382607-11	SEAL PLATE				M		0000	EA	6.00	6.00	11-00		001284
02	**47E382607-12	SEAL				M		0000	EA	1.00	1.00	12-00		001285
02	**47E382607-13	LOCKBOLT				M		0000	EA	AR		13-00		001286
02	**47E382607-14	WASHER				M		0000	EA	AR		14-00		001287
02	A15F6C18	RTV SILICONE SEALANT				M		0000	OZ	AR		15-00		001288
01	47E382608G1	ROTOR BLADE INSTL				M		0000	EA	1.00	1.00	6-00		001289
02	47B382396P1	SHIM,BRG				X		0000	EA	X		1-00		001290
02	47C381036P10	BOLT,FATIGUE RATED				B		0000	EA	60.00	60.00	2-00		001291
02	47C381087P6	LOCKNUT				B		0000	EA	60.00	60.00	3-00		001292
02	47C381088P9	WASHER,1.50 DIA				M		0000	EA	60.00	60.00	4-00		001293
02	47C381088P10	WASHER,1.50 DIA				B		0000	EA	60.00	60.00	5-00		001294
02	47C381036P21	BOLT				B		0000	EA	8.00	8.00	6-00		001295
02	47C381087P10	LOCKNUT				B		0000	EA	8.00	8.00	7-00		001296
02	47C381088P9	WASHER,1.50 DIA				M		0000	EA	8.00	8.00	8-00		001297
02	47C381088P10	WASHER,1.50 DIA				B		0000	EA	8.00	8.00	9-00		001298
02	N228P82080B	BOLT,LOCK				B		0000	EA	36.00	36.00	10-00		001299
02	N402P20B	WASHER				B		0000	EA	36.00	36.00	11-00		001300
02	**47E382608-12	TEETER POSN IND				M		0000	EA	1.00	1.00	12-00		001301
02	**47E382608-13	TEETER MOTION INSTL				M		0000	EA	1.00	1.00	13-00		001302
02	**47E382608-14	FLEX HOSE				M		0000	EA	2.00	2.00	14-00		001303
02	**47E382608-15	FLEX HOSE				M		0000	EA	2.00	2.00	15-00		001304
02	**47E382608-16	FLEX HOSE				M		0000	EA	2.00	2.00	16-00		001305
01	**47E382304-7	GND SPRT EQUIP INSTL				M		0000	EA	1.00	1.00	7-00		001306
01	47E382045	GEOMETRY ENVELOPE				X		0000	EA	X		8-00		001307
01	47E387081G1	ELEC EQUIP BUILDING				M		0000	EA	1.00	1.00	9-00		001308
02	**47E387081-1	GRND ENCLOSURE BLDG				M		0000	EA	1.00	1.00	1-00		001309
02	**47E387081-2	TRANSFORMER				M		0000	EA	1.00	1.00	2-00		001310

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	ECN PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
02	**47E387081-3	P.F. CAPACITOR				M		0000	EA	1.00	1.00	3-00		001311
02	**47E387081-4	CYCLOCONVERTER				M		0000	EA	1.00	1.00	4-00		001312
02	**47E387081-5	SWITCHGEAR LINE-UP				M		0000	EA	1.00	1.00	5-00		001313
02	**47E387081-6	INTERFACE CABINET				M		0000	EA	1.00	1.00	6-00		001314
02	**47E387081-7	ELECTRONICS CABINET				M		0000	EA	1.00	1.00	7-00		001315
02	47A380068	30-KVA XFMR SPEC				M		0000	EA	1.00	1.00	8-00		001316
02	47A380014	STATION BATTERY SPEC				M		0000	EA	1.00	1.00	9-00		001317
02	47A380067	CONT SYST U.P.S.SPEC				M		0000	EA	1.00	1.00	10-00		001318
02	**47E387081-11	ENG INSTR SUBSYSTEM				M		0000	EA	1.00	1.00	11-00		001319
02	**47E387081-12	OFFICE EQPT INSTL				M		0000	EA	1.00	1.00	12-00		001320
02	**47E387081-13	HECO ELEC INTERFACE				M		0000	EA	1.00	1.00	13-00		001321
02	**47E387081-14	SITE OPERATOR TERM				M		0000	EA	1.00	1.00	14-00		001322
02	**47E387081-15	FUSE PANELS				M		0000	EA	2.00	2.00	15-00		001323
02	**47E387081-16	AIR COND & HEATER				M		0000	EA	1.00	1.00	16-00		001324
02	**47E387081-17	COM DATA SYSTEM				M		0000	EA	1.00	1.00	17-00		001325
02	47E387112G1	SYS DISPLAY PNL ASSY				M		0000	EA	1.00	1.00	18-00		001326
03	47D381060P1	VIDEO MONITOR				M		0000	EA	1.00	1.00	1-00		001327
03	47E387027G1	ASSY,WTG CONTROL PAN*				*		0000	EA	1.00	1.00	2-00		001328
04	47D387028P1	PANEL,FRONT,WTG CONT*				*		0000	EA	1.00	1.00	1-00		001329
04	47D387029P1	CONNECTOR PANEL, WTG*				*		0000	EA	1.00	1.00	2-00		001330
04	CS-A-3-17	CHASSIS, SIDE				B	5	0000	EA	1.00	1.00	3-00	6666	001331
04	BC-A-17	BOTTOM COVER				B	5	0000	EA	1.00	1.00	4-00	6666	001332
04	TC-A-17	TOP COVER				B	5	0000	EA	1.00	1.00	5-00	6666	001333
04	FCA8	HANDLE				B	5	0000	EA	2.00	2.00	6-00	08730	001334
04	CR104PBM92R6C	PUSHBUTTON,MUSHROOM *				*		0000	EA	1.00	1.00	7-00	2295	001335
04	CR104PSK47A92Z	SWITCH,4 POSITION NO*				*		0000	EA	1.00	1.00	8-00	2295	001336
04	20001	METER,120V,60HZ				B	5	0000	EA	1.00	1.00	9-00	74400	001337
04	CR103HC2001G	INDICATOR LIGHT, GRE*				*		0000	EA	1.00	1.00	10-00	2295	001338
04	CR103HC2001R	INDICATOR LIGHT, RED				*		0000	EA	1.00	1.00	11-00	2295	001339
04	GE327	LAMP				*		0000	EA	2.00	2.00	12-00	8806	001340
04	N7003P14250	RESISTOR, WIRE WOUND*				*		0000	EA	1.00	1.00	13-00		001341
04	PT07SE-18-11P	CONNECTOR ELEC 11 PIN				*		0000	EA	1.00	1.00	14-00	77820	001342
04	17236	POWER CORD				B	5	0000	EA	1.00	1.00	15-00	16428	001343
04	939	STRAIN RELIEF,SMITH				B	5	0000	EA	1.00	1.00	16-00	83330	001344
04	47A380069P31	NAMEPLATE,IDENT (J1)				*		0000	EA	1.00	1.00	17-00		001345
04	47A380069P71	NAMEPLATE,IDENT(GND)				*		0000	EA	1.00	1.00	18-00		001346
04	NP-206417	NAMEPLATE				B	5	0000	EA	1.00	1.00	19-00		001347
04	47A380070P3	NPL, AN/REV STATUS				*		0000	EA	1.00	1.00	20-00		001348
04	N153P13005	SCREW, PAN HD				*		0000	EA	2.00	2.00	21-00		001349
04	N153P15006	SCR, PH, #8-32				*		0000	EA	12.00	12.00	22-00		001350
04	N153P16006	SCR, PH, #10-32				*		0000	EA	4.00	4.00	23-00		001351
04	N153P16012	SCREW,PAN HD #10-32X*				*		0000	EA	1.00	1.00	24-00		001352
04	N678P15008	SCREW, FLAT HD				B	5	0000	EA	8.00	8.00	25-00		001353
04	N415P13	WASHER, LOCK, #6				*		0000	EA	2.00	2.00	26-00		001354
04	N415P16	WASHER, LOCK, #8				*		0000	EA	16.00	16.00	27-00		001355
04	N400P39	WASHER, FLAT, #10				*		0000	EA	2.00	2.00	28-00		001356
04	N415P19	WASHER, LOCK, #10				*		0000	EA	7.00	7.00	29-00		001357

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LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	N226P13	NUT,PLAIN HEX, #6-32				*		0000	EA	2.00	2.00	30-00		001358
04	N226P15	NUT, HEX, #8-32				B	5	0000	EA	4.00	4.00	31-00		001359
04	N226P16	NUT, HEX, #10-32				*		0000	EA	6.00	6.00	32-00		001360
04	18RA-8FLX	TERMINAL LUG,CRIMP(2*				B	5	0000	EA	3.00	3.00	33-00	56501	001361
04	18RA-10FLX	TERMINAL LUG,CRIMP(2*				B	5	0000	EA	1.00	1.00	34-00	56501	001362
04	RB4	WIRE JOINT				*		0000	EA	1.00	1.00	35-00	56501	001363
04	44A0111-16-9	WIRE, AWG #16				B	5	0000	FT	AR		36-00	06090	001364
04	RC6	WIRE JOINT				*		0000	EA	1.00	1.00	37-00	56501	001365
04	47A380071PAR	SLEEVING, SHRINK				*		0000	FT	AR		38-00		001366
04	47A381038P3	TAPE,LACING				*		0000	FT	AR		39-00		001367
04	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		40-00		001368
04	47D387030	SCHEMATIC DIAGRAM EL*				X	5	0000	EA	X		41-00		001369
04	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		42-00		001370
03	47E387091G1	ASSY,GENERATOR PANEL				M		0000	EA	1.00	1.00	3-00		001371
04	47E387105P1	PANEL, FRONT				B		0000	EA	1.00	1.00	1-00		001372
04	47E387091P2	PANEL, SIDE				B		0000	EA	1.00	1.00	2-00		001373
04	47D387106P1	PANEL, REAR				B		0000	EA	1.00	1.00	3-00		001374
04	FCA4	HANDLE				B	5	0000	EA	2.00	2.00	4-00	08730	001375
04	47D387107P1	SGL CD FR.,MODIFIED				B		0000	EA	1.00	1.00	5-00		001376
04	47D387108P1	BRACKET, CARD FRAME				B		0000	EA	1.00	1.00	6-00		001377
04	DM-3100N	DIGITAL, METER				B	5	0000	EA	6.00	6.00	7-00	50521	001378
04	58-2073082	EDGE CONNECTOR				B	5	0000	EA	6.00	6.00	8-00	50521	001379
04	47D387089G1	ASSY,MTR SIG CONDTNR				M		0000	EA	3.00	3.00	9-00		001380
05	47E387116P1	DRILL & TRIM				M		0000	EA	1.00	3.00	1-00		001381
05	AWG-22-TYPE-S	BUS WIRE/QQ-W-343				B	5	0000	FT	AR		2-00		001382
05	47A381044PAR	SLEEVING,TEFLON				*		0000	FT	AR		3-00		001383
05	IC-314-SGT	SOCKET, 14 PIN				B		0000	EA	2.00	6.00	4-00	55322	001384
05	IC-316-SGT	SOCKET, 16 PIN				B		0000	EA	4.00	12.00	5-00	55322	001385
05	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		6-00		001386
05	47D387092	SCHEMATIC				X		0000	EA	X		7-00		001387
05	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		8-00		001388
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR1 -00	01295	001389
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR2 -00	01295	001390
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR3 -00	01295	001391
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR4 -00	01295	001392
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR5 -00	01295	001393
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR6 -00	01295	001394
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR7 -00	01295	001395
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR8 -00	01295	001396
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR9 -00	01295	001397
05	CKR05BX221KR	CAPACITOR, 200 PF				B		0000	EA	1.00	3.00	C1 -00		001398
05	199D106X0010BB1	CAPACITOR, 10 MFD				B		0000	EA	1.00	3.00	C2 -00	56289	001399
05	CKR06BX103KR	CAPACITOR, .01 MFD				B		0000	EA	1.00	3.00	C3 -00		001400
05	CKR06BX104KR	CAPACITOR, .1 MFD				B		0000	EA	1.00	3.00	C4 -00		001401
05	CKR06BX104KR	CAPACITOR, .1 MFD				B		0000	EA	1.00	3.00	C5 -00		001402
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E1 -00	55322	001403

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E10 -00	55322	001404
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E11 -00	55322	001405
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E12 -00	55322	001406
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E13 -00	55322	001407
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E14 -00	55322	001408
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E15 -00	55322	001409
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E16 -00	55322	001410
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E17 -00	55322	001411
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E18 -00	55322	001412
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E19 -00	55322	001413
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E2 -00	55322	001414
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E3 -00	55322	001415
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E4 -00	55322	001416
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E5 -00	55322	001417
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E6 -00	55322	001418
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E7 -00	55322	001419
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E8 -00	55322	001420
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E9 -00	55322	001421
05	53451-1	RELAY				B	7	0000	EA	1.00	3.00	K1 -00	18342	001422
05	53451-1	RELAY				B	7	0000	EA	1.00	3.00	K2 -00	18342	001423
05	53451-1	RELAY				B	7	0000	EA	1.00	3.00	K3 -00	18342	001424
05	RCR05G102JS	RESISTOR, 1K				B	7	0000	EA	1.00	3.00	R1 -00		001425
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R10 -00		001426
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R11 -00		001427
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R12 -00		001428
05	RNC55H1101FS	RESISTOR, 1.1K				B	5	0000	EA	1.00	3.00	R13 -00		001429
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R14 -00		001430
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R15 -00		001431
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R16 -00		001432
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R17 -00		001433
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R18 -00		001434
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R19 -00		001435
05	RCR05G102JS	RESISTOR, 1K				B	7	0000	EA	1.00	3.00	R2 -00		001436
05	64Y103	POTENTIOMETER, 10K				B		0000	EA	1.00	3.00	R20 -00	02111	001437
05	64Y102	POTENTIOMETER, 1K				B		0000	EA	1.00	3.00	R21 -00	02111	001438
05	64Y103	POTENTIOMETER, 10K				B		0000	EA	1.00	3.00	R22 -00	02111	001439
05	64Y102	POTENTIOMETER, 1K				B		0000	EA	1.00	3.00	R23 -00	02111	001440
05	64Y103	POTENTIOMETER, 10K				B		0000	EA	1.00	3.00	R24 -00	02111	001441
05	64Y102	POTENTIOMETER, 1K				B		0000	EA	1.00	3.00	R25 -00	02111	001442
05	RCR05G102JS	RESISTOR, 1K				B	7	0000	EA	1.00	3.00	R3 -00		001443
05	RCR05G102JS	RESISTOR, 1K				B	7	0000	EA	1.00	3.00	R4 -00		001444
05	RCR05G471JS	RESISTOR, 470				B	7	0000	EA	1.00	3.00	R5 -00		001445
05	RNC55H2490FS	RESISTOR, 249				B		0000	EA	1.00	3.00	R6 -00		001446
05	RNC55H2490FS	RESISTOR, 249				B		0000	EA	1.00	3.00	R7 -00		001447
05	RNC55H2490FS	RESISTOR, 249				B		0000	EA	1.00	3.00	R8 -00		001448
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R9 -00		001449
05	SN7475N	4-BIT BISTABLE LCH				B	5	0000	EA	1.00	3.00	U1 -00	01295	001450
05	UHP-407	DRIVER				B	7	0000	EA	1.00	3.00	U2 -00	56289	001451
05	TL084CN	QUAD JFET OPNL AMPL				B	7	0000	EA	1.00	3.00	U3 -00	01295	001452

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	AML12CBC3AA	SWITCH,(MOM)				B		0000	EA	9.00	9.00	10-00	91929	001453
04	**47E387091-11	LENS, ENGRAVED				M		0000	EA	1.00	1.00	11-00		001454
04	**47E387091-12	LENS, ENGRAVED				B		0000	EA	1.00	1.00	12-00		001455
04	**47E387091-13	LENS, ENGRAVED				B		0000	EA	1.00	1.00	13-00		001456
04	**47E387091-14	LENS, ENGRAVED				B		0000	EA	2.00	2.00	14-00		001457
04	**47E387091-15	LENS, ENGRAVED				B		0000	EA	2.00	2.00	15-00		001458
04	**47E387091-16	LENS, ENGRAVED				B		0000	EA	2.00	2.00	16-00		001459
04	**47E387091-17	LENS, ENGRAVED				B		0000	EA	3.00	3.00	17-00		001460
04	**47E387091-18	LENS, ENGRAVED				B		0000	EA	3.00	3.00	18-00		001461
04	AML21GBA2AC	SWITCH,(MOM)				B	5	0000	EA	6.00	6.00	19-00	91929	001462
04	86	LAMP,INCANDESCENT				B	5	0000	EA	12.00	12.00	20-00	91929	001463
04	47D387113G1	SECURITY ALARM BOARD				M		0000	EA	1.00	1.00	21-00		001464
05	11-DE-6P	COMPONENT CARD				M		0000	EA	1.00	1.00	1-00	50125	001465
05	E-1	CARD EJECTOR				M		0000	EA	1.00	1.00	2-00	50125	001466
05	T-1SF2-T	WIRE WRAP PIN				B	5	0000	EA	6.00	6.00	3-00	55322	001467
05	AWG-22-TYPE-S	BUS WIRE/QQ-W-343				B	5	0000	FT	AR		4-00		001468
05	47A381044P5	SLEEVING				B		0000	FT	AR		5-00		001469
05	IC-314-WWG	SOCKET, 14 PIN				B		0000	EA	7.00	7.00	6-00	55322	001470
05	IC-316-WWG	SOCKET, 16 PIN				B		0000	EA	3.00	3.00	7-00	55322	001471
05	AP-616-G-E	ADAPTER PLUG				M		0000	EA	2.00	2.00	8-00	55322	001472
05	47D387100	SCHEMATIC				X		0000	EA	X		9-00		001473
05	**47D387113-10	WIRE LIST				X		0000	EA	X		10-00		001474
05	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		11-00		001475
05	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		12-00		001476
05	47B381099PAR	WIRE,AWG 30,SLDRLESS				B		0000	FT	AR		13-00		001477
05	1N4148	DIODE				B	7	0000	EA	1.00	1.00	CR1 -00	01295	001478
05	CK06BX103K	CAPACITOR, .01 MFD				B	5	0000	EA	1.00	1.00	C1 -00	95275	001479
05	CK06BX104K	CAPACITOR, .1 MFD				B	5	0000	EA	1.00	1.00	C2 -00	95275	001480
05	CK06BX103K	CAPACITOR, .01 MFD				B	5	0000	EA	1.00	1.00	C3 -00	95275	001481
05	CK06BX473K	CAPACITOR, .47 MFD				B	7	0000	EA	1.00	1.00	C4 -00		001482
05	CK06BX104K	CAPACITOR, .1 MFD				B	5	0000	EA	1.00	1.00	C5 -00	95275	001483
05	RZ-12	RELAY				B		0000	EA	1.00	1.00	K1 -00	05292	001484
05	RCR05G203JS	RESISTOR, 20K				B		0000	EA	1.00	1.00	R1 -00		001485
05	RCR20G681JS	RES, 680 OHMS, 1/2 W				B	5	0000	EA	1.00	1.00	R10 -00		001486
05	RCR05G202JS	RESISTOR, 2K				B	7	0000	EA	1.00	1.00	R11 -00		001487
05	**47D387113-R12	VARISTOR				B		0000	EA	1.00	1.00	R12 -00		001488
05	3009-P-503	POTENTIOMETER, 50K				B		0000	EA	1.00	1.00	R2 -00	32997	001489
05	RCR05G563JS	RESISTOR, 56K				B		0000	EA	1.00	1.00	R3 -00		001490
05	RCR05G203JS	RESISTOR, 20K				B		0000	EA	1.00	1.00	R4 -00		001491
05	3009-P-104	POTENTIOMETER, 100 K				B		0000	EA	1.00	1.00	R5 -00	32997	001492
05	RCR05G753JS	RESISTOR, 75K				B		0000	EA	1.00	1.00	R6 -00		001493
05	RCR07G680JS	RES, 68 OHMS, 1/4 W				B		0000	EA	1.00	1.00	R7 -00		001494
05	RCR05G103JS	RESISTOR, 10K				B	7	0000	EA	1.00	1.00	R8 -00		001495
05	RCR05G103JS	RESISTOR, 10K				B	7	0000	EA	1.00	1.00	R9 -00		001496
05	MC14013BCP	DUAL D FLIP-FLOP				B		0000	EA	1.00	1.00	U1 -00	04713	001497
05	MC14081BCP	QUAD 2-INPUT AND G				M		0000	EA	1.00	1.00	U10 -00	04713	001498
05	MC14541BCP	PROGRAMMABLE OSC-TMR				M		0000	EA	1.00	1.00	U11 -00	04713	001499

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
05	MC14071BCP	QUAD 2-INPUT OR GATE				M		0000	EA	1.00	1.00	U12 -00	04713	001500
05	MC14490FP	CONTACT DEBOUNCER				B	5	0000	EA	1.00	1.00	U2 -00	04713	001501
05	UNC-4401A	LATCH/DRIVER				B		0000	EA	1.00	1.00	U4 -00	80183	001502
05	MC14528BCP	DUAL MONOSTABLE MV				B		0000	EA	1.00	1.00	U5 -00	04713	001503
05	MC14011BCP	QUAD 2-INPUT NAND G				B		0000	EA	1.00	1.00	U8 -00	04713	001504
05	MC14541BCP	PROGRAMMABLE OSC-TMR				M		0000	EA	1.00	1.00	U9 -00	04713	001505
04	2T1B215	RELAY				B		0000	EA	3.00	3.00	22-00	02289	001506
04	**47E387091-23	PANEL, SIDE				B		0000	EA	1.00	1.00	23-00		001507
04	108-0902-001	BANANA JACK (RED)				B	5	0000	EA	12.00	12.00	26-00	74970	001508
04	108-0903-001	BANANA JACK (BLK)				B	5	0000	EA	12.00	12.00	27-00	74970	001509
04	PT07A-14-5P	RECEPTACLE, JAM NUT				B		0000	EA	1.00	1.00	29-00	77820	001510
04	DBM-25P	CONNECTOR				B	5	0000	EA	2.00	2.00	30-00	71785	001511
04	3341-1L	JACK SOCKET KIT				*		0000	EA	2.00	2.00	31-00	52760	001512
04	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		32-00		001513
04	47E387103	SCHEMATIC				X		0000	EA	X		33-00		001514
04	**47E387091-34	WIRE LIST				X		0000	EA	X		34-00		001515
04	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		35-00		001516
04	AWG-22-TYPE-S	BUS WIRE/QQ-W-343				B	5	0000	FT	AR		36-00		001517
04	44A0111-24-9	WIRE, AWG 24				B	5	0000	FT	AR		37-00	06090	001518
04	47A381045P5	CABLE CLAMP				B		0000	EA	3.00	3.00	38-00		001519
04	47A380071PAR	SLEEVING, SHRINK				*		0000	FT	AR		39-00		001520
04	47A381044PAR	SLEEVING,TEFLON				*		0000	FT	AR		40-00		001521
04	47A381037P1	LACING TAPE				*		0000	FT	AR		41-00		001522
04	NP-206417	NAMEPLATE				B	5	0000	EA	1.00	1.00	42-00		001523
04	47A380069P31	NAMEPLATE,IDENT (J1)				*		0000	EA	1.00	1.00	43-00		001524
04	47A380069P32	NAMEPLATE,IDENT (J2)				*		0000	EA	1.00	1.00	44-00		001525
04	47A380069P33	NAMEPLATE,IDENT (J3)				B		0000	EA	1.00	1.00	45-00		001526
04	47A380070P3	NPL, AN/REV STATUS				*		0000	EA	1.00	1.00	46-00		001527
04	AWG-20-TYPE-S	WIRE, BUS/QQ-W-343				B		0000	FT	AR		47-00		001528
04	AWG-16-TYPE-S	WIRE, BUS/QQ-W-343				B	5	0000	FT	AR		48-00		001529
04	570-3650-02-01-00	TERMINAL, INSULATED				B	5	0000	EA	8.00	8.00	49-00	71279	001530
04	N153P16007	SCREW, PAN HD				*		0000	EA	4.00	4.00	53-00		001531
04	N153P13005	SCREW, PAN HD				*		0000	EA	15.00	15.00	54-00		001532
04	N415P19	WASHER, LOCK, #10				*		0000	EA	4.00	4.00	55-00		001533
04	N226P16	NUT, HEX, #10-32				*		0000	EA	4.00	4.00	56-00		001534
04	N678P15008	SCREW, FLAT HD				B	5	0000	EA	2.00	2.00	57-00		001535
04	N153P15008	SCREW, PAN HD				B		0000	EA	4.00	4.00	58-00		001536
04	N415P16	WASHER, LOCK, #8				*		0000	EA	6.00	6.00	59-00		001537
04	N226P15	NUT, HEX, #8-32				B	5	0000	EA	2.00	2.00	60-00		001538
04	N153P13004	SCR, PH, #6-32				*		0000	EA	8.00	8.00	61-00		001539
04	N153P13006	SCREW, PAN HD				B		0000	EA	6.00	6.00	62-00		001540
04	N400P37	WASHER, FL. #6				*		0000	EA	8.00	8.00	63-00		001541
04	N415P13	WASHER, LOCK, #6				*		0000	EA	29.00	29.00	64-00		001542
04	N226P13	NUT,PLAIN HEX, #6-32				*		0000	EA	21.00	21.00	65-00		001543
03	47E387085G1	ASSY, UTILITY PANEL				M		0000	EA	1.00	1.00	4-00		001544
04	47E387098P1	PANEL, FRONT				M		0000	EA	1.00	1.00	1-00		001545

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LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	47E387085P2	PANEL, SIDE				M		0000	EA	2.00	2.00	2-00		001546
04	47C387099P1	PANEL, REAR				M		0000	EA	1.00	1.00	3-00		001547
04	FCAB	HANDLE				B	5	0000	EA	2.00	2.00	4-00	08730	001548
04	108-0902-001	BANANA JACK (RED)				B	5	0000	EA	8.00	8.00	5-00	74970	001549
04	108-0903-001	BANANA JACK (BLK)				B	5	0000	EA	8.00	8.00	6-00	74970	001550
04	DM-3100N	DIGITAL, METER				B	5	0000	EA	3.00	3.00	7-00	50521	001551
04	58-2073082	EDGE CONNECTOR				B	5	0000	EA	3.00	3.00	8-00	50521	001552
04	47D387089G1	ASSY,MTR SIG CONDTNR				M		0000	EA	3.00	3.00	9-00		001553
05	47E387116P1	DRILL & TRIM				M		0000	EA	1.00	3.00	1-00		001554
05	AWG-22-TYPE-S	BUS WIRE/QQ-W-343				B	5	0000	FT	AR		2-00		001555
05	47A381044PAR	SLEEVING,TEFLON				*		0000	FT	AR		3-00		001556
05	IC-314-SGT	SOCKET, 14 PIN				B		0000	EA	2.00	6.00	4-00	55322	001557
05	IC-316-SGT	SOCKET, 16 PIN				B		0000	EA	4.00	12.00	5-00	55322	001558
05	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		6-00		001559
05	47D387092	SCHEMATIC				X		0000	EA	X		7-00		001560
05	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		8-00		001561
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR1 -00	01295	001562
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR2 -00	01295	001563
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR3 -00	01295	001564
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR4 -00	01295	001565
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR5 -00	01295	001566
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR6 -00	01295	001567
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR7 -00	01295	001568
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR8 -00	01295	001569
05	1N4148	DIODE				B	7	0000	EA	1.00	3.00	CR9 -00	01295	001570
05	CKR05BX221KR	CAPACITOR, 200 PF				B		0000	EA	1.00	3.00	C1 -00		001571
05	199D106X0010BB1	CAPACITOR, 10 MFD				B		0000	EA	1.00	3.00	C2 -00	56289	001572
05	CKR06BX103KR	CAPACITOR, .01 MFD				B		0000	EA	1.00	3.00	C3 -00		001573
05	CKR06BX104KR	CAPACITOR, .1 MFD				B		0000	EA	1.00	3.00	C4 -00		001574
05	CKR06BX104KR	CAPACITOR, .1 MFD				B		0000	EA	1.00	3.00	C5 -00		001575
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E1 -00	55322	001576
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E10 -00	55322	001577
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E11 -00	55322	001578
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E12 -00	55322	001579
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E13 -00	55322	001580
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E14 -00	55322	001581
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E15 -00	55322	001582
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E16 -00	55322	001583
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E17 -00	55322	001584
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E18 -00	55322	001585
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E19 -00	55322	001586
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E2 -00	55322	001587
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E3 -00	55322	001588
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E4 -00	55322	001589
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E5 -00	55322	001590
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E6 -00	55322	001591
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E7 -00	55322	001592
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E8 -00	55322	001593

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	3.00	E9 -00	55322	001594
05	53451-1	RELAY				B	7	0000	EA	1.00	3.00	K1 -00	18342	001595
05	53451-1	RELAY				B	7	0000	EA	1.00	3.00	K2 -00	18342	001596
05	53451-1	RELAY				B	7	0000	EA	1.00	3.00	K3 -00	18342	001597
05	RCR05G102JS	RESISTOR, 1K				B	7	0000	EA	1.00	3.00	R1 -00		001598
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R10 -00		001599
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R11 -00		001600
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R12 -00		001601
05	RNC55H1101FS	RESISTOR, 1.1K				B	5	0000	EA	1.00	3.00	R13 -00		001602
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R14 -00		001603
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R15 -00		001604
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R16 -00		001605
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R17 -00		001606
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R18 -00		001607
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R19 -00		001608
05	RCR05G102JS	RESISTOR, 1K				B	7	0000	EA	1.00	3.00	R2 -00		001609
05	64Y103	POTENTIOMETER, 10K				B		0000	EA	1.00	3.00	R20 -00	02111	001610
05	64Y102	POTENTIOMETER, 1K				B		0000	EA	1.00	3.00	R21 -00	02111	001611
05	64Y103	POTENTIOMETER, 10K				B		0000	EA	1.00	3.00	R22 -00	02111	001612
05	64Y102	POTENTIOMETER, 1K				B		0000	EA	1.00	3.00	R23 -00	02111	001613
05	64Y103	POTENTIOMETER, 10K				B		0000	EA	1.00	3.00	R24 -00	02111	001614
05	64Y102	POTENTIOMETER, 1K				B		0000	EA	1.00	3.00	R25 -00	02111	001615
05	RCR05G102JS	RESISTOR, 1K				B	7	0000	EA	1.00	3.00	R3 -00		001616
05	RCR05G102JS	RESISTOR, 1K				B	7	0000	EA	1.00	3.00	R4 -00		001617
05	RCR05G471JS	RESISTOR, 470				B	7	0000	EA	1.00	3.00	R5 -00		001618
05	RNC55H2490FS	RESISTOR, 249				B		0000	EA	1.00	3.00	R6 -00		001619
05	RNC55H2490FS	RESISTOR, 249				B		0000	EA	1.00	3.00	R7 -00		001620
05	RNC55H2490FS	RESISTOR, 249				B		0000	EA	1.00	3.00	R8 -00		001621
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	3.00	R9 -00		001622
05	SN7475N	4-BIT BISTABLE LCH				B	5	0000	EA	1.00	3.00	U1 -00	01295	001623
05	UHP-407	DRIVER				B	7	0000	EA	1.00	3.00	U2 -00	56289	001624
05	TL084CN	QUAD JFET OPNL AMPL				B	7	0000	EA	1.00	3.00	U3 -00	01295	001625
04	AML12CBC3AA	SWITCH,(MOM)				B		0000	EA	8.00	8.00	10-00	91929	001626
04	**47E387085-11	LENS, ENGRAVED				M		0000	EA	1.00	1.00	11-00		001627
04	**47E387085-12	LENS, ENGRAVED				M		0000	EA	1.00	1.00	12-00		001628
04	**47E387085-13	LENS, ENGRAVED				M		0000	EA	1.00	1.00	13-00		001629
04	**47E387085-14	LENS, ENGRAVED				M		0000	EA	1.00	1.00	14-00		001630
04	**47E387085-15	LENS, ENGRAVED				M		0000	EA	1.00	1.00	15-00		001631
04	**47E387085-16	LENS, ENGRAVED				M		0000	EA	1.00	1.00	16-00		001632
04	**47E387085-17	LENS, ENGRAVED				M		0000	EA	1.00	1.00	17-00		001633
04	**47E387085-18	LENS, ENGRAVED				M		0000	EA	1.00	1.00	18-00		001634
04	DB-25P	CONNECTOR, 25 PIN				B	5	0000	EA	1.00	1.00	19-00	71785	001635
04	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		20-00		001636
04	47E387097	SCHEMATIC				X		0000	EA	X		21-00		001637
04	**47E387085-22	WIRE LIST				X		0000	EA	X		22-00		001638
04	AWG-22-TYPE-S	BUS WIRE/QQ-W-343				B	5	0000	FT	AR		23-00		001639
04	44A0111-24-9	WIRE, AWG 24				B	5	0000	FT	AR		24-00	06090	001640
04	47A381045P5	CABLE CLAMP				B		0000	EA	3.00	3.00	25-00		001641

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LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	ECN PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	47A380071PAR	SLEEVING, SHRINK				*		0000	FT	AR		26-00		001642
04	47A381044PAR	SLEEVING,TEFLON				*		0000	FT	AR		27-00		001643
04	47A381037P1	LACING TAPE				*		0000	FT	AR		28-00		001644
04	NP-206417	NAMEPLATE				B	5	0000	EA	1.00	1.00	29-00		001645
04	47A380069P31	NAMEPLATE,IDENT (J1)				*		0000	EA	1.00	1.00	30-00		001646
04	47A380069P32	NAMEPLATE,IDENT (J2)				*		0000	EA	1.00	1.00	31-00		001647
04	47A380070P3	NPL, AN/REV STATUS				*		0000	EA	1.00	1.00	32-00		001648
04	AWG-20-TYPE-S	WIRE, BUS/QQ-W-343				B		0000	FT	AR		33-00		001649
04	PT07A-14-5P	RECEPTACLE, JAM NUT				B		0000	EA	1.00	1.00	34-00	77820	001650
04	570-3650-02-01-00	TERMINAL, INSULATED				B	5	0000	EA	8.00	8.00	35-00	71279	001651
04	3341-1L	JACK SOCKET KIT				*		0000	EA	1.00	1.00	36-00	52760	001652
04	AWG-16-TYPE-S	WIRE, BUS/QQ-W-343				B	5	0000	FT	AR		37-00		001653
04	N153P13005	SCREW, PAN HD				*		0000	EA	3.00	3.00	38-00		001654
04	N415P19	WASHER, LOCK, #10				*		0000	EA	4.00	4.00	39-00		001655
04	N226P16	NUT, HEX, #10-32				*		0000	EA	4.00	4.00	40-00		001656
04	N153P16007	SCREW, PAN HD				*		0000	EA	4.00	4.00	41-00		001657
04	N153P15008	SCREW, PAN HD				B		0000	EA	4.00	4.00	42-00		001658
04	N415P16	WASHER, LOCK, #8				*		0000	EA	6.00	6.00	43-00		001659
04	N678P15008	SCREW, FLAT HD				B	5	0000	EA	2.00	2.00	44-00		001660
04	N226P15	NUT, HEX, #8-32				B	5	0000	EA	2.00	2.00	45-00		001661
04	N415P13	WASHER, LOCK, #6				*		0000	EA	11.00	11.00	46-00		001662
04	N153P13004	SCR, PH, #6-32				*		0000	EA	8.00	8.00	47-00		001663
04	N400P37	WASHER, FL, #6				*		0000	EA	8.00	8.00	48-00		001664
04	N226P13	NUT,PLAIN HEX, #6-32				*		0000	EA	3.00	3.00	49-00		001665
03	47E387084G1	ASSY, STATUS PANEL				M		0000	EA	1.00	1.00	5-00		001666
04	47E387104P1	PANEL, FRONT				B		0000	EA	1.00	1.00	1-00		001667
04	47E387084P2	PANEL, SIDE				B		0000	EA	2.00	2.00	2-00		001668
04	47D387106P1	PANEL, REAR				B		0000	EA	1.00	1.00	3-00		001669
04	FCA4	HANDLE				B	5	0000	EA	2.00	2.00	4-00	08730	001670
04	47D387107P1	SGL CD FR.,MODIFIED				B		0000	EA	1.00	1.00	5-00		001671
04	47D387108P1	BRACKET, CARD FRAME				B		0000	EA	1.00	1.00	6-00		001672
04	DM-3100N	DIGITAL, METER				B	5	0000	EA	5.00	5.00	7-00	50521	001673
04	58-2073082	EDGE CONNECTOR				B	5	0000	EA	5.00	5.00	8-00	50521	001674
04	47D387089G1	ASSY,MTR SIG CONDTNR				M		0000	EA	5.00	5.00	9-00		001675
05	47E387116P1	DRILL & TRIM				M		0000	EA	1.00	5.00	1-00		001676
05	AWG-22-TYPE-S	BUS WIRE/QQ-W-343				B	5	0000	FT	AR		2-00		001677
05	47A381044PAR	SLEEVING,TEFLON				*		0000	FT	AR		3-00		001678
05	IC-314-SGT	SOCKET, 14 PIN				B		0000	EA	2.00	10.00	4-00	55322	001679
05	IC-316-SGT	SOCKET, 16 PIN				B		0000	EA	4.00	20.00	5-00	55322	001680
05	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		6-00		001681
05	47D387092	SCHEMATIC				X		0000	EA	X		7-00		001682
05	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		8-00		001683
05	1N4148	DIODE				B	7	0000	EA	1.00	5.00	CR1 -00	01295	001684
05	1N4148	DIODE				B	7	0000	EA	1.00	5.00	CR2 -00	01295	001685
05	1N4148	DIODE				B	7	0000	EA	1.00	5.00	CR3 -00	01295	001686
05	1N4148	DIODE				B	7	0000	EA	1.00	5.00	CR4 -00	01295	001687

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
05	1N4148	DIODE				B	7	0000	EA	1.00	5.00	CR5 -00	01295	001688
05	1N4148	DIODE				B	7	0000	EA	1.00	5.00	CR6 -00	01295	001689
05	1N4148	DIODE				B	7	0000	EA	1.00	5.00	CR7 -00	01295	001690
05	1N4148	DIODE				B	7	0000	EA	1.00	5.00	CR8 -00	01295	001691
05	1N4148	DIODE				B	7	0000	EA	1.00	5.00	CR9 -00	01295	001692
05	CKR05BX221KR	CAPACITOR, 200 PF				B		0000	EA	1.00	5.00	C1 -00		001693
05	199D106X0010BB1	CAPACITOR, 10 MFD				B		0000	EA	1.00	5.00	C2 -00	56289	001694
05	CKR06BX103KR	CAPACITOR, .01 MFD				B		0000	EA	1.00	5.00	C3 -00		001695
05	CKR06BX104KR	CAPACITOR, .1 MFD				B		0000	EA	1.00	5.00	C4 -00		001696
05	CKR06BX104KR	CAPACITOR, .1 MFD				B		0000	EA	1.00	5.00	C5 -00		001697
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E1 -00	55322	001698
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E10 -00	55322	001699
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E11 -00	55322	001700
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E12 -00	55322	001701
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E13 -00	55322	001702
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E14 -00	55322	001703
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E15 -00	55322	001704
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E16 -00	55322	001705
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E17 -00	55322	001706
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E18 -00	55322	001707
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E19 -00	55322	001708
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E2 -00	55322	001709
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E3 -00	55322	001710
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E4 -00	55322	001711
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E5 -00	55322	001712
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E6 -00	55322	001713
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E7 -00	55322	001714
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E8 -00	55322	001715
05	T-1R2-T	TERMINAL				B		0000	EA	1.00	5.00	E9 -00	55322	001716
05	53451-1	RELAY				B	7	0000	EA	1.00	5.00	K1 -00	18342	001717
05	53451-1	RELAY				B	7	0000	EA	1.00	5.00	K2 -00	18342	001718
05	53451-1	RELAY				B	7	0000	EA	1.00	5.00	K3 -00	18342	001719
05	RCR05G102JS	RESISTOR, 1K				B	7	0000	EA	1.00	5.00	R1 -00		001720
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	5.00	R10 -00		001721
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	5.00	R11 -00		001722
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	5.00	R12 -00		001723
05	RNC55H1101FS	RESISTOR, 1.1K				B	5	0000	EA	1.00	5.00	R13 -00		001724
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	5.00	R14 -00		001725
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	5.00	R15 -00		001726
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	5.00	R16 -00		001727
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	5.00	R17 -00		001728
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	5.00	R18 -00		001729
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	5.00	R19 -00		001730
05	RCR05G102JS	RESISTOR, 1K				B	7	0000	EA	1.00	5.00	R2 -00		001731
05	64Y103	POTENTIOMETER, 10K				B		0000	EA	1.00	5.00	R20 -00	02111	001732
05	64Y102	POTENTIOMETER, 1K				B		0000	EA	1.00	5.00	R21 -00	02111	001733
05	64Y103	POTENTIOMETER, 10K				B		0000	EA	1.00	5.00	R22 -00	02111	001734
05	64Y102	POTENTIOMETER, 1K				B		0000	EA	1.00	5.00	R23 -00	02111	001735
05	64Y103	POTENTIOMETER, 10K				B		0000	EA	1.00	5.00	R24 -00	02111	001736

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LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
05	64Y102	POTENTIOMETER, 1K				B		0000	EA	1.00	5.00	R25 -00	02111	001737
05	RCR05G102JS	RESISTOR, 1K				B	7	0000	EA	1.00	5.00	R3 -00		001738
05	RCR05G102JS	RESISTOR, 1K				B	7	0000	EA	1.00	5.00	R4 -00		001739
05	RCR05G471JS	RESISTOR, 470				B	7	0000	EA	1.00	5.00	R5 -00		001740
05	RNC55H2490FS	RESISTOR, 249				B		0000	EA	1.00	5.00	R6 -00		001741
05	RNC55H2490FS	RESISTOR, 249				B		0000	EA	1.00	5.00	R7 -00		001742
05	RNC55H2490FS	RESISTOR, 249				B		0000	EA	1.00	5.00	R8 -00		001743
05	RNC55H1002FS	RESISTOR				B	5	0000	EA	1.00	5.00	R9 -00		001744
05	SN7475N	4-BIT BISTABLE LCH				B	5	0000	EA	1.00	5.00	U1 -00	01295	001745
05	UHP-407	DRIVER				B	7	0000	EA	1.00	5.00	U2 -00	56289	001746
05	TL084CN	QUAD JFET OPNL AMPL				B	7	0000	EA	1.00	5.00	U3 -00	01295	001747
04	AML12CBC3AA	SWITCH,(MOM)				B		0000	EA	15.00	15.00	10-00	91929	001748
04	**47E387084-11	LENS, ENGRAVED				M		0000	EA	2.00	2.00	11-00		001749
04	**47E387084-12	LENS, ENGRAVED				B		0000	EA	2.00	2.00	12-00		001750
04	**47E387084-13	LENS, ENGRAVED				B		0000	EA	2.00	2.00	13-00		001751
04	**47E387084-14	LENS, ENGRAVED				B		0000	EA	1.00	1.00	14-00		001752
04	**47E387084-15	LENS, ENGRAVED				B		0000	EA	1.00	1.00	15-00		001753
04	**47E387084-16	LENS, ENGRAVED				B		0000	EA	1.00	1.00	16-00		001754
04	**47E387084-17	LENS, ENGRAVED				B		0000	EA	1.00	1.00	17-00		001755
04	AML21GBA2AC	SWITCH,(MOM)				B	5	0000	EA	1.00	1.00	18-00	91929	001756
04	AML27ABK2AC02AA	SWITCH, KEY				B		0000	EA	1.00	1.00	19-00	91929	001757
04	86	LAMP,INCANDESCENT				B	5	0000	EA	2.00	2.00	20-00	91929	001758
04	**47E387084-21	LENS, ENGRAVED				B		0000	EA	1.00	1.00	21-00		001759
04	**47E387084-22	LENS, ENGRAVED				B		0000	EA	1.00	1.00	22-00		001760
04	SNP-428	ALARM				B	5	0000	EA	1.00	1.00	23-00	90201	001761
04	PW1	WASHER, COMPRESSION				B	5	0000	EA	1.00	1.00	24-00	90201	001762
04	47D387113G1	SECURITY ALARM BOARD				M		0000	EA	1.00	1.00	25-00		001763
05	11-DE-6P	COMPONENT CARD				M		0000	EA	1.00	1.00	1-00	50125	001764
05	E-1	CARD EJECTOR				M		0000	EA	1.00	1.00	2-00	50125	001765
05	T-1SF2-T	WIRE WRAP PIN				B	5	0000	EA	6.00	6.00	3-00	55322	001766
05	AWG-22-TYPE-S	BUS WIRE/QQ-W-343				B	5	0000	FT	AR		4-00		001767
05	47A381044P5	SLEEVING				B		0000	FT	AR		5-00		001768
05	IC-314-WWG	SOCKET, 14 PIN				B		0000	EA	7.00	7.00	6-00	55322	001769
05	IC-316-WWG	SOCKET, 16 PIN				B		0000	EA	3.00	3.00	7-00	55322	001770
05	AP-616-G-E	ADAPTER PLUG				M		0000	EA	2.00	2.00	8-00	55322	001771
05	47D387100	SCHEMATIC				X		0000	EA	X		9-00		001772
05	**47D387113-10	WIRE LIST				X		0000	EA	X		10-00		001773
05	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		11-00		001774
05	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		12-00		001775
05	47B381099PAR	WIRE,AWG 30,SLDRLESS				B		0000	FT	AR		13-00		001776
05	1N4148	DIODE				B	7	0000	EA	1.00	1.00	CR1 -00	01295	001777
05	CK06BX103K	CAPACITOR, .01 MFD				B	5	0000	EA	1.00	1.00	C1 -00	95275	001778
05	CK06BX104K	CAPACITOR, .1 MFD				B	5	0000	EA	1.00	1.00	C2 -00	95275	001779
05	CK06BX103K	CAPACITOR, .01 MFD				B	5	0000	EA	1.00	1.00	C3 -00	95275	001780
05	CK06BX473K	CAPACITOR, .47 MFD				B	7	0000	EA	1.00	1.00	C4 -00		001781
05	CK06BX104K	CAPACITOR, .1 MFD				B	5	0000	EA	1.00	1.00	C5 -00	95275	001782
05	RZ-12	RELAY				B		0000	EA	1.00	1.00	K1 -00	05292	001783

LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	PC	TY	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/REF DESG	FSCM	CROSS REF
05	RCR05G203JS	RESISTOR, 20K				B		0000	EA	1.00	1.00	R1 -00		001784
05	RCR20G681JS	RES, 680 OHMS, 1/2 W				B	5	0000	EA	1.00	1.00	R10 -00		001785
05	RCR05G202JS	RESISTOR, 2K				B	7	0000	EA	1.00	1.00	R11 -00		001786
05	**47D387113-R12	VARISTOR				B		0000	EA	1.00	1.00	R12 -00		001787
05	3009-P-503	POTENTIOMETER, 50K				B		0000	EA	1.00	1.00	R2 -00	32997	001788
05	RCR05G563JS	RESISTOR, 56K				B		0000	EA	1.00	1.00	R3 -00		001789
05	RCR05G203JS	RESISTOR, 20K				B		0000	EA	1.00	1.00	R4 -00		001790
05	3009-P-104	POTENTIOMETER, 100 K				B		0000	EA	1.00	1.00	R5 -00	32997	001791
05	RCR05G753JS	RESISTOR, 75K				B		0000	EA	1.00	1.00	R6 -00		001792
05	RCR07G680JS	RES, 68 OHMS, 1/4 W				B		0000	EA	1.00	1.00	R7 -00		001793
05	RCR05G103JS	RESISTOR, 10K				B	7	0000	EA	1.00	1.00	R8 -00		001794
05	RCR05G103JS	RESISTOR, 10K				B	7	0000	EA	1.00	1.00	R9 -00		001795
05	MC14013BCP	DUAL D FLIP-FLOP				B		0000	EA	1.00	1.00	U1 -00	04713	001796
05	MC14081BCP	QUAD 2-INPUT AND G				M		0000	EA	1.00	1.00	U10 -00	04713	001797
05	MC14541BCP	PROGRAMMABLE OSC-TMR				M		0000	EA	1.00	1.00	U11 -00	04713	001798
05	MC14071BCP	QUAD 2-INPUT OR GATE				M		0000	EA	1.00	1.00	U12 -00	04713	001799
05	MC14490FP	CONTACT DEBOUNCER				B	5	0000	EA	1.00	1.00	U2 -00	04713	001800
05	UNC-4401A	LATCH/DRIVER				B		0000	EA	1.00	1.00	U4 -00	80183	001801
05	MC14528BCP	DUAL MONOSTABLE MV				B		0000	EA	1.00	1.00	U5 -00	04713	001802
05	MC14011BCP	QUAD 2-INPUT NAND G				B		0000	EA	1.00	1.00	U8 -00	04713	001803
05	MC14541BCP	PROGRAMMABLE OSC-TMR				M		0000	EA	1.00	1.00	U9 -00	04713	001804
04	108-0902-001	BANANA JACK (RED)				B	5	0000	EA	15.00	15.00	26-00	74970	001805
04	108-0903-001	BANANA JACK (BLK)				B	5	0000	EA	15.00	15.00	27-00	74970	001806
04	**47E387084-28	LENS, ENGRAVED				B		0000	EA	1.00	1.00	28-00		001807
04	PT07A-14-5P	RECEPTACLE, JAM NUT				B		0000	EA	1.00	1.00	29-00	77820	001808
04	DBM-25P	CONNECTOR				B	5	0000	EA	2.00	2.00	30-00	71785	001809
04	3341-1L	JACK SOCKET KIT				*		0000	EA	2.00	2.00	31-00	52760	001810
04	47A380052	ELECTRICAL FAB. STD				X	5	0000	EA	X		32-00		001811
04	47E387101	SCHEMATIC				X		0000	EA	X		33-00		001812
04	**47E387084-34	WIRE LIST				X		0000	EA	X		34-00		001813
04	SN60WRMAP2	SOLDER / QQ-S-571				B	5	0000	LB	AR		35-00		001814
04	AWG-22-TYPE-S	BUS WIRE/QQ-W-343				B	5	0000	FT	AR		36-00		001815
04	44A0111-24-9	WIRE, AWG 24				B	3	0000	FT	AR		37-00	06090	001816
04	47A381045P5	CABLE CLAMP				B		0000	EA	3.00	3.00	38-00		001817
04	47A380071PAR	SLEEVING, SHRINK				*		0000	FT	AR		39-00		001818
04	47A381044PAR	SLEEVING,TEFLON				*		0000	FT	AR		40-00		001819
04	47A381037P1	LACING TAPE				*		0000	FT	AR		41-00		001820
04	NP-206417	NAMEPLATE				B	5	0000	EA	1.00	1.00	42-00		001821
04	47A380069P31	NAMEPLATE,IDENT (J1)				*		0000	EA	1.00	1.00	43-00		001822
04	47A380069P32	NAMEPLATE,IDENT (J2)				*		0000	EA	1.00	1.00	44-00		001823
04	47A380069P33	NAMEPLATE,IDENT (J3)				B		0000	EA	1.00	1.00	45-00		001824
04	47A380070P3	NPL, AN/REV STATUS				*		0000	EA	1.00	1.00	46-00		001825
04	AWG-20-TYPE-S	WIRE, BUS/QQ-W-343				B		0000	FT	AR		47-00		001826
04	AWG-16-TYPE-S	WIRE, BUS/QQ-W-343				B	5	0000	FT	AR		48-00		001827
04	570-3650-02-01-00	TERMINAL, INSULATED				B	5	0000	EA	8.00	8.00	49-00	71279	001828
04	**47E387084-50	LENS, ENGRAVED				B		0000	EA	1.00	1.00	50-00		001829
04	**47E387084-51	LENS, ENGRAVED				B		0000	EA	1.00	1.00	51-00		001830
04	**47E387084-52	LENS, ENGRAVED				B		0000	EA	2.00	2.00	52-00		001831

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LVL	IDENTIFICATION NO.	NOMENCLATURE	ECN DWG INC	ECN DWG OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	U/M	PL-QTY	EXT/TOT QTY	ITEM/ REF DESG	FSCM	CROSS REF
04	N153P16007	SCREW, PAN HD				*		0000	EA	4.00	4.00	53-00		001832
04	N153P13005	SCREW, PAN HD				*		0000	EA	3.00	3.00	54-00		001833
04	N415P19	WASHER, LOCK, #10				*		0000	EA	4.00	4.00	55-00		001834
04	N226P16	NUT, HEX, #10-32				*		0000	EA	4.00	4.00	56-00		001835
04	N678P15008	SCREW, FLAT HD				B	5	0000	EA	2.00	2.00	57-00		001836
04	N153P15008	SCREW, PAN HD				B		0000	EA	4.00	4.00	58-00		001837
04	N415P16	WASHER, LOCK, #8				*		0000	EA	4.00	4.00	59-00		001838
04	N226P15	NUT, HEX, #8-32				B	5	0000	EA	2.00	2.00	60-00		001839
04	N153P13004	SCR, PH, #6-32				*		0000	EA	8.00	8.00	61-00		001840
04	N153P13006	SCREW, PAN HD				B		0000	EA	6.00	6.00	62-00		001841
04	N400P37	WASHER, FL. #6				*		0000	EA	8.00	8.00	63-00		001842
04	N415P13	WASHER, LOCK, #6				*		0000	EA	17.00	17.00	64-00		001843
04	N226P13	NUT,PLAIN HEX, #6-32				*		0000	EA	9.00	9.00	65-00		001844
04	**47E387084-66	LENS, ENGRAVED				B		0000	EA	1.00	1.00	66-00		001845
04	AML52-N10W	LENS				B		0000	EA	1.00	1.00	67-00	91929	001846
04	47A380102	FINISH				X		0000	PT	X		68-00		001847
03	**47E387112-6	COMM PANEL				M		0000	EA	1.00	1.00	6-00		001848
03	47A380030	SPEC,SYST DISP PNL				X		0000	EA	X		7-00		001849
03	**47E387112-8	BLOWER,130 CFM				B		0000	EA	1.00	1.00	8-00		001850
03	**47E387112-9	BLOWER				B		0000	EA	1.00	1.00	9-00		001851
03	**47E387112-10	ENCLOSURE,FRAME				M		0000	EA	1.00	1.00	10-00		001852
03	**47E387112-11	AIR EXHAUST UNIT L.H				B		0000	EA	1.00	1.00	11-00		001853
03	**47E387112-12	AIR EXHAUST UNIT R.H				B		0000	EA	1.00	1.00	12-00		001854
03	**47E387112-13	SCHEMATIC				X		0000	EA	X		13-00		001855
03	**47E387112-14	CABLE ASSY				X		0000	EA	X		14-00		001856
03	**47E387112-15	WIRE LIST				X		0000	EA	X		15-00		001857
02	**47E387081-19	C.L.S. OPR TERMINAL				M		0000	EA	1.00	1.00	19-00		001858
02	47E387018	POWER DISTBR SCHEM				X		0000	EA	X		20-00		001859
02	**47E387081-21	EYE WASH STATION				M		0000	EA	1.00	1.00	21-00		001860
02	**47E387081-22	EMER LIGHT UNIT				M		0000	EA	3.00	3.00	22-00		001861
02	**47E387081-23	FIRE EXT UNIT				M		0000	EA	5.00	5.00	23-00		001862
02	**47E387081-24	TEL & SITE INTERCOM				M		0000	EA	1.00	1.00	24-00		001863
02	47A380094	7500KVA VAR SP GEN				X		0000	EA	X		25-00		001864
01	47E387114	CONTROL SYSTEM SCHEM				X		0000	EA	X		10-00		001865
01	47A380023	POWER CABLING REQT				X		0000	EA	X		11-00		001866
01	47A380024	INSTL CABLING REQT				X		0000	EA	X		12-00		001867
01	47A380008	STEP-UP XFMR SPEC				X		0000	EA	X		13-00		001868
01	47A387005	I&C SIGNAL LIST				X		0000	EA	X		14-00		001869
01	47D382288	GENERAL SITE LCTN				X		0000	EA	X		15-00		001870
01	47D382298	SITE PLAN-1ST UNIT				X		0000	EA	X		16-00		001871
01	47E387014	SCHEM,NACELLE,GEN				X		0000	EA	X		17-00		001872
01	47D382000	TOWER GEOMETRY/DIAG				X		0000	EA	X		18-00		001873
01	47D382274	NACELLE GEOMETRY				X		0000	EA	X		19-00		001874

IDENTIFICATION NO.	NOMENCLATURE	--- ECN ---- DWG INC	OUT	PL-LATE APPLY	P C	T Y	CYCLE TIME	FSCM	U/M	NEXT HIGHER ASSEMBLY	QTY	EXT/TOT-QTY	CROSS REF
300H1-15CG-04-K	PRESSURE TRANSDUCER				B		0000	89326	EA	47J382313G1	03.000	03.000	000103
3009-P-104	POTENTIOMETER, 100 K				B		0000	32997	EA	47D387113G1	02.000	02.000	001492
3009-P-503	POTENTIOMETER, 50K				B		0000	32997	EA	47D387113G1	02.000	02.000	001788
3009P-1-102	POTENTIOMETER, 1 K				B	7	0000	32997	EA	47E387037G1	01.000	02.000	000720
3009P-1-202	POTENTIOMETER, 2 K				B		0000	32997	EA	47E387037G1	02.000	04.000	000715
3009P-1-501	POTENTIOMTR 500 OHMS				B		0000	32997	EA	47E387037G1	04.000	08.000	000718
3043T18	"U" BOLT & NUTS				B	5	0000	39428	EA	47J382313G1	06.000	06.000	000080
3059J-1-102M	POTENTIOMETER				M		0000	32997	EA	47D387130G1	02.000	02.000	000894
326T-FRAME	MOTOR, TEFC				B		0000		EA	47E382579G1	01.000	01.000	000471
3302-37	CABLE 12" LG				*		0000	75037	EA	47D387087G1	01.000	07.000	000741
3341-1L	JACK SOCKET KIT				*		0000	52760	EA	47E387072G1	07.000	07.000	000742
3341-1L	JACK SOCKET KIT				*		0000	52760	EA	47E387084G1	02.000	02.000	001810
3341-1L	JACK SOCKET KIT				*		0000	52760	EA	47E387085G1	01.000	01.000	001652
3341-1L	JACK SOCKET KIT				*		0000	52760	EA	47E387091G1	02.000	02.000	001512
3341-1L	JACK SOCKET KIT				*		0000	52760	EA	47E387095G1	04.000	04.000	000623
												16.000	
3417-7040	CONNECTOR				B	5	0000	75037	EA	47D387087G1	01.000	07.000	000740
3432-4205	HEADER				*		0000	52760	EA	47D387083G1	10.000	10.000	000658
350-SERIES-3DC	PUMP				B		0000	59180	EA	47E382579G1	01.000	01.000	000470
3502-1000	CONNECTOR				*		0000	75037	EA	47D387087G1	01.000	07.000	000739
3596A-3	TERMINAL BOARD				*		0000	75382	EA	47E387072G1	01.000	01.000	000745
3596A-3	TERMINAL BOARD				*		0000	75382	EA	47E387095G1	01.000	01.000	000608
												02.000	
47A380008	STEP-UP XFMR SPEC				X		0000		EA	47E382304G1	X		001868
47A380009	DES. REQMTS, ROTOR BL				X		0000		EA	47E382400G1	X		001118
47A380009	DES. REQMTS, ROTOR BL				X		0000		EA	47E382590G1	X		001224
												00.000	
47A380014	STATION BATTERY SPEC				M		0000		EA	47E387081G1	01.000	01.000	001317
47A380023	POWER CABLING REQT				X		0000		EA	47E382304G1	X		001866

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FOR
MOD-5A WIND TURBINE GENERATOR
MAY 1981

Prepared By: V. T. Sweet
V. T. Sweet, Engineer
Structural Analysis & Weights

Reviewed By: D. C. Anderson
D. C. Anderson, Manager
Structural Analysis & Weights

John M Medaglia
J. M. Medaglia, Sr. Proj. Engineer
MOD-5A Structural Analysis

W C Lucas 5/4/81
W. C. Lucas, Manager
MOD-5A Design Engineering

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REVISION LOG

This log identifies those portions of this document which have been revised since original issue. Revised portions of each page, for the current revision only, are identified by marginal striping.

Revision	Page No.	Paragraph Number(s) Affected	Rev. Date	Approval
B	Complete rewrite to clarify and add new information		July 83	AN-1

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GLOSSARY OF ABBREVIATIONS

A/C	Aircraft
Cd	Coefficient of Drag
CGT	Crack Growth Threshold
CI	Cut-In
CIS	Cycle Intercept Stress
CO	Cut-Out
COE	Cost of Energy
COV	Coefficient of Variation (Standard Deviation/Mean)
FMEA	Failure Modes Effects Analysis
Kips	Unit of Force or Weight (Kilo-Pounds, 1000 lbs.)
Ksi	Unit of Stress (Kips per sq. in., 1000 Psi)
KW	Kilowatts
KWH	Kilowatt - Hours
LEFM	Linear Elastic Fracture Mechanics
MS	Structural Margin of Safety
NASA	National Aeronautics and Space Administration
P	Per Revolution, Applied Load (Pounds or Kips)
PCS	Pitch Change System
PSC	Partial Span Control
PIR	Program Information Report
Psi	Unit of Stress (Pounds per sq. in.)
PWHT	Post Weld Heat Treatment
R	Stress Ratio (Actual/Allowable), Fatigue Stress Cycle Ratio (Minimum/Maximum)

GLOSSARY OF ABBREVIATIONS

RFP	Request for Proposal
RMC	Root Mean Cubed
S_{min}	Minimum Stress
S_{max}	Maximum Stress
TBD	To Be Determined
TBR	To Be Resolved
UBC	Uniform Building Code
V	Shear (Pounds or Kips)
W	Wind
WEPO	Wind Energy Project Office
WTG	Wind Turbine Generator

SECTION 1.0

INTRODUCTION

1.1 PURPOSE

This document presents the Structural Design Criteria and interpretive information to be utilized for structural design of the MOD-5A Wind Turbine Generator (WTG). Specifically, the objectives of this document are:

- To ensure the structural integrity of the WTG hardware end items.
- To accomplish design and development of the WTG to satisfy this structural integrity with lowest practical Cost of Energy and life cycle cost. Specifically, these parameters may be quantified, for the MOD-5A WTG, as the following:

  COE less than 3.75 cents per KWH (1980 Dollars)

  life greater than 30 years (approximately 4 X 10E8 cycles)

Structural design criteria presented in this document concentrates on the strength, stiffness, and structural performance aspects of the design. It is intended to supplement and expand on general structural design requirements specified in the Statement of Work for the MOD-5A WTG, Exhibit B.

It is the intent of this document to establish the requirements for structural design by:

a) Defining the basic design philosophy governing the structural design of the WTG for structural integrity objectives.

b) Defining the criteria or standards that the design structural integrity is based on.

c) Providing the basic design data necessary to perform the structural design.

Structural design criteria presented in this document also establish requirements for the structural analysis documentation and signature approval of formally controlled structural drawings issued through the print control system. The structural analysis approval signature on the drawing signifies the drawing complies with all criteria contained in this document.

1.2 SCOPE

This document presents the basic requirements and information governing the strength, stiffness, and structural performance aspects of the structural design for the MOD-5A WTG.

SECTION 2.0

APPLICABLE DOCUMENTS AND REFERENCES

2.1 APPLICABLE DOCUMENTS

The following documents apply to the structural design to the extent specified herein. In case of conflict between this document and the documents listed below, this document shall take precedence.

1. MIL-HDBK-5C
2. 1980 Structural Welding Code (AWS)
3. 1976 Uniform Building Code (UBC)
4. Specifications of the American Association of State Highway and Transportation Officials (AASHTO)
5. American Concrete Institute Code (ACI) 318-77
6. Manual of Steel Construction, American Institute of Steel Construction (AISC), 8th Edition, 1978
7. Specifications of the American Society of Mechanical Engineers (ASME)
8. Design and Construction of Steel Chimney Liners, American Society of Civil Engineers (ASCE).
9. Specifications of the American Society for Testing Materials (ASTM)
10. Wood Handbook, U.S. Department of Agriculture Forest Products Laboratory
11. Design of Wood Aircraft Structures, ANC-18, June 1951
12. Joining of Advanced Composites, Engineering Design Handbook, DARCOMP 706-316
13. Detection and Repair of Fatigue Damage in Welded Highway Bridges, NCHRP Report 206

2.2 REFERENCES

(a) Baker, E.H., et al, "Structural Analysis of Shells," McGraw-Hill Book Co., 1972

(b) Bruhn, E.F., "Analysis and Design of Flight Vehicle Structures," Tri-State Offset Co., Cincinnati, Ohio 45202, 1965

(c) Roark, R.J., "Formulas for Stress and Strain," Fourth Edition, McGraw-Hill Book Co., 1965.

(d) Rolf, S.T., and Barsom, J.M., "Fracture and Fatigue Control in Structures, Applications of Fracture Mechanics," Prentice-Hall, Mc., Englewood Cliffs, NJ 07632, 1977.

(e) Rolf, S.T., "Fracture and Fatigue Control in Steel Structures," Engineering Journal, American Institute of Steel Construction, First Quarter, 1977

(f) WEPO PIR No. 71, "Outline for Structural Analysis Reports," Spera/Finnegan to Distribution, dated 09/22/78.

(g) Aaronson, S. F., "Analyzing Critical Joints", Machine Design, January 21, 1982.

(h) Hanson, J. M., et al, "Considerations for Design of Concrete Structures Subjected to Fatigue Loading", ACI 215R-74, revised 1981.

(i) Helgason, T., et al, "Fatigue Strength of High-Yield Reinforcing Bars", NCHRP report 164, Portland Cement Association.

SECTION 3.0

DEFINITION OF TERMS

For purposes of interpreting this document and to achieve unambiguous criteria the following definitions will apply:

3.1 GENERAL

Buckling - An instability phenomenon in a column, plate or shell where an infinitesimal increase in the external loading produces a sudden, large, non-linear deformation in the structure.

Creep - A time dependent deformation under load and thermal environments which results in cumulative permanent deformation.

Crippling - A local inelastic deformation (i.e., collapse) of a structural element, plate or shell, substantially reducing the ability of the structure to withstand loads.

Critical - The extreme value of a load or stress, or the most severe environmental condition imposed on a structure during its service life. The design of the structure is based on an appropriate combination of such critical loads, stresses, and conditions.

Design Load Factors - A multiplying factor applied to load (or pressure) to obtain design load (or pressure). Refer to Table 4.2-1 through 4.2-4. The application of such factors is defined by the flow shart in Figure 4.2-1.

Design Gross Weight - For design purposes, the maximum system weight the foundation will be designed to support.

Detrimental Deformations - Deformations, either elastic or inelastic, resulting from the application of loads and temperatures which prevent any portion of the WTG structure from performing its intended function. Examples include structural deformations, deflections, or displacements which: (1) Cause unintentional contact, misalignment, or divergence between adjacent components; (2) Cause a component to exceed its established dynamic space envelope; (3) Reduce the strength or related life of the structure below specified levels; (4) Degrade the effectiveness of thermal protection coatings or shields; (5) Jeopardize the proper functioning of equipment.

Failure - Rupture, collapse, seizure, yielding, or any other phenomenon resulting in an inability to sustain design loads, pressures, or environments without detrimental deformation.

Pressure Vessel - A container designed primarily to carry fluids or gases at sustained internal pressure, and which may also carry some structural loads.

Structure - All components and assemblies designed to sustain loads or pressures, provide stiffness and stability, or provide support or containment.

3.2 LOADS

See paragraph 3.7 for definition of terms uniquely related to fatigue.

Limit Load - The maximum anticipated static or quasi-static load on a structure resulting from an expected operating environment.

Design Load - The product of the predicted load and the design load factors.

Allowable Load - The maximum load that can be permitted in a structure for a given design condition. See also Paragraph 3.4.

Predicted Load - The load expected by best estimate from mathematical models of the transient and steady dynamic response of the WTG mechanical system (including control system interaction, if necessary) in operation, starting, stopping, parked, in storms, due to seismic response, and also best estimate from models of thermal distortion or moisture distortion.

Proof Test Load - The product of the limit load and the proof test design factor.

Quasi-Steady Load - Maximum expected load factors expressed in gravity units (g) which are intended to generate static loads in the structure equivalent to the worst case of combined effects due to rigid body and elastic accelerations.

3.3 PRESSURES

3.3.1 DESIGN PRESSURES FOR PRESSURE VESSELS

Limit Pressure - The maximum differential pressure that can be anticipated to occur while the pressure vessel is in service in the expected operating environments. Limit pressures include combinations of such pressures as maximum operating pressure, transient pressure, and head pressure.

Design Pressure - The product of the limit pressure and the design factors.

3.3.2 OPERATING PRESSURES

Nominal Operating Pressure - The maximum pressure applied to a pressure vessel by the pressurizing system with the pressure regulators and relief valves at their nominal settings and with nominal fluid flow rate.

Maximum Operating Pressure - The maximum pressure applied to a pressure vessel by the pressurizing system with the pressure regulators and relief valves at their upper limit and with the maximum fluid flow rate.

3.3.3 TEST PRESSURES

Proof Test Pressure - The product of the limit pressure and the proof factor.

Burst Test Pressure - The pressure at which a pressurized component shall not rupture. The product of the limit pressure and the burst factor.

3.4 STRENGTH

Proportional Limit Strength - The stress level at which the material stress-strain relation ceases to be linear. This is especially applicable to wood and some man-made composites in compression.

Yield Strength - Corresponds to the tensile load or stress in a structure or material at which a permanent set of 0.2% occurs. Not applicable to wood laminate.

Ultimate Strength - Corresponds to the maximum load or stress that a structure or material can withstand without incurring rupture or collapse.

3.5 STRESSES

See Paragraph 3.7 for the definition of stress terms uniquely relating to fatigue.

Allowable Stress - The maximum stress that can be permitted in a material for a given design condition. See also Paragraph 3.4.

Applied Stress - The structural stress induced by a given applied load and environment.

Design Stress - The structural stress induced by the applied design load.

Predicted Stress - The structural stress induced by the applied predicted load.

Residual Stress - A stress that remains in a structure due to local yielding or creep after processing, fabrication, assembly, testing, or operation.

Thermal Stress - The structural stress arising from temperature gradients and differential thermal expansion in or between structural components, assemblies, or systems.

3.6 MARGIN OF SAFETY

The margin by which the allowable load (or stress) exceeds the design load (or stress) for a specific design condition when all design factors (see Paragraph 3.1) have been taken into account. Acceptable calculations for margins of safety are defined in Paragraph 4.2.3.

3.7 FATIGUE

Refer to Figures 4.3-3 through 4.3-6 for illustrative definitions and symbols pertaining to the following nomenclature.

Fatigue Loads - An applied load, or spectrum of loads, many repetitions of which result in a tendency for a material to fail at considerably less than its ultimate static strength.

<u>Fatigue Stresses</u> - The structural stresses induced by application of fatigue loads, as above defined, and including all stress concentration factors.

<u>Stress Cycle</u> - The smallest division of the stress-time function which is repeated.

<u>Maximum Stress</u> - The highest algebraic value of stress in the stress cycle.

<u>Minimum Stress</u> - The lowest algebraic value of stress in the stress cycle.

<u>Mid-Range Stress</u> - The algebraic mean of the maximum and minimum stress in a cycle.

<u>Stress Range</u> - The algebraic difference between the maximum and the minimum stress.

<u>Alternating Stress</u> - One-half of the stress range.

<u>Stress Ratio, "R"</u> - The algebraic ratio of the minimum stress to the maximum stress.

<u>Cycles Endured</u> - The number of cycles, at a given stress level, which a part has endured at any time during loading.

<u>Fatigue Strength</u> - The maximum stress which a material can withstand for a given number of stress cycles.

<u>Fatigue Life</u> - The number of cycles which a part can sustain at a given stress level, after which damage or failure is likely.

<u>S-N Curve</u> - A plot of stress vs. cycles to failure.

<u>Endurance Limit</u> - The maximum material stress which can be reversed an indefinitely large number of times without producing fracture. Some materials have no endurance limit and the S-N data must be extrapolated to encompass the number of cycles expected to be applied to the design.

Goodman Diagram. A graphic expression of empirical formula for the endurance limit, alternating stress vs. mean stress.

Constant Life Fatigue Diagram - Similar to the Goodman Diagram, described above, but relating the fatigue strength for any given number of cycles to any given range of stress variation.

Stress Intensity Factor - The single parameter that characterizes the fundamental concept of linear-elastic fracture mechanics. This parameter, related to both the stress level and the flaw size, defines the stress field ahead of a sharp crack for flat crack propagation. When a particular combination of stress and flaw size leads to a critical value of the intensity factor, unstable crack growth occurs.

Flaw - A crystal imperfection, dislocation, microcrack, lack of weld penetration, etc., resulting from a material imperfection or fabrication technique, such as welding. A conservative approach to fatigue failure prevention is to assume the presence of an initial flaw, dependent on the quality of fabrication and inspection, and analyze the fatigue-crack-growth behavior of the structural member.

Crack Growth Threshold (CGT) - A stress level below which flaw propagation is extremely slow or absent. Important variables include initial flaw size, location of the flaw, shape of flaw, stress distribution, stress intensity range threshold factor, and the arrangement of parts being joined, especially in weldment. Flaw growth occurs when applied stress range exceeds the CGT. When the flaw reaches a critical size failure is likely.

SECTION 4.0

GENERAL DESIGN CRITERIA AND PROCEDURES

4.1 GENERAL DESIGN PHILOSOPHY

The structure design shall serve to provide the necessary structural support and housing to effectively and efficiently position and environmentally protect the system and subsystem components. The mechanical design shall provide structural integrity with strength and rigidity characteristics adequate to withstand all operational and environmental constraints; as well as to withstand all pre-operational environments such as manufacture, ground handling, transportation, and erection; and to achieve minimum practical weight, within the constraints of obtaining a minimum COE.

The WTG structure shall be designed and analyzed to satisfy the stiffness requirements of paragraph 4.2.2 and for the loads that result from the critical design conditions and any qualification test levels. The qualification test levels will be intended to demonstrate a structural design of the applicable subsystems that is sufficiently conservative to give a high level of confidence in the reliability of the structure.

Pre-operational conditions and environments shall influence the structural design to the minimum extent possible. Where practicable, means shall be devised for assembling, handling, transporting, and erecting which do not require an increase in the WTG weight over that required for the operational conditions.

4.2 GENERAL DESIGN CRITERIA

4.2.1 STRENGTH REQUIREMENTS

At design load, the structure shall have sufficient strength to withstand simultaneously the design loads and the other applicable environments of the design condition without experiencing detrimental deformations (as defined in paragraph 3.1), a plastic deformation of 0.2%, or loss of functional capability.

Strength is assessed analytically by comparing design loads (or stresses) with allowable loads (or stresses). See paragraph 4.2.3

4.2.2 STIFFNESS REQUIREMENTS

When subjected to design loads, the structure or any component thereof shall not experience detrimental distortions. The fulfillment of the strength requirements of Paragraph 4.2.1 shall not be deemed sufficient in itself to satisfy this requirement.

Resonant frequency requirements will be used to control the dynamic response of the rotor, shaft, drive system, and components and to preclude dynamic interactions with the nacelle, yaw system, or tower. These resonant frequencies will be specified for the primary structure and for critical secondary support structure. The primary structure for any subassembly shall be designed independent of any potential stiffening effect provided by any subsystem component installations. These modules and components will be treated as mass items only and their inertial loads applied to the basic WTG substructures.

4.2.3 MARGIN OF SAFETY

The margin of safety shall be determined at design load levels versus allowable levels, and at the temperatures expected for all critical conditions. A high margin of safety shall not be used as a substitute for the appropriate design factor.

4.2.3 MARGIN OF SAFETY (cont'd)

For minimum-weight design, the margin of safety shall be the smallest practicable equal to or greater than zero. The margin of safety shall be calculated by the following equation:

$$\text{MS (design)} = \frac{\text{Allowable Design Load (or Stress)}}{\text{Design Load (or Stress)}} - 1$$

At the location of minimum margin of safety versus allowable load or stress in each stress analysis of a substructure, the margin of safety between the predicted stress and the material yield strength or proportional limit shall also be reported.

4.2.4 DESIGN LOAD FACTORS

Design load factors shall be used to account for uncertainties in design which cannot be analyzed or otherwise accounted for in a rational manner. Design factors shall be applied to limit loads and pressures and to the stresses arising from temperature differences and gradients, but not to the temperatures and temperature differences. These factors, as defined below, are to be combined for margin of safety calculations as prescribed by the flow chart of Figure 4.2-1.

The design load factors shown in Table 4.2-1 shall be used to obtain the design loads.

The pressure vessel design factors shown in Table 4.2-2 shall be applied to maximum expected operating pressures to obtain design pressures for all pressure vessels, lines, and fittings.

4.2.4 DESIGN LOAD FACTORS (cont'd)

The configuration design factors shown in Table 4.2-3 are used to account for uncertainties in load/stress distributions in fittings and joints and variations in the control of welding and bonding processes. The contingency load factors shown in Table 4.2-4 are used to account for the degree of confidence in the predicted loads.

FIGURE 4.2-1 DESIGN LOAD FACTOR FLOW CHART

*DESIGN LOAD = PREDICTED LOAD

X *DESIGN LOAD FACTOR
(TABLE 4.2-1)

X *CONFIGURATION DESIGN FACTOR
(TABLE 4.2-3)

X CONTINGENCY LOAD FACTOR
(TABLE 4.2-4)

$$MS = \frac{\text{ALLOWABLE *DESIGN LOAD}}{\text{*DESIGN LOAD}} - 1.$$

NOTES:

*1. The following may be substituted for the word "DESIGN": "FATIGUE," "PROOF TEST," or "BURST." The more critical of these shall govern the Margin of Safety calculation (Ref. Para. 4.2.3).

2. The following may be substituted for the word "LOAD": "PRESSURE" or "STRESS."

3. For pressure vessels, substitute Table 4.2-2 for Table 4.2-1.

Table 4.2-1

DESIGN LOAD FACTORS

LOAD CONDITION	DESIGN LOAD FACTOR FATIGUE	DESIGN LOAD FACTOR STATIC
Maximum Wind Loading	---	1.00
Operational Loads	1.00	1.00
System Qualification Test	---	1.00
Transportation, Hoisting & Handling Fittings:		
Hazardous to Personnel	---	4.00
Non-hazardous to Personnel	---	3.00
WTG Structure Critical to Alignment	---	1.15
Tower Overturning (see para. 4.3.3.3 and 4.3.4.2)	1.00	1.00

Table 4.2-2

PRESSURE VESSEL DESIGN FACTORS

PRESSURE CONTAINER	DESIGN	PROOF TEST	BURST
Hydraulic Systems	1.00	1.50	2.00
Pneumatic Systems	1.00	2.00	3.00

Table 4.2-3

MINIMUM CONFIGURATION DESIGN FACTORS

(Not to replace consideration of stress concentrations, eccentricities, etc., which are to be used in estimating the predicted load or stress)

ITEM	FATIGUE*	STATIC**
Fittings	1.00	1.15
Welded Joints	1.00	1.00
Bonded Joints	1.00	1.25
Shear Fasteners	1.00	1.15
Tension Fasteners	1.00	1.25
Stud Capacity in Wood	1.00	1.25
Castings	1.00	1.50
All Others	1.00	1.00
Buckling critical		
Verified by test	1.25	1.25
Analytical only	1.50	1.50

*Subject to AISC Range Stress Limitations which are based on critical crack-growth thresholds relating to specific stress concentration conditions.

**When two or more configuration factors apply, use more severe, but not both.

Table 4.2-4

CONTINGENCY LOAD FACTORS

LOAD TYPE	CRITERIA FOR SELECTION OF LOAD TYPE	CONTINGENCY FACTOR
A	Specified loads derived from analysis in which a high degree of confidence exists because the structural characteristics used in an analysis of the coupled substructures have been based on experimental data obtained from MOD-5A or similar machines.	1.00
B	Loads derived from analysis which involve complex methods and makes use of detailed structural drawings. The design has been frozen and there will only be small changes in structural details.	1.15
C	Loads derived from analysis which makes use of a simplified math model representative of the structure. Structural sketches or layouts are used to generate the math model. The design is in a state of evolution and there is a high likelihood of changes in structural details.	1.25
D	Loads derived by direct estimates.	*As assigned by Load Analyst
E	Hurricane, Seismic, Maximum overspeed, FMEA	1.0

*Dependent on degree of confidence and design importance of load.

NOTE: MORE SPECIFICALLY, THE LOAD TYPE MAY BE ASSIGNED, BASED ON MOD-5A WTG PROGRAM PLANNING, AS FOLLOWS:

(a) Conceptual Design Phase - Load Types "C" and "D".

(b) Preliminary Design Phase and Final Design - Load Type "B".

(c) After field data available (2nd MOD-5A WTG, or later) - Load Type "A".

4.2.5 EXTERNAL LOADS

External loads shall be determined by conservative analysis of the design environment, or with appropriate load contingency factors.

4.2.5.1 Dynamic Loads

Dynamic loads shall be determined for quasi-static and transient phenomena expected in each design environment. The calculation of all dynamic loads shall include the effects of WTG structural flexibilities and damping, and coupling of structural dynamics with the actuation and braking systems and the external environment. Control systems interaction with structural modes shall be included in the determination of the predicted loads.

Iterations of the dynamic loads calculations shall be performed as necessary to reflect design changes and/or mathematical model refinements. The final set of dynamic loads shall be determined with the use of experimental values of dynamic characteristics as obtained from appropriate tests and modal surveys.

4.2.5.2 Contingency Load Factors

The basis for the assignment of the contingency load factor to each load condition is given in Table 4.2.4.

4.3 DESIGN PROCEDURES

4.3.1 REFERENCE AXES

Loads are oriented with respect to the coordinate axes shown in Figure 4.3-1.

4.3.2 SYMBOLS

Standard symbols as per the Manual of Steel Construction, AISC, will be employed, unless specifically noted to the contrary. Symbols utilized only in the paragraph 4.3.6.2 discussion on Fatigue are per the MIL-HDBK-5C or reference(b), paragraph C13.6.

4.3.3 MATERIAL STATIC PROPERTIES (See paragraph 4.3.6 for Fatigue Material Properties)

4.3.3.1 Allowable Mechanical Properties

Values for allowable mechanical properties of structure and joints in their design environment shall be taken from approved sources. The Wood Handbook and ANC 18 shall be used for the wood blade properties, until test data is made available. When values for mechanical properties of materials or joints are not available because they are new or used in a new environment, they shall be determined by approved analytical or test methods. A sufficient number of tests shall be conducted to establish values for the mechanical properties on a statistical basis. The effects of temperature, thermal cycling and gradients shall be accounted for in defining allowable mechanical properties.

In general, the following guidelines apply, subject to modification by the stress analyst.

Steel Static Design Allowables (Ref. AISC Manual of Steel Construction)
The entire AISC specification for the design of structural steel for buildings is helpful as a mature and successful procedure for design allowables in steel. Some important values are listed here.

- Tension and compression: .60 yield
- Shear: .40 yield
- Simple bearing: .90 yield
- Fasteners, bending, buckling and combined stress per appropriate AISC Specification
- For very infrequent or "one time" type loads, such as seismic or hurricane, with the permission of the Project Structural Analysis Engineer, the allowable stresses may be increased by .33 as long as minimum yield is not exceeded nor are any stability criteria exceeded. Limit loads normally fall in this catagory except when determined by peak fatigue loads, which are "frequent".
  For buckling, the safety factors shall be reduced to 1.15 and 1.35 for test and analysis respectively in lieu of an increased allowable.

Wood Laminate Static Design Allowables - Based on no more than 80% of minimum tested value, where, minimum is defined as the lower 2 Sigma value of the scatter band, and as documented by the responsible engineer. The effects of size, temperature, rate and duration of load, and moisture content shall be used in converting the minimum test article strength to the Design Allowable strength for normal operating loads. See paragraphs 4.3.6.3 and 4.3.6.4 for static and fatigue Design Allowable Stresses. See load Type E in Table 4.2-4 for abnormal conditions.

Suitable laminate analysis shall be performed in a composite of layers of anisotropic materials at different orientations to one another, or of multiple materials having different moduli. The laminate stresses or strains shall be compared to allowable stresses or strains.

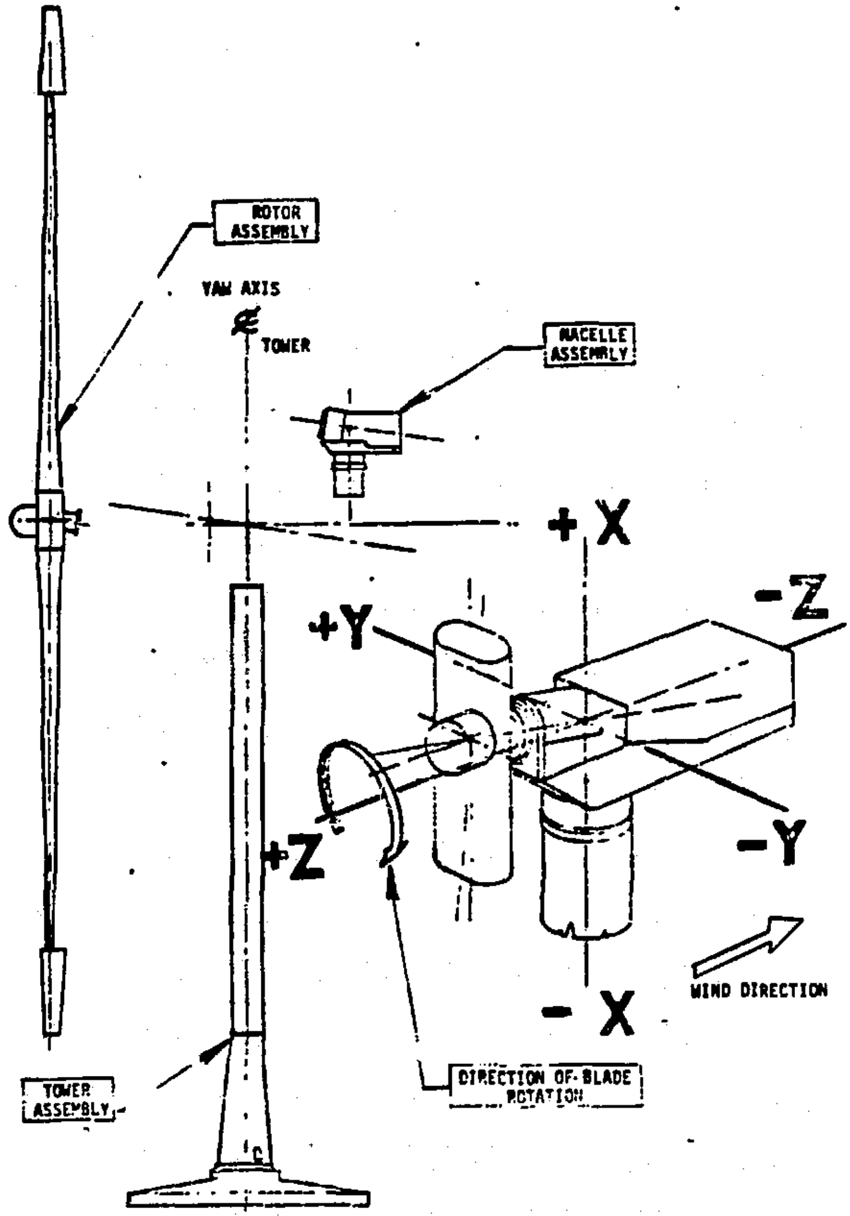


FIGURE 4.3-1 COORDINATE AXES OF MOD-5A WTG

4.3.3.2 Component Allowables

Component structural allowables shall be based on applicable component test data or analyses.

4.3.3.3 Foundation Properties

The foundation shall be of reinforced concrete design conforming with specifications of the Uniform Building Code 1976 and the ACI Code (documents 3 and 5). Concrete shall have a minimum 3000 Psi compressive strength at 28 days. Constituents shall conform to or exceed the following specifications:

ASTM C 150 type I Portland cement
ASTM C 33 concrete aggregates
ASTM A615 Grade 60 (reinforcing steel)

The foundation if designed for yielding soils shall use a net allowable soil bearing value substantiated by an adequate soils investigation. Expected settlements and the effects of cyclic loading must be addressed in the soils investigation.

The net allowable soil pressure will have a factor of safety of 3.0 against bearing capacity failure. After site selection the actual soil capacity will be measured and the allowable pressure set at one-third (1/3) of the actual static capacity. The preliminary design soil allowable pressure of 4000 PSF is one-third (1/3) of the expected soil static bearing capacity.

Under normal operating loads, the maximum toe pressure from applied loads shall not exceed the assumed 4000 psf net allowable bearing value of the soil. Net toe pressure includes weight of structure, and overturning moment due to normal operating loads. No uplift is allowed under normal loading conditions.

4.3.3.3 Foundation Properties (cont'd)

The foundation must have sufficient fatigue strength to withstand normal operating loads. See references (h) and (i). The maximum toe pressure shall not exceed 1.33 the assumed 4000 psf net allowable bearing value of the soil under very infrequent operating loads. Net toe pressure includes weight of structure, and overturning moment due to abnormal operating loads.

Very infrequent loading is considered non-cyclic in nature with frequency of occurrence spaced years apart.

4.3.4 BUCKLING, CRIPPLING, AND OTHER INSTABILITIES

4.3.4.1 Buckling and Crippling

Structural components loaded in compression that are subject to buckling (primary instability) or crippling (local instability) shall not fail under design load. Nor shall deformation from design loads degrade the functioning of any system or produce changes in loading that are not accounted for. Maximum crippling stresses are cut-off at the material compressive yield strength unless test results are obtained to substantiate the use of higher crippling stresses. Usage of the AISC criteria for "Compact Sections" (per document 8, Section 2, and Specification, Paragraph 1.5.1.4) will generally preclude the necessity for calculating local crippling allowables for sections normally used as columns or beams.

Structural panels or webs loaded in compression or shear shall not undergo initial compression or shear buckling at design load. References (a), (b), or (c), and Document (10.) provide acceptable criteria for calculating panel buckling allowables.

4.3.4.2 Tower Overturning

The foundation shall be designed so that no uplift occurs at any point on the base for normal design load condition, when the structure is founded on a yielding base. All base materials except solid rock and hard shale shall be considered as yielding. The soil dead weight directly above the foundation slab and structural weight, both inside and outside the ringwall can be used to resist the uplift.

With very infrequent loading, such as a hurricane, the point of zero soil pressure is allowed to be as much as 1/3 the diameter measured radially inward from the circumference of a spread footing or tangent to the ringwall whichever provides less uplift. The maximum toe pressure shall not exceed 1.33 x the allowable soil pressure (as determined by in situ and/or laboratory measurements) under these very infrequent conditions. Very infrequent loading is considered non-cyclic in nature with frequencies of occurence spaced years apart.

4.3.5 STRUCTURAL NON-LINEARITIES

The structure shall possess "linearity" to a degree which will allow accurate prediction of its behavior at any time. Important types of non-linearities which should be avoided or minimized are adverse non-linearities in energy dissipating mechanisms, mechanical backlash, and to a certain degree, elastic shear buckling in structural elements.

4.3.6 FATIGUE MATERIAL PROPERTIES

Consideration shall be given in the design of the WTG structure to insure good fatigue design characteristics. Caution shall be exercised to reduce residual stresses, and stress concentrations, and to avoid poor surface finishes. PWHT shall be used wherever practical for all weldments. Materials and structural details utilized shall exhibit satisfactory fatigue characteristics, with allowables below the CGT as the preferred approach. Since fatigue design will probably be the design driver for the rotor, hub and drive train, and to some extent, certain areas of the nacelle/bedplate and the yaw system, the following fatigue design guidelines shall be followed:

1. Use steels with adequate notch toughness (see paragraph 4.3.6.1 and Table 4.3-1).
2. Use CGT fatigue allowables based on AISC fatigue allowables for "Condition 4", if part receives a PWHT, otherwise use RMC method.
3. Assume a maximum permissable flaw size approximating 0.100 inches in all welded joints, and call-out appropriate inspection requirements to reject flaws larger than 0.100 inch.
4. Use material development tests to establish fatigue allowables in materials other than steels.

4.3.6.1 Fatigue Allowables - Steels

To insure adequate fracture toughness and fatigue resistance for steels utilized in the WTG design, they shall initially meet the Charpy Vee-Notch (CVN) test requirements of the American Association of State Highway and Transportation Officials (AASHTO) specifications of Table 4.3-1. The WTG operating regime (-40 degrees F to +120 degrees F) corresponds to Zone 3 of the AASHTO Specification, and most steels are anticipated to be in the low to medium strength ranges. These CVN requirements should be met or exceed in qualification of base metal and weld joints. Test samples taken from weld joints should include weld metal and the heat affected zone.

4.3.6.1 <u>Fatigue Allowables - Steels</u> (cont'd)

The AASHTO CVN requirements are based on empirical data which implies that the Nil-Ductility Transition (NDT) temperature for intermediate strain rates (10^{-3} sec^{-1}) will be about 50 to 120°F below the AASHTO test temperature. This rate is consistent with WTG operational loading. Steels selected on this basis should also meet additional requirements as listed in Table 4.3-1.

4.3.6.1.1 <u>Steel Weldments With PWHT</u>

Allowable stress ranges, derived from test data and supported by LEFM analysis, applicable to base metal and various welded joint configurations are defined by the 1978 AISC Specification Appendix B (document 6), and are outlined in Table 4.3-2. Figure 4.3-2a is included to illustrate various joint configurations.

Examples of welded joint configurations to be avoided are as follows:

1. Don't attempt to carry a tensile load through a material thickness in the development of a rigid welded joint. This configuration of load and joint may result in a laminar tear in the material thickness.

2. Don't weld closure members (ribs or bulkheads, for instance) in a closed cell section. Weld shrinkage in this case may result in dimpling the skin of the closed cell precipitating an early buckling failure and/or laminar tearing.

Illustrative examples appear in Figure 4.3-2b.

Table 4.3-1

AASHTO NOTCH-TOUGHNESS SPECIFICATIONS FOR BRIDGE STEELS

ASTM Designation**		Thickness (in)	CVN Impact Value, ft lb Zone 1*	Zone 2*	Zone 3*
A36			15 @ 70°F	15 @ 40°F	15 @ 10°F
A572		Up to 4 in. mechanically fastened	15 @ 70°F	15 @ 40°F	15 @ 10°F
		Up to 2 in. welded	15 @ 70°F	15 @ 40°F	15 @ 10°F
A440			15 @ 70°F	15 @ 40°F	15 @ 10°F
A441			15 @ 70°F	15 @ 40°F	15 @ 10°F
A242			15 @ 70°F	15 @ 40°F	15 @ 10°F
A588		Up to 4 in. mechanically fastened	15 @ 70°F	15 @ 40°F	15 @ 10°F
		Up to 2 in. welded	15 @ 70°F	15 @ 40°F	15 @ 10°F
		Over 2 in. welded	20 @ 70°	20 @ 40°F	20 @ 10°F
A514		Up to 4 in. mechanically fastened	25 @ 30°F	25 @ 0°F	25 @ -30°F
		Up to 2-1/2 in. welded	25 @ 30°F	25 @ 0°F	25 @ -30°F
		Between 2-1/2 - 4 in. welded	35 @ 30°F	35 @ 0°F	35 @ -30°F

* Zone 1: minimum service temperature 0°F and above.
Zone 2: minimum service temperature from -1°F to -30°F.
Zone 3: minimum service temperature from -31°F to -60°F.

** If the yield point of the material exceeds 65 ksi, the temperature for the CVN value for acceptability shall be reduced by 15°F for each increment of 10 ksi above 65 ksi.

Additional Parameters Recommended For Any Candidate Steel

1) Intermediate strain rate ($10^{-3}sec^{-1}$) NDT temperature shall be less than -40°F.

2) Stress corrosion cracking stress intensity threshold (K_{ISCC}) should exceed 50 KSI $\sqrt{IN}$ at room temperature (most steels with a minimum tensile yield point greater than 150 KSI are prohibited by the above requirements)

3) K_{IC} (ASTM Method E399) or K_c should exceed 100 KSI $\sqrt{IN}$ or
[Tensile Yield Point (Method E8)] times $\left[\frac{\text{plate thickness}}{2.5}\right]^2$

whichever is greater

Table 4.3-2

ALLOWABLE STRESS RANGE RELATED TO AISC CODE (1978 EDITION)

FOR CONFIGURATION WITH PWHT

	ALLOWABLE MAXIMUM FATIGUE STRESS RANGE				
CATEGORY [NOTE (1)]	R<0.1 S_r(KSI) RANGE	R=0.2 S_r	R=0.4 S_r	R=0.6 S_r	R=0.8 S_r
A	24	21.05	16.74	12.42	8.12
B	16	14.04	11.16	8.28	5.41
C	10	8.77	6.97	5.17	3.38
C*	12	10.53	8.37	6.21	4.06
D	7	6.14	4.88	3.62	2.36
E	5	4.39	3.99	2.09	1.69
F	8	7.02	5.58	4.14	2.72

NOTES:

1) "Categories" conform to Appendix B Manual of Steel Construction, 8th Edition. Configurations not conforming shall be individually evaluated.

2) R = Minimum Stress/Maximum Stress

3) The flaw detection size requirement shall be smaller than the size related to S_r, by fracture mechanics formulae, considering the local stress state and the propagation threshold versus R

4) S_r is Maximum Stress - Minimum Stress even if part of the time history is compressive

5) Post Weld Heat Treatment (PWHT) is required to assure applicability of these allowables

6) C*: Permitted if stiffener is less than the thickness of main sheet or flange. Otherwise revert to C.

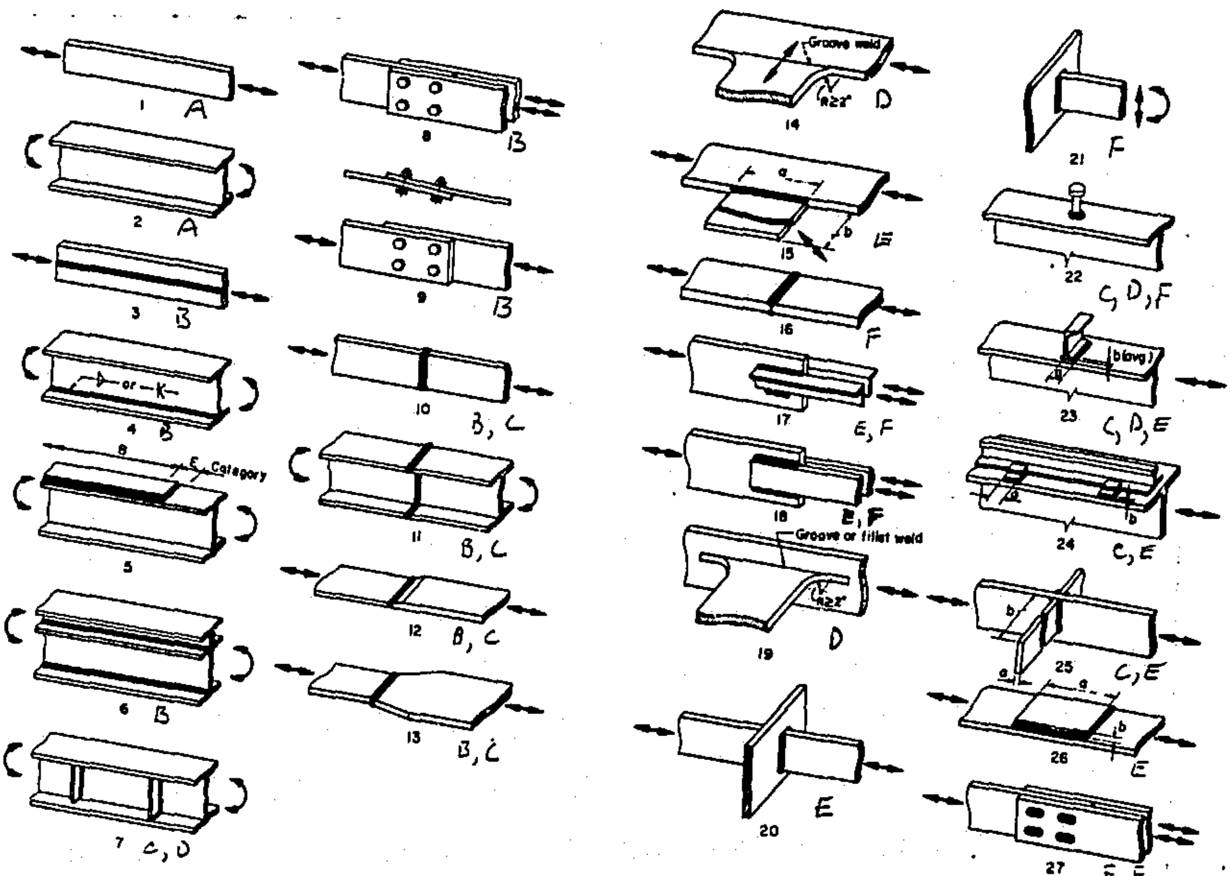
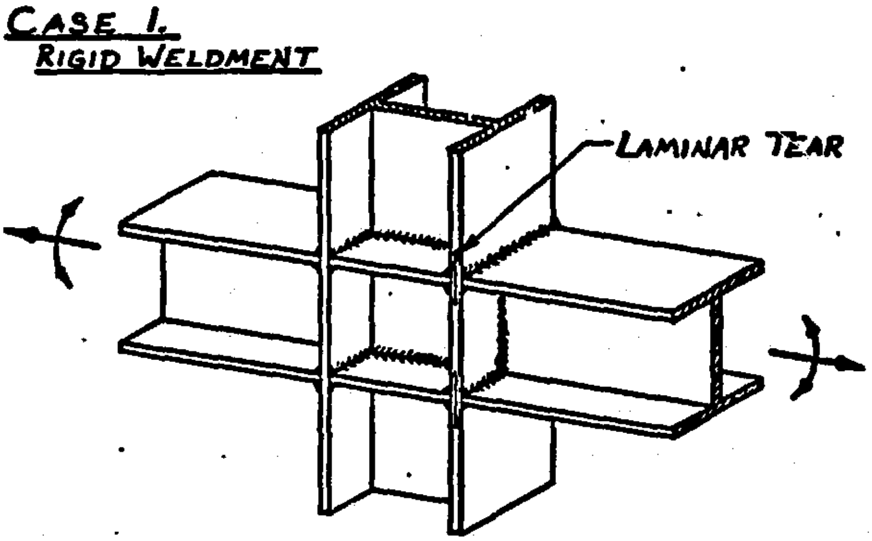


FIGURE 4.3-2a ILLUSTRATIVE EXAMPLES

See AISC Code (Document 6) Table B2 and Document 13 for further description of weld categories



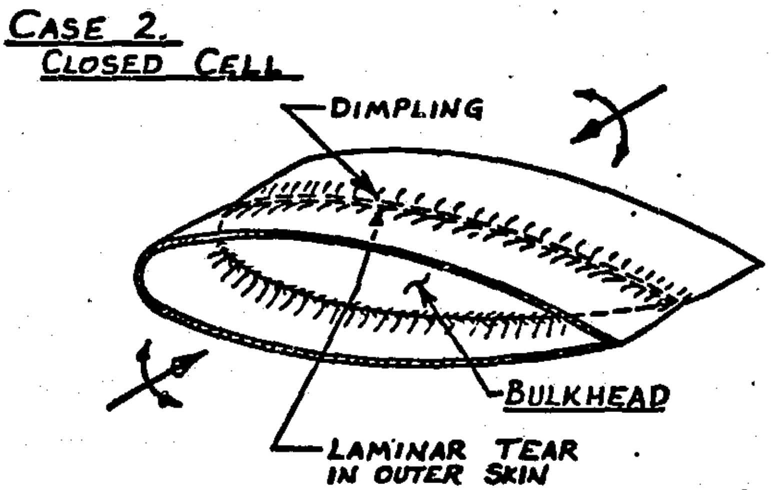


FIGURE 4.3-2b ILLUSTRATIVE EXAMPLES OF JOINTS TO BE AVOIDED

NOTES

1) Avoid intersecting welds as much as possible (coping helps).

2) Avoid details subject to displacement induced cracking such as local attachments to webs

3) Avoid the use of backing bars.

4.3.6.1.2 Steel Weldments Without PWHT

Table 4.3-3 provide allowable stress criteria based on the RMC method for weldments without PWHT which conform to configuration categories defined in the AISC Specification. Other configurations will be considered individually.

4.3.6.2 Fatigue Allowables for Multiple Environments

WTG designs must be concerned with two types of interrelated failures -- brittle failure and fatigue, which is normally related to welded joints. Generally speaking, as stated in reference (d), if a design for fatigue is adequate, brittle fracture considerations are often secondary; therefore, adequate fatigue analysis is mandatory for the multiple loading environments experienced by a WTG. Avoidance of brittle fracture away from welds at stress below strength allowables does require adequate toughness and separate design consideration. Dynamic analyses will be performed evaluating these multiple loading systems, with the output as loading histograms. From these will be developed stress histograms relating summaries of stress levels versus their respective numbers of occurrences. An assessment of the R value to be used in setting fatigue allowables will be made by the stress analyst.

References (d) and (e) present a Linear Elastic Fracture Mechanics (LEFM) approach, in which a known initial flaw size (crack) is assumed (in this case 0.100 inch), and a crack growth threshold determined.

Fatigue characteristics and terminology are discussed in paragraph 3.7. Figure 4.3-3 illustrates the construction of an allowable stress diagram for subsequent usage in the preferred fatigue analysis. This technique is outlined by Figure 4.3-4. Figure 4.3-5 illustrates S-N curves from the AISC code as applicable to the MOD-5A WTG.

EXAMPLE FOR CATEGORY C

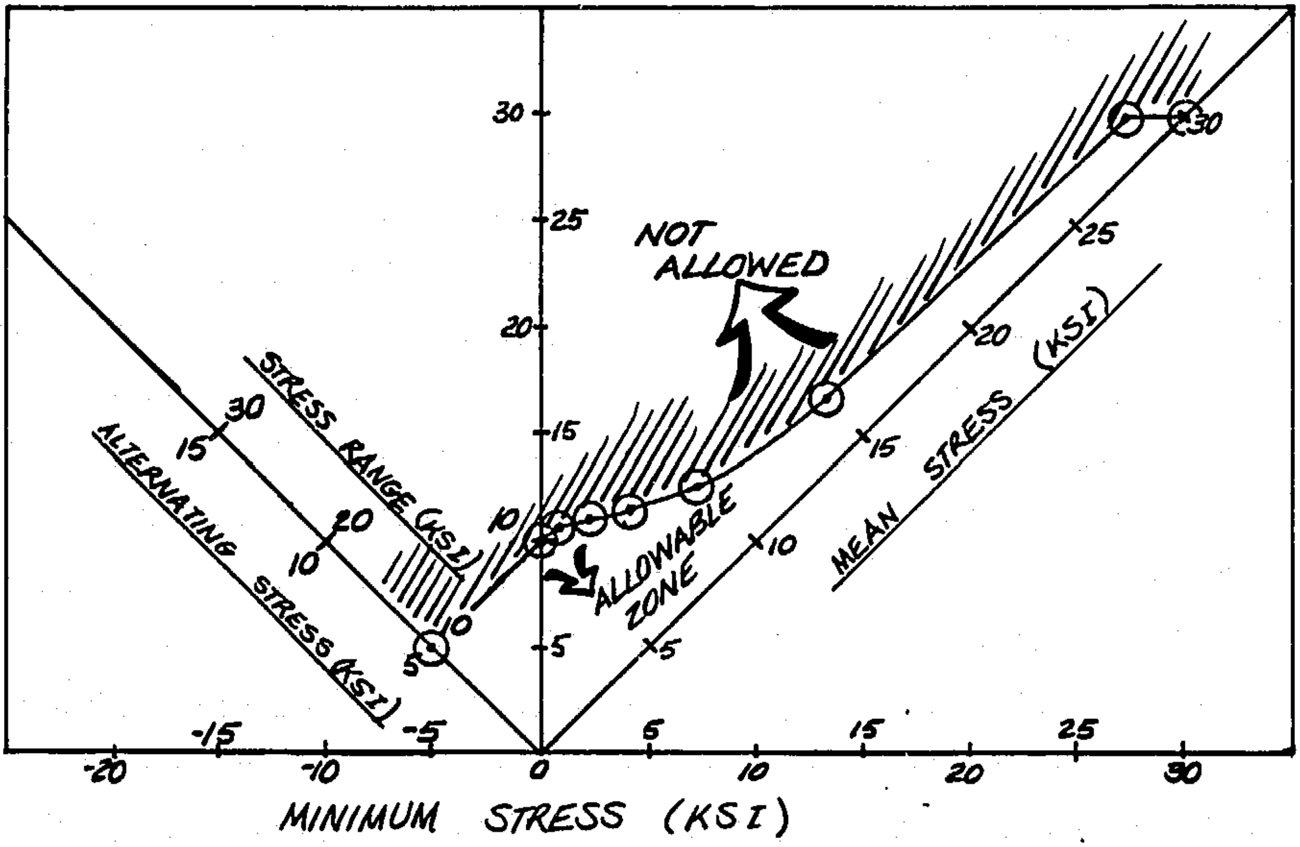
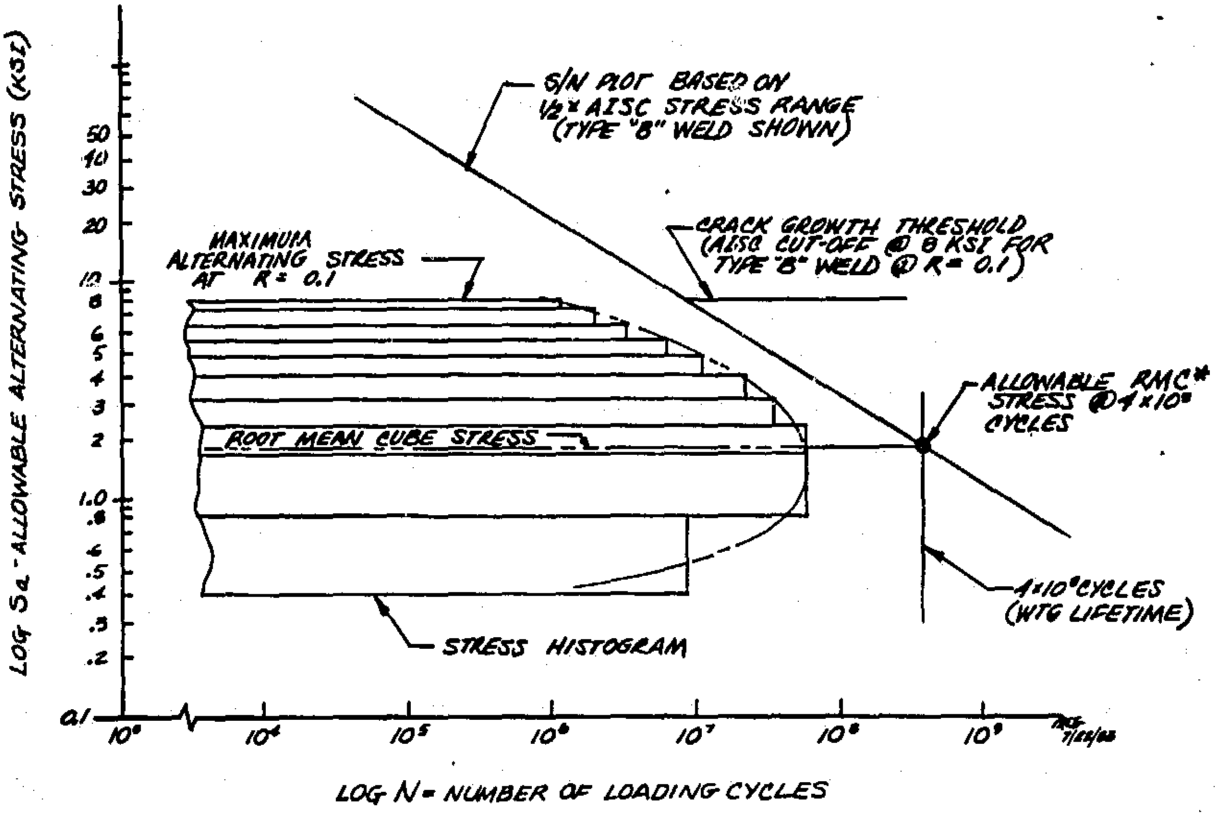


FIGURE 4.3-3

ALLOWABLE STRESS DIAGRAMS FOR

BRIDGE CONSTRUCTION STEEL ALLOYS (TABLE 4.3-1)



NOTES:

1. S-N Curve and Crack Growth Threshold allowables are dependent on S_{min}/S_{max} ratio.

2. All cycles of the stress histogram must lie below the Crack Growth Threshold. The CGT has been previously derived from a Linear-Elastic Fracture Mechanics Analysis (LEFM), assuming an initial flaw size (2a) of 0.100 inches. See Table 4.3-2 for CGT allowables versus R value. If some stress cycles are above the Crack Growth Threshold, then follow note 3.

3. The root mean cube of the stress histogram must lie below the extrapolated S-N Curve if the stress range exceeds the CGT or if no PWHT is used. This assumes the RMC stress is an equivalent constant amplitude stress. This criteria only applies if note 2 is not met. RMC procedure is equivalent to Palmgren-Miner cycle ratio summation, being less than 1 when the S-N curve has a slope of -3.

FIGURE 4.3-4 EFFECT OF FATIGUE SPECTRUM

TABLE 4.3-3

ALLOWABLE RMC STRESSES IN KSI WITHOUT PWHT FOR FATIGUE LIFE LONGER THAN 4 X 10^8 CYCLES

CATEGORY (NOTE 2)	Allowable Alternating CIS At Various A- Values A = 1 (R = 0)	A=0.5 (R=0.33)	A=0.1 (R=0.818)
A	2.07	1.99	1.51
B	1.58	1.53	1.23
C, C*	1.124	1.10	0.935
D	0.868	0.854	0.751
E	0.692	0.683	0.616
F	0.934	0.917	0.800

NOTES:

(1) The RMC Design alternating stress must not exceed the above values if there is no PWHT

(2) Categories are defined by AISC Manual of Steel Construction, 8th Edition

(3) Configurations not defined by note (2) shall be considered individually

(4) CIS = Total Cycle Intercept Stress found by extrapolation of S-N data to the number of cycles in the applied stress histogram

(5) $A = \frac{\text{RMC alternating stress}}{\text{average mean stress}}$

(6) $RMC = [\Sigma(s_{a_i}^3 n_i)/\Sigma n_i]^{1/3}$

(7) The maximum stress range in the histogram must be compared to the CGT allowables of Table 4.3-2. Flaw growth analysis shall be used to evaluate stresses in excess of CGT, Table 4.3-2.

(8) Table 4.3-3 is not effected by parent material yield point

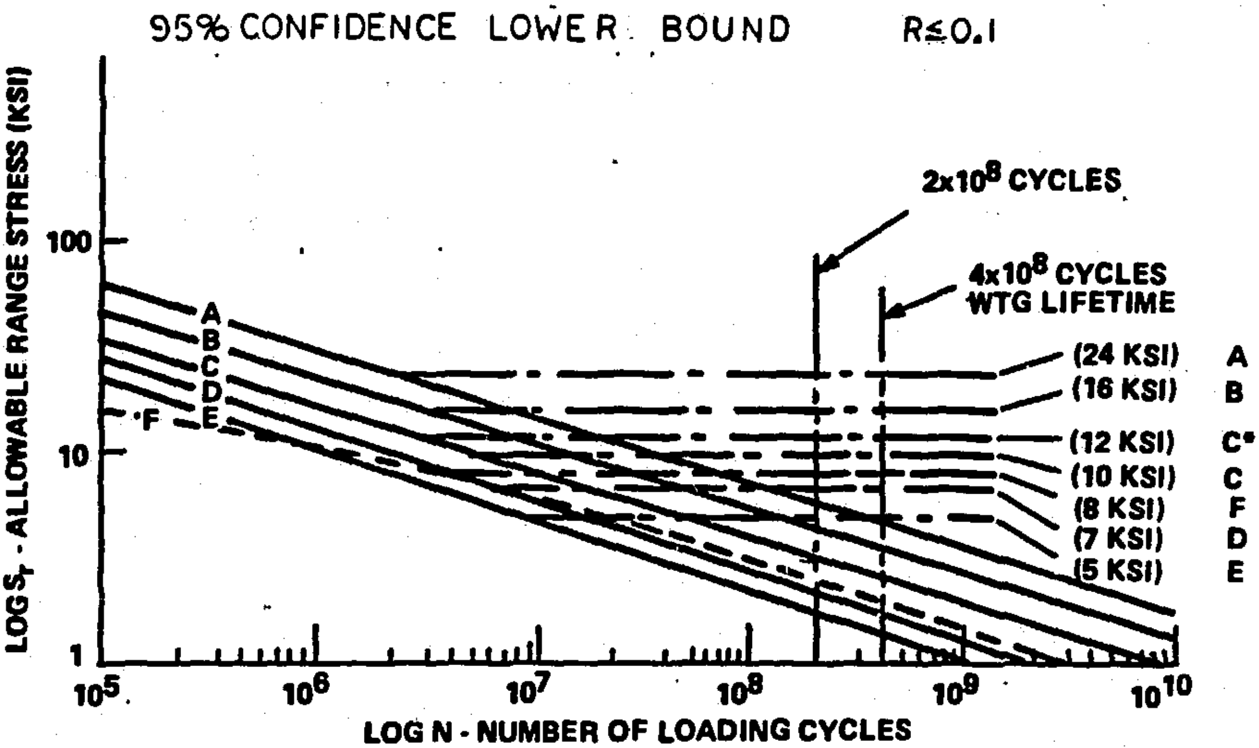


FIGURE 4.3-5

S-N CURVES FOR VARIOUS WELD CATEGORIES

See Table 4.3-2 for extrapolation to other R-values

4.3.6.3 Wood Allowable Stresses

Each component of stress due to the combined design loading must be less than the allowable values in Table 4.3-4 and Figure 4.3-6(b). In conceptual design the 99.9 percentile of the histogram of operating stress should be below the fatigue test data strength extrapolation for 4 x 10^8 cycles considering the MOD-5A moisture content, temperature, size, R- value, and duration of load versus those parameters in the material test program. Miner's ratio may be used with S-N data including stress ratio effects for detailed analysis of fatigue in the Final Design.

For a stud bonded in a prepared hole parallel to the grain according to Drawing 47D382086-G1, allowable loads are given in Figure 4.3-6c. The compressive mean side does not have reflective symmetry with the tensile mean side of Figure 4.3-6c.

4.3.6.4 Glass Fiber Reinforced Plastic Allowable Stresses

Each component of stress due to the combined design maximum or limit loading must be less than the strength reported in MIL-H-17 by the proportions listed in Table 4.3-5, until more applicable data is available.

The 99.9 percentile maximum stress in the fatigue stress histogram should, for conceptual design lie within the boundaries in Figure 4.3-7 which were derived by extrapolation of data in MIL-H-17. Damage accumulation methods considering the effect of stress ratio may be used during detailed analysis. Duration of load data shows that if the maximum steady stress is less than 60% of proportional limit stress, or of ultimate in tension, then no creep should occur. If room temperature curing resins are used, allowables shall be based on applicable test data.

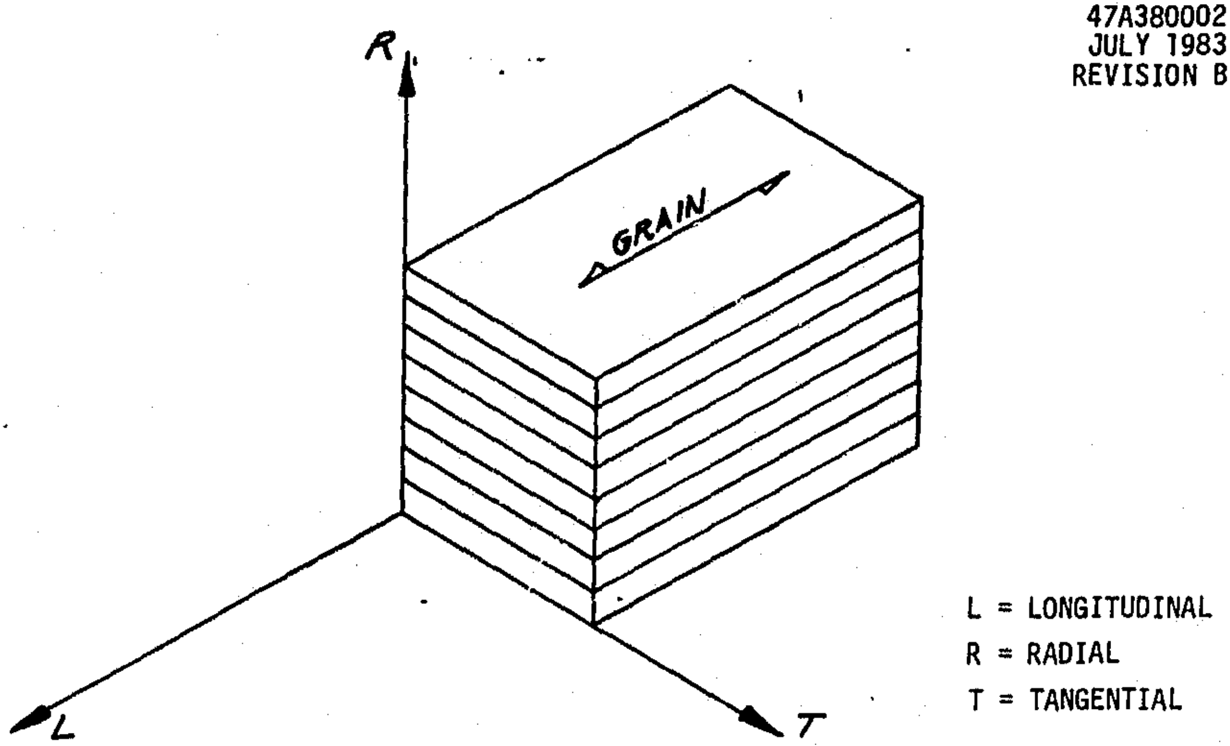
TABLE 4.3-4

Douglas Fir (Coastal) Laminated Veneer Allowables
at 10% M.C., Blade Grade 1*

	Allowable Stress (psi)		
Parallel To Grain	Working	Fatigue @ 4 x 10^8 Cycles R = -1	Fatigue @ 4 x 10^8 Cycles R=+1
Tension	4100	1280	3200
Compression	-4430	-1280	-3710
Shear LT	900	±300	730
Shear LR	1139	±300	730
Perpendicular To Grain			
Tension R	190	±60	150
Tension T	100	±30	75
Compression R	-230	±120	-289
Compression T	-440	±260	-630
Shear RT	110	±40	90

* Blade Grade 1 is selected ultrasonically for modulus greater than 2.45 x 10^6, and is used for the more highly stressed applications. Allowables for Blade Grade 2 are TBD.

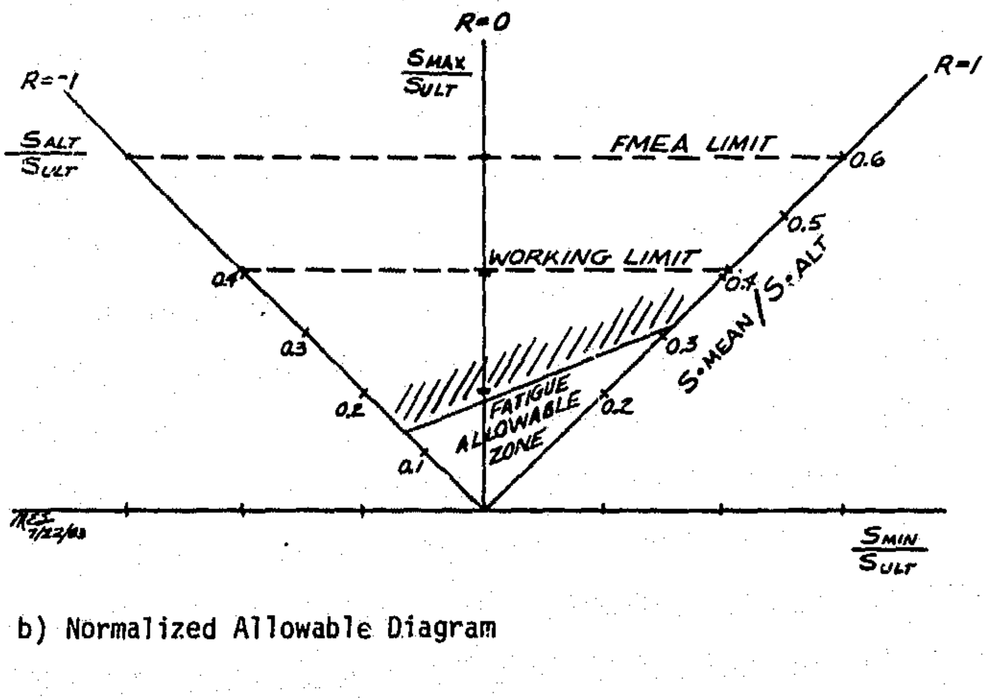
FMEA studies may use stress levels for full-scale minimum proportional limit or ultimate strength, depending on orientation of stress, which are approximately 1.5 times the above "Working" allowable maximum stresses.



a) Nomenclature

Veneers are tangential slices from timber by peeling 1/10 inch layer from rotating log.

Laminations are composed of veneers which are in the LT plane.



b) Normalized Allowable Diagram

FIGURE 4.3-6
WOOD NOMENCLATURE AND NORMALIZED ALLOWABLE DIAGRAM

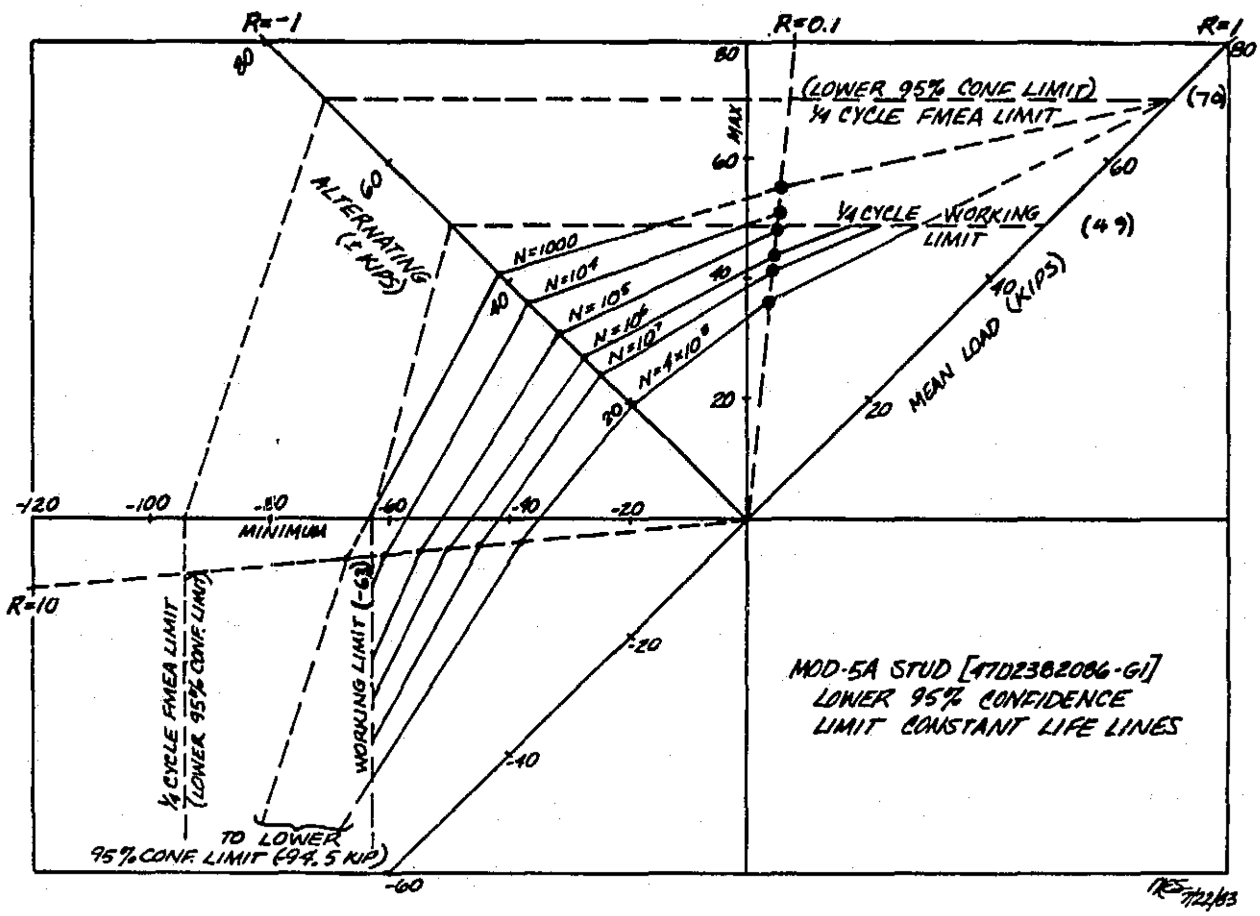


FIGURE 4.3-6 (c)

STUD DESIGN ALOWABLES

TABLE 4.3-5

FIBERGLASS STATIC STRENGTH

FACTOR OF SAFETY REQUIREMENTS

(ALL TEMPERATURES)

$$\frac{\text{Ultimate Strength}}{\text{Maximum Design Stress}} > 3.0$$

$$\frac{\text{Proportional Limit Stress}}{\text{Maximum Design Stress}} > 2.0$$

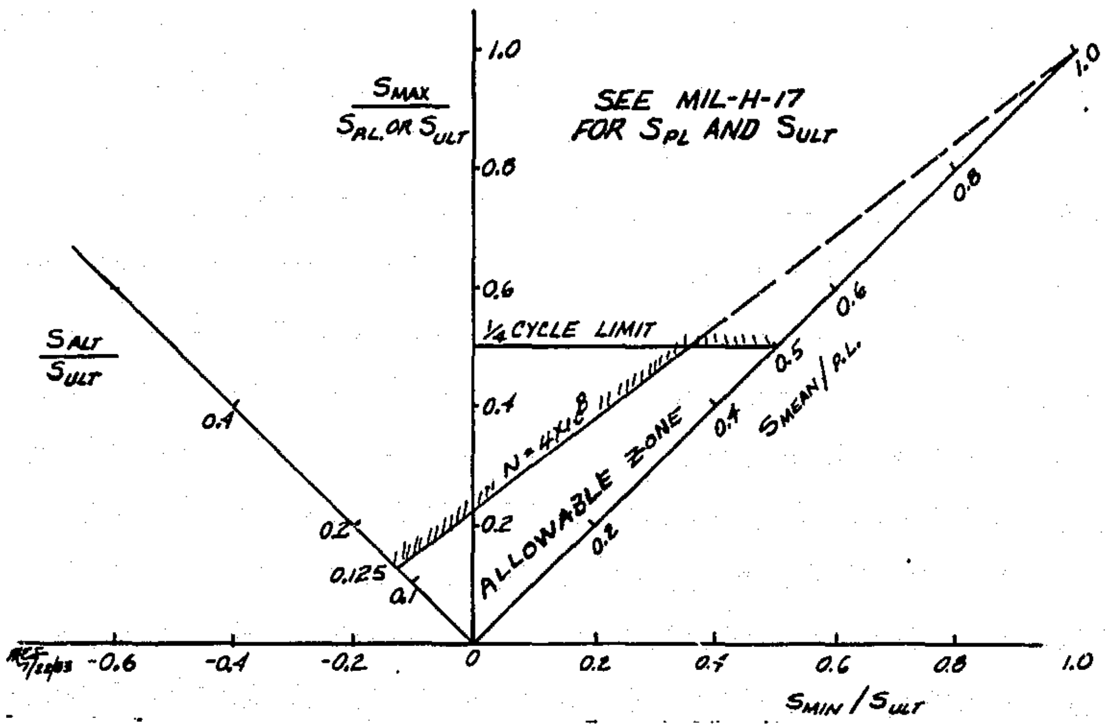


FIGURE 4.3-7
FIBERGLASS FATIGUE ALLOWABLE STRESS
FOR CONCEPTUAL DESIGN

4.3.7 ALIGNMENT

The WTG structure shall be designed to meet component installation mechanical and thermal alignment requirements within established error budget allocations. These requirements shall be met after exposure to all environments to which the WTG could be subjected throughout its design life.

Mechanical alignment includes consideration of load deflections during operation, maximum wind conditions, maneuvering, hysteresis effects, mechanical adjustment uncertainties, and manufacturing assembly tolerances.

Thermal alignment shall include distortion of equipment mounts and local supporting structure due to the thermal environment, overall thermal distortion of the primary structure, and thermal creep effects.

4.3.8 THERMAL EFFECTS

Consideration shall be given to thermal effects on the structure including temperatures, temperature gradients, thermal stresses, thermal deformations, and mechanical and physical material property changes. Mating of materials with widely varying coefficients of expansion in areas susceptible to large temperature variations shall be avoided. Temperature distributions shall be derived by rational analyses, considering the steady state and transient thermal environments.

The structural design shall account for: (1) Temperature distributions that vary with time; (2) Deflections due to creep as well as deflections due to short term applied loads and temperatures; and (3) compatibility of strains and deformations induced by differential thermal expansion and contraction of elements of the structure.

4.3.9 WELDING

Welded joints shall be in accordance with applicable welding specifications, as provided by the AISC Specification and the "Structural Welding Code" of the AWS (detailed specifications for MOD-5A to be determined). Full penetration weld call-outs are strongly recommended for joints in the primary load path. Other welds such as fillet welds may be considered on an individual basis.

4.3.10 FASTENERS

4.3.10.1 Bolted Joints

Bolted fasteners shall adhere to Paragraph 1.4.4 of the AISC Specification which recommends conformity to the latest edition of one of the following specifications:

> High Strength Bolts for Structural Steel Joints, Including Suitable Nuts and Plain Hardened Washers, ASTM A325, or special bolts from a reputable supplier.
>
> Quenched and Tempered Alloy Steel Bolts for Structural Steel Joints, ASTM A490 with additional specifications that maximum hardness be less than 36 on Rockwell C scale, threads shall be cold-rolled after heat treatment.
>
> Other bolts shall conform to the Specification for Low-Carbon Steel Externally and Internally Threaded Standard Fasteners, ASTM A307, latest edition, hereinafter designed as A307 bolts.

Manufacturer's certification shall constitute sufficient evidence of conformity with the specifications.

All threaded fasteners intended for fatigue application must have the thread form cold-rolled after heat treatment. Fasteners with hardness greater than Rockwell C 36 require certification for stress corrosion resistance. All fasteners should be zinc coated according to GE EMPIS Specification F70B1A.

4.3.10.1 Bolted Joints (cont'd)

The shanks of all structural bolts in shear shall have no threads in bearing in sheet or fittings equal to or less than .093 inch thickness. In thicker sheet or fittings, a maximum of two threads, including thread runout, is permitted in bearing when based on the maximum joint thickness and minimum bolt grip. However, not more than 25 percent of the minimum thickness of the sheet or fitting shall have threads in bearing. Structural bolts in primary load paths shall have a minimum diameter of 3/4 inches, except as approved by the Manager of Engineering.

Bolt and screw applications shall be pre-stressed as recommended for tension applications to obtain tight joints with minimum hysteresis effects. An hydraulic bolt tensioner is the recommended pre-tensioning device.

Residual preload after tightening should be verified by a test simulating the joint. All joints in which preload is required to achieve satisfactory structural integrity shall be checked for tightness at assembly and rechecked after 50 to 100 hours of WTG operation. Positive mechanical approaches should be used to preserve tightness. A paint stripe should be applied after tightning to indicate the tight position of studs, bolts and washers with respect to the parts being held, on critical bolts.

Bolt design load estimates shall include the effects of eccentric design load paths and joint flexibility. See Table 4.2-3 for minimum prying action value.

Residual preload shall be sufficient to preclude joint opening under maximum joint tension amplified by prying action. The maximum recommended residual preload is 75% of the bolt material yield point calculated with the reduced or "stress area" of the fastener. In order to achieve beneficial fastener flexibility in clamping together stiff flanges, the actual geometry and loading must be evaluated as in reference (g).

4.3.10.2 Torque Carrying Bolted Joints

The design of flanged joints which carry torque and bending through the joint must consider the combination of both types of loads in establishing the margin of safety. The bending portion involves design with bolts in tension for which good guidance can be found in reference (g) among others. The design for the torque load path must include some assumptions for the value of the coefficient of friction and the number of bolts simultaneously sharing the load in single shear. Close tolerance holes are mandatory so that bolt bending is minimal if the friction torque capability is overcome. Line-to-line or interference fit shear pins and keys may be required.

Table 4.3-6 summarizes some recommended values and assumptions. Shear forces from torque and all loads transverse to the tube axis must be combined with any bending and axial loads by the use of a suitable interaction formula.

TABLE 4.3-6

RECOMMENDED PARAMETERS FOR BOLTED JOINT DESIGN

Maximum Residual Preload of Bolts	75% of Yield
Maximum Fraction of Bolts Carrying Torque via Single Shear (Close Tol. Design)	34%
Coefficient of Static Friction Steel to Steel, surfaces grit blast cleaned, degreased	0.2
Coefficient of Static Friction with Thin Copper Shim	0.3
Minimum Torque Capability of Only the Bolts (34%) in Shear	1.5 x Maximum Torque
Minimum Torque Capability of Only the Friction (no loss of preload)	2.25 x Maximum
Minimum Grip Length Divided by Diameter	6.0
Embedment Factor to Estimate Residual Preload	0.8

4.3.11 VENTING

Consideration shall be given to providing adequate venting of each structural component in order to prevent significant loadings due to the ambier ressure differentials encountered during the WTG Service Life. A structure without satisfactory venting will be designed for an internal pressure of 5 psi, unless otherwise determined. The final design shall provide a blade venting arrangement which results in a blade internal gauge pressure (due to centrifugal gradients) of less than ±0.5 psi.

All airfoil cells and honeycomb shall be vented to preclude overpressure resulting from shipment by air cargo in an unpressurized cabin or bay.

4.3.12 MISALIGNMENT AND DIMENSIONAL TOLERANCES

The effects of allowable structural misalignments, deflections and other permissable and expected dimensional tolerances shall be included in the analysis of all loads, load distribution, and allowable loads.

SECTION 5.0

DESIGN CONDITIONS

5.1 GENERAL CONDITIONS

All static and dynamic loads and pressures (external and internal) which may affect structural integrity or influence design shall be defined and accounted for. The effects of thermally and mechanically induced structural deflections, allowable structural misalignments, and structural offsets and dimensional tolerances shall be included in analysis of loads, load distributions, and structural adequacy. Limit loads shall be determined for the WTG in all configurations for the design conditions identified in this document.

Loads shall be distributed throughout the structure by rational analysis which include the effects of structural non-linearities and temperature. Analysis of dynamic loads shall account for all significant changes in WTG mass properties with time and all significant structural flexibilities, damping, and load spectra. The analysis shall also account for coupling of the various components and subassemblies of the WTG; these include: the rotor system (blades, hub, teeter bearings, stops, etc.), drive system (shafts, gearbox, brake, generator, and associated equipment), nacelle, yaw system, tower, foundation, and soil stiffness.

5.2 DESIGN CONDITIONS AND ENVIRONMENT

This section presents the operational, non-operational, and environmental loading conditions that are considered significant to the structural design of the WTG.

5.2.1 OPERATIONAL LOADING CONDITIONS

5.2.1.1 Critical Environments

The WTG will be designed to survive, with adequate margin, the loads and environments associated with all phases of operation, including steady winds, gusts, maximum winds, shutdowns, startups, maneuvering, and braking.

5.2.1.2 Primary Structure

The primary structure may be defined as that structure which provides the system major load paths from the points of initiation of the loads to the loads to the system reaction point. In this case, the loads result from steady and cyclic loads on the rotor blades, rotational loads on the rotor system and drive system, and the gross weights of the major subassemblies which constitute the primary structure. The reaction point in this case is the tower foundation. The items constituting the primary structure of the WTG system are: the rotor blades, hub, teeter bearing, drive train, nacelle/bedplate, yaw system, tower, and foundation.

5.2.1.2.1 Critical Loading Conditions

For initial sizing of primary structure components maximum quasi-static limit applied loads and static weights distribution are used. These loads apply to areas where fatigue from cyclic loads is not expected to be the design driving force. These forces and weights are subject to the design load factors of Paragraph 4.2.4. Rechecks for fatigue will be made as loading histograms are derived.

5.2.1.2.1 Critical Loading Conditions (cont'd)

For areas in which fatigue design is probably the design driver (the rotor, hub and drive train), a dynamic analysis evaluating combinations of oscillatory and steady state effects will provide loadings.

5.2.1.2.2 Minimum Resonant Frequencies

The primary structure shall provide adequate stiffness to satisfy the system requirement for resonant frequency. The design selected for the MOD-5A WTG represents a "soft" tower approach with the first cantilevered bending mode frequency chosen, well below the predominant exciting frequency of 2P at normal RPM, and with sufficient separation at reduced RPM. The resulting loads alleviation provides roughly a 50% reduction of cyclic and seismic loading.

The placement of the coupled tower/foundation resonant frequency is complicated by the two-speed operation of the WTG, since the system natural frequencies should not coincide with the 1P, 2P, 3P, etc., forcing frequencies. A frequency separation of 1/2 P from the forcing frequency is recommended, but smaller separations may be permitted if verified by systems dynamic analysis.

Resonant frequencies for other WTG system subassemblies should be sufficiently separated from this system (tower/foundation) resonant frequency to preclude coupling between components.

5.2.1.3 Secondary Structure

For the purposes of WTG development, the secondary structure may be defined as that structure which constitutes and locally supports the various equipment modules or components; it also includes the operating panels, and other component support bracketry of a non-structural nature. Major items such as the gearbox, generator, brake, etc., are essentially load-carrying, and do not fall into this category.

5.2.1.3.1 Critical Loading Conditions

The general loads requirements for secondary structure, brackets, and components contained in the nacelle/bedplate or the tower are as follows:

Vertically (X-Axis) ± 2 g

Laterally (Y or Z-Axes) ± 5 g

NOTE: Axis definition is that established by Figure 4.3-1.

These load levels may be superseded by dynamic forced response analysis considering the mounting as excited by the predicted vibration of the primary structure.

For secondary structure, etc., contained in the rotating portion of the WTG outboard of the nacelle rotor bearing interface (rotor blades, PSC, and hub), the effects of centrifugal force (estimated at 20g at the PSC at 75% X/R) and gyroscopic moments must be considered.

These g factors are to be used for design and stress analysis of components and their attachments to the structure. Loads (g factor times weight) shall be applied separately for each of the three principal axes. These loads are the result of the vibration environment, and are subject to the factors of Paragraph 4.2.4. Transportation, operational and thermal loads shall be considered separately.

5.2.1.3.2 Resonant Frequencies

Individual components, when mounted to their secondary support structure, shall be designed to meet a design goal of 20 Hz or more in all directions.

5.2.2 NON-OPERATIONAL LOADING CONDITIONS

The structural design shall include consideration of all non-operational environments to which the subassemblies and their component parts are exposed during manufacture, ground handling, transportation and erection. Except for local areas at handling attachment points, the non-operational loads shall govern design of the structure to the minimum extent possible. Environments of MIL-STD-810B are deemed applicable to supplement information that follows:

5.2.2.1 Manufacturing

Fabrication and assembly operations effects on the structural design shall be evaluated for (1) material handling, forming, stretching or other processing; (2) misfit and misalignments; (3) welding, bonding and brazing; (4) heat treatment; and (5) checkout and acceptance operations including pressurization cycles.

5.2.2.2 Transportation and Ground Handling

During transportation and ground handling, the effects of natural and induced environments on the WTG structure shall be evaluated.

5.2.2.3 Transportation Limit Load Factors

Limit load factors for transportation of the WTG are as follows:

Longitudinal	± 3.0 (truck)
	± 9.0 (rail)
Lateral	± 1.0
Vertical	+3.0

5.2.2.3 Transportation Limit Load Factors (cont'd)

These load factors include the maximum expected quasi-steady accelerations expected from truck or rail transportation and are to be applied separately as equivalent static loads. The directional terms are with respect to the transport vehicle axes. The component effective weight shall be the design gross weight, plus the weight of any non-operational equipment supported by the component, during ground handling operations.

5.2.2.4 Hoisting Limit Load Factors

The limit load factor for hoisting the WTG components and subassemblies shall be applied upward in any direction within 20 degrees of vertical (see Table 4.2-1). The hoisting weight shall be the design weight of the applicable component or subassembly plus any attached weights.

5.2.2.5 Mating and Erecting Limit Load Factors

Limit load factors for vertical mating and erecting of the WTG subassemblies shall be TBD. The subassembly shall be within the attitude envelope established for erecting and mating. The effective weight shall be the component design weight plus any attached weights.

5.2.2.6 Storage

Loads and environments which the structural components may experience during storage shall be accounted for or the structure shall be protected against them. At least the following shall be considered:

1. Pressure-differential loads, including the effects of venting.
2. Natural and induced environments.
3. Environments and loads from stored fluids, considering pressure and temperature as well as chemical and physical effects on structural materials and adhesives.
4. Changes in moisture content of wood.

5.2.3 ENVIRONMENTAL CONSIDERATIONS

5.2.3.1 Temperature

The WTG shall be capable of survival in temperatures from -40 degrees C to +49 degrees C (-40 degrees F to +120 degrees F) ambient air, and operation from -30°C to +40°C (-22°F to +104°F) ambient air.

5.2.3.2 Seismic

The WTG, excluding the foundation, shall be designed to the seismic requirements characteristic of Zone 3 per the Uniform Building Code. The foundation shall be designed to seismic environments and soil conditions appropriate to the site. Prior to site selection, the foundation design shall be based on Zone 3 seismic requirements assuming firm soil conditions having a bearing design strength of 4000 psf (12000 psf static bearing capacity).

5.2.3.3 Precipitation

The WTG shall be subjected to the following precipitation environments after installation, per Paragraphs 3.4 and 3.5, SOW, Exhibit B:

Rain:	4 inches/hour
Hail:	1.0 inch dia., 50 lb/cu. ft., 66.6 ft/sec terminal velocity (for horizontal and vertical surfaces)
Ice:	2.0 inches, 60 lb/cu. ft. on all external surfaces non-operating
Snow:	Blade: 21 lb/sq. ft. Nacelle: 41 lb/sq. ft.

5.2.3.4 Lightning

The WTG shall be subjected to lightning strikes as defined in Figure B-1, SOW, Exhibit B.

5.2.3.5 Projectile Impact

The WTG shall be subjected to impact of 4 lb. birds moving at 35 mph, on surfaces above 150 feet. Failures are not permitted, but local yielding is allowed.

5.2.3.6 Corrosion

Steel alloys should be selected with a stress corrosion cracking stress intensity threshold (K_{ISCC}) of more than 50 KSI $\sqrt{IN}$. Protective coatings will be used and maintained on a schedule related to the durability of the coating.

SECTION 6.0

PROOF OF DESIGN

Proof of structural adequacy of the design under all critical combinations of design loads and environmental conditions shall be provided by analysis and/or tests, all of which shall be documented.

6.1 ANALYSIS DOCUMENTATION

Reports shall be prepared on analysis made to verify structural adequacy in compliance with criteria contained in this document.

6.1.1 DYNAMIC ANALYSIS

A dynamic analysis of the coupled WTG component assemblies, including the foundation and soil stiffness, will be performed. The mathematical model of the WTG system will be a linear, lumped-parameter, coupled system with up to six degrees of freedom per mass element.

This analysis will:

1. Support and verify the design of the WTG system to the fundamental frequency requirements.
2. Furnish the analytical model for operational loads and dynamic deflections analysis.

6.1.2 INTERNAL LOADS ANALYSIS

From the design loads and associated environments, the critical loads and/or critical combinations of loads on the structure shall be used in loads analysis to obtain the internal loads in the primary structure. The interactions of the various structural components shall be considered in this loads analysis.

Structural loads induced by ground handling, including hoisting, transportation, and erection of the WTG components shall be determined.

6.1.3 STRUCTURAL ANALYSIS

A structural analysis of the major components of the WTG assembly will be performed evaluating stresses and deflections resulting from critical loads, environments, and temperatures anticipated during its 30 year service life. For the purposes of this document, the major components of the WTG assembly will be limited to the rotor assembly (blades, PSC and hub), the nacelle/bedplate, the tower, the foundation, and all secondary structures contained by those components above the ground level as deemed necessary. This analysis shall define the critical loads and design conditions, and determine stress levels and margins of safety.

6.2 DOCUMENTATION FORMAT

It is desirable that documentation of individual structural analyses in support of the WTG development shall follow a consistent format. The following general format is suggested for utilization in PIR documentation of these structural analyses:

1.0	Introduction	(a) Objective (b) Approach (c) Background
2.0	Results	(a) Tables: Margins of Safety Natural Frequencies, if pertinent Fatigue results (b) Other pertinent summary data
3.0	Conclusions & Recommendations	(a) Are criteria, requirements, goals met? (b) Recommended changes, additional analysis, etc.
4.0	Substantiating Data	(a) Scope of Analysis (b) Approach, methods, models, etc. (c) Sample analysis, notes.

The objective of Sections 1.0 through 3.0 are to briefly describe the problem, the resulting data, and what it means. Section 4.0 will describe in greater detail the scope and methods of analysis, computer models, materials, assumptions, limitations, etc. Pertinent notes and critical element analyses should be attached.

The WEPO Outline for Structural Analysis Reports, per reference (f), is presented as a guide to more formal documentation, such as final reports, and also forms a logical guide to the organization of structural analysis work.

GENERAL ELECTRIC

47A380008

CONT ON SHEET ii SH NO. i

REV NO. A1

47A380008

CONT ON SHEET ii SH NO. i

TITLE

FIRST MADE FOR

REVISION

A REVISED PER AN-1 2/15/84

GENERATOR STEP-UP TRANSFORMER SPECIFICATION

FOR THE

MOD-5A WIND TURBINE GENERATOR

OCTOBER 1982

REV "A" JAN. 84

Keith E McFarland DATE: 11-4-82
Responsible Engineer

GP Schanzenbach DATE: 11-11-82
Subsystem Engineering

DATE: 15 NOV '82
Systems Engineering

A. Chedder DATE: 11-10-82
Quality Assurance

A. Evenko DATE: 11/12/82
WTG Integration

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A. E. P. DEPT.

KING OF PRUSSIA, PA. LOCATION

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REVISION LOG

This log identifies those portions of this document which have been revised since original issue. Revised portions of each page, for the current revision only, are identified by marginal striping.

Revision	Page No.	Paragraph Number(s) Affected	Rev. Date	Approval
A	2	2.1	Jan.'84	Dec.84-089
A	3	3.1, 3.1.1.2		
A	4	3.1.1.4		
A	6	Table 3-2		
A	7	3.2.2.2		AN-1
A	8	3.2.3.2		

TABLE OF CONTENTS

LIST OF TABLES

NUMBER PAGE

SECTION 1.0

SCOPE

This specification establishes the performance, design and test requirements for a generator step-up transformer hereafter referred to as the GSU transformer, intended for use on the MOD-5A Wind Turbine Generator System.

1.1 INTRODUCTION

The MOD-5A Wind Turbine Generator System extracts energy from wind to power a generator. The GSU transformer provides voltage matching and protective functions in order to connect the generator to an electric power network.

SECTION 2.0

APPLICABLE DOCUMENTS

The following documents of the date of this issue or as indicated below form a part of this specification to the extent referenced herein. In the event of conflict between this specification and the documents referenced herein, the contents of this specification shall be considered as superceding requirements.

2.1 GENERAL ELECTRIC

47E387080	Electrical System One-Line Diagram
47A380048	Specification For Material Finishes, MOD-5A

2.2 INDUSTRY STANDARDS

ANSI C57.12	Requirements, Terminology and Test Code for Transformers

SECTION 3.0

REQUIREMENTS

3.1 DEFINTION

The outdoor GSU transformer subsystem shall consist of the following components.

1. One oil immersed distribution service type transformer with ratings defined in Table 3-1 including fan assisted cooling and air filled connection compartments.
2. Current transformer mounted to measure current in the primary neutral and optionally, when so identified on an order, current transformers mounted to measure current in each phase of the primary voltage windings.
3. Accessories of paragraph 3.2.4

3.1.1 INTERFACE DEFINITION

3.1.1.1 Control Interface

Remotely mounted current sensing relays will be used by the purchaser to monitor the current transformer secondary currents.

Relays, fan and heater power circuits will be connected at terminal boards located within the transformer secondary terminal compartment.

Auxiliary power shall be 480 VAC 3-phase.

3.1.1.2 Structures Interface

The GSU transformer shall be anchored on a poured concrete foundation pad with a cable bus connecting the transformer secondary wiring to the ground control equipment and roof bushings for the primary wiring.

3.1.1.3 Utility Interface

The primary voltage, as defined in Table 3-2, will connect with the utility. The connection cable will be routed from the roof bushings to the utility company pole. The closest pole and/or the bushings will have lightning arrestors and fused cutouts suitable for primary winding protection.

3.1.1.4 WTG Interface

The 4.16 kV connections will be routed to the ground control equipment using cable bus. Connections for auxiliary power (fans) and instrument transformers will be by way of surface mounted or underground conduit.

3.2 CHARACTERISTICS

3.2.1 PERFORMANCE

The GSU transformer shall have standard ratings as listed in Table 3-1.

TABLE 3-1

TRANSFORMER RATING AND REQUIREMENTS

Capacity	5840/7300 KVA OA/FA 65 degrees C
Type and Frequency	60 Hz, 3 Phase
Impedance	5.5% at 5840 KVA
Primary 4 Wire	WYE connected Solidly Grounded Neutral Voltage and BIL per Table 3-2
Secondary 3 Wire	4.16 KV DELTA connected, 110 KV BIL
Primary and Secondary Components	Air filled, procelain bushings with accessories
Taps (With No Load Tap Changer)	4 - 2-1/2% TAPS on Primary 2 UP, 2 DOWN from Rating
Expected Life	30 years
Maintenance Interval	12 Months Nominal

TABLE 3-2
PART NUMBER/RATING TABLE

PART NO.	PRIMARY VOLTAGE	PRIMARY BIL	CT/RATIO NEUTRAL	CT/RATIO PRIMARY (WHEN REQ'D)	OTHER
001	69 KV	250	300/5	100/5	--
002	46 KV	200	400/5	200/5	--

3.2.1.1. Fill Type

Transformer shall be of oil-filled, +65°C rise construction.

3.2.1.2 Taps

The transformer shall have primary connections at 95, 97.5, 100, 102.5 and 105% of basic primary voltage.

Taps shall be brought to an externally operated manual tap changer for operating only when the transformer is de-energized.

3.2.2 INCOMING LINE

3.2.2.1 Primary Connection

The primary connection is by way of roof bushings on the high voltage compartment. Clamp type terminals for copper or aluminum cable up to 4/0 connecting to the busings and a solid neutral grounding point shall be provided.

3.2.2.2 Current Transformers

Six (6) current transformers, two (2) per phase on the primary line, with a ratio as defined in Table 3-2 with an accuracy of T200 shall be provided when so identified on an order. A current transformer, on the primary line neutral, with a ratio as defined in Table 3-2 and an accuracy of T200 shall also be provided.

Current transformers shall be mounted in the primary terminal compartment with provision for connection to remotely mounted relays by way of surface mounted or underground conduit.

3.2.3 OUTGOING LINE

3.2.3.1 Secondary Connection

The 4.16 K volt secondary shall be DELTA connected.

3.2.3.2 Secondary Terminal Compartment

An air-filled low-voltage terminal compartment shall be mounted integrally with the transformer with terminations available for attaching two (2) each per phase, 750 MCM cables through the cable bus to the ground control equipment. Connections shall be copper with silver plated joints.

3.2.4 ACCESSORIES

The transformer shall have the accessories called out in Table 3-3.

TABLE 3-3
ACCESSORIES

- Mechanical, resealing, pressure relief device
- Lifting eyes to permit pulling or hoisting transformer
- Provision for rolling or skidding in any direction
- Ground pads
- Hand hole
- Drain valve
- Oil sampling device
- Provision for jacking to level unit
- Diagrammatic nameplate
- Liquid-level gage with alarm contacts (Device 71)
- Thermometer relay for fan control
- Pressure-vacuum gage
- Fans for operation to 7300 KVA
- Winding temperature gage with alarm contacts. (Device 49)
- Key interlock system to prevent compartment access unless de-energized
- Anti-condensation heaters in connection compartments, for continuous operation
- Base anchor bolt holes or hold down clamps

3.2.5 PHYSICAL CHARACTERISTICS

3.2.5.1 Envelope

The GSU transformer assembly shall fit within an envelope of 119 inches in height, 84 inches in width, and 81 inches in depth, not including tap changer operation or roof bushings.

3.2.5.2 Paint Finish

Transformer shall be painted in accordance with GE Specification 47A380048 (semi-gloss blue/Fed - Std-595, Color 25177).

3.2.6 RELIABILITY

The expected lifetime of the GSU transformer shall be 30 years at greater than 99% availability.

3.2.7 MAINTAINABILITY

Routine maintenance shall be able to be performed on site. Interval between routine maintenance cycles shall be not less than one (1) year.

3.2.8 ENVIRONMENTAL CONDITIONS

Construction shall be suitable for typical truck and rail shipment and outdoor service. Operating altitude will be 0-7000 feet. Operation above 3300 feet will be subject to vendor specified derating. Unusual service conditions of operating near a coast with salt spray and moisture are optionally required where identified on an order. Zinc rich prime paint, anti-corrosion treatment, and high creep bushings are expected as appropriate on such order identification.

SECTION 4.0

VERIFICATION

4.1 STANDARD TEST

The following tests will be made as a minimum by the vendor. The numbers shown do not necessarily indicate the sequence in which the tests shall be performed. All tests shall be performed in accordance with the latest revision of ANSI Standard Test Code for Transformers C57.12.90-1980.

4.1.1 RESISTANCE MEASUREMENTS

Resistance measurements of all windings on the rated voltage connection of each unit and at the tap extremes.

4.1.2 RATIO TEST

Ratio tests on the rated voltage connection and on all tap connections.

4.1.3 POLARITY AND PHASE RELATION

Polarity and phase-relation tests on the rated voltage connection.

4.1.4 NO-LOAD LOSS

No-load loss at rated voltage on the rated voltage connection.

4.1.5 EXCITING CURRENT

Exciting current at rated voltage test on the rated voltage connection.

4.1.6 LOAD LOSS

Impedance and load loss test at rated current on the rated voltage connection of each unit and on the tap extremes of the unit.

4.1.7 LOW FREQUENCY VOLTAGE

Winding insulation tests between phases and from each phase to ground.

SECTION 5.0

PREPARATION FOR DELIVERY

The manufacturer shall submit a statement detailing the normal practice of packaging and method of delivery for approval by:

General Electric Company
Advanced Energy Programs Department
P.O. Box 527
King of Prussia, PA 19406

5.1 DOCUMENTS

o Certified detailed outline drawing	a, b
o Connection diagrams	a, b
o Complete instructions with parts list	b
o Detailed summary or equipment list	b
o Three (3) certified copies of test data	b

5.1.1 DOCUMENT SUBMITTAL

Documents marked "a" shall be submitted for examination or approval within six (6) weeks of order by sending two (2) copies to General Electric Company, Advanced Energy Programs Department, MOD-5A Engineering, P.O. Box 527, King of Prussia, PA 19406. Approval or comments will be returned within two (2) weeks of receipt.

Documents marked "b" shall be supplied with shipment. One (1) mylar reproducible and ten (1) copies of each drawing shall be supplied. Twelve (12) copies of instruction books shall be supplied. In addition, one copy of all documents shall be enclosed with shipment.

Documents marked "a, b" shall meet submittal requirements of both "a" and "b".

GENERAL ELECTRIC

47A380009

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47A380009 CONT ON SHEET ii SH NO. i	FIRST MADE FOR

REVISIO

DESIGN SPECIFICATION

FOR THE

DESIGN, FABRICATION, AND TEST

OF THE

MOD 5A WIND TURBINE BLADE

Prepared by: V. DiNenna, Blade Engineer — DATE: 6-4-84

Approved by: D. Hetzel, Subsystem Engineer — DATE: 6-1-84

R. Barton, Chief Engineer — DATE: 6-4-84

J. Wright/L. Jankauskas, Mfg. Engineering — DATE: 6-1-84

N/A A. Cheddar, Quality Assurance — DATE: —

J. Kern, Subcontracts Manager — DATE: 6-1-84

W. Pijawka, Program Manager — DATE: 6/4/84

ACGR-JHe 6/7/84

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REVISION LOG

This log identifies those portions of this document which have been revised since original issue. revised portions of each page, for the current revision only, are identified by marginal striping or text notes.

Revision	Page No.	Paragraph Number(s) Affected	Rev. Date	Approval

MOD-5A WTG
DESIGN SPECIFICATION
47A380009
NOVEMBER 1983

TABLE OF CONTENTS

SECTION 1.0
INTRODUCTION

1.1 SCOPE

This specification defines the design, fabrication, and test requirements for the blade assembly of the MOD-5A rotor. The blade is a component of a wind turbine system designed to produce 7.3 MW at a rated wind speed of 32 mph.

SECTION 2.0
APPLICABLE DOCUMENTS

GE-AEPD

47A380002	Structural Design Criteria
47A380011	System Specification
47A382285	Aerodynamic Profile Co-ordinates
PIR WTG-MOD-5A-84-316	Loads Definition
47A382590	Blade Assembly Drawing
47E382460	Rotor Blade Tolerance Diagram
47D382406	Blade Geometry
47A Later	Hydraulic Tubing Requirements
47A Later	Electrical Conduit Requirements
47A380074	Q.A. Requirements for Control of Raw Materials and Blade Fabrication Process
47E381057	Yoke Radial Bearing
47E381058	Yoke Thrust Bearing
47D382352	Teeter Brake Link Arm
47A380126	Douglas Fir Veneer
47A Later	Epoxy
47A Later	Carbon Filled Epoxy
47A Later	Fiberglas Cloth
47A Later	Paper Honeycomb
47A Later	Paint

AMERICAN NATIONAL STANDARDS INSTITUTE

ANSI-Y14	Drafting dimensioning and tolerancing standard
ANSI-Y10	Drafting lettering standard
ANSI-Y32	Drafting symbols standard

SECTION 3.0
REQUIREMENTS

3.1 OPERATING

The blade shall be designed to operate in the following environment for 30 years (4 X 10^8 cycles)

a) in winds up to 60 mph.

b) in 0° to 100°F ambient air.

c) in rain, 4"/hr.

d) in hail, 1" dia, 50#/ft³, 66.6 ft/sec.

e) in snow, 21#/ft².

f) Withstand lightning strikes as described in system specification 47A380011.

g) Withstand impact from projectiles, 4# @ 35 mph.

3.2 NON-OPERATING

The blade shall be designed to withstand the following non-operating natural environments:

a) Ambient air temperature of -40°F to 120°F.

b) Loads imposed during transportation. Limit load factors are as follows:

Longitudinal	(In direction of travel	± 3 g's (truck) ± 9 g's (rail)
Lateral	(Perpendicular to direction of travel)	± 1 g's
Vertical		± 3 g's

c) Wind velocities up to 130 mph.

d) Deposition of a 2" coating of ice @ 60/ft³.

3.3 STRUCTURAL

The blade shall be designed to the following:

a) Withstand frequently and seldom occurring limit loads shown in PIR 84-316, load definition, without yielding. The factor of safety shall be, with regard to yield stress, 1.5 for frequently occurring and 1.25 for seldom occurring limit loads.

b) Withstand catastrophic limit loads without exceeding the ultimate capability of the blade material. Loads are as shown in PIR 84-316, loads definition.

c) Withstand all loads without buckling. A factor of safety, with regard to the critical buckling load, shall be 1.5.

d) Preclude detrimental deflections due to resonance.

e) Withstand fatigue load histograms shown in PIR 84-316, loads definition, without exceeding a Miner's number of one.

3.4 DESIGN

The blade shall be designed incorporating the following features:

a) The aerodynamic contour as described in 47A382285, aerodynamic profile co-ordinates.

b) Use of a Douglas-Fir veneer/epoxy laminate as the blade primary structural material. Veneer shall be per 47A380126 and epoxy per 47A Later.

c) Suitable for both rail and truck transport. General constraints are shown in Table 1 and Figure 1.

d) Provisions to detect a layer of ice between .05 and .10 inches.

e) Provisions to install hydraulic and electrical conduits as defined by 47A Later, and 47A Later, hydraulic and electrical conduit requirements.

f) Provisions to obtain a static balance about the rotational axis to within requirements specified by 47A380011.

g) Provisions for man access into and thru the internal compartments of the blade. Cutouts in the wood structure are to be augmented with fiberglass cloth, 47A Later, Tp. 1, between each layer of veneer, extending at least one diameter into the surround wood. Raw edges of the wood around perimeter of cutout shall be protected with 2 layers of FRP cloth (See Section 3.5). Where access is provided to the inside of the blade a closure and weather seal shall be provided. The closures shall have provisions which prevent their loss and minimize the possibility of damage to personnel or equipment.

h) Provisions shall be provided to allow natural ventilation of the internal compartments of the blade with ambient air.

i) A painted white surface on the blade with the following exceptions: The outer 7.5% and the portion between 85% - 87.5% of span shall be painted orange. Paint and application shall be per 47A Later.

j) Provisions to tether blade assembly. Imposed loads are defined by PIR 84-316, loads definition.

k) Lifting provisions.

l) A means to attach and transfer loads to the rotor yoke through the yoke radial bearing, 47E381057, and thrust bearing, 47E381058.

m) A means to mount ailerons and aileron actuators and to transfer resultant loads into blade structure.

3.5 FABRICATION

The blade shall be fabricated to the following minimum requirements:

a) Material listed in Table 2.

1) The airfoil defined as the structural material between 0% and 60% of chord, shall be fabricated to the required thickness with Douglas Fir veneer conditioned to 8-10% moisture content (% of overdry weight). The outer 50% of the airfoil skin thickness shall be per 47A380126, BG1 and the inner 50% per 47A380126, BG2. Internal spars and ribs shall also be per 47A380126, BG2. The grain of veneer in the airfoil shall be oriented parallel to the spanwise direction.

2) The individual veneer sheets shall be laminated together with epoxy per 47A Later, Tp 1, using 30 lbs. per 1,000 ft^2 per face.

3) All outside and inside surfaces of airfoil, including internal spars and ribs shall be covered using 2 layers of FRP cloth per 47A Later, Tp 1, saturated with epoxy per 47A Later, Tp 1, at 30 lbs. per 1,000 ft^2 per face.

b) The veneer in the airfoil skin thickness shall utilize 12/1 scarf joints to form a continuous run of material in the spanwise direction. Scarf joints in the skin thickness shall be staggered every 3 inches. Veneer scarf joints are not permitted within 18 inches of the structural scarf joints noted in item "g". At any other spanwise location, the skin thickness shall not contain more than one scarf joint for every 32 layers of veneer. The veneer shall be butted together to form a continuous run of material in the chordwise direction. Butt joints in the skin thickness shall be staggered ever 3 inches. The skin thickness shall not contain more than one butt joint for every 18 layers of veneer.

c) The manufacturing facilities shall ensure that the design moisture content of 8-10% be maintained.

d) The finished aerodynamic contour shall meet the tolerances shown on 47A382460, rotor blade tolerance diagram.

e) Quality control provisions per 47A380074. Records shall be kept to maintain traceability of key structural material items, such as the wood veneer, epoxy components, etc.

f) The fabrication of the airfoil may utilize spanwise "V" joints to effect the finished shape if the joint is transferring primarily shear stress. These joints should be kept to a minimum. Joints shall utilize a nominal bond gap of .12 inch or less.

g) Scarf joints with slopes of 10/1 or greater may be utilized to extend the longitudinal length of structural members provided the joint area is locally reinforced to account for a 90% tensile joint efficiency.

3.6 DOCUMENTATION

a) A complete set of manufacturing drawings, including component and assembly drawings, which meet ANSI-Y14, ANSI-Y10, and ANSI-Y32, shall be provided.

b) A manufacturing plan which describes, in detail, all tasks required to fabricate the blade shall be required.

c) A quality control plan which details all quality control provisions which will be utilized shall be required.

3.7 MAINTENANCE

a) The blade shall be designed to minimize preventive maintenance.

b) The blade shall be designed for a 30 year life.

3.8 INTERFACES

a) The blade shall be designed to interface with the rotor yoke thru the yoke radial bearing 47E381057, thrust bearing, 47E381058, and teeter brake link arms 47D382352.

b) The blade shall be designed to provide a means to mount ailerons and actuators at blade stations shown on 47E382590.

c) The blade shall provide a means to interface with tether lines.

d) The blade shall provide a means to interface with the hydraulic and electric power supplies from the yoke.

3.9 PREPARATION FOR SHIPMENT

a) Blade sections are to be lifted using lift points when provided or otherwise slings. Use of slings shall not impose stresses which exceed allowables specified in 47A380002, Structural Design Criteria.

b) Provisions shall be made to ensure that the moisture content of the blade remains within $\pm$ 1% of nominal manufacturing level.

c) Fixtures shall be provided which will minimize the likelihood of damage occurring during blade shipment.

3.10 ASSEMBLY AND ERECTION

a) An assembly and erection plan shall be developed which defines in detail the tasks necessary to assembly and erect blade.

b) The blade segments shall be assembled in a protected environment which duplicates the manufacturing facilities.

c) The blade assembly shall meet assembly tolerances shown on 47E382460, blade tolerance diagram, and 47E382590, blade assembly drawing.

d) Blade sections are to be lifted at specific lift points if provided or otherwise slings. Use of slings shall not impose stresses which exceed allowables specified in 47A380002, Structural Design Criteria.

4.0 QUALITY ASSURANCE PROVISIONS

The raw materials and blade manufacturing processes shall meet quality control provisions specified in 47A380074. In addition, tests shall be performed and results documented to verify form, fit and function of blade components and assembly. Tests shall consist of the following:

a) In-house/factory acceptance tests.

b) On-site tests.

4.1 IN-HOUSE/FACTORY ACCEPTANCE TESTS

a) Outside envelope of blade sections.

b) Weight and center of gravity measurements of blade sections.

c) Moisture content.

d) Fit-up of field joints.

e) Interface dimensions.

4.2 ON-SITE TESTS

a) Static unbalance of blade assembly.

b) Flapwise and chordwise natural frequency.

c) Flapwise and chordwise 1-G deflection vs. span data for two methods of support.

d) Proof test not exceeding predicted limit stress.

e) Interface dimensions.

f) Hydraulic leaks.

g) Electrical continuity of sensor installation.

h) Electrical continuity of blade ground path.

TABLE 1 - GENERAL TRANSPORTATION CONSTRAINTS

ITEM	RAIL	TRUCK
Maximum weight	260,000 lb.	70,000 lb. (200,000 lb.)
Maximum length	85 ft. (120 ft.)	50 ft. (150 ft.)
Maximum width	Figure 1	12 ft. (14 ft.)
Maximum height	Figure 1	10 ft. (12 ft.)

Values in parenthesis are possible at added cost due to special routing, escorts and permits. Rail limits are more severe in the Northeast.

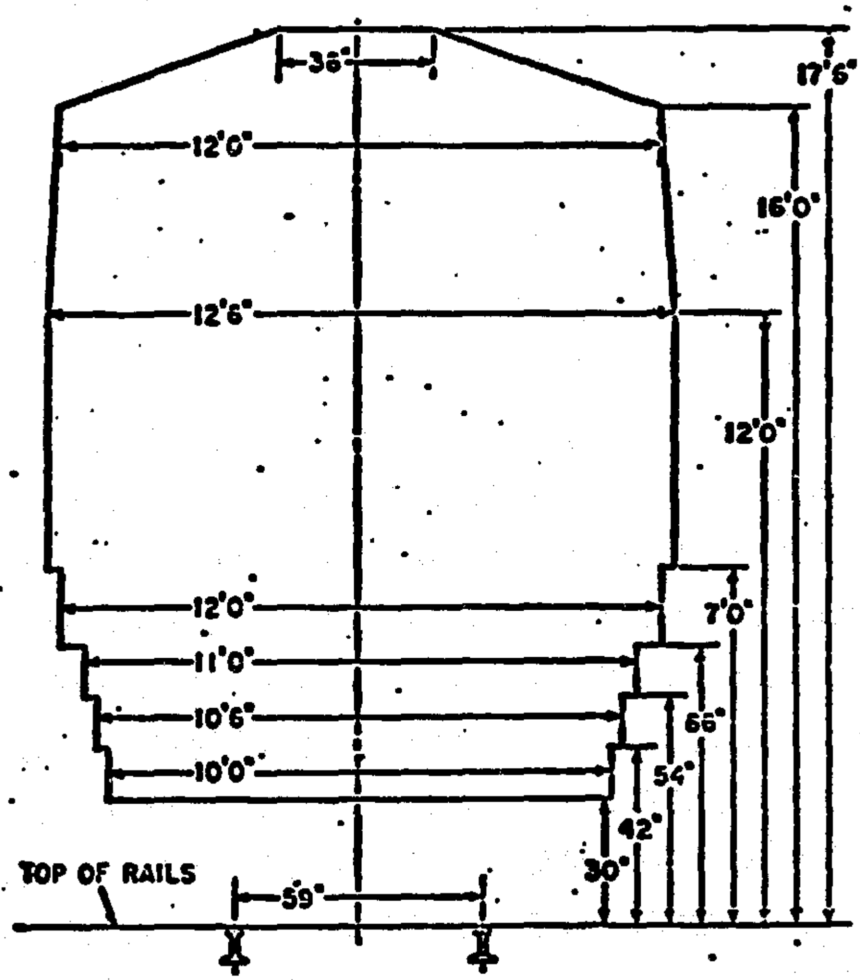
TABLE 2 - BLADE MATERIALS OF CONSTRUCTION

ITEM	MATERIAL SPECIFICATION
Douglas Fir Veneer	47A380126
Epoxy	47A Later
Carbon Filled Epoxy	47A Later
Fiberglas Cloth	47A Later
Paper Honeycomb	47A Later
Paint	47A Later

FIGURE 1 - MAXIMUM RAILROAD SHIPPING CLEARANCES

OF THE UNITED STATES

(New England Excepted)



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FIRST MADE FOR MOD-5A WIND TURBINE GENERATOR

REVISIONS

SPECIFICATION FOR A
WTG GROUND CONTROL ENCLOSURE

Keith E. McFarland 9-27-82
Responsible Engineer

G.P. Schanzenbach 10/4/82
Subsystems Engineer

[illegible] 10/1/82
Systems Engineering

A. Cheddar 10/5/82
Quality Assurance

[illegible] 10/1/82
WTG Integration

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SECTION 1.0

SCOPE

1.1 INTRODUCTION

This specification establishes the requirements for a Ground Control Enclosure (GCE) assembly for use on a seven (7) megawatt Wind Turbine Generator.

The Ground Control Enclosure shall house an integrated package for control of Wind Turbine Generator electrical power generation, site power distribution, and site control.

SECTION 2.0

APPLICABLE DOCUMENTS

The following documents of the date of issue noted form a part of this specification to the extent specified herein. In the event of conflict between this specification and the documents referenced herein, the contents of this specification shall supersede.

2.1 GENERAL ELECTRIC

47E387006 - Control Enclosure Outline

47E387001 - One Line Diagram

47D387016 - Wiring Interface

2.2 INDUSTRY STANDARDS

NEMA - National Electrical Manufacturers Association

NEC - National Electrical Code

OSHA

ANSI - American National Standards Institute

C37.2 Manual and Automatic Station Control, Supervisory and Associated Telemetering Equipments

C57.13 Requirements for Instrument Transformers

Y32.2 Graphic Symbols for Electrical and Electronic Diagrams

Y14.15 Electrical and Electronic Diagrams

SECTION 3.0

REQUIREMENTS

3.1 ENCLOSURE

3.1.1 GENERAL

The Ground Control Enclosure (GCE) shall be a self-supporting structure to house the items listed in this specification.

3.1.2 ENVIRONMENTAL

The enclosure must be able to survive without damage, the conditions listed in Table 3.1.

TABLE 3-1

ENVIRONMENTAL CONDITIONS

Shipping Shock	2 g's 100 ms lateral 5 g's 100 ms vertical and horizontal 20 g's 100 ms horizontal (uncushioned rail, only if so shipped)
Temperature	-40 degrees C to 50 degrees C ambient (survival) -30 degrees C to 40 degrees C ambient (operational)
Wind	120 mph
Altitude	0 - 7000 feet above sea level
Snow Loading	30 pounds/sq foot

3.1.3 GROUNDING

The GCE shall have two (2) NEMA standard copper faced grounding pads with taps on the outside lower surface, one (1) at each end.

3.1.4 SIZE

The maximum dimensions of the GCE shall not exceed the dimensions shown on GE drawing 47E387006. Removable lifting lugs shall not be included in these dimensions.

3.1.5 WEIGHT

Weight of completed GCE shall not exceed 45,000 pounds.

3.1.6 BASE AND FLOOR

The GCE shall have a welded steel base designed to assure structural integrity during shipping, handling, installation and service.

Inside floor shall be steel plate attached to the base. Floor plates shall be removable where necessary for access to interconnection wiring. Removable floor plates shall be secured with flush mounting hardware to prevent movement during shipment. Refer to Drawing 47E387006 for approximate location of wire interconnections.

Floor shall be smooth, level and free of gaps or sharp edges, dust and rodent proof.

The Control Enclosure shall be supplied with an anti-skid surface in all walk areas.

Floor must support the weight of the heaviest piece of equipment, in addition to providing 100 pounds per square foot active walk area.

3.1.7 SIDEWALLS AND ROOF

The sidewalls and roof shall be designed to withstand the climate conditions specified in 3.1.2.

3.1.7 SIDEWALLS AND ROOF (cont'd)

Roof pitch from center line to outer edge or edge to edge shall have minimum three (3) inch drop to provide water drainage.

Ceiling shall be constructed so as to prevent sag when in place.

Vertical wireways shall be concealed within the walls where possible. Surface mounted wireways shall have a maximum depth of 1.5 inches. All wireways shall have removable covers and have a finished appearance.

3.1.8 DOORS

Entrance doors shall be heavy duty industrial steel types, gasketed and flush mounted. Door size shall be a minimum of 30 inches wide X 6 foot, 8 inches high and 1-3/4 inches thick, supplied with door closers, opening outward.

All doors shall be supplied with a keyed lock set with braced knobs and to be key operated from the outside. Mortise type panic hardware shall be utilized for inside operation of doors.

A sloping drip shield extending out a minimum of six (6) inches shall be provided over the top of each door to prevent water running down the face of door. A lip shall be provided for side water run-off from the shield.

An outside light shall be provided above each door suitable for conditions specified in 3.1.2.

A three way switch circuit shall be utilized to control outside lights from either door.

3.1.9 ACCESS PANELS

Outside access panels when required shall be flush and shall seal the internal environment from conditions specified in 3.1.2. Panels shall be installed with tamper resistant hardware.

3.1.10 LIGHTING

Interior lighting shall be fluorescent, complete with fixtures and bulbs, a three (3) way switch circuit shall be provided by each door for control of lights.

The number of fluorescent fixtures shall be determined by operation with an initial light intensity of 50 foot-candles at three (3) foot level above the floor.

3.1.11 OUTLETS

120VAC, 30A, GFI protected outlets shall be provided in locations shown on GE Drawing 47E387006.

3.1.12 WINDOW

A window shall be installed as shown on GE Drawing 47E387006. Window shall have clear glazing (lexan preferred), size indicated, with a hinged steel protective cover or curtain to prevent vandalism or unauthorized entry. Cover or curtain to be easily secured in the open position for personnel to observe operation of the wind turbine.

3.1.13 INSULATION

Insulation shall be utilized in walls, ceiling and floor of Control Enclosure (GCE) to minimize heating and cooling demand.

3.1.14 INTERNAL ENVIRONMENT

The internal environment of the GCE shall be maintained between 65°F (18.3°C) and 86°F (30°C) with a thermostatically controlled heating cooling system. A dead band of at least 10°F (5.6°C) shall be provided between heating and cooling to preclude simultaneous operation of the two conditioning functions. User supplied components supply approximately 3412 BTU/hr to the heating load. Cooling load shall include four (4) operating personnel.

3.1.15 LIFTING

Lifting lugs near each corner, removable, with attachment hardware shall be supplied with the finished assembly.

3.1.16 INTERFACE

The GCE shall provide wiring interfaces for all items listed in Table 3.2 located in approximate locations shown on GE Drawing 47E387006. All external openings shall be protected for shipment.

TABLE 3.2

INTERFACES

a. Floor level entry termination for 5 KV class shielded Vulkene type cable. Two (2) each 350 MCM cables per phase from generator to main breaker (device 52).

b. Bus or cable duct between main breaker and utility step-up transformer.

c. Floor level entry for 300 KVA transformer primary (5 KV wiring) to fused disconnect. 2-1/2 inch conduit or wireway minimum.

d. Floor level entry of wiring from meteorological tower to interface panel. 2 inch conduit minimum

e. Side entry of power wiring to meteorological tower from panel boards. 2 inch conduit minimum.

f. Side entry power distribution wiring for pad mounted devices.

   2 inch conduit minimum
   - 15 KVA tranformer primary to 480 V panel board and secondary to 208/120Y panel board
   - 208 VAC, 3Ø from panel board to station battery charger
   - 120 VAC from panel board to UPS

   1 inch conduit minimum
   - Station battery output, 48 VDC, to interface panel
   - UPS output 120 VAC to interface panel

g. Floor level entry of utility step-up transformer fan and protective relay wiring to control enclosure. 1-1/2 inch conduit minimum

h. Floor level entry of instrumentation and control wiring from WTG tower to interface panel. 4 inch conduit or wireway minimum.

i Floor level entry of 300 KVA transformer secondary (480 V) to panel board. 3 inch conduit minimum.

j. Floor level entry of power wiring to WTG tower. 6 inch conduit or wireway minimum.

3.1.17 FINISH

All roof joints will be welded, filled and sanded before painting. Walls will have a continuous smooth finish except where there may be a removable wall section.

All steel surfaces will be thoroughly cleaned of all scale, rust, grease and other foreign matters and given a prime coat of zinc rich paint. This will include any and all conduit boxes, covers, sub-floor, walls, ceiling, inside-outside; no exposed areas will be left unpainted.

All doors and frames shall be finished.

All inside surfaces, sub-floor, and wire trays in sub-floor will be finished. Finish paint shall be applied to all surfaces. Color shall be (TBD). Outside paint shall be suitable for salt spray environment.

3.1.18 SECURITY

Doors and window protective covers shall be equipped with recessed magnetic contacts (rated 1 amp @ 120 VAC) that provide a closed contact when closed. Door and window circuits shall be wired in series and terminate at interface cabinet (Table 3.6).

3.1.19 DOOR STEPS

If required, detachable door steps shall be provided to maintain a maximum nine (9) inch rise to GCE entrance door. Door steps shall have a minimum of an eleven (11) inch tread with anti-slip surface.

3.1.20 MOUNTING

The GCE assembly shall be suitable for level installation on a concrete pad that provides support along the two (2) largest dimension sides. Two (2) anchor stud holes on each side shall be provided with external access providing 1/8 inch clearance for 1-1/4 inch diameter studs.

3.1.21 HANDLING

The GCE assembly design shall be suitable for dragging. Normal handling will be via crane with spreader connected cables to the lifting lugs specified in Section 3.1.15.

3.1.22 SKYLIGHT

The ground control enclosure shall be equipped with a skylight for personnel to observe operation of the wind turbine.

The skylight shall be a minimum of 30 inches square and located above the site control console as shown on drawing 47E387006.

The skylight shall be of break resistant material and tinted to reduce sun glare. Design of skylight shall minimize heat loss and limit condensation build-up.

The skylight shall have a hinged protective cover supplied to prevent vandalism or unauthorized entry. The cover shall be easily secured in the open or closed position from within the ground control enclosure. Skylight and protective cover must be capable of surviving the environmental conditions listed in Table 3-1.

3.2 GENERATOR CONTROL

3.2.1 GENERAL

The switchgear and protective relaying utilized for generator control shall be installed in the GCE.

The switchgear shall consist of one or more vertical sections mounted side by side and connected electrically and mechanically to form a complete switching assembly.

The following functions shall be included in the design and selection of the switchgear.

A. Main breaker - utilized for connecting generator to utility bus

B. Control, instrumentation, metering, protective, and regulating devices, including site step-up transformer instrumentation

C. Fused load break switch for 300 KVA auxiliary transformer

D. Potential transformers

E. Current transformers

F. Electrical heaters to minimize condensation

G. Main bus compartment

3.2.2 DESIGN

The one line diagram 47E387001 shall be used in conjunction with this specification for design and selection of switchgear equipment. The switchgear described in this specification is intended for use on a 4160 V, three phase, four wire, resistance grounded, 60 Hz system.

3.2.3 ENCLOSURE

Enclosure utilized to house switchgear shall form a rigid, self-supporting, completely metal-enclosed structure. The major parts of the primary circuit, such as the circuit breakers, buses, potential transformers, and control power transformers shall be completely enclosed by grounded metal barriers. This shall include an inner barrier in front of or as a part of the circuit breaker.

3.2.4 MAIN BREAKER COMPARTMENT

The main breaker compartment shall be designed to house a 4160 volt, removable element circuit breaker. The stationary primary disconnecting contacts shall be constructed of silver-plated copper. Grounded-metal safety shutters shall be provided which isolate all primary connections in the circuit breaker compartment when the breaker is withdrawn from the connected position.

3.2.5 GROUND BUS

A ground bus of 1/4 inch by 2 inch copper shall be extended throughout the line up with silver-plated station ground connection points located at each end.

3.2.6 BUS COMPARTMENT

The main bus shall be rated at 2000 Amperes. Bus bar shall have a continuous current rating, in accordance with ANSI standards of temperature rise and documented by design tests. All joints will be silver-plated with at least two bolts per joint. Bus bars shall be braced to withstand the magnetic stresses developed by currents equal to the main breaker close, carry, and interrupt ratings. The bus shall be provided with front access through removable panels.

3.2.7 MAIN BREAKER

The main circuit breaker shall be rated at 4160 volts, 60 Hz, with a continuous current rating of 2000 amperes and a normal interrupting rating of 250 MVA.

The circuit breaker shall be operated by an electrically charged, mechanically and electrically trip-free, stored energy operating mechanism. Provisions shall be included for manual charging of the mechanism and for slow closing of contacts for inspection or adjustment.

The circuit breaker shall be equipped with secondary disconnecting contacts which shall automatically engage in the operating positions.

The main breaker compartment shall be furnished with a mechanism which will move the breaker between the operating and disconnect positions. The mechanism shall be designed so that the breaker will be self-aligning and will be held rigidly in the operating position without the necessity of locking bars or bolts. In the disconnect position, the breaker shall be easily removable from the compartment.

Interlocks shall prevent moving the breaker to or from the operating position unless its contacts are in the open position. As a further safety precaution, the operating springs shall be discharged automatically when breaker is rolled fully into the compartment or is moved into the disconnect position. Means shall be provided for padlocking the breaker in either the connected (operating) position or the disconnected position. When locked in the disconnected position, the breaker shall be removable from the compartment. Padlocking shall not interfere with the operation of the breaker or its mechanism.

The circuit breaker control voltage shall be 48 VDC for tripping and closing. 208 VAC, 60 Hz for mechanism charging shall be supplied from a transformer located in the switchgear.

3.2.7 MAIN BREAKER (cont'd)

The circuit breaker shall be capable of a minimum of 2000 mechanical cycles before mechanism major maintenance. A mechanical operation counter, visible from the front of the circuit breaker shall be provided.

The circuit breaker shall have an expected life of 30 years with six (6) month maintenance intervals.

The circuit breaker shall have six (6) each "a" and "b" contacts available for user application. Contacts shall be wired to a terminal board within the switchgear enclosure.

Indicator lamps shall be provided and labeled on the front panel of the switchgear to indicate circuit breaker position.

3.2.8 CURRENT TRANSFORMERS

Three (3) current transformers shall be provided, rated at 1500/5, B-2.0 connected on the generator side of the main breaker as indicated on Drawing 47E387001.

The current transformers shall have mechanical rating equal to the momentary rating of the circuit breaker and shall be insulated for full voltage rating of the switchgear.

3.2.9 POTENTIAL TRANFORMERS

Six (6) potential tranformers, rated at 4800/120, .3-1.2Z, drawout type, equipped with primary current limiting fuses shall be provided, three (3) on each side of the breaker as indicated on Drawing 47E387001.

3.2.10 RELAYS

The following devices shall be mounted on the front panel of the switchgear, in draw out cases, where applicable. Interconnections shall be in accordance with Drawing 47E387001 (one line diagram). Device numbers are in accordance with ANSI C37.2. Lamacoid labels or equivalent, describing the function, shall be provided on the panel. A 48 VDC control power circuit shall be used.

3.2.10 RELAYS

Quantity	Description
1	Reverse Power Relay, device 32, (25-100 watts), Type ICW or equivalent. (Ref. 12ICW51A4A)
1	Negative Sequence Voltage Relay, device 47, type NBV or equivalent. (Ref. 12NBV11A1A)
1	Ground Relay, time over current, device 51T; 60 Hz tuned, type IAC or equivalent. (Ref. TBD)
3	Instantaneous and Time Overcurrent Relay, device 50/51, type IAC or equivalent. (Ref. 12IJCV51B22A)
1	Overvoltage Relay, device 59, type IAV or equivalent (Ref. 12IAV1A1A)
1	Lockout Auxiliary Relay, hand-reset, device 86G, Type HEA61 or equivalent. 48VDC coil. (Ref. 12HEA61)
1	Auxiliary Relay, multiple contact, device 94G, type HGA or equivalent. 48VDC coil. (Ref. 12HGA13A54F)
5	Auxiliary Relay, unidentified, DPDT, Type HGA or equivalent. 48VDC coils, all leads out. (Ref. 12HGA11)
2	Watthour meters, (1) detented to read power output, 3 element, 3 phase indicating and (1) detented to read power input. 3 element, 3 phase indicating. 120 V, 5 A, 60 Hz connections.
1	Differential Relay, device 87, type BDD or equivalent.
1	Power factor relay, device 55, synchronous motor type to be reverse connected for operation on leading power factor, with indicating meter, front panel mounted.
1	Synchronizing relay, device 25, type GES or equivalent. (See note.)
1	Synchronizing check relay, device 25A, type GXS or equivalent. (See note.)
NOTE:	Capability shall be provided for panel mounting of devices 25 and 25A. Actual devices will not be installed. Panel openings provided for devices 25 and 25A shall be covered in a way as not to deter from the overall appearance of the switchgear.

3.2.11 METERS

The following indicating switchboard instruments shall be mounted and wired in accordance with drawing 47E387001. Lamaccid or equivalent labels shall be used for identification.

QUANTITY	DESCRIPTION	DIAL	LABEL
1	Kilowatt Meter (4-1/2" Sq)	-1000/0/+12000	Power
1	Volt Meter (4-1/2" Sq)	0-6000 V	Volts
1	Ampmeter (4-1/2" Sq)	0-1500 A	Amperes
1.	Synchroscope (4-1/2" Sq)	--	Synchroscope (See note)
1	Kilovars (4-1/2" Sq)	-1000/0/+4000	Reactive Power

NOTE: Capability shall be provided for panel mounting of a synchroscope. Actual device will not be installed. Panel opening shall be covered in a way as not to deter from the overall appearance of the switchgear.

3.2.12 TRANSDUCERS

The following transducers shall be included in the design of the switchgear assembly and wired in accordance with 47E387001. Transducers shall supply an analog current output of 4-20MA.

QUANTITY	DESCRIPTION
1	VAR, 3 Element, 3 Phase
1	Current, One (1) 3-in-1 Type
1	Watt, 3 Element, 3 Phase
1	Voltage, One (1) 3-in-1 Type
1	DC Current (0-10A), in addition to an analog current output, DC current transducer shall have an adjustable limit control adequate for control of the 86 relay.

3.2.13 METER SWITCHES

The following switches, GE type SBM or equivalent instrument transfer switches shall be panel mounted and wired in accordance with 47E387001. Lamacoid or equivalent labels shall be used for identification.

QUANTITY	SWITCH LABEL	POSITION	POSITION LABEL
1	Volts	1	UTIL A-B
		2	UTIL B-C
		3	UTIL C-A
1	Amps	1	GEN A
		2	GEN B
		3	GEN C
1	Synchroscope		

NOTE: Capability shall be provided for panel mounting of a synchroscope switch. Actual switch will not be installed. Panel opening for switch shall be covered in a way as not to deter from the overall appearance of the switchgear.

3.2.14 VOLTAGE REGULATOR

A voltage regulator, Basler Model SR8A, or equivalent, shall be supplied and wired in accordance with 47E387001. Voltage regulator shall be mounted such that controls are accessible from the front panel of switchgear. Voltage regulator controls shall be protected for selective use.

3.2.15 POWER FACTOR CONTROLLER

A power factor controller, Basler Model SPC 250 or equivalent, shall be supplied and wired in accordance with 47E387001. Power factor controller shall be mounted such that controls are accessible from the front panel of the switchgear. The controls for the power factor controller shall be protected for selective use.

3.2.16 HEATERS

To minimize the occurrence of moisture condensation in the switchgear, a 300 watt heater shall be used in each vertical section for operation from a 120 VAC, 60 Hz source. Heaters shall be selected to operate at reduced voltage for extended life.

3.2.17 TRANSFORMER FEEDER

A three phase fused load break disconnect switch shall be supplied for primary isolation of a 300 KVA transformer. Indicator lights or a flag shall be supplied and wired to indicate status of the fused load break disconnect switch.

3.2.18 WIRING

All secondary wiring shall be tinned copper, 600 volt switchboard wire.

A. All wiring shall be adequately supported by vertical and horizontal wire ducts with removable covers. Where ducts are not applicable, wire bundles shall be supported by prewelded cleats or wiring rod for cable support.

B Solderless terminals shall be used for all secondary connections.

C No connections will be spliced or extended by soldering to another wire.

D Each lead entering or leaving the switchgear shall be brought to an approved terminal board bearing identification agreeing with the connection diagram.

3.3 POWER DISTRIBUTION

3.3.1 GENERAL

All auxiliary power required for the wind turbine generator site is supplied by a 300 KVA transformer (4160/480Y) located adjacent to the GCE. The secondary of the 300 KVA transformer is wired to the 480 volt panel board where all 480V circuits are distributed. A 30 KVA (480/208Y/120) transformer is used to supply the 208Y/120 circuits required.

3.3.2 480 VOLT PANEL BOARD

The 480 volt panel board shall be flush mounted with a combination catch and lock. Wiring access to the panel board shall be from the bottom (refer to Drawing 47E387006 for approximate location of panel board). The panel board shall be supplied with a 350 ampere (interrupting rating of 22,000 RMS symmetrical amperes) main breaker and a minimum of eight (8) 3 pole branch breaker locations. Branch breakers shall be of the size listed in Table 3.3 and have an interrupting rating of 14,000 RMS symmetrical amperes. Main breaker shall be capable of accepting 2 each, 3/0 copper cables per phase.

TABLE 3.3

480V PANEL BOARD INTERFACE

BRANCH BREAKER LOCATION	SIZE	FUNCTION
1	35A	30 KVA transformer feed
2	15A	Personnel lift
3	200A	Nacelle feed
4	40A	Transformer fans
5	70A	PIV
6	--	unused
7	--	unused
8	--	unused

NOTE: Circuit breakers shall not be installed in unused locations.

3.3.3 208Y/120 PANEL BOARD

The 208Y/120 panel board shall be flush mounted with a combination catch lock. Wiring access to the panel board shall be from the sides (refer to Drawing 47E387006 for approximate location of panel board). The panel board shall be supplied with 100 amp main lugs and a minimum of twenty-four (24) single pole branch breakers. Branch breakers shall be of the size listed in Table 3.4 and have an interrupting rating of 10,000 RMS symmetrical amperes. Circuit breakers shall not be installed in unused locations.

TABLE 3.4

208Y/120 PANEL BOARD INTERFACE

BRANCH BREAKER LOCATION	SIZE	FUNCTION	BRANCH BREAKER LOCATION	SIZE	FUNCTION
1	15A	Voltage Regulator	2		
3	(TBD)	GCE Air Conditioner	4 3	25A	Station Battery Charger 208V, 3Ø
5	(TBD)	GCE Heaters	6		
7	15A	Control Data System	8	25A	Site Console Assembly
9	15A	Recorder Rack	10	15A	GCE Lights
11	20A	Interior Tower Lights	12	30A	GCE Outlets
13	20A	Interior Tower Outlets	14	15A	Ground Multiplexer
15	20A	Meteorological Tower	16	--	Open
17	15A	Switchgear Heaters	18	--	Open
19	15A	Ground Intercom	20	--	Open
21	30A	Control System UPS	22	--	Open
23	--	Open	24	--	Open

3.4 SAFETY & AUXILIARY EQUIPMENT

3.4.1 FIRE EXTINGUISHER

Two (2) fire extinguishers, manual CO_2 type, 15 pounds capacity shall be supplied with the GCE, one mounted by each entrance.

3.4.2 ELECTRONICS CABINET

An electronics cabinet for purchaser supplied equipment shall be constructed in the GCE (refer to Drawing 47E387006 for approximate location). Electronics cabinet shall be a minimum of 42.00 inches wide x 94.00 inches high and 12.00 inches deep with a removable rear mounting panel. The Electronics cabinet shall have a hinged door with flush combination catch and lock. Hinged door shall provide ventilation through the use of louvers or equivalent. Wiring access to the elctronics cabinet shall be from the bottom.

3.4.3 EMERGENCY LIGHTING

Emergency lights (DC lamp, battery & charger) shall be supplied with the GCE, size and location shall be in accordance with OSHA requirements.

3.4.4 VIDEO MONITOR

An adjustable wall mount for support of a video monitor shall be supplied. Support shall provide 180° of horizontal adjustment and a minimum +0 to -40° vertical tilt angle. Support shall interface with a (later) video monitor (purchaser supplied). Wiring (coaxial cable, 75 OHM impedance, with BNC connector at each end) for the video monitor shall be supplied and installed between the video monitor and interface cabinet. 120 VAC power for the video monitor shall be from an outlet located near the monitor (refer to Drawing 47E387006 for approximate location of the video monitor).

3.4.5 TELEPHONE

Capability shall be supplied for mounting a standard wall mount telephone in approximate location shown on Drawing 47E387006. Wiring for the telephone shall be concealed and routed to the electronic cabinet. Telephone company will supply telephone and install wiring.

3.4.6 INTERCOM

Capability shall be provided for mounting a site intercom in the approximate location shown on Drawing 47E387006. Mounting shall interface with an industrial type paging intercom, part number (later), (purchaser supplied). All wiring for intercom shall be installed from intercom to interface cabinet and panel board in wire way.

3.4.7 INTERFACE CABINET

An interface cabinet shall be constructed in the GCE for site interconnections. The interface cabinet shall be a minimum of 23.00 inches wide x 94.00 inches high by 12 inches deep with a removable rear mounting panel. Interface cabinet shall have a hinged door with flush combination catch and lock. The hinged door shall provide ventilation through the use of louvers or equivalent. Wiring access to the interface cabinet shall be from the bottom of the cabinet. The interface cabinet shall provide support for all wiring. Terminal boards and coaxial feed-through connectors shall be supplied and mounted to the removable panel. Table 3.5 lists the requirements of the terminal boards and connections. Terminal boards shall be of the box type with pressure plate. Individual terminals shall be identified by terminal number in such a way as not to be covered when wiring is in place and shall be numbered in sequence. Refer to drawing 47D387016 for wiring interface.

TABLE 3.5

TERMINAL BOARD AND CONNECTOR REQUIREMENTS

TERMINAL	REQUIREMENT
1 through 10	30 amp, 600V,
11-150	10 amp, 600V
J1-J8	BNC Bulkhead Jack Adapter with Panel Insulating Bushing

3.5 SITE CONTROL AND INSTRUMENTATION CONSOLE

3.5.1 GENERAL

The site control console consists of a two (2) bay electronic cabinet with an attached writing surface that is permanently mounted in the GCE. In addition there are two (2) movable electronic racks for instrumentation. Site control console and instrumentation racks will be supplied and wired by purchaser.

3.5.2 INTERFACE

Capability shall be provided to attach the two bay site control console to the GCE floor. In addition, attachments for securing the writing surface to the wall must be provided. Wiring to the site control console shall be through the floor into the console. The vendor shall provide the necessary equipment for routing of wires between console, interface cabinet and panel board.

3.6 LIFE

The expected lifetime of the unit shall be 30 years upon performance of the maintenance called out in section 3.7.

3.7 MAINTAINABILITY

Routine maintenance shall be able to be performed on site. Interval between routine maintenance cycles shall not be less than one (1) year. Supplier shall identify required maintenance of major components.

4.0 VERIFICATION

4.1 GENERAL

The vendor shall perform standard commercial tests to demonstrate proper operation and connection of the GCE assembly. Three (3) certified copies of actual test data shall be provided with shipment. Tests shall include, but not be limited to the following.

4.2 INSPECTION

4.2.1 TRANSFORMERS

Polarity and ratio check of all transformers.

4.2.2 INSTRUMENTS

All relays, instruments and other devices shall be checked for internal or concealed shipping damage.

4.2.3 WIRING

All wiring shall be checked for loose connections.

4.3 FUNCTIONAL TEST

4.3.1 ENVIRONMENTAL

Heater and air conditioner operational check

4.3.2 CONTINUITY

Continuity check of all wiring

4.3.3 MAIN BREAKER

Main breaker shall be checked for operation at 80, 100, and 110 percent of normal operating voltages, open and closed circuits. Also opening, closing and trip free times of the main breaker at normal operating voltages shall be checked. Average and range of ten (10) tests after all adjustments have been made shall also be recorded.

4.3.4 PRIMARY CIRCUITS

A high potential test shall be performed on all high voltage circuits. A contact resistance check of all 5KV circuits shall be performed and recorded.

4.3.5 SECONDARY CIRCUITS

An insulation check of all secondary circuits shall be performed.

5.0 DOCUMENTATION

5.1 APPROVAL

Upon award of a contract, the vendor shall furnish drawings (2 sets) for approval prior to manufacturing. Drawings for approval shall include a plan view, outline drawings, and an elementary diagram. Comments or approvals will be returned within two (2) weeks of receipt.

5.2 DELIVERABLE

The following documents shall be supplied with shipment.

- Certified outline drawing
- Wiring diagrams
- Elementary diagrams
- Complete instruction books with parts lists
- Detailed summary or equipment list
- Schematics
- Test data
- Operational and maintenance manual for all equipment

One regular reproducible and ten (10) copies of drawings, twelve (12) copies of instruction books, and three (3) copies of test data shall be supplied. In addition, one copy of all documents shall be enclosed with shipment.

6.0 PREPARATION FOR DELIVERY

The vendor shall submit a statement detailing his normal practice of packaging and method of delivery for approval by the General Electric Company, Advanced Energy Programs Department, MOD-5A WTG Engineering, 501 Allendale Road, P.O. Box 527, King of Prussia, PA 19406.

GENERAL ELECTRIC

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TITLE

FIRST MADE FOR

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SYSTEM SPECIFICATION

FOR THE

MOD-5A WIND TURBINE GENERATOR

November 1983

SYSTEMS ENGINEERING DATE: 3 JAN 1984

CHIEF ENGINEER DATE: 12 JAN 1984

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This log identifies those portions of this document which have been revised since original issue. Revised portions of each page, for the current revisions only, are identified by marginal striping or text notes.

Revision	Page No.	Paragraph Number(s) Affected	Rev. Date	Approval
A	ALL	ISSUED; DOCUMENT NOW UNDER CONFIGURATION CONTROL	NOV-83	[illegible]

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SECTION 1.0

SCOPE

This specification establishes performance, design, development and test requirements for the Model 304.2 MOD-5A Wind Turbine Generator (WTG).

SECTION 2.0
APPLICABLE DOCUMENTS

This specification incorporates the following documents, of exact issue date shown, to the extent referenced. In the event of conflict in document requirements, the detail content of Section 3 and following shall supercede the documents noted in this section.

2.1 GOVERNMENT DOCUMENTS

Contract DEN 3-153 (April 11, 1983)
FAA-Circular 70/7460-1F "Obstruction Marking and Lighting"
MIL-STD-210 Climactic Extremes
MIL-STD-1472 Human Engineering Design Criteria, Military

2.2 NON-GOVERNMENT DOCUMENTS

AGMA Aircraft Specification
AFBMA Section #11, Load Ratings Method
AWS D1.1-76 Structural Welding Code
SSPC-SPIO-63T Structural Steel Painting Council
NEMA MG-1, MG2 Motor and Generator Standards
ANSI C50.10, C57.12 Machine, Transformer Standard
NFPA 70-1980 National Electrical Code
ANSI Y14.1 Drawings

IEEE 519 Guide for Harmonic Control, etc, of Static Power Converters

47A380013 Control System Specification

47E387080 One-line System Diagram

47A380094 Variable Speed Subsystem Specification (Scherbiustat)

47A380115 Variable Speed Subsystem Specification (Generic)

47A387005 Signal & Command List

47A380002 Structural Design Criteria

ANSI C114.1 Grounding

47A380020 RAM Plan for MOD-5A

2.3 OTHER DOCUMENTS

NASA TP 1359 Engineering Handbook on the Atmospheric Environmental Guidelines for use in Wind Turbine General Development, W. Frost, B.H. Long, R.E. Turner, December 1978.

SECTION 3.0
REQUIREMENTS

The MOD-5A WTG system shall be designed in accordance with NASA requirements defined in Contract DEN 3-153 Statement of Work and attached exhibits. The MOD-5A WTG system shall also be designed in accordance with good commercial and General Electric Company practice. As specified in the following paragraphs, the MOD-5A WTG system shall be designed to accomplish specific functions, include specific characteristics, meet design, construction and maintenance requirements and be operated in a specific manner.

The MOD-5A WTG system shall be primarily designed for a single unit installation. Multiple installations or clusters of units shall be accomplished by interconnecting several single unit installation type WTG's at a distribution or sub-transmission voltage level.

Primary program requirements are that cost of energy (COE) at the electrical system grid interface be less than 3.75 cents per kilowatt-hour (1980 dollars) in a 14 mph mean wind regime with acceptable design risk. COE shall be computed in accordance with DEN 3-153, Exhibit E, summarized as follows:

$$\text{COE} = \frac{\text{Levelized Annual Cost (1980 \$)}}{\text{Available Annual Energy}}$$

Where Levelized Annual Cost (LAC) =

$$(\text{IIC}) \times (\text{EFCR}) + (\text{LC}) \times (\text{LFCR}) + (\text{PRC}) \times (\text{PLF}) + (\text{AOM}) \times (\text{ALF})$$

and

IIC = Initial installed cost - turnkey
EFCR = Equipment fixed charge rate = .18
LC = Land cost = $750/acre
LFCR = Land fixed charge rate = .15
PRC = Periodic replacement cost
PLF = Periodic levelizing factor = CRF $((C1+e)/(1+r))^{i}$
AOM = Annual operation and maintenance costs, average

ALF = Annual levelizing factor = 2.0
CRF = Capitol recovery factor = 0.089
e = Price escalation rate = 0.06
r = Discount rate = 0.08
i = Years after installation that PRC cost is incurred

and

Available Annual Energy (AAE) = (AKWH) x (AF)

where

AKWH = Annual grid Kwh energy based on the wind speed duration regime specified in Section 3.2.3.1.3, the system efficiency specified in Section 3.2.1.3, and 100% availability.

AF = Availability factor, based on the allocated values specified in Section 3.2.2.9.

For cluster installations, the per WTG pro-rata cost and efficiency of cluster equipment shall be included in the appropriate COE equation categories.

All tradeoffs shall be responsive to the goals of achieving COE below 3.75 cents per kilowatt-hour (1980 dollars) and minimizing COE with commercially acceptable risk.

3.1 SYSTEM DEFINITION

The MOD-5A WTG design shall be based on the description of Paragraph 3.1.1, for the purpose of Paragraph 3.1.2 when installed per Paragraph 3.1.3, defined per paragraph 3.1.4, and compatible with interfaces per Paragraph 3.1.5. The WTG system shall utilize customer furnished elements per Paragraph 3.1.6, and be capable of operating in the modes described in Paragraph 3.1.7.

3.1.1 SYSTEM DESCRIPTION

The WTG shall be a large, two bladed rotor, horizontal axis, propellor type wind turbine producing electrical energy. It will be designed for operation while electrically connected to an energized conventional 60 Hertz alternating current utility system. The rotor will be mounted on a tower and be capable of maintaining upwind orientation relative to the tower. The WTG will be designed for unattended, fully automatic, failsafe operation for a 30 year operational service life, and be compatible with electric utility company operating, interface, maintenance and equipment requirements.

The WTG system is comprised of the following equipment and elements:

a) Foundation and site
b) Ground electrical equipment
c) Operation and maintenance
d) Rotor assembly (control surfaces, blades, yoke, hydraulics)
e) Drivetrain assembly (gearbox, shafting, generator)
f) Nacelle assembly (structure for rotor and drivetrain support)
g) Tower assembly
h) Control subsystem
i) Reliability, availability, maintainability and spares

3.1.2 PURPOSE

Terms used in this section are defined and specified in Paragraph 3.2.1 and following subparagraphs.

The WTG shall generate 60 Hz electrical power while connected to an energized utility network in rated sea level air density wind speeds from low (wind) cut-out (VLCO) to high cut-out (VHCO) wind speeds. Startup for generation shall be accomplished in rated air density wind speeds from low cut-in (VLCI) to high cut-in (VHCI). The WTG shall generate rated power output at the utility network side of the WTG site step-up transformer when wind speeds are between rated wind speed and VHCO wind speed.

3.1.3 INSTALLATON

The WTG shall be capable of installation at a site accessible to conventional rail and/or truck surface transportation. Transportation and erection limitations on weight, size and availability of equipment shall be considered in the definition of system transportable assemblies.

3.1.4 DRAWINGS

The WTG and its components shall be defined by drawings and specifications. All engineering drawings shall conform to American National Standard ANSI Y 14.1 (drawing sheet size and format). The set of drawings shall provide the necessary design, engineering, manufacturing and quality support information directly or by reference to enable the procurement, without additional design effort or recourse to the original design activity, of an item that duplicates the physical and performance characteristics of the original design. These drawings shall not provide manufacturing process information unless this information is essential to accomplish manufacture of an identical item by other than the original source.

3.1.5 INTERFACE

The WTG shall be operated by and interface with an electrical utility company. An interface control document shall be prepared by GE that clearly defines necessary interfaces and responsibilities. GE will maintain the document and obtain mutual agreement to its contents by GE and the utility company. Major interfaces are as follows.

3.1.5.1 Electrical Network Interface

The WTG will feed its net output of up to 7300 KW into a 60 Hz, 3-phase utility network. Nominal connection to the network is at the terminals of a fused manual disconnect switch with visible break at the high voltage side of the site step-up transformer via overhead or underground circuit. The utility line shall provide between 0.05 and 0.45 per unit impedance per phase to an infinite bus equivalent on a 4.16 KV 7.5 MVA base and operate at no less than 11 KV and no more than 80 KV L-L. Automatic reclosing devices on the utility circuit shall be provided with voltage blocks or their equivalent to prevent asynchronous reclosing. Loads may be served by tapping the tie line between the WTG and the utility transformer substation, but may be subject to more than 3% voltage fluctuation. The nominal WTG output at the connection will deliver variable average real power from zero to 7300 KW and constant reactive (lagging) power at up to 1500 KVAR (0.98 Pf at 7300 KV). Operation in a constant voltage mode with fluctuating vars shall be a selectable option. Auxiliary power requirements of the WTG when not generating shall be supplied by the utility at the connection per Paragraph 3.1.6.4. The connection point at the transformer will be located about 200 ft from the WTG support tower to avoid interference with maintenance and erection operations.

3.1.5.2 Communication and Control Interface

Telephone circuits defined per Paragraph 3.1.6.2 shall be provided for voice and data communication between the WTG and the utility operator/dispatcher (nominally located up to 50 miles away). The WTG control system as a minimum will enable the utility operator/dispatcher to:

a) Receive WTG status information
b) Enable automatic WTG operation.
c) Disable automatic WTG operation, causing a normal shutdown if generating.
d) Alter maximum power set point to below rating.

3.1.5.3 Operating and Maintenance Interface

The Operation and Maintenance Manuals and training materials shall provide documentation of the utility and other service and operation personnel interfaces with the WTG.

3.1.6 CUSTOMER FURNISHED OR SPECIFIED ITEMS

The WTG design shall be compatible with customer furnished or specified items in contract DEN 3-153 or elsewhere. The term customer identifies either NASA or the WTG owner or user.

3.1.6.1 Location

The site shall be consistent with Paragraph 3.1.3. For design purposes, the assumed site is in the Cleveland, Ohio, area. The site is located on generally flat terrain with a substrate presenting no unusual or adverse features. Soil to a depth of 15 feet is assumed to consist of a very stiff to hard brown sandy, silty clay with gravel and shale fragments. Split spoon penetrations of 20 to 60 blows per foot are assumed, increasing with depth. Minimum allowable bearing pressures of 4000 psf are asssumed. No drainage problems are assumed. A soil minimum effective modulus of elasticity of 5000 psi is assumed.

3.1.6.1.1 Area

The nominal design site area required for construction and operation of a single WTG shall be 400 feet by 480 feet, (192,000 square feet = 4.41 acres). Permanent land use during operation may be limited to a 100 feet by 300 feet strip (1.45 acres) with limited air rights and maintenance equipment access rights on adjacent land.

3.1.6.1.2 Access

An access road shall be provided from the nearest public road to the WTG site with the following characteristics:

a) Twenty-four foot wide all-weather roadbed or eighteen foot wide with turnoffs with one time maximum load capability of 300,000 lbs gross weight, nominal maximum load capability of 180,000 lbs gross weight and 4,000 lb per wheel.

b) Right-of-way as required to accommodate a 100 foot long load around corners with a 70 foot axle distance.

c) Eleven percent maximum grade.

d) Twenty foot minimum overhead clearance.

e) Seventy-five foot minimum turn radius measured to inside of roadbed.

3.1.6.1.3 Approvals

The customer will furnish all necessary Federal, State and local government approvals, including any FAA approvals or Environmental Impact Statement(s) (EIS) related to WTG installation and operation. Permits and licenses for construction will be the responsibility of the contractor.

3.1.6.2 Communication

The customer shall provide at least two dedicated voice grade unswitched telephone circuits between the WTG site and the utility's operator/dispatcher site compatible with Bell 103/113 modem/data set operating characteristics to be used for transmission of information specified in Paragraph 3.1.5.2 and voice communication. Optionally, the customer shall provide for transmission of parallel signals instead of the standard serial signals on one circuit.

3.1.6.3 Distribution Line

The customer shall furnish a distribution line from the WTG with the interface and characteristics specified in Paragraph 3.1.5.1 to carry power to the utility when the WTG is generating and supply auxiliary power when the WTG is not generating. A source of construction power shall also be provided.

3.1.6.4 Electrical Power Requirements

The customer shall provide the following power requirements at the interface of Paragraph 3.1.5.1:

a) 80 KVA, 0.8 power factor 60 Hz ± 1% for continuous consumption while the WTG is not generating, which includes power for the mobile data acquisition system.

b) 1000 KVA, 0.9 power factor, 60 Hz ± 1% for periods of up to 5 minutes for startup, auxiliaries, and unloaded generator motoring during low wind conditions.

c) 200 KVA, 0.8 power factor, 60 Hz, ± 1% at 480 VAC ± 10%, 3-phase temporary construction power.

d) 0.1 KVA, 0.8 power factor, 60 Hz ± 1%, at 120 VAC ± 10%, 1-phase at the utility operator/dispatcher location to power the remote control equipment.

3.1.6.5 Color and Markings

The customer shall specify the WTG color and marking scheme. The assumed color of the system is white with aviation red double bands at the blade extremities and on the tower for daytime hazard warning. Assumed FAA hazard lighting consists of a white flashing dusk/night duty lamp located only on the nacelle.

3.1.6.6 Mobile Data Acquisition System

The customer shall provide the contractor with the use of a Mobile Data Acquisition System as defined in Contract DEN 3-153, Exhibit B, Paragraph 2.5.3, including skilled operation and maintenance personnel, during WTG checkout, acceptance and initial operation testing.

3.1.6.7 Utility Control and Storage Space

The customer shall provide, at the utility's facilities, the following space requirements:

a) At the utility operator/dispatcher location, an office environment area of 8 feet by 6 feet, including a standard desk and chair shall be provided for installation and operation of the remote control interface.

b) At a utility substation or storage location near the WTG site, an area approximately 8 feet by 20 feet by 8 feet high shall be provided for storage of WTG spares and maintenance equipment.

3.1.7 SYSTEM MODES

The WTG system shall have automatic and manual operational modes.

3.1.7.1 Automatic Modes

The WTG automatic sequence modes shall be as follows:

a) Lockout
b) Standby
c) Startup
d) Generating
e) Normal Shutdown
f) Emergency Shutdown

Mode interactions and major entry and exit conditions shall be as shown in Table 3.1-1.

3.1.7.2 Manual Modes

The WTG shall have manual modes under control at the site only, with capability to:

a) Initiate a shutdown to lockout.

b) Initiate a transition from lockout to standby when the lockout causing condition has been removed.

c) Initiate specific control of subsystems, within the constraints of the automatic mode operating limits, to:

1) Operate the yaw drive

2) Operate the rotor control surfaces

3) Operate the WTG rotor at less than 1 RPM for rotor positioning.

4) Operate system commands individually

TABLE 3.1-1
AUTOMATIC MODE INTERACTIONS

MODE	ENTRY	EXIT
Lockout	From power-up, manual mode, standby, or shutdown on sensor change or command established as lockout condition	To standby on removal of lockout causing condition and site manual entry
Standby (Ready for operation with wind in operating range and enabled)	From normal shutdown or lockout on manual entry	To startup on satisfactory wind conditions, with enable. To lockout on sensor change or command established as lockout condition.
Startup (Wind in operating range and procedure to get to generating speed)	From standby on operating wind conditions present	To normal shutdown or emergency shutdown on sensor change or command established as shutdown. To generating mode after synchronized
Generating (Delivery of power to grid)	From startup after synchronized	To normal shutdown or emergency shutdown on sensor change or command established as shutdown
Normal shutdown (orderly disconnect from grid and slow stop of rotation)	From startup or generating on sensor change or command established as shutdown. From emergency shutdown where appropriate to change type.	To standby on completion of shutdown sequence. To emergency shutdown where appropriate to change type.
Emergency shutdown (Rapid, limited control feathering and disconnect from grid)	From startup, generating, or normal shutdown on sensor change or command	To normal shutdown or lockout depending on type of sensor change or command.

3.2 CHARACTERISTICS

The WTG shall meet the following system and subsystem design requirements and characteristics.

3.2.1 SYSTEM REQUIREMENTS

3.2.1.1 System Power Output

The WTG shall provide a rated electrical output at the utility interface defined in paragraph 3.1.5.1 of 7300 KW at up to 1500 KVAR (0.98 PF at 7300 KW) at 69 KV line to line, 60 hertz, 3 phase. A specific utility distribution line voltage, between 11 KV and 80 KV, may be utilized instead of 69 KV. For cluster application, the rated output is defined at the cluster tie to the utility network and is an average unit rating. The rated power output shall be produced in wind speeds from rated wind speed (VRAT) to high cut out wind speed (VHCO) at sea level air density and for ambient temperatures defined in paragraph 3.2.3.2.1. Less than rated output shall be provided at all prescribed ambient conditions for wind speeds between cut-in wind speed and rated wind speed. The general relation of power output to wind speed at sea level and 7000 feet for standard atmospheric conditions is illustrated in Figure 3.2-1. Power varies directly as the atmospheric density ratio for wind speeds below rated power. Power quality at the utility tie shall meet IEEE 519 guidelines.

3.2.1.2 Design Wind Speed Values

The WTG shall be designed for operation at the hub height wind speeds defined in Table 3.2-1 for sea level air density of 0.0763 pcf., and 250 ft. hub height above grade.

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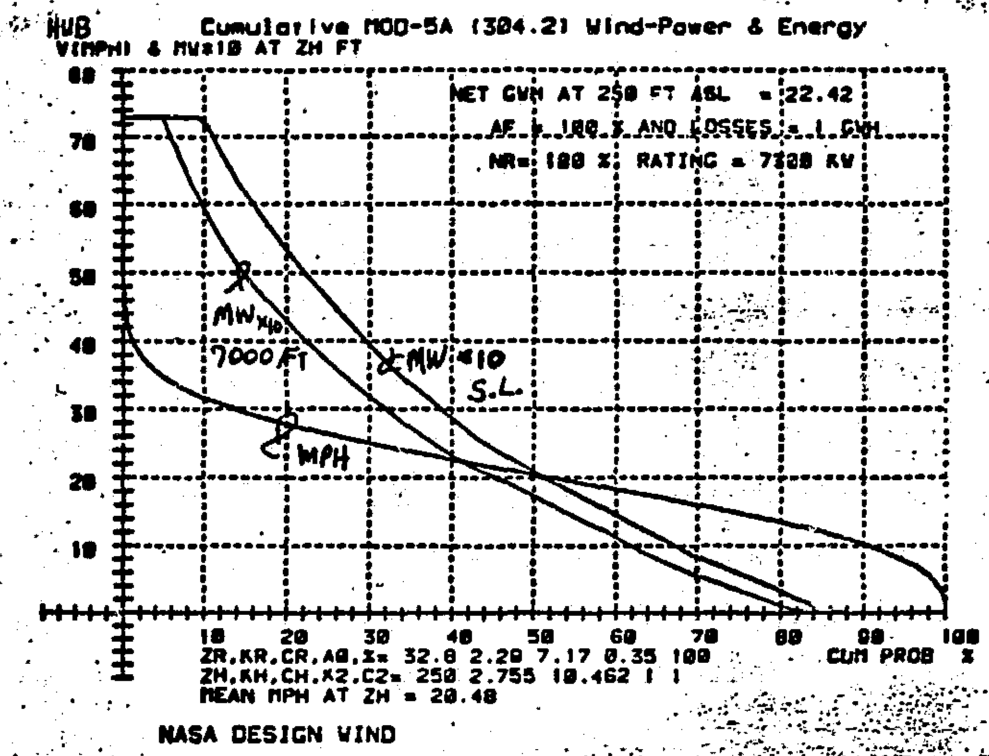

FIGURE 3.2-1

OUTPUT POWER VS. WIND SPEED

TABLE 3.2-1 DESIGN WIND SPEED VALUES

REFERENCE	DESCRIPTION	HUB WIND SPEED (MPH)
VLCO	Low cut-out wind speed where light motoring at low RPM can just be sustained and shut-down cycle begins as wind speed falls	12.0
VLCI	Low cut-in wind speed where acceleration to normal low RPM can be made in less than 15 minutes and startup cycle begins as average wind speed rises	14.0
VRAT	Nominal rated wind speed where WTG produces rated power output	32.0
VHCI	High cut-in wind speed where startup cycle begins as average wind speed falls	55.0
VHCO	High cut-out wind speed where shutdown cycle begins as average wind speed rises	60.0

3.2.1.3 Design Efficiency

The system design shall be based on the following maximum losses, expressed as percent of rated input such that component efficiency is equal to

$$1 - (\%\ \text{loss}/100)$$

Fixed drivetrain loss	1.5%
Variable drivetrain loss	1.5% at rating
Fixed Electrical loss	1.5%
Variable Electrical loss	3% at rating
Miscellaneous loss	4.2% below rating

Rotor aerodynamic efficiency shall be based on the data in Figure 3.2-2. Miscellaneous losses consist of changes in rotor aerodynamic efficiency due to tilt, teeter, wind turbulance, and heading error. Auxiliary power consumption and startup time losses based on 35,000 starts in 30 years shall be included separately in energy capture calculations.

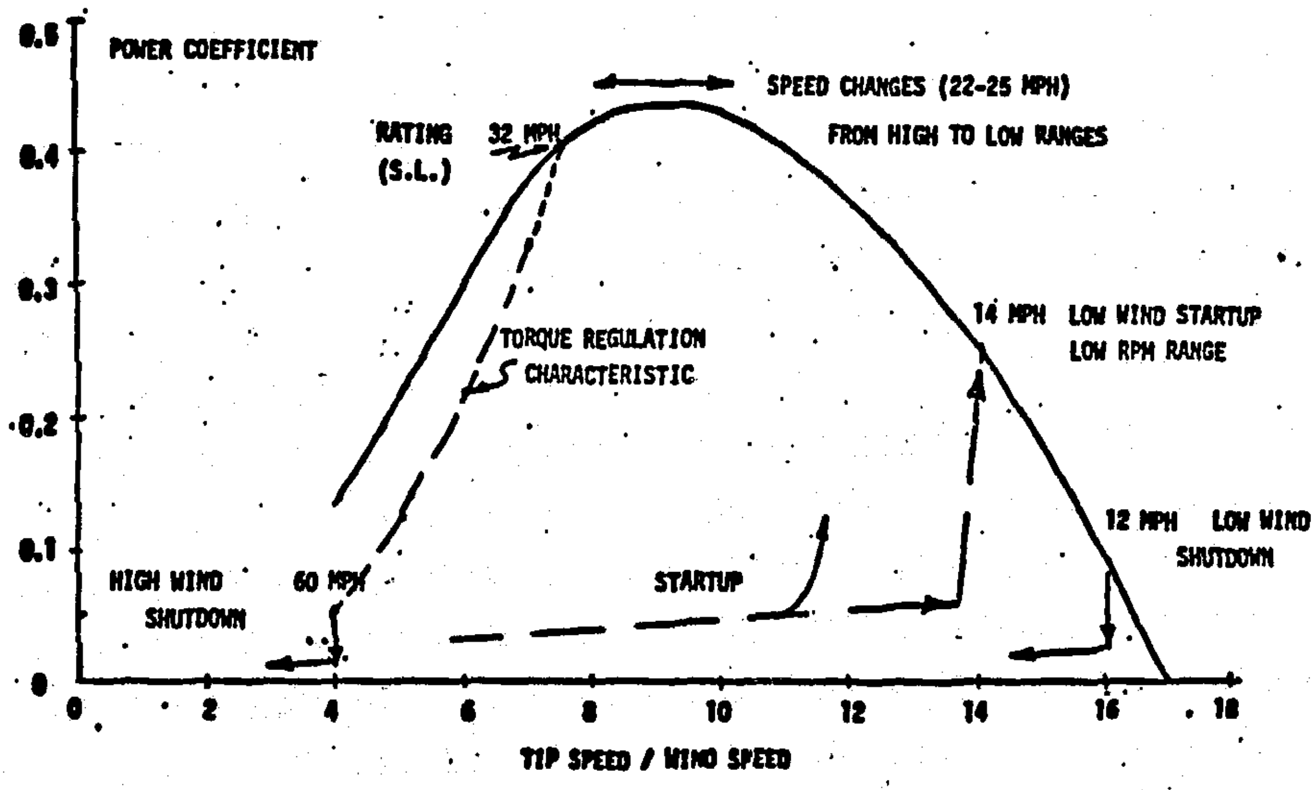

FIGURE 3.2-2
ROTOR DESIGN PERFORMANCE

3.2.1.4 Design Life

The WTG design service life shall be 30 years. Periodic replacement of components shall be used to meet this requirement if lower cost of energy can be calculated per paragraph 3.0. Life shall be based on 220 million rotor revolutions and 35,000 start-stop cycles.

3.2.1.5 Frequency Placement

The WTG system frequencies and operating speeds shall be located to avoid load amplification at integer multiples of the operating speeds. Specific frequencies to avoid shall include, but not be limited, to:

a) Tower bending and all integer multiples
b) Blade flapwise bending and even integer multiples
c) Blade chordwise bending and odd integer multiples
d) Drivetrain torsion and all integer multiples

3.2.1.6 Wind Characteristics

3.2.1.6.1 Design Wind

The design wind regime is defined in section 3.2.3.1.

3.2.1.6.2 Site Specific Wind

Wind regimes with characteristics other than the design wind regime shall be considered with respect to the system effects of at least:

a) Altitude/air density effects on cooling and dielectric strength.

b) Turbulence effects on loads, number of starts, high wind cut-out and cut-in.

c) Duration effects on load/life.

Where appropriate, rating revision shall be utilized to accommodate the site specific data.

3.2.2 SUBSYSTEM REQUIREMENTS

The WTG includes the subsystems and elements in paragraph 3.1.5. Performance and design requirements for these are defined in the following paragraphs.

3.2.2.1 Foundation and Site

The foundation and site elements consist of the tower foundation, ground electrical equipment foundation, grounding, fencing, maintenance tie downs, erection area preparation and grading.

3.2.2.1.1 Tower Foundation

The tower foundation shall be designed to carry the steady and cyclic loads due to WTG weight, rotor thrust and wind forces, and also carry the infrequently occurring limit loads due to seismic disturbance, extreme wind speeds and rotor overspeed. Soil pressures in accordance with paragraph 3.1.6.1 shall be considered in the design. The design shall provide anchor bolts or other suitable anchor provisions to carry tower loads at the tower interface. The design shall provide for conduits for power and signal wiring from the tower interior to the ground equipment location using below grade routing. The design shall provide for the grounding system of paragraph 3.2.2.1.3. The design shall include blade tether and hoist tie down points. The general foundation design shall be modifiable to accommodate site specific soil conditions.

3.2.2.1.2 Ground Electrical Equipment Foundation (GEEF)

The GEEF shall be located about 200 feet from the tower base and provide a level support surface for the weight and limit wind and seismic loads of the ground electrical equipment (GEE) of paragraph 3.2.2.2. The design shall provide for conduits for power and signal wiring from the GEE to the tower foundation using below grade routing. The design shall provide for grounding conductors from at least four points on the GEE equipment base to the grounding system of paragraph 3.2.2.1.3. The design shall provide anchor studs to secure the GEE.

3.2.2.1.3 Grounding

The WTG shall have a grounding system that provides less than five ohms effective resistance to earth as measured at both the tower base and the GEE base. Connection methods and measurement techniques shall conform to section 4 of IEEE Standard 142 (Green Book)/ANSI C114.1 "IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems". The grounding system shall be adequate to accommodate the transient currents due to the lightning definition of paragraph 3.2.3.2. Test wells shall be provided by each foundation. All foundations shall be electrically connected together by the grounding system.

3.2.2.1.4 Fencing

A utility type galvanized fence with lockable gates shall be provided around at least the ground electrical equipment (GEE) described in paragraph 3.2.2.2. A fence may be provided around the tower base. The fencing shall be located at least 15 feet from the structure and shall be at least 8 feet high. The fencing shall be connected to the grounding system.

3.2.2.1.5 Grading

A crushed rock fill surface shall be provided within the fencing confines. A suitable surface for light vehicle parking and movement around the WTG tower base and the GEE installation shall be provided. If necessary, provision shall be made for drainage away from foundation to soil interfaces.

3.2.2.1.6 Maintenance and Access

Foundation and site equipment shall be substantially maintenance-free. The fencing shall have site security alarm sensors for unauthorized intruder detection.

3.2.2.2 Ground Electrical Equipment (GEE)

The GEE consists of the site step-up transformer, switchgear, converter, filters, capacitors, UPS, auxiliary power supply, battery power supply, switchboard, and ground control interface. The GEE shall be installed on the foundation of paragraph 3.2.2.1.2, as factory subassembled and wired units. Items and accessories shall be provided as shown on single line drawing 47D387080 and the following. Indoor rated equipment shall either be provided with a protected aisle enclosure or be housed in a site fabricated building.

3.2.2.2.1 Step-up Transformer

An outdoor oil filled transformer, rated 7450 KVA for 65 C oil rise with forced air cooling shall provide step-up of 4,160 volt generator output to a nominal 69,000 volt electrical network as described in paragraph 3.1.5.1. A high voltage visible break fused disconnect switch shall be provided either as part of the transformer assembly or mounted on the first distribution line pole.

3.2.2.2.2 Switchgear Assembly

A switchgear assembly shall be connected to the transformer and house or provide for mounting of the following.

3.2.2.2.2.1 Circuit Breakers

Circuit breakers shall be suitable for starting, switching and fault protection at 7450 KVA, 4160 volt. Interrupting rating shall be suitable to clear generator or network fed faults.

3.2.2.2.2.2 Converter

The converter portion of the variable speed generator system defined in specification 47D380094 or 47D380115 shall convert from generator variable speed frequency to 60 hertz grid frequency at 4160 volts.

3.2.2.2.2.3 Filters

Harmonic filters shall be provided as required to limit voltage fluctuations at the grid connection to IEEE 519 guidelines, when the WTG is operating.

Site specific requirements may require filtering in excess of IEEE 519 guidelines on a requisition-only basis.

3.2.2.2.2.4 Capacitors

Power factor correction capacitors, including the 60 hertz effect of filters, shall be provided as necessary to operate in a controlled Var mode at greater than 0.98 power factor.

3.2.2.2.2.5 UPS

An uninterruptable power supply at 120 VAC shall be provided with suitable rating to operate the control system for a minimum of 30 minutes, including sensors and actuators.

3.2.2.2.2.6 Accessory Power

Air insulated transformers and protective devices rated to provide 300 KVA, 480 volt, 3 phase and 208Y/120 volt, 3 phase multiple circuit accessory power by step-down from the 4,160 volt system shall be provided.

3.2.2.2.2.7 Battery Power

A DC stationary battery and charger system shall be provided for switchgear control system operation. Temperature control, voltage drop and venting shall be considered in the battery system and connection design.

3.2.2.2.2.8 Switchboard

A switchboard shall be provided with electrical protective relaying, transducers, and meters. Instrument transformers and connection areas shall be located in metalclad bays as part of the overall assembly.

3.2.2.2.2.9 Enclosure

The equipment enclosure shall have anti-condensation heaters provided in insulation areas. Two lockable doors with security system sensors shall be provided, with panic-bar type inside latch releases. A means shall be provided for observing the WTG from inside the enclosure. Fluorescent interior lighting and convenience outlets shall be provided in the aisle area. Rodent and insect barriers shall be included in the design. Exterior area lighting shall be provided. Inlet air shall be mechanically filtered to remove airborne particulates.

3.2.2.2.3 Interlocks

Key interlocks or tamper-proof hardware shall be provided on equipment access doors, to mechanically prevent door opening while equipment is energized.

3.2.2.2.4 Ground Control Equipment

The ground level control system site interface defined in paragraph 3.2.2.8.2 shall be installed as part of the GEE.

3.2.2.2.5 Interfaces

The GEE equipment has interfaces with the WTG per paragraph 3.2.2.1.2 and with the utility per paragraph 3.1.5.1.

3.2.2.2.6 Lightning Protection

Lightning protection shall be provided such that the lightning model of paragraph 3.2.3.2 will not cause damage to the GEE enclosure or equipment.

Station class lightning arrestors shall be applied at the utility grid connection and elsewhere to avoid over voltages.

3.2.2.2.7 Instrumentation

3.2.2.2.7.1 Operational Instrumentation

The GEE shall provide for sensors, controls and wiring per 47A387005, Signal and Command List.

3.2.2.2.7.2 Engineering Data Instrumentation

GEE Engineering Data Instrumentation shall be per 47A387005. This instrumentation is required on initial units and is a requisition option for volume production. A GEE mounted multiplexor capable of handling at least 32 channels simultaneously shall be used with the Engineering Data Instrumentation.

3.2.2.2.8 Maintenance and Access

GEE equipment shall be substantially maintenance free. Periodic inspection of insulation, contact surfaces, and moving parts shall be simplified with drawout type construction with adequate access space. Provision shall be made for at least two voice telephone circuits and a monitor for closed circuit nacelle video display.

3.2.2.3 <u>Operation and Maintenance</u>

MOD-5A WTG operation and maintenance functions shall be eased by equipment design features and personnel training.

3.2.2.3.1 Personnel

The WTG shall be designed for operation and maintenance by trained technicians having electrician, machinist, and mechanic qualifications. Operation of the WTG, from either the site or remote control locations, shall only require a single technician. Maintenance shall be based on a crew of two technicians for most operations. All operation and maintenance personnel shall have completed the training of paragraph 3.2.2.3.5.

3.2.2.3.2 Site Operation

Site operation shall consist of the automatic and manual modes of paragraph 3.1.7. A portable maintenance input/output device may be used to provide site control of these modes.

3.2.2.3.3 Remote Operation

Remote operation shall consist of the automatic modes of paragraph 3.1.7.1 using the interface of paragraph 3.1.5.2.

3.2.2.3.4 Scheduled Maintenance

Periodic scheduled maintenance shall be used in the design of the WTG, totaling an allocated number of hours per year per section 3.2.2.9 for a volume production WTG. Periodic maintenance shall be used for servicing and lubrication functions that do not require automatic operation and for detection and repair of non-critical failures such as lamp burnout and minor leakage. The nominal interval shall be 90 days between inspections, with maintenance only as required.

3.2.2.3.5 Training

The contractor shall provide a training course for utility operation and maintenance personnel, based on the operation and maintenance manuals of paragraph 3.2.2.3.6. Training shall consist of classroom and on-the-job sessions as appropriate to the subject matter and be completed within one month of acceptance.

3.2.2.3.6 Manuals

The contractor shall prepare operation and maintenance manuals containing material of sufficient depth and scope to enable personnel of the skills level of paragraph 3.2.2.3.1 to perform all work related to the manual descriptive title.

3.2.2.4 Rotor Subsystem

The rotor subsystem consists of all WTG elements that rotate with the rotor and are located on the rotor side of the drivetrain to rotor interface of paragraph 3.2.2.4.7 as follows. The rotor shall be capable of operation at a 7 degree tilt from 16.2 to 16.8 RPM and from 13.2 to 13.8 RPM. Design overspeed shall be 21 RPM (1.25 x 16.8). Survival overspeed shall be 25 RPM.

3.2.2.4.1 Yoke Assembly

The yoke assembly consists of the yoke, teeter, brake, bearing assembly, and rotor hydraulic assembly.

3.2.2.4.1.1 Yoke

The yoke shall support the rotor and react all rotor loads through bearings into a rotor support spindle. It shall accommodate installation of the assembled rotor on the nacelle mechanically and electrically and provide for routing of wiring. The yoke shall accommodate installation of a rotor stopping brake assembly.

3.2.2.4.1.2 Teeter Assembly

The teeter assembly shall provide for up to +/- 9 degrees of teeter motion of the blade longitudinal axis about an axis normal to the hub shaft axis. Compliant stops or energy dissipating means shall be provided at the limits of teeter travel to limit reaction loads to non-design driver levels. A teeter motion restricting means shall be provided capable of being controllably released and applied. The teeter assembly shall carry blade loads into the yoke.

3.2.2.4.1.3 Rotor Hydraulic Assembly

The rotor hydraulic assembly shall consist of motor, pump, reservoir, accumulator, piping, valving, and environmental protection devices necessary to provide normal and emergency hydraulic pressure and flow to operate the aerodynamic control of paragraph 3.2.2.4.3 and rotor mounted hydraulic device needs. The rotor hydraulic assembly shall be a packaged subassembly design suitable for mounting on the yoke.

3.2.2.4.2 Blades

The blades shall consist of a structural/airfoil geometry optimized for low cost and weight and high performance. The reference configuration shall be the NACA 64XXX airfoil series rotating clockwise when observed from upwind. All blade loads shall be carried into the yoke. A means for one time field joining of spanwise sections of the blade shall be provided. A means for field joining non-structural chordwise (trailing edge) sections of blade to extend beyond transportation dimensions shall be provided. The blades shall consist of a center 100 ft. section, two inner sections and two outer sections. The outer 80 ft. of each blade shall incorporate a means for aerodynamic torque control. The blades shall provide a means for adjusting static mass balance to within 7000 ft. lb. on the complete rotor about the teeter axis. Nominal blade performance shall be per paragraph 3.2.1.3.

3.2.2.4.3 Aerodynamic Control (Ailerons)

The aerodynamic control shall be a multiple section, hydraulically powered, electrically controlled device for changing the position of the trailing edge portion of the outer blade. The range shall be from aligned with the leading edge portion of the blade to at least 75 degrees toward the low pressure (down wind) side of the airfoil.

3.2.2.4.3.1 Configuration

The aerodynamic control shall have at least three mechanically independent sections on each blade. Each section shall be provided with an actuating means with position servocontroller and energy storage means that provides motion to full deflection on loss control power and/or main blade hydraulics. A spring applied, hydraulically released mechanical latch shall be provided to secure the control surfaces in the deflected position in the absence of hydraulic power. The hydraulic and structural interface with the leading edge portion of the blade and the mechanical properties and support of the control surfaces shall prevent any aerodynamic instability. The control surface design and actuation means shall produce retarding torque with one surface jammed in an aligned position for a hub wind speed of 1.25 times high cut-out (VHCO). The aerodynamic control shall slow the rotor to an equilibrium velocity ratio (tip speed/wind speed) of 1.5 or less with all surfaces operating or 2.0 or less with one surface jammed.

3.2.2.4.3.2 Rates and Storage Requirements

The aerodynamic control and the hydraulic supply of paragraph 3.2.2.4.1.4 shall have the following rate and storage capabilities.

a) Accumulator Recharge - The pump capacity shall be adequate to charge hydraulic accumulators within 6 minutes from a no-fluid condition.

b) Continuous Operation - The pump capacity shall be adequate for up to 2 degree/second motion of all control surfaces. Flow will be distributed between control motion and operating accumulator recovery. Operating accumulators shall be sized for 120 degrees of motion of all control surfaces. The continuous operating servo system shall be adequate for a peak rate of 5 degrees per second.

c) Emergency Feather - The actuator stored energy and control shall provide for full control motion per blade. A passive means for scheduling emergency feather rate from 1 to 10 degrees per second shall be provided.

3.2.2.4.4 Lightning Protection

Lightning protection shall be provided such that the lightning model of paragraph 3.2.3.2 will not cause damage to the rotor structure, bearings, hydraulic lines and devices, or electrical lines and devices. Lightning conductors shall be added in a manner to minimize electromagnetic reflecting area. Shunt current paths shall be provided around bearings.

3.2.2.4.5 Ice Detection

The rotor shall have provisions for installation and wiring of an aircraft type icing detector on each blade. The detector location shall be accessible from the yoke.

3.2.2.4.6 Instrumentation

The rotor shall have provision for operational and engineering data instrumentations and wiring as follows.

3.2.2.4.6.1 Operational Instrumentation

Rotor operational sensors, and controls shall be per 47A387005, Signal and Command List.

3.2.2.4.6.2 Engineering Data Instrumentation

Rotor Engineering Data sensors and controls shall be per 47A387005. This instrumentation is required on initial units and is a requisition option for volume production. A rotor mounted multiplexor capable of handling at least 32 channels simultaneously shall be used with the Engineering Data instrumentation.

3.2.2.4.6.3 Wiring

Rotor operational wiring shall be routed in continuous metallic conduit, with appropriate surge protection installed at the conduit entry. Rotor

Engineering Data Wiring from strain gages shall be surface routed with environmental protection up to conduit entry points then routed similarly to operational wiring.

3.2.2.4.7 Interfaces

The rotor subsystem shall interface mechanically with the rotor support spindle bearings, stopping brake and drivetrain low speed shaft. Rotor thrust and gravity loads shall be transferred to the spindle and rotor torque loads shall be transferred to the low speed shaft during operation and through the stopping brake and spindle support while stopping and parked. Electrical signal and power leads shall be connectable on the yoke structure and be routed both across the teeter axis to the blade and to the low speed shaft interior.

3.2.2.4.8 Maintenance and Access

Access and support features shall be provided on the rotor subsystem to minimize inspection and maintenance life cycle costs. Minimum requirements are as follows.

a) Blade tether points shall be provided near the outer end of the main blade for restraining blade position in either a horizontal or a vertical position, for tethering to foundation.

b) The blade and aerodynamic control design shall provide for removal of control sections and actuators with minimum equipment while the rotor is oriented, restrained and tethered.

c) The aerodynamic control design shall provide for hardware, seal, sensor and bearing inspection access and minimize disassembly for repair.

d) The rotor hydraulic assembly shall provide for inspection access and have provisions for the securing of test devices and for attaching rigging for handling components.

e) The rotor shall have provision for manually positioning and restraining teeter angle at either limit of travel.

f) The rotor assembly shall be capable of being slowly manually positioned in rotation and restrained (locked) in either the vertical or horizontal blade orientations by drivetrain devices.

g) The teeter assembly shall have provisions for bearing removal and replacement while the rotor assembly is mounted on the drivetrain and restrained and tethered in a horizontal blade orientation.

h) The yoke shall have provision for personnel access to the rotor hydraulic assembly, teeter assembly and provide attachment points for rigging of blade inspection and maintenance devices.

3.2.2.5 Drive Subsystem

The drivetrain subsystem consists of all WTG elements that rotate when the rotor is turning and their principal accessories. The main elements are the low speed shaft, gearbox, high speed shafting, and the generator.

3.2.2.5.1 Low Speed Shaft

The low speed shaft shall transmit torque from the rotor yoke to the gearbox. A hollow shaft shall be used to provide for a rotating wiring conduit to the rotor. The shaft shall have floating ends to accommodate misalignment and differential expansion.

3.2.2.5.2 Gearbox

The gearbox shall provide for single ratio speed increase from the rotor speed to the generator speed, static torque reaction, lubrication and mounting of accessory devices.

3.2.2.5.2.1 Operating Characteristics

Nominal gearbox characteristics shall be:

a) Rated output speed: 1380 RPM

b) Rated input speed: 16.8 RPM

c) Rated input torque: 3.39 million ft. lb.

d) Static limit torque: 2 times rated torque

e) Operating limit torque: 1.3 times rating for 1.35 percent of life

f) Operating life: 220 million input revolutions over 30 years.

g) Rotation: CW input when viewed from input shaft end

3.2.2.5.2.2 Lubrication

The gearbox shall provide for both auxiliary shaft driven and motor driven lubrication pumps. The WTG nacelle subsystem shall provide heating and cooling functions for the lubrication system. The lubrication system shall provide the proper lubrication of all gearbox bearings, while the WTG is operating within the design environmental conditions. The lubrication system shall provide for bringing the gearbox input from rated RPM to a stop, unloaded, without electric power available and for one complete rotation of the input shaft unloaded at .2 RPM without lubricant flow.

3.2.2.5.2.3 Accessories

The gearbox shall provide for mounting of sensors, railings, holding brake caliper, rotor manual positioner, and attachment and rigging points for maintenance. A continuously engaged shaft shall be provided for mounting of a holding brake disk. A rotating wiring conduit shall be provided concentric with the input shaft. Mounting for a mating slip ring shall be provided on the gearbox opposite the rotor end. The slipring shall provide for continuous rotation of electrical circuits between the nacelle and the rotor.

3.2.2.5.3 High Speed Shafting

The high speed shafting shall transfer torque from the gearbox to the generator and provide floating ends for alignment compensation.

3.2.2.5.4 Generator

The generator shall be part of a variable speed subsystem as defined in specifications 47D380094 or 47D380115 with the following characteristics.

a) Rated output: 7300 KW, 0.98 pf.

b) Rated voltage: 4160 V L-L 3-phase, 60 hertz

c) Speed: 0 - 300 RPM motoring, 960 - 1440 RPM generating, rotation either direction.

d) Temperature: class F insulation and class F rated rise at rated output.

e) Cooling: shaft fans, ducted outlet.

f) Bearings: two, oil ring and flood lubricated, thrust and external load capability at drive end.

g) Ambient: ANSI standard ratings. System derating for temperature and altitude as appropriate.

h) Protection and Accessories: per drawing 47D387080 (electrical single line diagram).

3.2.2.5.5 Rotor Stopping Brake

The rotor stopping brake operating on the rotor yoke shall be hydraulically powered from the yaw hydraulic assembly. The design shall provide for 100 hours of engagement without hydraulic pump operation. The rotor brake holding torque shall be two million ft. lb. and the design shall thermally provide for stopping the rotor inertia from a speed of 12 RPM. The rotor stopping brake shall be capable of being manually applied for rotor locking.

3.2.2.5.6 Rotor Positioner

The rotor positioner shall provide for manual and automatic control of rotor orientation. Operation shall be at no more than 2 degrees per second average rate at a torque level of no more than 0.15 of rated gearbox torque. Intermittent drive motion is acceptable.

3.2.2.5.7 Lightning Protection

Lightning protection shall be provided such that the lightning model of paragraph 3.2.3.2 will not cause damage to the gearing, structure, bearings, hydraulic lines and devices or electrical lines and devices. Shunt current paths (around bearings), surge capacitors, and voltage limiting devices shall be provided where necessary.

3.2.2.5.8 Instrumentation

3.2.2.5.8.1 Operational Instrumentation

Drivetrain operational instrumentation sensors and controls shall be per 47D387005, Signal and Command List.

3.2.2.5.8.2 Engineering Data Instrumentation

Drivetrain engineering data instrumentation sensors and controls shall be per 47D387005. This instrumentation is required on initial units and is a requisition option for volume production. Rotor and nacelle mounted multiplexors shall be used to transmit data.

3.2.2.5.9 Interfaces

The drivetrain subsystem mechanically interfaces with the rotor subsystem at the yoke and brake and with the nacelle subsystem at the gearbox and generator mounting locations. All interfaces shall provide for interchangeable connection of hydraulic lines and electrical power and signal circuits.

3.2.2.5.10 Maintenance and Access

Access and support features shall be provided on the drivetrain subsystem to minimize inspection and maintenance life cycle costs. Minimum requirements are as follows.

a) The gearbox and generator structure shall have provision for personnel access to inspection and service locations and provide attachment points for rigging of maintenance devices and safety lines.

b) The lubrication system shall have provision with a filter for connection of a portable pump for manual filling, draining, and circulation of lubricant.

c) Grease lubricated seals and couplings shall be provided with accessible lubrication fittings.

d) Generator bearings shall be replaceable without generator rotor removal.

e) Valving and fittings shall be provided for connection of a manual pumping device to the rotor stopping brake.

f) Gearbox covers and high speed stage design shall provide for major maintenance operations without gearbox removal from the nacelle.

g) Replaceable element filters, delta pressure indicators, access openings, sample valves, sight gages and similar devices shall be provided in the lubrication system.

3.2.2.6 Nacelle Subsystem

The nacelle subsystem consists of the rotor support structure bedplate structure, fairing, yaw subsystem, hydraulic assembly, lubrication system components, control system assembly, maintenance hoist and accessories. The nacelle subsystem supports the rotor and drivetrain.

3.2.2.6.1 Bedplate and Rotor Support

The bedplate and rotor support shall provide structural support for the rotor spindle and drivetrain subsystems, and carry all reaction loads through the yaw bearing into the tower. The bedplate shall provide for mounting of all items in section 3.2.2.6, accessories and accessible routing of hydraulic and electrical circuits. Minimum access and work spaces shall be provided using MIL-STD-1472 as a guide. The bedplate shall have attachment points for assembled nacelle lifting. Metal containers shall be secured to the bedplate for storage of standard tools. A lube oil subsystem shall be field mounted underneath the bedplate. The rotor support spindle shall support the yoke of paragraph 3.2.2.4.1 using a rolling element bearing assembly capable of reacting weight, thrust and dynamic loads.

3.2.2.6.2 Fairing

The fairing shall provide an enclosed space around nacelle mounted WTG items and reduce environmental exposure for these items and maintenance personnel.

The fairing structure shall provide for: mounting of two wind sensor supports at the end opposite the rotor; mounting of generator cooling exhaust ducting; mounting of maintenance lighting fixtures; mounting of convenience outlet and conduit runs; mounting of a fire protection system; mounting of aircraft hazard lighting; mounting of personnel access openings and safety fittings for access to the rotor and fairing mounted items; mounting of openings for major maintenance access by external crane or hoist; mounting of lube oil cooler.

3.2.2.6.2.1 Wind Sensor Mounting

The two wind sensor mountings shall locate the sensors at a minimum of 30 feet apart parallel to the rotor plane, and with sufficient vertical height above the rotor axis to prevent simultaneous rotor blockage of both sensors. The mountings shall provide for sensor servicing from the nacelle.

3.2.2.6.2.2 Air Flow and Ducting

Generator cooling air shall be drawn from within the fairing and the heated exhaust air shall be ducted. The exhaust ducting shall provide a temperature controlled means of directing exhaust air to either inside or outside the fairing. Air entrance to the fairing shall be mechanically filtered to remove airborn particulates with louvers for controlled shutoff.

3.2.2.6.2.3 Fire Protection

The fire protection system shall provide for releasing a non-toxic fire extinguishing agent within the nacelle and for control system sensor inputs indicating that fire conditions are sensed and that the agent has been released.

3.2.2.6.2.4 Maintenance Hoist

A boom type maintenance hoist shall be installable on top of the rotor support structure. The hoist shall be capable of raising 10,000 lb. from the ground. The hoist shall be maneuverable to reach fairing access hatches and yoke equipment and be usable for rotor inspection and maintenance.

3.2.2.6.2.5 Maintenance Light and Power

a) Maintenance lighting shall provide for illumination of at least 10 foot candles in all accessible areas and at least 50 foot candles in maintenance working areas using fixed and moveable sources.

b) Maintenance power outlets shall provide GFI protected 120 volt, 15 ampere, 60 hertz service and be located 20 feet apart around the interior of the fairing. Each end of the nacelle shall also contain protected outlets for two 208 volt, and two 480 volts, 3 phase circuits, each rated at 15 amperes. Nacelle power shall be supplied from one feeder 480 volt, 3 phase circuit with step-down and circuit protection provided in the nacelle.

3.2.2.6.2.6 Hazard Lighting

The fairing shall provide for mounting of FAA approved white flashing dusk/dark hazard lighting fixtures. The lighting shall comply with the requirements of DOT, FAA Advisory Circular 70/7460 - 1F "Obstruction Marking and Lighting".

3.2.2.6.3 Yaw Subsystem

The yaw subsystem shall carry all bedplate loads into the tower, provide for controlled continuous rotation in either direction, provide personnel access from the tower to the nacelle, and provide for electrical circuit continuity.

3.2.2.6.3.1 Yaw Drive Assembly

The yaw drive assembly shall consist of the yaw bearing assembly, drive actuators and grippers, holding brakes, a nacelle mounted hydraulic supply, and controls. The drive shall be capable of rotating the nacelle at an average rate of at least 0.250 degrees per second in either direction. The holding brakes shall provide sufficient torque to lock yaw in all operating conditions. Yaw drive stiffness and damping in both driving and non-driving modes shall minimize system response to periodic excitations. The hydraulic supply shall be designed to supply the yaw drive and the rotor stopping brake flow and pressure requirements.

3.2.2.6.3.2 Slip Ring

The yaw slipring shall provide continous rotation capability for circuits between the nacelle and tower.

3.2.2.6.4 Lightning Protection

Lightning protection shall be provided such that the lightning model of paragraph 3.2.3.2 will not cause damage to structure, bearings, hydraulic lines and devices, or electrical lines and devices. Shunt current paths around bearings and voltage limiting devices shall be provided where necessary.

3.2.2.6.5 Instrumentation

3.2.2.6.5.1 Operational Instrumentation

Nacelle operational instrumentation sensors, controls and wiring shall be per 47D387005, Signal and Command List.

3.2.2.6.5.2 Engineering Data Instrumentation

Nacelle engineering data instrumentation sensors, controls and wiring shall be per 47D387005. This instrumentation is required on initial units and is a requisition option for volume production. A nacelle mounted multiplexor shall provide for at least 32 data channels.

3.2.2.6.6 Interfaces

The nacelle subsystem interfaces with the rotor subsystem at the support spindle, with the drivetrain subsystem at the gearbox and generator mounting locations and with the tower subsystem below the yaw structure. All interfaces shall provide for connection of hydraulic lines and electrical power and signal circuits.

3.2.2.6.7 Maintenance and Access

Access and support features shall be provided on the nacelle subsystem to minimize inspection and maintenance life cycle costs. Minimum requirements are as follows; in addition to requirements shown in other paragraphs of this section.

a) The nacelle and yaw areas shall have modular jacks located by maintenance areas and wiring for telephone communication on at least two circuits.

b) The nacelle shall have provision for mounting and wiring of a closed circuit video monitor.

c) Valving and fittings shall be provided for connection of a portable pumping device to the yaw drive hydraulic system.

d) The yaw area shall have suitable attachment points for removal and servicing of the slipring and yaw drive components.

3.2.2.7 Tower Subsystem

The tower subsystem consists of the tower structure, nacelle access device, tower lighting and tower wiring.

3.2.2.7.1 Tower Structure

The tower structure shall carry its own and all nacelle reaction loads into the tower foundation, and provide for personnel access into the tower base by means of a lockable metallic door. The top of the tower shall provide for anchoring and servicing of the nacelle access device and provide for personnel access from the tower into the nacelle. The tower shall locate the rotor axis for blade clearance of 50 feet above the local grade. For operating loads, the absolute wind azimuth can be assumed to vary in a Gaussian manner with 30 degree standard deviation.

3.2.2.7.2 Nacelle Access Device

The tower shall provide an internally mounted 480 volt, electrically powered nacelle access device capable of moving up to 650 pounds of personnel and equipment from the ground to nacelle level in less than 4 minutes one way. Control of device movement shall be provided on the device, at ground level, and at the top of the tower. A means of descending the tower from any access device elevation without the use of electrical power shall be provided. A protected landing platform shall be provided at the top of the tower. Access device power shall be interruptable from the Ground Electrical Equipment enclosure.

3.2.2.7.3 Tower Lighting and Power

Tower interior lighting shall provide for illumination of at least 10 foot candles when switched on at either the top or bottom of the tower. Maintenance power outlets shall provide weatherproof GFI protected 120 volt, 15 ampere, 60 hertz service and be located at the tower base and at the nacelle access device and landings. A weatherproof 480 volt, 3 phase outlet shall be provided at the tower base and at the nacelle access device landings.

3.2.2.7.4 Tower Wiring

The access device installation shall provide for supporting and protecting power and signal wiring from the yaw slipring to the tower foundation conduiting.

3.2.2.7.5 Lightning Protection

Lightning protection shall be provided such that the lightning model of paragraph 3.2.3.2 will not cause damage to the structure or electrical lines and devices. Lightning currents shall be transferred from at least three points at the tower base into the grounding system specified in paragraph 3.2.2.1.1.

3.2.2.7.6 Interfaces

The tower subsystem interfaces with the nacelle subsystem at the yaw bearing and with the tower foundation anchors. The tower structure shall provide suitable bearing and anchor reaction features to carry tower loads into the foundation. All interfaces shall provide for connection of electrical power and signal circuits.

3.2.2.7.7 Instrumentation

3.2.2.7.7.1 Engineering Data Instrumentation

Tower engineering data sensors shall be per 47D387005, Signal and Command List. This instrumentation is required on initial units and is a requisition option for volume production. The ground mounted multiplexor shall be used for data transmission.

3.2.2.7.8 Maintenance and Access

The tower shall be designed for low maintenance and provide features that minimize inspection and maintenance life cycle costs. Minimum requirements are:

a) The tower base, nacelle access device, and access device landings shall have modular jacks and wiring for telephone communications on at least two circuits.

b) The tower shall provide for rigging points for interior and exterior access to all surfaces for inspection and refinishing.

c) The tower shall provide for controlling condensation runoff on interior surfaces if necessary to avoid corrosion acceleration.

d) The tower door and nacelle access device and landing gates shall have site security system sensors for intruder detection.

3.2.2.8 Control Subsystem

The control subsystem consists of the equipment necessary to sense and manipulate data from WTG operational sensors and controls; perform decision logical processes; perform computations; generate operational and maintenance commands; store data windows of WTG performance both before and after shutdown initiation fault occurrance; and maintain communication for transmittal of data and commands between elements of the WTG, the local control interface, and the remote control interface specified in paragraph 3.1.5.2. The control subsystem shall provide for operation in the modes of paragraph 3.1.7 with continually operating data collection, communication and fault monitoring functions.

3.2.2.8.1 Controller

The controller equipment shall consist of an enclosed rack located in the nacelle which senses and controls all WTG functions. The controller equipment shall as a minimum provide for: connection and signal conditioning of sensor inputs and command outputs; dynamic control of blade and generator control elements; failsafe electronics; real time generation; data window memory; non-volatile memory; watchdog electronics; and ports. The controller equipment shall be powered by the uninterruptable power supply defined in section 3.2.2.2.2.5.

3.2.2.8.2 Site Interface

The site interface shall consist of a display panel and a terminal. The panel shall provide: discrete mode indication; limited data indication of blade control position, RPM, power, wind speed and wind direction; key switch control over WTG mode; port for connecting the terminal; port and modem for connecting link to remote interface per paragraph 3.1.6.2; connection to controller. The terminal shall provide the functions generally available on a printing data terminal including alphanumeric display and keyboard entry.

3.2.2.8.3 Remote Interface

3.2.2.8.3.1 Standard Remote Interface

The standard remote interface shall consist of a modem and a terminal that provides the functions generally available on a printing terminal including alphanumeric display and keyboard entry.

3.2.2.8.3.2 Site Specific Remote Interface

Where user requirements are for parallel rather than serial signals, the user shall provide for signal handling of standard WTG signals at the site interface.

3.2.2.8.4 Supervisory Control Priority

The controller of paragraph 3.2.2.8.1 shall be capable of failsafe automatic WTG operating control after enabled by the site and remote interfaces. Continuous interface communication shall not be required to maintain automatic operation. The remote interface shall be able to enable and disable automatic mode, alter maximum power setting, alter reactive power setting, and transfer control to the other interface. The site interface shall be able to do all remote interface functions plus enter manual control functions of paragraph 3.1.7.2, and read out information stored in the data window. Lockout conditions occurring during automatic operation shall require site interface operation in order to enforce on-site inspection.

3.2.2.8.5 Control Functions

The controller shall provide control of sequencing between the automatic modes of paragraph 3.1.7.1 and the following control functions.

3.2.2.8.5.1 Yaw Position Control

The yaw position control function shall provide for:

a) Averaging wind azimuth error.

b) Generating commands to the yaw drive to position the rotor axis upwind of the tower within an average wind azimuth error of +/- 8 degrees for rotational modes.

c) Generating commands to the yaw drive for directional rotation of the nacelle in manual mode.

d) Monitoring of drive operation for fault detection.

e) Local control of drive components for coordination and sequencing.

3.2.2.8.5.2 Rotor Torque Control

The rotor torque control function shall provide for:

a) Sending position reference signals to pairs of control surface position servoactuators.

b) Electrical adjustment of individual control surface position reference offset relative to a single collective position reference.

c) Generating an initial position reference and a speed reference command ramp for startup to achieve operating speed in a reasonable time with respect to wind conditions.

d) Generating position reference commands for speed control with a goal to maintain +/- 1.0 RPM to a speed reference from 3 to 17 RPM at the rotor.

e) Generating a speed reference command ramp for shutdown.

f) Monitoring of differential control angle and command mismatch for fault detection.

g) Closed loop control of each control surface position in response to position reference commands (incorporated with actuation of paragraph 3.2.2.4.3.1.

h) Generating a speed reference command to maximize subrated wind power output.

i) Generating position reference commands for limited position control in manual mode.

3.2.2.8.5.3 Hydraulic Systems Control

The hydraulic systems control function shall provide for:

a) Generating commands to enable and disable the rotor, yaw and lubrication hydraulic systems for automatic and manual modes.

b) Monitoring pressure, flow, level and temperature conditions as appropriate for fault detection.

c) Local control of accumulator pressure, flow, cooling and heating as appropriate to system operation.

3.2.2.8.5.4 Electrical System Control

The electrical system control function shall provide for:

a) Generating commands to enable operation of the generator as a variable speed drive to accelerate the wind rotor from zero to approximately 4 RPM.

b) Generating commands to synchronize the generator to the utility at wind rotor speeds anywhere between 12 and 17 RPM.

c) Generating airgap torque commands as a function of speed and maximum user power set point to provide no more than 120% of rated torque and an effective dynamic airgap characteristic of 160% +/- 20% rated torque per RPM at the wind rotor. The converter of paragraph 3.2.2.2.2.2 shall follow the command.

d) Generating reactive power reference commands or optionally voltage reference commands as a function of user set point. The converter of paragraph 3.2.2.2.2.2 shall follow the commands and provide for a manual selection of reactive power or voltage control mode.

e) Monitoring voltage, power position and temperature conditions as appropriate for fault detection and command mismatch.

3.2.2.8.5.5 Teeter Restrictor Control

The teeter restrictor control function shall provide for applying the restrictor at rotor speeds below 11 RPM and releasing the restrictor at rotor speeds above 11 RPM. Local control of the restrictor shall be used to apply light damping restriction.

3.2.2.8.5.6 Rotor Stopping Brake Control

The rotor brake control shall provide for:

a) Generating a command to release the brake for startup.

b) Generating a command to apply the brake on shutdown for rotor speed less than 8 RPM or after aerodynamic control surfaces are deployed.

c) Generator commands to release and apply the brake for rotor positioning and manual modes.

3.2.2.8.5.7 Rotor Positioning Control

The rotor positioning control shall provide for:

a) Generating commands to the rotor positioning device of paragraph 3.2.2.5.6 for rotation of the rotor.

b) Generating coordination commands for the rotor stopping brake of paragraph 3.2.2.8.5.6 during positioning operation.

3.2.2.8.5.8 Failsafe Emergency Shutdown Control

The failsafe control function shall provide for separate hardware to initiate an emergency shutdown in response to critical backup sensor anomaly, manual input, controller command, controller malfunction or loss of control power. An emergency shutdown shall consist as a minimum of aerodynamic control surface operation at the emergency feather rate of paragraph 3.2.2.4.3.3 and application of the rotor stopping brake after a time delay. When the aerodynamic controls are fully feathered, an emergency shutdown shall lead to a normal shutdown sequence if the controller is active and power is available.

3.2.2.8.5.9 Fault Monitor Control

The fault monitor control function shall provide for:

a) Comparing all sensor values to expected state and alarm reference values.

b) Generating commands for mode transfer or shutdown on value mismatches.

3.2.2.8.5.10 Manual Control

The manual control function shall provide for site interface controlled operation in the manual modes of paragraph 3.1.7.2.

3.2.2.8.5.11 Data Window

The data window function shall provide for:

a) Retention of all sensor and critical average values time sampled and tagged at 1.0 second intervals for up to 120 seconds prior to any fault indication.

b) Retention of all sensor and critical average values sampled and time tagged at 1.0 second intervals for up to 180 seconds following the last fault indication.

c) Selectable display of retained values at the site interface in engineering units. Display shall be required prior to exit from a lockout mode.

3.2.2.8.5.12 Operating Accumulation

The operation accumulation function shall provide hardware and software for:

a) Accumulation of total time and hours when average wind is: less than VLCI, from VLCI to VRAT, from VRAT to VHCI, and greater than VHCI as defined in paragraph 3.2.1.2 and based on one minute average wind speeds, and hours when output is positive.

b) Accumulation of unavailable time when system mode is manual or lockout and user commanded unavailability in standby inhibit mode.

c) Accumulation of daily KW-hours based on a one minute average and overall total KW-hours.

d) Accumulation of rotor revolutions.

e) Display of selected software accumulated values periodically at the site or remote interface.

3.2.2.8.5.13 Data Display

The data display function shall provide for display of time tagged sensor, average and command values in engineering units with automatic updating at approximately 15 minute intervals or on change of mode at the site and remote interface.

3.2.2.8.6 Instrumentation

3.2.2.8.6.1 Operational Instrumentation

Operational instrumentation sensors, controls, device range, resolution, accuracy and other parameters shall be per 47D387005, Signal and Command List. Signal conditioning shall be supplied as needed.

3.2.2.8.6.2 Engineering Data Instrumentation

Engineering data instrumentation sensors, controls, device ranges, resolution, accuracy and other parameters shall be per 47D387005, Signal and Command List. This instrumentation is required on initial units and is a requisition option for volume production.

The control subsystem shall provide signal conditioning and multiplexing of Engineering Instrumentation System (EIS) sensors. Each data channel shall be frequency modulated into a band of +/- 125 Hz about a center frequency of from 1000 to 8500 Hz in 500 Hz increments. The resulting 16 data channels plus a 9500 Hz reference frequency shall be multiplexed and be capable of driving 2000 ft. of 75 ohm coaxial cable with BNC connector termination. A triple conductor calibration line shall interconnect all signal conditioners.

Up to six multiplexed lines shall be provided per WTG for a total of 96 data channels. Interface information provided by GE to the customer furnished recording and processing function shall include channel assignments, calibration data, and display requirements.

3.2.2.8.6.3 User Instrumentation

User instrumentation shall be provided as necessary to meet the reasonable needs of the connected utility for maintenance and operating data collecton. Initial device ranges, resolution accuracy and other parameters shall be per 47D387005, Signal and Command List.

3.2.2.8.6.4 Wiring

Control system wiring external to the controller cabinet shall be routed in continuous metallic conduit.

3.2.2.8.7 Lightning Protection

Lightning protection shall be provided such that the lightning model of parargraph 3.2.3.2 will not cause damage to the control system. Shielding and voltage limiting devices shall be provided where necessary. Strain gages mounted on the rotor may be expendable.

3.2.2.8.8 Interfaces

The control subsystem interfaces with the nacelle, rotor, drivetrain, tower and site equipment for mechanical and electrical installation. The network interface is per paragraph 3.1.5.2. Site and remote operator interfaces are described in paragraphs 3.2.2.8.1 through 3.2.2.8.5.

3.2.2.8.9 Maintenance and Access

Control system hardware shall be provided with features to minimize WTG inspection and maintenance life cycle costs. Minimum requirements are as follows:

a) Diagnostic functions shall be built into the controller.

b) No lower than board level replacement shall be used for maintenance.

c) All electrical connections at major devices shall be keyed to ease assembly, test and replacement.

d) All sensor and command lines shall have test points where they leave the controller for single location maintenance checks.

e) A sensor simulator and connection shall be available for major checkouts. This is a non-deliverable simulator for use on installation.

f) The site and remote interfaces shall have the capability to drive either hard copy or non-hard copy terminal devices.

g) All motor control circuits shall have local/automatic and local start/stop switches on controllers located near the motor.

3.2.2.9 Reliability, Availability, Maintainability, Spares

3.2.2.9.1 Reliability, Availability, Maintainability

The WTG reliability shall be consistent with the requirement that availability shall not be less than 92 percent when wind is between VLCO and VHCO as defined in paragraph 3.2.1.2 over a 30 year operational life for volume production in single or cluster installations.

3.2.2.9.2 Reliability

Reliability allocations shall be as shown in Table 3.2.2.9-1.

System Mean Time Between Failures (SMTBF) are for the duty cycle of paragraph 3.2.1.1 and the wind characteristic of paragraph 3.2.1.2 on an annualized basis. A mature system (after infant mortality) is assumed.

Reliability methodology shall be per document 47A380020 "Reliability, Availability, Maintainability and Failure Modes and Effects Analysis Plan".

3.2.2.9.3 Availability

System availability allocations shall be as shown in Table 3.2.2.9-1.

Average Annual Outage (AAO) time is the sum of scheduled and unscheduled times.

Availability methodology shall be per document 47A380020.

3.2.2.9.4 Maintainability

System maintainability allocations shall be as shown in Table 3.2.2.9-1.

Mean Time To Repair (MTTR) hours per system failure assume a full spares and on-site maintenance crew availability. Single unit installations and first units have higher MTTR reflected due to experience.

Maintainability methodology shall be per document 47A380020.

TABLE 3.2.2.9-1
RAM ALLOCATIONS

Installation	Mature Volume Production	Cluster	Cluster	Single	First
Subsystem	SMTBF	MTTR	AAO	AAO	AAO
Rotor	2731	28	89.8	197.7	250
Drivetrain	3063	19.8	56.6	124.5	141
Nacelle & Tower	3650	15.0	35.5	68.0	110
Controls, Instrumentation & Switchgear	1460	6.4	38.6	85.1	120
Cluster (Per WTG)	105,162	48.0	4.0	--	--
Unscheduled	602		224.5	475.3	621
Scheduled AAO			90.0	120.0	180.0
Total AAO			314.5	595.5	801.0
Availability			.964	.932	.908

3.2.2.9.5 Maintainability Features

The WTG shall have the maintainability and access features described in the subsystem requirements paragraph of this Section 3.2.2. General shop facilities shall be assumed for off-site work. MIL-STD-1472 shall be used as a guide for access. Single person lifting requirements shall not exceed 40 lb. Commercially available test equipment and tools shall be used as much as possible.

3.2.2.9.6 Spares

The WTG design shall include a listing of spare parts required to meet the availability goals of paragraph 3.2.2.9.3 based on the reliability allocations of paragraph 3.2.2.9.2. Separate listings shall be prepared for 1st, 2nd, 3rd, single and cluster installations.

3.2.2.9.7 Maintenance Personnel

Cluster installation maintenance and repair manpower shall be based on a dedicated crew and single installation maintenance and repair manpower shall be based on a per-job basis contract or general crew. Crews shall be trained per paragraph 3.2.2.3 in order to meet the maintainability goals of paragraph 3.2.2.9.4

3.2.3 Environment

3.2.3.1 Design Wind Environment

The WTG shall be designed for optimum cost-of-energy computed per paragraph 3.0 in a mean wind environment of 14 miles per hour (6.3 mps) measured at 32.8 feet (10m) above ground level.

3.2.3.1.1 Extreme Wind

The WTG shall be designed to survive a maximum design wind of 120 miles per hour (53.6 mps) measured at 32.8 feet (10m) above ground level. Loads shall be computed for no turbulence (zero gusts) and a vertical gradient exponent of 0.04 as used in paragraph 3.2.3.1.2.

3.2.3.1.2 Design Vertical Wind Gradient

The steady wind speed varies with vertical distance above ground level dependent on wind speed and surface roughness as:

$$\text{Log } (VZ/VR) = A \times \log (Z/ZR)$$

A = AO x (1 - (Log(VR/2.237)/Log(VH/2.237)))

Where VZ = Steady wind at elevation Z, mph

VR = Steady wind at reference elevation ZR, mph

A = Vertical gradient exponent

Z = Elevation of interest, feet

ZR = Reference elevation, 32.8 feet (10m)

AO = Surface roughness exponent, 0.35

VH = Homogeneous wind speed for A = 0, 150 mph (67 mps)

3.2.3.1.3 Design Annual Wind Duration

The steady wind speed varies annually in accordance with a Weibull distribution as:

H = 8760 x EXP [- (V/CR) ** KR]

Where H = Annual time that VR is greater or equal to V, hours

V = Wind speed at reference elevation ZR, mph

CR = Weibull scale factor at ZR, 16.04 mph (7.17 mps)

KR = Weibull shape factor at ZR, 2.29

** = denotes operation of raising to a power

The above defines a mean wind of 14 mph at ZR = 32.8 feet. Weibull parameters for elevations other than ZR may be derived in accordance with the method of Exhibit B, 3.1.2, Contract DEN 3-153.

3.2.3.1.4 Design Wind Turbulence

Wind turbulence is characterized as a Gaussian random process around the steady wind speed at reference elevation with standard deviations of:

SD(R,X) = VR/(ln ((ZR/ZO) +1))
SD(R,Y) = 0.8 x SD(R,X)
SD(R,Z) = 0.5 x SD(R,X)

Where SD(R,X) = Turbulence standard deviation associated with VR, mps
VR = Reference elevation steady wind speed, mps
ZR = Reference elevation, 32.8 feet (10m)
ZO = Surface roughness length, 0.0162 feet (0.053 m)
X = denotes longitudinal directional
Y = denotes lateral direction
Z = denotes vertical direction

3.2.3.1.4.1 Spectrum

The spectrum of turbulence is characterized by:

FX (N,Z,V) = (((SD(R,X))**2.)/n) x ((0.164 x FIX)/(1 + 0.164 x (FIX**(5/3))))

Where FX (n,z,v) = average annual spectrum for longitudinal component of wind turbulence, MPS x MPS x Sec., for frequency n, at height Z, and wind speed V.

n = circular frequency, hz

FIX = N/NOX

N = reduced frequency = NZ/V, dimensionless

NOX = constant for X direction = 0.0144, dimensionless using similar equations, lateral and vertical components are characterized with:

NOY = constant for Y direction = 0.0265

NOZ = constant for Z direction = 0.0962

The turbulence longitudinal standard deviation, SDX, for use in determining gust amplitude is obtained from the square foot of the integral of FX(N,Z,V) x dn over the frequencies from n(min) to n(max) where the limits are representative of the WTG response characteristics. Gust amplitude probability is determined by use of the standard deviation in a Gaussian random process as:

P(AX) = (0.299/SDX) x EXP (-(0.5) x (0.75 x AX/SDX)**2)

Where P(AX) = probability density function of longitudinal gust amplitude, AX

AX = longitudinal gust amplitude, mps

SDX = longitudinal direction gust standard deviation from integral evaluation, mps

This probability model is valid to AX = 2*SDX. For larger amplitudes, a Rayleigh filtered distribution should be used to fit measured data. The above model produces conservatively large amplitude probabilities for AX greater than 2*SDX. The P(AX) expression is based on NASA WEPO PIR #151 which utilizes a 4/3 multiplier on SDX instead of the Contract DEN 3-153, Exhibit B, section 3.1.3 multiplier of 1.

3.2.3.1.4.2 Time History Gust Model

A first estimate of gust model shape is:

VX (t) = +/- (AX/2) x (1 - cos (6.283 x t/TX))

Where VX(t) = longitudinal gust amplitude with time relative to steady wind, mps

AX = longitudinal gust amplitude, mps

TX = gust period, sec

The gust period may be selected at the modal periods of the WTG for worst case response. The most probable period is:

TAX (50%) = .74 x (ST/SA) x AX

Where TAX = longitudinal period of amplitude AX, sec

ST = (4/3) x TM

SA = (4/3) x SDX

TM = .5 x square root of
((integral of FX(N Z,V) x dn)/(integral of n*n*FX(N,Z,V) x dn)) with
integrals evaluated from n(min) to n(max) as in paragraph 3.2.2.1.4.1

Similar relationships apply in the y and z directions. The above amplitude is based on NASA WEPO PIR #151 which is half the amplitude in Contract DEN 3-153, Exhibit B, section 3.1.3.

3.2.3.2 Other Environmental Conditions

3.2.3.2.1 Temperature

The WTG shall be designed to survive in ambient temperatures from -40^{o} C to $+52^{o}$ C (-40^{o} F to $+125^{o}$ F). The WTG shall be designed to operate in ambient temperatures from -18^{o} C to $+40^{o}$C (0^{o} F to $+104^{o}$ F).

3.2.3.2.2 Seismic

The WTG shall be capable of withstanding Zone 3 siesmic intensity as defined in the Uniform Building Code of issue date in effect on April 2, 1982.

3.2.3.2.3 Moisture

The WTG shall be designed to withstand exposure to precipitation and ambient humidity conditions of:

Rain - 4 inches/hour

Hail - 1 inch diameter, 50 lb/cu.ft., 66.6 ft/sec impact velocity on horizontal and vertical surfaces

Ice - 2 inch thickness, 60 lb/cu.ft. non-operating on all external surfaces

Snow - 21 lb/sq.ft. blades, 41 lb/sq.ft. other horizontal surfaces

Humidity - Exposure equivalent to MIL STD 210 B.

3.2.3.2.4 Lightning

Direct and nearby strikes with current-time histories per Figure 3.2.3-1 shall be considered in the design of lightning protection details. The WTG shall withstand such strikes and provide for a discharge path to earth.

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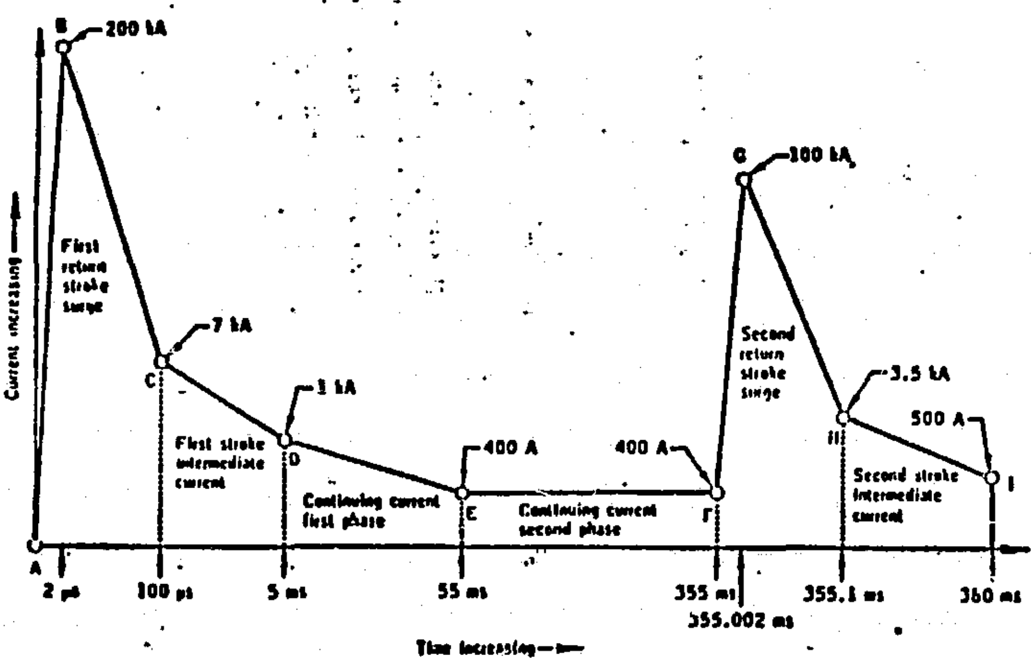

- DIAGRAMMATIC REPRESENTATION OF LIGHTNING MODEL
(Note that the diagram is not to scale.)

FIGURE 3.2.3-1
LIGHTNING CURRENT VS. TIME

3.2.3.2.5 Impact

The WTG shall be designed to sustain impact of a 4 lb. bird moving at 51.3 ft/sec into the rotor plane. Small arms projectiles shall be deflected or absorbed without structural degradation.

3.2.3.2.6 Intruders

Unauthorized personnel are considered as an environmental condition. The WTG design shall consider vandalism and prevent entry to secured areas.

3.2.3.2.7 Altitude

The WTG shall be designed for application at altitudes from sea level to 7000 feet. Derating of cooling and insulation characteristics dependent on air density may be utilized for application above 3300 feet.

3.2.3.2.8 Miscellaneous

Design sand, dust, salt spray, and fungus exposure shall be equivalent to MIL STD 210 B. Solar radiation shall be 363 BTU/sq.ft.-hr for 4 hours per day. Other environmental data shall be per NASA Technical Paper 1359.

3.2.4 Transportation

The WTG shall be designed for both rail and truck transport. Elements that exceed general truck limitations shall be rail transportable to a site rail-head then transferred to the site on the access roadway defined in paragraph 3.1.6.1.2. General constraints are as follows:

Item	Rail	Truck
Maximum weight	260,000 lb.	70,000 lb. (200,000 lb.)
Maximum length	85 ft. (120 ft.)	50 ft. (150 ft.)
Maximum width	Figure 3.2.4-1	12 ft. (14 ft.)
Maximum height	Figure 3.2.4-1	10 ft. (12 ft.)

Values in parenthesis are possible at added cost due to special routing, escorts and permits. Rail limits are more severe in the Northeast.

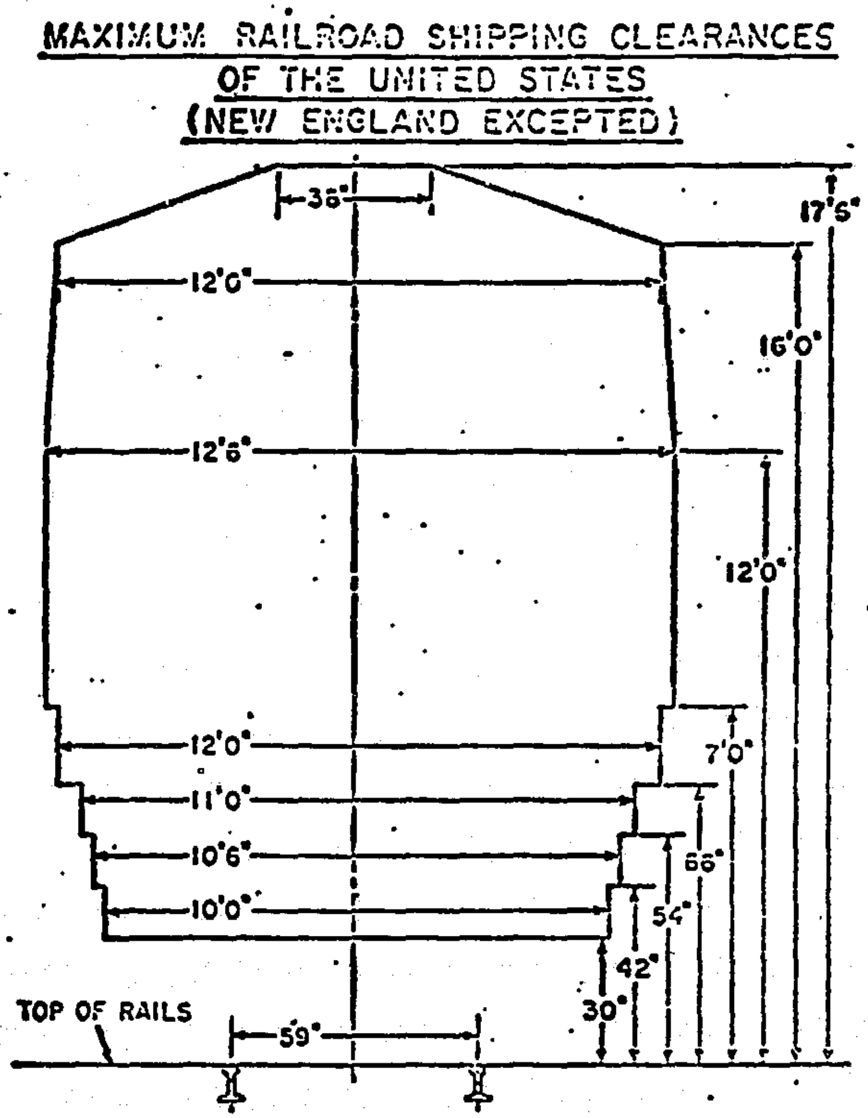

FIGURE 3.2.4-1

RAIL SIZE LIMITS

3.2.5 Design Loads

Design loads shall be computed with an analytical model representative of the transient dynamic behavior of the wind turbine structure, control system and wind.

3.2.5.1 Normal Operating Loads

Normal operating loads shall be based on the conditions of Table 3.2.5-1.

3.2.5.2 Abnormal Operating Loads

Abnormal operating loads shall be based on the conditions of Table 3.2.5-2. Abnormal operating loads are infrequently occurring and produce limit load conditions or define extent of survivable damage.

3.2.5.3 Handling Loads

Handling loads are those resulting from shop operations, shipping, erection, and repair activities. Attachment points and rigging lines of action shall be considered in addition to wind, temperature, shock and vibration loads. Section 5.2.2 of 47A38002, Structural Design Criteria, provides definition of handling load factors with respect to weight.

TABLE 3.2.5-1 NORMAL OPERATING LOAD CONDITIONS

Environment (See Temperature Note)

	Wind			Shock		Impact		Weight	
	10-60 MPH Mean	Gust	120 MPH Extreme	Seismic	Vibration	Hail	Fauna	Ice	Snow
Parked			x	x	x	x		x	x
Startup/Shutdown	x	x			x				
Motoring	x	x			x				
Generating	x	x		x	x	x	x	x	
Loss of Load	x	x							

The survival temperature range shall be considered in the parked condition and the operating temperature range shall be considered in other normal operating conditions.

TABLE 3.2.5-2 ABNORMAL OPERATING LOAD CONDITIONS

	Environment								
	Wind			Shock		Impact		Weight	
	10-60 MPH Mean	Gust	120 MPH Extreme	Seismic	Vibration	Hail	Fauna	Ice	Snow
Partial Control Jam (one surface stuck)	x	x							
Control Malfunction (hard over to maximum torque)	x	x							
Overspeed (50% survival)	x				x				
Brakes On (application while generating)	x				x				
Partial Blade Failure	x				x				
Generator Malfunction (bad sync)	x				x				

SECTION 4.0
VERIFICATION

4.1 Verification Methods and Requirements

Verification that the WTG complies with the requirements of Section 3.0 shall be accomplished by the methods of inspection, analysis, demonstration, and test.

4.1.1 Inspection Method

The inspection method consists of visual observation or measurement of drawings, items or higher level assemblies to establish compliance with requirements.

4.1.2 Analysis Method

The analysis method consists of calculations and evaluation using mathematical models, extrapolation of data from similar units, hand or computer methods, and drawing review to predict performance or establish compliance with requirements.

4.1.3 Demonstration Method

The demonstration method consists of performing an observed activity where the observer qualifications and/or the activity procedure permit establishing compliance with requirements by opinion.

4.1.4 Test Method

The test method consists of performing an activity with calibrated instrumentation or special equipment, following a detailed procedure, to acquire data establishing compliance with requirements or definition of performance.

4.1.5 Verification Requirements

The requirements of Section 3 shall be verified in accordance with Table 4.1-1.

TABLE 4.1-1
of
VERIFICATION REQUIREMENTS

REQUIREMENT PARAGRAPH	ITEM	VERIFICATION LEVEL N = NONE, SY = SYSTEM, SS = SUBSYSTEM, I = INSPECTION, A = ANALYSIS, D = DEMONSTRATION, T = TEST
3.0	REQUIREMENTS	N
3.1	System Definition	N
3.1.1	System Description	N
3.1.2	Purpose	T,SY
3.1.3	Installation	D,SY
3.1.4	Drawings	I,SY
3.1.5	Interface	N
3.1.5.1	Electrical Network Interface	A,SY
3.1.5.2	Communication and Control Interface	T,SY
3.1.5.3	Operating and Maintenance Interface	N
3.1.6	Customer Furnished or Specified Items	N
3.1.6.1	Location	I
3.1.6.1.1	Area	I
3.1.6.1.2	Access	A
3.1.6.1.3	Approvals	N
3.1.6.2	Communication	I
3.1.6.3	Distribution Line	I,SY
3.1.6.4	Electrical Power Requirements	T,SY
3.1.6.5	Color and Markings	I,SY
3.1.6.6	Mobile Data Acquisition System	I
3.1.6.7	Utility Control and Storage Space	I
3.1.7	System Modes	T,SY
3.1.7.1	Automatic Modes	T,SS,SY
3.1.7.2	Manual Modes	T,SS,SY
3.2	Characteristics	N
3.2.1	System Requirements	N
3.2.1.1	System Power Output	T,SY
3.2.1.2	Design Wind Speed Values	A,T,SY
3.2.1.3	Design Efficiency	A,T,SS
3.2.1.4	Design Life	A,SS,SY
3.2.1.5	Frequency Placement	A,T,SY
3.2.1.6	Wind Characteristics	A
3.2.1.6.1	Design Wind	A
3.2.1.6.2	Site Specific Wind	A
3.2.2	Subsystem Requirements	N
3.2.2.1	Foundation and Site	N

REQUIREMENT		VERIFICATION LEVEL
PARAGRAPH	ITEM	N = NONE SY = SYSTEM SS = SUBSYSTEM I = INSPECTION A = ANALYSIS D = DEMONSTRATION T = TEST
3.2.2.1.1	Tower Foundation	I,A,SS
3.2.2.1.2	Ground Electrical Equipment Foundation (GEEF)	I,SS
3.2.2.1.3	Grounding	I,A,T,SS
3.2.2.1.4	Fencing	I
3.2.2.1.5	Grading	I
3.2.2.1.6	Maintenance and Access	I
3.2.2.2	Ground Electrical Equipment (GEE)	N
3.2.2.2.1	Step-up Transformer	A,SY
3.2.2.2.2	Switchgear Assembly	A,SS
3.2.2.2.2.1	Circuit Breakers	A,SY
3.2.2.2.2.2	Converter	A,T,SS,SY
3.2.2.2.2.3	Filters	A,T,SY
3.2.2.2.2.4	Capacitors	A,T,SY
3.2.2.2.2.5	UPS	A,D,SS
3.2.2.2.2.6	Accessory Power	A,D,SY
3.2.2.2.2.7	Battery Power	A,D,SS
3.2.2.2.2.8	Switchboard	A,D,SY
3.2.2.2.2.9	Enclosure	I,T,SS
3.2.2.2.3	Interlocks	I,SS
3.2.2.2.4	Ground Control Equipment	I,SS
3.2.2.2.5	Interfaces	A,SS,SY
3.2.2.2.6	Lightning Protection	A,SS,SY
3.2.2.2.7	Instrumentation	N
3.2.2.2.7.1	Operational Instrumentation	I,SS,SY
3.2.2.2.7.2	Engineering Data Instrumentation	I,T,SS
3.2.2.2.8	Maintenance and Access	I
3.2.2.3	Operation and Maintenance	N
3.2.2.3.1	Personnel	N
3.2.2.3.2	Site Operation	D,SY
3.2.2.3.3	Remote Operation	D,SY
3.2.2.3.4	Scheduled Maintenance	N
3.2.2.3.5	Training	D
3.2.2.3.6	Manuals	I
3.2.2.4	Rotor Subsystem	N
3.2.2.4.1	Yoke Assembly	A
3.2.2.4.1.1	Yoke	A,SS,SY
3.2.2.4.1.2	Teeter Assembly	A,SS,SY
3.2.2.4.1.3	Rotor Hydraulic Assembly	A,SS,SY
3.2.2.4.2	Blades	A,T,SS,SY
3.2.2.4.3	Aerodynamic Control (Ailerons)	A,T,SS,SY
3.2.2.4.3.1	Configuration	A,T,SS
3.2.2.4.3.2	Rates and Storage Requirements	A,T,SS

REQUIREMENT PARAGRAPH	ITEM	VERIFICATION LEVEL N = NONE SY = SYSTEM SS = SUBSYSTEM I = INSPECTION A = ANALYSIS D = DEMONSTRATION T = TEST
3.2.2.4.4	Lightning Protection	A,SY
3.2.2.4.5	Ice Detection	A,T,SS
3.2.2.4.6	Instrumentation	N
3.2.2.4.6.1	Operational Instrumentation	A,I,T
3.2.2.4.6.2	Engineering Data Instrumentation	I,T,SS
3.2.2.4.6.3	Wiring	I,SY
3.2.2.4.7	Interfaces	D,SY
3.2.2.4.8	Maintenance and Access	I,A,SS
3.2.2.5	Drive Subsystem	N
3.2.2.5.1	Low Speed Shaft	A,T,SS,SY
3.2.2.5.2	Gearbox	A,T
3.2.2.5.2.1	Operating Characteristics	A,T,SY
3.2.2.5.2.2	Lubrication	A,T,SS
3.2.2.5.2.3	Accessories	I,T,SS
3.2.2.5.3	High Speed Shafting	A,T,SS
3.2.2.5.4	Generator	A,T,SS,SY
3.2.2.5.5	Rotor Stopping Brake	A,T,SY
3.2.2.5.6	Rotor Positioner	A,T,SY
3.2.2.5.7	Lightning Protection	A,SY
3.2.2.5.8	Instrumentation	N
3.2.2.5.8.1	Operational Instrumentation	A,I,T
3.2.2.5.8.2	Engineering Data Instrumentation	I,T,SS
3.2.2.5.9	Interfaces	D,SY
3.2.2.5.10	Maintenance and Access	I,A,SS
3.2.2.6	Nacelle Subsystem	N
3.2.2.6.1	Bedplate and Rotor Support	A,I,SY
3.2.2.6.2	Fairing	I,SS,SY
3.2.2.6.2.1	Wind Sensor Mounting	I,SS
3.2.2.6.2.2	Air Flow and Ducting	A,T,SY
3.2.2.6.2.3	Fire Protection	A,T,SS
3.2.2.6.2.4	Maintenance Hoist	A,T,SS
3.2.2.6.2.5	Maintenance Light and Power	A,D,SS
3.2.2.6.2.6	Hazard Lighting	A,T,SS
3.2.2.6.3	Yaw Subsystem	N
3.2.2.6.3.1	Yaw Drive Assembly	A,T,SS
3.2.2.6.3.2	Slip Ring	A,T,SY
3.2.2.6.4	Lightning Protection	A,SY
3.2.2.6.5	Instrumentation	N
3.2.2.6.5.1	Operational Instrumentation	A,I,T
3.2.2.6.5.2	Engineering Data Instrumentation	I,T,SS
3.2.2.6.6	Interfaces	D,SY
3.2.2.6.7	Maintenance and Access	I,A,SS

REQUIREMENT PARAGRAPH	ITEM	VERIFICATION LEVEL N = NONE SY = SYSTEM SS = SUBSYSTEM I = INSPECTION A = ANALYSIS D = DEMONSTRATION T = TEST
3.2.2.7	Tower Subsystem	N
3.2.2.7.1	Tower Structure	A,T,SY
3.2.2.7.2	Nacelle Access Device	A,T,SS
3.2.2.7.3	Tower Lighting and Power	A,T,SS
3.2.2.7.4	Tower Wiring	A,I
3.2.2.7.5	Lightning Protection	A,SY
3.2.2.7.6	Interfaces	D,SY
3.2.2.7.7	Instrumentation	N
3.2.2.7.7.1	Engineering Data Instrumentation	I,T,SS
3.2.2.7.8	Maintenance and Access	I,A,SS
3.2.2.8	Control Subsystem	N
3.2.2.8.1	Controller	A,T,SS,SY
3.2.2.8.2	Site Interface	A,T,SS
3.2.2.8.3	Remote Interface	N
3.2.2.8.3.1	Standard Remote Interface	A,T,SY
3.2.2.8.3.2	Site Specific Remote Interface	A,T,SY
3.2.2.8.4	Supervisory Control Priority	A,T,SS
3.2.2.8.5	Control Functions	N
3.2.2.8.5.1	Yaw Position Control	T,SS,SY
3.2.2.8.5.2	Rotor Torque Control	T,SS,SY
3.2.2.8.5.3	Hydraulic System Control	T,SS,SY
3.2.2.8.5.4	Electrical System Control	A,T,SS,SY
3.2.2.8.5.5	Teeter Restrictor Control	A,T,SS,SY
3.2.2.8.5.6	Rotor Stopping Brake Control	T,SS,SY
3.2.2.8.5.7	Rotor Positioning Control	T,SS,SY
3.2.2.8.5.8	Failsafe Emergency Shutdown Control	T,SS,SY
3.2.2.8.5.9	Fault Monitor Control	T,SS,SY
3.2.2.8.5.10	Manual Control	T,SS,SY
3.2.2.8.5.11	Data Window	T,SS,SY
3.2.2.8.5.12	Operating Accumulation	T,SS,SY
3.2.2.8.5.13	Data Display	T,SS,SY
3.2.2.8.6	Instrumentation	N
3.2.2.8.6.1	Operational Instrumentation	I,T,SS
3.2.2.8.6.2	Engineering Data Instrumentation	I,T,SY
3.2.2.8.6.3	User Instrumentation	I,T,SY
3.2.2.8.6.4	Wiring	I
3.2.2.8.7	Lightning Protection	A,SY
3.2.2.8.8	Interfaces	D,SY
3.2.2.8.9	Maintenance and Access	I,A,SS
3.2.2.9	Reliability, Availability, Maintainability, Spares	N
3.2.2.9.1	Reliability, Availability, Maintainability	N

REQUIREMENT		VERIFICATION LEVEL
PARAGRAPH	ITEM	N = NONE SY = SYSTEM SS = SUBSYSTEM I = INSPECTION A = ANALYSIS D = DEMONSTRATION T = TEST
3.2.2.9.2	Reliability	A,SY
3.2.2.9.3	Availability	A,SY
3.2.2.9.4	Maintainability	A,SY
3.2.2.9.5	Maintainability Features	A.I
3.2.2.9.6	Spares	A,I
3.2.2.9.7	Maintenance Personnel	N
3.2.3	Environment	N
3.2.3.1	Design Wind Environment	N
3.2.3.1.1	Extreme Wind	A,SY
3.2.3.1.2	Design Vertical Wind Gradient	A,SY
3.2.3.1.3	Design Annual Wind Duration	A,SY
3.2.3.1.4	Design Wind Turbulence	A
3.2.3.1.4.1	Spectrum	A
3.2.3.1.4.2	Time History Gust Model	A
3.2.3.2	Other Environmental Conditions	N
3.2.3.2.1	Temperature	A,SY
3.2.3.2.2	Seismic	A,SY
3.2.3.2.3	Moisture	A,SY
3.2.3.2.4	Lightning	I,A,SY
3.2.3.2.5	Impact	A,SS
3.2.3.2.6	Intruders	A,SS
3.2.3.2.7	Altitude	A,SY
3.2.3.2.8	Miscellaneous	A,SY
3.2.4	Transporation	A,D,SS
3.2.5	Design Loads	N
3.2.5.1	Normal Operating Loads	A,SY
3.2.5.2	Abnormal Operating Loads	A,SY
3.2.5.3	Handling Loads	A,SS

4.2 Test, Types Requirements

In addition to requirements verification tests of Section 4.1, tests shall be conducted for the purposes of item, assembly, or system acceptance, integration, functional verification and design development.

4.2.1 Acceptance Tests

Acceptance tests are conducted as formal demonstration of performance or function with customer witnesses and in accordance with a mutually approved test procedure. Test results shall be approved by the witnesses as a prerequisite to delivery of the item, assembly or system.

4.2.2 Integration Tests

Integration tests verify interface compatibility between an item and a mating item or assembly. Physical and functional integration of all WTG subsystems is required.

4.2.3 Functional Tests

Functional tests verify the item or assembly function or performance (including structural integrity) and ability to operate at design capability or within design limits.

4.2.4 DEVELOPMENT TESTS

Development tests provide substantiation for a design concept, material configuration, allowable load level or manufacturing process prior to final release of production drawings. WTG development testing is expected in the design of the rotor and drivetrain.

4.2.5 Test Requirements

WTG items, assemblies and systems shall be tested in accordance with Table 4.2-1.

TABLE 4.2-1

Test Requirements

Paragraph	Item	Test Category A = Acceptance I = Integration F = Functional D = Development
3.1.3.2.1	SYSTEM	A (Customer)
3.1.7	System Modes	A,I,F (Local & Remote)
3.2.1.1	Power Output	A,I,F (Rating, P vs V)
3.2.1.2	Design Wind Speed	I,F (Cut-in, Rating)
3.2.1.5	Frequency Placement	I,F (Measurements)
3.2.2.1	Foundation & Site	A
3.2.2.1.1	Tower Foundation	A,I (Tower)
3.2.2.1.2	GEE Foundation	A,I (GEE)
3.2.2.1.3	Grounding	I,F (Check Resistance)
3.2.2.1.4	Fencing	I (Grounding, Security)
3.2.2.2	Ground Electrical Equipment	A
3.2.2.2	All Items	A,I,F,D (Variable Speed Subsystem)
3.2.2.4	Rotor Subsystem	A
3.2.2.4.1	Yoke Assembly	A,I,F (All Subsystems)
3.2.2.4.2	Blades	A,I,F (Proof), D (Properties)
3.2.2.4.3	Aerodynamic Control	A,I,F (Actuators & Surface), D (Actuators)
3.2.2.4.5	Ice Detection	I,F
3.2.2.4.6	Instrumentation	I,F (Calibration)
3.2.2.5	Drivetrain	A
3.2.2.5.1	Low Speed Shaft	I,F (Alignment)
3.2.2.5.2	Gearbox	A,I,F (Ratio, Sensors, Lube)
3.2.2.5.3	Highspeed Shafting	I,F
3.2.2.5.4	Generator	A,I,F,D (Variable Speed Subsystem, Tilt)
3.2.2.5.5	Stopping Brake	I,F (Yoke/Nacelle)
3.2.2.5.6	Rotor Positioner	F
3.2.2.5.8	Instrumentation	I,F (Calibration)

Paragraph	Item	Test Category A = Acceptance I = Integration F = Functional D = Development
3.2.2.6	<u>Nacelle</u>	A
3.2.2.6.1	Bedplate & Rotor Support	I (Rotor & Drivetrain)
3.2.2.6.2	Fairing	I,F
3.2.2.6.2.1	Wind Sensor Mounting	I,F
3.2.2.6.2.2	Air Flow & Ducting	I,F (Filtration)
3.2.2.6.2.3	Fire Protection	I,F (Alarm, Sealing)
3.2.2.6.2.4	Maintenance Hoist	I,F (Accessibility)
3.2.2.6.2.5	Light & Power	F
3.2.2.6.2.6	Hazard Lighting	I,F (Control)
3.2.2.6.3.1	Yaw Drive ASM	I,F (Rates, Control)
3.2.2.6.3.2	Slipring	A,I,F (Resistance)
3.2.2.6.4	Lightning Protection	I
3.2.2.6.5	Instrumentation	I,F (Calibration)
3.2.2.7	<u>Tower Subsystem</u>	A
3.2.2.7.1	Structure	A,I
3.2.2.7.2	Access Device	A,I,F (Weight, Rate)
3.2.2.7.3	Lighting & Power	F
3.2.2.7.4	Wiring	I,F
3.2.2.7.5	Lightning Protection	I
3.2.2.7.7	Instrumentation	I,F (Calibration)
3.2.2.8	<u>Control Subsystem</u>	A,I,D (Software)
3.2.2.8.1	Controller	A,I,F
3.2.2.8.2	Site Interface Device	I,F
3.2.2.8.3	Remote Interface Device	A,I,F (Customer)
3.2.2.8.4	Supervisory Control Priority	I,F,D
3.2.2.8.5	Control Functions (All)	I,F,D (Interaction, Software Development)
3.2.2.8.6	Instrumentation	I,F (Calibration, EIS)
3.2.2.8.7	Lightning Protection	I

SECTION 5.0

PREPARATION FOR DELIVERY

The contractor shall provide control of the delivery requirements of all deliverable items in order to assure quality and prevent damage, loss, deteriorization or unauthorized substitution. Procedures for packaging, packing, marking and shipping shall be established and maintained, in compliance with Interstate Commerce Commission rules and regulations, in order to provide secure transport and clear identification at the destination and during erection.

GENERAL ELECTRIC

47A380012

CONT ON SHEET ii SH NO. i

REV NO. A | B | C | D

47A380012

CONT ON SHEET ii SH NO. i

TITLE

FIRST MADE FOR

REVISIONS

A REVISED PER AN-1

B REVISED

C REVISED PER AN-3

D REVISED

SLIP RING SPECIFICATION

FOR THE

MOD-5A WIND TURBINE GENERATOR

SEPTEMBER 1982

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REVISION LOG

This log identifies those portions of this document which have been revised since original issue. Revised portions of each page, for the current revision only, are identified by marginal striping.

Revision	Page No.	Paragraph Number(s) Affected	Rev. Date	Approval
A	11	3.5.3	4/6/83	AN-1
A	12	3.5.4.1	4/6/83	
B	7	3.4.3	5/16/83	AN-2
B	8	3.4.4.1	5/16/83	
C	7	3.3.10 Added	6/14/83	AN-3
D	8	3.4.4.1, 3.4.4.2	Feb. 84	DCC 84-085
D	12	3.5.4.2		AN-4

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1.0 SCOPE

This specification defines the requirements for slip ring assemblies to be used in the Electrical System of the MOD-5A Wind Turbine System.

One assembly is used to transfer electrical power and other signals across the unidirectional rotating shaft of the turbine. A second assembly is used to transfer the output power of a 7 megawatt generator and various other signals across an intermittently rotating bi-directional joint which couples the movable nacelle to a stationary supporting tower.

2.0 APPLICABLE DOCUMENTS

The following documents form a part of this specification to the extent specified herein. Documents not identified by date, revision, or amendment shall be of the latest current issue in effect.

2.1 GENERAL ELECTRIC

47E381017 - Yaw Slip Ring Electrical Interface

47D381018 - Rotor Slip Ring Electrical Interface

47D381024 - Rotary Position Sensor

47D381019 - Yaw Slip Ring Assembly Outline

47D381020 - Rotor Slip Ring Assembly Outline

2.2 MILITARY

MIL-STD-210B - Climate Extremes For Military Equipment

2.3 INDUSTRY

NFPA NO. 70-1981

3.0 REQUIREMENTS

3.1 GENERAL REQUIREMENTS

The equipment, in addition to satisfying the specific requirements of this specification, shall also meet the applicable portions of NEC.

3.1.1 WORKMANSHIP

Quality of workmanship shall be in accordance with good commercial practice for this type of equipment.

3.1.2 INTERCHANGEABILITY

All parts or components having the same vendor part number shall be identical in design and construction, and shall be interchangeable without rework.

3.1.3 IDENTIFICATION

Identification numbers shall be permanently fixed to the equipment.

3.1.3.1 Identification Nameplates

Display of the vendor name or logo on the finished product shall be acceptable.

3.1.3.2 Information Plates

Information plates for maintenance or operational instructions shall be affixed in accordance with the vendor's standard procedures and normal industry standards. The information plates shall be visible in the final installation.

3.1.4 MATERIAL

Material shall be as specified herein. Material not specified herein or on applicable drawings shall be of a good commercial quality entirely suitable for the purpose. Material shall be free from all defects and imperfections that might affect the serviceability of the finished product.

3.2 ENVIRONMENTAL CONDITIONS

In the WTG installation, the equipment will be protected from direct exposure to the outside environment by the nacelle enclosure. The equipment shall not be adversely affected by high humidity, high temperature, sand, dust, fungus, salt air or similar environmental conditions such as are normally associated with outdoor, unprotected installations.

3.2.1 ALTITUDE AND TEMPERATURE

The equipment shall be capable of operating in accordance with the performance requirements of this specification at any current within and including its rating under the following conditions:

Altitude : From Sea Level to 7,000 feet

Temperature: Ambient Air from -40°C to 50°C (survival)
Ambient Air from -30°C to 40°C (operational)

3.2.2 FLUIDS

The materials employed in the assembly shall not be adversely affected by the presence of lubricating and hydraulic fluids.

3.2.3 SEISMIC

The equipment while operating or non-operating, shall be capable of withstanding exposure to seismic loads of ±0.35G in any horizontal direction combined with ±0.25G in the vertical direction without damage.

3.2.4 CONDENSATION

The operational duty of the slip ring assmblies shall include ambient cycling that produces external surface condensation. Internal condensation (100% relative humidity) shall be avoided by use of heaters, dessicant, or other approved means.

3.3 CONSTRUCTION

3.3.1 SIZE

Overall size and mounting features shall be in accordance with envelope drawings. Weight, mounting, and connection details shall be subject to approval by General Electric.

3.3.2 ENCLOSURE

The enclosure shall be as defined in the specific requirements.

3.3.3 LIFE

The assembly shall have a minimum useful life of 30 years with routine maintenance.

3.3.4 ELECTRICAL CONNECTIONS

Where multiple brushes are used on a single ring, jumpers shall be installed so that field terminations can be made at one point only. Electrical connections shall be as defined in the specific requirements.

3.3.5 ELECTRICAL INSULATION

All insulating material shall be capable of meeting the voltages defined and shall be of good commercial grade. Insulation shall not be adversely affected by the operating and environmental conditions specified herein for the minimum useful life.

3.3.5.1 Dielectric Strength

All circuits shall withstand the voltage noted below applied between each circuit and all other circuits and ground for a period of not less than one minute.

Circuits rated 600 volts or less: 1,000 volts RMS, 60 Hertz

Circuits rated 601 volts or more: 10,000 volts RMS, 60 Hertz

3.3.6 ELECTRICAL NOISE

The dynamic resistance across all signal rings shall not exceed 10 milliohms.

3.3.7 DIRECTION AND SPEED OF ROTATION

The rated speed and direction of rotation of the slip ring rotor shall be as defined in the specific requirements.

3.3.8 COOLING

The slip ring assembly shall be self-cooled.

3.3.9 MAINTENANCE

The maintenance interval for the assembly shall be six (6) months or longer. Easily removable access covers shall be designed into the structure to facilitate cleaning and inspection. Bearing lubrication, if required, shall be possible without disassembly.

3.3.10 SHIELD

An EMI brush, or equivalent, shall be used to provide a continuous metallic shield across the rotating interface of the slip ring housing.

3.4 SPECIFIC REQUIREMENTS, ROTOR SLIP RING ASSEMBLY (47D381020)

3.4.1 APPLICATION

The rotor slip ring assembly will be a part of the drive train and will be used to transfer electrical power, commands and signals between the WTG nacelle and the low speed shaft directly driven by the wind turbine rotor.

3.4.2 EQUIPMENT TO BE FURNISHED

The rotor slip ring assembly shall consist of a single integrated unit providing an enclosure, enclosure support bearings, brush assemblies, brush electrical terminals and all other required parts necessary to permit its installation and connection in the wind turbine.

3.4.3 NUMBER OF CIRCUITS

The rotor slip ring assembly shall contain 100 isolated electrical circuit paths.

3.4.4 ELECTRICAL RATINGS

The rotor slip ring assembly shall be capable of completing three (3) types of circuits: power, command and signal. The rings, brushes and other equipment assigned to each of these circuits shall be capable of continuously carrying the rated current at the rated voltage specified herein.

3.4.4.1 Power Ring Rating

Slip rings and brushes labeled "P" on the interface drawing will be used to complete power circuits and will be known as the power rings.

Rings numbered 1 through 4 shall have a rated current capacity of 80 amps and a rated voltage of 600 volts with a motor inrush duty to 400 amperes.

Rings numbered 5 through 16 shall have a rated continuous current capacity of 25 amps and a rated voltage of 600 volts.

Other rings labeled "P" shall have a rated continuous current capacity of 10 amps and a rated voltage of 600 volts.

3.4.4.2 Command Ring Rating

Slip rings and brushes labeled "C" on the interface drawing shall be used to complete command circuits and will be known as command rings. Command rings shall have a rated continuous current capacity of five (5) amps and a rated voltage of 600 volts.

3.4.4.3 Signal Ring Rating

Slip rings and brushes labeled "S" on the interface drawing shall be used to complete low level signal circuits and will be known as signal rings. The maximum current to flow through any one signal circuit will not exceed one (1) amp and the voltage will not exceed 125 volts. A minimum of 50 db isolation for signals up to 50,000 hertz shall be provided.

3.4.4.3 Signal Ring Rating (cont'd)

Signal slip rings shall also be capable of operation specified herein with any of the following signals:

- o 4-20 milliampere control signal of varying voltages
- o 0-±100 milliampere servo coil circuits
- o 20 milliampere serial communications circuits
- o Standard utility telephone circuits
- o Composite video signal

3.4.5 SLIP RING AND BRUSH IDENTIFICATION NUMBER

Each slip ring and its associated brush shall be assigned a consecutive number according to its sequential position. Ring number 1 shall be closest to the rotor mounting flange, as noted on interface drawing 47D381018.

3.4.6 ELECTRICAL CONNECTIONS

3.4.6.1 Rotor

Electrical connections to the rotor portion of the slip ring assembly shall be made to a screw clamp type terminal strip provided as an integral part of this assembly. This terminal strip shall accommodate wire sizes specified on 47D381018 and shall be accessible when the slip ring is installed.

3.4.6.2 Brushes

Electrical connections to the brush portion of the assembly shall be made to a screw clamp type terminal strip provided as an integral part of the assembly. This terminal strip shall accommodate wire sizes specified on 47D381018.

3.4.6.3 Markings

All terminals and connectors shall be identified or marked per applicable standards.

3.4.7 POSITION SENSOR

The rotor slip ring shall be provided with a position sensor. The position sensor, Drawing Number 47D381024 will be supplied by General Electric. The vendor shall install and wire the position sensor to the terminal strip used for brush interconnection in accordance with 47D381018.

The shaft of position sensor shall follow the rotor portion of the slip ring assembly (using a flex coupling) while the sensor case is secured to the stator portion of the slip ring. The mounting of the position sensor is by means of a servo type mounting face using cleats to prevent rotation, but allowing for field adjustment in rotation for "zero". Final installation access to the unit and hardware securing the cleats must be provided.

3.4.8 ENCLOSURE

The rotor slip ring assembly shall be totally enclosed and sealed to provide protection from water and lubricating and hydraulic fluids. Removable covers shall be provided to permit convenient access for initial installation, connection, regular inspection and maintenance.

3.4.9 PHYSICAL SIZE AND MOUNTING PROVISIONS

The assembly shall fit within the envelope and have mounting and handling provisions as defined on 47D381020.

3.4.10 ROTATION

Under normal conditions the slip ring rotor will turn clockwise (CW) when viewed from the drive end. The assembly shall not be damaged by slow rotation in the opposite direction. The rated rotational speed shall be approximately 17 RPM. It shall function satisfactorily at any speed from 0 to 125% of rated.

3.4.11 WEIGHT

The total weight of the assembly shall not exceed TBD pounds.

3.5 SPECIFIC REQUIREMENTS, YAW SLIP RING ASSEMBLY (47E381019)

3.5.1 APPLICATION

The yaw slip ring assembly will be used to transfer electrical power and signals between the MOD-5A WTG tower, a fixed member, and the nacelle, a movable member, that orients the system into the wind.

3.5.2 EQUIPMENT TO BE FURNISHED

The yaw slip ring assembly shall consist of a single integrated unit providing an enclosure, enclosure support bearings, brush assemblies, brush electrical terminals and all other required parts necessary to permit its installation and connection in the wind turbine.

3.5.3 NUMBER OF CIRCUITS

The yaw slip ring assembly shall contain 152 isolated electrical circuit paths.

3.5.4 ELECTRICAL RATINGS

The yaw slip ring assembly shall be capable of completing four types of circuits: high-voltage, power, command and signal. The rings, brushes and other equipment assigned to each of these circuits shall be capable of continuously carrying the rated current at the rated voltage specified herein.

3.5.4.1 High-Voltage Ring Rating

Slip rings and brushes numbered 1 through 7 inclusive, will be used to complete high-voltage circuits and will be known as the high-voltage rings.

These rings shall have a rated current capacity of 1500 amps and a rated voltage of 5000 volts, and shall withstand an RMS symmetrical fault current of 23,000 amperes for 1/12 of second.

3.5.4.2 Low Power Ring Ratings

Slip rings and brushes labeled "P" on the interface drawing will be used to complete power circuits and will be known as the power rings.

Rings labeled "P-1" shall have a rated continuous current capacity of 300 amperes and a rated voltage of 600 volts.

Rings labeled "P-2" shall have a rated continuous current capacity of 50 amperes and a rated voltage of 600 volts.

Rings labeled "P-3" shall have a rated continuous current capacity of 30 amperes at a rated voltage of 600 volts.

3.5.4.3 Command And Control Ring Rating

Slip rings and brushes labeled "C" on the interface drawing shall be used to complete command and control circuits and will be known as command control rings. Those rings shall have a rated continuous current of 5 amperes and a rated voltage of 600 volts.

3.5.4.4 Signal Ring Rating

Slip rings and brushes labeled "S" on the interface drawing shall be used to complete low level signal circuits and will be known as signal rings.

The maximum current to flow through any one signal circuit will not exceed one (1) ampere and the voltage will not exceed 125 volts. A minimum of 50 db isolation for signals up to 50,000 hertz shall be provided.

Those rings shall have a rated continuous current of 5 amperes and a rated voltage of 300 volts, 60 hertz.

Signal slip rings shall also be capable of operation specified herein with any of the following signals:

- 4-20 milliampere control signal of varying voltages
- 0-±100 milliampere servo coil circuits
- 20 milliampere serial communications circuits
- Standard utility telephone circuits
- Composite video signal

3.5.4.5 High Voltage Guard Rings

The assembly shall have provisions to prevent high voltage line-to-line faults. The high voltage power rings shall be constructed such that in the case of a flashover the fault current will go to ground. A grounded guard ring, ground shield or equivalent shall be used between high voltage rings. Guard rings are not numbered.

3.5.5 SLIP RING AND BRUSH IDENTIFICATION NUMBERS

Each slip ring and its associated brush shall be assigned a consecutive number according to its sequential position. Ring number 1 shall be as noted on interface Drawing 47E381017.

3.5.6 ELECTRICAL CONNECTIONS

All circuits from the high voltage power rings shall terminate in high voltage bushings that will accept Elastimold type power distribution connectors. Circuits from the low power rings shall have screw clamp type terminals in a junction box that contains only these circuits (labeled "P"). Circuits from the signal rings shall have screw clamp type terminals located in another junction box that contains only signal circuits. The junction box shall contain terminals for circuits labeled "C" and "S" with terminals that shall accommodate wire sizes specified on Drawing 47E381017.

3.5.7 POSITION SENSOR

The yaw slip ring shall be provided with a position sensor. The position sensor, Drawing Number 47D381024 will be supplied by General Electric. The vendor shall install and wire the position sensor to the signal junction box in accordance with Drawing 47E381017.

The shaft of the position sensor shall follow the stator portion of the slip ring assembly (using a flex coupling) while the sensor case is secured to the rotor portion. The mounting of the position sensor is by means of a servo type mounting face using cleats to prevent rotation, but allowing for field adjustment in rotation for "zero". Final installation access to the unit and hardware securing the cleats must be provided.

3.5.8 ENCLOSURE

The yaw slip ring assembly shall be totally enclosed and sealed to provide protection from water and lubricating and hydraulic fluids. Removable, gasketed, covers shall be provided to permit convenient access for initial installation, connection, regular inspection and maintenance.

3.5.9 PHYSICAL SIZE AND MOUNTING PROVISIONS

The yaw slip ring assembly shall fit within the envelope and have mounting and handling provisions as defined on Drawing 47D381019.

3.5.10 ROTATION

Under normal conditions the slip ring rotor may turn either clockwise or counterclockwise. Over the required life the rotation in each direction will be approximately equal.

Extended periods, i.e., days, are possible with no rotation. The rated rotational speed shall be 25 degrees per minute. The slip ring assembly shall function satisfactorily at any speed from zero to 125% of rated.

3.5.11 WEIGHT

The total weight of the assembly shall not exceed TBD pounds.

4.0 QUALITY ASSURANCE PROVISIONS

4.1. GENERAL REQUIREMENTS

4.1.1 TEST SITE

All inspections, examinations and tests of the slip ring assembly shall be made at the vendor's plant unless otherwise specified.

4.1.2 TEST CONDITIONS

All tests shall be performed at room ambient conditions of temperature, humidity and atmospheric pressure unless otherwise specified.

4.1.3 TEST PROCEDURE

All tests shall be conducted using documented test procedures approved by GE. All test procedures shall contain data sheets on which the results of the individual tests may be recorded.

4.1.4 TEST REPORTS

A test report containing the test procedure, test results and test conclusions shall be provided with each slip ring assembly presented for delivery when specified.

4.1.5 ACCEPTANCE TESTS

The following acceptance tests shall be performed on each slip ring assembly presented for delivery. The tests may be performed in any sequence unless otherwise specified.

- 4.2.1 Visual Examination
- 4.2.2 Dimensional Inspection
- 4.2.3 Insulation Resistance Test
- 4.2.4 Dielectric Strength Test
- 4.2.5 Circuit Continuity Test
- 4.2.6 Dynamic Resistance Test
- 4.2.7 Position Sensor Functional Test

4.2 SPECIFIC TEST REQUIREMENTS

4.2.1 VISUAL EXAMINATION

The assembly shall be visually examined to assure that it is free from all defects that could adversely affect its life or make it unsuitable for its intended use.

4.2.2 DIMENSIONAL INSPECTION

The assembly shall be measured to verify that it fits within the space envelope defined and that the mechanical interface dimensions comply with the defined requirements.

4.2.3 INSULATION RESISTANCE TEST

The insulation resistance between each circuit and all other circuits and ground shall be measured at 500 ±10% volts DC. The insulation resistance shall not be less than 10 meg ohms.

4.2.4 DIELECTRIC STRENGTH TEST

The dielectric strength test voltage defined in paragraph 3.3.5.1 shall be applied for one minute between each circuit and all other circuits and ground. There shall be no evidence of damage, arcing, dielectric breakdown or leakage current in excess of one milliampere.

4.2.5 CIRCUIT CONTINUITY TEST

The end-to-end continuity of each circuit shall be verified by test and shall satisfy the requirement of the applicable circuit diagram.

4.2.6 DYNAMIC RESISTANCE TEST

The peak-to-peak noise of each circuit of the slip ring assembly shall be measured with the rotor rotating at rated RPM and with the rotor not rotating. A test current of 100 ±3% DC milliamperes shall be used. The measured equivalent noise shall not exceed that resulting from the resistance variation defined in paragraph 3.3.6.

4.2.7 APPROVAL

Review and approval of all test results by a General Electric Quality Assurance representative is required prior to shipment of the slip ring assemblies.

5.0 PREPARATION FOR DELIVERY

The vendor shall submit a statement detailing the normal method of packaging for shipment and the method of delivery for approval by General Electric.

6.0 NOTES

GENERAL ELECTRIC

REV NO. A / B	TITLE	47A380013 CONT ON SHEET ii SH NO. i
47A380013 CONT ON SHEET ii SH NO. i	FIRST MADE FOR	

REVISIONS

A ISSUED REV "A" PER AN-1 7/22/83

B ISSUED REV "B" PER AN-2 4/19/84

REV "B"
DEC 1983

CONTROL SYSTEM SPECIFICATION

FOR THE

MOD-5A WIND TURBINE GENERATOR

NOVEMBER 1982

Theodore J. Hoop DATE: 11-17-82
Responsible Engineer

[signature] DATE: 11-19-82
Systems Engineering

W C Lucas DATE: 11-19-82
Engineering Manager

A. Cheddar DATE: 11-19-82
Quality Assurance

G. Doenker DATE: 11/19/82
WTG Integration

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REVISION LOG

This log identifies those portions of this document which have been revised since original issue. Revised portions of each page, for the current revision only, are identified by marginal striping.

Revision	Page No. / Paragraph Number(s) Affected	Rev. Date	Approval
A	This revision is a general specification update to reflect the Model 304 configuration, as to: (a) incorporate a variable speed subsystem (b) eliminate dual speed operation by mechanical gearing addition of an Alarms level of data output, and (d) update of the "Shutdown" logic	July 83	[illegible] 9/2/83 T. J. Hoop 7/21/83
B	This revision is a general specification update to reflect the aerodynamic control configuration change to Model 304.2, i.e., aileron control versus earlier partial span control.	Dec. 83	T. J. Hoop 4/12/8[illegible] AN-2

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GLOSSARY OF TERMS

BESD	Backup Emergency Shutdown
C/C	Converter Control
CDS	Controls Data System
CEC	Controls Electronic Cabinet
CS	Control System
ESD	Emergency Shutdown
ESP	Emergency Shutdown Panel
FLIC	Feather Logic Initial Checks
MPH	Miles Per Hour
MW	Megawatts
N_G	Generator Speed
N_R	Rotor Speed
NSD	Normal Shutdown
$P_{ave\ 5}$	Five Minute Power Average
P_{sp} =	Power Set Point
RAM/FMEA	Reliability/Availability/Maintainability and Failure Mode and Effects Analysis
RSC	Rotor Speed Control
RPM	Revolutions Per Minute
RTU	Remote Terminal Unit
SPS	Samples Per Second
STBY	Standby
UPS	Uninterruptible Power Supply
V_W	Wind Velocity

VLCO	See Table 3.2-1	Low Cut Out
VLCI		Low Cut In
VRAT		Rated
VHCI		High Cut In
VHCO		High Cut Out

WTG	Wind Turbine Generator
Ye	Yaw Error
α_T	Teeter Angle
δ	Aileron Deflection Angle

SECTION 1

INTRODUCTION

1.1 GENERAL

The purpose of the Control System is to provide the coordination and control of all phases of operation of the MOD-5A Wind Turbine Generator system, so as to meet the requirements set forth in the Systems Specification, #47A380011.

1.2 SCOPE

This specification establishes performance, design, development and test requirements for the Control System, hereinafter referred to as the CS, for the MOD-5A Wind Turbine Generator (WTG). The requirements stated herein are a balance for design implementation to meet the goal to (1) maximize the WTG system reliability, (2) minimize the potential for nuisance shutdowns, and (3) retain the necessary system checks for safe operation.

1.3 CS DEFINITION

The CS consists of those components and assemblies which, when functioning jointly, will provide the capability to perform the sensing, computation, actuation, and the data and command transmittal necessary to meet the purpose of paragraph 1.1. The primary phases of operation requiring coordination and control are the various manual and automatic control functions for maintenance and normal operation from startup, through various levels of power generation in varying wind regimes, to normal shutdown; including also provisions for failsafe and emergency shutdowns. In addition to transmittal of data and commands between components of the WTG, hardware and software will be provided by the CS for data and command interchange with the local ground located control interface (Site Operator Terminal/Controls Data System) and the remote utility control interface (Remote Operator Terminal). The data sensing and transmittal function includes the basic operational data storage and retrieval.

1.3.1 CS FUNCTIONS

The discrete functions of the CS are listed below:

1. Yaw orientation control
2. Rotor speed control or "aileron control"
3. Rotor position control
4. Rotor brake control
5. Teeter brake control
6. Hydraulic and lube system pressure, heating, and cooling control/monitor
7. Electrical power output control (generator, converter, bus/utility tie)
8. Emergency shutdown control
9. Operator interface control (site, remote dispatch, manual operations)
10. Operational data display

1.3.2 CS COMPONENTS/ASSEMBLIES

The CS will consist of the following listed components and/or assemblies and their interconnections:

1. Controller
2. Control Sensors, Actuation, and Signal Conditioning
3. Variable Speed Generator Subsystem (specified separately - 47A380015)
4. Emergency Shutdown Panel
5. System Display Panel
6. Site Operator Terminal
7. Remote Dispatch Terminal/Interface
8. Controls Data System
9. Back-up Emergency Shutdown System

SECTION 2

APPLICABLE DOCUMENTS

The following documents of the date of issue noted form a part of this specification to the extent specified herein.

2.1 GOVERNMENT DOCUMENTS

NASA/LERC - Statement of Work, DEN 3-153, April 2, 1982

2.2 GENERAL ELECTRIC DOCUMENTS

47A380011	System Specification for the MOD-5A WTG
--	MOD-5A Baseline Mass Properties Report
--	MOD-5A Aerodynamic Characteristic Document
47A380002	Structural Design Criteria for MOD-5A WTG
47A380052	Electrical Fabrication and Workmanship Standard
47A380058	Electrical and System Test Equipment Design, Fabrication and Test Specification
47A387005	Signal and Command List
47E387080	One Line Systems Diagram
47A380115	MOD-5A WTG 7500 KVA Variable Speed Generator Subsystem Specification
47A380020	RAM/FMEA Requirements

SECTION 3

REQUIREMENTS

3.1 CONTROL SYSTEM DESCRIPTION

3.1.1 GENERAL

The Control System (CS), defined in paragraph 1.3 for the purpose described in paragraph 1.1, shall perform manual and automatic control, sensing, signal conditioning and buffering, remote utility dispatcher communication, and data recording functions for the model 304.2 type MOD-5A Wind Turbine Generator (WTG). The control of most functions is dependent on multiple inputs and varying "logic" depending on operational sequence or control modes. Accordingly, the Control System with its data gathering and processing capability is the system controller, with the brain of this capability contained within the component called the Controller. The Controller shall implement the logic and signal processing for system speed control using generator and rotor speed. In subrated power conditions generator speed shall effectively be the controlled parameter obtained by regulation of generator air gap torque by operation of a variable speed generator subsystem. Subrated operation shall be at either a low speed or a high speed region as a means to obtain increased wind/rotor efficiency. The generator speed reference shall automatically be moved between these two speed regions as a function of averaged output power. At rated wind conditions, $32 \leq V_W \leq 60$ mph, both the rotor speed control (see Section 3.3.2) and the generator speed control (see Section 3.3.7) will be functioning jointly. The rotor speed control provides proportional plus integral control per rotor speed error. The low-gain integral action functions to regulate the input rotor aerodynamic torque by control of aileron deflection so as to drive the system to the reference rotor speed, nominally 16.8 rpm. The high-gain proportional path of this rotor speed loop remains inactive until the rotor speed error exceeds a deadband threshold of ± 0.07 rpm. This deadband significantly reduces the dither of the ailerons that would result from system noise and low level wind turbulence. Large wind gusts or loss-of-load create conditions where this proportional path calls for rapid aileron position corrective action. The generator speed loop remains active until occurrence of conditions producing rotor speeds greater than + 0.06 rpm above the rotor reference of 16.80 rpm. The air gap torque then is limited to 1.1 * rated value. The CS shall autonomously and automatically bring the WTG on and off line as a function of wind conditions and operator commands to provide maximum energy capture capability while maintaining safe control of rotor speed and load. A remote dispatcher shall be capable of receiving periodic data and of issuing commands using a conventional telephone line. In the event of shutdown, diagnostic data shall be recorded and preserved so that the cause can be evaluated.

3.1.2 CS COMPONENTS AND ASSEMBLIES

The major components and assemblies of the CS and their relationship to other WTG subparts are shown by the general Control System Block Diagram of Figure 3.1-1. A detailed Information Flow Diagram is shown on Figure 3.1-2. The primary parts of the CS are defined below.

(a) Controller --- the central or key component containing the software and the input/output hardware to coordinate and control all phases of the WTG operation. It receives the site and/or remote operator commands and the various sensor inputs, generates the operational sequencing and control of aileron deflection, yaw, generator, and emergency shutdown; and transmits performance data to the operator stations.

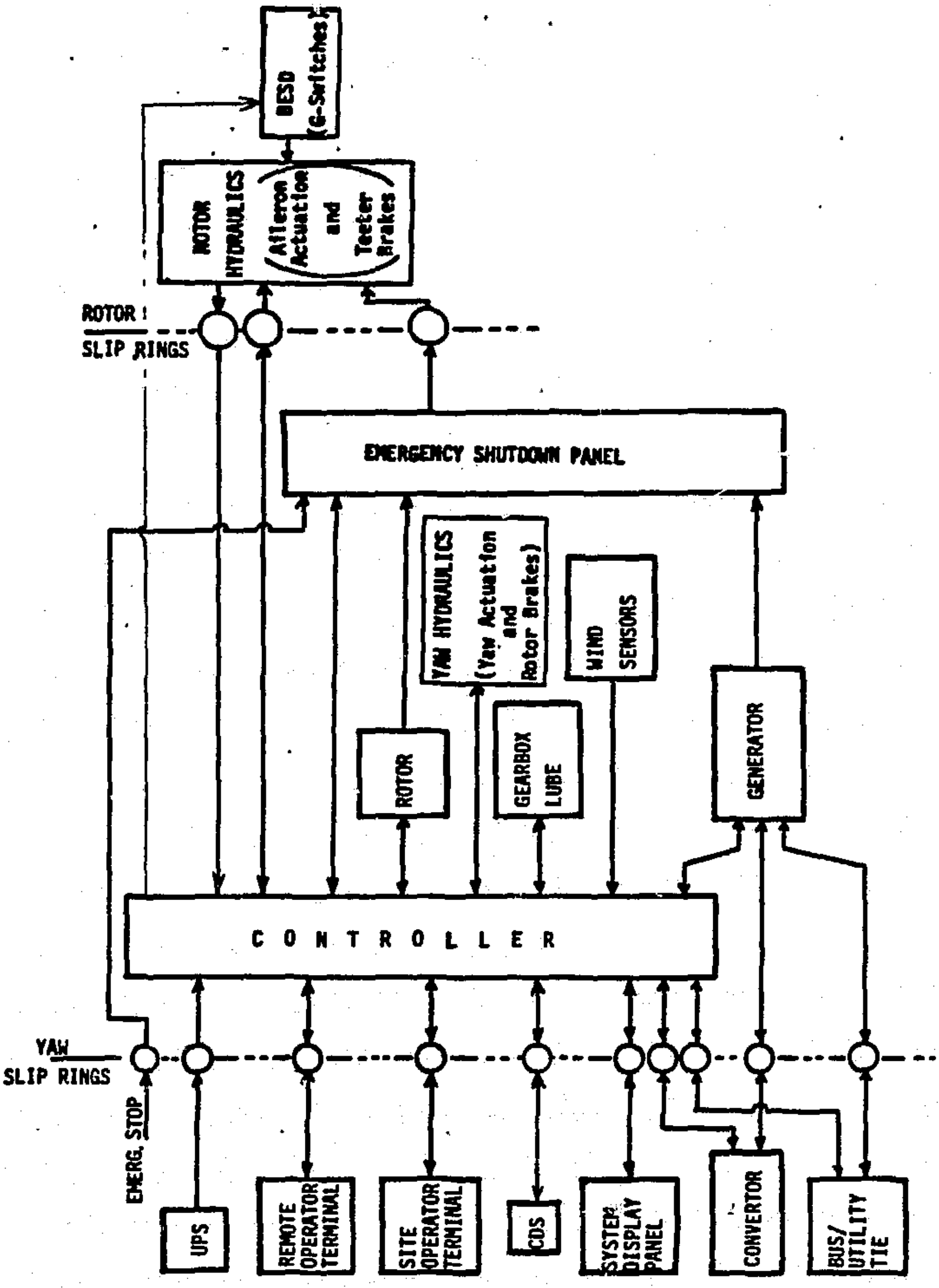

FIGURE 3.1-1

GENERAL CONTROL SYSTEM BLOCK DIAGRAM

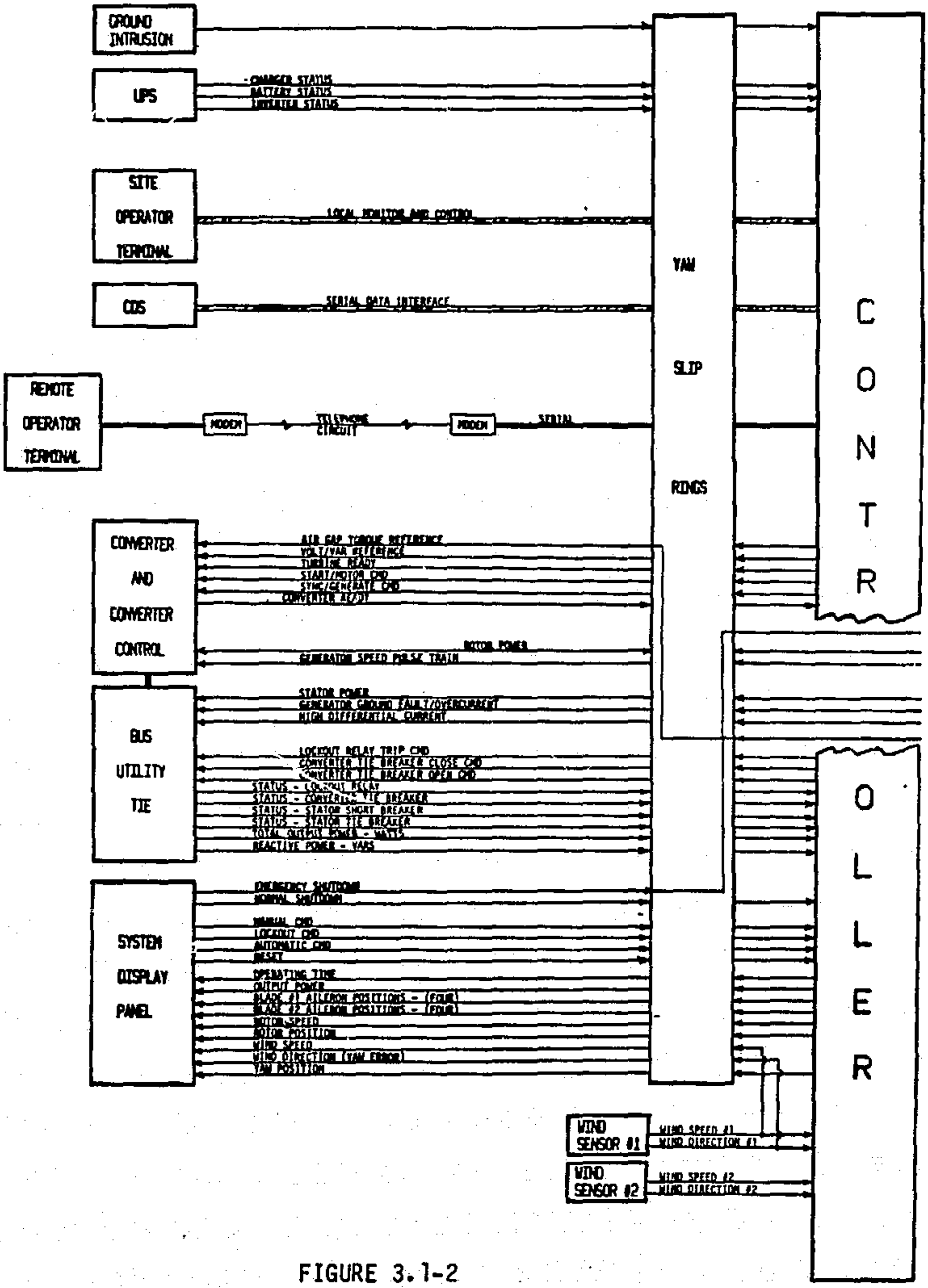

FIGURE 3.1-2

CS INFORMATION FLOW DIAGRAM

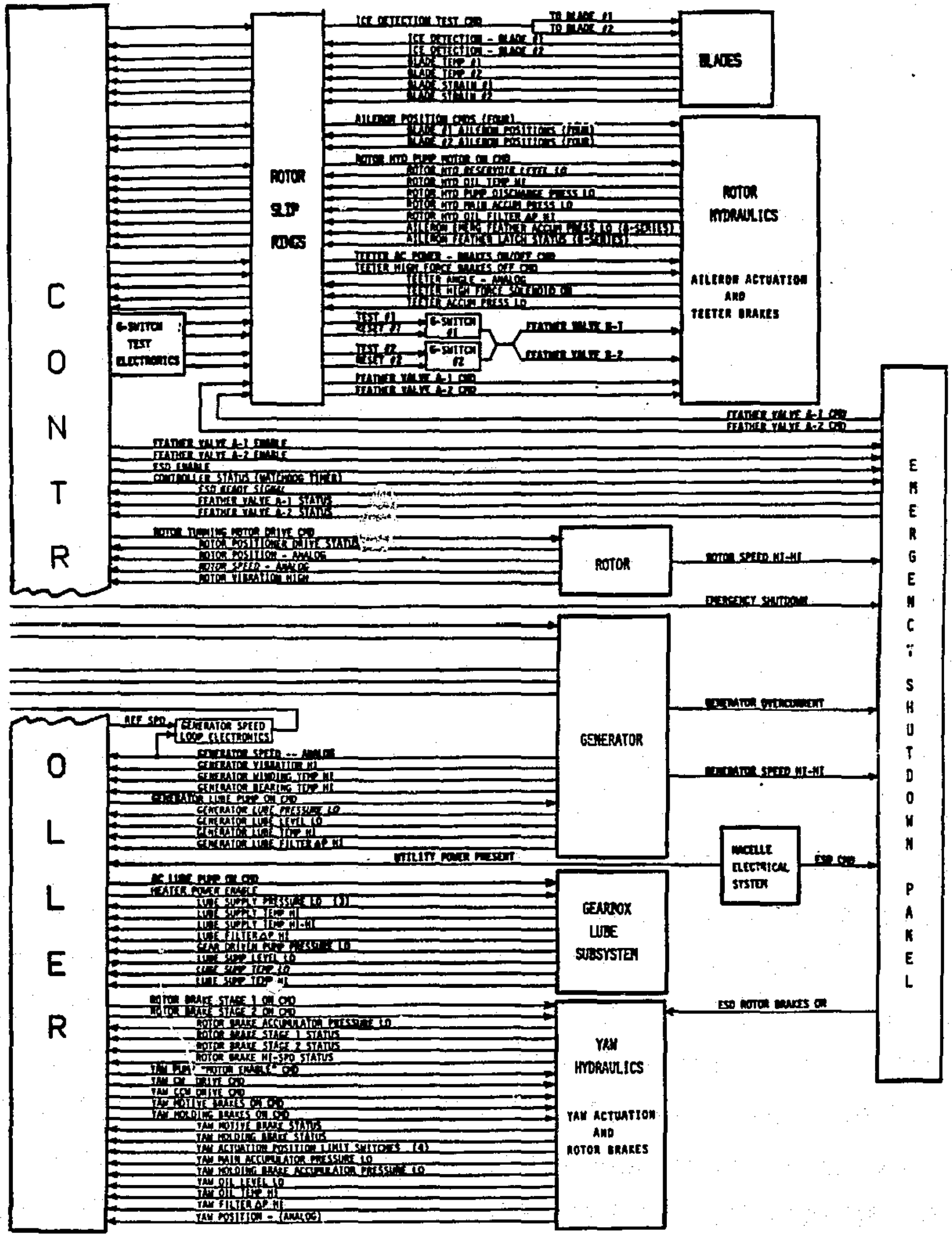

FIGURE 3.1-2 (cont'd)

3.1.2 CS COMPONENTS AND ASSEMBLIES (cont'd)

(b) Aileron Actuation --- the mechanical mechanisms, the hydraulic actuation assemblies, the servo valve drive electronics, and the aileron angle feedback sensors necessary to provide closed loop aileron position control in response to commanded aileron angle (δ_{cmd})) outputs from the Controller.

(c) Variable Speed Generator Subsystem --- includes the generator, converter, converter control, transformers, and accessories for regulation of air gap torque and reactive power as part of the generator speed control. (separately specified-47A380115).

(d) Emergency Shutdown Panel--- a component which monitors sensor inputs as a fault monitoring function independent of the Controller and issues an emergency shutdown command upon sensed occurrence of an emergency condition.

(e) Site Operator Terminal --- located on the ground and used for operating and manual control commands to the Controller and for data readout.

(f) Controls Data System --- performing the function of data recording and processing of control system operational data.

(g) System Display Panel --- a panel for key switch control of operating mode (manual, automatic, lock out or reset), for emergency stop "mushroom" switch, and for display of primary WTG status signals.

(g) Remote Operator Terminal --- a remotely located operator station with limited capability for control command of WTG operation and for data read out.

(h) BESD --- the acceleration sensor and additional hydraulic actuation components which can initiate and implement a Backup Emergency Shutdown if overspeed conditions are detected.

(i) Other --- all other sensors and control devices not otherwise noted, such as motor starters, switchgear, wind sensors, etc.

3.1.3 SIGN CONVENTIONS

The sign conventions and coordinate systems used for all MOD-5A Control System related activities shall be as shown in Figures 3.1-3 and 3.1-4.

3.1.4 WTG CHARACTERISTIC

All CS analysis, design, and test definition activities will use as baseline the following WTG mechanical and aerodynamic characteristics

3.1.4.1 Mechanical Characteristics

The baseline mechanical characteristics of the MOD-5A WTG are as given in the MOD-5A Baseline Mass Properties Document.

3.1.4.2 Aerodynamic Characteristics

The baseline aerodynamic characteristics of the MOD-5A WTG are as given in the MOD-5A Aerodynamic Characteristics Document.

3.2 OPERATIONAL REQUIREMENTS

3.2.1 OPERATING WIND SPEED RANGE

The CS shall be designed for operation at hub height wind speeds as defined in Table 3.2-1 and shown on Figure 3.2-1.

3.2.2 OPERATING MODES

The CS shall be designed for operation in automatic and manual modes. The automatic conditions exist when the WTG is operating autonomously. Each operating mode is a clearly defined functional state of the WTG at a particular time. Transitions, or sequencing, between modes when in the automatic mode shall be in accordance with the control logic defined in subsequent sections. Automatic operation is defined in section 3.2.2.1 and manual mode operation is defined in section 3.2.2.2

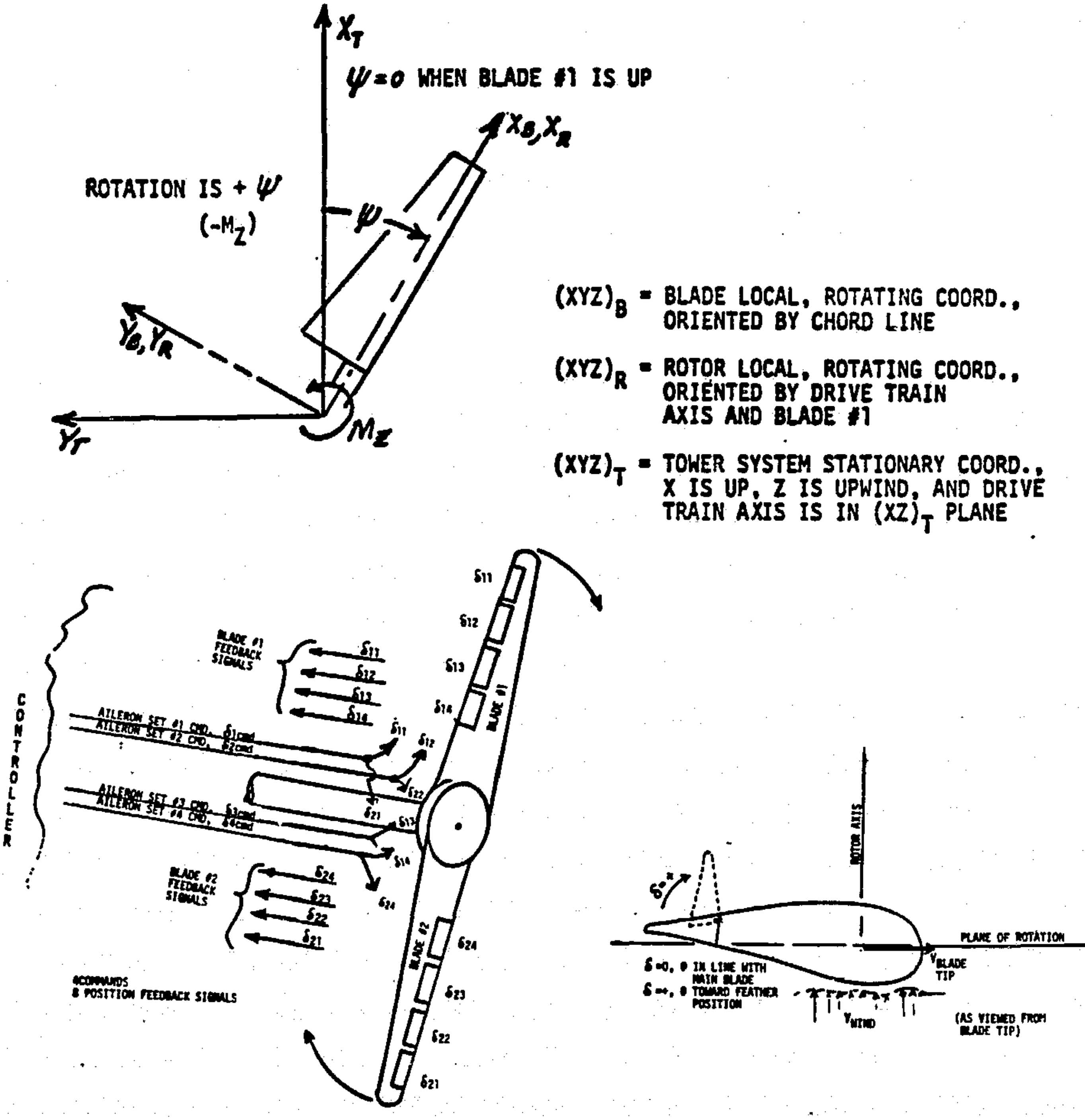

FIGURE 3.1-3

SIGN CONVENTIONS - ROTATING BLADE COORDINATES

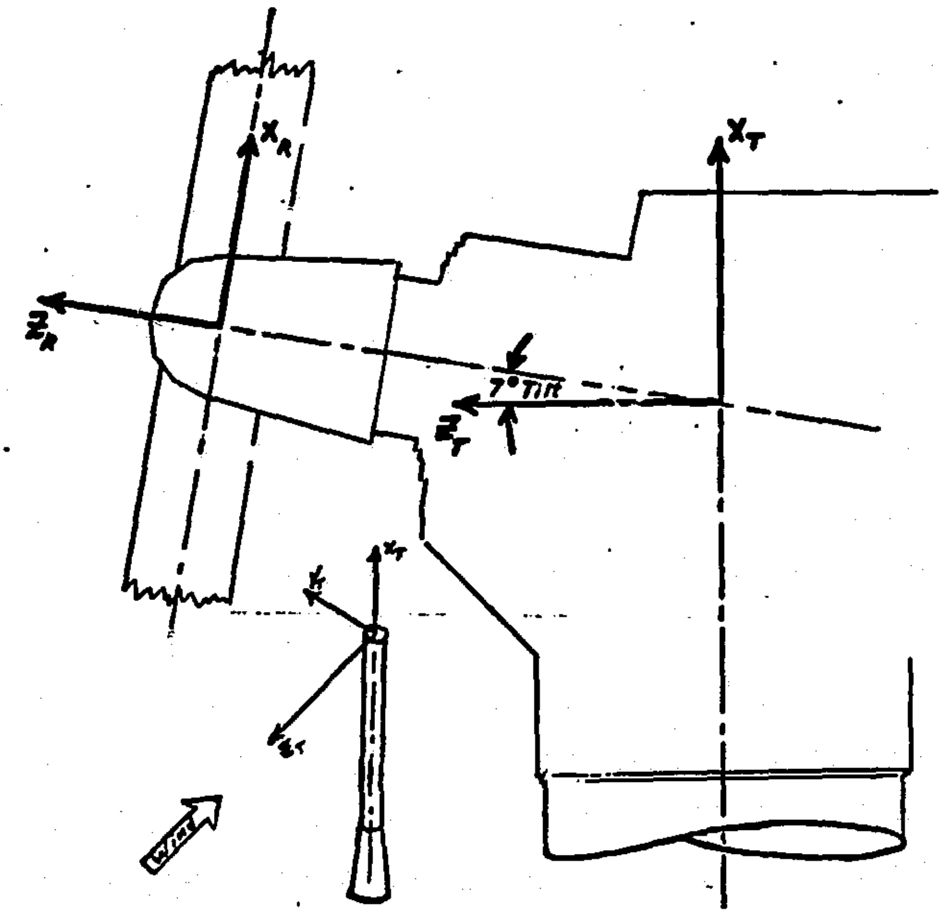

FIGURE 3.1-4

SIGN CONVENTIONS - STATIONARY COORDINATES

TABLE 3.2-1 DESIGN WIND SPEED VALUES

REFERENCE	DESCRIPTION	HUB WIND SPEED (MPH), SEA LEVEL
VLCO	o Low cut-out wind speed where net power at low operating speed can just be sustained and shutdown cycle begins as wind speed falls (shutdown based on power, a 5 minute average)	12.0
	o Also, active yaw control enabled at wind speed (5 minute average) greater than VLCO	
VLCI	Low cut-in wind speed (5 minute average) where acceleration to RPM can be made in less than 15 minutes and startup cycle begins as average wind speed rises	14.0
VRAT	Nominal rated wind speed where WTG produces rated power output	32.0
VHCI	High cut-in wind speed (a 5 minute average) where the re-startup cycle begins as average wind speed falls	55.0
VHCO	High cut-out wind speed where shutdown cycle begins as average wind speed rises (shutdown based on power and blade tip angle, a one minute average)	60.0

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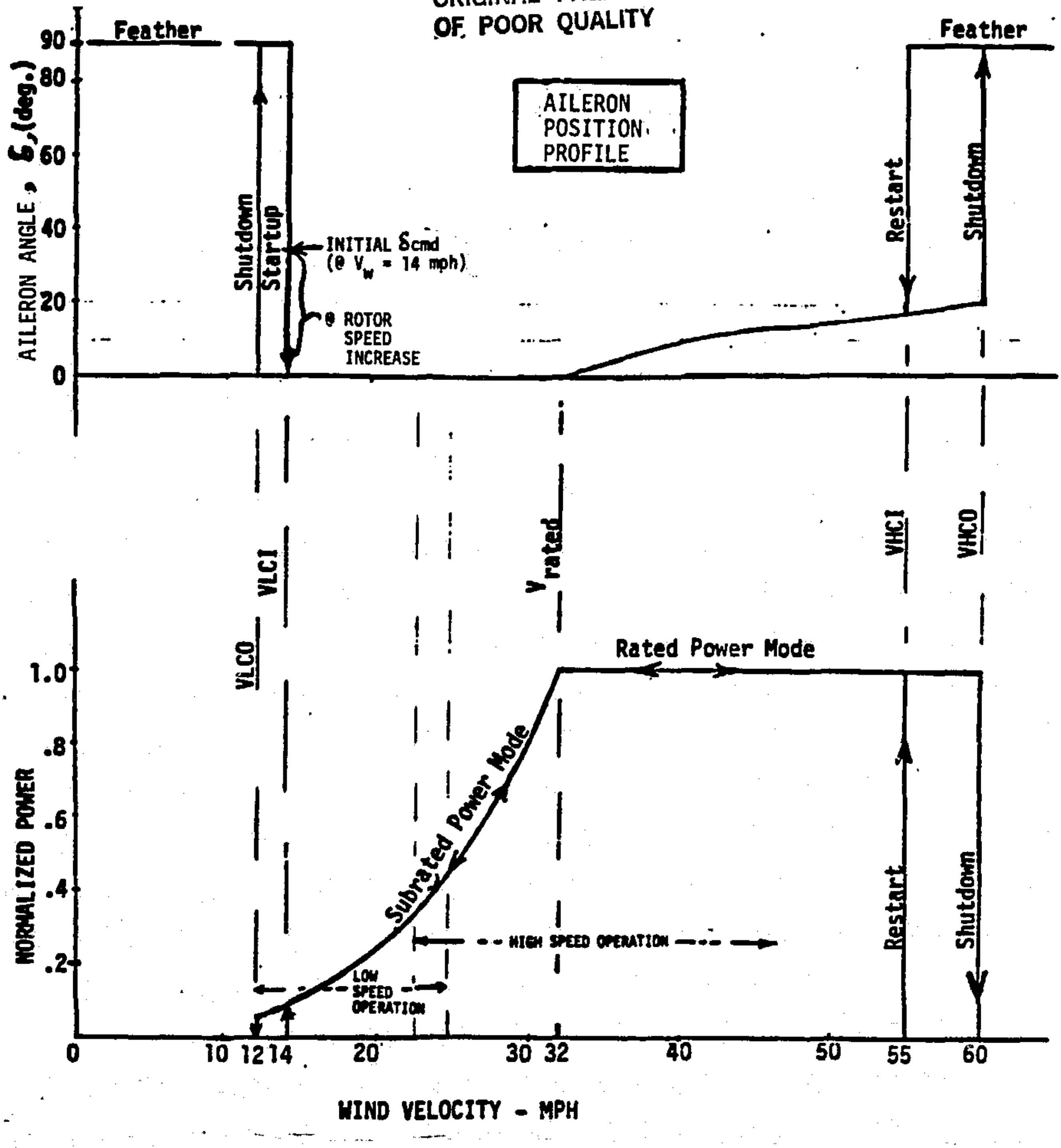

FIGURE 3.2-1

AILERON PROFILE AND OPERATING MODES

AS A FUNCTION OF WIND SPEED

3.2.2.1 Automatic Control Modes

The seven automatic operating modes are:

1. Lock out
2. Standby/Inhibit
3. Standby/Enabled
4. Startup, Ramp-up & Sync.
5. Generating
6. Normal Shutdown
7. Emergency Shutdown

The mode interactions, including manual, are as shown on Figure 3.2.-2 and shall have the characteristics given below.

3.2.2.1.1 Lockout

This mode is entered upon initial power-up or after a fault requiring on-site checkout has been detected in the WTG. The primary function of this mode is to prevent untimely and inadvertent startup and subsequent damage to the WTG or the grid or risk harm to the person investigating or repairing the problem due to restarting the WTG prior to the correction of the sensed problem. After correction of the fault creating condition, the system is reinitialized by turning the key switch on the System Display Panel and enters the Standby/Inhibit Mode. At power-up all control outputs shall be to a safe state. The system initial conditions shall be as follows:

o Controller is ON, performing readiness and status checks.

Yaw Hydraulics

o Yaw hydraulic pump enabled, (yaw pump operated under local control as required to maintain pressure for brakes)
    o Yaw Holding Brake ON. (solenoids unenergized)
    o Yaw Motive Brake ON.
    o Rotor Holding Brakes ON. —(solenoids energized)

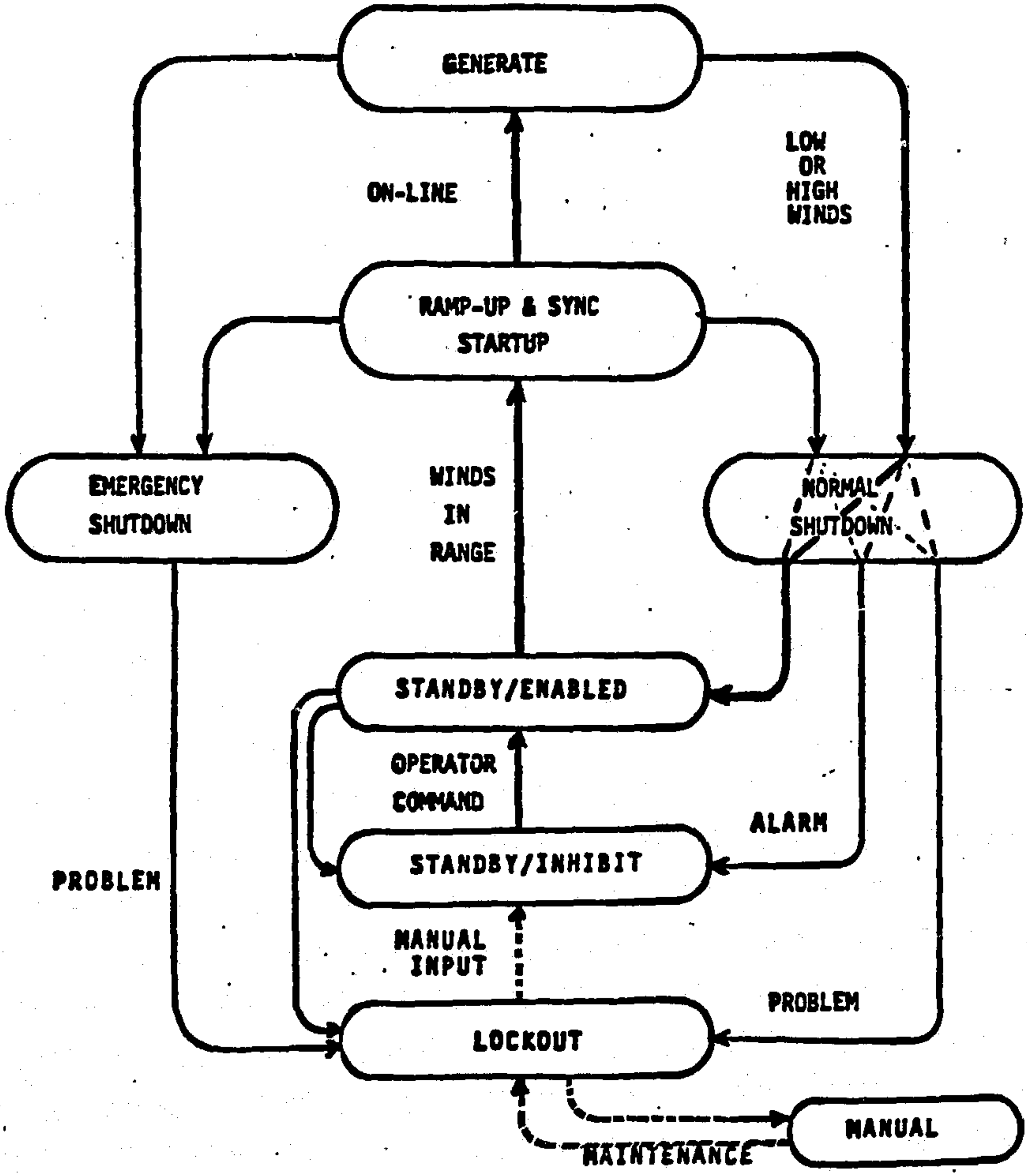

FIGURE 3.2-2
WTG MODE INTERACTIONS

Rotor Hydraulics

- o Rotor Hydraulic Pump ON/OFF (per Controller for teeter brake pressure).
  - o Teeter brakes are ON (solenoids unenergized).
  - o Feather valves A-1 and A-2 (See Figure 3.3-8) are electrically unenergized. (All ailerons latched at feathered position.)

3.2.2.1.2 Standby/Inhibit

This mode places the CS in a "hold" condition wherein the WTG is inhibited from continuation into the automatic control sequence. This mode can be entered from Lockout via keyswitch operation, or as part of Normal Shutdown (NSD) initiated by (1) the Remote Operator Terminal, (2) the Site Operator Terminal, or (3) the Controller upon certain test failures (see 3.3.9.1.2). The return to active automatic control is by signal from either the Site or Remote Operator Terminals to the Controller for return to the Standby/Enabled mode.

3.2.2.1.3 Standby/Enabled

In this mode, the WTG has no detected faults and is awaiting acceptable wind conditions. A summarized Sequence of Operation for this mode shall be as given by the flowchart of Figure 3.2-3. As shown on this flowchart, wind condition checks at startup monitored to detect the existence of acceptable startup conditions. As a means to eliminate delays due to large yaw error at startup, active yaw control shall be initiated when the 5 minute wind average (5 successive 1 minute averages) equals or exceeds VLCO mph (wind speed values defined in Table 3.2-1). The transfer of the system to the Startup mode shall occur when the 5 minute average of the hub wind velocity is VLCI $\leq V_W \leq$ VHCI mph. Averaging times are approximate.

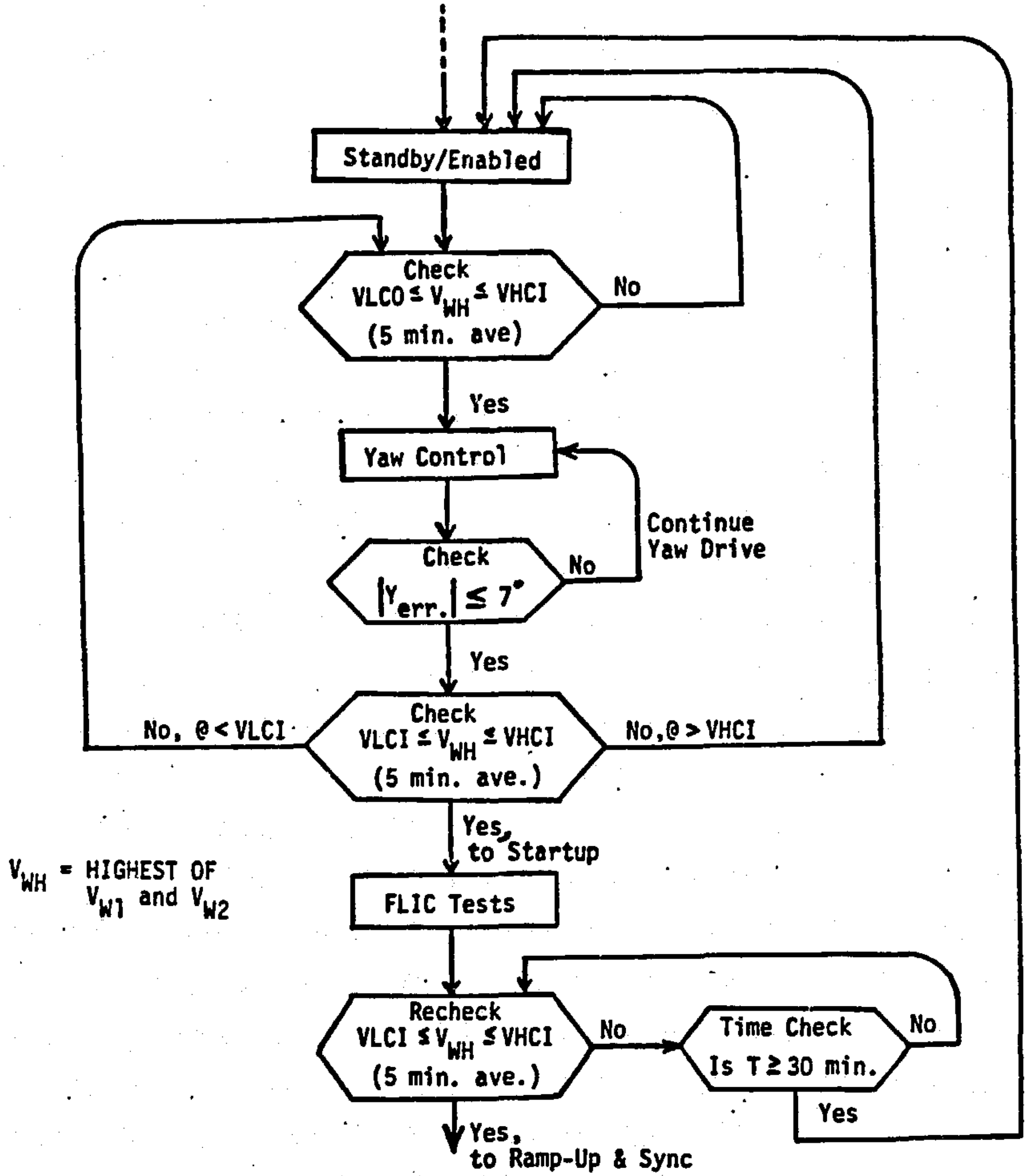

FIGURE 3.2-3

WIND CONDITION CHECKS @ STARTUP

3.2.2.1.4 Startup, Ramp-Up And Sync

The objective of this mode is to bring the WTG from standby to the generating mode. The Sequence of Operation for Startup, Ramp-up and Sync shall be as given below. During this sequence active yaw orientation control is maintained. Also, the wind and general operating conditions are continuously monitored to determine whether to continue toward the generating mode or to shutdown the WTG. In the event of failure of any portion of this test sequence, the software logic shall immediately initiate the Standby/Inhibit mode of operation per paragraph 3.3.9.1

Startup Sequence:

- Set N_R set pt → 13.8 rpm } ← – – – Default values
- Set N_G set pt → 13.8(82.14) rpm }
- Verify prestartup status of sensors
- Rotor hydraulic pump to steady state "ON" - (per Controller Cmd)
- Gearbox lube pump "ON"
- Generator lube pump "ON"
- Verify pumps "ON" status
- Verify "Converter Ready" signal present
- Issue "Turbine Ready" signal
- Issue converter tie breaker close and verify
- Command feather position for all ailerons
- Verify Emergency Shutdown Panel status okay
- Reset G-Switch 1 & 2
- Energize feather valves A-1 & A-2 –
  - releases aileron feather latches
  - enables aileron actuation control
- Verify status (all latches released)

- - - continue to FLIC Tests - - -

FLIC TESTS (per 3.3.2.2.1)

1. Check BESD Process

A. Feather via G-Switch #1 Test:

- o δ_{cmd} from full feather to 80° (@ 1°/s) → Aileron Motion
- o Delay - settling time - (5 sec)
- o Verify $|\delta_{cmd}-\delta_{xy}| \leq 5°$ for each aileron
- o Issue "Half Level" Test Cmd to G-SW#1
- o Verify "No Response"
- o Issue "Full Level" test Cmd to G-SW#1
- o Aileron motion to feather
- o Software verify all ailerons @ feather ± 5°
- o Issue δ_{cmd} to full feather
- o Reset G-SW#1
- o Verify aileron feather latches released

B. Feather via G-Switch #2

This sequence shall be a repeat of the process used for BESD item A above, except for use of G-Switch #2.

2. Check Emergency Shutdown Process and Rotor Hydraulic Filter ΔP

- o δ_{cmd} from full feather to 70° such that a δ rate = 5°/sec is achieved. During aileron motion, verify Rotor Hyd Oil Filter ΔP HI signal is not received (See Section 3.3.2.2.1)
- o Delay - settling time - (5 sec)
- o Verify $|\delta_{cmd} - \delta_{xy}| \leq 5°$ for each aileron
- o Remove feather valve A-1 enable signal

  Verify blade 1 ailerons - motion to feather

  Remove feather valve A-2 enable signal
- o Verify blade 2 ailerons - motion to feather

  Issue δ_{cmd} to full feather
- o Enable Emergency Shutdown Panel, verify ESD status Okay and aileron feather latches released

3. Teeter Brake Checks (Ref. Fig. 3.3-5)

- o Initial Condition
  - o Controller output cmd = Teeter Power "OFF"

    .•. No power to teeter brake system

    Both L.F. and H.F. brakes = "ON"

    where L.F. = Low Force

    H.F. = High Force
- o Verify accumulator pressure = charged
- o Issue Teeter Power "ON" cmd. (120 volt available to teeter system)
- o Verify H.F. brakes = "ON"

---- End Of FLIC Tests ---

Recheck Wind Status

- o For VLCI $\leq V_W \leq$ VHCI mph → continue to Ramp-Up & Sync
- o For V_W outside bounding values
  - o Continue rechecks of wind status, if continuation to Ramp-up and Sync does not occur in 30 minutes, then return to Standby/Enable - start

Ramp-Up And Sync Sequence

- o Release rotor brake
- o Vary δ_{cmd} to all ailerons from feather position to

  $\delta_{cmd} = 25° + 0.363 * V_{WO}$, @ $\simeq$ 5°/sec

  where $\left\{ \begin{array}{l} \delta_{cmd} = \text{commanded aileron angle in degrees} \\ V_{WO} = \text{wind speed in mph} \rightarrow \text{1 min. ave. (max) prior to rotation} \end{array} \right.$

- o Begin rotor acceleration via converter and generator in "motoring" mode
  - o Issue "Start/Motor" signal - (Controller to converter control)
  - o Converter control shall
    1. Verify stator tie breaker is open
    2. Close stator short breaker
  - o Verify stator tie breaker is closed
  - o Issue NG_{Ref} ramp command from zero to (3.7 * 82.14) rpm @ (3.7 * 82.14) rpm/min [See Section 3.3.7.3.1]

- o Converter shall commence motoring following generator speed error signal
- o @ N_R = 3.7 rpm,
  - o Hold NG_{Ref} @ (3.7 * 82.14) rpm
  - o Transfer the δ_{cmd} value to integrator initial condition (Fig. 3.3-3)
  - o Initiate closed-loop rotor speed control @ $N_{R_{Ref}}$ = 3.7 rpm
- o Increase $N_{R_{Ref}}$ to 4.0 rpm @ 3.7 rpm/min
- o @ Generator power ~ zero, remove "Start/Motor" signal to converter
- o Converter to cease motoring and open stator short breaker
- o Verify stator short breaker is open
- o Verify blade temperature sensors indicate "In-Range"

  @ Yes - continue sequence

  @ No - hold at N_R = 4.0 rpm until readings return to "In-Range" then continue sequence.

  Upon failure to reach "In-Range" readings within 30 minutes,
  - o Shutdown to Standby/Inhibit mode
  - o Issue alarm message

- o Increase $N_{R_{Ref}}$ from 4.0 rpm to [$N_{R_{set\ pt}}$ - 0.6 rpm] (nominal value = 13.2 rpm)

  as $N_{R_{Ref}} = 4.0 \text{ rpm} + \left(.145\ V_{wo} \frac{rpm}{min}\right) * T_{min}.$
- o Vary $N_{G_{R_{Ref}}}$ to track $N_{R_{Ref}}$
- o @ $N_R > 6$ rpm <u>and</u> $|\alpha_T| < 2.4°$
  - o Release teeter H.F. brakes (See Fig. 3.3-5)
    - o Close H.F. OFF relay
    - o Verify state change on Sense "A"
    - o Open H.F. OFF relay
    - o Verify no change in Sense "A" (remains @ "HI-Brks OFF")
      If changed to "HI-ON", go to NSD/L.O.
  - o @ $N_R \geq 9$ rpm, check gearbox shaft driven pump pressure and if "Hi" turn off AC lube pump
  - o @ $N_R \geq$ 12.5 rpm, verify teeter H. F. brakes = OFF,
    If brakes remain "ON", then NSD/Lockout

- o $N_{R_{Ref}} = N_{R_{set\ pt}} - 0.6$ rpm, change ramp rate to 1 rpm/min while increasing $N_{R_{Ref}}$ to $N_{R_{set\ pt}}$ [nom. 13.8 rpm]
- o Hold operation at $N_{R_{Ref}} \approx N_{R_{set\ pt}}$ for 10 seconds
- o Issue "sync/generate" command to converter control
- o Verify receipt of converter "sync complete" via "stator tie close"
  - o @ verification, exit to power generation mode
  - o If not verified within 15 seconds → NSD/Lockout

3.2.2.1.5 Power Generation

The transition to power generation shall be by transfer of speed control from rotor aerodynamic torque control via the ailerons to generator air gap torque control via the converter/generator.

- o Hold $N_{R_{Ref}}$ at $N_{R_{set\ pt}}$ nom. → 13.8 rpm
- o Decrease $N_{G_{Ref}}$ to $[N_{R_{set\ pt}} - (0.6)(P_{SP})]$ nom. → 13.2 rpm (power set point, value range, 0 to 1.0)

During subrated conditions, the speed regulation is provided by the generator torque-speed control characteristic, per Figure 3.2-3 and Section 3.3.7. System efficiency is near optimum by operating in two speed ranges. The following changes in speed reference levels shall apply during subrated operation.

(1) Speed Reference Levels

[See Section 3.2.2.2.1]

	$N_{G_{Ref}}$	$N_{R_{Ref}}$
@ $0 \le P_{ave5} \le 4.5$ MW, Low Speed	13.2 rpm	13.8 rpm
@ 3.0 MW $\le P_{ave5}$, High Speed	16.2 rpm	16.8 rpm

Transitions

- o From Low to High, when P_{ave5} rises above 4.5 MW
  - o Ramp both references up 3.0 rpm @ 1.0 rpm/min
- o From High to Low, when P_{ave5} drops below 3.0 MW
  - o Ramp both references down 3.0 rpm @ 1.0 rpm/min

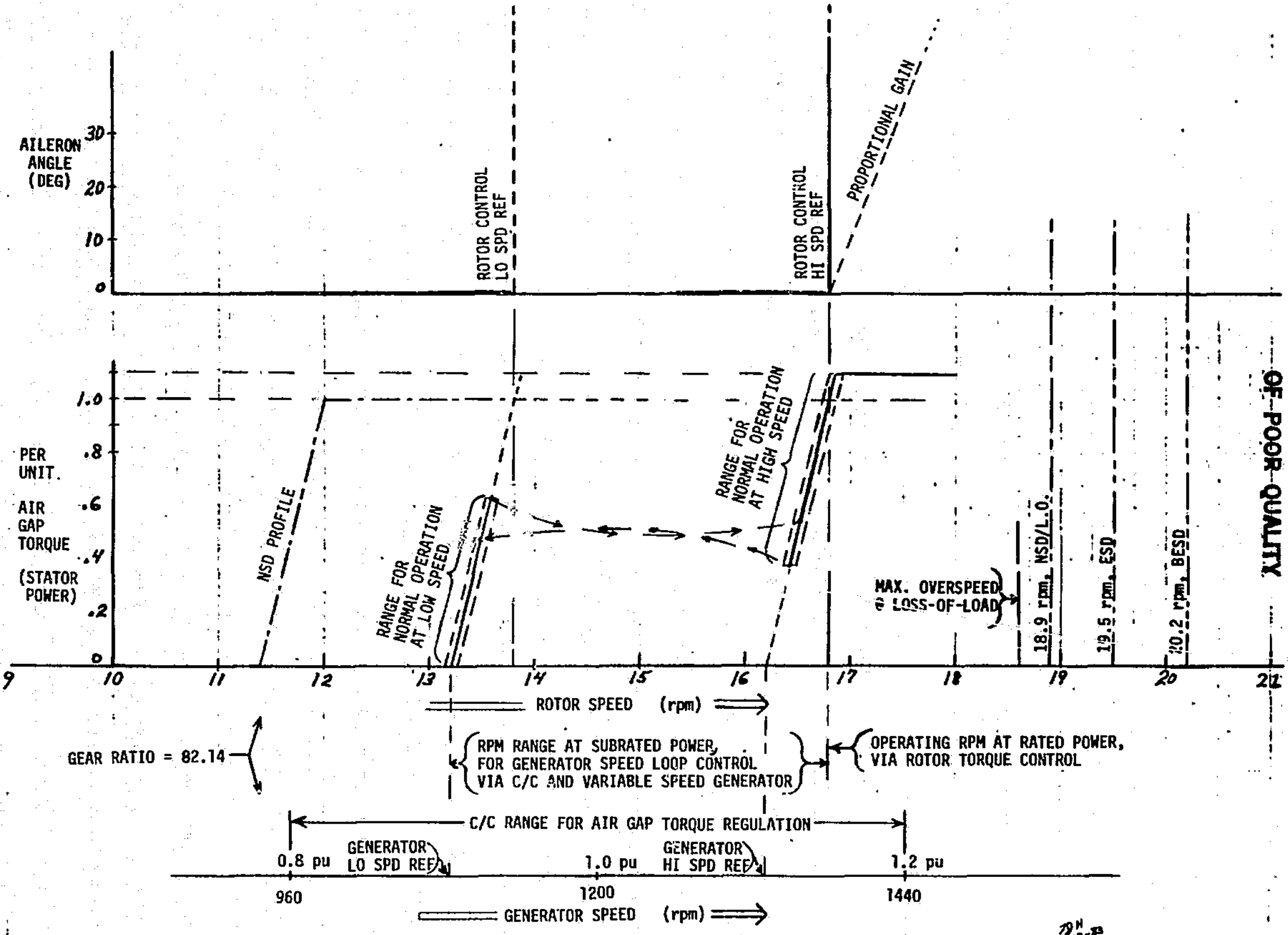

FIGURE 3.2-4 POWER GENERATION OPERATING REGIONS

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3.2.2.1.5 Power Generation (cont'd)

During rated or set point power conditions, speed regulation is provided jointly by the rotor aerodynamic control torque-speed characteristic, utilizing the ailerons per Section 3.3.2, and the generator air gap torque control per Section 3.3.7.

The converter control shall operate for constant generator bus VAR control to setpoints that are manually selected at the site during prestartup procedures, or optionally set by remote utility control.

While in the power generation mode, the conditions of the WTG and the utility grid shall be continuously monitored to detect unacceptable conditions that may require a warning message or that the system to be shut down, per Section 3.3.8

3.2.2.1.6 Normal Shutdown

Upon determining that the conditions necessary for generating power are no longer present, the Controller logic will initiate a controlled shutdown. (See Section 3.3.9.1) The sequence of operation is as follows.

<u>Initiate Normal Shutdown Routine</u>

- o Ramp both $N_{R_{Ref}}$ and $N_{G_{Ref}}$ downward from their existing values at 10 rpm per minute, and (10 * 82.14) rpm per minute respectively, with a minimum $N_{G_{Ref}}$ = (11.4 * 82.14) rpm
- o @ N_R = 11.4 rpm, remove the "sync/generate" command to converter control
- o Verify converter shutdown status via stator tie breaker, open position
- o @ $N_R \leq 9$ rpm, Gearbox AC lube pump "ON"
- o @ δ_{11} or > δ_{12} > 70°, apply rotor brakes (per sequence of Section 3.3.3)

- @ $N_R \leq 0.2$ rpm, De-energize both feather valves A-1 & A-2
- Command and verify trip of converter tie breaker
- Remove "Turbine Ready" signal
- Open teeter brake power ON/OFF relay
- Verify "sense A" indicates HI brakes ON
- Gearbox AC lube pump "OFF"
- Generator lube pump "OFF"
- Rotor hydraulic pump to teeter brake pressure control (per 3.3.6.1)
- Verify status

Upon completion of the above sequence, the system is transferred to one of the three following modes, depending on the condition causing the shutdown.

A. Standby/Enabled -- part of the normal automatic cycle dependent on wind conditions. (See 3.3.9.1.1)

B. Standby/Inhibit -- a state requiring remote or site operator intervention before restart. (See 3.3.9.1.2)

C. Lockout -- due to detection of "Second Level Fault" conditions, identified as requiring on-site intervention. (See 3.3.9.1.3)

3.2.2.1.7 Emergency Shutdown

The emergency shutdown mode is used when certain critical conditions are encountered requiring immediate shutdown. In this mode, the Emergency Shutdown Panel is are triggered to feather the ailerons. In addition, the Controller shall continue the usual procedures executed during a normal shutdown. Such conditions as overspeed, critical sensor failure, or Controller failure are examples of conditions requiring an emergency shutdown. Performance requirements for ESD are given in 3.3.9.2.

3.2.2.2 Manual Modes

Two distinct manual modes for manual entry of data or commands into the Controller, referred to as "Manually Entered Inputs" and as "Manual Control", are to be implemented and are as defined in the following paragraphs. For additional related information, see paragraph 3.2.4.2 (Operator Terminal Priority) and paragraph 3.2.4.3 (System Display Panel).

3.2.2.2.1 Manually Entered Inputs

A listing of the parameters and commands that shall be implemented during automatic modes as "Manually Entered Inputs" from either the Site Operator Terminal and the Remote Operator Terminal is given below:

1. Standby Enable
2. Power Set Point
3. Var Set Point
4. Normal Shutdown
5. Emergency Shutdown
6. Request/Enable Site Terminal Control
7. Request/Enable Remote Terminal Control

The Standby Enable command input shall initiate a sequence within the Controller to check for satisfactory wind conditions for continuation into Startup per paragraph 3.2.2.1.3.

The Power Set Point, P_{set}, and the Var Set Point, Var_{set}, shall be setable values entered into the Controller from either the Site or Remote Terminals, whichever is in control. The Controller logic will accept no input value greater than the default baseline rated values. The change capability for P_{set} shall cover a range of zero to 7.3 MW with a quantization equal to or less than 0.25 MW. The Var_{set} shall be setable for system operation at 0.98 to 1.0 pf.

The Normal Shutdown command input from either the Site Operator Terminal or the Remote Operator Terminal shall cause the Controller software to be routed directly to the NSD-Standby/Inhibit via standard shutdown routine utilized in automatic operation, (see Section 3.3.9.1).

The Emergency Shutdown command shall initiate the shutdown process per Section 3.3.9.2.

The operator terminal control priority shall be as defined in paragraph 3.2.4.2.

3.2.2.2.2 Manual Control/Key Switch

"Manual Control" shall refer to the state, or conditions, which exist when an on-site operator is in control of the WTG, in contrast to the automatic control condition. This manual control state is initiated from the Lockout mode by key switch selection on the System Display Panel per Section 3.2.4.3. Key switch selection out of "automatic" shall be treated as a normal shutdown command to Lockout. All manual control commands shall be routed through the Controller where limiting conditions shall be applied to preclude inadvertent unsafe operating conditions by not accepting invalid commands. The manual control functions to be implemented via the Site Operator Terminal shall be as listed below.

1. Data output - dump archive
   The "Data Output - Dump Archive" command to the Controller from the Site Operator Terminal shall initiate a selectable transmittal of the time tagged past history data of the analog and digital discrete status information from Controller memory to the Site Operator Terminal per the requirements of Section 3.2.3 and 3.3.11. This capability shall be permitted only during the Lockout mode.

2. Rotor brake control - OFF/ON
3. Rotor position control - OFF/ON to turning gear motor
4. Individual hydraulic pump motors - OFF/ON,
5. Yaw brake control - OFF/ON
6. Yaw position control - a) direction selection
   b) OFF/ON of yaw drive
7. Individual pairs of aileron motion - over full range of travel

3.2.3 FAULT MONITORING

3.2.3.1 Fault Determination

The CS shall contain the sensors, control logic and associated hardware to continuously monitor the MOD-5A WTG operation for safe operating conditions. The various levels of fault monitoring and resultant control response to be implemented shall be as follows:

(a) Alarm messages
(b) 1st level fault shutdown - NSD/STBY INHIBIT
(c) 2nd level fault shutdown - NSD/L.O.
(d) 3rd level fault shutdown - ESD/L.O.
(e) 4th level fault shutdown - BESD/L.O.

Alarm messages shall be processed as alerts for conditions that do not as yet warrant WTG shutdown, but are indicative as early warnings of potentially more serious failure. The Controller shall issue an alarm or warning message to both the Site and Remote Operator Terminals (see Section 3.3.8), indicating at least time, fault identifier, and mode.

The 1st level faults for normal shutdown to Standby/Inhibit (see Section 3.3.9.1.2) are for conditions that merit shutdown and operator review prior to continued operation. The 2nd, 3rd and 4th level faults shall be allocated as increasingly more serious system safety related items, with each resulting in shutdown to a lockout condition. In each case, the Controller, if active, shall issue a message to both terminals indicating the initial source of any shutdown event. In addition, the Controller shall establish an interlock such that a hard copy dump of the diagnostic memory must be prompted prior to permitting a restart of the WTG system. The NSD/L.O. of level 2 is to be conducted under Controller operation utilizing the RSC in the normal mode of operation, per Section 3.3.9.

The third level of shutdown, as an ESD independent of the Controller, shall be provided by the Emergency Shutdown Panel (see Section 3.3.9.2). A fourth level, BESD, shall be via a g-sensing of overspeed conditions (see Section 3.3.9.3).

3.2.3.2 Data Window

The CS shall provide the capability for special data retrieval in the event a fault condition is determined. This shall consist of retention within Controller memory of a minimum of 90 samples of all sensor values according to the following time line related to a fault occurrence at t = zero seconds

for	t = -30 to t = 0,	30 samples @ 1 SPS
	t = 0 to t = 30,	30 samples @ 1 SPS
	t = 30 to t = 180,	30 samples @ 1 sample/5 sec.

Provisions for display of this retained data shall be provided a "mushroom" switch for initiation of ESD and at the site interface.

3.2.4 SUPERVISORY CONTROL PRIORITY

3.2.4.1 Operation Without Communication

The CS design shall be such that the Controller, after previously having been enabled by either the Site Operator Terminal or the Remote Operator Terminal, will be capable of continuous failsafe automatic WTG operating control without interface communication with either or both the site and remote operator terminals.

3.2.4.2 Operator Terminal Priority

The CS design shall provide ground operator command capability to the Controller from two locations, which are:

1. Local site - via (A) Site Operator Terminal
   (B) System Display Panel
2. Remote location - via Remote Operator Terminal

Communication with this remote terminal, nominally located up to 50 miles from the site, shall be by conventional telephone line.

The Operator Terminals will have the command capability specified per paragraph 3.2.2.2, with only one terminal having command capability at any one time. The Controller design shall be such that it will accept command inputs only from the terminal deemed to have "priority control". The transfer of this command authority shall occur only by issuance of a command to the Controller from the existing priority location for transfer of "priority control" to the alternate location. A key switch function on the System Display Panel can be used to override this "priority control", if required, as defined in Section 3.2.4.3.

3.2.4.3 System Display Panel

The system display panel shall provide a "mushroom" switch for initiation of ESD and a four position key switch for the following four functions, in the sequence noted.

1. Manual - Manual control only
2. Lockout - Prevents all command operations
3. Automatic - Normal operating position
4. Reset - Enables transition from Lockout to the automatic sequence Standby/Inhibit mode

3.2.4.3 System Display Panel (cont'd)

Position #4 preferably shall be spring loaded for free return to position #3. The permitted operations while at a key position and the resultant actions due to a change of key position are given below. The key shall be removable in any position, locking the switch in that position.

3.2.4.3.1 Automatic Position

This shall be the normal key switch position for all normal operating modes while either the Site Operator Terminal or the Remote Operator Terminal has "priority control". A key position change from either Lockout or Manual position to Automatic, without having gone to Reset, shall have no effect. The return to Automatic from Reset shall place the Controller in the Standby/Inhibit mode with "priority control" placed at the Site Operator Terminal.

3.2.4.3.2 Manual Position

In order to carry out the "Manual Control" function per 3.2.2.2.2 from the Site Operator Terminal, the key switch must be in the manual position. A change of key switch position from Automatic through Lockout to Manual shall cause the Controller to initiate a NSD to Lockout. This is a "no restart" condition via command signals from either the Remote or the Site Operator Terminals.

3.2.4.3.3 Lockout Position

The key switch in the Lockout position shall prohibit both automatic and manual command functions. Only data readout capability to the Site and Remote Operator Terminals is permitted. Also, the key switch shall be placed to this Lockout position as part of any sequence for total WTG shutdown. If, while in normal automatic mode operation, the key switch is moved from Automatic to Lockout, a signal shall be issued from the System Display Panel to the Controller to initiate an NSD to Lockout.

3.2.4.3.4 Reset Position

The Reset position preferably shall be a spring loaded position, for free return to Automatic, which yields the only means to leave the Lockout mode. Movement to Reset shall cause the panel to issue a signal to the Controller to place it in the Standby/Inhibit mode with "priority control" placed at the Site Operator Terminal. The restart of automatic operation then can be initiated at the Site Operator Terminal via the Standby/Enable signal. Transfer of "priority control" to the Remote Operator Terminal will permit a restart from that location, also by use of a Standby/Enable signal.

3.2.5 ICE OPERATION

3.2.5.1 Ice Detection

The CS shall provide an ice detection function by monitoring within the Controller on a once per second interval the status of two signals from the ice detection devices (one on each blade). Upon a change of state of either signal, indicating blade icing conditions, the Controller shall initiate a NSD to Standby/Inhibit.

3.2.5.2 Ice Test

The CS shall include within the Controller software an automatic ice test procedure when entering the Startup mode. The Controller shall initiate a test signal sent, and subsequently removed, to each ice detection device and verify a resulting change of state of the feedback signals. The failure of this test (i.e., no response within 5 seconds) shall place the Controller into the Standby/Inhibit mode.

3.2.6 MAINTENANCE AND ACCESS

Control system hardware shall be provided with features to minimize WTG inspection and maintenance life cycle costs. Minimum requirements are as follows:

a) Diagnostic functions shall be built into the Controller.

b) No lower than board level replacement shall be used for maintenance.

c) All electrical connectors shall be supplied with appropriate keying to ease installation, test and replacement.

d) Access shall be provided to all sensor and command lines where they leave the controller cabinet.

e) The site terminal interface shall have the capability to drive either hard copy or non-hard copy terminal devices.

f) All motor control circuits shall have local/automatic and local start/stop switches on controllers located near the motor.

3.3 PERFORMANCE REQUIREMENTS

3.3.1 YAW ORIENTATION CONTROL

The CS shall provide command signals for yaw orientation control for automatic and manual control operation. The signal interface of the Controller and the yaw actuation hardware shall be as shown schematically on Figure 3.3-1.

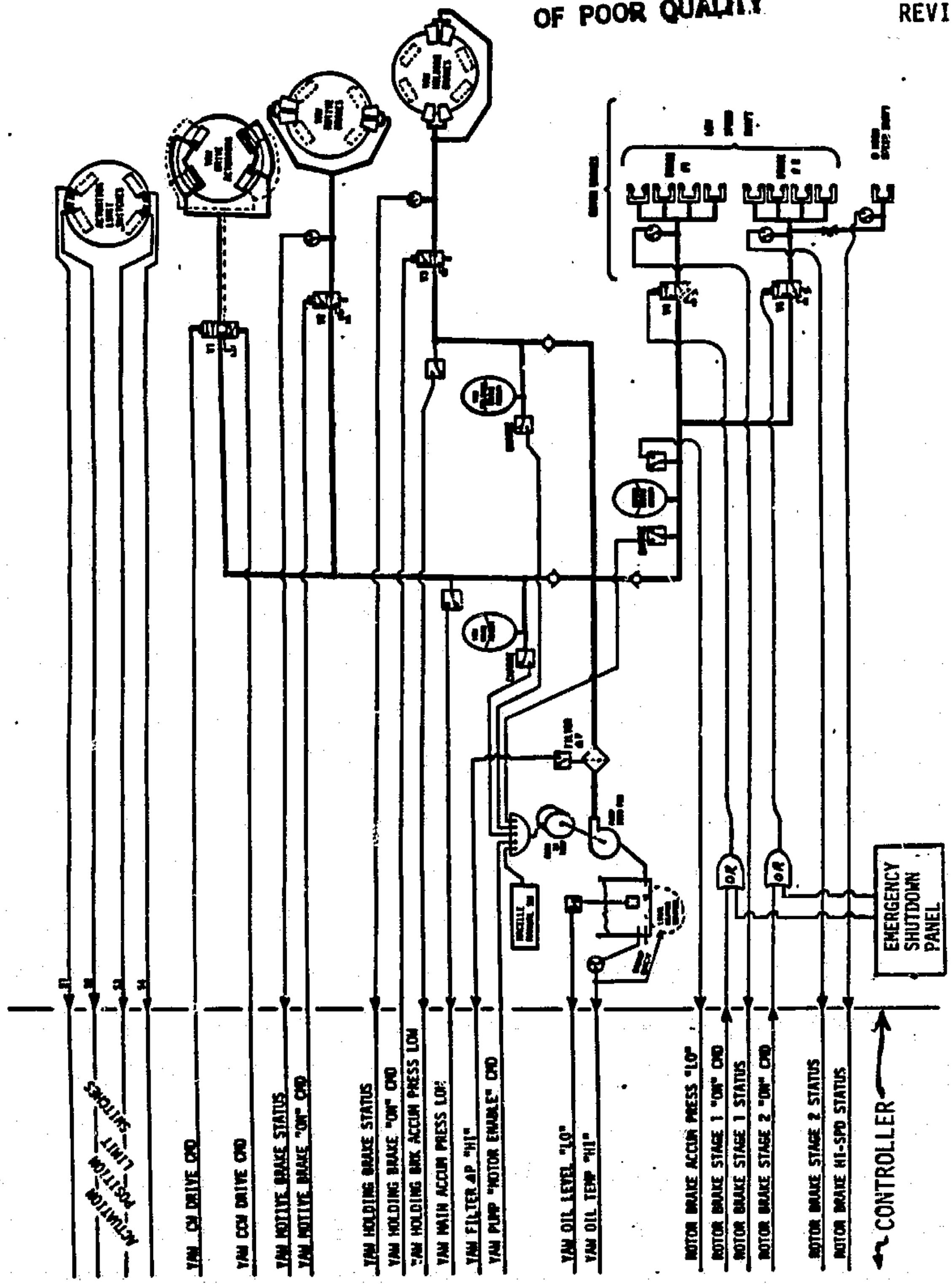

FIGURE 3.3-1

YAW ACTUATION & ROTOR BRAKE SIGNAL INTERFACE

3.3.1.1. Automatic Yaw Control

Automatic control sequencing and logic, implemented within the Controller shall command the yaw to move clockwise or counter clockwise, based on yaw error. The yaw error is defined as the relative difference between the wind velocity vector and the $-Z_T$ axis of the nacelle, per Figure 3.1-4. This error will be an averaged measurement per Section 3.3.1.1.2. The automatic yaw orientation control shall position the rotor upwind of the tower during startup (per Section 3.2.2.1.3) and maintain this orientation during startup and generating modes. Capability shall be provided to implement a yaw bias in the range of 0 ±10°. [Note: Tentative null for yaw drive is at a yaw bias of +2.5°.]

3.3.1.1.1. Wind Sensors

Two sets of wind sensors shall be used for dual sources of wind speed and wind direction (yaw error) information to the Controller. During wind condition checks leading to startup, the highest averaged wind speed sensor output shall be used for all logic decisions, per flow chart of Section 3.2.2.1.3. One of the yaw error signals shall be used by the Controller for yaw correction computations. The second set of sensors in each case shall be used as a comparison with the first set as a means for determination of sensor malfunctions. The wind speed sensors shall be analog output with a range of zero to 150 MPH with a ± 2 MPH accuracy and have a distance constant no greater than 36 feet, such that the effective time constant (seconds) is no more than 25/Hub Wind Speed. The wind direction error sensors shall provide for unambiguous ± 180° orientation with an accuracy of ±2° and shall have a distance constant no greater than 21 feet, such that the effective time constant (seconds) is no more than 15/Hub Wind Speed.

Wind speed values are not used directly for control operations while the blade is rotating, but are inferred by "equivalent wind speed conditions". The equivalent conditions for $V_W \geq 45$ mph shall be that N_R is at the high speed range and the blade pitch angle is $\delta \geq 13.0$ degrees at rated operation for greater than one minute. Equivalent conditions for wind speeds for shutdown are defined in Section 3.3.9.1.1.

3.3.1.1.2 Yaw Error Logic/Commands

- o Normal Operation - Enable the yaw drive and command yaw corrections when the wind direction error is greater than 7°. Yaw drive shall continue until the wind direction error is less than 3.5°, at which time the yaw drive will be shut down. During a "down" state, both the yaw motive brakes and the yaw holding brakes shall be "ON" with the associated solenoid valves unenergized. During yaw correction maneuvers, these sets of brakes are to be controlled in an "apply-before-release" sequence such that a positive indication of pressure in the "2nd" set of brakes must exist before the other set is released. The data averaging process for wind direction error determination shall be nominally a 50 second period based on three levels of block averages.

- o NSD Due To Rapidly Changing Wind Direction - The Controller shall implement control logic to provide capability for Normal Shutdown to the Standby/Enabled mode when large yaw wind inflow angles result due to rapidly changing wind direction. This logic shall be equivalent to the following cases:

(1) @ V_W < 45 mph and $|Y_{e_{ave}}| > 45°$

(2) @ $V_W \geq$ 45 mph and $|Y_{e_{ave}}| > 115° - 5.4\ \delta_{ave}$

o Malfunction Detection → Alarms, The Controller shall issue alarm messages for anomalous wind sensor and yaw actuation operation as given in Section 3.3.8. Additional clarification for referenced items is given below.

(1) Wind speed sensor mismatch - If, while sensing wind speeds greater than 10 mph, the absolute value of the difference in the wind speed sensor values exceeds 5 mph for a continuous time period of 8 seconds issue an alarm message.

(2) Wind direction sensor mismatch - If, while sensing wind speeds greater than 10 mph, the absolute value of the difference in the wind direction sensor values exceeds 10° for a continuous time period of 8 seconds issue an alarm message.

o Malfunction Detection → NSD/L.O. - The Controller normal shutdown sequence to Lockout shall be initiated if any one or more of the following conditions are detected: (also listed in Section 3.3.9.1.3)

(1) If, during startup, the average yaw error change is less than 10° in one minute and magnitude of the yaw error remains greater than 7°.

(2) If during normal power generation mode, the magnitude of the yaw error is greater than 7° for a time period of five (5) minutes while yaw drive is enabled.

(3) If the yaw holding brake status differs from the commanded state for greater than two seconds.

(4) If both the yaw motive brakes and the yaw holding brakes are simultaneously off.

(5) If the magnitude of the yaw rate is greater than 1 deg/sec. In addition, for this case where |Yaw Rate | $\geq$ 1°/s, the Controller, (while continuing initiation of NSD/L.O.), shall immediately cause the generator air gap torque to drop to zero.

(6) If (a) the "wind direction sensor mismatch" alarm condition and (b) the "NSD Due To Rapidly Changing Wind Direction" condition both exist.

3.3.1.2. Manual Yaw Control

Capability shall be provided for manual control of the yaw drive from the Site Operator Terminal to rotate the nacelle about the tower vertical axis. However, the issuance of yaw drive commands to the yaw drive actuation shall be permitted only at those conditions when the rotor brake is engaged and the ailerons are feathered.

3.3.1.3 Yaw Rate

The yaw actuation assembly shall have the capability to yield an average yaw rate of 0.25°/sec for the given WTG inertia properties and aero loading characteristics.

3.3.2 ROTOR SPEED CONTROL (Aileron Control)

3.3.2.1 General Requirements

3.3.2.1.1 Control Loops

The CS shall implement the Rotor Speed Control (RSC) shown in general form on Figure 3.3-2 and in more detailed form for Controller functions and interfaces on Figure 3.3-3. The operation of the RSC, which is synonymous with control of

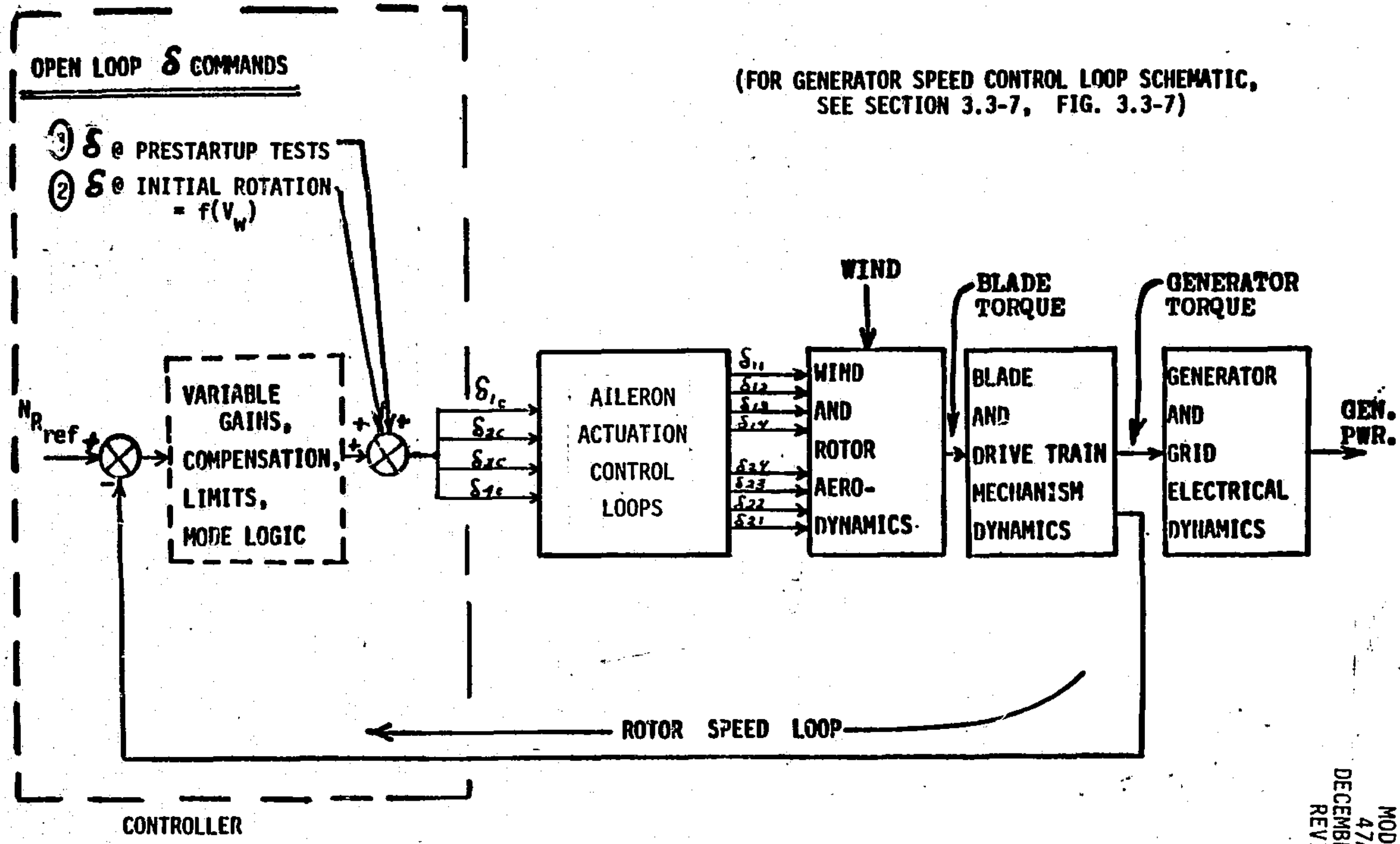

FIGURE 3.3-2

ROTOR SPEED CONTROL BLOCK DIAGRAM

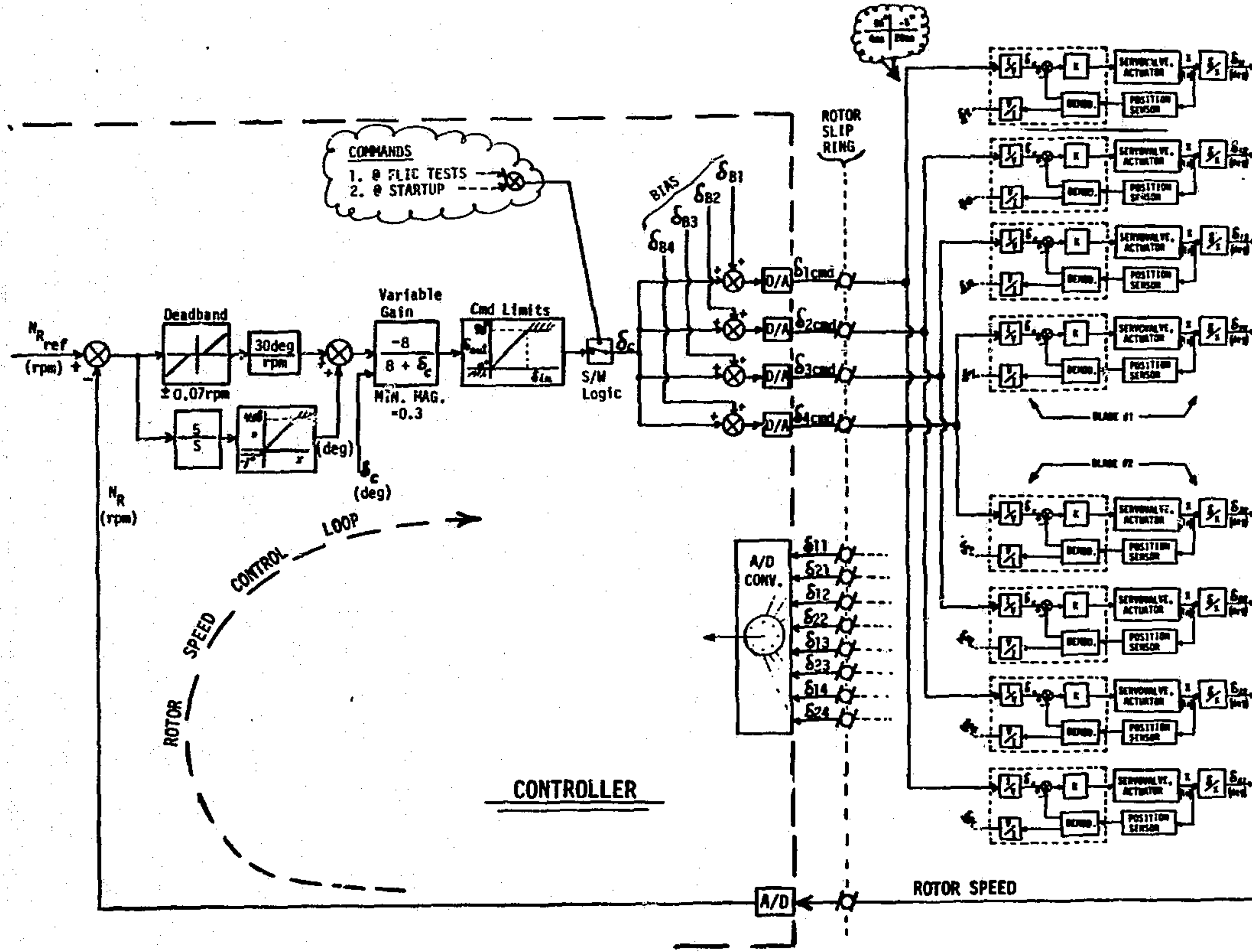

FIGURE 3.3-3
AILERON CONTROL IMPLEMENTATION BLOCK DIAGRAM

the aileron angular positions, i.e., "Aileron Control", shall take various forms during the operating cycle from startup, to power generation, and back to shutdown. The requirements for the aileron actuation loops, i.e. the inner control loops, shall be as given in paragraph 3.3.2.4. The outer control loop for rotor speed (N_R) control shall yield closed loop generated δ command values. This shall be provided by Controller software implementation of the computational model shown on Figure 3.3-3. The software computational cycle time for generation of updated δ_{com} values utilizing new sensor feedback data shall be no greater than 200 milliseconds. The mode switching, per discussion in 3.3.2.2 and shown on Figure 3.3-3, shall be on a Controller cycle time of less than or equal to 1.0 second. The speed control loop will have a gain margin greater than 6 db and phase margin greater than 30°. Output power variations will be maintained at less than $\pm$15% in steady wind and less than 130% of rated power for 0.1 percentile gust events to meet system level requirements.

3.3.2.1.2 Design Capability

The RSC hardware, (i.e. the controller input/output A/D and D/A and the software equations, scaling and logic; the aileron actuation assembly, and the aileron angle feedback sensors), shall be implemented to have the following design capability:

(1) Operate over a range of aileron angles from -5.0° to +95.0°.

(2) Provide continuously adjustable position control of aileron pitch angle of each aileron assembly over the above range to the accuracy of paragraph 3.3.2.4.2..

(3) Provide means for adjustment of individual aileron angle offsets (bias control)at:

(a) The Controller command output signals (individual δ_{bias} values added to the basic reference, δ_c,--- See Figure 3.3.-3, where the δ_{bias} values are setable via the Site Operators Terminal,

and (b) The aileron actuation assemblies

by (1) electrical bias adjustment at error junction

and (2) mechanical bias adjustment for actuator position limiting relative to $\delta_{xy} = 0°$.

(4) Sign convention will be in accordance with Figure 3.1-3 wherein zero degrees (referred to as power position) shall place the ailerons in continuity with respect to the main blade and plus angle shall refer to rotation of the aileron trailing edge toward the low pressure (downwind) side of the airfoil. Aileron rotation to the region of +90° shall be the feather position.

3.3.2.2 Aileron Control States

Consistent with the modes of operation given in paragraph 3.2.2.1 under Operational Requirements, there shall be three aileron control states . These are summarized below, in normal sequence.

1. Initial "FLIC" Tests	-	Aileron motions for "Feather Logic Initial Checks", by direct δ command
2. Startup Aileron Position	-	A direct δ_{cmd} to position to ailerons as a function of initial wind velocity during motoring to $N_R = 3.7$ rpm

3. Closed-Loop Rotor Speed Control - Aileron position commands in response to P plus I of rotor speed error during:

   (a) Ramp Up - as the rotor reference speed, $N_{R_{Ref}}$ is increased

   (b) Power Generation

      (1) @ Subrated - Ailerons driven to maximum power position limit (speed control via generator air gap torque regulation)
      (2) @ Rated - Ailerons positioned to maintain a nominal rotor reference speed at 16.8 rpm (generator air gap torque nominally at rated value)

   (c) Shutdown - as the rotor reference speed is decreased.

Further discussion/requirements of these states is given in following paragraphs.

3.3.2.2.1 Initial FLIC Tests

Early in the Startup mode an automatic sequence shall be used to checkout the aileron actuation loop operation, the Backup Emergency Shutdown and the Emergency Shutdown functions per FLIC tests of Section 3.2.2.1.4.

The extent of rotor hydraulic filter clog is evaluated during the Emergency Shutdown process checks of the FLIC tests. A ramp command of δ_C shall be issued to change the aileron positions from feather by 20° at a rate of ≈5°/sec. During this ramp, specific monitor of the rotor hydraulic oil filter ΔP signals shall be made. Upon occurrence of a high ΔP signal during this period of operation, the Controller shall issue an alarm message to the operator terminals.

3.3.2.2.2 Startup Aileron Positioning

During the initial motoring phase to N_R = 3.7 rpm, the ailerons shall be directly commanded to the position of approxiate zero rotor torque @ N_R = 3.7 rpm. This position, which is a function of wind velocity, shall be approximated by the expression given per Section 3.2.2.1.4.

3.3.2.2.3 Closed-Loop Rotor Speed Control

The aileron positioning during ramp-up at N_R > 3.7 rpm, power generation and shutdown shall be by the proportional plus integral of rotor speed error as shown on Figure 3.3-3. The sequence of operation shall be as defined in Section 3.2.2.1 and as discussed briefly below.

@ Ramp-Up - Aileron positioning commands for closed loop rotor speed control is initiated during the ramp up sequence when the generator speed reference has reached 3.7* (82.14) rpm. The exisiting δ_{cmd} shall be used as the control integrator initial condition to yield a smooth transition. The increase of the rotor speed reference to N_R = 4.0 rpm while holding the generator speed reference fixed will assure generator motoring power passes through zero to end the motoring phase. Rotor speed control will be maintained at N_R = 4.0 rpm as required to meet blade temperature requirements. The ramp up from 4.0 rpm to ($N_{R_{set\ pt}}$ - 0.6 rpm) will be at a variable rate dependent upon wind speed. The ramp rate of the speed reference command, $N_{R_{Ref}}$, shall vary linearly from approximately 2 rpm/min at V_{wo} = 14 mph to 8.0 rpm/min at V_{wo} = 55 mph, per the expression of Section 3.2.2.1.4. The ramp rate is reduced to 1 rpm/min as $N_{R_{Ref}}$ is increased to the Low Speed Reference set point, nominally at 13.8 rpm.

@ Power Generation - @ Subrated Power - During the subrated power operating state, i.e. at wind speeds less than 32 mph, the RSC will function to drive ailerons to command limits at zero degrees for maximum power extraction from existing winds. If, while operating in the "low speed region" and at conditions where the power reaches the power set point value, the RSC shall function per Figure 3.3-3 to control rotor speed to the "LO SPD REF" @ N_R = set point. Such conditions may exist during high wind startups or at strong up gusts initiated while the average wind is less than 25 mph.

@ Power Generation - @ Rated or @ Set Point Power - Control at rated power is referred to herein as the WTG operation at winds greater than 32 mph where the RSC shall function to limit the rotor aerodynamic torque while the stator air gap torque is at the rated or other power set point value. Rotor speed shall be controlled, per implementation of Figure 3.3-3, to the high speed reference of N_R = 16.8 rpm as shown on Figure 3.2-3.
At setpoint power conditions, where "setpoint" is less than the rated value, there will be no change in the RSC operation. The rotor speed control loop which drives the ailerons shall continue to function to hold the rotor speed to the referenced "LO SPD" or "HI SPD" values, when required, independent of the effect of the power setpoint value on the generator speed loop operation.

@ Normal Shutdown - During normal shutdown, the ailerons will continue to be driven as part of the closed loop rotor speed control operation as the rotor speed reference is reduced per the sequence of operation of Section 3.2.2.1.6.

3.3.2.3. Manual PSC

The capability shall be provided to drive individual pairs of ailerons, via δ_{cmd}, etc., and to command angles over the full range of travel by the process defined in paragraph 3.2.2.2.2. The rotor brake shall remain applied during this manual operation.

3.3.2.4 Aileron Actuation Loops

3.3.2.4.1 Inner Loop Definition

The Aileron Actuation Loops are the inner control loops of the rotor speed control function and yield closed loop angular position control of each of the ailerons. The requirements contained herein for these loops are a necessary condition so as to enable CS hardware compliance with the outer control loop requirements of paragraph 3.3.2.1.1. The hardware elements of these loops include the valve drive electronics, servovalves, actuators, hydraulic power supply, and position feedback sensors.

3.3.2.4.2 Position Control

The implementation of the RSC actuation shall be consistent with the design requirements of paragraph 3.3.2.1.2. Also, the collective distribution of error sources shall yield actual aileron angle deflections, (in response to a given command, δ_c), which have an absolute accuracy of $\pm 1.0°$ over the range $-5.0° \leq \delta_c \leq +50.0°$. At $\delta_c > 50°$ the accuracy required is reduced to $\pm$ 2.0°. As part of the fault detection process (Section) 3.3.9.1.2), the

Controller shall perform differential aileron angle evaluations of each set of ailerons during all operating modes at $N_R >$ 3.7 rpm. A sensed differential value of $|\delta_{1x}-\delta_{2x}|>5.0°$ at eight (8) consecutive samples taken at one (1) second intervals shall initiate an NSD Lockout. Also, a differential value of $|\delta_{cmd}-\delta_{11}|> 10°$ by the above process shall initiate NSD/Lockout

3.3.2.4.3 Frequency Response

The frequency response capability of each of the aileron actuation loops shall meet the requirement shown on Figure 3.3-4. The boundaries shown are the maximum allowable deviation of performance of the total closed loop, $(\delta/_{\delta com})$, from the nominal values. The primary factors included in the nominal system are a basic first order lag, at T = 0.2 seconds, representing the servovalve, actuator and mechanical elements, plus the effects of long line hydraulics and the friction and non-linearity factors at low frequencies.

3.3.2.4.4 Slue Rate

The actuation for the aileron during normal closed loop operation shall have a continuous minimum slue rate capability for all ailerons simultaneously of ±2.0°/sec under all normal operating blade loading conditions. A transient slue rate of +5.0^0/sec (toward feather) for up to six (6) seconds also is required from the system under all operating environmental conditions. The slue rate requirement during Emergency Feather, (which is not a closed loop control operation) is given in paragraph 3.3.9.2.

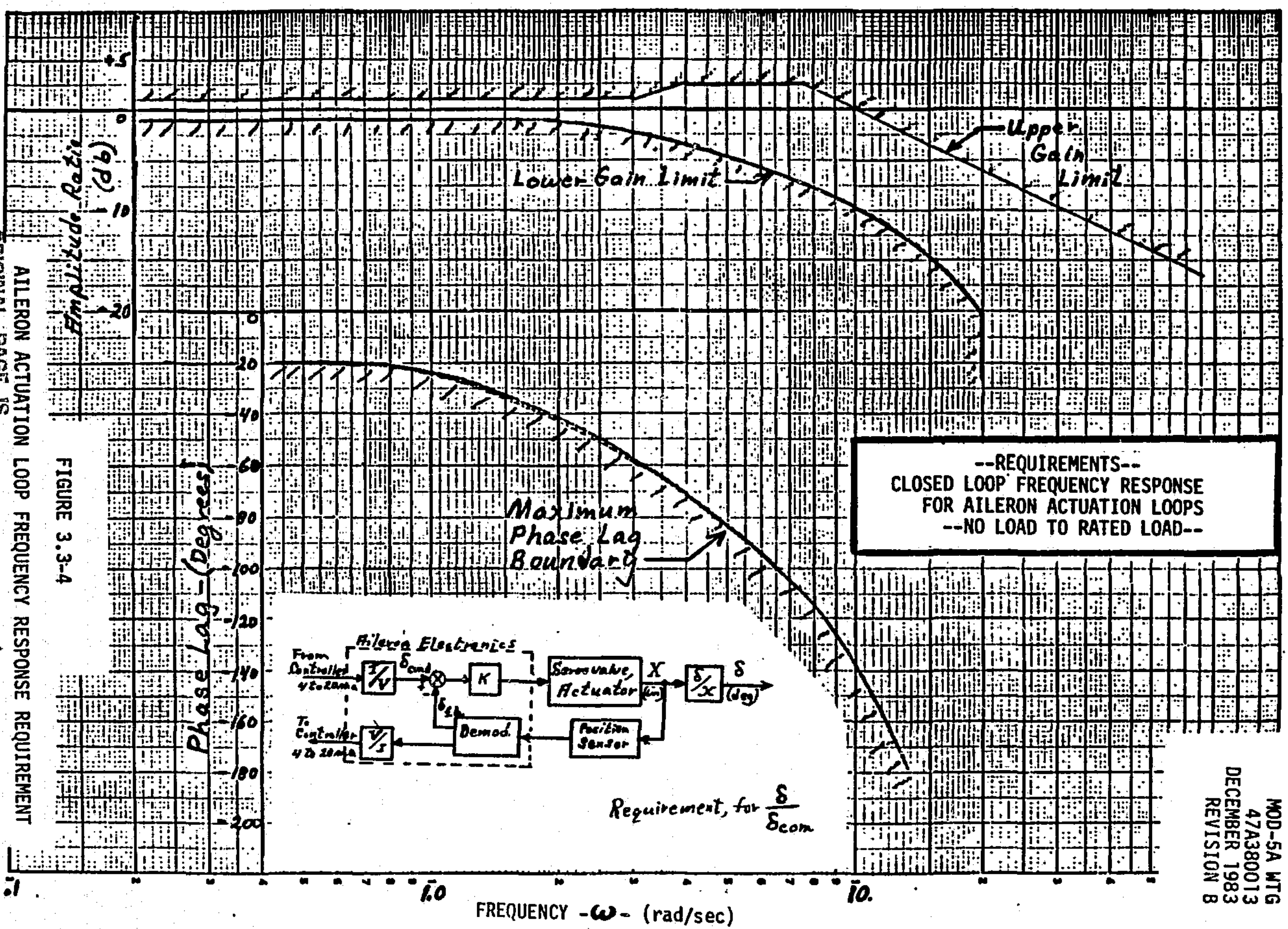

FIGURE 3.3-4

AILERON ACTUATION LOOP FREQUENCY RESPONSE REQUIREMENT

3.3.2.4.5 Failsafe Aileron Deployment

The aileron actuation assemblies shall incorporate failsafe design features to provide for deployment towards a retarding torque (feather) position upon:

a) Loss of δ_{cmd} input signal from the Controller,

b) Loss of signal (open lead) to the servovalve coil, and

c) Loss of system power (120 VAC) to the assembly.

3.3.3 ROTOR BRAKE CONTROL

The CS shall provide commands for the application and release of the rotor parking brake, both in the manual and automatic control modes, and shall monitor operational status for anomalous conditions. A schematic diagram of the rotor brake configuration and the rotor brake electrical signal interface is shown on Figure 3.3-1, "Yaw Actuation and Rotor Brake Signal Interface." Manual control of the rotor brakes shall be via the Site Operator's Terminal per 3.2.2.2.2.

3.3.3.1 Automatic Operation

While in the automatic control mode in a non-rotating state, the rotor brakes shall be "ON" via electrically energized solenoid valves, V_4 and V_5. The Yaw Pump "Motor Enable" command shall remain "HI" to permit automatic recharge of the rotor brake accumulator under local control, as required. The rotor brake release at startup (de-energize solenoid valves V_4 and V_5) shall be per controller command at the start of the Ramp up and Sync sequence (Section 3.2.2.1.4).

During shutdown, the Controller software shall initiate the rotor brake application per the sequence given below when

(a) the software is in the shutdown routine

and (b) either $\delta_{11} > 70°$ while $|\delta_{11} - \delta_{21}| \leq 5°$

or $\delta_{12} > 70°$ while $|\delta_{12} - \delta_{22}| \leq 5°$

The sequence for application shall be:

(a) Apply voltage for "Rotor Brake Stage 1 ON"

(b) Delay K seconds, where K=TBD (in a range of 0 to 20 seconds)

(c) Apply voltage for "Rotor Brake Stage 2 ON"

3.3.3.2 Malfunction Detection

The Controller shall monitor the rotor brake status and command signals to detect anomalous conditions and provide the following responses:

@ non-rotating, status ≠ Cmd, @ 5 seconds after cmd change

Issue alarm, @ Cmd = "ON", but status indicators are not all "ON"

Issue alarm and Inhibit Startup — @ Startup, with Cmd = "OFF", but status indicators are not all "OFF"

@ rotating, Status ≠ Cmd, @ 5 seconds after Cmd change

To NSD/LO, (plus message) — @ Cmd = "OFF", but all status indicators are not "OFF"; @ (during shutdown), Cmd = "ON", but related status indicator remain "OFF"

@ under all conditions

Issue alarm, @ Rotor Brake Accumulator Pressure "LO"

3.3.3.3 Brake Application During ESD

The Control System shall provide for application of the rotor brakes during ESD via the Emergency Shutdown Panel. The Emergency Shutdown Panel shall at K seconds, with K setable over a range from 5 to 50 seconds (initial estimated value - 15 seconds), after initiation of ESD apply both the Stage 1 and Stage 2 rotor brakes for shutdowns not initiated by the Controller.

3.3.4 ROTOR POSITIONING CONTROL

A capability of slow rotor rotation for rotor positioning independent of wind conditions shall be provided by manual control per 3.2.2.2.2. The ON/OFF control signal from the Site Operator's Terminal to a turning gear motor in the nacelle shall yield either clockwise or counterclockwise rotation at approximately 2°/sec. The Controller software shall protect against rotor positioning attempts while the rotor brake is engaged. All ailerons shall be at and shall remain in the feathered position during rotor positioning.

3.3.5 TEETER BRAKE CONTROL

The CS shall interface with the teeter brake system to control availability of power to the Low Force (LF) and the High Force (HF) solenoid valves and to monitor the system operational status. These interfaces are shown on the schematic diagram of Figure 3.3-5. Application of the brakes during automatic mode operation shall be by local control at the hub by switch operation as a function of teeter angle. The Controller shall back up local control by monitoring a teeter angle analog sensor.

3.3.5 TEETER BRAKE CONTROL (Cont'd)

Three states of operation shall denote normal operation of the two sets of brakes. These are:

State #1 = No brakes applied. This is the normal condition during all blade rotation operation after an initial startup sequence. Both solenoid valves shall be continuously rated and electrically energized to remove hydraulic pressure from the brakes.

State #2 = LF brakes "ON". During all periods of operation, when teeter power is available, the LF teeter brakes shall be applied or released as a function of teeter angle, $|\alpha_T|>2.5°$ or $|\alpha_T|\leq 2.5°$ respectively by local control at the hub per operation of switch SW1.

State #3 = HF brakes "ON" (plus LF brakes "ON"). Upon the sensing of $|\alpha_T|>5°$, the local control switch, SW2, shall open and thereby remove power from solenoid valve, V2, thus applying the HF brakes. This occurrence during any automatic operating mode, after the startup initialization sequence, shall result in NSD/L.O. by the Controller after Controller receipt of the "Hi-brakes ON" indication per the Sense A signal. Once applied, the HF brakes shall remain ON by opening of PS2, independent of subsequent teeter angle variations, as the WTG is shut down. The Controller shall remove power (AC power ON/OFf) to apply teeter brakes if the analog signal exceeds ±6.5°.

The sequence of command signals and sense signals from and to the Controller are summarized in the sequence of operation of Section 3.2.2.1. At complete system shutdown the ON/OFF teeter power relay shall be open, per Controller command at the end of any shutdown sequence. Thus both solenoid valves shall be unenergized and the LF and the HF brakes will be ON. Teeter brake hydraulic pressure provided by the aileron hydraulic system shall be maintained during shutdown periods per the requirements of Section 3.3.6.1. During ramp-up, the HF brakes are released when (a) the rotor speed exceeds 6 rpm and the $|\alpha_T|< 2.4°$ (evaluated in the Controller per analog input of teeter angle). The teeter brake system then is fully operational under local switch control at the hub.

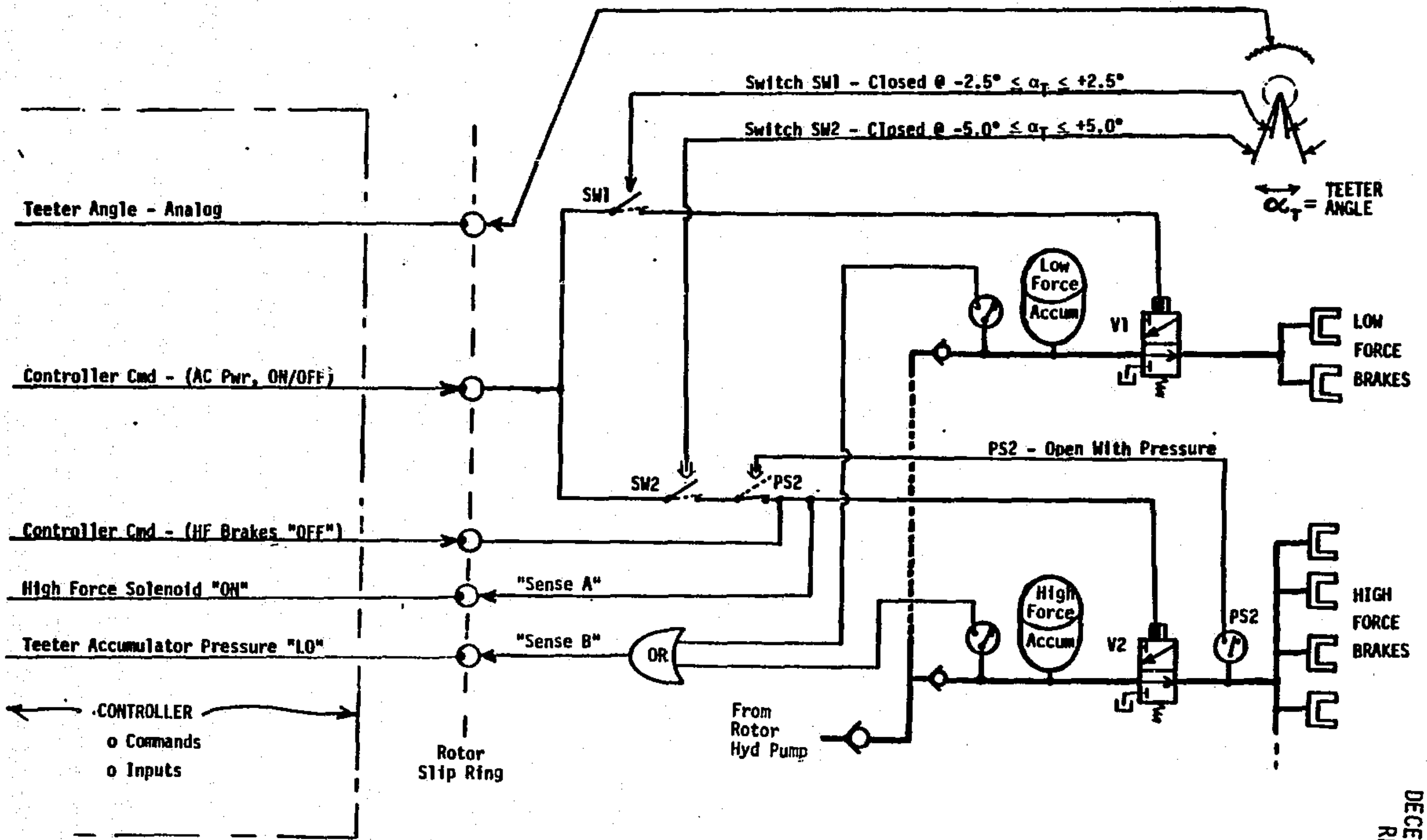

FIGURE 3.3-5
TEETER BRAKE SIGNAL INTERFACE

3.3.6 HYDRAULIC SUBSYSTEMS CONTROL

The CS shall provide hydraulics subsystems control commands for pump operation to minimize parasitic power for enable and disable of the Rotor Hydraulics, the Yaw Hydraulics, the drive train lubrication and the generator lubrication systems. The command signals and sensor signals for each of these hydraulics areas shall be as defined for each system below and as given by Document No. 47A387005, Signal and Command List. The Controller software shall provide the required sequencing during each automatic control mode. Manual commands shall be per 3.2.2.2.2. The various system pressure, fluid level, and temperature values shall be monitored as required for fault monitoring per paragraph 3.3.9.

3.3.6.1 Rotor Hydraulic Pump Control

The control of the rotor hydraulic pump which serves both the aileron actuation and the teeter brakes shall have two distinct modes of operation. The first mode, applicable for all operating (blade rotation or preparation for blade rotation) states, shall be continuous pump motor operation by receipt of an ON command from the Controller. The second mode, applicable during all shutdown non-rotating conditions including lockout and manual, shall call for OFF/ON operation of the hydraulic pump motor. The hydraulic pump motor normally shall be OFF except as required to maintain teeter brake pressure, as indicated by the Teeter Accumulator Pressure "LO" signal to the Controller. When the signal changes state (indicating P ~ 2300 psi), the Controller shall turn on the rotor hydraulic pump motor for a period of two minutes to ensure recharge to the nominal pressure at approximately 3000 psi. Manual local control switches shall permit ON/OFF control of the rotor hydraulic pump motor, for maintenance, independent of and overriding the Controller signal.

3.3.6.2 Yaw Hydraulic Pump Control

During automatic control modes, the presence of the normally "ON" Controller output "Motor Enable" command shall be required for operation of the yaw hydraulic pump motor. The actual pump ON/OFF operation shall be via local control from one or more charging switch signals based on the yaw hydraulic system and rotor brake accumulator pressures. When the system is under manual control at the Site Operator Terminal, capability shall be provided to disable the yaw pump by removal of the Controller "Motor Enable" command. Manual control switches in the nacelle shall permit ON/OFF control of the yaw pump operation for maintenance independent of and overriding the Controller "Motor Enable" command.

3.3.6.3 Gearbox Lube Control

3.3.6.3.1 Signal Definition

The Gearbox Lube control functions shall be those pressure, temperature, level and command signals shown schematically on Figure 3.3-6. Signals to the Controller shall be monitored on a once-per-second rate. Basic lube subsystem operation will use two pumps, one AC driven pump for normal startup and shutdown periods of operation and one gear driven pump for operation when rotor speed is sufficiently high. The ON/OFF of the AC pump shall be via signal from the Controller as defined in the Sequence of Operation, Section 3.2.2.1 and as given below.

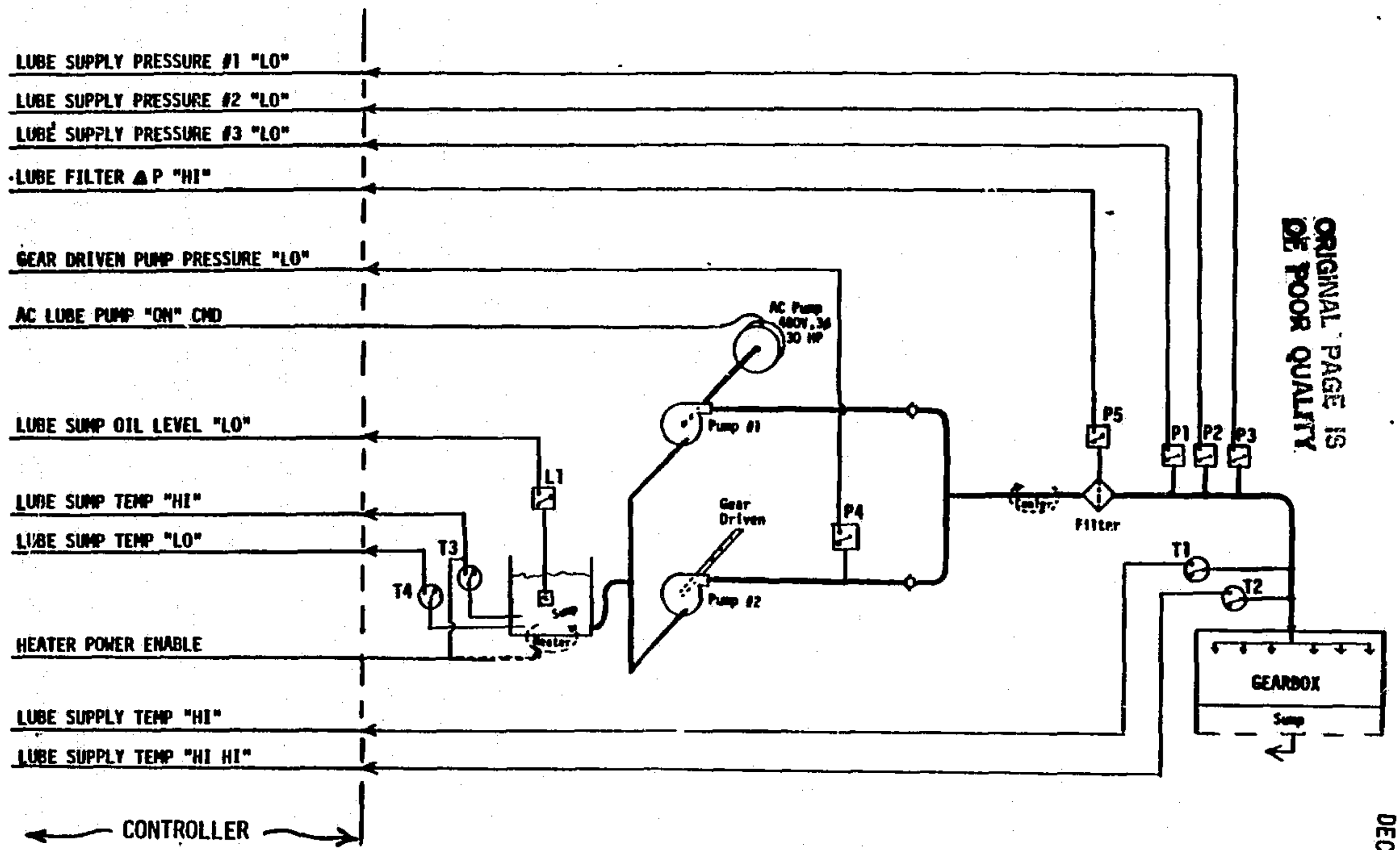

FIGURE 3.3-6
GEARBOX LUBE SIGNAL INTERFACE

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3.3.6.3.2 Lube Control Sequence Of Operation

(a) Prior to startup -- verify each sensor status for proper "non-operational" reading.

- o Verify P_1, P_2, P_3, P_4 and P_5 = "LO"
- o Verify T_1, T_2 and T_3 = "LO"
- o Verify L1 ≠ "LO"

The Controller shall provide proper notification to the operator terminals of sensors with anomolous readings.

(b) @ Startup

- o Issue AC Lube Pump "ON" Command
- o Delay 5 seconds (Pump start and line pressurization delay)
- o Verify pressure state changes on P_1, P_2 and P_3

(c) @ $N_R \geq 9$ rpm

- o Check P_4 Pressure
- o If P_4 is "Normal" → turn AC pump "OFF"
- o If P_4 is not "Normal" → do not turn off AC pump
  → issue alarm message
- o Continue operation

(d) During operation -- if P_4 changes state from "Normal" to "LO",

- o Turn AC pump "ON"
- o Issue alarm message
- o Continue operation

(e) During shutdown -- Turn AC pump "ON" @ $N_R \leq 9$ rpm

(f) @ Completion of shutdown -- Turn AC pump "OFF"

3.3.6.3.3 Lube Oil Heater Operation

For cold weather region operation, gearbox lube heaters are to be provided. Two levels of control of heater operation shall be used. The first level shall be the local control of ON/OFF operation of the sump heaters by thermostatic control, whenever heater power is available. The second level, the control of power available to the heaters, shall be under Controller output control such that the heaters are OFF while the system is in a Lockout mode but are enabled during all other modes of system operation. Manual circuit breaker control shall be provided for seasonal control of actual power to the sump heaters.

A Sump Oil Temperature "LO" signal will be input to the Controller for use only during prestartup checks. If this signal, T4 = "LO", is indicated, the Controller shall remain in Standby while the gearbox oil heaters continue to operate under local control. A message shall be sent to the operator terminals indicating the cause of the "hold". Once startup has commenced, a change of state of T4 to "LO" will be ignored by the Controller.
Implementation of this cold weather operation capability may be eliminated per Section 3.3.15.

3.3.6.3.4 Alarm And Shutdown Operation

The Alarm and Shutdown signals to the Controller for gearbox lube control are as given on Tables 3.3-1 and 3.3-3 respectively.

3.3.6.4 Generator Lube Pump Control

The enable/disable of the generator lube pump for normal operation shall be by ON/OFF command from the Controller as part of the normal sequence of operation, per Section 3.2.2.1. The interface of the generator lube system and the Controller are shown schematically on Figure 3.1-2. The generator lube alarm and shutdown signals are as given on Tables 3.3-1 and 3.3-3 respectively.

3.3.7 GENERATOR, CONVERTER AND BUS/UTILITY TIE CONTROL

3.3.7.1 General Description

The electrical power generation hardware consists of the:

(a) generator/motor — @ nacelle
(b) converter
(c) converter control unit — @ ground
(d) generator speed loop electronics
(e) Controller functions — @ nacelle
(f) bus/utility tie hardware — @ ground

This hardware shall be designed to function jointly to provide the capabilities defined in the sequence of operation as given in Section 3.2.2 and in the following operational requirements. Detailed requirements for the converter control and the variable speed generator shall be as defined in the specification 47A380115, "Functional Requirements for a 7500 KVA Variable Speed Generator Subsystem, MOD-5A WTG".

3.3.7.2 Interface

The electrical generation equipment interfaces shown on Figure 3.1-2 list the various command, signal, and power interfaces between the Controller, generator, converter and bus/utility tie hardware. The Bus/Utility Tie functional interfaces shall be as shown generally on Drawing 47E387080, "One Line System Diagram". Site specific drawings shall be prepared, as required.

3.3.7.3 Operating Modes

3.3.7.3.1 Startup (Motoring) Operation

Capability shall be provided by this subsystem for motoring action to accelerate the rotor, drive train and generator inertias from 0 to 300 rpm at the generator in approximately one (1) minute, independent of any additional startup torque which may be provided by the blade produced aero torques. The variable speed generator subsystem shall produce a "motoring" torque in response to a reference signal from the Controller. This signal shall be proportional to generator speed error (See Figure 3.3-7) as a generator speed reference command, $N_{G_{Ref}}$, increases from zero to 300 rpm. The control sequencing required shall be per definition in Section 3.2.2.

3.3.7.3.2 Synchronization

Capability shall be provided by the variable speed generator subsystem to synchronize the generator to the utility line within 0.1 minute on command, "sync/generate", from the Controller, while at any generator speed in the range of 960 to 1400 rpm. For nominal operation, the Controller shall issue this discrete (per sequence of operation, Section 3.2.2.1.4) when the rotor speed reaches 13.8 rpm.

3.3.7.3.3 Power Generation (Air Gap Torque Control)

The terminology "air gap torque" control, or the synonomous terms "generator stator power" control, refer to the primary control function of the Variable Speed Generator Subsystem. During subrated power conditions, this subsystem plus the Controller and the Generator Speed Loop Electronics shall function to provide generator speed loop control per (a) Figure 3.3-7, "Generator, Converter and Bus/Utility Tie Control Schematic, (b) Figure 3.2-3, "Power Generation Operating Regions", and (c) the sequence of operation of Section 3.2.2. In order to provide drive train dynamic damping, this generator speed control loop shall have a bandwidth greater than 15 rad/sec. The converter and converter control shall have a response characteristic per Figure 3.3-7 for high response control of stator watts and total vars. The Variable Speed Generator Subsystem shall be capable of stator power control, from zero to rated, over a generator speed range from 960 to 1440 rpm with smooth transition through 1200 rpm.

Capability shall be provided within the controller to implement power set point limiting via a shift of the rotor speed reference value. The "Power Set Point" value shall be an input to the controller from either the local or the remote operator terminal and shall be in the range of zero to 1.0 per unit, where 1.0 per unit is 7300 kw. During the low speed operation:

$$N_{G_{Ref}} = \underbrace{13.8 \text{ rpm}}_{\text{(nominal or default base value at low speed)}} - 0.6*\underbrace{P_{sp}}_{\text{"pwr set pt", (range = 0 to 1.0)}}$$

During the high speed operation:

$$N_{G_{Ref}} = 16.8 \text{ rpm} - 0.6*P_{sp}$$

The dynamic range of the signal to the converter control from the generator speed loop electronics shall cover an equivalent air gap torque range of -0.2 to + 1.2 per unit.

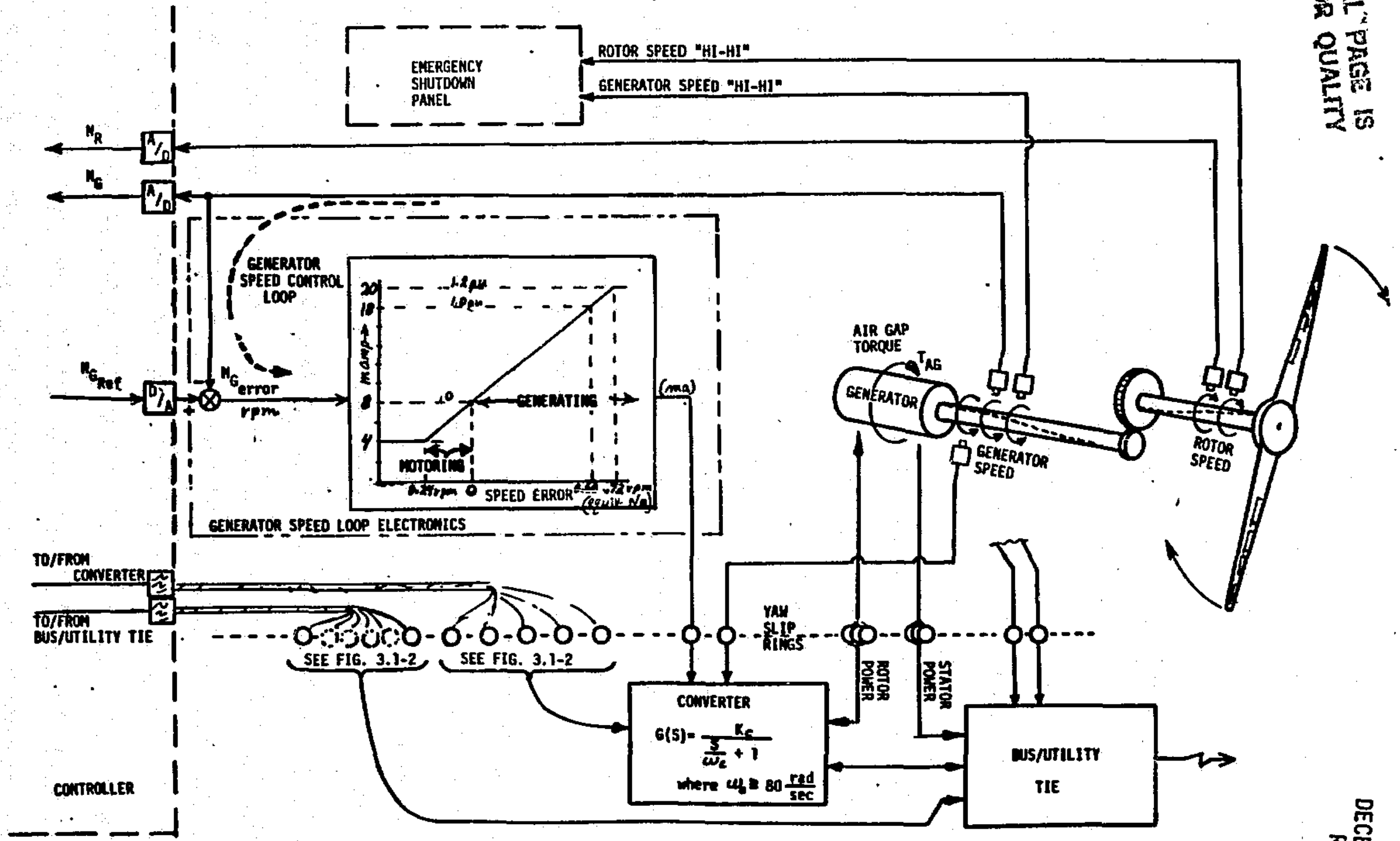

FIGURE 3.3-7
GENERATOR, CONVERTER AND BUS/UTILITY TIE CONTROL SCHEMATIC

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3.3.7.3.4 Shutdown

During normal shutdowns, the electrical power generation hardware shall provide the functions defined in the sequence of operation per Section 3.2.2. Additional requirements rising as a result of WTG system malfunctions are as given in Section 3.3.9, "Shutdown Control". The special case of shutdown due to loss-of-load is given in Section 3.3.7.4.2.

3.3.7.4 Fault Operation

3.3.7.4.1 General

Switchgear protective relaying is provided as identified on the one-line drawing. This relaying will directly operate either the lockout or tripping relays and result in opening of the bus tie device. All circuit breaker control circuits shall be of antipump configuration to prevent reclosure after opening unless a sustained close signal has been removed.

3.3.7.4.2 Loss Of Load

Special consideration shall be provided to yield hardware/software capability to produce a NSD/Standby Inhibit as a result of a noted "Loss-of-Load" or "Loss-of-Utility" condition. Such a condition while in normal operation shall be indicated to the Controller by (a) the removal of the "Converter Ready" signal from the converter control to the Controller, and (b) the presence of signal indicating "Stator Tie Breaker tripped" without the presence of signal indicating "Lockout Relay tripped", (i.e. Stator Tie Breaker trip as a result of the Tripping Relay, not the Lockout Relay). While in this shutdown process the Controller shall not respond to subsequent signals calling for NSD/Lockout. The electrical system shall have the capability to maintain this status in the Standby Inhibit mode without the presence of utility power for at least thirty (30) minutes. Upon return of utility power to the system within the 30 minute period, by indication to the Controller of the "Utility Power Present" signal, and upon a subsequent operator command for mode change to Standby Enabled, the Controller shall initiate the system status checks for allowable mode change and resultant normal automatic sequence of operation.

3.3.8 CONTROL SYSTEM ALARMS

The CS shall implement the means to issue alarm messages to each of the operator terminals for warning level indications, per the operational requirements of Section 3.2.3.1. These warning level indications are listed on Table 3.3-1. Any change of state from "alarm-to-normal" also shall be transmitted. More detailed information is given by the sections referenced on Table 3.3-1.

TABLE 3.3-1
Alarm Messages

Condition	Trigger Condition	Expected Cause
I GENERAL CS		
A1.1 Aircraft Warning Strobes Inop.	Local Sensor	Strobe Failure
A1.2 Fire Equipment Activated	Local Sensor	Fire Conditions
A1.3 Control Enclosure Cabinet Temp "HI"	T > 104°F	Heat Exchanger Failure
A1.4 Wind Speed Sensor Mismatch	Δ > 5 mph (See 3.3.1.1.2)	Sensor Failure
A1.5 C.E.C. Temp. Out-of-Range	T > 50°C or T < 0°C	Heat/Cooling Equip. Failure
II AILERON ACTUATION & TEETER BRAKE		
A2.1 Rotor Hyd Oil Filter ΔP "HI"	ΔP > 40 psi	Filter Clog/Cold oil
A2.2 Rotor Hyd Main Accum Press "LO"	P < 2000 psi	Leak/pump failure
A2.3 Rotor Hyd. Res. Oil Level "LO"	P ≤ 5 psi = low oil	Leak/bad sensor
A2.4 Rotor Hyd. Oil Temp. "HI"	T > 145°F	Heater failure
A2.5 Rotor Hyd. Pump Discharge Press. "LO"	P < 2000 psi	Leak/pump failure
A2.6 Teeter Angle "Hi"	$\lvert\alpha_T\rvert$ > 4° (analog signal)	Blade unbalance/Loose sensor
A2.7 Teeter Accum Press "LO"	P < 2000 psi	Leak/pump failure
III ROTOR		
A3.1 Blade Temperature "HI"	T > 105°F (See 3.2.2.1.4)	Temp. Soak @ Standstill
IV GEARBOX LUBE		
A4.1 One-of-three Supply Press. "LO"	P < 60 psi	Leak/pump failure
A4.2 Shaft Driven Pump Press. "LO"	P < 60 psi	Leak/pump failure
A4.3 Lube Filter ΔP "HI"	ΔP > 10 psi	Filter clog/cold oil
A4.4 Lube Supply Temp. "HI"	T > 120°F	Cooler failure
A4.5 Lube Supply Temp. "HI-HI"	T > 135°F	Cooler failure
A4.6 Lube Sump Temp. "HI"	T > 140°F	Heater failure
A4.7 Lube Sump Temp. "LO"	T < 60°F	Heater failure/Initial Start
A4.8 Lube Sump Oil Level "LO"	Level < 100 gal.	Leak/bad sensor
V GENERATOR/CONVERTER		
A5.1 Generator Lube level "LO"	Level < 5 gal.	Leak/bad sensor
A5.2 Generator Lube Filter ΔP "HI"	P > 10 psi	Filter clog/cold oil
VI YAW ACTUATION & ROTOR BRAKES		
A6.1 Yaw Holding Brk. Accum. Press. "LO"	P < 1800 psi	Leak/pump failure
A6.2 Yaw Main Accum. Press. "LO"	P < 1800 psi	Leak/pump failure
A6.3 Hyd. Filter ΔP "HI"	P > 80 psi	Filter clog/cold oil
A6.4 Oil Temperature "HI"	T > 140°F	Heater failure
A6.5 Oil Level "LO"	Level < 10 gal.	Yaw hyd. leak
A6.6 Yaw Motive Brk Status Fault	Status ≠ Cmd	Leak/pump failure
A6.7 Wind Direction Sensor Mismatch	Angle > 10° (See 3.3.1.1.2)	Loose Mounting
A6.8 Rotor Brake Status Fault	Status ≠ Cmd (non-rotating)	Solenoid Failure
A6.9 Rotor Brake Accum. Press "LO"	P <1800 psi	Leak/pump failure

3.3.9 SHUTDOWN CONTROL

The process of MOD-5A shutdown shall be initiated by one of five sources, follow one of five shutdown sequences and settle to one of three states, as shown on Table 3.3-2. The detailed requirements are given below for each sequence.

3.3.9.1 Normal Shutdown

The normal shutdown (NSD) process, whether to Standby/Enabled (3.3.9.1.1), to Standby/Inhibit, (3.3.9.1.2) or to Lockout (3.3.9.1.3), shall proceed per the sequence of operation of Section 3.2.2.1.6. In each case, the Controller shall continue the existing rotor speed and generator speed control functions as the reference values, $N_{R_{Ref}}$ and $N_{G_{Ref}}$, are ramped downward.

As an assist, to aid in rotor deceleration in the normal shutdown process, the electrical power generation hardware of Section 3.3.7 shall be controlled to yield generator air gap torque, per the sequence of operation of Section 3.2.2.1.6.

3.3.9.1.1 NSD To Standby/Enabled

When the CS is in the automatic control mode, adverse wind conditions, either low, high, or rapidly changing in direction, shall cause the shutdown sequence of Section 3.2.2.1.6 to be initiated. All shutdowns due to low or high winds shall be made on the basis of aileron angle and average power output for the equivalent wind conditions.

TABLE 3.3-2

Shutdown Control Process

Shutdown Decision Source	Shutdown Sequence	Final Controller State	Comments
Controller	NSD	Standby/Enabled	• Normal Automatic Cycle Dependent on Wind Conditions
Local Operator	NSD	Standby/Inhibit	• Requires Operator Enable Command For Restart
Remote Operator	NSD	Lockout	• Second Level Fault Shutdown • Normal Shutdown for Problem Resolution
Emergency Shutddown Panel	ESD	Lockout	• Third Level Fault Shutdown • Open Loop/via Aileron Emergency Feather Accumulator
G-Switch	BESD	Lockout	• Fourth Level Fault Shutdown • Also Open Loop/via Aileron Emergency Feather Accumulator

3.3.9.1.1 NSD To Standby/Enabled (contd)

The equivalent wind speed conditions referenced herein are:

(1) Low wind shutdown → NSD/STBY Enabled,

(a) If, during ramp-up, the system is unable to maintain the actual rotor speed, N_R, within ±1.0 rpm of the commanded rotor speed, N_{Rref}. (Limited to 3 attempts without success, per 3.3.9.1.2)

(b) If during, the power generation mode, the average power output is at less than or equal to zero for five minutes and the aileron angle is at its "power angle limit", i.e., ($\delta_C = 0°$).

(2) High wind shutdown → NSD/STBY Enabled, where N_R is at high speed range, and the commanded aileron angle is $\delta_C \geq 33°-(12° * P_{sp})$ for a time interval greater than one minute.

Automatic restart following either a low or high wind shutdown shall be per sequence of operation in 3.2.2.

Rapidly changing wind direction conditions which result in unacceptable yaw wind inflow angles, per paragraph 3.3.1.1.2, also shall cause a NSD to the Standby/Enabled mode.

3.3.9.1.2 NSD To Standby/Inhibit

The CS design shall permit any one of three sources to initiate the sequence from NSD to Standby/Inhibit. Two of these sources are (1) the local operator, from either the Site Operator Terminal or the System Display Panel, or (2) the Remote Operator. The Controller shall contain the logic to carry out this sequence when receiving a command from either source, subject to the control priority requirements of paragraph 3.2.4, while in any mode of automatic control operation. The third source for this sequence shall be the Controller upon detection of "first level fault" conditions that merit shutdown and operator review prior to continued operation.

TABLE 3.3-3
"First Level Faults" Shutdowns NSD to STBY/INHIBIT

Condition	Trigger Condition	Expected Cause
FLIC Test Failure (¶ 3.2.2.1.4 and ¶ 3.3.2.2.1)	o Controller Sensed or Computed Conditions • Aileron Angle vs Cmd Errors • Aileron Feather Latches Not Released • Rotor Hyd Oil Filter ΔP=Hi @ $\dot{S}$= 5^{o}/S	Aileron actuation failure
	• Aileron Feather @ Half-Level G-test	G-Switch failure, or
	• Failure to Feather @ Full-level G-test	Hyd or electrical failure
Repeated Startups (¶ 3.3.9.1.1)	o Three Consecutive startups without Reaching Power Generation	o Low, variable winds o Operational failure in ramp-up sequence
Prolonged Startup Hold @ N_R=4 rpm (¶ 3.2.2.1.4)	o Time ≥ 30 minutes at N_R=4 rpm @ ramp-up	o Hi blade temperature or sensor problem
Electrical Power Distribution Problem	o Stator Tie Breaker Trip without Lockout Relay Trip	o Voltage unbalance/improper phase sequence o Over/under frequency operatic o Unbalance line side neutral o Total system overcurrent
(¶ 3.3.7.4) →	o Stator Tie Breaker Trip without Lockout Relay Trip plus "Converter Ready" Signal Removed	o Loss-of-Load
Generator Winding Temp. "HI"	o T ≥ 275°F	o Generator cooling problem
Blade Icing (¶3.2.5)	o Ice Detected Signal	o Weather icing conditions

3.3.9.1.2 NSD To Standby/Inhibit (contd)

These conditions are tabulated on Table 3.3-3. Upon completion of this NSD sequence, a Standby/Inhibit state shall exist which prevents automatic restart. The return to active automatic control shall be initiated by command from either the Remote Operator Terminal or the Site Operator Terminal to cause Controller logic to return to the Standby/Enable state.

3.3.9.1.3 NSD To Lockout

This Controller initiated event shall be implemented per the sequence of 3.2.2.1.6 to occur whenever any "second level"or higher fault condition as listed on Table 3.3-4 is detected. No commands for restart shall be accepted by the Controller until after receipt of a Reset signal from the System Display Panel (sent only after fault evaluation and correction). The Reset command shall place the Controller in a Standby/Inhibit mode. Either the local or remote operator then shall have the capability of the later change to Standby/Enable.

TABLE 3.3-4
"Second Level Fault" Shutdowns → (NSD To Lockout)

Condition	Trigger Condition	Expected Cause
I GENERAL CS		
1.1 Intrusion Alarm	- event -	Unauthorized entry
1.2 Emergency Shutdown Panel Failure	Signal from ESP	Relay circuit fault
1.3 Control Enclosure Cabinet Temp "HI-HI"	T > 122°F	Heat exchanger out
1.4 Rotor/Generator Speed Mismatch	$\lvert N_R - N_R \rvert > 0.2$ rpm	Speed sensing error
1.5 C.E.C. Temp. Out-of-Range	T > 60°C or T < -10°C	Heat/Cooling Equip. Failure
II AILERON ACTUATION & TEETER BRAKE		
2.1 Aileron Emergency Feather Accum. Press."LO"	$\Delta P < 2000$ psi	Leak/pump failure
2.2 Aileron Cmd vs Position Mismatch	$\lvert \delta_{cmd} - \delta_{11} \rvert > 10°$	G-Switch Activation
2.3 Aileron Deflection Mismatch	$\lvert \delta_{1x} - \delta_{2x} \rvert > 5°$	Actuation failure
2.4 Teeter High Force (HF) Brakes "ON"	Angle > 5° (See 3.3.5)	Unbalance condition
2.5 Teeter HF Brakes Stay "ON" @ Ramp-up	HF = "ON" and $N_R > 12.5$ rpm	Brake system failure
2.6 Teeter Angle Large	Analog Signal, $\lvert \alpha_T \rvert > 6.5°$	Brake system failure
III ROTOR		
3.1 Rotor Speed "HI"	$N_R \geq 18.9$ rpm	Control failure
3.2 Rotor Vibration "HI"	Vib ≥ 0.1 g	Unbalance condition
3.3 Rotor Structure Strain "HI"	TBD Overstrain	
IV GEARBOX LUBE		
4.1 Lube Supply Pressure "LO"	"2-of-3" sensors @ P < 60 psi	Leak/pump failure
4.2 Lube Supply Temp. "HI"	"2-of-3" sensors Hi (See 3.3.6.3)	Heater or cooler failure
V GENERATOR/CONVERTER		
5.1 Generator Lube Press. "LO"	P < psi	Leak/pump failure
5.2 Generator Lube Temp. "HI"	T > 250°F	Cooling failure
5.3 Generator Bearing Temp. "HI"	T > 275°F	Bearing problem
5.4 Generator Vib. "HI",	Vib. > 0.1 g	Unbalance
5.5 Stator Tie Breaker Trip	Lock Out Relay Tripped	(See 3.3.9 discussion)
5.6 "Converter Ready" Signal Removed	Event per converter control	Converter fault
VI YAW ACTUATION AND ROTOR BRAKES		
6.1 Yaw Rate Correction Low	Low yaw rate @ startup (see 3.3.1.1.2)	Actuation failure
6.2 Yaw Error Remains High	$\lvert Ye \rvert > 7°$ for $\Delta t = 5$ min.	Actuation failure
6.3 Yaw Holding Brake Status Fault	Status ≠ Cmd	Leak/pump failure
6.4 Yaw Holding & Motive Brakes OFF	P < 2000 psi, both systems	Operating logic failure
6.5 Yaw Rate Excessively High	Yaw rate > 1°/s (See 3.3.1.1.2)	Brake failure & drive train loaded
6.6 Yaw Error Large and Wind Direction Sensor Mismatch	Mismatch > 10° (See 3.3.1.1.2)	Loose mounting plus high winds
6.7 Rotor Brake Status Fault	Status ≠ Cmd (Rotating)	Solenoid Failure

3.3.9.2 ESD, Per ESP

This Emergency Shutdown Panel (ESP) initiated event shall be implemented (See Figure 3.3-8) to occur whenever any "third level fault" condition as listed on Table 3.3-5 is detected. All ailerons will be hydraulically driven in a feather direction by interruption of the aileron servo valve flow while activating a means to apply local accumulator stored hydraulic pressure to the head (stationary) end of each actuator and connecting the rod ends to the sump. Capability shall be provided to yield a minimum 10°/sec aileron rotation rate while also limiting the rate to no more than 20°/sec. Upon the initiation of ESD, the ESP shall issue a status change signal to the Controller which in turn shall carry out all steps of the shutdown sequence per Section 3.2.2.1.6 and go to a Lockout mode, as per paragraph 3.3.9.1.3. The rotor brake application per Section 3.3.3.3 also shall be implemented.

3.3.9.3 BESD

A Backup Emergency Shutdown (BESD), the "fourth level fault" shutdown, shall be implemented (See Figure 3.3-8) to occur if an overspeed event equivalent to $N_R \geq 20.2$ rpm is sensed by either of two g-switches located on the blade, one on each tip. The g-switches shall operate the emergency feather hydraulic system of paragraph 3.3.9.2 independently of the ESP. The implementation shall provide for driving all ailerons to feather upon the trip of either one of the g-switches. The Controller shall attempt to execute the shutdown process upon detection of "Aileron Cmd vs Position Mismatch," i.e., $|\delta_{cmd}-\delta_{11}|> 10$ degrees.

TABLE 3.3-5

"THIRD LEVEL FAULT" SHUTDOWNS (ESD)

Condition	Trigger Condition
1. Local Operator Emergency Stop Switch "ON"	Manual Switch
2. Nacelle Emergency Stop Switch "ON"	Manual Switch
3. Controller Output	"Health Check" Evaluations
4. Prolonged NSD Time (Section 3.3.2.4.2)	ΔT for NSD > 5 minutes
5. Rotor Speed (HI HI)	$N_R > 19.5$ rpm
6. Generator Speed (HI HI)	$N_G > 1600$ rpm

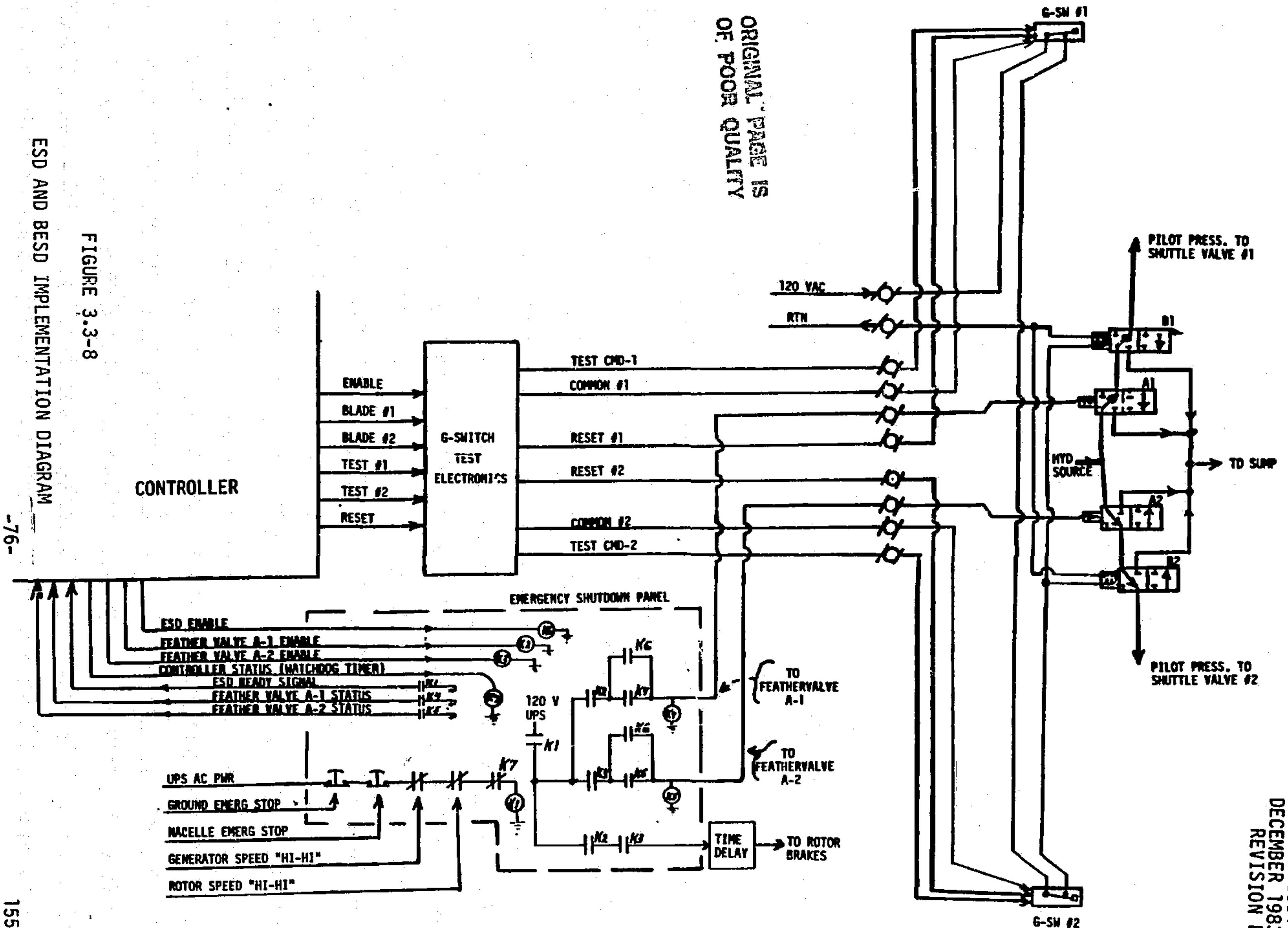

FIGURE 3.3-8

ESD AND BESD IMPLEMENTATION DIAGRAM

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3.3.10 REMOTE UTILITY INTERFACE

The CS design for interface with the remote utility terminal shall be capable of either serial or parallel data/cmd information transmission. This customer interface with each utility is expected to be site specific. For the first unit, to the Hawaiian Electric Company, the list of signals on Table 3.3-5 shall be made available to a Remote Terminal Unit located at the site EEB.

TABLE 3.3-6

REMOTE UTILITY INTERFACE SIGNAL LIST

REFERENCE NO.	SIGNAL DESCRIPTION
1	Breaker Trip - For transfer trip arrangement to assure that MOD-5A is off-line immediately. Operation trips stator breaker.
2	Breaker Position - Stator breaker "A" contact indicating closed or open position.
3	Disable - Discrete to MOD-5A controller that produces automatic shutdown sequence to Standby-Inhibit state, disabling automatic operation.
4	Enable - Discrete to MOD-5A controller that produces automatic startup sequence from Standby and enables automatic operation.
5	Power Set - Analog to MOD-5A controller to set maximum output reference to less than rating.
6	VAR Set - Analog to MOD-5A controller to set reactive power (or voltage) reference within permitted range.
7	Major Alarm - Discrete from MOD-5A controller indicating a major alarm status exists. This is a combination of existing controller inputs.
8	Minor Alarm - Discrete from MOD-5A controller indicating an alarm combination that requires some maintenance action on a non-time critical basis, such as filter change.
9	Intrusion Alarm - Discrete to RTU indicating that site security sensors are in alarm state.
10	Warning Light Alarm - Discrete to RTU indicating that aircraft warning lighting is in need of maintenance.
11	KW - Analog to RTU indicating instantaneous real power flow at the MOD-5A.
12	KVAR - Analog to RTU indicating instantaneous reactive power flow at the MOD-5A.
13	Voltage - Analog to RTU indicating instantaneous 4160 volt bus voltage at the MOD-5A.
14	KWH-IN - Discrete pulse generator to RTU for accumulating energy from detented incoming KWH meter.

REMOTE UTILITY INTERFACE SIGNAL LIST (cont'd)

REFERENCE NO.	SIGNAL DESCRIPTION
15	KWH-OUT - Discrete pulse generator to RTU for accumulating energy from detented outgoing KWH meter.
16	RPM - Analog to RTU showing MOD-5A instantaneous rotor speed.
17	Wind Speed - Analog to RTU showing instantaneous wind speed at hub height.
18	Aileron Angle - Analog to RTU showing instantaneous deflection angle of ailerons, δ_{11}.
19	Wind Error - Analog to RTU showing wind direction relative to nacelle at hub height.
20	Yaw Heading - Analog to RTU showing present absolute yaw orientation.
21	Lockout - Discrete to RTU indicating lockout status or site controlled manual operation status.
22	Standby-Inhibit - Discrete to RTU indicating MOD-5A status.
23	Standby-Enabled - Discrete to RTU indicating MOD-5A status as enabled or in startup or operation.
24	Startup/Shutdown - Discrete to RTU indicating MOD-5A status in transition between Standby and Generate. (NOTE: Stator breaker position indicates Generate state)

3.3.11 INSTRUMENTATION

The CS shall provide the instrumentation, recording and display capability for the following:

(1) Operational data --- i.e. the data necessary for CS operational control of the WTG, generally digital data,

(2) Operational Instrumentation Sensor data (OIS) --- the NASA requested utility related data for maintenance and operating data collection,

The CS command and signal list is given in Document #47A387005, Signal and Command List in terms of measured item, sensor type, range and accuracy. A serial data port shall be provided on the Controller for output to the Control Data System (CDS) of all sensor and command data processed by the Controller. The CDS shall provide as a minimum (a) tape recording of data in serial data form for later playback and data reduction, (b) limited capability for quick look of a minimum of eight (8) selected channels of control data, and (c) ability to command change in Controller parameters.

3.3.12 ELECTRICAL

3.3.12.1 Power Requirements

The CS shall be powered from a 120 VAC, 60 Hz, 1 phase circuit through an uninterruptible power supply. The UPS shall provide sufficient capacity to operate controller, communication, and connected sensor and actuator functions for at least thirty minutes. A means shall be provided for connecting a backup engine generator at the UPS AC power input.

3.3.12.2 Signals

o Output Signals

Analog	---	4 to 20 ma, driving up to 2 K ohms
Digital	---	120 VAC output, driving up to 3 A ss/20A surge
Serial Data	---	20 ma

o Input Signals

Analog	---	4 to 20 ma, 500 ohms max.
Digital	---	120 VAC output, 10 ma (nom.)
Serial Data	---	20 ma

3.3.13 MAINTAINABILITY

The CS maintainability shall be in accordance with the allocated values per the RAM/FMEA requirements of specification 47A380020.

3.3.14 DESIGN AND FABRICATION

The equipment fabricated by AEPD shall conform to the fabrication and workmanship requirements specified in the following documents.

47A380052	Electrical Fabrication and Workmanship Standard
47A380058	Electrical and System Test Equipment Design, Fabrication and Test Specification

The design service life shall be no less than 30 years. Periodic replacement of components may be used to meet this requirement contingent on lowest cost of energy approach. Life shall be based on 2.14×10^8 rotor revolutions and 35,000 startups.

3.3.15 ENVIRONMENT

The CS shall be designed to meet the conditions of 47A380002, Structural Design Criteria for MOD-5A WTG, Section 5.2 Design Conditions and Environment. However, in the event of planned installation of a particular WTG in a basically warm weather location, certain control functions delineated below may be eliminated upon general concurrence of Engineering and Program Office. These shall include:

1. Blade ice detectors
2. Rotor hydraulic oil heaters
3. Yaw hydraulic oil heaters
4. Gearbox lube oil heaters
5. Generator lube oil heaters

and associated electrical power wiring, sensors, and signal processing.

SECTION 4

VERIFICATION

4.1 GENERAL

The Control System requirements of this specification become the basis for a series of additional subsystem, assembly, and component specifications. As such, the verification for compliance with the CS requirements shall be by the test definition identified by the appropriate subsystem, assembly, and component specifications. Specific development and environmental tests are given in the following section.

4.2 TESTS

4.2.1 DEVELOPMENT TESTS

4.2.1.1 General Requirements

The CS Development test shall verify all internal and external subsystem interfaces; electrically integrate subsystem components, harness and test facilities; demonstrate system response to commands; determine the correctness of phasing, measure transfer functions and verify dynamic performance. The responses of the CS shall be recorded to generate a data base against which to compare subsequent WTG System Level testing.

The CS Development test shall use a specifically designed rack mounted WTG simulator called the "CS Factory Test Set". This test set shall be mobile for use during systems tests and for on-site testing.

4.2.1.2 Specific Test Requirements

The following tests shall be conducted on the aileron actuation hardware to verify aileron actuation assembly and rotor hydraulic supply capability. Records of operating time and actuation cycles shall be maintained. The tests will include:

Frequency Response Tests --- The following tests shall be conducted to verify compliance of the aileron actuation hardware with the dynamic requirements of paragraph 3.3.2.4.3.

With the rotor hydraulic system at rated pressure (~3000 psi), for a test configuration closely matching the planned operational configuration, apply the sinusoidal δ_{cmd} signal to all actuators. The actuation loops will be tested as jointly functioning loops, according to the conditions listed on Table 4-3.

First apply a sinusoidal δ_{com} sweep frequency varying from 0 to 10 Hz such that resonant peaks can be located, using a varying amplitude such that δ rate remains at approximately 1°/sec maximum.

Discrete test frequencies then shall be used at 0.1, 0.2, 0.4, 0.6, 1.0, 2.0, and 3.0 Hz, as well as at any observed resonant frequencies, with a varying amplitude to hold δ rate at approximately 1°/sec max. The remaining runs shall be made at discrete frequencies (0.1, 0.4, 1.0, 2.0 Hz) for the listed varying conditions.

The following signals shall be monitored and recorded:

(a) δ_{com} and the feedback signals, (actuator positions and aileron angles)

(b) the head and rod end pressures of each actuator

TABLE 4-3

Test Run	Amplitude	Hyd. Oil Temperature	Operating Point	Test Frequency
1	Varying, for $\delta_{max} \sim 1°/sec$	120°F	$\delta = 0°$	Sweep
2	Varying, for $\delta_{max} \sim 1°/sec$	200°F	$\delta = 0°$	Listed Discrete Frequencies
3	0.5°	40°F	$\delta = 0°$	1 Hz
4	0.5°	120°F	$\delta = 15°$	1 Hz

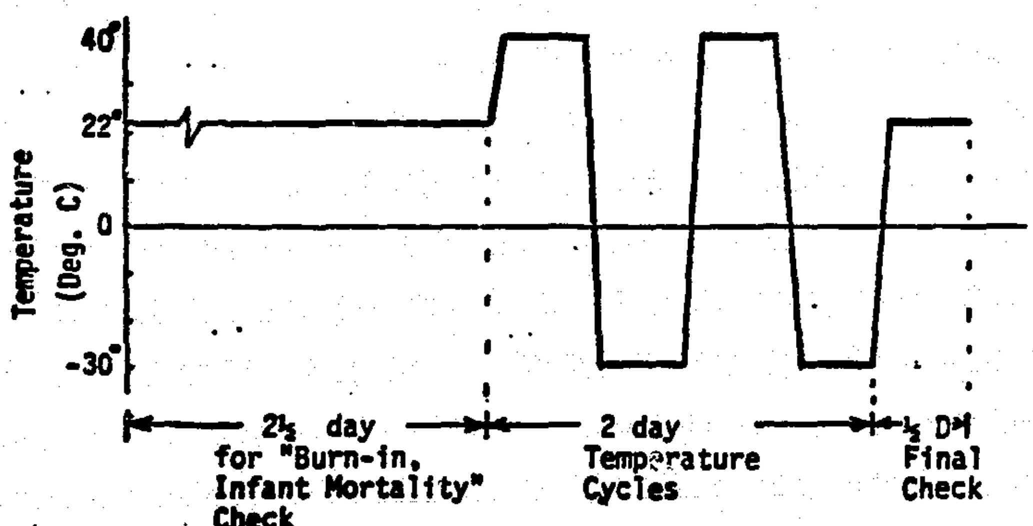
4.2.1.2 Specific Test Requirements (cont'd)

Transient Response/Slue Rates --- A full step command change of $\delta_{com} = 10°$ (from $\delta_c = 0$ to $\delta_c = 10°$) shall be applied simultaneously to eight aileron assemblies. The equivalent aileron slue rate values shall be determined for compliance with paragraph 3.3.2.4.4. The hydraulic system shall be monitored for pressure decay and for abnormal surge amplitudes in the high pressure supply loop and in the low pressure return loop.

4.2.2 ENVIRONMENTAL TESTS

4.2.2.1 Controls Equipment Cabinet Thermal Test

The field unit Controls Equipment Cabinet, containing the Controller, sensor transducers, signal conditioning, Emergency Shutdown Panel, and associated power supplies, as well as any critical sensors shall undergo a five day test to demonstrate satisfactory operational performance over the design external environment operating temperature range of -30°C to +40°C. Primary emphasis will be demonstration of Controller performance for internal hardware functions plus all input/output functions. A typical cycle shall be similar to the adjacent temperature profile.



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GENERAL ELECTRIC

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REV NO. A B

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CONT ON SHEET ii SH NO. i

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SPECIFICATION FOR A

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NOVEMBER, 1982

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REVISION LOG

This log identifies those portions of this document which have been revised since original issue. Revised portions of each page, for the current revision only, are identified by marginal striping.

Revision	Page No.	Paragraph Number(s) Affected	Rev. Date	Approval
A	Complete Revision and Update Retyped Title Page including new listing of approval signatures adding Subsystems Engineer, Quality Assurance and WTG Integration. Original Responsible Engineer was D. W. Dale. Document is now under Formal Configuration Control.		Nov. 1982	See Title Page & DCC-82-020
B	1	All	Dec. 1983	DCC-83-074
	3	3.1, 3.2.1.2, 3.2.1.3		AN-1
	4	3.2.2.1, 3.2.2.5		
	5	Figure		
	6	3.2.2.6		
	7	All		
	8	3.3.4, 3.3.6.1, 3.3.6.2, 3.3.7		
	9	3.3.8, Table 3-1		

TABLE OF CONTENTS

SECTION 1

SCOPE

This specification establishes the performance, and design requirements for a D.C. power supply to power switchgear intended for use on the MOD-5A Wind Turbine Generator (WTG). The requirements are for either an indoor or outdoor unit. The outdoor unit requirements are indicated on pages where they apply.

SECTION 2

APPLICABLE DOCUMENTS

The following documents of the date of this issue or as indicated below form a part of this specification to the extent referenced herein. In the event of conflict between this specification and the documents referenced herein, the contents of this specification shall be considered a superceding requirement.

INDUSTRY STANDARDS

GENERAL ELECTRIC

47A380048 - Specification For Material Finishes, MOD-5A

47A380011 - System Specification MOD-5A WTG

SECTION 3

REQUIREMENTS

3.1 ITEM DEFINITION

The DC power supply assembly shall consist of the following subassemblies and conform to Figure 3-1:

a) 125 VDC battery pack, ungrounded

b) Charger

c) Outdoor cabinet with battery strip heaters and forced air compartment heater

d) 2 tier battery rack (indoor unit only)

3.2 PERFORMANCE

3.2.1 BATTERIES

3.2.1.1 Battery Type

Batteries shall be of the lead calcium type with a life of 15 years under normal operation.

3.2.1.2 Battery Capacity

The battery pack shall have a capacity not less than 50 ampere hours, with an 8 hour discharge rate to 1.75 volts per cell.

3.2.1.3 Battery Voltage

The battery assembly shall have a terminal voltage of 125 VDC +15-0 V fully charged at 25°C ambient.

3.2.2 CHARGER

3.2.2.1 Voltage Output

The float charger shall be capable of maintaining a per cell voltage between 2.20 to 2.25 volts for a total cell stack of 60 cells.

3.2.2.2 Current Limiting

Current limiting shall be adjustable from 110% to 125% of rated continuous output and it shall hold down to a short circuit.

3.2.2.3 Voltage Regulation

The DC float voltage regulation shall be maintained to within ±1% from no load to full load with AC input frequency and voltage variations of ±5%.

3.2.2.4 Alarm

The battery charger shall be equipped with a low voltage alarm relay across the charger output. Alarm setting shall be adjustable with a minimum setting of 80% of rated output voltage.

Alarm output shall provide an open set of contacts (held closed during normal operation) to indicate low voltage.

3.2.2.5 Charger Capacity

The charger shall be capable of restoring the batteries from 1.75 V/cell to a fully charged condition (2.20-2.25 V/cell) in twelve (12) hours. The charger shall be able to supply 10 amperes continuously.

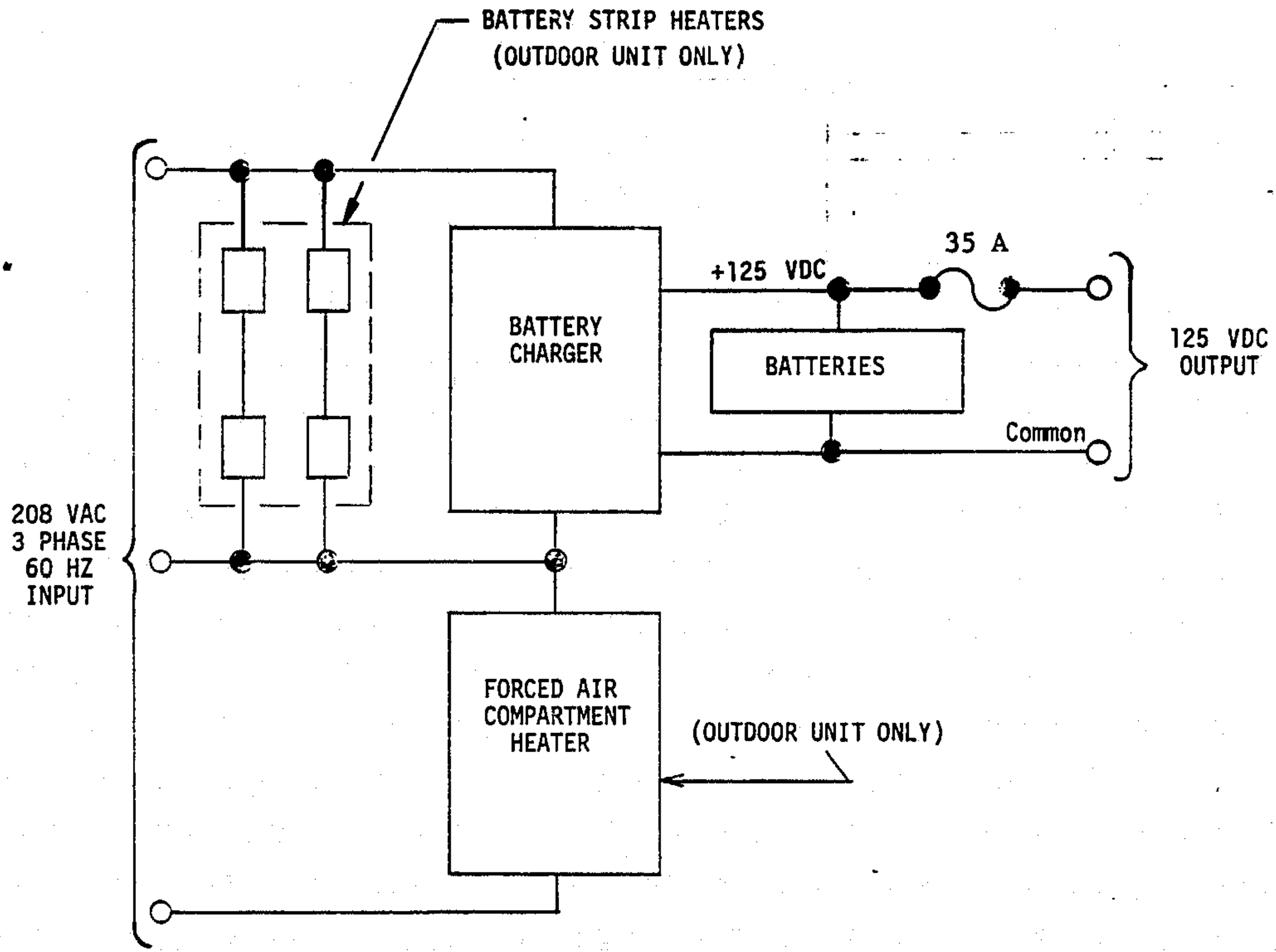

FIGURE 3-1 SIMPLIFIED BLOCK DIAGRAM

3.2.2.6 Charger Input Voltage

The charger input voltage shall be 208 VAC, 60 Hz., 1Ø at a maximum of 10 amperes.

3.2.2.7 AC Power Alarm

The battery charger shall be equipped with a loss of AC power alarm. A relay contact opening (held closed during normal operation) shall be used to indicate AC power failure.

3.2.2.8 DC Meters

The battery charger shall be supplied with a DC voltmeter and a DC ammeter. Meters shall have a minimum accuracy of ±2%.

3.2.2.9 Circuit Breakers

AC input and DC output circuits of the battery charger shall be protected using circuit breakers or fuses.

3.3 PHYSICAL CHARACTERISTICS

3.3.1 ENVELOPE

The DC power supply assembly shall fit within the envelope dimensions shown in Figure 3-2.

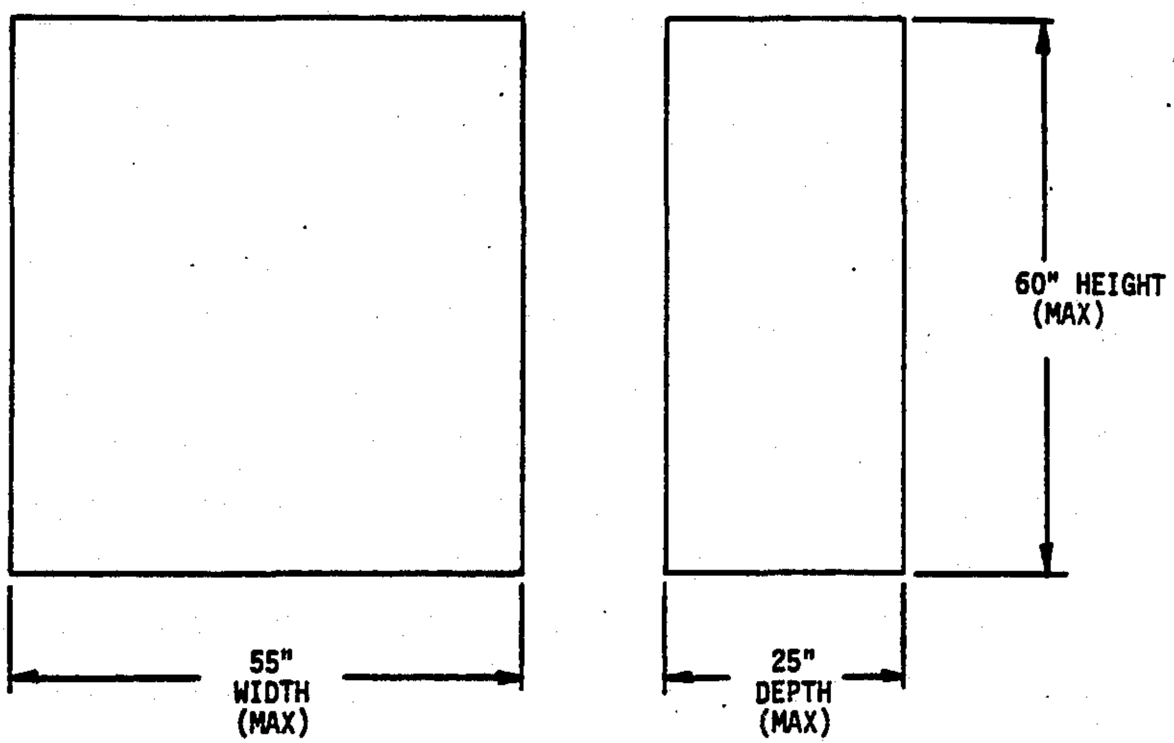

Figure 3-2 Envelope Drawing

3.3.2 SERVICE

Lockable doors shall be provided to permit servicing battery cells and charger (outdoor unit only). A hydrometer and thermometer shall be furnished with the assembly.

3.3.3 CABINET (OUTDOOR UNIT ONLY)

The cabinet shall be suitable for outdoor service with environmental conditions listed in Table 3-1. Venting provision shall be made in the cabinet to prevent the accumulation of gases. The cabinet shall be equipped with a dropped bottom feature permitting the bottom opening to be closed. Storage locations shall be provided for the hygrometer and thermometer of 3.3.2.

3.3.4 COLD WEATHER PACKAGE

The cabinet of paragraph 3.3.3 shall be equipped with insulation and heaters sufficient to insure battery capacity as specified in paragraph 3.2.1.2 with outside ambient conditions listed in Table 3-1.

3.3.5 WEIGHT

The total weight of the power supply, including batteries, charger, cabinet, and miscellaneous items shall be 1200 pounds maximum.

3.3.6 ELECTRICAL

3.3.6.1 Input Power

The power input to the DC power supply shall be 208 Volt AC, 60 Hz, 3Ø with a maximum current rating of 20 amperes. Battery charger, strip heaters, and forged air compartment heater shall be wired such as to provide the maximum balance on the 3Ø line (outdoor unit only). Input power to indoor unit shall be 208 VAC, 60 Hz., 1Ø.

3.3.6.2 Fuses

A fuse block shall be provided in the battery output circuit for protection of user wiring. Fuses shall be of the 250 V, quick acting type and size shown in Figure 3-1.

3.3.7 ENVIRONMENTAL CONDITIONS (OUTDOOR UNIT ONLY)

In addition to the requirements specified in Table 3-1, internal condensation (100% relative humidity) shall be avoided by the use of heaters, dessicant, or other approved means.

3.3.8 FINISH (OUTDOOR UNIT ONLY)

Inside and outside of battery assembly cabinet shall be painted in accordance with GE Specification 47A380048 (Semigloss Blue/Fed Std - 595, Color 25177).

TABLE 3-1

Environmental Operational Conditions And Requirements

Shipping Shock	Up to 5 g's, 100 ms vertical Up to 20 g's, 100 ms horizontal (uncushioned rail, only if so shipped) Up to 2 g's, 100 ms lateral
Temperature	-40°C to 50°C ambient (survival) -30°C to 40°C ambient (operational) (outdoor unit) 0°C to 50°C ambient (operational) (indoor unit)
Humidity	0 to 100% (refer to paragraph 3.3.6)
General	Outdoor conditions typical of any location in the continental United States, Alaska, Hawaii and Puerto Rico
Altitude	0-7000 feet above sea level
Wind	Up to 120 miles per hour (outdoor unit)

3.4 LIFE

The expected lifetime of the battery assembly, excluding batteries shall be thirty (30) years with routine maintenance specified by manufacturer.

3.5 MAINTAINABILITY

Routine maintenance per manufacturer's instructions shall be able to be performed on site. Interval between routine maintenance cycles shall not be less than one (1) year.

SECTION 4

QUALITY ASSURANCE PROVISIONS

4.1 GENERAL REQUIREMENTS

4.1.1 TEST SITE

All inspections, examinations and tests of the power supply shall be made at the vendor's plant unless otherwise specified.

4.1.2 TEST CONDITIONS

All tests shall be performed at room ambient conditions of temperature, humidity and atmospheric pressure unless otherwise specified.

4.1.3 TEST PROCEDURE

All tests shall be conducted using documented test procedures approved by GE. All test procedures shall contain data sheets on which the results of the individual tests may be recorded.

4.1.4 TEST REPORTS

A test report containing the test procedure, test results and test conclusions shall be provided with each power supply presented for delivery when specified.

4.1.5 ACCEPTANCE TESTS

The following acceptance tests shall be performed on each power supply assembly presented for delivery. The tests may be performed in any sequence unless otherwise specified.

- 4.2.1 Visual Examination
- 4.2.2 Dimensional Inspection
- 4.2.3 Insulation Resistance Test
- 4.2.4 Dielectric Strength Test
- 4.2.5 Circuit Continuity Test
- 4.2.6 Charger Verification

4.2 <u>SPECIFIC TEST REQUIREMENTS</u>

4.2.1 VISUAL EXAMINATION

The assembly shall be visually examined to assüre that it is free from all defects that could adversely affect its life or make it unsuitable for its intended use.

4.2.2 DIMENSIONAL INSPECTION

The assembly shall be measured to verify that it fits within the space envelope defined.

4.2.3 INSULATION RESISTANCE TEST

The insulation resistance between each circuit and all other circuits and ground shall be measured at 500 ±10% volts DC. The insulation resistance shall not be less than 10 meg ohms.

4.2.4 DIELECTRIC STRENGTH TEST

The dielectric strength test voltage, 500 Volts AC R.M.S., 60 Hz, shall be applied for a minimum of 10 seconds between each circuit and all other circuits and ground. The leakage current shall not exceed 50 microamperes as measured by a micro-ammeter or other suitable means.

4.2.5 CIRCUIT CONTINUITY TEST

The end-to-end continuity of each circuit shall be verified.

4.2.6 CHARGER VERIFICATION

The battery charger performance shall be checked to verify that the following functions are within specifications.

- o Voltage Per Paragraph 3.2.2.1
- o Current Limiting Per Paragraph 3.2.2.2
- o Voltage Regulations Per Paragraph 3.2.2.3
- o Low Voltage Alarm Per Paragraph 3.2.2.4
- o Charger Capacity Per Paragraph 3.2.2.5
- o AC Power Failure Alarm Per Paragraph 3.2.2.7

4.2.7 APPROVAL

Review and approval of all test results by a General Electric Quality Assurance representative is required prior to shipment of the power supply assembly.

SECTION 5.0

PREPARATION FOR DELIVERY

The manufacturer shall submit a statement detailing the normal practice of packaging and method of delivery for approval by General Electric Company, Advanced Energy Programs Department, MOD-5A Engineering, P.O. Box 527, King Of Prussia, PA 19406.

5.1 DOCUMENTS

o Certified detailed outline drawing	a, b
o Connection diagrams	a, b
o Elementary diagrams for approval	a, b
o Detailed equipment list	b
o Three (3) certified copies of test data	b

5.1.1 DOCUMENT SUBMITTAL

Documents marked "a" shall be submitted for examination or approval within six (6) weeks of order by sending two (2) copies to General Electric Company, Advanced Energy Programs Department, MOD-5A Engineering, P.O. Box 527, King of Prussia, PA 19406. Approval or comments will be returned within two (2) weeks of receipt.

Documents marked "b" shall be supplied with shipment. One (1) mylar reproducible and ten (1) copies of each drawing shall be supplied. Twelve (12) copies of instruction books shall be supplied. In addition, one copy of all documents shall be enclosed with shipment.

Documents marked "a, b" shall meet submittal requirements of both "a" and "b".

GENERAL ELECTRIC

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REV NO. A B C D

47A380018
CONT ON SHEET ii SH NO. i

TITLE

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REVISIONS
A-C GEN. CHANGES
D ISSUED-DOC. NOW

REV "D"
MARCH 84

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PRODUCT ASSURANCE PROGRAM PLAN

FOR THE

MOD-5A WIND TURBINE GENERATOR PROGRAM

PREPARED BY: A. Cheddar DATE: 8-12-81
A. Cheddar, Product Assurance
Engineer
Energy Support Operations

APPROVED BY: E. J. Urbanik DATE: 8-13-81
E. J. Urbanik, Manager
Product Assurance
Energy Support Operations

APPROVED BY: G. Drenker DATE: Aug 13, 1981
G. Drenker, Manager
MOD-5A WTG Hardware Integration

TOTAL NUMBER OF PAGES 38

WTG 500
PRINTS TO

MADE BY A. CHEDDAR	APPROVALS	A.E.P	DIV OR DEPT.	47A380018
ISSUED 4/6/84		KING OF PRUSSIA	LOCATION	CONT ON SHEET ii SH NO. i

FF-803-WB (3-81)
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REVISION LOG

This log identifies those portions of this document which have been revised since original issue. Revised portions of each page, for the current revision only, are identified by marginal striping.

Revision	Page No.	Paragraph Number(s) Affected	Rev. Date
A	18	Section B. - Removed reference to system Safety and incorporated in separate safety plan. Defined specific responsibility for preparation of FMEA.	8-11-80
B	All	Issued to correct type-graphical error in page numbering.	8-20-80
C	All	Changed document number from PA-MOD-5A-81-001 to 47A380018 Changed paragraph numbering system.	8-06-81
D	All	General Rewrite to remove references PSC, to update organization chart and to correct miscellaneous type-graphical errors.	3-14-84 a.e.

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TABLE OF CONTENTS

SECTION 1.0

GENERAL

1.1 APPLICABILITY

This Product Assurance Program Plan describes the Program to be implemented by the General Electric Company, Advanced Energy Programs Department, to fulfill the quality requirements of the NASA-Lewis Research Center MOD-5A Wind Turbine Generator Program. It is designed to provide effective controls which will result in a contractually compliant Wind Turbine Generator for all phases of the contract, from customer specification through design, procurement, manufacture, test and utilization. This plan shall be the controlling document governing the execution of the defined tasks. All revisions, deletions or additions shall be submitted to NASA/LeRC for approval. The Quality System is documented through the use of selected Quality Assurance Procedures (QAP's). These procedures will be implemented with the required revisions, deletions, or additions necessary for meeting the requirements of the MOD-5A Wind Turbine Generator Program.

1.2 MANAGEMENT

Program Management together with Engineering, Product Assurance, Manufacturing and Reliability have the responsibility for interpreting contractual quality and reliability requirements and will determine the applicable policies and detailed procedures under which the MOD-5A Wind Turbine Generator Program will function, subject to NASA/LeRC review.

To implement the quality, reliability and safety requirements, a project team organization is used. The organizational relationships are shown in Figure 1.

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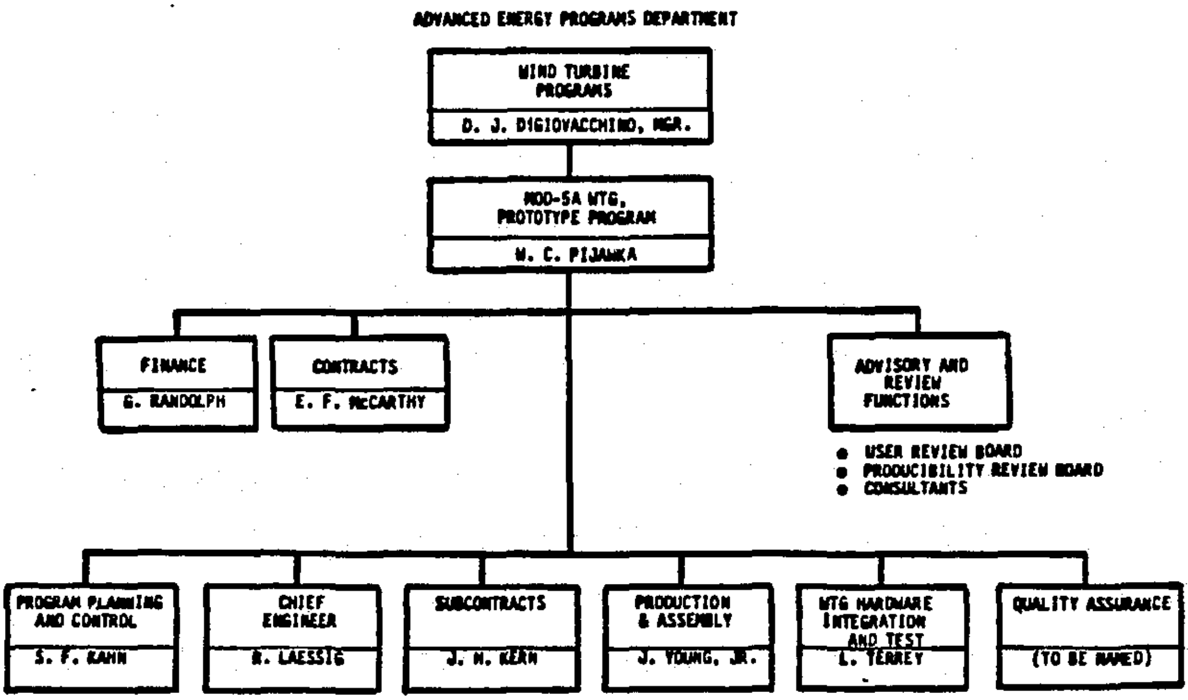

Figure 1

The Product Assurance Engineer (PAE) reports technically to the Manager, Hardware Integration, who, in turn, reports to the MOD-5A Program Manager. This provides a line of communication to the Program Manager concerning all aspects of Product Assurance Program implementation.

The Product Assurance Engineer reports administratively to the Product Assurance Manager, who reports to the Energy Support Operations Manager. He has at his disposal the facilities and capabilities of the entire PA organization, dedicated to the product assurance of hardware developed and built at the GE Advanced Energy Programs Department.

The Product Assurance Engineer assigned to the MOD-5A WTG Program is responsible for assuring that contractual, technical and quality requirements are met.

During the design and development phases, he will:

- o Review and sign off WTG drawings and specifications for the inclusion of quality requirements.
- o Establish supplier quality assurance requirements and generate the quality assurance provisions for product and process specifications.
- o Define acceptance requirements with the design engineer.

During the fabrication, inspection and test phases, he will:

- o Incorporate quality requirements in purchase orders.
- o Review and sign off inspection planning.
- o Participate in operations readiness reviews to assure that hardware, test equipment, facilities and personnel are ready for test.

- o Review test procedures.
- o Assist in the preparation and presentation of hardware data packages for customer acceptance.

Additional quality activities as defined in this Plan are performed by Quality Specialists, Technicians, Planners or Inspection personnel.

1.3 GOVERNMENT REVIEW

The operations and work of GE, its subcontractors and suppliers are subject to audit and review by the government (NASA-LeRC). Upon request, applicable information, documents, records, and other data will be made available for review by NASA-LeRC.

SECTION 2.0

RELIABILITY

2.1 DESIGN REVIEWS

Product Assurance, Reliability, and Safety personnel will maintain cognizance of Design Engineering activities; participate in in-house design reviews; contribute to "Quality Assurance Provisions" for specifications; advise Engineering in areas of inspection, test, reliability, and safety requirements; provide any required inspection and test support; and review drawings and specifications. Engineering is responsible for the technical adequacy of the Design, Test Specifications, and applicable Technical documentation.

2.2 TECHNICAL DOCUMENT REVIEW

Product Assurance Engineering will review those technical documents and changes associated with the MOD-5A WTG hardware, such as specifications, drawings and procedures, to ensure that they contain adequate requirements for determining and controlling the quality of all hardware. The major role undertaken by the Product Assurance Engineer in the review of technical documents will be to assure that the design definition is adequate and clear, that the parameters are measurable, that required tolerances are specified and appropriate, and that any special quality requirements are reflected in the design definition.

Through participation in design reviews and technical document reviews, the Product Assurance Engineer will plan for measuring and test equipment requirements, inspection and test procedures, vendor surveillance, and process control requirements.

2.3 FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

An FMEA will be prepared during Preliminary Design to identify initial elements which may cause failures, result in unplanned down time, or adversely affect the operating life of the MOD-5A WTG. The FMEA will be prepared by Design Engineering. Product Assurance, Reliability and Safety representatives will contribute to the FMEA and participate in reviews of the analysis. Similar analyses and reviews on other programs, including the recently completed MOD-1 WTG, have proved beneficial to modifying design concepts, selection of components, establishing planned maintenance intervals and in defining specific inspections and checks to be performed at each planned maintenance interval. The FMEA will be revised and updated during Final Design to incorporate results of design changes and modifications.

SECTION 3.0

PRODUCT ASSURANCE

3.1 QUALITY CATEGORIES

Articles to be used in this program are divided into two (2) categories. The applicable quality assurance requirements for each category are indicated in parentheses following the applicable requirements title.

3.1.1 UNIQUE

Specific unique articles are defined as the blades, ailerons, planetary gearbox and yoke. These specific articles have been designated as unique because of criticality to the success of the program and "state-of-the-art" category in their design and production.

3.1.2 NON-UNIQUE

All other components and equipment designed or procured for the wind turbine are included in this category.

3.2 QUALITY SYSTEMS (Unique and Non-Unique)

The General Electric Company, AEPD, is presently operating an effective system for controlling quality consistent with the requirements of this Product Assurance Plan. The system is integrated with all functions to assure that quality requirements are determined and satisfied throughout all phases of the contract. This system is documented through the use of selected sections of the Quality Assurance Procedures (QAP) Manual. Selected procedures will be implemented to meet the requirements of the MOD-5A WTG Program.

GE Product Assurance prepares and maintains the Quality Assurance Procedures (QAP) Manual. The QAP Manual documents all quality related procedures in detail; it is subject to continuous audit and review.

3.2.1 PRODUCT ASSURANCE ENGINEERING (PAE) MEMOS

It is the responsibility of the MOD-5A WTG Product Assurance Engineer to maintain, interpret and update the Product Assurance Plan as required. To assist in this endeavor, he is authorized to prepare and issue Product Assurance Engineering (PAE) Memos. The PAE Memo, when approved by NASA-LeRC, becomes an integral part of the Product Assurance Plan.

3.2.2 QUALITY ASSURANCE PROCEDURES

Product Assurance has the responsibility for maintenance of the Quality Assurance Procedures Manual and for auditing conformance to the requirements specified therein. In addition, they will be responsible for modifications of GE QAP's as required to effectively satisfy the requirements of the MOD-5A WTG Program.

Product Assurance also has the responsibility for maintaining the configuration verification records and preparation of the equipment logs.

3.2.3 SUPPLIER AND PROCESS CONTROL

Product Assurance has the responsibility for quality surveillance of suppliers, participation in vendor surveys where required and performance of supplier quality audits. In addition, Product Assurance prepares/reviews the process portion of manufacturing instructions and inspection procedures, participates in process readiness reviews and specifies discrepancy corrective action requirements.

3.3 DRAWING AND CHANGE CONTROL (Unique)

The drawing change control program will be in accordance with the standard GE Advanced Energy Programs Department (AEPD) Engineering Section Instructions, Drafting Practices Manual, and Quality Assurance Procedures. These will insure controlled distribution of all unique and non-unique drawings and specifications.

Drawing changes will be incorporated by revision as defined by Alteration Notices (AN's) or Design Change Control (DCC) forms and signed prior to release by Design Engineering, Manufacturing and Quality Assurance.

Upon approval of changes, AN's or DCC's will be issued to define the changes and their effectivity. Copies of all approved AN's and DCC's will be distributed to Product Assurance by the drawing custodian and processed to the responsible PAE and inspection personnel. All inspection and test documentation affected by the changes will be expeditiously revised by Product Assurance Engineering to reflect the new requirements. Drawings and procedures are kept only in one specific area, under the control of Engineering. Obsolete drawings are replaced promptly by Production Control with newly revised signed off copies. Inspections and tests will be performed against the latest MOD-5A WTG released design definition. The configuration status of all assemblies will be continuously monitored by inspection to assure compliance with the latest design definition. This monitoring includes the review of previously accepted hardware to assure that it has not become obsolete by virtue of subsequent design changes.

3.4 PROCUREMENT SOURCE CONTROL (Unique and Non-Unique)

3.4.1 UNIQUE ITEMS

Performance/Design requirements of unique items will be defined by GE-AEPD prepared specifications. Procurement sources will be evaluated and approved prior to issuance of the Purchase Order or Subcontract. Prior to award, suppliers selected must either have a quality record of supplying high quality articles of the type being purchased, or, if no up-to-date quality rating is available, pass a GE survey of the suppliers' facilities and quality control system.

The Quality Assurance Provisions of the Performance/Design specifications will be reviewed by the PAE to assure that the quality requirements are adequately covered. The PAE will also review the procurement documents (Purchase Order, Subcontract, Work Statement, as applicable) to insure that design and test requirements, Quality Assurance provisions, raw material controls, identification, preservation and packaging, cleanliness and contamination criteria, data requirements, etc., are specified.

Detailed inspection and test plans covering inspections and tests to be performed by the supplier will be generated by the supplier and reviewed and approved by the GE-PAE prior to their implementation. These will delineate specific parameters to be inspected or tested, data to be recorded and specific accept/reject criteria for parameters checked. The PAE or his designated representative will verify the quality of hardware supplied through periodic audits of vendor's system and processes, through source inspections of items prior to release for shipment and by witnessing or monitoring acceptance tests at the vendor's facility. Discrepancies, test failures and non-conformances will be documented and will require GE disposition prior to hardware acceptance. Documentation will be included with hardware shipments and will be maintained by GE as part of the Product Assurance Documentation file.

Figure 2 shows a typical flow chart for purchased materials, both unique and non-unique.

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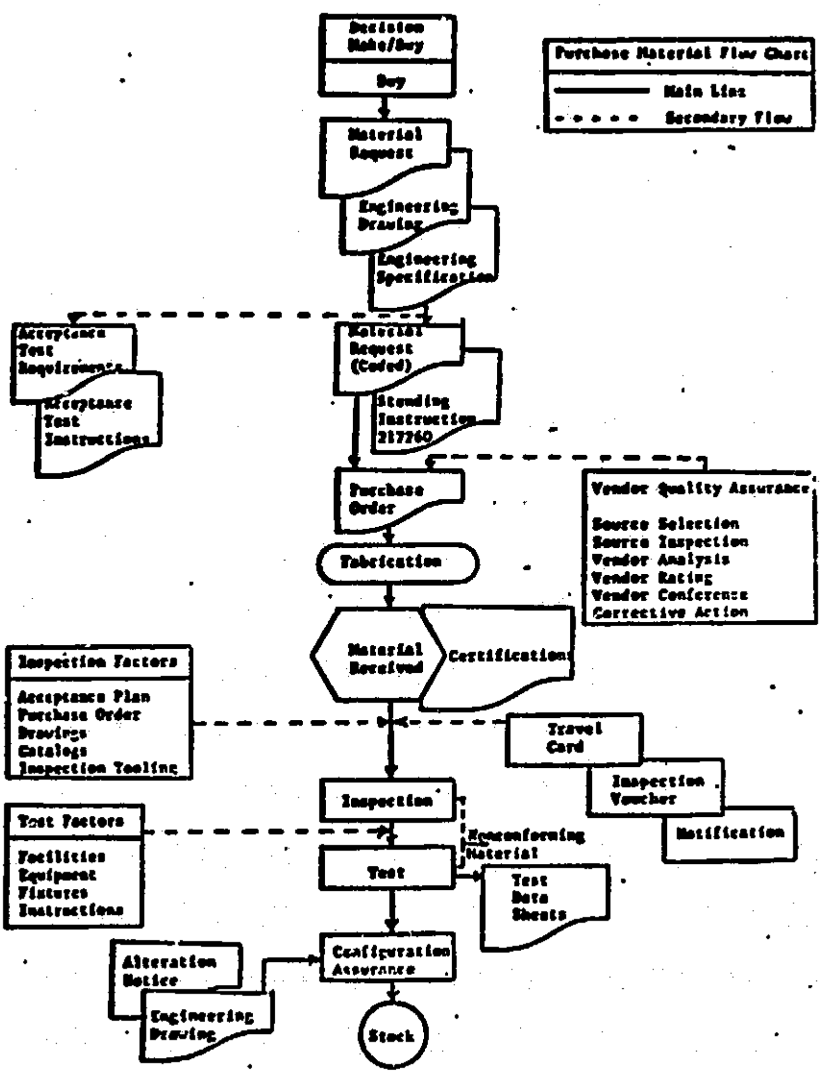

Figure 2. PURCHASED MATERIAL FLOW CHART (TYPICAL)

3.4.2 NON-UNIQUE ITEMS

Normally, non-unique items and materials will be procured to industry, military, or catalog item standards. In the event that Engineering and/or Reliability deems it necessary, in order to satisfy program requirements, specifications or source control drawings will be prepared and used as the basis for procurement. This will be done for critical, long lead, non-standard items such as the generator, yaw and hub bearings, transformers, controls, etc. Product Assurance will review all procurement documents and insure incorporation of the necessary quality requirements into these documents.

Material used in the fabrication of non-unique items will not normally require analysis by the Material and Process Laboratory, unless specified by the drawing or specification.

3.5 GOVERNMENT SOURCE INSPECTIONS (Unique and Non-Unique)

All purchase orders will include a statement to the effect that the government reserves the right to inspect all materials at the supplier's plant.

3.6 GOVERNMENT FURNISHED PROPERTY (Unique and Non-Unique)

Government furnished property will be controlled and stored under suitable conditions to protect it from loss or damage. Any damage to government property will be reported to NASA-LeRC and the cause and extent of damage will be investigated.

3.7 MATERIAL IDENTIFICATION, HANDLING AND STORAGE (Unique and Non-Unique)

3.7.1 MATERIAL IDENTIFICATION

All materials including critical high cost, long lead unique items such as the yaw bearing, blades, gearbox, etc. will be identified according to their respective engineering definitions. Identification will be on the material and/or documentation that is traceable to the material. Material will be further identified by serial or lot numbers when practical. Upon completion of inspection and/or test, the material will be identified as "accepted" or "rejected" by stamping the item and/or its associated documentation.

3.7.2 HANDLING AND STORAGE

Standard procedures now in effect will be used, as applicable, on the MOD-5A WTG program. Procedures for the controls imposed on storage, handling, preservation and shipping will be patterned after existing procedures.

Any additional procedures or deviations from existing procedures will be reviewed by the PAE prior to their implementation.

3.8 RAW MATERIALS CONTROL (Unique)

3.8.1 RAW MATERIAL FOR UNIQUE HARDWARE

Material used in the fabrication of the WTG Unique Hardware will be identified by type, lot number, heat number, or serial numbers as appropriate, and as specified in drawings, specifications and procurement documents.

3.8.2 CHEMICAL/PHYSICAL TEST DATA

Chemical/Physical Test Data supplied by accredited suppliers will be used normally to certify material properties. Chemical/Physical tests on materials will be conducted internally or by independent laboratories when specifically required by drawings or specifications.

3.9 INSPECTION AND TEST (Unique)

3.9.1 INSPECTION OF UNIQUE HARDWARE

Inspection of unique hardware will be to requirements of engineering specifications and drawings as detailed in written inspection planning.

The PAE, together with the responsible Design Engineer, will determine the necessary inspections to assure that all articles meet the requirements specified in the drawings and specifications.

The requirements for inspections will be specified in all procurement documents, as will the documentation required to prove successful completion of these inspections.

Critical high cost, long lead items such as the gearbox, generator, yaw bearings, main rotor bearing, etc. will have critical inspections witnessed and verified at the suppliers plant, as directed by the PAE and specified in the procurement documents.

The PAE will be responsible for verifying the completion of fabrication and processing operations, and the accuracy and completeness of required documentation by review of inspection records.

3.9.2 INSPECTION OF NON-UNIQUE HARDWARE

The majority of non-unique procured items will be standard commercial or industrial hardware and catalog items. Unless specified otherwise in specifications or drawings the procurement documents will not specify any inspections or test by the supplier other than his standard factory inspections and tests. GE receiving inspection will inspect for completeness of the order, shipping damage, conformance to catalog requirements and specified documentation.

Non-Unique articles fabricated and assembled at GE will be inspected to written planning integrated with manufacturing planning. Characteristics designated for recording as variables data will be defined in the planning. In addition, any requirements for special tools, gages or fixtures will be determined and specified. A typical flow of documentation and events in fabrication and assembly is shown in Figure 3.

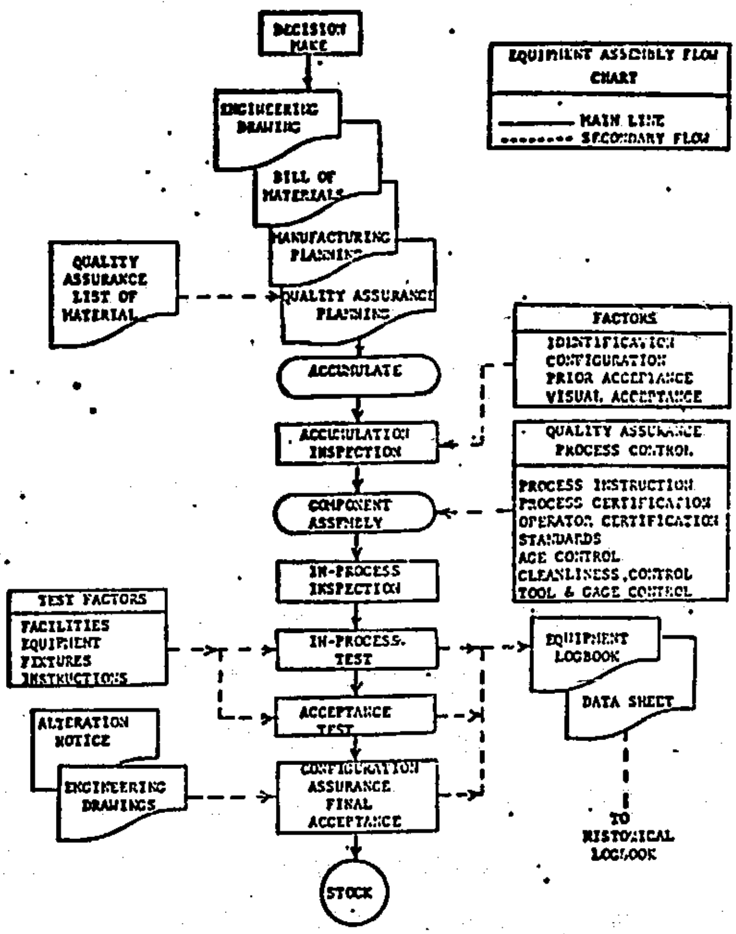

Figure 3. TYPICAL FABRICATION OR ASSEMBLY FLOW CHART

3.9.3 SYSTEMS TESTS

Systems tests will be performed in accordance with written Standing Instructions. Product Assurance will monitor the tests and will be an integral part of the Test Readiness Review Team. The Test Readiness Review Team consisting of personnel from Engineering, Product Assurance and Test have the responsibility for reviewing procedures, facility, personnel requirements, availability of safety requirements and procedures, and availability and operability of equipment prior to initiation of test.

Systems test will include the calibration and check out of the complete instrumentation link. Sensors, corresponding indicators, and their associated signal sources or power supplies will be checked out and calibrated. Periodic recalibration requirements will be imposed on those individual items where it is feasible and deemed to be beneficial. Ordinary commercial panel meters and quick-look, non-critical gauges will not be subjected to periodic calibration.

3.10 PROCESS CONTROL (Unique)

Special Processes, metallurgical, chemical and physical tests performed at GE and subcontractors will be performed to written procedures by qualified operators. General Electric operates a "Process Readiness" and "Operator Certification" program to insure the process is fully proven and that operators are appropriately qualified prior to application of the process to deliverable equipment.

General Electric will insure that procured parts are processed using developed processes and skilled operators. Existing QAP's establish procedures for specifying, reviewing and approving supplier special processes certifications. Critical processes being performed at a suppliers facility will be monitored by General Electric personnel as deemed necessary by the PAE in coordination with the responsible Design Engineer.

The work statement, specification, or purchase order will specify the documentation and controls necessary to insure satisfactory evidence of the end item quality.

3.11 NON-CONFORMING ARTICLES (Unique and Non-Unique)

3.11.1 GENERAL

Any deliverable material, part, or assembly in which one or more characteristics do not conform to the requirements specified in the contract, specification, drawing or other applicable document shall be designated as non-conforming material. All non-conformances, with the exception of subcontractor or vendor supplied material, will be initially documented on a defect report (DR) (Figure 4). Subcontractor/supplier supplied material will be documented on a Non-Conformance Report only (Figure 5).

All non-conforming material will be identified and controlled until disposition is made and corrective action taken. The system is illustrated in Figure 6. Disposition of non-conformances shall be based on engineering assessments of the ability of the non-conforming item to perform its intended function.

3.11.2 MATERIAL REVIEW

An initial review of the non-conforming material (DR) will be made by the responsible Product Assurance Engineer and Design Engineer and classified into two categories. The first is material that can be reworked to conform to the applicable drawing or specification requirements. Disposition of material in this category will be made on the "floor" by the Quality Control & Design Engineers.

The second category is material that cannot be "reworked" or completed to conform to the applicable requirements. A Non-conformance report (Figure 5) will be prepared for this category, and the material and report forwarded for Material Review Board (MRB) action.

3.11.2.1 Reworkable Material

When inspection reveals a non-conformance that can be corrected through "rework" or "completion" of the material, the material shall be identified to indicate its non-conformance. Upon correction of the non-conformance, the material shall be resubmitted for inspection.

3..11.2.2 Non-reworkable Material

Non-reworkable material shall be identified as non-conforming and placed in a controlled area which segregates it from other material. A non-conformance report shall be submitted to the "Material Review Board" (MRB) for review and disposition.

NO. 7545		DEFECT REPORT				
NOMENCLATURE	DWG NO.	REV	AN	JOB-LOT-SN	[illegible]	DATE
ORIGINATING AREA	ORIGINATOR	PROGRAM-[illegible]	QTY INSP	QTY REJ	TOTAL ACC.	

DEFECT DESCRIPTION

CORRECTED BY OPERATOR DATE

PRELIMINARY DISPOSITION

- ☐ AN REQ'D — DWG CHG ONLY — CONT PROCESSING — BUYBACK PER ⇨ AN NUMBER ISSUED
- ☐ AN REQ'D — HDWE IMPACTED — RWK PER DCR NO. DTD OR ⇨
- ☐ REWORK TO ISSUED DWG
- ☐ REFER TO MRB
- ☐ SCRAP
- ☐ STD REPAIR

MR NUMBER

OTHER (SPECIFY, IE, NOT A DEFECT, ETC) ___

DISPOSITIONED BY DATE

FINAL DISPOSITION (NOT REQ'D IF MR IS WRITTEN OR PRELIMINARY DISPOSITION IS UNCHANGED)

DISPOSITIONED BY DATE

DEFECT CAUSE (NOT REQUIRED IF MR IS WRITTEN)

DETERMINED BY DATE

CLOSEOUT STAMP DATE

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Figure 4.

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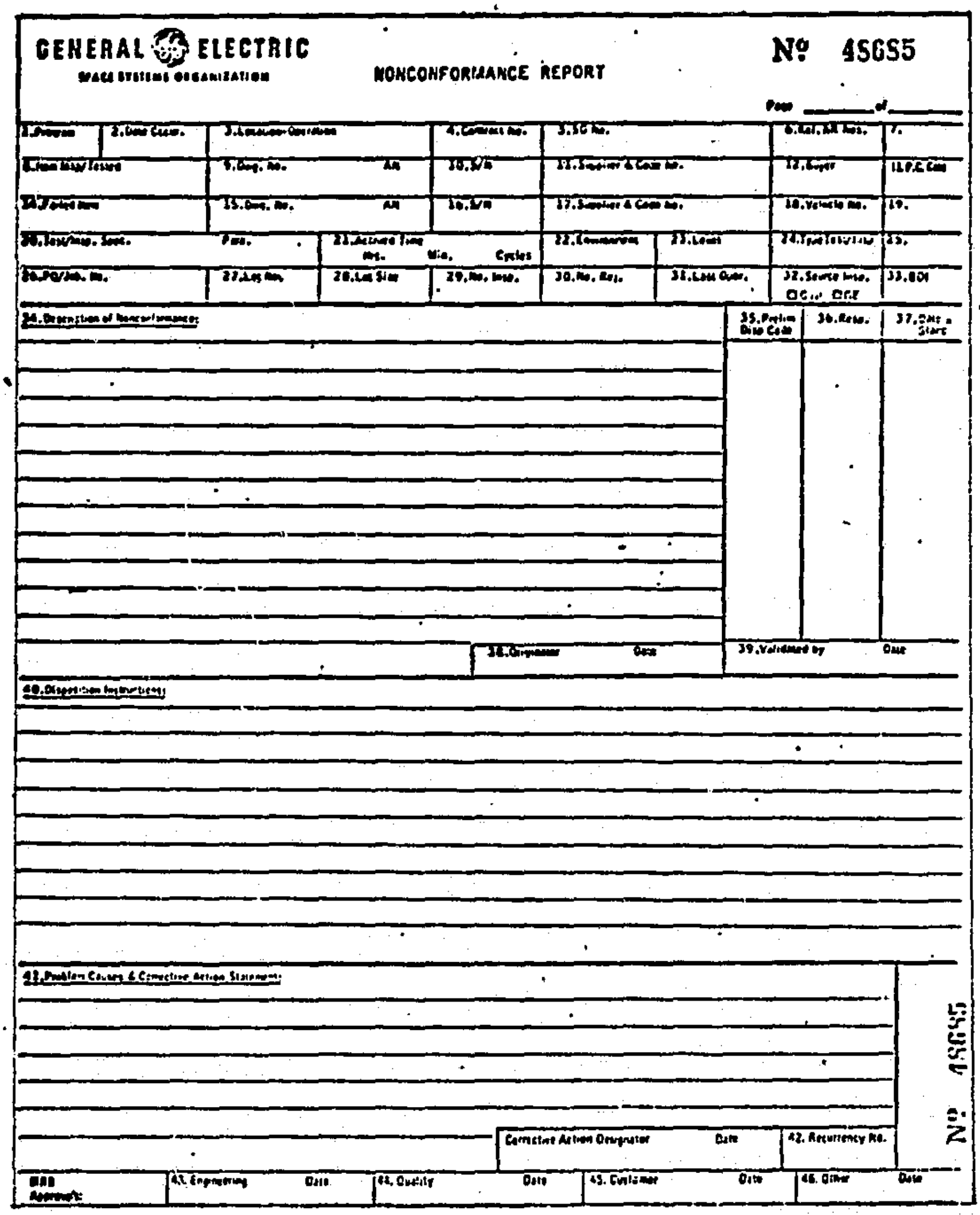
GENERAL ELECTRIC
SPACE SYSTEMS ORGANIZATION
NONCONFORMANCE REPORT
Nº 45655

Figure 5.

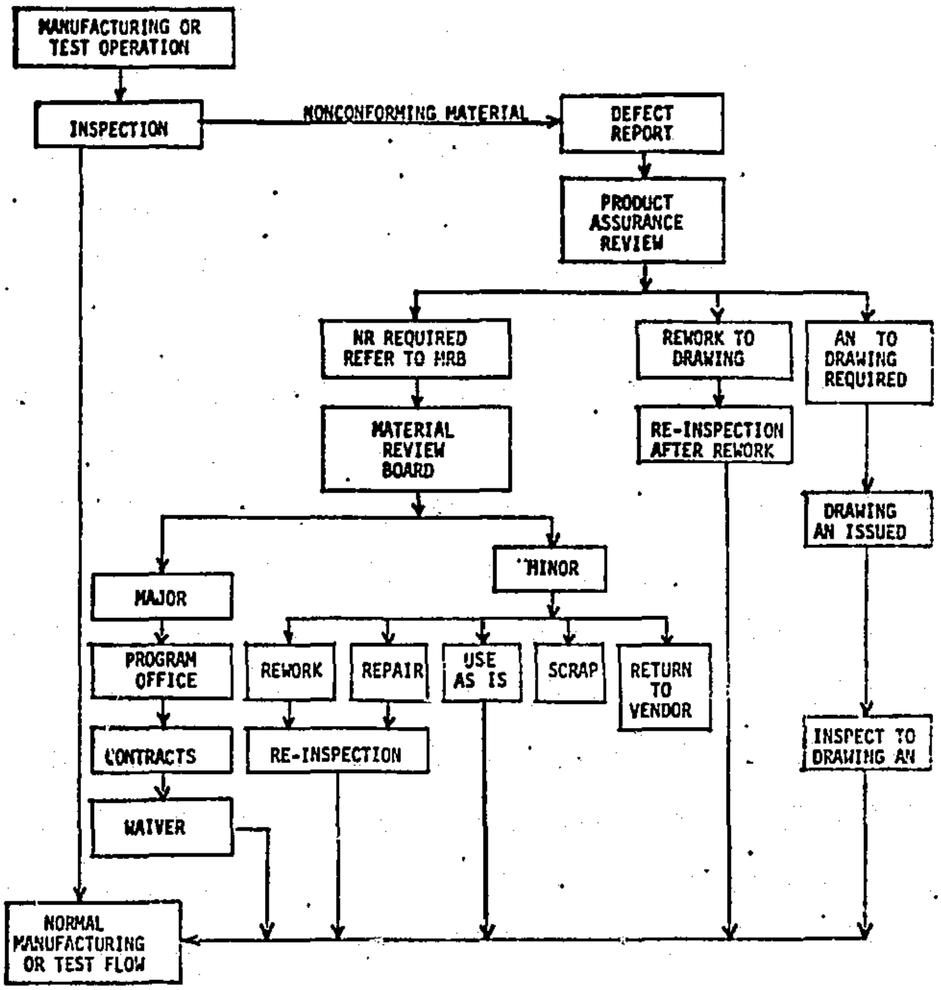

Figure 6. NONCONFORMING MATERIAL FLOW

The material will then be processed in accordance with the MRB disposition and identified accordingly. Disposition may be either "use as is", return to vendor, scrap or repair. If repair is indicated, the repair and inspection procedures shall be approved by the MRB prior to implementation. Records of all non-conformances, their disposition, and corrective action taken shall be maintained.

3.11.3 MATERIAL REVIEW BOARD (MRB)

The Material Review Board shall consist of one representative from GE Design Engineering, and one representative from Quality Control Engineering (who will serve as MRB Chairman). The Review Board shall convene to review and make disposition of non-conforming material. The disposition shall be by mutual agreement based on the ability of the hardware to perform its intended function. The responsibility for authorizing subcontractor and supplier MRB action shall lie with GE. MRB authority will not be delegated to subcontractor/suppliers.

3.11.4 NASA NOTIFICATION AND/OR PARTICIPATION IN MRB

On any non-conformances that may adversely affect safety, reliability, durability, performance, interchangeability, or the basic objectives of the contract, one copy of the "NR" and the Review Board disposition shall be submitted to the NASA/LeRC Project Manager for his approval within five (5) working days after the decision. General Electric will be notified in writing of any NASA/LeRC disapprovals. This notification will be made within five (5) working days after NASA/LeRC receipt of the "NR". As delineated in this Quality Plan, applicable portions of the existing QAP's will be used.

3.11.5 LOG BOOK

One copy of each "DR", "NR" and other Review Board documentation shall be maintained by Quality Control for inclusion in the Equipment Log.

3.12 INSPECTION, MEASURING, AND TEST EQUIPMENT CONTROL (Unique and Non-Unique)

3.12.1 GENERAL

Control of gages, standards, measuring equipment, and test equipment shall be in accordance with existing procedures.

3.12.2 CALIBRATION

All inspection, measuring, and test equipment is periodically calibrated against standards that are traceable to the National Bureau of Standards (NBS). Records are maintained in the form of punched card listings and all equipment bears a calibration sticker which indicates the date when calibration was last performed, when next calibration is due, and the Inventory Control Number of the equipment. In addition to internal controls on calibration of equipment and instrumentation, these requirements will be imposed on subcontractors and outside suppliers. All inspection equipment and test instrumentation will require periodic calibration to standards traceable to the NBS. Data compiled with other than currently calibrated equipment or instrumentation will not be considered acceptable. Ordinary commercial or industrial grade instruments such as pressure gages, panel meters (volts, amps, etc.), thermometers and the like, normally used as functional indicators only, will not be subjected to periodic calibration. These items will be functionally checked as part of the hardware and system check-out.

3.12.3 CALIBRATION FACILITIES AND STANDARDS

The GE Calibration Laboratory has standard industrial air conditioning for controlling temperature. The relative humidity does not exceed 55 percent and dust is controlled by the use of filters in the air supply and by selective use of dust covers on equipment. Within state-of-the-art limitations, the accuracy ratio of the calibrating standard to the instrument being calibrated will be maintained between 4 and 10 to 1; the accuracy ratio of the calibrated equipment with respect to the characteristic being measured will be 10 to 1 where possible.

3.12.4 EQUIPMENT EVALUATION

Special equipment (e.g. automatic test and checkout equipment) shall be evaluated to determine its accuracy and tolerance capability to provide the desired indications or records, its compatibility with the articles to be inspected or measured and the correctness and completeness of operating instructions.

3.12.5 MAINTENANCE AND CONTROL

Periodic inspection, maintenance and recalibration of equipment shall be performed at specified intervals. The intervals shall be predetermined in accordance with the individual requirements of the equipment as determined by:

a. Frequency of use
b. Required accuracy
c. Type of equipment
d. Other conditions affecting its ability to measure

Equipment which proves to be faulty shall be identified as defective and removed from service until corrective action has been taken. Hardware identified as having been inspected/tested using discrepant measuring equipment will be documented on a Defect Report and will require disposition by Product Assurance and Design Engineering prior to acceptance for use.

3.12.6 WRITTEN PROCEDURES

Calibration and maintenance procedures are prepared for all test equipment and will be available for review by NASA/LeRC.

3.12.7 RECORDS

Records will be maintained for all inspection, measuring, and test equipment, including such information as current location and custodian, calibration status, preventive maintenance dates, etc.

3.13 INSPECTION STATUS INDICATION (Unique and Non-Unique)

3.13.1 GENERAL

The General Electric AEPD maintains a system for the use of inspection stamps to indicate the inspection/test status of all hardware. In instances where hardware cannot be physically stamped, a stamped identification card will be attached or enclosed in the package. In addition, documentation such as purchase orders, travel tags, data sheets, and inspection planning are stamped to indicate hardware status.

3.14 PRESERVATION, PACKAGING AND SHIPPING (Unique and Non-Unique)

GE-AEPD, subcontractors for unique items, and other suppliers, when so specified on purchase orders or work statements, will prepare written procedures for the preservation, packaging and shipping of articles in a manner to provide protection of hardware throughout the length of the contract and to prevent damage, loss, deterioration, degradation or substitution. Other hardware will be packaged and shipped in accordance with good commercial practices. All required shipping and technical documents including handling instructions, operating instructions, end-item reports, drawings, parts lists, test data and approved waivers will accompany each shipped item as applicable.

All articles shipped by GE will be inspected prior to shipment to assure that they are: completed units; adequately packed and preserved; properly identified; that all required documentation accompanies the article.

3.15 INSPECTION AND TEST RECORDS (Unique and Non-Unique)

Integrated manufacturing and inspection planning provides complete documented inspection results. Test instructions detail test requirements and data to be recorded. Any deviations or anomalies are recorded on "DR" sheets and/or NR's. All inspection and test data will be made available to NASA/LeRC upon request.

3.16 EQUIPMENT LOG (Unique and Non-Unique)

A separate log will be established and maintained for each WTG as a means of documenting the continuous manufacturing, test and inspection history. Logs will be identified with the equipment to which they pertain, will be maintained in chronological order, will account for all periods of time or any movement of the item and will accompany the item. They will include: Certification of Compliance, Shipping Document, List of Materials (as built), DR Sheets, NR Reports, Test Data, and Significant Events Log.

3.17 FAILURE REPORTING (Unique)

Non-conformance Reports will be generated at the final performance test level of unique items, major items (gearbox, generator, brake hydraulic systems) and the WTG by System Test Personnel and will reflect all out of specification test conditions and results. NASA/LeRC will be notified by letter containing a copy of the NR for each functional failure. This report will contain the analysis of the failure, recommended corrective action and corrective action taken.

The initial NR will state the symptoms of the problem. Subsequent analysis, disposition, and corrective action will be added after the problem is investigated by the Product Assurance Engineer, Design/System Engineer, and Program Management where applicable.

The responsible Design Engineer will complete the diagnosis of the problem and is required to initiate corrective action.

The NR and associated documentation will be made available to NASA/LeRC and a copy will accompany the hardware on delivery.

The failures occurring during each month shall be summarized in the Monthly Narrative Status Report, and the status of open NR's from previous monthly reports will be updated. Failures of a repetitive nature, even on minor non-unique items, will be included in the Monthly Status Report.

3.18 CLEANLINESS CONTROL

General Electric maintains cleanliness controls on manufacturing areas, test areas, inspection and storage areas. It is anticipated that the majority of Wind Turbine manufacturing assembly and test will be conducted in "standard" areas. "Standard" areas are defined as those areas subject to routine cleanliness/housekeeping requirements only, and include the following specific requirements:

- There shall be no eating, drinking of beverages, or smoking in the areas.
- Hardware not in the fabrication cycle must be adequately protected against dirt or contamination.
- Good housekeeping practices shall be followed and shall include, but not be limited to, the following:
  - Floors, storage racks, test equipment, work benches, lockers, and cabinet tops shall be dusted regularly; suitable containers shall be provided for refuse which is generated during processing operations. Work area and benches shall be cleaned upon completion of work performed.

3.19 RADIOGRAPHIC INSPECTION (Unique)

Unique and Non-unique items, will be subjected to radiographic inspection in accordance with the requirements specified in test/inspection procedures and as determined by Design Engineering and Reliability Engineering. Inspection records will be maintained at GE-AEPD and/or its subcontractors. Records shall be available for review by NASA-LeRC at the specific maintenance sight.

3.20 PRODUCTION INSPECTION FLOW DIAGRAM

A preliminary production flow diagram indicating inspection points in the cycle is included in Figure 7. As design progresses and details become available, the diagram can be updated to indicate inspection and test points in greater detail.

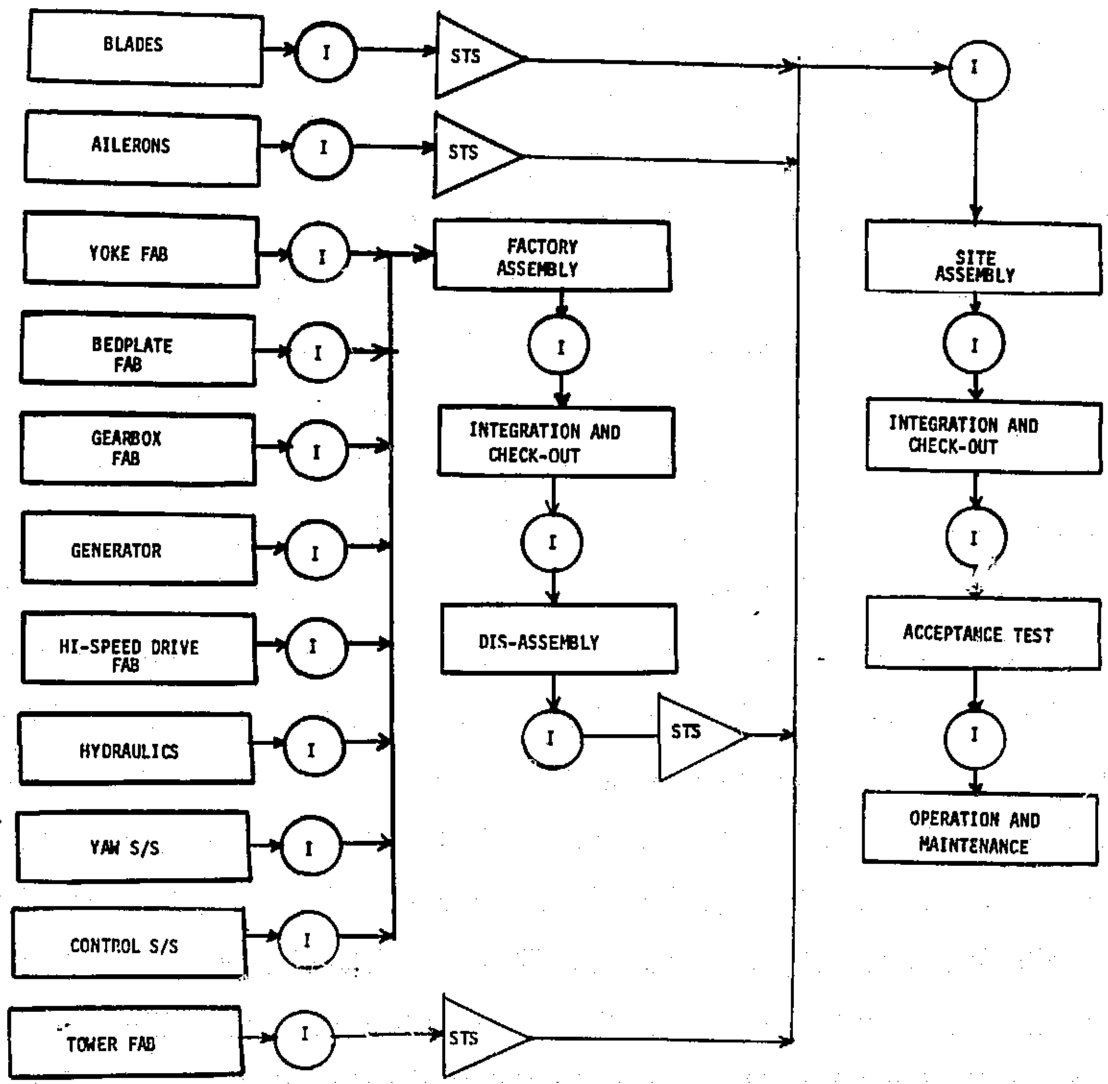

Figure 7. PRODUCTION/INSPECTION FLOW DIAGRAM

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TITLE

FIRST MADE FOR

REVISIONS
A GENERAL CHANGES 5/1/81
B ISSUED-DOC. NOW UNDER CONFIG. CONT. 4/4/84

SYSTEM SAFETY PLAN
FOR THE
MOD-5A WIND TURBINE GENERATOR PROGRAM

REV "B"
MAR. 84

PREPARED BY: A. Cheddar DATE 5/1/81
A. Cheddar
MOD-5A WTG Product and Safety Assurance Engineer

CONCURRED BY: E. J. Urbanik DATE 5/1/81
E. J. Urbanik, Manager
AEPD Product Assurance

CONCURRED BY: W. Lucas DATE 5/1/81
W. Lucas, Manager
MOD-5A WTG Design Engineering

CONCURRED BY: R. S. Barton DATE May 1, 1981
R. S. Barton, Manager
MOD-5A WTG Systems Engineering

CONCURRED BY: G. Drenker DATE May 1, 1981
G. Drenker, Manager
MOD-5A WTG Hardware Integration

CONCURRED BY: G. Drenker for DATE May 1, 1981
J. H. Kern, Manager
MOD-5A WTG Subcontracts & Procurement

CONCURRED BY: T. P. Hardle, for DATE May 1, 1981
A. W. Kobylinski
Industrial Safety and Hygiene

APPROVED BY: L. Terrey DATE May, 1981
L. Terrey, Manager
MOD-5A WTG Program

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MADE BY	APPROVALS		DIV OR DEPT.	
A. Cheddar		A.E.P.		47A380019
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REVISION LOG

This log identifies those portions of this document which have been revised since original issue. revised portions of each page, for the current revision only, are identified by marginal striping or text notes.

Revision	Page No.	Paragraph Number(s) Affected	Rev. Date	Approval
A	All	General rewrite to incorporate NASA review comments.	5-1-81	A. Cheddar
B	All	Assign document control number and issue. Change page numbering. Correct typographical errors.	3-15-84	A. Cheddar

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SECTION 1.0

SCOPE

This plan defines the requirements to be implemented to insure product and personnel safety during all phases of the MOD-5A WTG Program. It applies to design, development, production, factory test and evaluation and to the assembly, operation and support at the WTG site location.

By agreement with the General Electric Space Division, GE, AEPD will use the GE, Valley Forge Space Center Safety Manual. This document is referenced in this plan and copies of pertinent instructions and/or procedures are included in the Appendix.

SECTION 2.0

PURPOSE

The purpose of this plan is to insure that:

a. Safety consistent with the program objectives is designed into the WTG system.

b. Potential hazards inherent in the system are identified and evaluated and that action required to eliminate or control them within acceptable limits is taken.

c. Proven designs and materials are used where feasible and new designs and materials are fully evaluated to minimize risks.

d. Changes or modifications to the system do not compromise the level of safety inherent in the system.

e. Production, assembly and test methods, equipment and facilities will not degrade the level of safety designed into the system.

C-6

SECTION 3.0

POLICY

It is the policy of the WTG Program to provide the equipment and environment that provides maximum safety for personnel and equipment during all operations and applications, and to take all required measures to eliminate, within the limits of controllable hazards, the risk of injury or damage to personnel or equipment during all phases of the WTG Program.

Full adherence to GE Corporate and Space Division Policies on Safety, applicable industry standards, federal and local regulatory requirements, technological developments, and contractual requirements shall be maintained at all times.

SECTION 4.0

APPLICABLE DOCUMENTS

4.1 GENERAL ELECTRIC DOCUMENTS

1. General Electric Corporate Executive Office - Organization and Policy Guide 20.12 - Product Safety.
2. General Electric Corporate Executive Office - Organization and Policy Guide 20.14 - Employee Health and Safety.
3. General Electric Valley Forge Space Center Safety Manual.
4. General Electric Space Division Policy 7.1 - Employee Health and Safety.

4.2 OTHER DOCUMENTS

1. Occupational Safety and Health Act of 1970.
2. (TBD) State Safety Code.
3. NASA PR 1.5204 (d).
4. Code of Federal Regulations, Title 29, Parts 1910 and 1926.

SECTION 5.0

RESPONSIBILITIES

5.1 MANAGER - MOD-5A WTG PROGRAM

The Manager of the MOD-5A WTG Program has overall responsibility for the safety and performance of the MOD-5A WTG Program. He will define the top level organization roles and responsibilities, lines of authority and limitations as it applies to program/product safety and will also participate in Safety Review Board Meetings and all Design Reviews.

5.2 MANAGER - MOD-5A WTG SYSTEMS ENGINEERING

The Manager of MOD-5A WTG Systems Engineering is responsible for assuring that the WTG System Requirements minimize the possibility that a failure or malfunction will create a hazardous or catastrophic condition that can affect personnel or WTG equipment safety. He is also responsible for designing a system concept that provides for adequate personnel and equipment protection throughout the test and operational phases of the Program. In addition, he will participate in all Design Reviews.

5.3 MANAGER - MOD-5A DESIGN ENGINEERING

The manager of MOD-5A WTG Design Engineering is responsible for assuring that the designs for the individual subsystems, subassemblies and components are compatible with the overall system concept and that risk that the failure of any of these subtier components will jeopardize the overall system objectives will be below acceptable levels. In addition to the above, he will participate in Safety Review Board Meetings and all Design Reviews.

5.4 MANAGER - MOD-5A WTG HARDWARE INTEGRATION

The manager of MOD-5A WTG Hardware Integration is responsible for the manufacturing and assembly aspects of the program, for quality assurance, reliability and FMEA, and for systems integration, installation and test. His function is to insure that the safety level designed into the system is not compromised during the production and test stages of the program. In addition to the above, he will:

- Serve on the Safety Review Board
- Participate in Design Reviews
- Coordinate assembly and test facility requirements.
- Provide for assembly and test personnel training

5.5 PRODUCT AND SAFETY ASSURANCE ENGINEER - MOD-5A WTG PROGRAM

The Product and Safety Assurance Engineer assigned to the MOD-5A program is responsible for insuring that the detailed requirements specified in the MOD-5A Safety Plan are implemented and adhered to by the responsible program personnel. He will interface with the managers of the various MOD-5A WTG operations and with the Space Division Manager of Industrial Safety and Hygiene on all matters relating to system and personnel safety. In addition to the above, he will:

- o Serve on the Safety Review Board
- o Participate in Design Reviews
- o Prepare facility safety checkoff list
- o Act as the Safety Monitor during all phases of assembly, checkout and test.

5.6 MANAGER - MOD-5A WTG SUBCONTRACTS AND PROCUREMENT

The Manager of the MOD-5A WTG Subcontracts is responsible to insure that safety requirements are imposed on each major subcontractor through the subcontract SOW. Each major subcontractor is to prepare a safety plan for review and approval by the GE MOD-5A Product and Safety Assurance Engineer. This safety plan will identify each feature of the design which could cause hazardous conditions or catastrophic failures and will outline the procedures to be followed to eliminate these conditions or to reduce them to a level acceptable to GE and the customer.

5.7 MOD-5A WTG TEST CONDUCTOR/TEST FOREMAN

During factory test, a Test Conductor/Test Foreman will be in charge of testing. He is responsible for assuring that procedures are followed and safety requirements are adhered to. The Test Conductor shall have the authority to approve procedure variations for troubleshooting and test expediency. All variations will be recorded on the Procedure Variation Sheet and approved by the Test Conductor and the Product and Safety Assurance Engineer.

5.8 MOD-5A GE-AEPD SITE MANAGER

The GE-AEPD Site Manager has overall responsibility for safety during construction, erection and checkout at the WTG site. He will insure that potential hazards have been identified, that procedures to prevent injury to personnel or damage to equipment have been prepared and that these procedures are followed. He will verify that site subcontractors are in full compliance with local, state and federal safety regulations and will also serve as a member of the site Safety Review Board.

5.9 MOD-5A SUBCONTRACTOR SITE MANAGER

The Subcontractor Site Manager is responsible for insuring that all work performed by the subcontractor complies with local, state and federal regulations. He shall prepare safety procedures for review by the GE-AEPD Site Manager. He is responsible for obtaining all permits, licensing and/or certifications required by local, state or federal regulations and will serve as a member of the site Safety Review Board.

5.10 MOD-5A WTG SAFETY REVIEW BOARD

The MOD-5A Safety Review Board is responsible for insuring that specified safety requirements or procedures have been implemented in each phase of the program prior to the commencement of any operations involving hardware in that phase. The Board's approval of procedures, equipment, facilities and the level of personnel training and competence is required before any operations may proceed.

The MOD-5A Safety Review Board shall consist of the following:

1. MOD-5A Product and Safety Assurance Engineer - Chairman.
2. Manager - MOD-5A WTG Design Engineering.
3. Manager - MOD-5A WTG Hardware Integration.
4. Manager - MOD-5A WTG Program.

5.11 DELEGATION OF RESPONSIBILITY

Each of the above managers has the authority to delegate portions of his responsibility to individuals within his operation. The ultimate responsibility, however, for all aspects of safety within his operational jurisdiction remains with the individual operation manager.

SECTION 6.0

DESIGN AND DEVELOPMENT

WTG equipment and personnel safety has its foundation in the design of the product. The WTG will be designed to minimize the probability that a failure will create a hazardous or catastrophic condition that can affect WTG equipment or personnel safety.

6.1 PROGRAM CONTROLS

The disciplines and program controls which will be applied during the design and development phases of the Program to insure product and personnel safety include:

6.1.1 FMEA

An FMEA will be completed during the Preliminary Design Phase which will identify potential hazards inherent in the design. Hazards will be evaluated and the necessary steps taken to eliminate them or to reduce them to an acceptable level. The FMEA will be updated during the Final Design Phase to assess the effects of design changes or modifications.

6.1.2 DESIGN ANALYSES

Design analyses will be performed in the areas of stress, fatigue, dynamics and control stability. New designs and materials will be evaluated. Tests and validation requirements to verify that the designs meet operating and environmental requirements will be identified. Results and recommendations of the analyses will be documented.

6.1.3 DESIGN REVIEWS

Formal design reviews, attended by participants from GE and NASA, will be held at the end of the Conceptual, Preliminary and Final Design Phases. Representatives from Engineering, Manufacturing, Product Assurance, Reliability and Safety will participate in these reviews. In addition to these reviews, informal design reviews will be performed on a continuing basis prior to the issuance of each drawing and specification. Review and approval of these documents is required by Design Engineering, Manufacturing and Product Assurance.

6.1.4 INDEPENDENT SAFETY REVIEW

During the Final Design Phase, a safety review of the RAM and FMEA analyses will be performed by an independent review board designated by the Manager - Wind Turbine Programs. This independent review board will be staffed by senior representatives of the various departmental operations who are not members of the MOD-5A WTG team.

SECTION 7.0

ASSEMBLY AND TEST FACILITY

The WTG Assembly and Test Facility will be reviewed by the WTG Product and Safety Assurance Engineer and the Manager - WTG Hardware Integration to verify that the facility provides the equipment, personnel safety and security that is required.

7.1 FACILITY SAFETY REVIEW

Prior to commencing any assembly or test operations in the facility, a Facility Safety Review will be performed by the MOD-5A Safety Review Board. This review will be made, using a comprehensive checkoff list prepared by the WTG Product and Safety Assurance Engineer and the Manager, MOD-5A Hardware Integration, which includes those items necessary for a safe and expeditious assembly of the MOD-5A WTG. This review will assure the facility meets the following broad criteria:

1. Adequate building security including fire protection and alarms.
2. Secure and adequate equipment storage facilities.
3. Adequate and safe utility supplies:
    a) Electrical
    b) Heating
    c) Sanitary
    d) Water

4. Adequate and safe crane facilities:

   a) Cranes will be proof loaded to at least 1.5 times the maximum load to be lifted.

   b) Cranes will be proof loaded at least once per year.

   c) Cranes shall be inspected carefully for damage or wear prior to each major lift.

   d) The Manager - MOD-5A Hardware Integration, the MOD-5A Product and Safety Assurance Engineer, or the assembly foreman may require special inspections and/or proof loading of cranes should they deem this necessary or beneficial.

5. Adequate floor loading capabilities and foundations to support WTG equipment during assembly and test operations.

6. Access for personnel and equipment.

7. Adequate space for storage, assembly, test and shipping operations.

SECTION 8.0

SYSTEM ASSEMBLY, DISASSEMBLY AND SHIPPING

8.1 SYSTEM ASSEMBLY, DISASSEMBLY AND SHIPPING

System assembly, disassembly and shipping will require potentially hazardous operations to personnel and equipment. Included are:

1. Movement and lifting of large, heavy equipment.
2. High voltage electrical connections.
3. High pressure hydraulic systems.
4. Rotating equipment.

8.2 ASSEMBLY, DISASSEMBLY AND SHIPPING PROCEDURES

All assembly, disassembly and shipping operations will be performed to written instructions/procedures prepared by WTG Manufacturing and approved by WTG Design Engineering. These procedures will describe the equipment, facilities, personnel requirements, interfaces and connections in addition to the operations necessary to assemble the MOD-5A. They shall be reviewed by the WTG Product and Safety Assurance Engineer.

8.3 TOOLING AND FIXTURE CHECKOUT

Prior to the start of assembly operations, the conformance of all special fixturing and tooling to specified requirements will be verified. All lifting slings, cables and chains will be proof-loaded to drawing requirements prior to use in the WTG assembly operations and will be marked or tagged to indicate proof load and date tested.

8.4 ASSEMBLY SAFETY REVIEW

Prior to start of assembly operations, a Safety Review will be conducted by the MOD-5A Safety Review Board. This review will verify:

1. All safety and security devices, signs and procedures are implemented and operational.
2. All personnel have been trained in the assembly sequence, procedures and special precautions.
3. All tooling and handling equipment are available and have been verified to satisfy applicable requirements.
4. The test and assembly facility has been prepared for the assembly operation, potential hazards have been eliminated and adequate protection and warning signs have been installed.
5. Personnel access lists have been prepared and are posted and personnel safety equipment (hardhats, safety shoes, and safety glasses) is available.
6. First aid equipment, fire extinguishers and emergency telephone numbers are in place.

8.5 PROCEDURE VARIATIONS

It is anticipated that occasions will arise where deviations from the issued procedure will be required because of unanticipated problems. This will be documented on a Procedure Variation Sheet, which will become a permanent part of the WTG documentation. The Procedure Variation Sheet is an integral part of each written procedure and is filled out whenever a deviation from the procedure is required or authorized.

8.6 ASSEMBLY SAFETY

The WTG Product and Safety Assurance Engineer will monitor the assembly operations and will be present during all operations. He will have the authority to stop any operation because of a hazardous condition. Operations may proceed when he is satisfied that the condition has been satisfactorily corrected.

8.7 TRAINING

Because of the complexity or potentially hazardous condition of some assembly operations, it may be necessary to provide training or orientation for personnel performing these operations. The Manager - MOD-5A Hardware Integration will determine which assembly operations require special training for personnel and will be responsible to insure such training is provided.

SECTION 9.0

SYSTEMS TEST

WTG Systems Test personnel will operate in close proximity to potentially hazardous conditions. Typical conditions which must be considered in the preparation of test procedures and safety precautions and restrictions are:

1. Rotating equipment in confined areas.
2. Personnel operating on elevated platforms.
3. Large static loads being imposed during mechanical loading of the system.
4. High electrical voltages.
5. High pressure hydraulic systems.
6. Movement and lifting of large, heavy equipment.
7. Movement of mechanisms in confined areas.

9.1 TEST PLANS AND PROCEDURES

All test operations will be performed to Standing Instructions (S.I.'s). Each S.I. is assigned a six digit number from a block of numbers assigned for S.I.'s. Standing instructions are controlled by Print Control in the same manner as drawings and specifications. Permanent changes to S.I.'s are made by Standing Instruction Revisions (S.I.R.'s) which are controlled in the same manner as drawing change notices. Non-permanent deviations from a procedure are documented on a Procedure Variation Sheet which is an integral part of each S.I. and is filled out whenever a deviation from a procedure is required or authorized. S.I.'s and S.I.R.'s require approval by the Managers of Design Engineering, Hardware Integration (Test) and the Product and Safety Assurance Engineer. Procedure Variation Sheets require approval by the Test Conductor and the Product and Safety Assurance Engineer. Copies of an S.I. cover sheet, an S.I.R. form and a PVS form are included in Appendix A of this plan.

Standing Instructions shall contain the following as a minimum:

1. Equipment and facilities required for test.

2. Precautions, limitations and requirements imposed for WTG equipment and personnel safety.

3. Operating parameters, required inputs to the system and expected outputs from the system.

4. Acceptance/rejection criteria.

5. Emergency Procedures.

9.2 TEST ANOMALIES AND FAILURES

All test anomalies and failures will be recorded on Defect Reports (DR's) and Nonconformance Reports (NR's) in accordance with the WTG Product Assurance Plan (Document No. 47A380018). The disposition of the DR or NR documents the specific actions required to correct the deficiency noted. Copies of the DR and NR forms are included in Appendix A of this plan.

9.3 TEST SAFETY REVIEW

Prior to the initiation of any test operations, a Test Safety Review will be performed by the MOD-5A Safety Review Board. This review will verify as a minimum:

1. The test procedure has been prepared, approved and issued.
2. All personnel associated with the testing are familiar with the procedures, hazards, special precautions and are competent in their assigned tasks.
3. All preliminary assembly operations and subassembly inspections and tests have been completed satisfactorily.
4. All test equipment, tooling and fixtures are available and have been verified to satisfy documented requirements.
5. All safety and security devices, signs and procedures are implemented and operational.
6. Personnel access lists have been prepared and are posted.

9.4 TEST LOG BOOK

A log book will be maintained during all test operations. This log book will be continuously maintained by the Test Conductor. This log book will include records of the following:

1. Significant events - anomalies, failures, trouble-shooting, changes to equipment.
2. Changes in personnel.
3. Safety briefings and violations.

9.5 TEST SAFETY

The WTG Product and Safety Assurance Engineer will monitor testing operations and will be present during all operations. He shall have the authority to stop any operation because of a hazardous condition. Operations may proceed when he is satisfied that the condition has been eliminated.

9.6 TRAINING

Prior to initiation of any testing, all operations will be reviewed for the need for any special safety training. When required, this training will take place prior to initiation of testing. The Manager, WTG Hardware Integration is responsible for identifying operations requiring special training for personnel and to provide the necessary training on a timely basis.

SECTION 10.0

SITE PREPARATION AND TOWER ERECTION

Site preparation and tower erection will be performed by subcontractors under direction of the General Electric Advanced Energy Programs Department. The subcontractors' safety procedures shall be used for this phase of the field operation.

The GE-AEPD Site Manager will review the subcontractors' safety procedures to assure:

1. Procedures meet all local, state and federal requirements.
2. Adequate provisions are included to preclude damage to WTG equipment.
3. Subcontractors have assigned individuals responsible for personnel and equipment safety.

The GE-AEPD Site Manager shall maintain responsibility for program safety and shall provide an audit function during the site preparation phase.

Prior to use, equipment such as the lift, work platforms and access ladders shall be checked for safe operation, evidence of proof loading, adequate safety railings and other protective devices. Certification or licensing, where required by state laws, shall be obtained by the supplier or subcontractor and will be verified by the GE-AEPD Site Manager.

SECTION 11.0

WTG ASSEMBLY AND ERECTION

11.1 TRANSPORTATION

The WTG equipment shall be shipped by conventional transportation, rail or truck, in several large, heavy modules. During the shipment phase, GE-AEPD will monitor critical shipment operations, with particular emphasis on transfer of equipment from truck to rail and the reverse. Emphasis will be placed on:

1. Adequacy of transportation equipment and fixtures.
2. Adequacy of protective equipment.
    a) Skids and packaging
    b) Tie downs
    c) Protection against weather
3. Adequacy of cranes, slings, cables and other transfer equipment.
4. Capability and training of personnel performing transfer and transportation operations.

11.2 INSPECTION AND CHECKOUT

On receipt at the erection site, the WTG equipment will be inspected for transportation damage and completeness of shipment. The inspection shall include, where possible, checkout of the equipment to assure maintenance of alignments and freedom of moving parts prior to erection. These operations will be performed to written planning prepared by Product Assurance. The P.A. representative at the site will be responsible for performing these inspections. In the event there is no P.A. representative at the site, the GE-AEPD Site Manager is responsible to insure these inspections are performed.

11.3 SAFETY REVIEW

Prior to erection of the total WTG and/or the individual modules (nacelle, hub, blades), a Safety Review will be performed by a special Review Board composed of the following:

1. GE Site Manager.
2. Construction Subcontractor Site Manager.
3. WTG Assembly & Test Operations Representative.
4. WTG Product and Safety Assurance Engineer.

This review will ascertain:

1. Lifting equipment is available and verified to satisfy applicable requirements.
2. All procedures to be implemented are in place and have had the appropriate reviews and approvals.
3. Preceding equipment inspections and checkouts have been satisfactorily completed.
4. Required personnel are available and have been adequately trained, and personnel safety equipment (hardhats, safety glasses, shoes, safety belts and lines) is available and in good condition.
5. All required tools and fixtures are available and have been accepted by Product Assurance as conforming to design documentation.

6. Atmospheric conditions are suitable for the required lifts, including a maximum allowable wind for lifting conditions.

11.4 SITE SAFETY

The WTG erection shall be continuously monitored for personnel and equipment safety. The GE Site Manager shall be responsible for monitoring safety during the erection operation and shall have authority to discontinue any operation that he considers hazardous to personnel or WTG equipment. An operation discontinued for safety reasons can be resumed when the GE Site Manager is assured the hazardous condition has been corrected. The GE Site Manager may delegate this responsibility to the WTG Assembly and Test Operations Representative at his discretion.

SECTION 12.0

WTG OPERATIONAL CHECKOUT AND TEST

12.1 SAFETY CONSIDERATIONS

The WTG shall be checked out, started and acceptance tested to written procedures following erection. Included in these procedures will be the safety regulations and precautions required for safely testing the fully assembled WTG. Included in these safety requirements will be:

1. Personnel access during various test and weather conditions.
    - a) No personnel in nacelle or yaw structure when the rotor is turning.
    - b) Access limitations due to weather, maximum allowable wind speed, etc.
2. Personnel limitations and safety equipment required when on nacelle, yaw structure or tower.
3. Conditions required for test:
    - a) Weather conditions
    - b) Equipment status
4. Emergency procedures:
    - a) Nacelle, yaw structure and tower evacuation
    - b) Equipment failures or malfunctions
    - c) Adverse weather
5. Safety and emergency equipment required:
    - a) Harnesses, lifelines, platforms, hats, glasses, shoes

b) Fire extinguishers

c) First-aid equipment

6. Emergency telephone numbers:

a) Fire

b) Ambulance

c) Police

d) Utility

12.2 PROCEDURES

Test procedures will be Standing Instructions and will be issued and controlled as specified in Paragraph 9.1 of this plan.

12.3 PROCEDURE CHANGES

Changes to Standing Instructions will be issued and controlled as specified in Paragraph 9.1 of this plan. For purposes of expediency, however, all changes at the field site may be initially documented on the PVS sheet of the S.I., but all changes of a permanent nature must be followed up with a formal change to the S.I. with an S.I.R. The Manager, MOD-5A Design Engineering will determine which variations are of a permanent nature and, therefore, require issuance of an S.I.R.

12.4 TEST ANOMALIES AND FAILURES

All test anomalies and failures will be recorded on DR's and NR's in accordance with the WTG Product Assurance Program Plan (Document No. 47A380018).

12.5 OPERATIONAL TEST SAFETY REVIEW

Prior to any operational testing of the WTG, an Operational Safety Review will be performed by the Site Review Board of Paragraph 11.3. The purpose of the review is to ascertain:

1. All previous erection, assembly and checkout operations have been completed satisfactorily.
2. Procedures are available and test personnel have been trained in their use.
3. Test personnel have been trained in emergency procedures and are knowledgeable of safety controls and equipment.
4. Equipment and tools are available and have been properly inspected, accepted and calibrated as required.
5. Safety and emergency equipment are available and have been found to be complete and acceptable.
6. Warning notices, signs and emergency numbers are prominently displayed.

Upon completion of the review, documentation regarding minutes of the meeting, action items and action item closeouts will be prepared and made part of MOD-5A permanent records.

12.6 TEST LOG BOOK

A log book will be maintained during all operations. This log book will be continuously maintained by the Site Manager or his delegate. This log book will include records of the following:

1. Significant events - anomalies, failures, trouble-shooting, changes to equipment (WTG and test).
2. Changes in personnel.
3. Safety briefings and violations.

12.7 OPERATIONAL CHECKOUT AND TEST SAFETY

The WTG Product and Safety Assurance Engineer will monitor testing operations and will be present during any potentially hazardous operation. He shall have the authority to stop any operations because of a hazardous condition. Operations may proceed when he is satisfied that the condition has been eliminated.

12.8 TRAINING

Prior to initiation of any testing, all operations will be reviewed for the need for any special training. When required, this training will take place prior to initiation of testing and will be a Safety Review requirement.

SECTION 13.0

UTILITY TRAINING AND OPERATION

13.1 PURPOSE

Utility training will be a two-phase operation to assure total familiarity with the WTG system and its operation.

13.2 UTILITY TRAINING PLAN

Utility training will be conducted in accordance with the Operations and Maintenance Manuals. This training will insure that utility personnel are knowledgeable in all phases of WTG operation including:

1. Safety features incorporated into the design.

2. Emergency procedures.

3. Personnel safety features and procedures.

4. Maintenance Procedures.

13.3 UTILITY OPERATIONS AND MAINTENANCE MANUALS

Utility Operations Manuals and Maintenance Manuals will be prepared for use by the operating utility. In addition to operational information, these manuals will contain:

1. Maintenance and inspection requirements and procedures.

2. Emergency procedures.

3. Equipment and personnel safety features and procedures.

SECTION 14.0

SAFETY REPORTS AND DOCUMENTATION

14.1 ACCIDENT REPORTING (SPACE DIVISION)

All accidents will be reported in accordance with Section A-4.0 of the Valley Forge Space Center Safety Manual. A copy of this instruction is included in Appendix A of this plan.

14.2 ACCIDENT REPORTING (NASA-LeRC)

All accidents or incidents (mishaps) will be reported to the General Electric WTG Program Manager immediately. He, in turn, will immediately notify the NASA-LeRC Project Manager and Contracting Officer of any accident resulting in a fatality, disabling injury or property damage of $10,000 or more. He will take immediate steps to initiate investigations and analyses to determine the cause and the corrective actions proposed or taken. He shall forward two full reports to the NASA-LeRC Contracting Officer.

Accidents/incidents of a non-severe level will be subject to appraisal by the General Electric WTG Product and Safety Assurance Engineer. He will take the necessary steps to effect a remedy for the mishap and corrective action to avoid repetition. These will be documented and a copy forwarded to the NASA-LeRc Contracting Officer. Specific safety hazards and significant safety matters will be included in the monthly status reports as appropriate.

APPENDIX A

GENERAL ELECTRIC

ADVANCED ENERGY PROGRAMS DEPARTMENT

SI NO. ____________

REVISIONS			
LTR	DESCRIPTION	DATE	BY

CONTRACT NO. ____________

TITLE:

TABLE OF CONTENTS

APPROVALS:

PROGRAM OFFICE ____________ DATE ____________

ENGINEERING ____________ DATE ____________

SAFETY ____________ DATE ____________

QUALITY CONTROL ____________ DATE ____________

GENERAL ELECTRIC

ADVANCED ENERGY PROGRAMS DEPARTMENT

STANDING INSTRUCTION REVISION

Security Classification	S.I.R. No.	S.I.R. Issue Date	
Drawing No.	**Component Name**	**Program**	**Class**

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GENERAL ELECTRIC

ADVANCED ENERGY PROGRAMS DEPARTMENT

SI NO.________
PAGE____ OF____

PROCEDURE VARIATION SHEET

ITEM NO.	REFERENCE PARAGRAPH	VARIATION DESCRIPTION	GE TC	GE QC	GOV. QC		SIR NO.	ACTION REQUIRED

(2057A)

NO. 7545 **DEFECT REPORT**

NOMENCLATURE	DWG NO.	REV	AN	JOB-LOT-SN	PLNG OPN	DATE

ORIGINATING AREA	ORIGINATOR	PROGRAM-SYST.	QTY INSP	QTY REJ	TOTAL ACC.

DEFECT DESCRIPTION

CORRECTED BY OPERATOR DATE

PRELIMINARY DISPOSITION

- ☐ AN REQ'D – DWG CHG ONLY – CONT PROCESSING – BUYBACK PER ⇒
- ☐ AN REQ'D – HDWE IMPACTED – RWK PER DCR NO. DTD OR⇒
- ☐ REWORK TO ISSUED DWG
- ☐ REFER TO MRB
- ☐ SCRAP
- ☐ STD REPAIR

AN NUMBER ISSUED

MR NUMBER

OTHER (SPECIFY, IE, NOT A DEFECT, ETC) ____

DISPOSITIONED BY DATE

FINAL DISPOSITION (NOT REQ'D IF MR IS WRITTEN OR PRELIMINARY DISPOSITION IS UNCHANGED)

DISPOSITIONED BY DATE

DEFECT, CAUSE (NOT REQUIRED IF MR IS WRITTEN)

DETERMINED BY DATE

CLOSEOUT STAMP DATE

FORM [illegible]

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GENERAL ELECTRIC
SPACE SYSTEMS ORGANIZATION

NONCONFORMANCE REPORT

№ 4S6S5

Page ______ of ______

1. Program	2. Date Occur.	3. Location-Operation	4. Contract No.	5. SO No.		6. Ref. NR Nos.	7.
8. Item Insp/Tested		9. Dwg. No. Alt	10. S/N	11. Supplier & Code No.		12. Buyer	13. P.E. Code
14. Failed Item		15. Dwg. No. Alt	16. S/N	17. Supplier & Code No.		18. Vehicle No.	19.
20. Test/Insp. Spec.	Para.	21. Accrued Time Hrs. Min. Cycles		22. Environment	23. Level	24. Type Test/Insp	25.
26. PO/Job. No.	27. Lot No.	28. Lot Size	29. No. Insp.	30. No. Rej.	31. Last Oper.	32. Source Insp. ☐ Gmt. ☐ GE	33. E.I

34. Description of Nonconformance:

35. Prelim Disp Code | 36. Resp. | 37. [illegible]

38. Originator Date | 39. Validated by Date

40. Disposition Instructions:

41. Problem Causes & Corrective Action Statement:

Corrective Action Designator Date | 42. Recurrency No.

№ 4S6S5

MRB Approvals	43. Engineering Date	44. Quality Date	45. Customer Date	46. Other Date

Form 91235 (Rev. 5/75)

Valley Forge Space Center Safety Manual

SUBJECT	CLASSIFICATION	ISSUED	NUMBER
ACCIDENT REPORTING	ADMINISTRATIVE PROCEDURE	MARCH 1981	A-4.0

4.1 PURPOSE

This instruction outlines the responsibilities, procedures, and basic information on accident reporting.

4.2 PERSONNEL INJURY REPORTING

If you are injured, no matter how slight the injury, report it to your supervisor and then go to the dispensary. (In case of emergency, go directly to the dispensary.) If not treated, a neglected cut, bruise, burn, or scratch may become infected. Accident form FF-40C is requested for injuries of a serious nature or that have a serious potential. This form should be filled out by the injured's immediate supervisor and, as it can and should serve as both an investigative and preventive tool, is best completed with the injured person present.

4.3 VEHICLE ACCIDENT REPORTING

Any accident involving a company vehicle must be filed on accident report ML-2 with the Accountant, Taxes and Insurance, and a copy for the Industrial Safety and Hygiene Office.

4.4 ACCIDENT/INCIDENT REPORTING

Accidents involving property damage, injury to personnel or an incident with loss or injury potential, shall be verbally reported immediately to the Industrial Safety and Hygiene Office. The following Accident/Incident classes are defined for formal reporting purposes:

- Class I — Catastrophe - Any event with loss or damage in excess of $50,000 or results in one or more fatalities or hospitalization of [illegible] or more employees.
- Class II — Major - Any event with loss or damage in excess of $5,000 or results in disabling injury or hospitalization of more than one employee.
- Class III — Significant - Any event with loss or damage in excess of $100 or that requires medical treatment (other than First Aid) to any employee.
- Class IV — Minor - Any event which results in a loss or damage to property or injury to personnel and not qualifying for other classes.

INTERPRETATION CONTACT		
SAFETY ENGINEER	NOVEMBER 1980	A-4-1

Class I or II Accident/Incident will be reported as follows:

Supervisor in the accident area	**Terminates all activity associated with the accident. Immediately reports the accident/incident by dialing A-FIRE (2-3473) and then his manager.**
Patrol Communications Center	**Upon receipt of a report of a Class I or II accident, activates emergency system to alert appropriate emergency stations, notifies Manager, Security and Distribution Services.**
Manager, Industrial Safety and Hygiene	**Notifies Manager, Industrial Security, Safety, Medical and Administrative Services and initiates Plant Fire and Safety Protection activity as situation demands.**
Manager, Industrial Security, Safety, Medical and Administrative Services	**Notifies the following and directs initial investigative action:** **Division Vice President** **Appropriate General Manager** **Mgr. Relations, Organization and Manpower Operation** **GE Liaison with AFPRO** **Legal Counsel (as required)** **Division Public Relations (as required)**

Class III Accident/Incident shall be reported as follows:

Supervisor in the accident area	**Takes necessary steps to prevent additional injury or damage. Notifies the Industrial Safety and Hygiene Office (2-4570) as soon as possible, and his manager.**
Industrial Safety and Hygiene Office	**Notifies the Manager Industrial Safety and Hygiene. Implements regular accident procedure and, in injury cases, coordinates accident procedures with Medical Services.**
Manager, Industrial Safety and Hygiene	**Notifies the Manager Industrial Security, Safety, Medical and Administrative Services. Directs and coordinates accident investigation and corrective action activity.**
Manager, Industrial Security, Safety, Medical and Administrative Services	**Directs overall accident/incident investigation, reporting and correction actions. Submits final accident/incident report according to requirements of authorized private and government agencies.**

A-4-2

Class IV Accident/Injury

Supervisor in the accident area	Notifies the Industrial Safety and Hygiene Office within 24 hours of the incident and notifies his Manager.
Industrial Safety and Hygiene	Reviews accident report, investigates situation as dictated by scope of the problem and maintains records for reference when needed.

4.8 WORKERS' COMPENSATION INFORMATION

The following information applies if you are injured as a result of an accident, or in the course of your employment, or if you are suffering a disability due to an occupational disease.

1. In Pennsylvania, unless you or someone in your behalf, or some of your dependents or someone in their behalf, shall give notice to the employer within 21 days after the accident, no Workers' Compensation shall be due until notice is given. Unless notice is given to the employer within 120 days after the accident, no compensation shall be allowed.

   In cases of personal injury all claims for compensation shall be forever barred, unless a petition is filed with the Workers' Compensation Bureau within two years from the data of accident or date of death.

   Under the Pennsylvania law, if your employer will not accept your claim or enter into an agreement to pay compensation, then you should file a petition with the Bureau of Occupational Injury and Disease, Department of Labor and Industry, Labor and Industry Building, Harrisburg, Pennsylvania. This Bureau will furnish petition forms or any other information you desire concerning your rights.

2. Occupational disease contracted in the course of your employment should be reported to your employer immediately.

   In Pennsylvania, unless you or someone in your behalf, or some of your dependents or someone in their behalf, shall give notice of disability to the employer liable for compensation within 21 days after compensable disability begins, no compensation shall be due until such notice is given. Unless such notice is given to the employer within 120 days after the beginning of compensable disability, no compensation shall be allowed.

   In cases of disability due to an occupational disease, all claims for compensation shall be forever barred, unless a petition is filed within two years after compensable disability begins.

   For additional information concerning your benefits or for any other information about Workers' Compensation or occupational disease, write:

   Bureau of Occupational Injury and Disease
   Labor and Industry Building
   Harrisburg, Pennsylvania 17120.

A-4-3

REV NO. B

47A380020
CONT ON SHEET ii SH NO. i

TITLE RELIABILITY/AVAILABILITY/MAINTAINABILITY AND FAILURE MODE & EFFECTS ANALYSIS PLAN

FIRST MADE FOR MOD-5A WIND TURBINE GENERATOR

REVISION

47A380020
REVISION B
JANUARY 1982

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RELIABILITY/AVAILABILITY/MAINTAINABILITY AND FAILURE MODE & EFFECTS ANALYSIS PLAN FOR THE MOD-5A WIND TURBINE GENERATOR

PREPARED BY: Ken Hofmockel DATE: 14 Sept 1981
KEN HOFMOCKEL
MOD-5A WTG RELIABILITY ENGINEER

CONCURRED BY: W. Lucas DATE: 9/22/81
W. LUCAS, MANAGER
MOD-5A WTG DESIGN ENGINEERING

E. Urbanik DATE: 9/22/81
E. URBANIK, MANAGER
AEPD PRODUCT ASSURANCE

R Barton DATE: 9/16/81
R. BARTON, MANAGER
MOD-5A WTG SYSTEMS ENGINEERING

APPROVED BY: G Drenker DATE: 9/15/81
G. DRENKER, MANAGER
MOD-5A WTG HARDWARE INTEGRATION

L Terrey DATE: 9/22/81
L. TERREY, MANAGER
MOD-5A WTG PROGRAM

CR 1/28/82 REV B
dj

Total Number of Pages 38

PRINTS TO

REVISION LOG

This log identifies those portions of this document which have been revised since original issue. Revised portions of each page, for the current revision only, are identified by marginal striping or text notes.

Revision	Page No.	Paragraph Number(s) Affected	Rev. Date	Approval
A	1-1	1.2	17 Aug 81	B 9/1 KSH
A	2-3	Figure 2	17 Aug 81	B 9/1 KSH
A	2-4	2.2.1, 2.3	17 Aug 81	B 9/1 KSH
A	2-5	Figure 3	17 Aug 81	B 9/1 KSH
A	2-6	Figure 4	17 Aug 81	B 9/1 KSH
A	3-2	Figure 5	17 Aug 81	B 9/1 KSH
A	A-	APPENDIX A	17 Aug 81	B 9/1 KSH
A	B-	APPENDIX B	17 Aug 81	B 9/1 KSH
			RCR 9/29/81	
B	All	General Update	21 Jan 82	KSH RLD
			RCR 1/28/82 dj	

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SECTION 1.0

INTRODUCTION

1.1 PURPOSE

This Reliability/Availability/Maintainability (RAM) and Failure Mode and Effects Analysis (FMEA) Plan for the MOD-5A Wind Turbine Generator (WTG) has been prepared to define the methods for measuring, assessing and tracking the RAM and FMEA to asure that the MOD-5A WTG design will achieve the maximum reliability and therefore the maximum availability and minimum maintenance consistent with the cost of energy constraints.

1.2 SCOPE

This plan covers the RAM/FMEA effort during the Conceptual, Preliminary and Final Design Phases; development, fabrication and two-year operational phases. This plan incorporates comments from NASA LeRC and supercedes the RAM/FMEA PLAN dated April 24, 1981.

SECTION 2.0

ORGANIZATION AND MANAGEMENT

2.1 RELIABILITY ORGANIZATION

The RAM and FMEA effort is organized functionally under WTG Hardware Integration with support from Systems Engineering, Design Engineering, Quality Assurance and Manufacturing. A Reliability Engineer has been assigned to the MOD-5A Program and is responsible for the implementation of the tasks detailed in this plan. A flow diagram of this effort is shown in Figure 1.

2.2 RAM/FMEA GUIDELINES AND PROCEDURES

2.2.1 RAM GUIDELINES

The Reliability Engineer will promote specific attention to the application of Reliability, Maintainability, and Safety considerations by the design engineers through the use of RAM guidelines. These guidelines, attached as Appendix A, were distributed to all MOD-5A design Task Leaders early in the Conceptual Design Phase. These guidelines were updated and reissued early in the Preliminary Design Phase and will be used as the basis of a checklist as part of each design review.

2.2.2 FMEA PROCEDURE

FMEA worksheets will be filled out by the cognizant design engineers, with the guidance of the Reliability Engineer, using the format and procedure attached as Appendix B. The FMEA worksheets will be integrated into the FMEA Analysis per paragraph 4.2 of this plan.

RAM REQUIREMENTS →	CONCEPTUAL DESIGN →	PRELIMINARY DESIGN →	DEVELOPMENTAL & QUAL. TESTING →	FINAL DESIGN →	OPERATIONAL TEST
• AVAILABILITY GOALS	• RELIABILITY TRADEOFFS	• COMPLETE FMEA	• ANALYZE RESULTS OF ACCELERATED LIFE TEST	• UPDATE FMEA • UPDATE SPARES LIST	• MAINTENANCE ANALYSIS
• LIFE REQUIREMENTS	• RAM METHODOLOGY FOR ASSESSING AND TRACKING	• RAM ANALYSIS	• MODIFY RAM ANALYSIS AS REQUIRED	• UPDATE RAM ANALYSIS	• FORCED OUTAGE ANALYSIS
• FAULT PROTECTION	• PRELIMINARY O&M COST	• MAINTENANCE REQUIREMENTS ESTABLISHED	• RECOMMENDED DESIGN IMPROVEMENTS	• O&M UPDATE ↑	• FAILURE RATE
	• PRELIMINARY SPARES	• CONTINUE RELIABILITY TRADEOFFS		DESIGN IMPROVEMENT RECOMMENDATIONS	
	• RELIABILITY GUIDELINES	• UPDATE SPARES LIST			
	• INITIATE FMEA	• TRACK O&M COSTS			
	• SUBSYSTEM RELIABILITY APPORTIONMENT				

FIGURE 1 RAM/FMEA FLOW DIAGRAM

2.3 RAM/FMEA STATUS REPORTS

Monthly reports on the status of the MOD-5A WTG RAM/FMEA activities will be prepared and submitted as part of the monthly technical status report. These reports will include, but not be limited to, the following items:

- Technical Progress: Significant achievements of the reporting period; cumulative status of the RAM/FMEA effort versus program schedule.
- Review of Significant Events: Comments on major design changes and their effect on RAM; assessment of significant failures occurring during the reporting period; discussion of current and/or anticipated reliability problem areas, with recommendations.
- Technical Data and Analyses Summary: Updates and summaries of RAM/FMEA analyses performed during the reporting period including tables of reliability, availability, maintainability and O&M costs.

2.4 INTEGRATION WITH OTHER DISCIPLINES

The Reliability Engineer, working with Engineering and Product Assurance, is responsible for integrating the RAM/FMEA effort with the Product Assurance Program Plan No. 47A380018, the Safety Plan No. 47A380019 and the design engineering effort to assure and effective, timely accomplishment.

SECTION 3.0

RAM/FMEA REQUIREMENTS

The RAM/FMEA requirements are described in Paragraph 2.1.2 of the Statement of Work, Exhibit B to Contract No. DEN 3-153. "The MOD-5A shall be designed for a minimum availability, when the wind is between cut-in and cut-out of 91 percent over the 30 year life, with special considerations given to ease of servicing and maintenance of critical areas."

As a result of Conceptual Design analyses, a design goal of 96 percent availability is assigned for cluster MOD-5A's. Mean Time Between Failures (MTBF) and average annual forced outages are allocated to the subsystem level as shown in Figure 2. In addition to the system forced outage time, scheduled outages for inspection and periodic maintenance are allocated at 90 hours per year. the sum of forced and scheduled outage times are utilized in the availability formula described in Section 4.1. The allocated values meet the availability goal.

SUBSYSTEMS	ALLOCATED MTBF (HRS)	ALLOCATED MTTR (HRS)	ALLOCATED AVG. ANNUAL OUTAGE (HRS)
Hub	18,638	61	28.6
PSC Mechanism	14,600	24	14.4
Blades	130,750	254	17.0
Drive Train	5,500	39	62.3
Hydraulics	2,680	12	38.7
Yaw Mechanism	97,000	177	16.0
Tower	25,000	60	21.0
Controls	1,800	8	38.3
PWR Gen	87,600	48	4.8
WTG SYSTEM	768*	21	241.1**

* The total system MTBF is the reciprocal of the sum of the reciprocals of the subsystem MTBF's.

** The WTG system availability includes a yearly scheduled maintenance for all subsystems of 90 hours.

$$A_{sys} = \frac{8760 - 241.1 - 90}{8760}$$

FIGURE 2 RAM/FMEA SUBSYSTEM MTBF ALLOCATION

SECTION 4.0

RAM/FMEA TASKS

4.1 RAM

4.1.1 DEFINITIONS

Availability (A) - The portion of the time that the WTG is capable of producing power, calculated by dividing the number of hours in a year (8760) less then the total Average Annual Outage (AAO) hours and the yearly Scheduled Maintenance time (SM) by the number of hours in a year.

$$A = \frac{8760-AAO-SM}{8760}$$

Average Annual Outage (AAO)

The product of the number of failures per year (FPY) and the Mean Time to Repair (MTTR).

$$AAO = FPY * MTTR$$

Operations & Maintenance (O&M) Costs

The sum of the annual Direct Labor (DL). Replacement Parts (RP), Consummables (C) and Outside Services (OS).

$$O\&M = DL + RP + C + OS$$

The initial cost of spare parts and support equipment is not included as part of O&M.

Maintainability

The ability of a unit to be restored to operating condition after a failure or preventative maintenance shutdown. This is measured by the mean time to repair (MTTR).

Reliability

The probability that a product will successfully perform a specified function under specified conditions for a specified period of time.

4.1.2 RAM ANALYSIS

During Conceptual, Preliminary and Final Design Phases, the RAM functions will be analytically predicted by the MOD-5A Reliability Engineer, using failure rates, maintenance times, and operating and maintenance costs from similar equipment. The calculated RAM functions will be documented as part of each design review data package. Significant changes will be included as part of each monthly technical report.

Maintainability will be continually reviewed with the Design Task Leaders to assure that maintainability receives significant emphasis. The size and limitations of the standard human figure, as detailed in MIL-STD-1472B; Human Engineering design criteria for Military Systems, equipment and Facilities; will be used as a guide in determining necessary accessibility in order to provide good maintainability of the design.

During the Conceptual Design Phase, the initial predicted RAM functions were calculated using preliminary parts lists. (1) These values were used as allocated subsystem goals against which future assessments will be made.

During Preliminary Design Phase, the RAM functions will be updated with the latest design details and compared to the CDR predicted values and the MOD-5A system Availability requirements. Those portions of the design that contribute the most to the unreliability will be identified and recommendations made in order to modify the design to improve reliability or decrease repair time.

During the Final Design Phase, the predicted RAM functions will be updated using assembly drawings, detailed parts lists and schematics. These values will be compared to the previous predictions and the system availability requirements to assure that the system as designed will meet the minimum availability requirements.

(1) See Preliminary Report - MOD-5A Availability, Operations and Maintenance and Logistics support by R. Lynette and Associates, December 4, 1980 and updated February 4, 1981.

The results of program developmental and qualification testing will be analyzed to determine the validity of the reliability failure rates and predicted availability.

During the two year Operational Test Phase, updated historical failure data will be used to calculate the actual RAM functions. It is anticipated that during the early use and testing of the MOD-5A, there will be design, manufacturing, installation and operational problems that will result in RAM functions less than the requirement. However, improvements will be made and operational solutions implemented that will result in reduced equipment failure, less human error, better procedures and reduced maintenance time. The MOD-5A program will use an effective closed-loop Problem Reporting/Corrective Action system the involves Product Assurance, Design Engineering and Systems Engineering. Details of the failure reporting system to be implemented on MOD-5A are described in the Product Assurance Plan for the MOD-5A Wind Turbine Generator.

4.2 FMEA

A preliminary FMEA was performed during the Conceptual Design Phase to identify the top level hazards that could cause danger to personnel or result in loss of the WTG structural integrity. The FMEA worksheets were completed by the Reliability Engineer and the results were reviewed with the Design Task Leaders in insure that compensating provisions are included in the design.

During the Preliminary Design Phase, a detailed FMEA will be completed. Worksheets for this FMEA will be filled out by the cognizant Design Engineers and reviewed and integrated into the FMEA by the MOD-5A Reliability Engineer. the FMEA procedure to implement this effort is attached as Appendix B. During the Final Design Phase, the FMEA will be keyed to assembly drawings and updated as appropriate to assure that all parts of the design are covered and the effect of any design changes can be readily assessed.

4.3 DESIGN REVIEW AND TRACKING

The MOD-5A Reliability Engineer will participate in all formal design reviews (CDR, PDR and FDR), internal design reviews on subassemblies, and subcontractors PDR's and FDR's. The design reviews shall include:

1) A review of current RAM functions
2) FMEA summary
3) Identification of major items contributing to the unreliability
4) Review of RAM/FMEA milestones and schedules

The Reliability Engineer will also informally monitor RAM and FMEA analyses by periodic contact with engineering Task Leaders.

APPENDIX A

MOD-5A RELIABILITY, MAINTAINABILITY

& SYSTEM/PERSONNEL SAFETY GUIDELINES

SECTION 1

GENERAL

1.1 Have attachment points been provided for hoists jacks, etc. for use during assembly/disassembly and erection?

1.2 Have fixtures and tools been identified for use during assembly/disassembly and erection?

1.3 Have provisions been made to lock and/or tether the rotor in both the horizontal and vertical positions during maintenance?

1.4 Have the means of detecting a failed redundant part been included?

1.5 Have the effects of a hostile environment (wind, ice, salt spray, etc.) been considered?

1.6 Have all modes of operation; manual, start-up, generating, normal shutdown, emergency shutdown, lockout, standby and weathervaning been considered?

1.7 Has an adequate structural safety margin been provided for all design and other extreme loads?

1.8 Have extra foundation points been provided for tie/tag lines?

1.9 Have foundation points been provided for winch/crane?

1.10 Have provisions been made to lock yaw movement - even with a loss of hydraulic pressure?

1.11 Have provisions been made for field repair of items such as the PSC mechanism?

1.12 Have provisions been made to inspect the condition of the paint on the tower, nacelle and rotor periodically?

1.13 Has each maintenance and inspection task been made as easy as possible?

1.14 Have the design load factors (fatigue, yield & ultimate) been considered in all structural parts of the design?

SECTION 2

ROTOR

2.1 Can the rotor and blade survive repeated lightning strikes? (Is system designed for lightning?)

2.2 Is the system capable of surviving impact by a 4 pound bird?

2.3 Has a means of attaching a hoist of bosun's chair/safety lines been provided at the hub?

2.4 Are teeter bearings capable of being replaced without removal of the rotor?

2.5 Has a means of checking the condition/capability of the snubbers been considered?

2.6 Have provisions been made for field repair/replacement of the pitch mechanisms?

2.7 Has a means of detecting ice on the blades been provided?

2.8 Can the blades be inspected for cracking and effects of humidity?

2.9 Can the condition of the teeter bearings be confirmed by inspection?

2.10 Can the condition of hydraulic lines and PSC mechanisms be confirmed by inspection?

2.11 Are all sensors, that are operationally critical, redundant? Can the failure of a redundant sensor be detected?

2.12 Have provisions been made for lube oil level inspection, replenishment and draining?

2.13 Have means of checking the torque on bolts been provided?

2.14 Are the teeter bearing seals replaceable without removing bearings?

2.15 Are the teeter brake/lock inspectable?

2.16 Have tie down points been provided on the blade?

2.17 Have provisions been made for access from the nacelle to the shaft or hub?

2.18 Is the low speed shaft capable of being locked?

2.19 Is the blade tip designed to move to the feathered position if hydraulics are lost?

2.20 Can blade tips be lowered to the ground for maintenance without the use of a crane?

2.21 Can the snubbers be replaced without removing the rotor?

2.22 Have provisions been made to filter the lube oil at the time of filling?

SECTION 3

PITCH CONTROL SYSTEM

3.1 Will one blade tip prevent overspeed if the other tip fails in the full power position?

3.2 Is the lubrication system capable of operating at least 6 months between checks?

3.3 Have provisions been made to prevent the loss of the blade tip if bearings fail?

3.4 Have partial failures of valves and solenoids been considered in the FMEA?

3.5 Have provisions been made to drain the hydraulics when removing/servicing a component?

3.6 Are all flex hoses capable of being inspected?

3.7 Are blade tips capable of being locked when the actuators are being repaired/replaced?

3.8 Is the emergency accumulator condition continuously monitored during operation?

3.9 Is the feather latch fail safe?

3.10 Will valves and solenoids withstand G loading?

3.11 Has ease of service of hydraulics at P.S.C. been considered?

SECTION 4

YAW DRIVE SYSTEM

4.1 Are limit switches of the proximity type?

4.2 Can conditions of the yaw bearing be checked periodically?

4.3 Is the yaw bearing and joint weather resistant?

4.4 Can the yaw bearing be easily oiled/greased periodically?

4.5 Can the yaw drive system be periodically checked for yaw action and drive rates?

4.6 What type of position sensors are anticipated? What will they be checked (correlated) against?

4.7 Is the inspection of the gripper drive plates in the maintenance procedure?

SECTION 5

NACELLE

5.1 Have provisions been made for lifting heavy items within the nacelle?

5.2 Have provisions been made to hoist or store oil and maintenance items into the nacelle?

5.3 Has a fail-safe automatic fire extinguisher system been provided?

5.4 Have personnel tethering places been provided on top of the nacelle and provisions for inspection/testing of these tethering places?

5.5 Is covering of nacelle removeable in sections?

5.6 Have adequate convenience outlets been provided?

5.7 Has work space been provided to maintain last two stages of gearbox?

5.8 Has access been provided from nacelle to hub?

5.9 Are lights (normal and emergency) available inside nacelle and tower?

5.10 Has a means of communication with the base of the tower or the Generator Control Unit been provided?

5.11 Are aircraft warning lights and wind sensors accessible?

5.12 Is there an exit at each end of the nacelle for safety reasons.(egress)?

5.13 Can caccumulated moisture (water) escape from bedplate?

5.14 Are electrical lines and/or hydraulic lines routed in inaccessible areas?

5.15 Can wind sensors be pulled into nacelle (from inside nacelle) for maintenance purposes?

5.16 Where are rescue-matics stored, and are they periodically inspected?

5.17 Has a means of evacuating injured or sick personnel been included?

SECTION 6

CONTROLS

6.1 Can on and off modes of all controls be sensed?

6.2 Have remote (base of tower or Generator Control Unit) diagnostic provisions been made and what are the indicators?

6.3 Does the electronics need to be cooled? heated?

6.4 Can system be operated as a single speed system?

6.5 Can condition of battery and charger be periodically measured?

6.6 Are controls fail safe on loss of power?

6.7 Are adequate isolation provisions, to protect against lightning and EMI, provided?

SECTION 7

ELECTRICAL

7.1 Are generator bearings replaceable in the nacelle, without removing the geneator rotor?

7.2 Are all high voltage lines shielded?

7.3 Have lightning arrestors been provided?

7.4 Have junction boxes been provided to make cable or sensor changeovers readily?

7.5 Have proper aircraft warning lights been included in the nacelle design?

7.6 Is the system protected against islanding while delivering power?

7.7 Has intrusion protection been provided for the ground equipment and tower?

7.8 Has a reclosure block been provided for momentary line faults?

7.9 Has a means of preventing the generator from driving the blade been provided?

7.10 Has phase sequence and line voltage anomaly protection been provided?

7.11 Do the main breakers have redundant means of disconnect?

7.12 Are all components, critical to shutdown, powered from redundant sources?

7.13 Have generator and transformer thermal protection been provided?

7.14 Is overspeed protection fail safe?

7.15 Has a means been provided to prevent voltage surges from causing winding to wind overvoltage?

SECTION 8

TOWER/FOUNDATION

8.1 Are electrical outlets available inside tower?

8.2 Are lights (normal and emergency) available inside the tower?

8.3 Have foundation points been identified for blade tie down and/or gin pole and winch anchors?

8.4 Does paint confrom to FAA marking requirements?

8.5 Has an emergency ladder been provided?

8.5.1 Does ladder contain a safety cable?

8.6 Are guard rails provided on upper platform?, on access device?

8.7 Are sliprings and power cables protected so personnel can not accidentally contact connections?

8.8 Does tower base contain a solid landing for tower lift?

8.9 Is tower access door interlocked to prevent unauthorized entry?

8.10 Are safety interlocks provided for lift and gate on personnel fence at both ends?

SECTION 9

DRIVE TRAIN

9.1 Have provisions been made for protection of the drive train during over-torque conditions?

9.2 Has a positive lock been provided on the rotor?

9.3 Has enough room been left for removal of high speed shaft components?

9.4 Has enough room been left for removal and/or repair of brake on high speed shaft?

9.5 Has enough room been left for removal and/or repair of drivetrain slipring?

9 6 Has room been left for inspection of torque striping on bolts or the use of bolt tensioners during bolt inspection?

9.7 Do bolted connections have adequate shear capability as well as friction?

APPENDIX B

Reliability Procedure

For

Failure Mode and Effects Analysis
(FMEA)

For

MOD-5A WTG

SECTION 1.0

INTRODUCTION

1.1 PURPOSE

This document provides guidelines for the accomplishment of Failure Mode and Effects Analysis as required by the Statement-of-Work, Exhibit A, to Contract DEN 3-153. It is a procedure for analysis of hardware items to determine those items contributing most to the MOD-5A System unreliability, and to reduce to the greatest extent possible, catastrophic single point failures. It will also be used as a basis for the System Safety Analysis.

1.2 SCOPE

This document is applicable to the MOD-5A Wind Turbine Generator design, development and test. The FMEA will be initiated during the Conceptual Design Phase, completed during the Preliminary design Phase and updated during the Final Design Phase. The FMEA will include all modes of operation and environmental conditions.

1.3 DEFINITION OF FMEA

Failure Mode and effects Analysis is a reliability task which documents all possible failures in a system design within specified ground rules, determines by failure mode analysis the effect of each failure on the system operation, and identifies critical single failure points, i.e., those failures that can cause catastrophic damage to the MOD-5A hardware or affect the safety of maintenance and operating personnel. The FMEA will be performed on the basis of single independent failures. Contributory failures will not be included.

2.0 FMEA DETAILS

Accomplishment of the MOD-5A WTG FMEA consists of the following steps:

a) Define the MOD-5A WTG system. Obtain all descriptive information available such as block diagrams, specifications and drawings.

b) Construct a reliability logic block diagram of the MOD-5A WTG system for each mode of operation. The diagrams are developed starting at the top level of the system and extending downward to the lowest level of system definition at the time of the analysis, using drawing tree SK80-12-5 as a guide. These reliability logic diagrams are not descriptive block diagrams of the system that show the interconnection of equipment. The logic diagrams used for an FMEA show the functional interdependencies between the components so that the effects of a functional failure may be readily traced through the system. All redundancies or other means for preventing failure effects should be shown as parallel blocks or notes.

c) At the lowest level of system definition, FMEA worksheets shall be completed using the format of Figure B-1. Entries on the format shall be as follows:

1. SUBSYSTEM - The major division of the MOD-5A WTG, as defined in Figure 2 of the RAM/FMEA Plan, will be referenced.

2. COMPONENT - The lowest level of system definition will be referenced including the drawing number when available.

3. PAGE NUMBER - Sequential number to be assigned when FMEA analysis is issued.

4. FMEA NUMBER - A number assigned by the Reliability Engineer to correlate the reliability block diagram to the FMEA worksheet.

5. FUNCTION OF COMPONENT - Concise statement of the function(s) performed by the component.

6. FAILURE MODES & EFFECTS - Give the specific failure mode after considering the four basic failure conditions: (a) failure during operation, (b) failure to operate at a prescribed time, (c) failure to cease operation at a prescribed time and (d) premature operation.

7. APPLICABLE OPERATING MODES - Reference all the applicable modes of operation as defined in block No. 17.

8. FAILURE MODE FREQUENCY - The percentage of the failure rate attributed to each failure mode.

9. FAILURE RATE - The number of failures expected per million hours of operation.

10. MEAN TIME BETWEEN FAILURES - The reciprocal of the failure rate expressed in years.

11. FAILURE SEVERITY - Indicate the failure severity in one of the four categories: (I) Minimal - minor items that can be repaired when convenient and no possible personnel injury; (II) Marginal - no loss of generating capability, but repair must be accomplished within two weeks to avoid shutdown and possible personnel injury that requires first aid; (III) Critical - causes WTG shutdown and possible personnel injury that requires hospitalization; (IV) Catastrophic - destruction of a major element of the WTG such as rotor or gearbox and possible personnel fatal injury or permanent disablement.

12. FAILURE DETECTION METHODS - A description of the means by which this failure mode could be detected. Special attention should be paid to detecting a failure of a standby redundant component.

13. FAILURE CAUSE & COMPENSATING PROVISIONS - For each applicable failure mode, describe the cause including environmental stress factors and operational modes and a description of any compensating provisions that reduce the effects of this failure.

14. NAME - The name of the cognizant Design Engineer or Task Leader.

15. DATE - The date the worksheet was first completed.

16. REV. - The date of any revision.

17. OPERATING MODES - A list of the operating modes that are to be referenced in block No. 17.

d) A summary list of catastrophic potential single point failure modes including both those that could affect hardware and personnel.

GENERAL ELECTRIC
ADVANCED ENERGY PROGRAMS DEPARTMENT

FMEA WORK SHEET

FIGURE B-1

FAILURE MODE AND EFFECTS ANALYSIS

SUBSYSTEM (1)	COMPONENT (2)	PAGE: (3) FMEA NO: (4)

FUNCTION OF COMPONENT: (5)

FAILURE MODES & EFFECTS (6)	APPLICABLE OPERATING MODES (7)
1	
2	
3	
4	

FAILURE FREQUENCY				FAILURE SEVERITY* (11)			
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	(8)	(9)	(10)				
2							
3							
4							

FAILURE DETECTION METHODS

1 (12)
2
3
4

FAILURE CAUSE AND CORRECTIVE ACTION (IF APPLICABLE)

(13)

NAME (14) DATE (15)

OPERATING MODES (17)
A. GENERATING
B. STARTUP
C. NORMAL SHUTDOWN
D. EMERGENCY SHUTDOWN
E. LOCK OUT
F. STANDBY
G. WEATHERVANING

REV.
REV. (16)

REV NO. A B

47A380021

CONT ON SHEET ii SH NO. i

TITLE

FIRST MADE FOR MOD-5A WTG PROJECT

REVISIONS

A INCORP AN-1 12/28/82 A2/1/4

B INCORP ...

REV. "B"
APRIL 1984

SPECIFICATION FOR

NACELLE FAIRING

AUGUST 1981

PREPARED BY: Serge Onufrey 9/10/81
Responsible Engineer

REVIEWED BY: W C [signature] 9/10/81
Design Engineering

[signature] 9/11/81
System Engineering

J. C. Jankauskas 9-2-81
Manufacturing

A. Cheddar 9-10-81
Quality Assurance

TOTAL NUMBER OF PAGES 12

WTG 50

PRINTS

MADE BY

ISSUED [signature] 9/17/81

APPROVALS

AEPD
Philadelphia, PA

REVISION LOG

This log identifies those portions of this document which have been revised since original issue. Revised portions of each page, for the current revision only, are identified by marginal striping.

Revision	Page No.	Paragraph Number(s) Affected	Rev. Date	Approval
A	2-1	2.0	12/13/82	
A	3-1	3.1, 3.4		S.O./WCL
A	3-2	3.5, 3.6		AN-1
A	3-4	3.11, 3.13, 3.14		
B	2-1	2.0	04/11/84	
B	3-1	3.1		
B	3-2	3.6		S.O. 4/11/84
B	3-4	3.11, 3.14		AN-2

TABLE OF CONTENTS

SECTION 1.0

SCOPE

This specification establishes the design requirements for an environmental enclosure for the MOD-5A Wind Turbine Generator, hereinafter referred to as the fairing.

SECTION 2.0

APPLICABLE DOCUMENTS

General Electric Drawing 47E381113 Fairing Envelope

SECTION 3.0

REQUIREMENTS

3.1 ENVELOPE CONFIGURATION

The external configuration shall be as shown on GE Drawing 47E381113, but the manufacturer may suggest alternate construction details for GE approval provided the intent of this specification is met.

Maximum Wall Thickness (At Frames) 4.0 inches

3.2 WEIGHT

19,000 lb. maximum

3.3 LOADING (External)

Walls: Must withstand horizontal wind loading of 50 lb/ft. sq.

Roof: a) vertical uplift wind loading of 51 lb/ft. sq.

b) live load of 50 lb/ft. sq., or snow load of 42 lb/ft. sq.

3.4 INSTALLATION

Must be capable of being lifted as an assembly and bolted to horizontal surfaces. Access to mounting bolts from outside only, to mate with tapped holes or retained nuts in fairing wall. Mating bedplate surface will be flat within .25 in.

3.5 ROOF ATTACHMENT

Roof attachment to walls shall have provisions to facilitate partial removal of the roof in individual pieces using built-in lifting lugs, for access to interior equipment. Roof fasteners will be accessible only from the interior. Roof joints to be of a design that eliminates leaks after reassembly.

3.6 PENETRATION

Provisions shall be made for the following penetrations, (location shown on GE Drawing 47E381113.

a) Inlet vent in side walls: 30.5 x 30.5 with provision for making weather tight

b) Ventilation fan and louvers: 30.5 x 30.5 with provision for making weather tight

c) Generator Cooling Air Louver: 30 x 50 Side Wall

d) Roof Access and Skylight: 37 x 46-1/2

3.7 INSULATION

Thermal insulation shall be provided on the interior between frames. Insulation shall have an "R" factor of 11 or more.

3.8 ENVIRONMENT

The MOD-5A shall be designed to withstand the following environmental conditions.

Temperature -	-40 degrees C to +49 degrees C (-40 degrees F to +120 degrees F) ambient air
Rain -	10 cm/hr (4 inches/hour)
Hail -	2.5 cm. (1 in.) diameter 20 m/sec (45 mph) velocity
Ice (Glaze) -	5 cm (2 in) thickness 961 kg/cum (60 lb/cuft) on all external surfaces
Snow-	200 kg/sqm (42 lbs/sq ft.)
Humidity - Sand/dust - Fungus -	exposure equivalent to Mil-std-210B for exposed or sheltered around equipment as applicable
Fauna -	insects and 1814 gm (4 lb) birds moving at 16 m/sec (35 mph)
Solar Radiation -	98,500 cal/square meter hr (363 btu/square ft./hr) 4 hours daily
Altitude -	sea level to 7,000 ft.

3.9 LIFE

30 yr. minimum with periodic maintenance.

3.10 MATERIAL

Material of construction may be aluminum or steel, provided corrosion protection is adequate. If fairing is aluminum construction, an elastomeric gasket or other means shall be provided to protect against galvanic corrosion of aluminum in contact with steel bedplate. Fasteners shall be protected by zinc or cadmium plating.

3.11 EXTERIOR FINISH

Exterior finish shall be as shown on Drawing 47E381113.

3.11.1 MARKINGS

Exterior shall be painted with markings as shown on Drawing (Later).

3.12 WORKMANSHIP

Workmanship, details of construction, and general appearance shall be to the best commercial practice for similar enclosures for power generation equipment as used by electric utility companies.

3.13 INTERIOR HOIST

(Deleted)

3.14 WORK PLATFORMS

(Deleted)

SECTION 4.0

QUALITY ASSURANCE PROVISIONS

4.1 DRAWING APPROVAL

Prior to the start of fabrication, the supplier shall submit construction drawings to General Electric for approval.

4.2 CONSTRUCTION DRAWINGS

The fairing shall be accompanied by three (3) copies and one reproducible copy of all construction drawings showing the as-built definition.

SECTION 5.0

PREPARATION FOR DELIVERY

The fairing shall be shipped broken down as flat panels, (walls and roof) with accompanying hardware for assembly on site, separately boxed. Panels shall be packed for shipment by road or rail. For rail shipment, the shipping configuration shall not exceed the envelope shown in Figure 1.

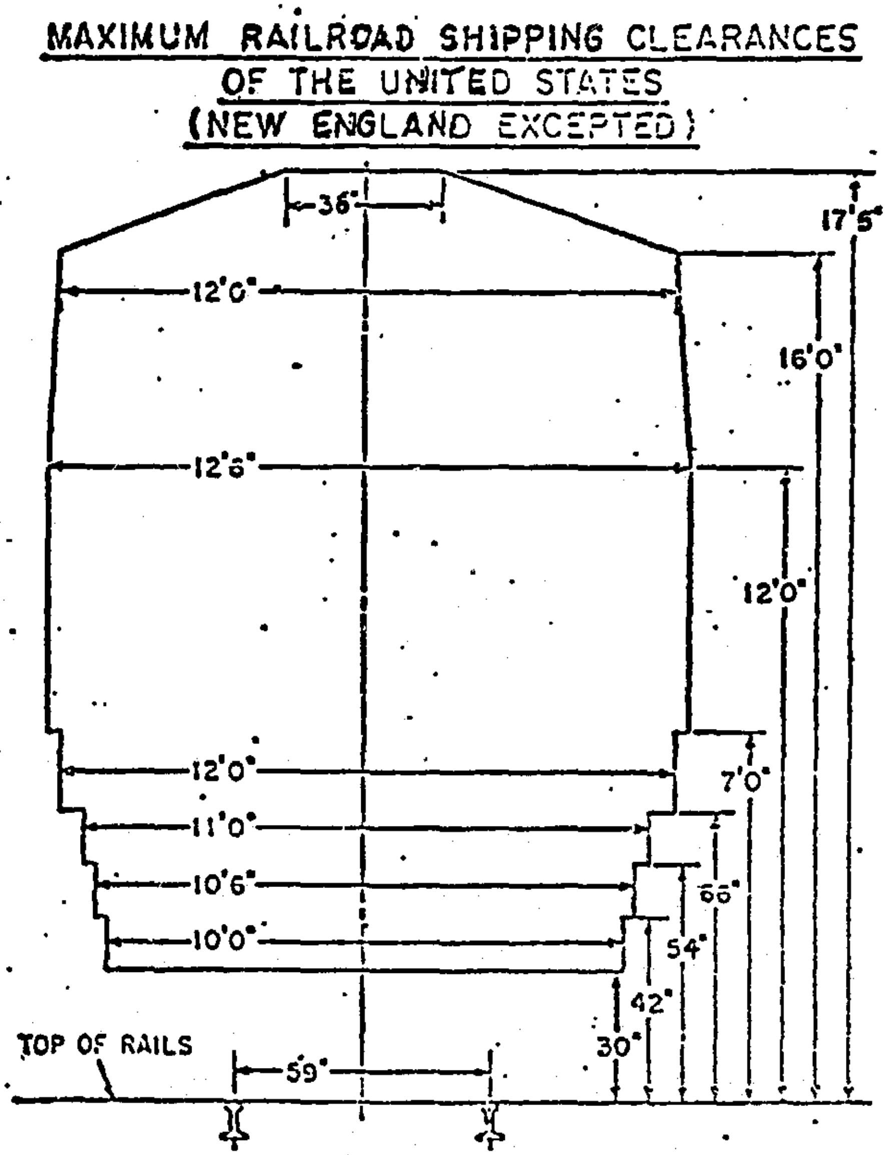

Figure 1

Rail Size Limits

GENERAL ELECTRIC

47A380022
CONT ON SHEET ii SH NO. i

REV NO. A B

47A380022
CONT ON SHEET ii SH NO. i

TITLE

FIRST MADE FOR

REVISION

SUPPORT TOWER AND FOUNDATION SPECIFICATION

FOR THE

MOD-5A WIND TURBINE GENERATOR

AUGUST 1983

REV "B"
Nov 1983

A ISSUED REV-A PER AN-1 11/7/83

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Systems Engineer DATE: 18 Aug 83

Engineering Manager DATE: 8/18/83

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WTG 508

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KING OF PRUSSIA PA. LOCATION

47A380022
CONT ON SHEET ii SH NO. i

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Revision	Page No.	Paragraph Number(s) Affected	Rev. Date	Approval
A	2	ALL	2 Nov. 83	UAK RBS
A	4	3.1.1	2 Nov. 83	
A	5	Table 3.1.2	2 Nov. 83	
A	6	3.1.3.2	2 Nov. 83	
A	7	3.1.3.3, 3.1.4.1	2 Nov. 83	
A	9	3.1.4.2	2 Nov. 83	AN-1
A	9	3.1.5	2 Nov. 83	
A	10	3.1.8	2 Nov. 83	
A	13	3.1.9	2 Nov. 83	
A	14	3.3	2 Nov. 83	
A	15	3.5.1, 3.5.2	2 Nov. 83	
A	16	3.5.3, 3.5.5	2 Nov. 83	
A	17	3.5.6	2 Nov. 83	
B	2	ALL	1 Dec. 83	UAK RBS
B	5	3.1.2	1 Dec. 83	AN-2
B	13	3.1.9	1 Dec. 83	
B	16	3.5.4	1 Dec. 83	

TABLE OF CONTENTS

SECTION 1.0

SCOPE

This specification establishes the design requirements for the MOD-5A Wind Turbine Generator (WTG) Tower and Foundation.

SECTION 2.0

APPLICABLE DOCUMENTS

The latest issue of the following documents apply to the extent specified herein. In the event of conflict between this document and the documents listed below, this document shall take precedence.

General Electric Drawings

47D382000	MOD-5A Tower Geometry and Tolerance Diagram
47E382354	Tower/Yaw Platform Assembly
47E382355	MOD-5A Tower Structure Assembly
47E382356	MOD-5A Tower Assembly
47E382260	Nacelle Access Lift Installation
47A380002	Structural Design Criteria for MOD-5A WTG
TBD	Wiring Installation
47A380054	General Welding and Surface Preparation
47E382219	Lower Yaw Housing Structure
47A380048	Specification for Material Finishes MOD-5A Structure
47D382283	Tower Requirements for WTG Assembly
47A380062	Material Control Data Specification for the MOD-5A WTG

General Electric PIRs and Memorandums

WTG-MOD-5A-83-280	Loads Update for Model 304.1
WTG-MOD-5A-83-283	Final Design Limit Loads for Model 304.1

Industry Standards

ASCE Design and Construction of Steel Chimney Liners, 1975

AISC Specification for Design, Fabrication and Erection of Structural Steel for Buildings, & AISC Code of Standard Practice, 1980

ANSI/AWS-D1.1-82 Structural Welding Code - Steel

SSPC-SP10-63T Steel Structures Painting Council Surface Preparation

Uniform Building Code, 1982 Edition

ANSI/ASME A17.1a Safety Code For Elevators and Escalators, 1982

ASME Boiler and Pressure Vessel Code, 1983

ACI 215 R-74 "Considerations for Design of Concrete Structures Subjected to Fatigue Loading

ACI SP-41 "Fatigue of Concrete"

PCA Bulletin RD 059.01E "Design of Reinforced Concrete for Fatigue"

PCA Bulletin RD 045.01E "Fatigue Strength of High-Yield Reinforcing Bars"

ACI 318-77 "Building Code Requirements for Reinforced Concrete"

SECTION 3.0

REQUIREMENTS (BASELINE)

3.1 DESIGN CRITERIA

The tower shall serve as a support structure for the wind turbine generator topside components (yaw drive subsystem, nacelle - containing the gearbox and generator, and rotor - consisting of yoke and blades). The tower shall afford access, through the interior of the shell, to the topside components. The tower shall be a cylindrical shell structure of circular cross-section, formed from steel plate, with the lower section flaring out to form a stable base. The top section interfaces with the lower yaw bearing adapter structure. The tower shall be erected on a level concrete foundation and secured by anchor bolts.

The design approach shall follow the Structural Design Criteria (47A380002) as a guide except as noted herein.

3.1.1 CONFIGURATION

The tower shall be a cylindrical shell with a conical base. The cone shall taper from a base outer diameter of 22.5 feet to 14.5 feet nominal outer diameter at an approximate 50 foot elevation. At this point, it transitions to a circular shell through a knuckle section. Overall tower height shall be 224.73 feet to the yaw bearing interface, per GE Drawing 47E382000. This height includes the lower yaw adapter section, which is procured separately. Plate thickness will be varied to maintain a nearly constant safety margin over the length of the tower.

3.1.2 MATERIALS

The materials used shall be those indicated in Table 3.1.2. The basic tower shell shall be constructed of steel plate having a minimum yield strength of 60,000 PSI. The material shall meet the toughness requirements (minimum CVN >15 ft-lb) at the temperature indicated in Table 3.1.2. Depending on the actual WTG site, GE will specify either the cold or moderate temperature. If no temperature is indicated, no impacts will be required.

TABLE 3.1.2 TOWER AND FOUNDATION MATERIALS

COMPONENT	MATERIAL (ASTM)	IMPACT TEMPERATURE	
TOWER:		COLD	MODERATE
Tower Shell	A678 GR B Q&T	-55°F	+ 40°F
Knuckle	A633 GR D	-55°F	+ 40°F
Base Plate	A516 GR 60 Q&T	-55°F	+ 40°F
Chair Details	A678 GR B Q&T	-55°F	+ 40°F
Door	A36	--	--
Door Reinforcing	A678 GR B Q&T	-55°F	+ 40°F
Platforms	A572 GR 50	--	--
Anchor Bolts	A193 B 7	-40°F	+ 40°F
FOUNDATION:			
Portland Cement	C150		
Aggregate	C33		
Reinforcing Steel	A615 and A184		
A-D Mixtures	C260 and C494		
Ready-Mixed Concrete	C94		

3.1.3 LOADS

GE Drawing 47E382000 shows the load application coordinate system as used by General Electric in all referenced GE PIR documentation. Current loads are per PIR 280 and PIR/283.

Additional loads, e.g. tower construction are to be applied by the contractor as required. Wind loads shall be computed on the basis of the design wind pressures given in Table 3.1.3 and projected area normal to the wind.

TABLE 3.1.3
DESIGN WIND PRESSURE ON TOWER

PRESSURE (LB/FT^2)

HEIGHT (FT)	HURRICANE	ALL OTHER
0 - 50'	29.6	7.4
50 - 100'	30.7	8.1
100 - 150'	31.4	8.5
150 - 200'	31.8	8.7
200 - 250'	32.1	8.9

3.1.3.1 Normal Operation

The loads for normal operation are given in GE PIR 280 as mean and fatigue type loads. A factor of safety of 2.0 on buckling or yield shall be used. It is expected that the tower will be designed by the abnormal loads and stiffness specified below and then checked for adequacy for fatigue and seismic loadings. Fatigue loads at points in between the top and bottom of the tower shall be linearly interpolated. Seismic loads shall be in accordance with the latest Uniform Building Code method for Zone 3. Seismic loads shall be added to the 99.9 percentile normal operating loads, and the one-third (1/3) increase in allowables allowed by the AISC specification shall be applied.

3.1.3.2 Abnormal Conditions

Limit loads are due to rarely occurring operating and non-operating conditions and are given in PIR 283. The tower shall have a factor of safety against buckling or yield allowables of 1.5 for all limit load conditions. Since the factor of safety is reduced for abnormal conditions, the one-third increase in allowables provided for by the AISC specification shall not be used.

3.1.3.3 Special Cases

The subcontractor shall investigate vortex shedding induced stresses, and transportation, handling and tower and WTG erection stresses. Vortex shedding shall consider the tower with and without the nacelle attached and shall investigate the need for reducing tower motion during tower erection and WTG erection.

The tower shall be designed for the "Twin Boom" method of installing the yaw, nacelle and rotor subassemblies. Estimated maximum lift load is 350 Kips at a 30 foot radius from the tower centerline. Geometry and weight of the various modules shall be as specified in GE Drawing 47D382283.

The tower, boom and boom falls seats, foundation, etc., shall be designed with the same allowables and factors of safety as for normal operation when subjected to the proof test load. The proof test load shall be equal to 1.25 times the sum of the maximum lift load and all lifting fixture and cable weight. The proof test load shall be applied at the maximum reach specified in GE Drawing 47D382283. Other lift loads shall be investigated to ensure they do not exceed the maximum lift moment.

3.1.4 STRESSES

In designing the tower, the AISC Steel Construction Manual allowable stress and interaction formulas shall be followed. However, the allowable buckling stresses shall be those specified in paragraph 5.6 "Design and Construction of Steel Chimney Liners", ASCE, except the critical load shall be modified to consider the tower weight and the weight at the top of the tower per Table 2-7, Theory of Elastic Stability, by Timoshenko & Gere, 2nd edition, McGraw Hill, pg. 104. The Structural Design Criteria Specification 47A380002 will be used as a guideline. The foundation design shall conform to "General Requirements" part 4 of ACI 318-77.

3.1.4.1 Tower Fatigue Analysis

The fatigue analysis for the tower shall be based on the RMC/CIS (Root-Mean-Cubed/Cyclic-Intercept-Stress) method. The method simply requires the RMC stress to be less than the CIS number. The CIS value is the stress from the S-N curve for the weld category in question that corresponds to the total number of WTG lifetime cycles (400×10^6 cycles).

To compute the RMC stress at any tower height, the M_y and M_z RMC alternating (half-range) values at the yaw bearing and tower base are first computed from PIR 280 Tables H-83, H-84, H-107, H-108 and III-13 & 17. That is, the Type III start/stop cycles must be combined with the Type I/II RMC values. Then M_y and M_z RMC values can be linearly interpolated, are vectorially summed, and the RMC nominal stress using the tower modulus, Z, found. This value multiplied by any stress concentration factor, K_f, should be less than the CIS alternating value, i.e.:

$$K_f * \frac{(M_y^2 + M_z^2)^{1/2}}{Z} \leq \text{CIS}$$

The CIS alternating values for the weld categories expected are:

B Weld, CIS = 1,580 psi
C Weld, CIS = 1,124 psi
E Weld, CIS = 692 psi

The stress concentration values shall be based on the Finite-Element-Model study conducted by CBI in May of 1983, which shall be subsequently approved and documented by GE.

All tower welds shall be checked including the chair, door, baseplate and other details.

The maximum stress range and the mean stress shall also be reported so that GE may evaluate the state of fatigue stress.

3.1.4.2 Foundation Fatigue Analysis

The fatigue analysis, for the concrete foundation, will be based on using the guidelines and statistical material contained in ACI 215R-74, "Considerations for Design of Concrete Structures Subjected to Fatigue Loading" (or any more recent ACI update), ACI SP-41, and PCA Bulletins RD 059.01E and RD 045.01E. All dynamic loadings are supplied by GE in terms of cycles per lifetime of structure.

The foundation anchor bolts shall be sized to the effective external limit load within the AISC allowables. The effective external load is the nominal external load increased by the best estimate of the bolt prying action or by a 1.25 factor whichever is greater. All stresses shall be based on the thread pitch stress area and include bending and tension. The bolts shall then be checked for fatigue using the RMC/CIS method. The effective bolt load for fatigue shall be reduced to account for joint resiliency and load introduction factors based on a finite-element analysis of the selected anchor bolt configuration. For 2-1/2 inch or less diameter bolts the allowable CIS alternating stress shall be 692 psi. Bolts shall be specified for 8 threads/inch rolled after heat treatment.

3.1.5 STIFFNESS

The tower structure shall be designed to provide suitable stiffness to control the frequency of the WTG lower frequencies (first tower bending modes) in the y and z directions to fall between .34 Hz and .35 Hz. Frequencies shall be calculated assuming a rigid mass of 1,085,000 lb. (nacelle mass) a distance of 208 inches above the lower yaw bearing mounting surface and a rigid foundation attachment.

3.1.6 ENVIRONMENT

The tower shall be designed to withstand environmental conditions specified.

3.1.6.1 Temperature

The WTG shall be capable of survival in temperatures from -40°C to +49°C (-40°F to +120°F) ambient air, and operation from -30°C to +40°C (-22°F to +104°F) ambient air.

3.1.6.2 Seismic

The WTG, excluding the foundation, shall be designed to the seismic requirements characteristic of Zone 3 per the Uniform Building Code.

3.1.6.3 Precipitation

The WTG shall be subjected to the following precipitation environments after installation:

Rain:	4 inches/hour
Hail:	1.0 inch. dia., 50 lb./cu. ft., 66.6 ft./sec terminal velocity (for horizontal and vertical surfaces)
Ice:	2.0 inches, 60 lb./cu. ft. on all external surfaces non-operating
Snow:	Blade: 21 lb./sq. ft. Nacelle: 41 lb./sq. ft.

3.1.6.4 Lightning

The WTG shall be subjected to lightning strikes as defined in Figure 3.1.6.4 (Figure B-1, SOW, Exhibit B).

3.1.6.5 Projectile Impact

The WTG shall be subjected to impact of 4 lb. birds moving at 35 mph, on surfaces above 150 feet. Failures are not permitted, but local yielding is allowed.

3.1.7 DESIGN LIFE

The tower shall be designed to meet a 30 year life or 400 x 10^6 load cycles without structural failure. The tower shall be protected by a paint system specified in paragraph 3.4.

3.1.8 INTERFACES

The tower shall interface with the lower yaw adapter structure as specified in GE drawing 47E382355. Note that the yaw adapter structure has thirty-six (36) gussets that are full length welded (see GE Drawing 47E382219). The electrical cabling will run through a port in the foundation ring wall at locations shown on 47E382356.

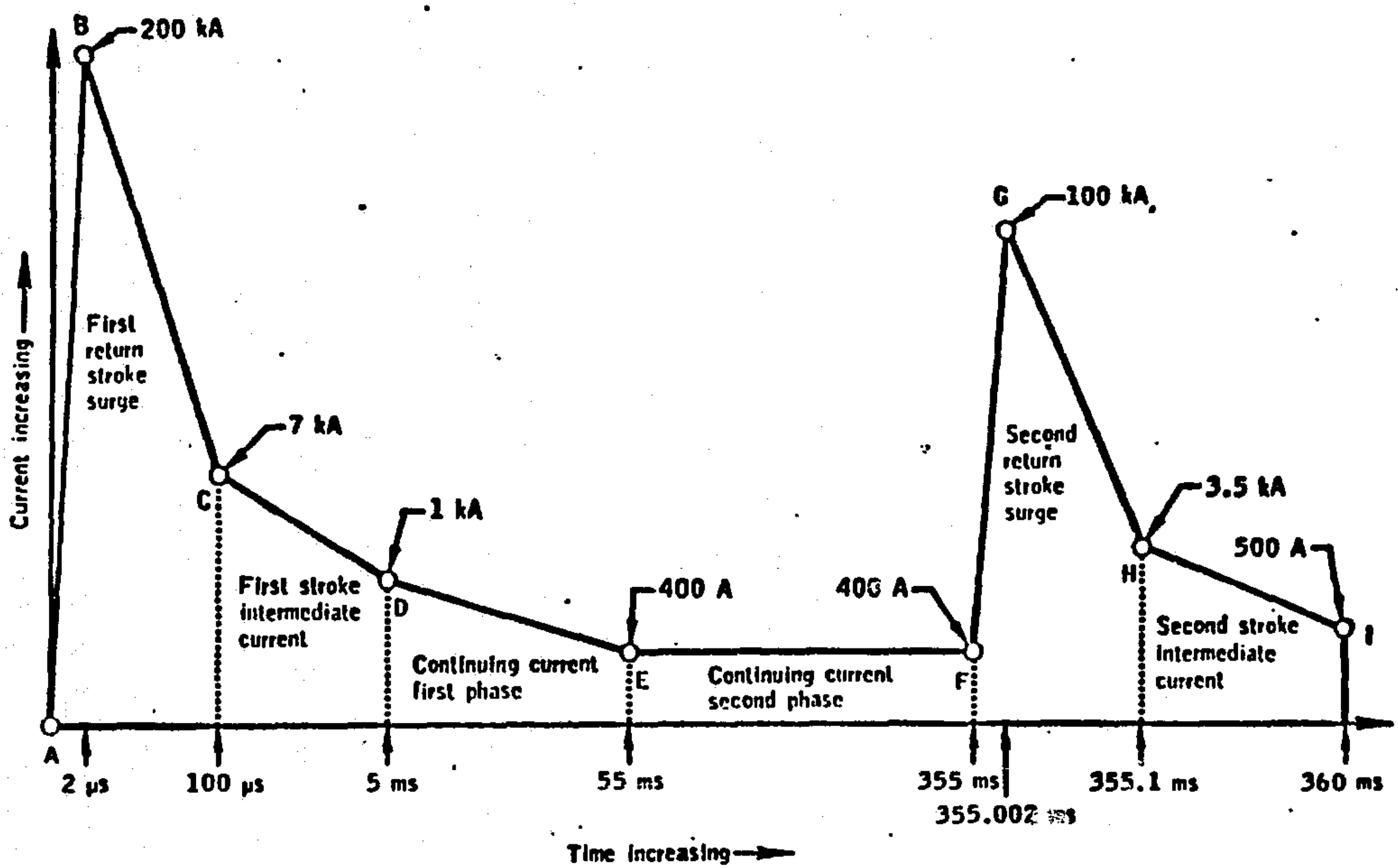

Figure3.1.6.4 - Diagrammatic representation of lightning model.
(Note that the diagram is not to scale.)

3.1.9 FOUNDATION

The foundation shall be designed based upon site soil test data. Anchor bolting is to be included in the design, along with the excavation and compacted back-filling required. The foundation design shall consider the vibratory nature of the WTG loads and limit differential settlement to a 1:250 slope measured at the anchor ring over the 30 year life. Total settlement shall be less than 1.0 inch. The foundation shall include anchor points for the twin boom proof load test as specified in 3.1.3.3.

3.2 FABRICATION

Fabrication shall be in accordance with the applicable specifications of the AISC and the Code of Standard Practice of the AISC unless specified herein or noted on the drawings.

3.2.1 TOLERANCES

The allowable imperfection in the fabricated tower shall meet the out-of-roundness and out-of-straightness measures as follows:

1) The maximum deviation from the theoretical radius shall not exceed the smaller of one-half (.50) the plate thickness or 0.50 inch.
2) The out-of-straightness shall not exceed 1/2" in any 10' length.
3) The maximum out-of-straightness within a band ±5 inches from a weld joint shall not exceed one-fourth (.25) the minimum plate thickness at that joint.
4) The tower overall straightness and yaw bearing surface level requirements shall meet the tolerances given in GE Drawing 47E382000.
5) Seam mismatch in girth weld shall not exceed the smaller of one-tenth (.10) the minimum plate thickness or 1/10 inch.

3.3 WELDING

Welding shall be in accordance with applicable drawing requirements and GE Specification 47A380054 or with an approved equivalent specification. However the following shall apply to either specification.

1) All circumferential (girth) welds shall use as the discontinuity greatest dimension in paragraph 5.2.1-(1) 1/8 inch for surface flaws and 3/16 inch for subsurface flaws and shall be 100% inspected radiographically.

2) Longitudinal welds shall be inspected radiographically for a distance of 12" on each side of intersection where they intersect with circumferential welds.

3) All other welds shall a) be inspected by dry powder magnetic particle per Section 6.75 of ANSI/AWS 01.1-82 and b) otherwise meet the requirements of section 9.4 "Fatigue Stress Provisions".

4) Inspection shall be by radiographic (RT) per AWS Section 6. Ultrasonic inspection (UT) shall be used only with prior GE approval.

3.4 FINISH

All exposed exterior and interior metal shall be suitably prepared and factory primed and finish coated in the field per Painting Specification 47A380048, with colors as specified. All touch up painting shall also conform to the specification.

Provision for tower exterior platform scaffolding support shall be provided from the nacelle, whereas the tower design shall incorporate provision to support temporary tower interior scaffolding support.

3.5 DETAIL REQUIREMENTS FOR TOWER

All welded attachments to the inside or exterior of the tower shall be avoided whenever possible. All temporary attachments needed for tower erection, etc. shall be minimized and upon removal the weld area shall be ground and inspected to meet the "B" weld category of AISC Code of Standard Practice.

3.5.1 TOWER ELEVATOR

Access from ground level to the nacelle shall be provided by a lift which meets the requirements of ANSI/ASME A17.1a, part XV, Special Purpose Personnel Elevators. The lift shall be supported by its own support structure on the inside of the WTG tower. This support structure can be used as much as possible as a construction and support aid, e.g. support welder platforms for tower girth welds. The elevator and support structure will be purchased separately. The placement of the elevator and interface to tower and foundation is shown in GE Drawing 47E382260 "Nacelle Access Lift Installation"". The elevator will be bolted to the foundation in a maintenance pit, thereby requiring a platform at ground level. The maintenance pit shall be provided with a sump suitable for a portable pump.

3.5.2 TOWER WIRING

The tower shall not directly provide for supporting and protecting power and signal wiring from the yaw slip ring to the tower foundation conduiting. Wiring shall be attached to the elevator support structure but will need to pass through the foundation ring wall. See GE Drawings 47E382355 and 47E382356 for placement requirements. GE Drawings TBD specify the MOD-5A power and instrumentation cabling requirements respectively.

3.5.3 LIGHTNING PROTECTION

Lightening protection shall be provided by a grounding system that has less than five ohms effective resistance to earth as measured at the tower base. Connection methods and measurement techniques shall conform to Section 4 of IEEE Standard 142 (Green Book)/ANSI C114.1 "IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems". The grounding system shall be adequate to accomodate the transient currents due to the lightning definition of paragraph 3.1.6.4. Lightning currents shall be transferred from at least three (3) points at the tower base into the ground system.

3.5.4 TOWER LIGHTING AND POWER (Information only)

a) Tower interior three way lighting will provide for illumination of at least 10 foot candles, with switches at both the top and bottom of the tower. The lights will be mounted on the elevator support structure. Battery powered emergency lights will be located at each elevator landing and illuminate the emergency ladder.

b) Maintenance power outlets will provide weatherproof GFI protected 120 volt, 15 ampere, 60 hertz service as well as 480 volt, 3 phase service and will be located at the tower base and at the nacelle access device landing.

3.5.5 TOWER ACCESS

An access door shall be provided at the tower base. The door shall be lockable and have site security system sensors (provided by GE) for intruder detection. Should the door be more than 12 inches above the foundation, suitable steps inside and out of the tower shall be provided. Door opening size shall be 30 inches wide by 60 inches high properly shaped and reinforced to minimize fatigue stresses. Location of access door shall be per GE Drawing 47E382355.

3.5.6 PLATFORMS

There are three (3) platforms near the top of the tower. The uppermost, or yaw platform, is part of the lower yaw adapter and procured separately. The lowest is the elevator access platform nd intermediate is an elevator maintenance platform, as shown in GE Drawing 47E382354. These platforms are considered part of the tower structure, but can be hung from the lower yaw adapter to fully meet the intent of Paragraph 3.5, i.e. no welded attachments to the tower when not required. Rubber bearing pads shall be used to isolate the platforms from the elevator support structure. A platform will be required for elevator access at ground level. An opening and stairway to the foundation top shall be provided to allow access to the elevator pit and cable opening in the ring wall.

3.6 DESIGN REVIEW

The design of the tower and foundation shall be subject to review and approval by General Electric, along with supporting analyses, to verify that the tower and foundation satisfy the requirements of this specification. All material and process specifications for the tower and foundation shall be approved by General Electric.

3.6.1 DRAWINGS

A set of reproducible and three (3) sets of prints of all layouts, fabrication and erection drawings will be submitted as part of the design review. General Electric shall approve all those drawings prior to any fabrication or construction. All subsequent drawing changes shall also be approved by General Electric.

SECTION 4.0

QUALITY ASSURANCE PROVISIONS

4.1 MANUFACTURING AND TEST FLOW PLAN

The supplier shall submit a manufacturing and test flow plan showing the basic manufacturing operations, special processes, inspections and tests for General Electric review and establishment of GE inspection points.

4.2 INSPECTION BY GENERAL ELECTRIC AND/OR THE CUSTOMER

GE shall maintain cognizance over the supplier's quality system and performance. The supplier shall notify GE at least forty-eight (48) hours in advance of the time that work, processes, inspections or tests are ready for review or witnessing as specified in the manufacturing and test flow plan.

4.3 PROCESS AND OPERATOR RECORDS

The supplier shall maintain on file, for review by GE, written procedures and specifications covering prequalified joint welding procedures and records certifying the qualification of other than prequalified procedures and of welders and welding operators. Records should be of the format recommended in Appendix E of the AWS Structural Welding Code. Welders and welding operators qualified to ASME Section VIII need not be requalified to AWS specifications.

4.4 RAW MATERIAL CERTIFICATION

The supplier shall obtain material certification records (physical and chemical data) for all steel plate material used in fabrication of the tower. Each plate shall be traceable to the specific heat or slab number for which data is maintained on file. The supplier shall also obtain material certification for the foundation materials. The supplier shall review all data to insure compliance with Paragraph 3.1.2 of this specification. Data files shall be available for GE and/or customer review.

4.5 VERIFICATION OF REQUIREMENTS

The supplier shall perform sufficient tests, inspections, analyses or demonstrations to assure compliance with all requirements of this specification. The foundation concrete shall be tested following the ASTM procedures listed in Table 4.5. The supplier shall submit a list of requirements he wishes to certify by analysis or demonstration to GE for prior review and approval.

TABLE 4.5 APPLICABLE ASTM CONCRETE TEST STANDARDS

ASTM NO.	TITLE
C31	Standard Method of Making and Curing Concrete Test Specimens in the Field.
C39	Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens
C42	Standard Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete (if deemed necessary by GE or field engineer)
C143	Test for Slump of Portland Cement Concrete
C172	Standard Method for Sampling Fresh Concrete

4.6 TEST AND INSPECTION RECORDS

The supplier shall maintain on file, for GE and/or customer review, radiographic reports, ultrasonic reports, magnetic particle reports and all inspection and test data related to the WTG tower supplied to GE.

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CONT ON SHEET ii SH NO. i

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POWER CABLING REQUIREMENTS SPECIFICATION

FOR THE

MOD-5A WIND TURBINE GENERATOR

SEPTEMBER 1982

REV "B" FEB 84

Responsible Engineer DATE: 9/30/82

Subsystems Engineer DATE: 9/30/82

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A	5	3.3.4	9/83	
A	6	3.5.1, 3.5.3, 3.6	9/83	AN-1
A	7	All	9/83	
A	8	All	9/83	
B	5	3.3.4, 3.3.6	2/84	DCC#84-086
B	6	3.5.3, 3.4	2/84	AN-2

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SECTION 1.0

SCOPE

This document establishes the requirements for electrical power cabling intended for use on the MOD-5A Wind Turbine Generator (WTG) System.

SECTION 2.0

APPLICABLE DOCUMENTS

The following documents are a part of this requirement to the extent referenced herein.

NUMBER	NAME
47A380011	WTG System Specification
NFPA 70-1980	National Electric Code

SECTION 3.0

REQUIREMENTS

3.1 INSULATION

3.1.1 VOLTAGE RATING

All conductors for service lines up to 480 volts shall be individually insulated with a minimum insulation rating of 600 volts. All conductors for service lines of 4160 volts shall be individually insulated with a minimum insulation rating of 5000 volts.

3.1.2 FLAME RESISTANCE

All conductor insulation shall be flame retardant and self extinguishing.

3.1.3 OIL RESISTANCE

Insulation performance shall not be degraded after exposure to hydraulic or lubrication oils.

3.1.4 CABLE SEPARATION

Separate conduit or wireways shall be provided for high voltage cables (greater than 600 volts) and low voltage cables (less than 600 volts).

3.2 CONDUCTORS

3.2.1 STRANDING

Conductors shall be copper with NEMA Class B or C stranding for fixed wiring, and extra flexible stranding (Class G or H) shall be used for movable wiring and loops across rotating or flexible joints. Solid wire shall not be used.

3.2.2 SIZE

Wire size for all conductors between boxes, panels, cabinets and devices shall be No. 14 AWG minimum. Internal wiring with both conductor terminations inside a single device, cabinet, box or panel enclosure shall be No. 16 AWG minimum. Individual conductor size shall be chosen at the minimum or larger size as required to assure that line losses at full rated load between the utility interface and the source or load are less than two percent.

3.2.3 CONTINUITY

Conductors shall be continuous and shall have no splices or taps in conduit or wireway. Splices and taps as required shall be made only at junction, pull and device boxes using terminations as specified in Section 3.4. Splices and taps shall be insulated to the equivalent of the conductor insulation except at apparatus terminal boards not requiring insulation.

3.3 CABLE PROTECTION

3.3.1 PHYSICAL PROTECTION

Physical protection for all cables shall be provided in the form of conduit or wireways.

3.3.2 WIREWAYS

Wireways may be used in the nacelle, yaw area, and within the tower where they will not experience severe mechanical forces. The sum of the cross-sectional areas of all conductors, including insulation, shall not exceed 20% of the interior cross-sectional area of the wireway. The maximum number of current-carrying conductors in any size wireway is 30. Oil tight wireways are preferred in the vicinity of hydraulic pumps, lubrication pumps, accumulators, valves and lines.

3.3.3 HIGH VOLTAGE CABLE-BUS

Cable-bus for the generator output cable is recommended for the vertical run down the tower due to its support system and free air current rating. Cable supports shall be provided every one and one-half feet (1-1/2').

3.3.4 CONDUIT

Galvanized or cadmium coated rigid conduit shall be used for exterior installations. Conduit serving as the support member shall be rigid conduit. Where required for flexibility or to facilitate installation, liquid-tight flexible metal conduit may be used. The sum of the cross-sectional areas of all conductors, including insulation, shall not exceed 40% of the interior cross-sectional area of the conduit.

3.3.5 VERTICAL SUPPORT

Vertical runs of conduit or wireway for conductor size 0 AWG or smaller (other than cable-bus, see 3.3.2) shall have support provisions for cable every 20 feet (minimum) of height, starting at the top of the run.

3.3.6 JOINTS

All conduit and wireway joints shall include a means for assuring full circumferential electrical continuity (single screw connectors are not to be used) around the conduit or wireway as well as electrical continuity across the joint.

3.4 TERMINATION

Termination for power cables shall be of a type utilizing compression screws bearing on a captive wire inserted in the hole of a terminal block or lug such as Burndy type QA or equivalent. Properly executed crimp connections are permitted where space prohibits the use of lugs or where the crimp is part of an approved termination device.

3.5 GROUNDING

3.5.1 GROUNDING CABLE

A ground conductor shall be used to provide a positive connection from the generator lightning arrestors, surge capacitors and grounding transformer to the tower foundation rebar structure and ground grid.

3.5.2 FIXED STRUCTURE GROUNDING

Bonding straps shall be used to cross all major structural joints including the tower base to the tower foundation rebar structure and ground grid.

3.5.3 MOVABLE STRUCTURE GROUNDING

Dedicated elements (brushes) shall be used to interconnect structural elements across rotor bearings. Flexible bonding strap loops shall be used to interconnect limited range moving structural elements such as the ailerons and across the teeter bearing.

3.6 ENVIRONMENT

Cabling shall withstand without degradation ambient temperatures of -40°C to +50°C (-40°F to 122°F).

SECTION 4.0

VERIFICATION

4.1 ACCEPTANCE TESTS

4.1.1 CONTINUITY

All wiring shall be checked for routing, continuity and for workmanship.

4.1.2 INSULATION RESISTANCE

All wiring shall be subjected to an insulation resistance test to insure isolation between circuits. Insulation resistance shall not be less than ten (10) megohms with 500 VDC applied between each wire and every other wire, NOT IN A COMMON CIRCUIT, and between each wire and ground.

4.1.3 DIELECTRIC STRENGTH

All wiring shall be subjected to a dielectric strength test to verify its voltage withstanding capability.

4.1.3.1 Low Voltage

For wiring up to and including 480 VAC, a hi-pot test shall be performed between each wire and every other wire, NOT IN A COMMON CIRCUIT, and between each wire and ground. Leakage current shall not exceed one hundred (100) microamperes with 1000 VAC, 60 Hz applied. Voltage shall be applied for a minimum of thirty (30) seconds.

4.1.3.2 High Voltage

For wiring intended for service at 4160 VAC a hi-pot test shall be performed between each wire and every other wire, NOT IN A COMMON CIRCUIT, and between each wire and ground. Leakage current shall not exceed two (2) milliamperes with 19000 VAC, 60 Hz applied. Voltage shall be applied for a minimum of thirty (30) seconds.

4.2 TEST PROCEDURE

All tests shall be conducted using documented test procedures approved by quality assurance. All test procedures shall contain data sheets on which the results of the individual tests may be recorded.

4.3 TEST CONDITIONS

All tests shall be performed at room ambient conditions of temperature, humidity and atmospheric pressure unless otherwise specified.

4.4 APPROVAL

Review and approval of all test results by a General Electric Quality Assurance Representative is required prior to Acceptance.

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INSTRUCTIONS CABLING REQUIREMENTS SPECIFICATION

FOR THE

MOD-5A WIND TURBINE GENERATOR

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A	6	3.5	9/83	
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SECTION 1.0

SCOPE

This document establishes the requirements for instrumentation cabling intended for use on the MOD-5A Wind Turbine Generator (WTG) System.

SECTION 2.0

APPLICABLE DOCUMENTS

The following documents are a part of this requirement to the extent referenced herein.

NUMBER	NAME
47A380011	WTG System Specification
NFPA 70-1980	National Electric Code

SECTION 3.0

REQUIREMENTS

3.1 INSULATION

3.1.1 VOLTAGE RATING

All conductors shall be individually insulated with a minimum insulation rating of 600 volts.

3.1.2 CABLE SEPARATION

All instrumentation cabling shall be separated over its entire length by a minimum of two inches from power cabling unless each cabling type is in a separate conduit or wireway.

3.1.3 FLAME RESISTANCE

All conductor insulation shall be flame retardant and self-extinguishing.

3.1.4 OIL RESISTANCE

Insulation performance shall not be degraded after exposure to hydraulic or lubrication oils.

3.2 CONDUCTORS

3.2.1 STRANDING

Conductors shall be copper, with NEMA Class B or C stranding for fixed wiring. Extra flexible stranding (Class G or H) shall be used for movable wiring and loops across rotating or flexible joints. Solid wire shall not be used.

3.2.2 SIZE

Wire size for all conductors between boxes, panels, cabinets and devices shall be No. 16 AWG minimum. Internal wiring with both conductor terminations inside a single device, cabinet, box or panel enclosure shall be No. 22 AWG minimum.

3.2.3 CONTINUITY

Conductors shall be continuous and shall have no splices or taps within the conduit or wireway. Splices and taps as required shall be made only at junction, pull and device boxes. Splices and taps shall be insulated to the equivalent of the conductor insulation except at apparatus terminal boards not requiring insulation.

3.3 CABLE PROTECTION

3.3.1 PHYSICAL PROTECTION

Physical protection for cables (conduit or wireway) shall be provided. All cables must be protected; no open wire runs are permitted.

EXCEPTION: Temporary strain gage wiring may be surface mounted with metal tape protection.

3.3.2 WIREWAYS

Wireways may be used in the nacelle, yaw area, and within the tower where they will not experience severe mechanical forces. The sum of the cross-sectional areas of all conductors, including insulation, may not exceed 20% of the interior cross-sectional area of the wireway. Oil tight wireways are preferred in the vicinity of the hydraulic pumps, lube pumps, accumulators, valves and lines.

3.3.3 ENCLOSURES

Instrumentation cable shall not be placed in enclosures (boxes, wireways, conduit, etc.) with light or power cables unless separated by a partition. Where possible, instrumentation cables shall be widely separated from power cables to reduce the introduction of 60 Hz. noise.

3.3.4 CONDUIT

Galvanized or cadmium coated rigid conduit shall be used for exterior installations. Conduit serving as the support member shall be rigid conduit. All other conduit installations may be electrical metallic tubing (EMT). Where required for flexibility or to facilitate installation, liquid tight flexible metal conduit may be used. The sum of the cross-sectional areas of all conductors, including insulation and shields, shall not exceed 40% of the interior cross-sectional area of the conduit.

3.3.5 VERTICAL SUPPORT

Vertical runs of conduit or wireway shall have support provisions for cable every 25 feet (minimum) of height, starting at the top of the run.

3.3.6 JOINTS

All conduit and wireway joints shall include a means for assuring full circumferential electrical continuity (single screw connectors are not to be used) around the conduit or wireway as well as electrical continuity across the joint.

3.4 SHIELDING

Analog signal conductors shall be twisted and shielded leads. Conductor shields shall be grounded at the signal processing end of the conductor.

3.5 ENVIRONMENT

Cabling shall withstand without degradation, ambient temperatures of -40°C to +50°C (-40°F to +122°F)

SECTION 4.0

VERIFICATION

4.1 ACCEPTANCE TESTS

4.1.1 CONTINUITY

All wiring shall be checked for routing, continuity and for workmanship.

4.1.2 INSULATION RESISTANCE

All wiring shall be subjected to an insulation resistance test to insure isolation between circuits. Insulation resistance shall not be less than ten (10) megohms with 500 VDC applied between each wire and every other wire, not in a common circuit, and between each wire and ground.

4.1.3 DIELECTRIC STRENGTH

All wiring shall be subjected to a dielectric strength test to verify its voltage withstanding capability. A hi-pot test shall be performed between each wire and every other wire, NOT IN A COMMON CIRCUIT, and between each wire and ground. Leakage current shall not exceed 50 microamperes with 500 VAC, 60 Hz applied. Voltage shall be applied for a minimum of thirty (30) seconds.

4.2 TEST PROCEDURE

All tests shall be conducted using documented test procedures approved by quality assurance. All test procedures shall contain data sheets on which the results of the individual tests may be recorded.

4.3 TEST CONDITIONS

All tests shall be performed at room ambient conditions of temperature, humidity and atmospheric pressure unless otherwise specified.

4.4 APPROVAL

Review and approval of all test results by a General Electric Quality Assurance Representative is required prior to Acceptance.

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A	General Revisions and added 3.8, 4.2.5 and Figure 4		09/15/82	AN-1
B	7	3.2	06/16/83	AN-2
	9	Table I		
	16	Figure 4		
	19	4.2.1		
	2	2.0		
	15	3.9		
	20	4.3		

TABLE OF CONTENTS

SECTION 1.0
INTRODUCTION

This specification provides the requirements for a bearing which is used to provide a yaw (azimuth) motion of the nacelle of the MOD-5A Wind Turbine Generator (WTG). In the event of conflict of requirements between this specification and higher level documents the higher level document shall have precedence.

This specification is to be the technical basis for procurement of the yaw bearing.

SECTION 2.0

APPLICABLE DOCUMENTS

47D381002	Bearing, Yaw (Source Control Drawing)
47E382050	Yaw Housing Structure, Upper
47E382219	Yaw Housing Structure, Lower

DIN Standard No. 5402 "Rolling Bearing Components, Cylindrical Rollers", June, 1973

ASTM Standard E45

SECTION 3.0

REQUIREMENTS

3.1 FUNCTIONAL REQUIREMENTS

The yaw bearing is to provide an axis of full 360 degrees rotation with low rotational friction for the nacelle of the MOD-5A Wind Turbine Generator (WTG). The axis of rotation is vertical with the inner race of the yaw bearing fixed to the tower and the outer race fixed to the upper yaw adapter structure, as shown in Figure 1 and 2. To minimize structural loading of the tower, the bearing type shall be the three-row roller.

3.1.1 ROTATION

The yaw motion of the WTG keeps the rotor pointed into the wind. Typically when the wind reaches sufficient speed the yaw drive will rotate the nacelle into the wind before blade rotation begins, hence the maximum motion at any one time is 180 degrees. The yaw drive is intermittant, with an average speed of less than 15 degrees/min. (1/24 RPM) and a maximum speed of 30 degrees/min. (1/12 RPM). After blade rotation begins, the yaw drive will make adjustments to keep the WTG pointed into the wind. There is expected to be a maximum bearing motion of 3 full revolutions per day, and 30,000 revolutions in the desired 30 year lifetime. While the WTG is operating, the yaw drive shall keep the nacelle pointed to within ± 5 degrees of the wind, thus the yaw bearing will see static load conditions and dynamic loads when stationary and rotating.

3.1.2 MECHANICAL INTERFACES

The yaw bearing will be located at the top of the WTG tower as illustrated in Figure 1. As shown in Figure 2 the yaw bearing inner race is bolted to a disc welded to the top of the tower. The disc also acts as a brake surface. A reinforcing ring helps to support the disc. The outer race is bolted to a nacelle adapter section.

Both mating surfaces shall be either (1) machined flat to tolerances specified by the manufacturer or (2) epoxy grouted per manufacturer specifications. Choice of method shall be selected later by GE based on the above requirements traded off against machining costs of the interface surfaces and assembly costs. Bolt circle diameters and number of bolts are specified in GE Drawing 47D381002. The size and type of the mounting bolts shall be specified by the manufacturer with the limitation that the bolt diameter shall be 1.75 inch or less. This allows the use of hydraulic pretensioning device that can fit into the confines of the nacelle adapter structure.

3.1.3 DIMENSIONAL CONSTRAINTS

The bearing shall meet the dimensional constraints shown in GE Drawing 47D381002. The bearing shall be designed such that the diameter of the line of action of the vertical loads passing through the bearing will be 173 inches $\pm$ 1 inch. This ensures that the loads will act on the tower wall. The inner diameter of the bearing shall be 163.25 inches or more and the outer diameter shall be 184.5 inches or less. Height of the bearing shall be 9.05 inches or less.

FIGURE 1 - MOD 5-A

WTG CONFIGURATION

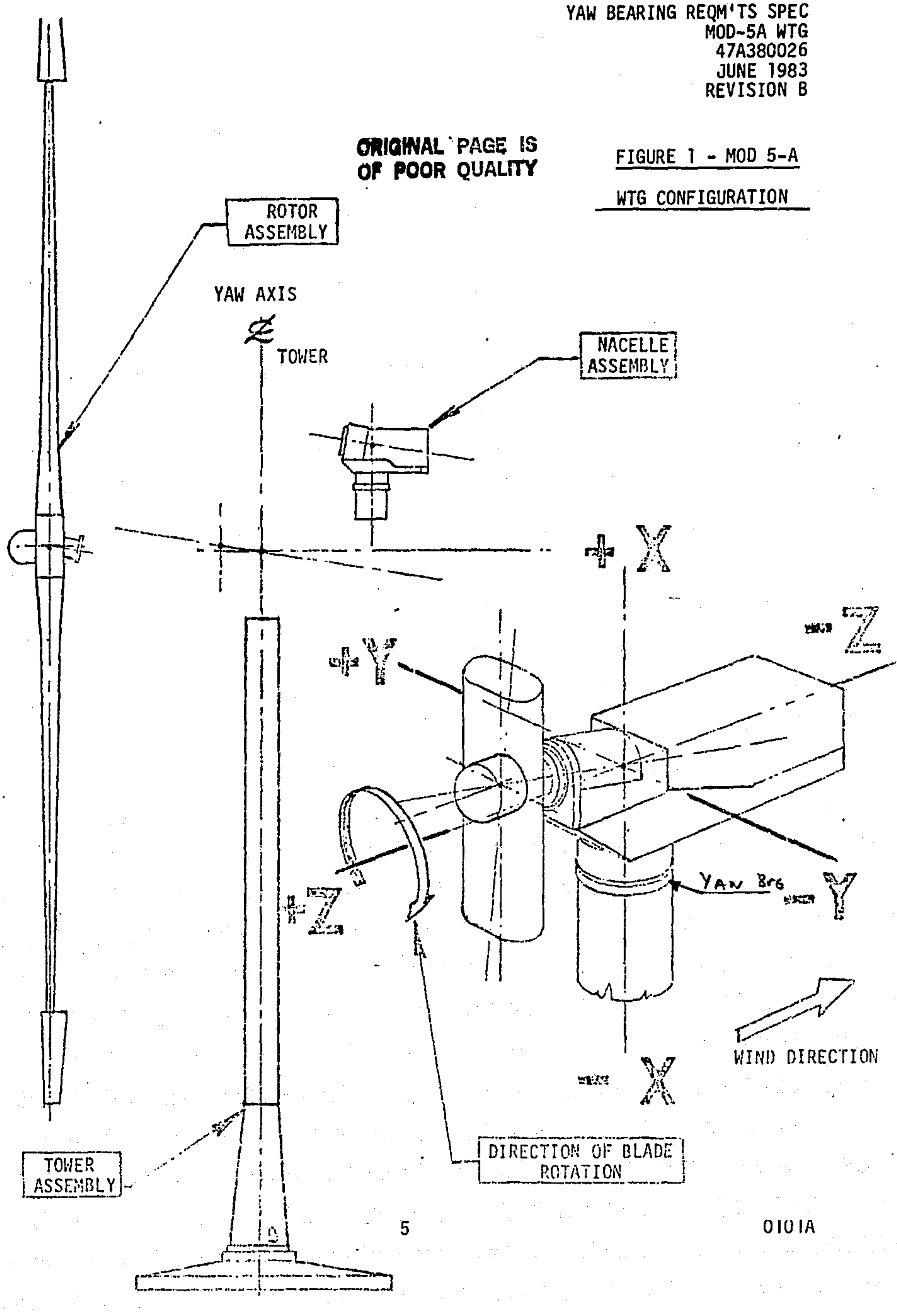
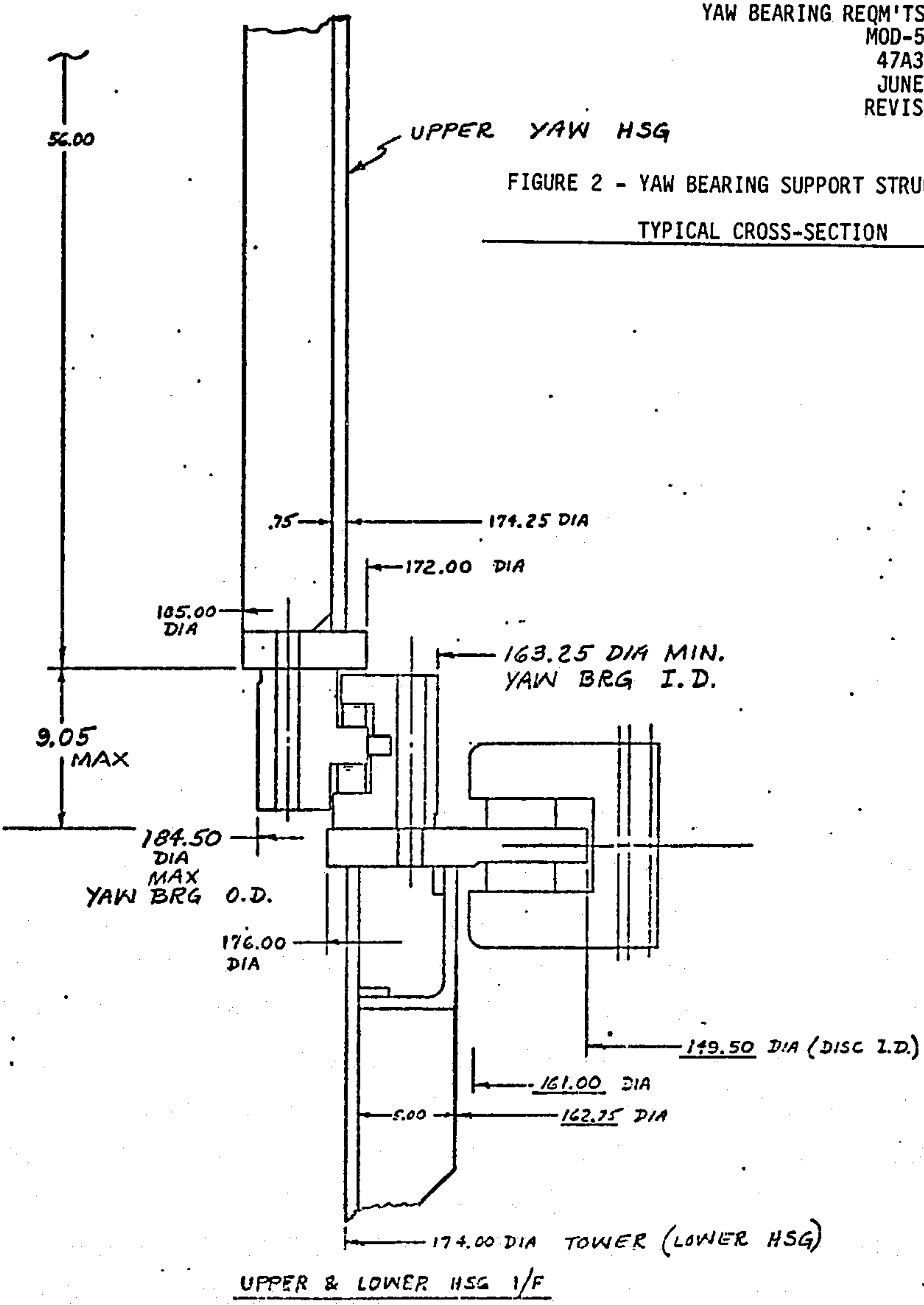


FIGURE 2 - YAW BEARING SUPPORT STRUCTURE

TYPICAL CROSS-SECTION



3.1.4 FRICTION

When the yaw bearing is mounted to the structure defined in Figure 2 with the manufacturer's mounting specification and loaded as in paragraph 3.2.1, the static breakaway frictional torque shall not exceed 240,000 ft-lbs, with the average value of a number of yaw bearings expected to be less than 80,000 ft-lbs.

3.1.5 LUBRICATION

The yaw bearing shall be lubricated with a good grade low temperature grease equivalent to (TBD). The bearing shall have grease fittings, (TBD) in number, (TBD) in size and located at (TBD). All fittings shall be accessible from inside the tower. Lubrication interval shall be (TBD) as recommended by the bearing vendor. The yaw bearing shall incorporate appropriate seals. To mitigate possible fretting conditions under dynamic operating loads (see paragraph 3.2.2) in constant wind directions, the WTG control shall yaw the nacelle $\pm$ 2 degrees (TBD) every 60 min. (TBD) to spread lubricant.

3.2 LOADING CONDITIONS

The yaw bearing shall be capable of withstanding the loading conditions defined herein without detriment to the expected life and frictional requirements. The basic loads that are transmitted from the nacelle to the tower through the yaw bearing are of two types, static and dynamic. The static loads are a thrust and moment caused by the weight of the nacelle structure and its C.G. offset from the yaw axis. The dynamic loads are caused by the wind in normal and abnormal WTG operating conditions. The dynamic loads are of concern because of the large number of cycles that can occur, i.e. 382×10^6 in the 30 year WTG lifetime.

The loads presented herein include a contingency factor to account for the maturity of the design and analyses. The bearing supplier shall also apply to these loads whatever additional factors of safety and operational factors that are appropriate based on the suppliers design and experience in order to properly size the bearing and analyze its capabilities. The loads are summarized in Table 1.

3.2.1 NON-OPERATING LOADS (1510 hours per year)

When the WTG is not operating, the rotor will be locked in a horizontal orientation (3-9 o'clock). The only significant yaw bearing loads are the dead weight loads of 893 kips (thrust on the bearing) and a moment of 7.60*E6 ft-lbs. A small portion of the time will be storm (i.e., high wind) conditions with the WTG parked. These storm loads will give a small increase with respect to the dead weight nominal.

3.2.2 NORMAL OPERATING LOADS (7250 hours per year)

During normal operation, the blades of the WTG generate a thrust and torque. As seen in Figure 1, the thrust is taken as a radial load at the yaw bearing. Note also that it offsets the dead weight moment. The blade torque is reacted by the gearbox first stage and eventually through the yaw bearing to the tower. With non-uniform wind conditions, both loads will vary and also small side forces and moments are generated. The yaw force and moments are tabulated below. The varying components of load are harmonic in shape, made up of different frequency components which are all even integral multiples of the WTG operating speed (RPM). The magnitude of these varying components can be approximated as a log-normal distribution.

TABLE 1

YAW BEARING LOADS

	V_x	V_y (KIPS)	V_z	M_y (lb-ft)*E6	M_z
Non-operating	-994	0	0	-11.1	0
Normal-Operating					
Mean	-954	-2.5	-191	-10.1	-2.85
±99.9%*	26	26	59	1.0	1.79
RMC**	18	19	18	.37	.49
Abnormal (limit)					
Hurricane	-867	0	+455	-18.62	0
Gust	-994	60	180	-14.4	.7

*Half-range loads with log-normal distribution - see Fig. 3 for typical distribution.

**Root-Mean-Cube loads, i.e., the RMC of the load histogram which could be calculated from Figure 3's log-normal distribution.

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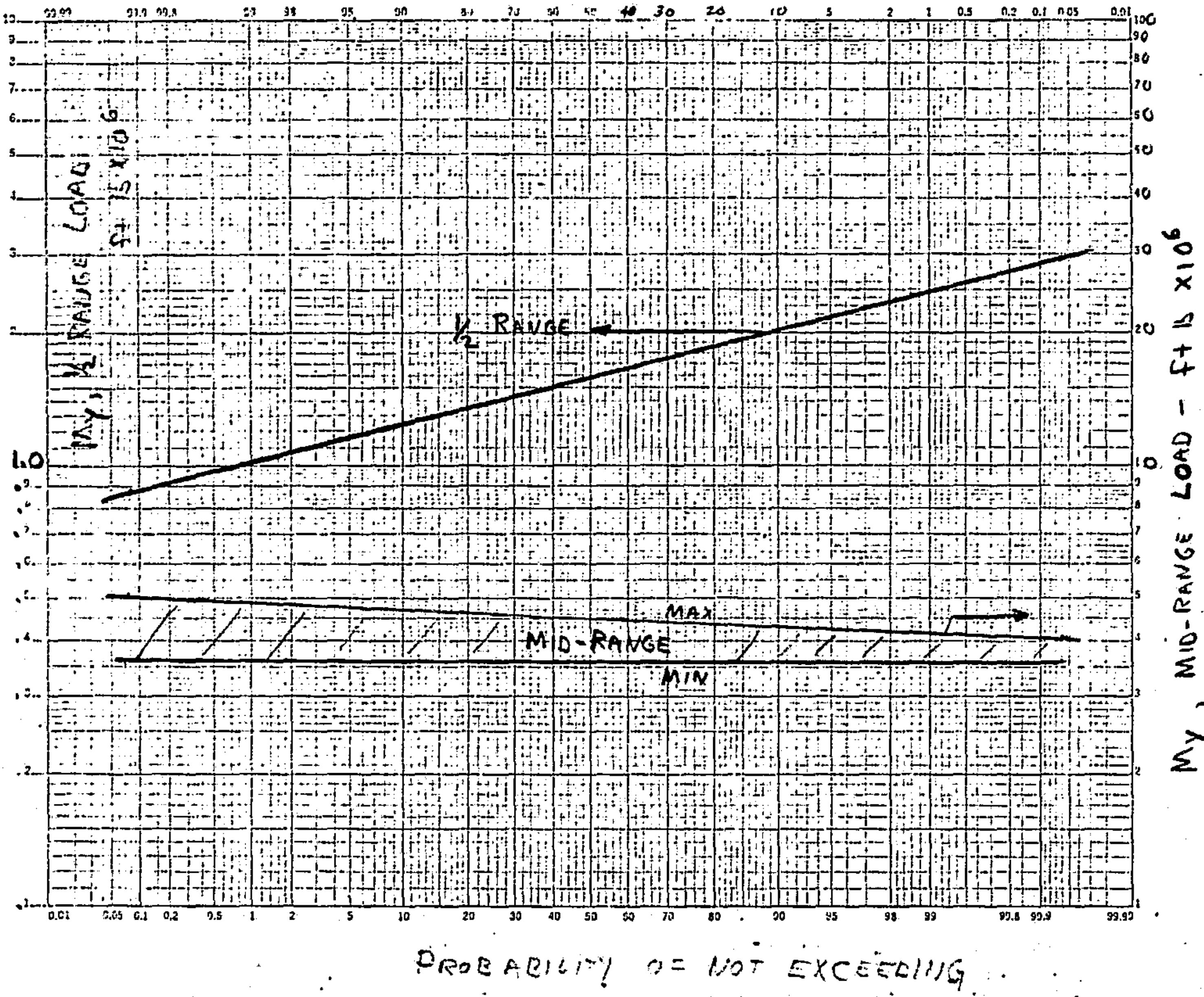
OF POOR QUALITY**

FIGURE 3 - SAMPLE LOG-NORMAL LOADS



3.2.3 ABNORMAL LOADS

A few times during the life of the WTG certain conditions will cause the yaw bearing to see higher than normal loads. The two principle causes are, 1) a hurricane with the WTG in a stowed condition and, 2) abnormal gust conditions while starting or stopping which causes the teetered rotor to hit its stops, these two conditions are called limit loads. During these conditions the bearings static capacity should be capable of withstanding the loads given in Table 1.

3.3 AMBIENT ENVIRONMENTAL CONDITIONS

The bearing is to be used in an outdoor environment. However, with the present yaw drive layout the yaw bearing will be partially shielded from direct exposure to solar radiation, rain, hail, snow, sand, dust, ozone, fungus and insects, see Figure 2.

3.3.1 ALTITUDE

The bearing shall be exposed to ambient pressure at altitudes anywhere between sea level and 7,000 feet.

3.3.2 TEMPERATURE RANGE

The bearing shall be subjected to a temperature range of +140 degrees F to -40 degrees F. The upper range includes an allowance for local surrounding structure temperature increase from solar radiation.

3.3.3 SPECIAL PRECAUTIONS

During conditions of assembly and maintenance of the yaw bearing the bearing could be subjected to the environments identified in paragraph 3.3. To prevent damage and contamination of the bearings the following special precautions shall be taken: (TBD)

3.4 LIFE

The bearings shall operate for 30 years within the limits of the requirements of this specification without major overhaul or replacement. The reliability will be the normal 90%, i.e., a B-10 life of 30 years minimum.

3.4.1 PLANNED MAINTENANCE

Planned maintenance of the bearings shall consist of:

a) sampling of grease for contamination - once every three (3) months for the first three years (TBD), yearly thereafter.
b) replacement of grease - once every year (TBD).
c) inspection of seals - once every 3 months (TBD) for the first three (3) years (TBD), yearly thereafter.
d) replacement of bearing seals - once every 10 years (TBD) or as needed
e) bolt tensioning - re-checked after fifty (50) operating hours (TBD) and yearly thereafter (TBD).

3.5 WEIGHT

The weights of the bearings shall not exceed: (TBD - lbs.)

3.6 STIFFNESS

The axial and radial spring rates of the bearings shall not be less than specified below.

Axial Spring Rate (lbs/in)	Radial Spring Rate (lbs/in)	Rotational Spring Rate (in-lb/degree)
(TBD)	(TBD)	(TBD)

3.7 WORKMANSHIP

The bearing shall be constructed in a thorough workmanlike manner. All parts shall be free of burrs, sharp edges and other damage or defects that could make the unit unsatisfactory for the intended use.

3.8 MATERIAL

3.8.1. ROLLING ELEMENTS

The rolling elements shall be in accordance with or equivalent to DIN Standard #5402 "Rolling Bearing Components, Cylindrical Rollers", June 1973. Rolling separators are to be provided between every rolling element in the bearing. Material of the separators shall be consistent with the other requirements of this specification.

3.8.2 RACES

3.8.2.1 Materials

The bearing rings shall be manufactured as rolled ring forgings. The ring steel cleanliness shall be according to ASTM E45 Method "A" or equivalent and not exceed the values given in Table II.

The material used shall be selected considering the minimum operating and survival temperature (paragraph 3.3.2). All forged rings shall possess the following impact properties as measured by the Charpy V-notch test:

Minimum Average Energy	= 42 Joules at -40°C
Single Value Minimum	= 27 Joules at -40°C

TABLE II

RATING UNITS

THIN SERIES	HEAVY SERIES
A - 2-1/2	A - 1-1/2
B - 2	B - 1-1/2
C - 2	C - 1-1/2
D - 1-1/2	D - 1-1/2

3.8.2.2 Heat Treatment

The rolled forged rings shall be normalized, quenched and tempered to a hardness of BHN 285 to 320. This hardness is to exist at least to 13 mm below all finished ground roller contact surfaces.

Roller raceways shall be induction heat treated and tempered to R_C 58-62 at the surface and to a minimum depth to be specified by the manufacturer. Depth of hardness is defined as the depth to R_C 50. The required depth is to exist after finish grinding of the roller paths.

3.8.2.3 <u>Case Hardening Pattern</u>

The case hardening pattern shall be satisfactory for the full roller contact area. The required depth of hardness shall be maintained over this contact area and, at least, 3 mm beyond any edge of the contact area. A "feathering-out" or "tapering-off" of this depth of hardness shall be permissible only beyond the minimum boundaries described above.

The case hardening pattern shall extend beyond the fillet radius of the nose ring or "T" washer as described on Figure 4.

These pattern requirements are to exist after finish grinding.

3.8.2.4 <u>Microstructure</u>

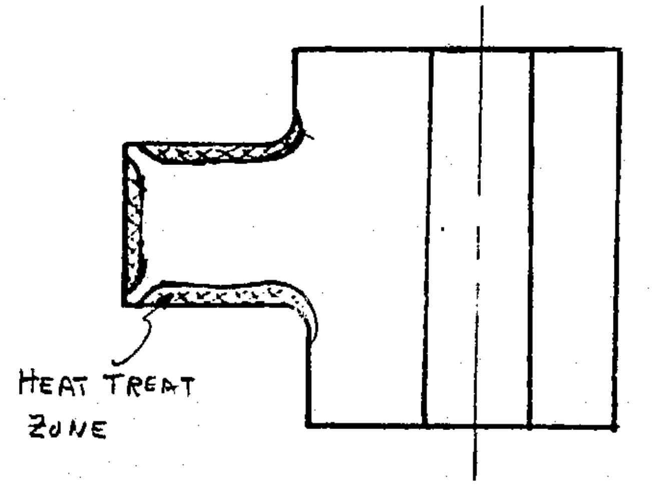
Martensitic transformation of the hardened case is to equal or exceed 85%. Grain size of the hardened case is to be equal to or greater than #8 according to ASTM E-112-80.

3.9 <u>GENERAL</u>

Identification markings shall be in accordance with standard commercial practice and shall include the following:

a) GE part number 47D381002.
b) Vendor's name, symbol or code identification.
c) Vendor's part number, lot number and serial number.

FIGURE 4 - SCHEMATIC SKETCH OF NOSE RING HEAT TREAT PATTERN



SECTION 4.0

QUALITY ASSURANCE PROVISIONS

The bearing vendor shall be responsible for the performance of all inspections and tests specified herein. The vendor shall utilize his own facilities or any commerical laboratory acceptable to GE. GE reserves the right to witness any of the inspections and tests set forth in this specification where such inspections and tests are deemed necessary to assure that supplies and services conform to prescribed requirements. GE and/or its representatives intends to witness certain final inspections including NDT. Final acceptance will be contingent upon successful completion of any such tests and/or review of all test results as well as the required certification by GE prior to approval for shipment.

4.1 PREPARATION OF TEST PROCEDURE

The procedure and methods for performing all tests specified herein shall be prepared by the bearing vendor. These procedures and methods must be approved by GE prior to their implementation.

4.1.1 CLASSIFICATION OF TESTS

Tests shall be classified as Acceptance Tests (see paragraph 4.3).

4.1.2 TEST CONDITIONS AND TOLERANCES

All static and dynamic tests shall be performed at ambient room temperature.

4.1.3 MEASUREMENTS

All measurements shall be made with instruments that have been calibrated against certified instruments. Calibration of the certified instruments shall be traceable to the National Bureau of Standards.

4.1.4 DIMENSIONAL CHECKS

All dimensions shall be measured using measuring instruments calibrated to reference standards at 20C. The reference standard shall be certified by the National Bureau of Standards. Standard gages shall be used for checking all radii and chamfers. Critical dimensional data shall be recorded and shall be available for review by GE prior to shipment of finished bearings.

4.1.5 QUALITY CONFORMANCE INSPECTION

Each bearing shall be examined and acceptance tested per paragraph 4.2.

4.1.6 TEST SUCCESS CRITERIA

Any deviation from the performance parameters specified herein, or any physical/mechanical out-of-tolerance condition that is noted during or after the performance of the tests specified herein, shall constitute a failure of the bearing.

4.2 ACCEPTANCE TESTS (TBD)

Each bearing shall be subjected to and shall have passed the following tests prior to acceptance by GE:

Examination of Product	4.2.1
Identification	4.2.2
Weight	4.2.3
Workmanship	4.2.4
Material	4.2.5

4.2.1 EXAMINATION OF PRODUCT

Examine each bearing for strict conformance to the dimensional requirement of GE Drawing 47D381002.

4.2.2 IDENTIFICATION

Examine each bearing and check for conformance to the requirements of paragraph 3.8.

4.2.3 WEIGHT

Examine each bearing for conformance to paragraph 3.5.

4.2.4 WORKMANSHIP

Examine each bearing to verify conformance to paragraph 3.7.

4.2.5 MATERIAL

Examine the bearing components at the appropriate manufacturing step to verify conformance to paragraph 3.8. Manufacturer must be able to satisfactorily demonstrate his ability to meet the "heat treatment" and "case hardening pattern" requirements of this specification.

All forgings and finished rings shall be inspected by the manufacturer, using appropriate NDT methods, to insure that no harmful internal and external defects are present.

Appropriate NDT methods are to include, but not necessarily be limited to, Ultrasonic (UT), Magnetic Particle (MT) and Nital Etch. Particular attention must be paid to roller contact areas of the raceway and the fillet area of the "T" washer.

Manufacturer is to specify the type and extent of each NDT procedure planned for this procurement.

4.3 QUALITY ASSURANCE DATA

Certification of conformance to the requirements of this specification and GE Drawing 47D381002 is required. Engineering analysis supporting bearing conformance to life requirements under loading and operation specified herein snall also be provided. Results of dimensional checks and test results shall be available for GE review prior to approval for shipment.

SECTION 5.0

PREPARATION FOR DELIVERY

The completely assembled bearing, lubricated per paragraph 3.1.5, shall be sealed per the vendor's commercial practice. Kraft paper shall not be used. The bearing shall be crated for shipment in a manner that will preclude damage or contamination. The overall packaging shall provide storage for up to one (1) year.

GENERAL ELECTRIC

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CONT ON SHEET ii SH NO. i

REV NO.

47A380028

CONT ON SHEET ii SH NO. i

TITLE

FIRST MADE FOR

REVISIO

FUNCTIONAL REQUIREMENTS FOR THE CONTROLLER

FOR USE ON THE

MOD-5A WIND TURBINE GENERATOR

MAY 1984

GP Schaugenbach

Responsible Engineer DATE: 5-22-84

N/A

Subsystem Engineer DATE: ______

N/A

Systems Engineering DATE: ______

Chief Engineer DATE: 23 MAY 1984

N/A

Quality Assurance DATE: ______

N/A

WTG Integration DATE: ______

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KING OF PRUSSIA, PA. LOCATION

47A380028

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REVISION LOG

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Revision	Page No.	Paragraph Numbers(s) Affected	Rev. Date	Approval

TABLE OF CONTENTS

SECTION 1.0

INTRODUCTION

1.1 SCOPE

This document describes the functional and performance requirements for the MOD-5A Control Electronics Controller.

1.2 GENERAL DESCRIPTION

The controller receives operator commands and sensor inputs, generates the mode sequence and control of pitch, yaw, and generator, and transmits performance data to the operator station. Figure 1 is a block diagram of the MOD-5A control system.

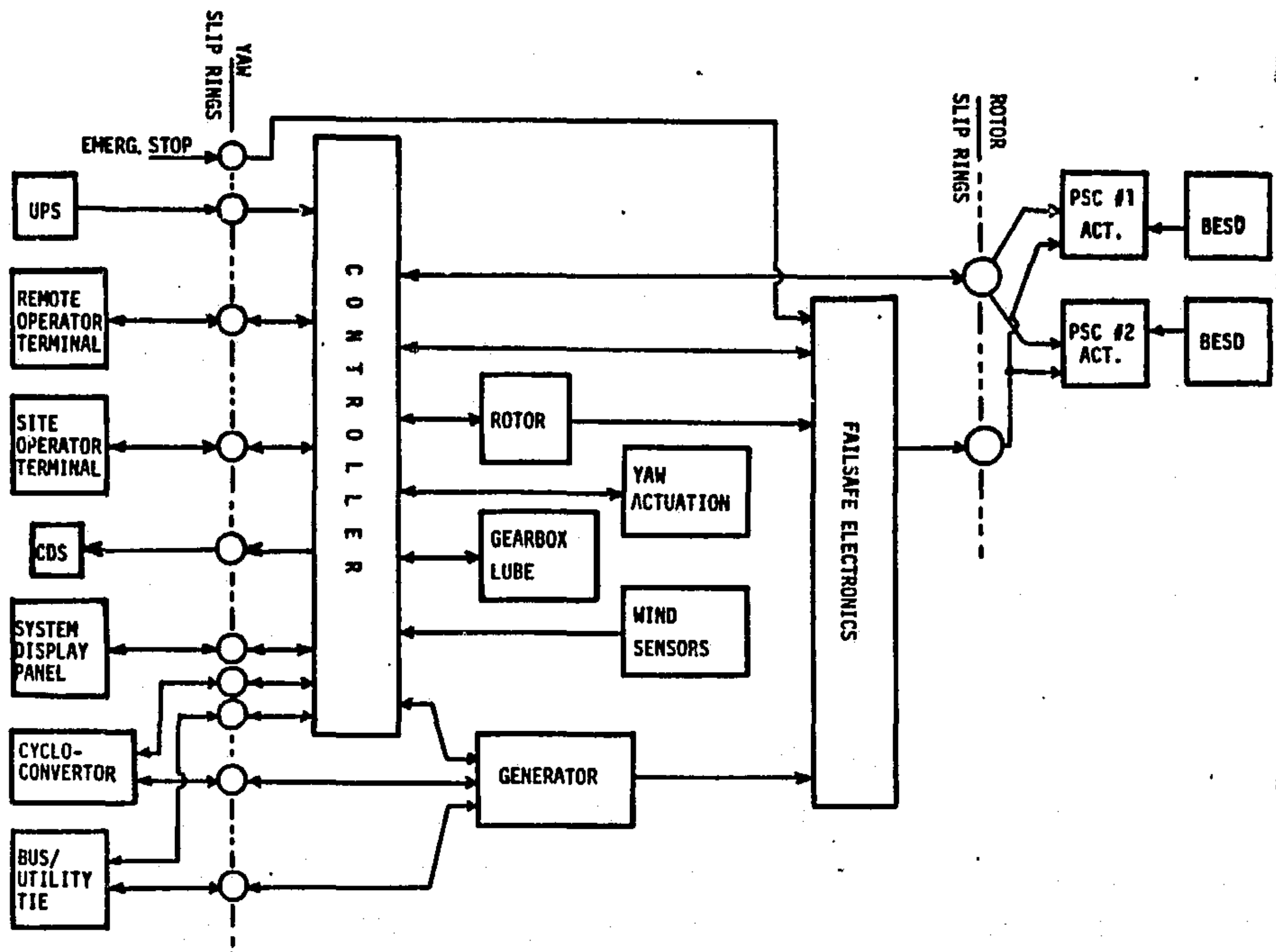

Figure 1 General Control system Block Diagram

SECTION 2.0

APPLICABLE DOCUMENTS

The following documents of the date of issue noted form a part of this specification to the extend specified herein. In the event of conflict between this specification and the documents referenced herein, the contents of this specification shall supersede.

2.1 GENERAL ELECTRIC DRAWINGS

47A390011	System Specification MOD-5A WTG
47A390013	Control Electronics Specification for MOD-5A WTG
TBD	Lightning Protection Requirements for MOD-5A WTG

SECTION 3.0

REQUIREMENTS

3.1 FUNCTIONAL REQUIREMENTS

The Controller:

1. Accepts analog sensor inputs.
2. Accepts digital sensor inputs.
3. Accepts serial data inputs from operator terminals
4. Contains program to select and execute WTG operating modes.
5. Produces analog control outputs.
6. Produces digital (bi-level) outputs
7. Produces serial data outputs to operator terminals.

3.1.1 ANALOG SENSOR INPUTS

The controller shall have an analog input capacity of at least 16 channels.

3.1.2 DIGITAL SENSOR INPUTS

The controller shall have a digital (bi-level) input capacity of at least 78 channels.

3.1.3 SERIAL DATA

The controller shall have a capacity of at least 3 serial data ports.

3.1.4 ANALOG OUTPUTS

The controller shall have the capacity to output at least 8 channels of analog data.

3.1.5 DIGITAL OUTPUTS

The controller shall have the capacity to output at least 34 bi-level channels.

3.1.6 MEMORY CAPACITY

The controller shall have a memory capacity of at least 25K bytes (16 bits/byte) or 48K bytes (8 bits/byte).

3.2 OPERATIONAL REQUIREMENTS

3.2.1 A/D CONVERSION

- 12 bit minimum resolution

3.2.2 SPEED OF OPERATION

- Sufficient to support 100 msec cycle time

3.3. PERFORMANCE REQUIREMENTS

3.3.1 ANALOG INPUTS

The controller analog inputs shall accept a 4 to 20 mA current loop signal. The input voltages shall be less than 10V when the loop current is 20 mA.

3.3.2 DIGITAL INPUTS

The controller digital inputs shall accept a 120 vac signal and load the circuit to a maximum current of 10 mA.

3.3.3 ANALOG OUTPUTS

The controller shall generate analog outputs in the form of a 4 to 20 mA current loop signal. It shall be capable of supplying this 20 mA current to loop resistance of up to 2kΩ (40 ν supply).

3.3.4 DIGITAL OUTPUTS

The controller shall provide digital outputs in the form of a 120 vac signal with 3A continuous and 20A surge capability.

3.3.5 SERIAL DATA PORTS

The controller shall provide at least 3 serial data ports which are 20 mA compatable. The BAUD rate shall be selectable from 300 to 9600 Baud. (300, 600, 1200, 1800, 2000, 2400, 3600, 4800, 7200, 9600) Baud.

3.3.6 CYCLE TIME

The controller shall have a cycle time of less than 100 msec. to execute the analog dynamic control functions.

3.4 <u>ELECTRICAL</u>

3.4.1 POWER REQUIREMENTS

The controller shall be powered from a 120 VAC, 60 Hz, 1 phase circuit and 500 watts maximum. The controller shall withstand a 50 msec interruption of input power and resume operation upon the return of power input.

3.5 <u>MECHANICAL</u>

The controller shall have provision for mounting in a standard 19 inch rack.

3.6 ENVIRONMENT

The controller shall function in an environment of 0 to 40 degrees C with 5 to 90% relative humidity. The elevation of the controller installation may be sea level to 7000 ft.

3.7 MAINTAINABILITY

MTBF 1800 hrs.

MTTR 8 hrs. --- (.9956 availability)

The lowest level of repair is at the plug-in card level.

SECTION 4.0

VERIFICATION

4.1 GENERAL

4.1.1 TEST LOCATION AND RESPONSIBILITY

A combination of analyses, tests and inspection documentation generated in design, development, fabrication and test phases of the MOD-5A program shall be employed to establish conformance of the controller with Section 3 requirements. The activities applied to the Control Electronics Controller verification shall be performed at the General Electric Company Advanced Energy Programs Department.

4.1.2 REQUIREMENTS VERIFICATION

Table 4-1, Requirements Verification Matrix, defines the method of verification (test, analysis, inspection, or design) for each requirement specified in Section 3.

TABLE 4-1

	REQUIREMENT	VERIFICATION METHOD
3.1.1	Analog Sensor Inputs	I
3.1.2	Digital Sensor Inputs	I
3.1.3	Serial Data	I
3.1.4	Analog Outputs	I
3.1.5	Digital Outputs	I
3.1.6	Memory Capacity	I
3.2.1	A/D Conversion	A,T
3.2.2	Speed of Operation	A,T
3.3.1	Analog Inputs	I,T
3.3.2	Digital Inputs	I,T
3.3.3	Analog Outputs	I,T
3.3.4	Digital Outputs	I,T
3.3.5	Serial Data Ports	I,A,T
3.3.6	Cycle Time	A,T
3.4.1	Power Requirements	I,T
3.5	Mechanical	I
3.6	Environment	A,T
3.7	Maintainability	I,A

I = Inspection

T = Test

D = Design

A = Analysis

GENERAL ELECTRIC

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CONTROLLER SOFTWARE SPECIFICATION

FOR THE

MOD-5A WIND TURBINE GENERATOR

MAY 1984

______________ DATE: ______
Responsible Engineer

______________ DATE: 21 MAY 1984
Systems Engineering

N/A DATE: ______
Engineering Manager

______________ DATE: 21 MAY 1984
Chief Engineer

N/A DATE: ______
Quality Assurance

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Revision	Page No.	Paragraph Number(s) Affected	Rev. Date

Approval

TABLE OF CONTENTS

SECTION 1.0
INTRODUCTION

1.1 SCOPE

This document describes the functional requirements for the MOD-5A Control Electronics Controller Software.

1.2 GENERAL DESCRIPTION

The Controller Software is the set of instructions which program the controller to perform its function. The controller receives sensor and operator inputs, determines the operating mode, and processes the input signals to actuate the controller outputs to operate the MOD-5A Wind Turbine Generator.

The MOD-5A WTG is designed for automatic unattended operation. The control system monitors wind conditions for startup and shutdown, and controls the startup and the electrical power generated. Non-critical anomalous conditions are indicated to the operator and WTG operation is continued; critical anomalous conditions are indicated and the WTG is shut down. Operator interface terminals provide operator commands and receive summary date to produce a hard copy system operating log. A more extensive operator command capability and detailed data output is provided via the Controls Data System (CDS). Detailed data is provided to a data system.

SECTION 2.0
APPLICABLE DOCUMENTS

The following documents of the date of issue noted form a part of this specification to the extent specified herein. In the event of conflict between this specification and the documents referenced herein, the contents of this specification shall supersede.

2.1 GOVERNMENT DOCUMENTS

NASA/LERC - Statement of Work, DEN 3-153, April 2, 1982

2.2 GENERAL ELECTRIC DOCUMENTS

47A380011	System Specification for the MOD-5A WTG
47A387005	Signal and Command List
47A380013	Control System Specification
47A380044	Software Management Plan

SECTION 3.0
REQUIREMENTS

3.1 FUNCTIONAL REQUIREMENTS

3.1.1 CONTROL FUNCTIONS

The controller software shall perform the following control functions:

- o Mode Determination
- o Aileron Position
- o Generator Speed-Torque Reference
- o Yaw Orientation
- o Hydraulic Pump (Pitch & Yaw) Motor Control
- o Gearbox & Generator Lub System, Pump Motor Control
- o Rotor Position
- o Rotor Brake
- o Teeter Brake
- o Electrical Power Output
- o Normal Shutdown
- o Alarm
- o Operator Interface (Site, Remote, and Manual)
- o Operational Data Display
- o Data Archive

3.1.2 MODE DESCRIPTION

There are 7 operating modes defined as follows:

- o Lockout
- o Standby/Inhibit
- o Standby/Enable
- o Startup
- o Ramp-up and Sync
- o Power Generation
- o Normal Shutdown

The automatic mode sequence is based on available wind energy. When the available wind is unsuitable for operation (<14 mph or >60 mph), the WTG is shutdown and the Standby/Enable mode is established. When the wind velocity is within the operating range, the Startup, Sync and Power Generation modes are established.

The non-operating modes of Standby/Inhibit and Lockout are generated by operator command or by sensed anomalous conditions.

The mode sequence as a function of output power and hub wind velocity is shown in Figure 1. A logic diagram of the mode sequence is shown in Figure 2.

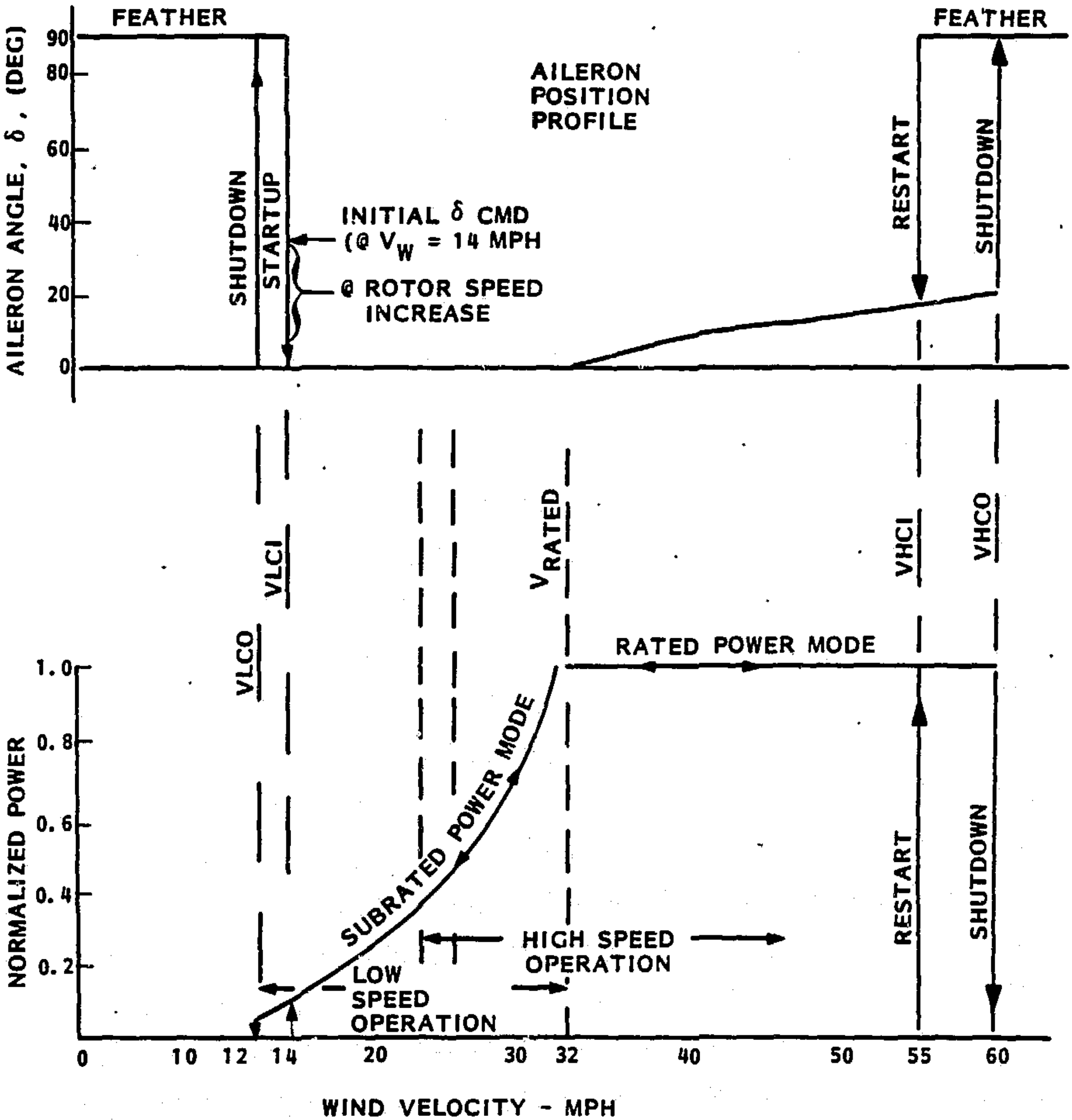

Figure 1 Operating Mode Description

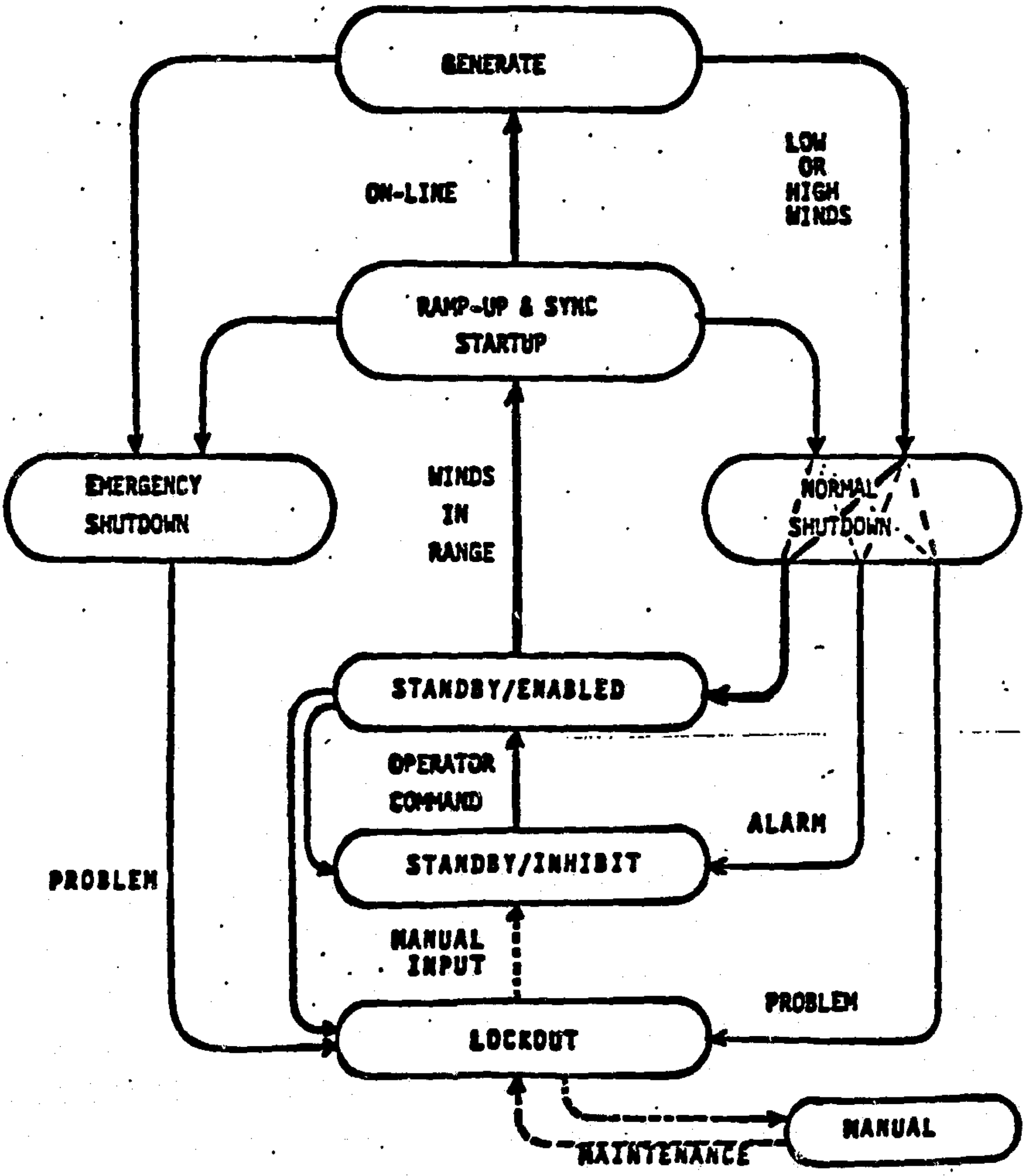

Figure 2 Control System Mode Logic

3.1.3 SOFTWARE MODULE DEFINITIONS

The software function of the controller is divided into the following software modules:

- Executive
- Input Signal Manager (ISM)
- Data Processing
- Mode Logic
- Data Archive
- Power Generation
- Manual
- Communication
  - Remote Terminal
  - Site Terminal
  - Control Data System (CDS)
- Startup
- Ramp
- Yaw
- Alarm
- Normal/Emergency Shutdown
- Rotor Hydraulic Pump
- Output Signal Management
- Memory Test (background)

3.1.3.1 Executive

The executive is initiated at 100 msec intervals and addresses the modules in sequence. The ISM, OSM, data processing, mode and data communications modules are continuously called by the executive. The yaw and data archive modules are called continuously by the executive if the controller is in the automatic run mode sequence. Startup, Ramp, Power Generation, Shutdown, and Standby/Enable are automatic run sequence modules and are called as determined by the mode module. Standby/Inhibit, Lockout, and Manual modes are determined by operator command. Standby/Inhibit and Lockout modes are also generated at the conclusion of a safety shutdown.

3.1.3.2 Input Signal Management (ISM)
The ECL executive controls the signal input/output to the EPTAK system and is transparent to the user application software. The input signal manager transfers the signals read in by the ECL executive into user RAM throughout the user executive cycle.

3.1.3.3 Data Processing
The data processing module calculates signal averages, computer data output, and discrete signal packing.

The calculation of signal average includes wind velocity, wind direction and electrical power produced.

Data output calculations are energy produced for summary printout by the operators terminals.

Discrete signals are read in as one byte for each signal. The data processing module packs each discrete signal as a single bit in an 8 bit word. Thus 8 signals are packed into a single 8 bit word for data output and data archiving.

Analog signals used for computation are 12 bit resolution. For data output and data archive, the data processor terminates the 12 bit analog value to an 8 bit value.

3.1.3.4 Mode
Mode determines which of the automatic sequence modules are to be called by the executive. Signal inputs, processed data, and operator input commands are processed by the mode logic to activate/deactivate the operating modes.

3.1.3.5 Data Archive
The purpose of data archive is to preserve the operating data prior to and immediately after a 2nd level fault that results in a shutdown to lockout. The ongoing operational data is rendered and overwritten such that only the most recent data preserved. On event the ongoing data set is preserved and a second data set of post event data is generated. The data archive is maintained in RAM for subsequent read-out through the operators terminal.

3.1.3.6 Power Generation

Power generation calculates the control signals to position the ailerons and the reference signal for the converter (torque) control. The aileron control signal is based on proportional plus integral computation of rotor speed error. The converter reference signal is a steady state value. There are two nominal operating reference speeds defined. The power generation module computes the reference signal for the two control loops and processes the aileron control.

3.1.3.7 Manual

Manual is a non-operating mode where the operator can exercise control of individual component functions. The basic purpose of the manual mode is to support maintenance operations where it is desired to operate and checkout functions individually. Operator command inputs are via the site operator terminal Minimum inhibit logic prevents the execution of undesireable commands.

3.1.3.8 Communication

a) Control Data System The CDS communication is two-way between the controller and the CDS. The controller outputs data at a rate of one data set per second. The operator can request for read-out of a specified RAM location and on operator command the value of operating parameters can be changed.

b) Site Terminal Communication with the site terminal is two-way. The controller prints at 15 min. interval or on event summary data such as: average power, energy, wind speed, mode, and any alarms present. Site to controller communications sends commands such as speed set point, power set point, and standby enable. Manual control inputs are entered via the site terminal.

c) Remote Terminal Remote terminal to controller communication is the same as communication with the site terminal except the manual control function as deleted.

3.1.3.9 Startup

Startup is the first module executed in the automatic sequencing operation when the wind turbine is in Standby/Enable and ready to generate power. Startup is designed to do a function checkout of critical items such as emergency shutdown, aileron position command and sensors, "G" switches, and teeter brakes prior to rotation.

3.1.3.10 Ramp

Ramp is designed to accelerate the turbine rotor to operating speed by control of the aileron angle and the generator/motor torque.

3.1.3.11 Yaw

The yaw module controls the yaw position to turn the nacelle so the wind turbine is facing into the wind. Yaw is active in the Standby/Enable, Startup, Ramp, and Power Generation modes.

3.1.3.12 Alarm

This module senses an alarm condition and sets up the alarm code for output by Data Communication to site and remote terminals, and CDS.

3.1.3.13 Shutdown

Normal Shutdown is achieved by changing the aileron cont ol angle and simultaneously adjusting air gap torque reference to apply deceleration torque and a speed ramp to stop. This module also controls to engage teeter brakes, latch tips and turn pumps off.

3.1.3.14 Output Signal Management (OSM)

The output command signals generated during the executive cycle are read-out by the OSM at the completion of the active portion of the executive cycle.

3.1.3.15 Memory Test

(later).

3.2 OPERATIONAL REQUIREMENTS

The following paragraphs define the operational requirements for the software modules defined in paragraph 3.1.3.

3.2.1 EXECUTIVE

Each module shall have one RAM (Random Access Memory) location that is used as an activation flag and another that is a segment counter. The activation flag(s) are set by the mode module and used by the executive to execute the corresponding modules. The segment counter calls a part of the module for execution.

3.2.2 ISM

These modules read the sensor signals into the controller memory (ISM). The sensor inputs are scanned by the ISM and a digitized value for each input is stored in an assigned RAM location.

3.2.3 DATA PROCESSING

<u>Calculations</u>

- energy produced yesterday and today
- machine mechanical availability yesterday and today - mechanical availability is defined as equal to

  $$1 - \frac{\text{time in lockout mode}}{\text{total elapsed time}}$$
- aileron angle correction (aileron pairs)

  corrected angle = (angle reading - bias)*slope

<u>Signal Averaging</u>

Signal averages are calculated by a succession of averaging the averages. An average of eight Ø.1 samples is calculated and stored. An average of the 8 sample averages is calculated and stored. This process is continued to obtain the desired time average.

The 12.4 sec power average is calculated by averaging 2 - eight sample averages of 8 (Ø.1 sec) samples. The 51.2 sec average of wind velocity and yaw error is the average of 8 averages of 8 averages of 8 (Ø.1 sec) samples.

3.2.4 MODE

MODE is the main decision making module of the controller software. MODE decides which mode and/or module the controller should be executing and then activates the proper module flags.

Possible Modes	Modules Scheduled by MODE
Lockout	Startup
Standby Inhibit	Ramp Up and Sync
Standby Enable	Power Generation
Startup	NSD
Ramp Up and Sync	Alarms
Power Generation	Yaw
Normal Shutdown (NSD)	Data Archiving
	Communications (Site and Remote)

Mode sequences the normal startup ramp/sync, power generation, & shutdown. The mode logic is shown in Figure 2.

The default and initial mode is lockout. To exit from lockout to standby inhibit, the keyswitch on the system display panel must be switched to automatic. To get to standby enable from standby inhibit, an enable command from the site or remote terminal is needed. Standby enable will go to startup when the five minute average is between 14 mph and 55 mph. After a successful completion of startup, ramp is entered and after ramp is completed, power generation is entered. Figure 3 is the logic diagram for the Turn On sequence.

A normal shutdown can be activated upon detection of an abnormal condition during any operation i.e., mode, startup, ramp, or power generation. On the completion of normal shutdown three possible modes could be entered depending on the condition that caused the shutdown. Those modes are lockout, standby inhibit, and standby enable. A second level fault causes an exit from the present state to lockout. A first level fault causes an exit to standby inhibit. There are four conditions that cause a normal shutdown to standby enable.

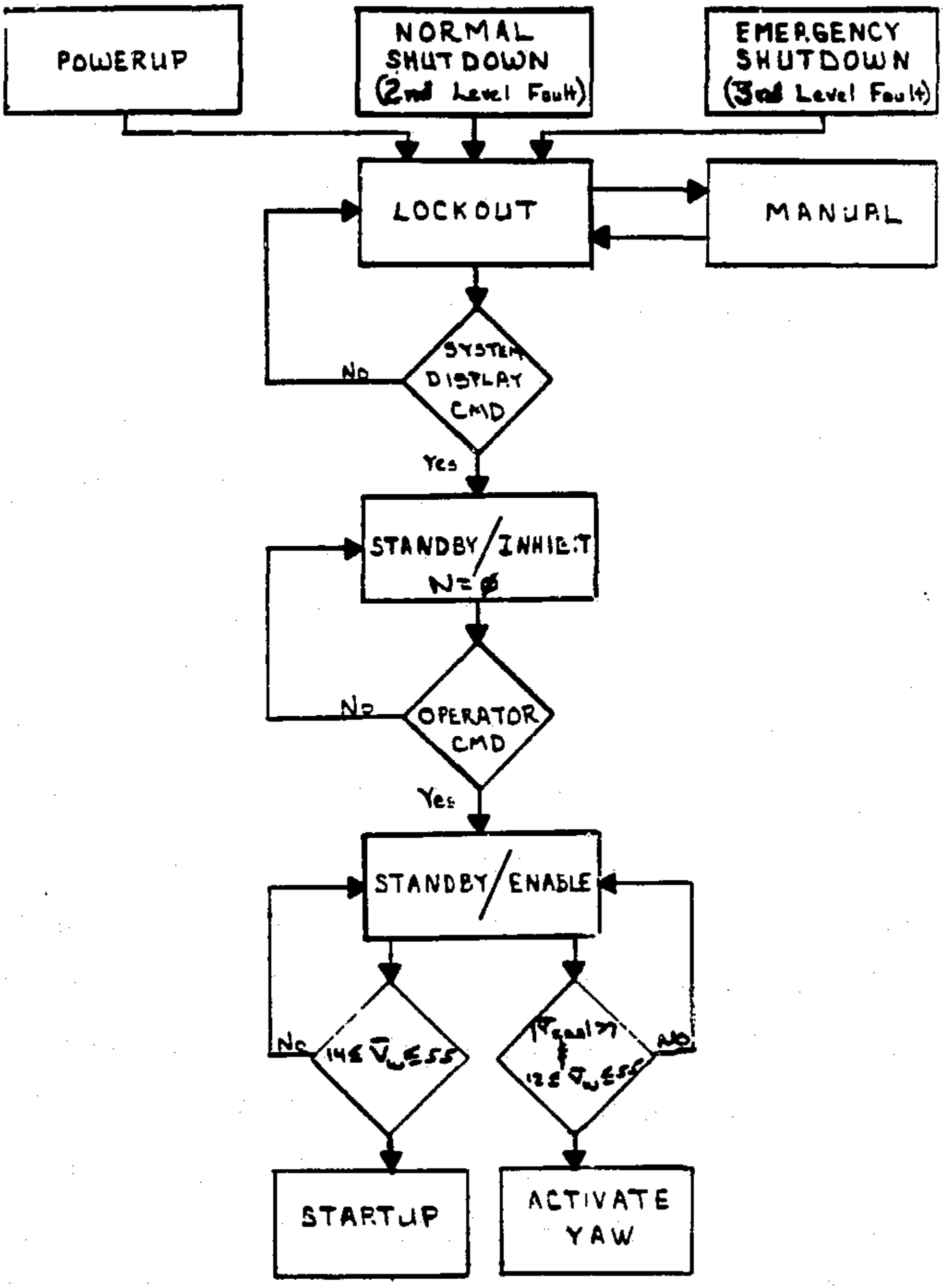

Figure 3 Turn on Sequence

They are:

1. In power generation, average power less than zero for 5 minutes
2. In power generation, $\delta > 33° - 12*Psp$ for 1 min.
3. In ramp, unable to keep ramp rate
4. In any operating mode, large yaw error (E_y)
   $E_y > 45$ when wind speed <45
   $E_y \geq (145 - 7.7* \delta ave)$ when wind speed > 45

3.2.4.1 <u>Lockout</u>

Lockout is called on initial power up change from manual to automatic, or after a 2nd level fault. After the fault has been corrected, the keyswitch on the System Display Panel will reinitialize the system and place the system in the Standby/Inhibit mode.

3.2.4.2 <u>Standby/Inhibit</u>

This mode is a hold state. The WTG is ready, there are no faults detected, but startup is inhibited.

Standby/Inhibit mode can be entered from lockout with ESD READY via the system display panel keyswitch. It can also be entered at the conclusion of Normal Shutdown (NSD) initiated by a terminal command (site or remote) or by certain recoverable alarm conditions (1st level fault).

3.2.4.3 <u>Standby/Enable</u>

In Standby/Enable the WTG has no detected faults and the controller is awaiting acceptable wind conditions.

-- $14 \leq$ Wind Velocity ≤ 55 mph
   (5 min. ave)

-- $|$Yaw Error$| \leq 7°$
   (1 min. ave)

Enable yaw where the wind velocity (5 min. ave) > 12 mph.

3.2.5 DATA ARCHIVING

The base data log sample is comprised of fifty (50) words of analog and packed discrete functions. A 30 second running data log running at 1 sample per second is maintained during operation. When a forced shutdown occurs the 30 second log presenting the data before shutdown is preserved. The data representing post shutdown performance is preserved in two (2) segments as follows:

30 samples at 1 sample per second
30 samples at 1 sample per 5 seconds

3.2.6 POWER GENERATION

Throughout Power Generation the aileron control is proportional plus integral where the control angle command is calculated by:

$$\delta_c = \delta_{-1} + G_1 \Delta E_n + G_2 E_n \Delta t$$

Where δ_{-1} is the position in the last cycle

$E_n = N_R - N_{R\ ref}$
$\Delta E_n = N_{R-1} - N_R$
Δt = controller cycle time
G_1 = proportional gain
G_2 = integral gain

The rotor speed reference $N_{R\ ref}$ is 13.8 (low speed) & 16.8 (high speed).

Low wind shutdown is defined by the output power less than/equal to Ø for 5 min.

High wind shutdown is defined by the aileron angle greater than:
$\delta_{av} \geq (33° - 12{*}P_{sp})$.

The transition from low speed ($N_{R\ ref}$ = 13.8 rpm) to high speed ($N_{R\ ref}$ 16.8 rpm) is initiated when the power output 5 min. average is greater than 4.5 MW.

The transition from high speed (16.8 rpm) to low speed (13.8 rpm) is initiated when the power output 5 min. average is less than 3.0 mw.

The transition between hi and lo speed is implemented by simultaneously changing the speed reference $N_{R\ ref}$ & $N_{G\ ref}$ at a 1 rpm/min referred to rotor speed. Figure 4 is a logic diagram of power generation.

3.2.7 MANUAL

This is the state where the site operator is in control of the WTG. Manual mode is entered from Lockout mode and is initiated via the keyswitch located on the System Display panel.

3.2.8 COMMUNICATIONS

Communications is two way between the site operator terminal or remote operator terminal and the controller. Only one of the terminals may communicate to the controller at a time and the terminal that has control must relinquish the control to the other terminal for it to be in control. For security purposes, each terminal has a password. The correct password must be inserted before commands will be accepted.

There will be continued operation of the controller in the event of loss of communication. Communications is necessary to bring the controller out of the Standby/Inhibit mode. All other times it provides added capabilities or information.

3.2.8.1 Remote Operator Terminal

-- Commands to Controller
  - Standby enable
  - Power set point
  - Var set point
  - Normal shutdown
  - Emergency shutdown
  - Request remote terminal control
  - Enable site terminal control
  - Set month, day, hour, and minute

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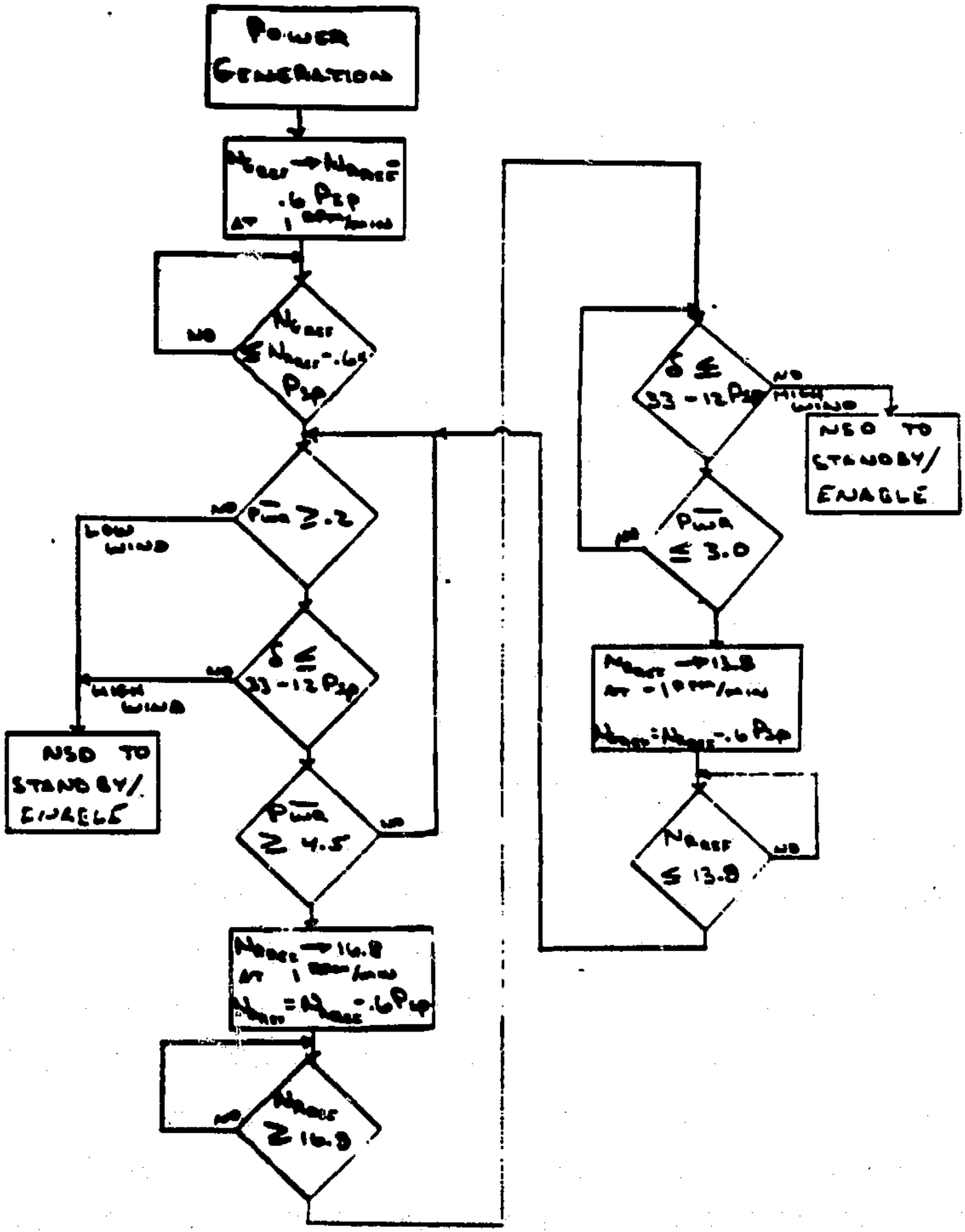

Figure 4 Power Generation

-- Output to terminal
- Month, day, hour, minute, and second
- Terminal control
- Cumulative energy produced yesterday
- Cumulative energy produced since specified date
- Speed set points
- Power set points
- Var set point
- Alarm number
- Wind speed
- Power
- Energy
- Mode (LO, SBI, SBE, SU, RMP, PWR, NSD)

3.2.8.2 Site Operator Terminal

-- Commands to Controller
- Standby enable
- Rotor speed set point
- Power set point
- Var set point
- Normal shutdown
- Emergency shutdown
- Request site terminal control
- Enable remote terminal control
- Set month, day, hour, and minute

-- Manual control commands to controller
- Dump data archive
- Rotor brake control
- Rotor position control
- Individual hydraulic pump motors
- Yaw brake control
- Yaw position control
- Individual aileron motion
- Teeter brake LF
- Teeter brake HF

-- Output to terminal
(Same as Remote Terminal)

3.2.9 STARTUP

The conditions for startup are:
- o STANDBY/ENABLE
- o $14 \leq$ Wind velocity (5 min) ≤ 55
- o Yaw error $\leq 7°$

Startup is the following sequence. Figure 5 is a logic diagram of STARTUP. The failure of a verify check results in NSD to LO.

o Command gear & gearbox lub and rotor hydraulic pumps on and verify operating pressure.

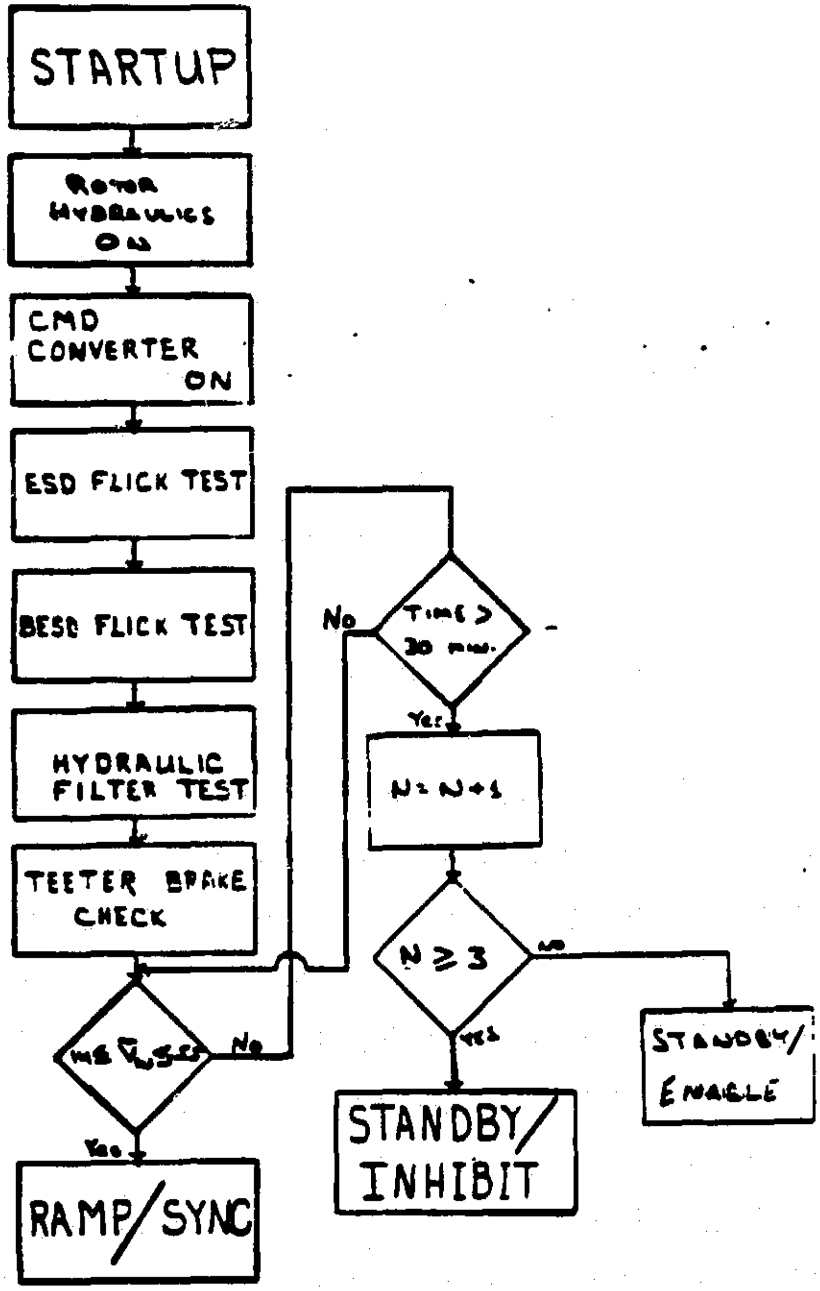

Figure 5 Startup

o RESET G - switch 1 and 2 with the following sequence:
- G Switch disable OFF
- ENABLE G Switch test
- BLADE 1 RESET
- BLADE 2 RESET
- Remove Blade 1 & Blade 2 Reset

o Unlatch aero controls with the following sequence:
- Command feather position
- Command ENABLE FEATHER
  VALVE A1 and A2 and verify unlatch.

o Check BESD G - switch #1 with following sequence:
- Command aero control to 85° at 1°/s and stabilize
- Command 1/2 level G - switch #1 test and verify no response.
- Command full level G switch #1 test and verify all aero controls are driven to feather and latch.
- Reset "G" Switch
- Unlatch aero control

o Check BESD G - Switch #2 with same sequence used for G Switch #1.
- Remove EN B11, B12 1/2 EN TEST, G SW DISABLE.

o Hydraulic filter ΔP check.
- Command aero control to 70° at 5°/S and while the aero controls are moving at the 5°/S rate, check the filter ΔP signal and issue an alarm if the ΔP signal indicates a high pressure drop.

o ESD Check
- Remove feather valve A1 enable and verify the 1-1 thru 1-4 aero controls are driven to feather
- Remove feather valve A2 enable and verify the 2-1 thru 2-4 aero controls are driven to feather and all aero controls are latched
- Unlatch the aero controls

o Teeter brake check
(later)

- o Recheck wind velocity (V_w)
  - If $14 \leq V_w < 55$ proceed to ramp/sync.
  - If $55 < V_w < 14$ for 30 minutes return to standby ENABLE.

3.2.10 RAMP/SYNC

Ramp/Sync is activated after completion of startup when the wind velocity is within the acceptable operating range. The following describes the ramp/sync sequence. The failure to verify a command shall result in normal shutdown to lock out. Unless otherwise indicated during ramp,

$\delta_c \quad = \delta_{-1} + G_1 \Delta E_n + G_2\ E_n \Delta t$

where δ_{-1} is aileron position last cycle

$E_n \quad = N - N_{ref}$

$\Delta E_n \quad = N_R - N_{R-1}$

$\Delta t \quad$ = integral constant

$G_1 \quad$ = proportional gain

$G_2 \quad$ = integral gain

Figure 6a, 6b, & 6c is a logic diagram of RAMP/SYNC.

- o Initialize
  - Calculate $\delta_{1c} = .36\ V_{wavg} + 25°$
  - Command aero control to δ_{1c} at 5°/S and settle
  - Release rotor brake and verify

- o Ramp - Ø to 3.7 rpm
  - CMD START MOTOR
  - Command $N_{G\ ref}$ to the converter

    $N_{G\ ref}$ = 300 rpm/min *Δt
  - $\delta_c = \delta_{1c}$

- o at N_R= 3.7 rpm shift to aero torque control and unload generator (motoring).
  - $N_{G\ ref} = N_G$
  - $N_{R\ ref} = 3.7 + 1.8t$
  - When P > - Ø.2 COMMAND MTR OFF
  - $N_R = 4 + N_{R\ ref} = 4.0$, $N_{G\ ref} = N_{R\ ref} * GR$ (gear ratio)
  - Check blade temp

    if $\leq$105°F then continue

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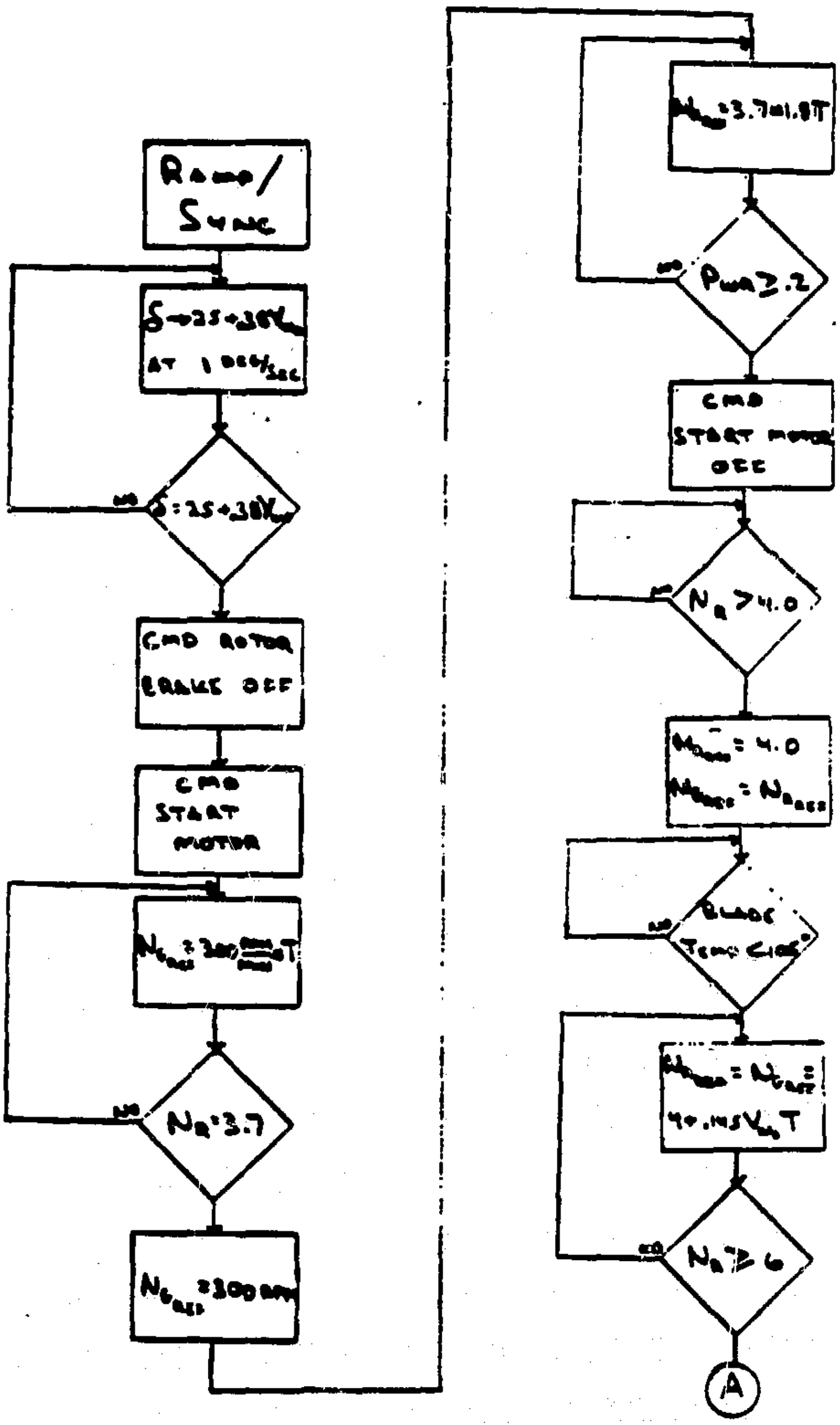

Figure 6a RAMP/SYNC

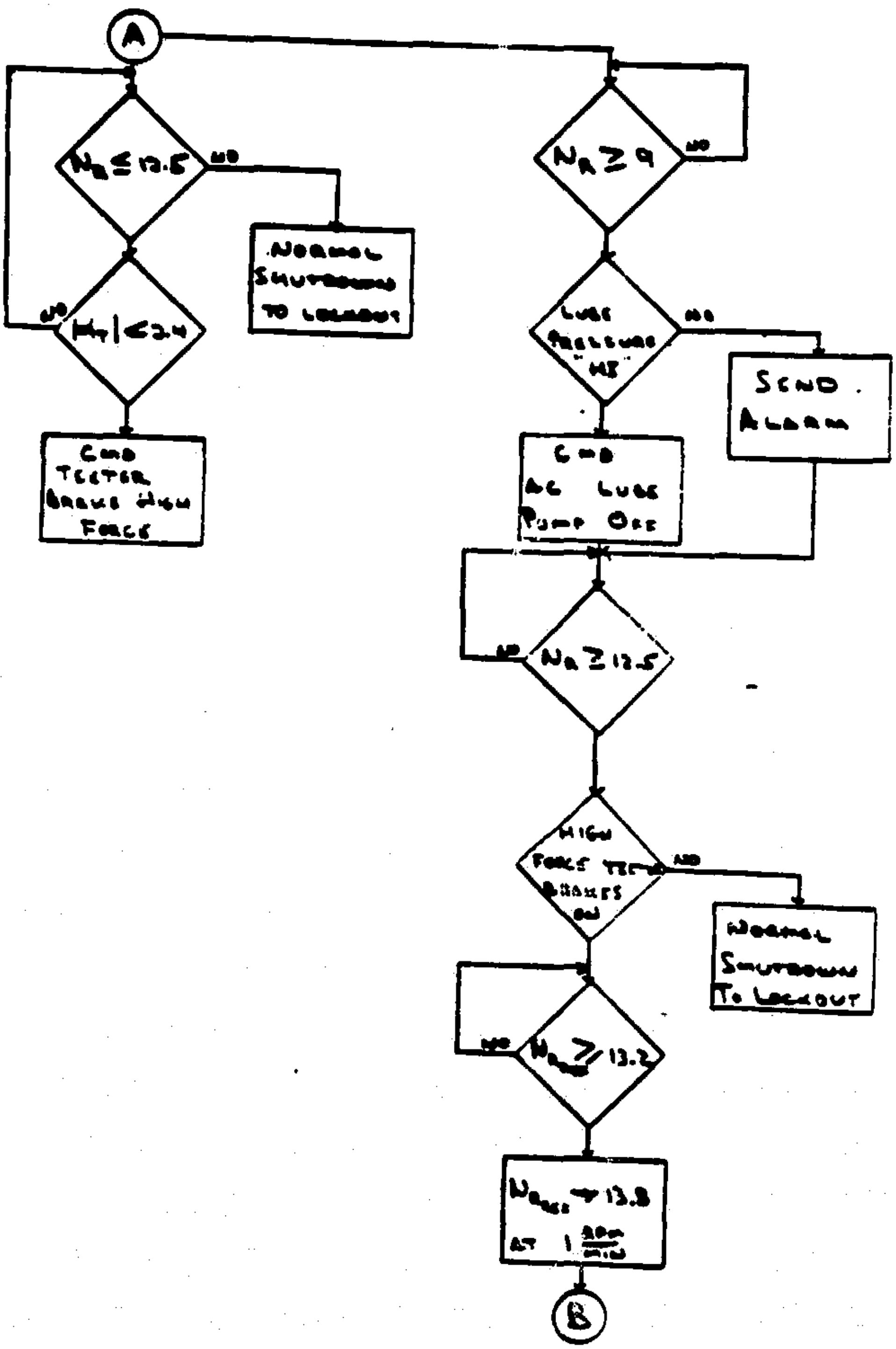

Figure 6b RAMP/SYNC (CONT'D)

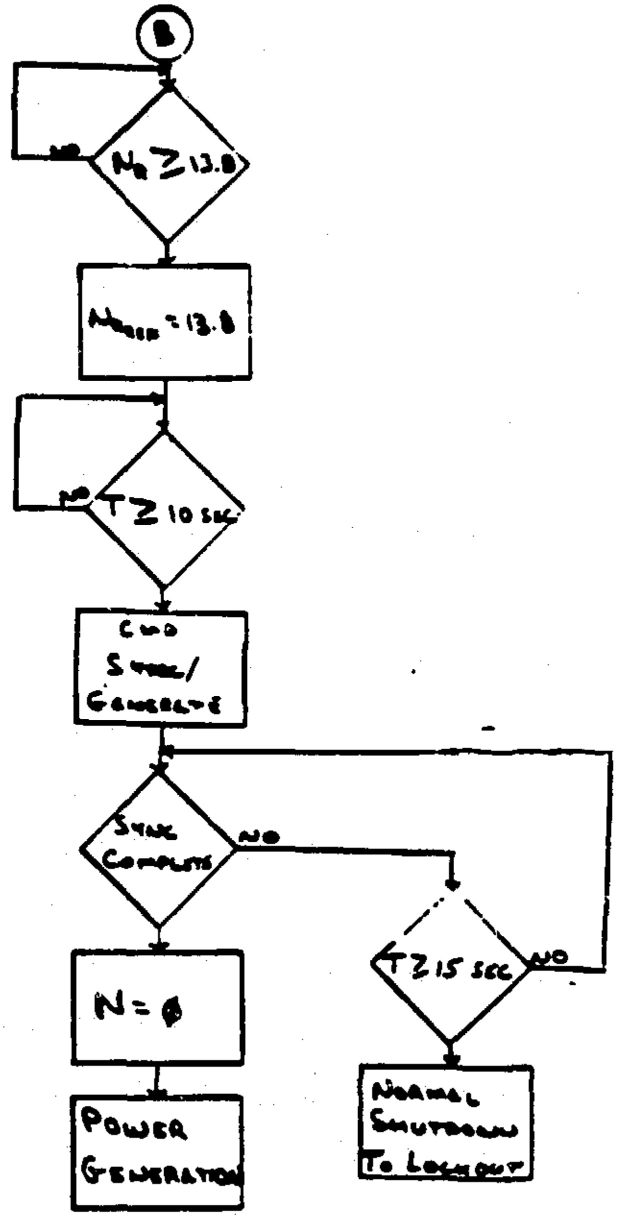

Figure 6c RAMP/SYNC (CONT'D)

o Ramp 4.0 rpm to 13.8 rpm

- $N_{R\ ref}$ = 4.0 + (.145 V_{wo}) * t min
- $N_{R\ ref}$ = $N_{R\ ref}$ * GR
- at $N_R > 6$ and when $|\delta t| \leq 2.4°$ command teeter HF brakes OFF and verify
- at $N_R \geq 9$ command gearbox lube pump OFF, ... etc.
- at $N_R = 12.5$ check sense A
- at $N_R = 13.8$, $N_{R\ ref} = 13.8$ & $N_{G\ ref} = N_{R\ ref}$ * GR settle & hold 30 sec.
- CMD $N_{G\ ref} = N_G$
- command SYNC GEN
- $N_{G\ ref} = N_{G\ ref-1} - 1.8t$
- at $N_{G\ ref} < (13.8 - .6)\ P_{sp}$ set $N_{G\ ref} = 13.8 - .6P_{sp}$

o Set N = Ø (Start up attempt count)

o Exit to power gen.

3.2.11 YAW

The yaw module is activated during the automatic sequence when the wind velocity is greater than 12 mph. This module commands the yaw to move clockwise or counterclockwise based on the yaw error. The yaw error is the relative difference between the present yaw orientation and the wind direction relative to the nacelle position. Yaw correction is executed when the yaw error is greater than 7° and stops when the yaw error is less than 3.5°. At this time, the yaw drive is not active and both the yaw motive brakes and the yaw holding brakes will be "ON". During operation, the brakes and gripper are operated in "apply-before-release" sequence.

There will be two sets of wind sensors for wind speed and a wind direction. During wind condition checks leading to startup, the highest average wind speed sensor output shall be used for all the logic decision. One of the wind direction sensors will be used in determining yaw error. the second set of sensors in both cases will be used as a comparison for the first set of sensors to determine malfunctions.

3.2.12 ALARM

This module detects the rising and falling (turn on and turn off) of all alarms and assigns a number depending on the alarms location in assigned RAM. For example, Alarm #1 is 001 if rising, and 129 (1 + 128) if falling. fourteenth alarm is 014 if rising, 142, (14 + 128) if falling. This alarm number is stored in an alarm table for output by CDS, Remote Terminal and Site Terminal.

The alarms conditions are identified in Table 1. Upon occurrence of an alarm condition, the alarm identification number is transmitted to the CDS and the operator terminals. A second alarm message is transmitted when the alarm condition is removed.

3.2.12.1 <u>First Level Fault - (NSD → SBI)</u>

The first level fault conditions are given in Table 2. The NSD → SBI sequence is initiated by (a) operator command and (b) recoverable fault conditions.

3.2.12.2 <u>Second Level Fault - (NSD → LO)</u>

The second level fault signifies non-recoverable fault conditions and initiates a manual shutdown to lockout sequence. Table 3 lists the second level faults condition.

3.2.12.3 <u>Third level fault - ESD</u>

The third level fault is executed by the ESC and assumes the controller has failed. However, in the event of third level fault, the controller logic shall command and execute a normal shutdown procedure but shall not be responsive to signal inputs for the purpose of command verification.

3.2.12 SHUTDOWN

A manual shutdown can be initiated at anytime and under all operating conditions. The shutdown is implemented by controlling the speed ramp down rate at 10 rpm/min by ramping the speed reference for aileron control and the converter reference. Gearbox lube pump is turned on at 9 rpm. Rotor brakes are turned on when aileron controls reach 70°. The converter ready OFF, teeter brake ON, lube pumps OFF, and the circuit breaker OPEN are executed at the completion of shutdown. Figure 7 is a logic diagram of shutdown.

Table 1 Alarms

Condition	Trigger Condition	Expected Cause
I GENERAL CS		
A1.1 Aircraft Warning Strobes Inop.	Local Sensor	Strobe Failure
A1.2 Fire Equipment Activated	Local Sensor	Fire Conditions
A1.3 Control Enclosure Cabinet Temp "HI"	T > 104°F	Heat Exchanger Failure
A1.4 Wind Speed Sensor Mismatch	Δ > 5 mph (See 3.3.1.1.2)	Sensor Failure
A1.5 C.E.C. Temp. Out-of-Range	T > 50°C or T < 0°C	Heat/Cooling Equip. Failure
II AILERON ACTUATION & TEETER BRAKE		
A2.1 Rotor Hyd Oil Filter ΔP "HI"	ΔP > 40 psi	Filter Clog/Cold oil
A2.2 Rotor Hyd Main Accum Press "LO"	P < 2000 psi	Leak/pump failure
A2.3 Rotor Hyd. Res. Oil Level "LO"	P $\leq$ 5 psi = low oil	Leak/bad sensor
A2.4 Rotor Hyd. Oil Temp. "HI"	T > 145°F	Heater failure
A2.5 Rotor Hyd. Pump Discharge Press. "LO"	P < 2000 psi	Leak/pump failure
A2.6 Teeter Angle "HI"	$\lvert\alpha_T\rvert > 4°$ (analog signal)	Blade unbalance/Loose sensor
A2.7 Teeter Accum Press "LO"	P < 2000 psi	Leak/pump failure
III ROTOR		
A3.1 Blade Temperature "HI"	T > 105°F (See 3.2.2.1.4)	Temp. Soak @ Standstill
IV GEARBOX LUBE		
A4.1 One-of-three Supply Press. "LO"	P < 60 psi	Leak/pump failure
A4.2 Shaft Driven Pump Press. "LO"	P < 60 psi	Leak/pump failure
A4.3 Lube Filter ΔP "HI"	ΔP > 10 psi	Filter clog/cold oil
A4.4 Lube Supply Temp. "HI"	T > 120°F	Cooler failure
A4.5 Lube Supply Temp. "HI-HI"	T > 135°F	Cooler failure
A4.6 Lube Sump Temp. "HI"	T > 140°F	Heater failure
A4.7 Lube Sump Temp. "LO"	T < 60°F	Heater failure/Initial Start
A4.8 Lube Sump Oil Level "LO"	Level < 100 gal.	Leak/bad sensor
V GENERATOR/CONVERTER		
A5.1 Generator Lube level "LO"	Level < 5 gal.	Leak/bad sensor
A5.2 Generator Lube Filter ΔP "HI"	P > 10 psi	Filter clog/cold oil
VI YAW ACTUATION & ROTOR BRAKES		
A6.1 Yaw Holding Brk. Accum. Press. "LO"	P < 1800 psi	Leak/pump failure
A6.2 Yaw Main Accum. Press. "LO"	P < 1800 psi	Leak/pump failure
A6.3 Hyd. Filter ΔP "HI"	P > 80 psi	Filter clog/cold oil
A6.4 Oil Temperature "HI"	T > 140°F	Heater failure
A6.5 Oil Level "LO"	Level < 10 gal.	Yaw hyd. leak
A6.6 Yaw Motive Brk Status Fault	Status $\neq$ Cmd	Leak/pump failure
A6.7 Wind Direction Sensor Mismatch	Angle > 10° (See 3.3.1.1.2)	Loose Mounting
A6.8 Rotor Brake Status Fault	Status $\neq$ Cmd (non-rotating)	Solenoid Failure
A6.9 Rotor Brake Accum. Press "LO"	P <1800 psi	Leak/pump failure

Table 2 First Level Fault Cond. (NSD → SBI)

- o Operator Command
- o Blade temp 30 min time out
- o Ice detected
- o Generator winding temp > 275°F
- o stator tie breaker trip without lockout relay trip indicating one or more of the following:
  - voltage unbalance
  - over/under frequency (islanded)
  - unbalance line side neutral
  - over current
- o FLIC verification check failure
- o 3 consecutive startup attempts without achieving power gen mode

Table 3 Second Level Fault Conditions (NSD To Lockout)

Condition	Trigger Condition	Expected Cause
I GENERAL CS		
1.1 Intrusion Alarm	- event -	Unauthorized entry
1.2 Emergency Shutdown Panel Failure	Signal from ESP.	Relay circuit fault
1.3 Control Enclosure Cabinet Temp "HI-HI"	$T > 122°F$	Heat exchanger out
1.4 Rotor/Generator Speed Mismatch	$\lvert N_R - N_G \rvert > 0.2$ rpm	Speed sensing error
II AILERON ACTUATION & TEETER BRAKE		
2.1 Aileron Emergency Feather Accum. Press."LO"	$\Delta P < 2000$ psi	Leak/pump failure
2.2 Aileron Cmd vs Position Mismatch	$\lvert \delta_{cmd} - \delta_{11} \rvert < 10°$	G-Switch Activation
2.3 Aileron Deflection Mismatch	$\lvert \delta_{1x} - \delta_{2x} \rvert < 5°$	Actuation failure
2.4 Teeter High Force (HF) Brakes "ON"	Angle > 5° (See 3.3.5)	Unbalance condition
2.5 Teeter HF Brakes Stay "ON" @ Ramp-up	HF = "ON" and $N_R > 12.5$ rpm	Brake system failure
2.6 Teeter Angle Large	Analog Signal, $\lvert \alpha_T \rvert > 6.5°$	Brake system failure
III ROTOR		
3.1 Rotor Speed "HI"	$N_R \geq 18.0$ rpm	Control failure
3.2 Rotor Vibration "HI"	Vib ≥ 0.1 g	Unbalance condition
3.3 Rotor Structure Strain "HI"	TBD Overstrain	
IV GEARBOX LUBE		
4.1 Lube Supply Pressure "LO"	"2-of-3" sensors @ $P < 60$ psi	Leak/pump failure
4.2 Lube Supply Temp. "HI"	"2-of-3" sensors Hi (See 3.3.6.3)	Heater or cooler failure
V GENERATOR/CONVERTER		
5.1 Generator Lube Press. "LO"	P < psi	Leak/pump failure
5.2 Generator Lube Temp. "HI"	$T > 275°F$	Cooling failure
5.3 Generator Bearing Temp. "HI"	$T > 250°F$	Bearing problem
5.4 Generator Vib. "HI",	Vib. > 0.1 g	Unbalance
5.5 Stator Tie Breaker Trip	Lock Out Relay Activated	(See 3.3.9 discussion)
5.6 "Converter Ready" Signal Removed	Event per converter control	Converter fault
VI YAW ACTUATION AND ROTOR BRAKES		
6.1 Yaw Rate Correction Low	Low yaw rate @ startup (see 3.3.1.1.2)	Actuation failure
6.2 Yaw Error Remains High	$\lvert Ye \rvert > 7°$ for $\Delta t = 5$ min.	Actuation failure
6.3 Yaw Holding Brake Status Fault	Status ≠ Cmd	Leak/pump failure
6.4 Yaw Holding & Motive Brakes OFF	P < 2000 psi, both systems	Operating logic failure
6.5 Yaw Rate Excessively High	Yaw rate > 1°/s (See 3.3.1.1.2)	Brake failure & drive train loaded
6.6 Yaw Error Large and Wind Direction Sensor Mismatch	Mismatch > 10° (See 3.3.1.1.2)	Loose mounting plus high winds
6.7 Rotor Brake Status Fault	Status ≠ Cmd (Rotating)	Solenoid Failure

(2264A)

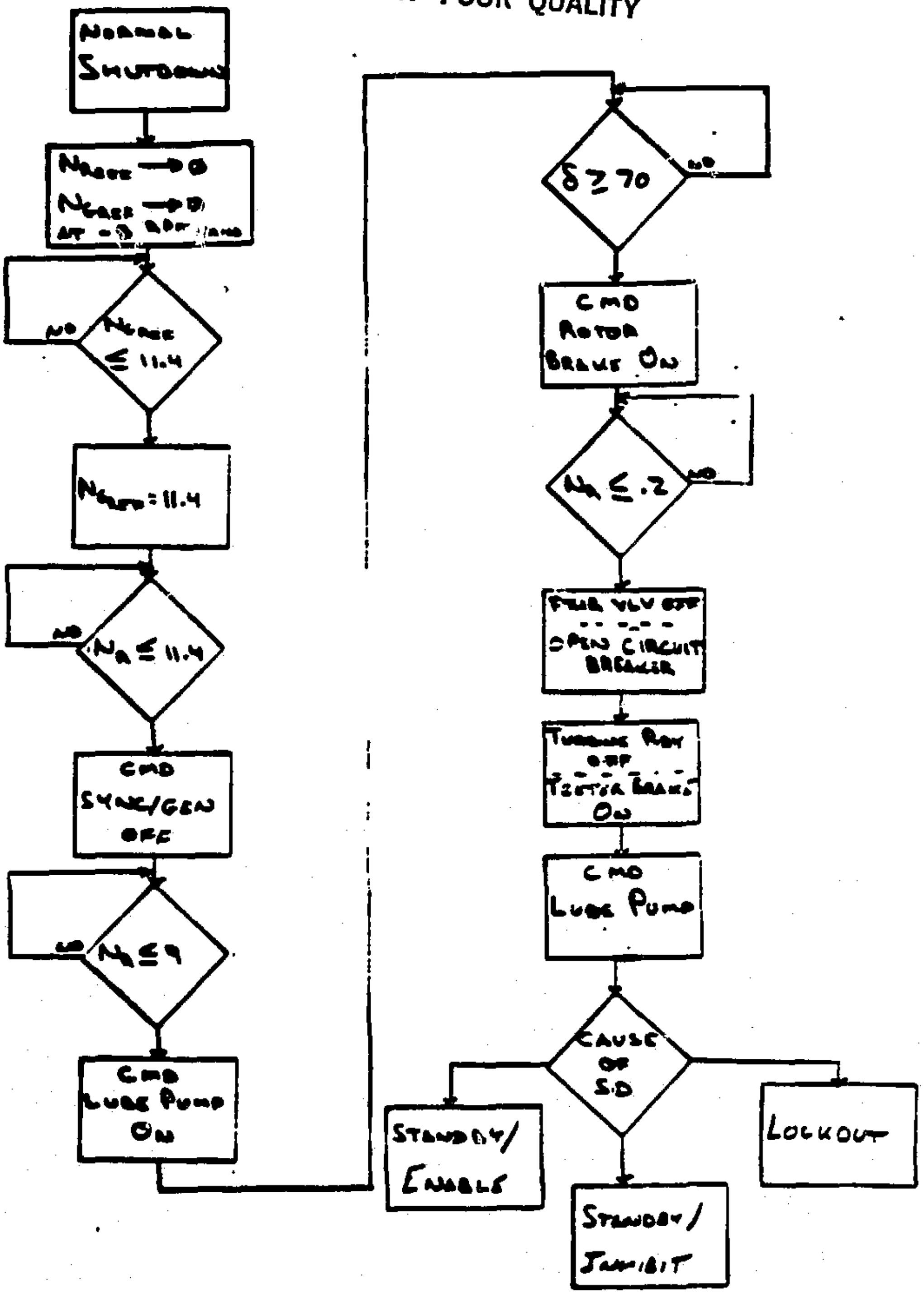

Figure 7 Normal Shutdown

Upon completion of shutdown, the SBE, SBI, or LO mode is established depending on the cause initiating the shutdown.

Aileron control is based on the algorithm:

$$\delta_c = \delta_{-1c} + G_1 E_n + G_2 \Delta E_n \Delta t$$

The shutdown sequence is as follows:

o initiate by setting

$N_{R\ ref} = N_{R\ ref-1}$

$N_{G\ ref} = N_{G\ ref-1}$

o start ramp down

$N_{R\ ref} = N_{R\ ref-1}$ - 8 rpm/min

$N_{G\ ref} = N_{G\ ref-1}$ - 8 rpm/min

o at $N_R < 11.4$ rpm set $N_{G\ ref} = 11.4$ rpm

o when $P \leq \emptyset$ CMD SYNC GEN OFF

and set $N_{G\ ref} = N_{R\ ref}$

o at $N_R \leq 9$ turn gearbox lub pump ON

o at $\delta \geq 70°$ turn rotor brake ON

o At $N_R \leq \emptyset.2$

- turn A1, A2 ENABLE OFF
- open CKT BKR
- turn TURBINE READY OFF
- turn TEETER BRAKE ON
- turn LUBE PUMPS OFF

o if low/high wind shutdown go to SBE

o if level 1 shutdown go to SBI

o if level 2 shutdown go to LO

3.2.14 OUTPUT SIGNAL MANAGEMENT

The output signal manager module issues the output commands generated during the executive cycle.

3.2.15 MEMORY TEST

(Later)

3.3 CONTROLLER INPUTS AND OUTPUTS

3.3.1 CONTROLLER OUTPUTS

	Discrete	Analog
o Ice detector Blade 1	X	
o Ice detector Blade 2	X	
o Blade 1		X
o Blade 2		X
o Pitch hydraulic pump on	X	
o Feather valve A-1	X	
o Feather valve A-2	X	
o Enable ESD command	X	
o Enable feather valve A-1	X	
o Enable feather valve A-2	X	
o G Switch 1/2 scale test Blade 1	X	
o G Switch 1/2 scale test Blade 2	X	
o G Switch full test Blade 1	X	
o G Switch full test Blade 2	X	
o G Switch test Blade 1 Reset	X	
o G Switch test Blade 2 Reset	X	
o Teeter brake AC power	X	
o Teeter brake high force	X	
o Rotor positioner drive	X	
o Rotor brake	X	
o Gearbox lube pump	X	
o Turbine ready command	X	
o Start/motor CMD	X	
o Sync/generate CMD	X	
o Torque/speed ref.		X
o Var/volt ref.		X

o Lockout relay CMD	X
o Converter tie close	X
o Converter tie trip	X
o Yaw pump enable	X
o Yaw CW CMD	X
o Yaw CCW CMD	X
o Yaw motive brakes	X
o Yaw holding brakes	X

3.3.2 SIGNAL INPUTS

NOTE: All signals are discrete unless noted.

ICE DETECTION BLADE 1
ICE DETECTION BLADE 2
HI TEMP BLADE 1
HI TEMP BLADE 2
HI STRAIN BLADE 1
HI STRAIN BLADE 2
PITCH HYD. RESV. STATUS
PITCH HYD. OIL FILTER STATUS
PITCH HYD. OIL TEMP. STATUS
PITCH ACCUM LO PRESS. BLADE 1
PITCH ACCUM LO PRESS. BLADE 2
PITCH PUMP LO PRESS.
MAIN FILTER ΔP STATUS
SERVO VLV FILT STATUS BLADE 1
SERVO VLV FILT STATUS BLADE 2
TEETER BRAKE STATUS - HIGH FORCE SOLENOID ON
TEETER BRAKE STATUS - ACCUM. PRESSURE LOW
TEETER ANGLE -- ANALOG
ROTOR VIBRATION
ROTOR RPM -- ANALOG
ROTOR POSITION -- ANALOG
ROTOR POSITIONER DR. STATUS
ROTOR BRAKE STATUS
LUBE RESV. LEV.
LUBE RESV. HI TEMP.

LUBE RESV. LO TEMP.
LUBE SUPPLY TEMP. HI
LUBE SUPPLY TEMP. HI-HI
LUBE SUPPLY LO PRESS. "A"
LUBE SUPPLY LO PRESS. "B"
LUBE SUPPLY LO PRESS. "C"
LUBE SUPPLY FILT. STATUS
LUBE PUMP STATUS, SHAFT DRIVE
GEN. RESV. LUBE LEVEL LO
GEN. RESV. LUBE TEMP HI
GEN. LUBE PRESS. LO
GEN. BEARING TEMP HI
GEN. LUBE FILTER ΔP
GEN. WINDING TEMP. HI
GEN. VIBRATION HI
GENERATOR RPM -- ANALOG
GENERATOR TOTAL OUTPUT (KW) -- ANALOG
GENERATOR TOTAL OUTPUT (KVAR) -- ANALOG
YAW FILTER STATUS
YAW HOLDING BRAKES STATUS
YAW MOTIVE BRAKES STATUS
YAW OIL PRESSURE LOW
YAW HOLDING BRAKES PRESS. LOW
YAW OIL LEVEL LOW
YAW OIL TEMPERATURE HI
UPWIND CYLS CW POS'N
UPWIND CYLS CCW POS'N
DOWNWIND CYLS CW POS'N
DOWNWIND CYLS CCW POS'N
AIRCRAFT STROBE STATUS
ESD SYSTEM STATUS
FEATHER VLV. A-1 CMD STATUS
FEATHER VLV. A-2 CMD STATUS
LOCKOUT RELAY STATUS
UTILITY POWER STATUS
STATOR TIE STATUS

STATOR SHORT STATUS
CYCLOCONVERTER TIE STATUS
INSTRUSION ALARM
OIS/EIS STATUS RELAY
CHARGER STATUS RELAY
UPS BATTERY STATUS
UPS INVERTER STATUS
WIND SPEED #1 -- ANALOG
yaw error #1 -- ANALOG
WIND SPEED #2 -- ANALOG
YAW ERROR #2 -- ANALOG
AUTO/MANUAL
NACELLE FIRE ALARM
C.E.C. HEAT EXCHANGER ALARM - AIR FLOW
C.E.C. TEMP. HI
C.E.C. TEMP HI-HI

3.3.3 REMOTE UTILITY INTERFACE SIGNAL LIST AND SIGNAL DESCRIPTION

The following signals are site specific to the Hawaiian Electric company:

<u>Disable</u> - Discrete to MOD-5A controller that produces automatic shutdown sequence to Standby-Inhibit state, disabling automatic operation.

<u>Enable</u> - Discrete to MOD-5A controller that produces automatic startup sequence from Standby and enables automatic operation.

<u>Power Set</u> - Analog to MOD-5A controller to set maximum output reference to less than rating.

<u>VAR Set</u> - Analog to MOD-5A controller to set reactive power (or voltage) reference within permitted range.

<u>Major Alarm</u> - Discrete from MOD-5A controller indicating a major alarm status exists. This is a combination of existing controller inputs.

<u>Minor Alarm</u> - Discrete from MOD-5A controller indicating an alarm combination that requires some maintenance action on a non-time critical basis, such as filter change.

<u>Standby-Inhibit</u> - Discrete to RTU indicating MOD-5A status.

<u>Standby-Enabled</u> - Discrete to RTU indicating MOD-5A status as enabled or in startup or operation.

<u>Startup/Shutdown</u> - Discrete to RTU indicating MOD-5A status in transition between Standby and Generate. (NOTE: Stator breaker position indicates Generate state).

3.3.4 DATA COMMUNICATION LINKS

There are three (3) data communication links. One link each for the CDS, site terminal, and remote terminal. The site and remote terminal data link transmits ASCII character at 300 BAUD. The CDS data link transmits binary information at 1200 BAUD.

SECTION 4.0
VERIFICATION

Development integration and test with simulator.

- o First unit checkout and evaluation with simulator.
- o Factory test.
- o Initial operation.

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Harry Straub
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SECTION 1.0

SCOPE

1.1 INTRODUCTION

This specification establishes the requirements for a systems display panel (SDP) for use with a seven (7) megawatt variable speed wind turbine generator system. The system display panel will provide controls for selected operator commands, and will display basic operating parameters. The system display panel will include the site telecommunications system, site security system as well as the site video system. The system display panel will be located in the office portion of the electrical equipment building for use with the remote operator's terminal.

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47A381060	CCTV Monitor
47A380013	Control System Specification for MOD-5A WTG
47A380052	Electrical Fabrication and Workmanship Standard
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(Later)	Intercom System Schematic
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47E387080	One Line Diagram

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EIA - RS-310 (Electronic Industries Association)

2.2 INDUSTRY STANDARDS (cont'd)

ANSI - American National Standards Institute

C37.2	Manual and Automatic Station Control, Supervisory and Associated Telemetering Equipments
Y32.2	Graphic Symbols for Electrical and Electronic Diagrams
Y14.5	Electrical and Electronic Diagrams

SECTION 3.0

REQUIREMENTS

3.1 ENVIRONMENTAL

The system display panel assembly, conforming to this specification shall be suitable for operation within the following conditions.

Temperature: Operating: 0 to 40°C

Non-operating: -20 to 50°C

Humidity: 0-80% relative humidity (non-condensing)

Elevations: sea level to 7000 feet

3.2 SIGNAL REQUIREMENTS

3.2.1 ANALOG INPUT

4-20 milliamperes into a maximum load resistance of 250 ohms.

3.2.2 DISCRETE OUTPUT

120 VAC, 60 Hz. The phase line shall be switched to provide the output. Discrete outputs shall be capable of supplying a minimum of 2 amperes into a load with a 75% power factor.

3.2.3 RELAY OUTPUT

Normally open contacts capable of carrying 10 amperes, continuously @ 120 VAC, 60 Hz.

3.3 COMMANDS

3.3.1 MODE CONTROL

The mode control command shall be achieved with a four (4) position key switch for controlled access. The key switch shall be arranged and wired such as to issue the following commands in the sequence specified (clockwise rotation of keyswitch). Key shall be removeable in any position. Output shall be 120 VAC, 60Hz into a 10 milliampere load.

1. MANUAL
2. LOCKOUT
3. AUTOMATIC
4. RESET

3.3.2 EMERGENCY SHUTDOWN

The emergency shutdown command shall be accomplished with a push-pull switch. The emergency shutdown switch shall be supplied with a large mushroom cap (2 inches in diameter minimum) and red in color.

3.4 POWER

The power feed to the system display panel is 120 VAC ±10%, single phase 60 Hertz fused at 15 amperes.

3.5 OPERATING TIME

The operating time of the WTG (sync time) shall be displayed with an elapsed time meter with an accuracy of ±1% and 0.1 hour resolution utilizing an external contact closure.

3.6 ANALOG DISPLAY

Digital panel meters, (3-1/2 digit) shall be used for display of selected system parameters. The digital panel meter used shall have as a minimum the following requirements:

- o Resolution - 1 millivolt
- o Input impedance = 100 megohms, minimum
- o Accuracy = ±1% of reading, ±1 count

3.6.1 SCALE

The analog display for each parameter shall be displayed in engineering units. Multipliers such as (x10), (x100), etc. may be used.

3.6.2 SIGNAL GROUPING

A mutually exclusive switching arrangement shall be used whenever practical to minimize the number of digital panel meters required.

3.6.3 ACCURACY

Accuracy of conversion from 4-20 milliamperes to meter reading (engineering units) shall be within ±2%.

3.6.4 PARAMETERS

As a minimum the parameters listed in Table 3.1 shall be monitored and displayed in real time.

3.7 STATUS DISPLAY

As a minimum the status of the functions listed in Table 3.2 shall be included in the system display panel. Illuminated indicators shall be used to identify the status. Indicators shall provide wide angle visibility and be distinguishable to a distance of six (6) feet.

TABLE 3.1

REAL TIME PARAMETERS

PARAMETER	RANGE
Wind Velocity No. 1	0 to 150 MPH
Wind Velocity No. 2	0 to 150 MPH
Utility Voltage, Phase A-B	0 to 5.00 KV
Utility Voltage, Phase B-C	0 to 5.00 KV
Utility Voltage, Phase C-A	0 to 5.00 KV
Utility Power	-10.00 to +10.00 MW
Utility Reactive Power	-2.50 to +2.50 MVAR
Utility Current, Phase A	0 to +1500 Amps
Utility Current, Phase B	0 to +1500 Amps
Utility Current, Phase C	0 to +1500 Amps
Blade Tip No. 1 Position	-5.0 to +95.0 Deg.
Blade Tip No. 2 Position	-5.0 to +95.0 Deg.
Hub Position	-180.0 to +180 Deg.
Hub Speed	0 to 30.0 RPM
Yaw Position	-180.0 to +180.0 Deg.
Yaw Error No. 1	-180.0 to +180.0 Deg.
Yaw Error No. 2	-180.0 to +180.0 Deg.
Stator Voltage, Phase A-B	0 to 5.00 KV
Stator Voltage, Phase B-C	0 to 5.00 KV
Stator Voltage, Phase C-A	0 to 5.00 KV
Stator Current, Phase A	0 to 1500 Amps
Stator Current, Phase B	0 to 1500 Amps
Stator Current, Phase C	0 to 1500 Amps
Rotor Current, Phase A	0 to 1500 Amps
Rotor Current, Phase B	0 to 1500 Amps
Rotor Current, Phase C	0 to 1500 Amps
Generator Frequency	55 to 65 Hz
Generator Power	0 to 10 MW
Generator Reactive Power	-2.50 to +250 MVAR

TABLE 3.2

STATUS DISPLAY

FUNCTION	DISPLAY
Stator Breaker	Open/Closed
Rotor Breaker	Open/Closed
Starting Breaker	Open/Closed

3.8 VIDEO

The system display panel shall include a dual CCTV monitor as defined on GE Drawing 470381060P1.

3.8.1 VIDEO CONTROLS

Illuminated push button switches shall be used for control of the following functions as indicated on the video systems schematic (later).

- o Nacelle video camera ON/OFF control
- o Nacelle video camera panning ON/OFF control
- o Roof mounted video camera ON/OFF control
- o Roof mounted video camera windshield wiper ON/OFF control

Illuminated switches shall provide wide angle visibility and be distinguishable to a distance of six (6) feet.

3.9 TEST POINTS

Each parameter listed in Table 3.1 shall have a set of test jacks wired across the input load resistor for external monitoring.

To maintain measurement accuracy external mounitoring device must have a minimum input impedance of 500,000 ohms.

Test jacks shall be located on the front panel of the system display panel and accept a standard banana plug (4.44 MM/.175 diameter).

3.10 INTERCOM

The system display panel shall provide the capability of connecting a push to talk, hand-held microphone as part of the intercom system defined on schematic (later). In addition, a method for holding the microphone when not in use shall also be provided.

3.10.1 VOLUME CONTROL

A volume control for the office paging and communications speaker shall be mounted on the system display panel.

3.10.2 CONTROLS

Illuminated push button switches shall be used for control of the following intercom system controls.

- o Nacelle talk-back speaker control
- o Outdoor paging enable
- o Office speaker enable/disable

Illuminated switches shall provide wide angle visibility and be distinguishable to a distance of six (6) feet.

3.11 INTRUSION ALARM

Capability shall be provided to accept the loss of continuity of a series connected security loop as indication of an unauthorized intrusion. The response to the intrusion shall energize an audible alarm mounted on the front panel, with an entrance time delay to permit authorized personnel to enter and disable the alarm by way of a front panel mounted switch (key operated). After the entrance delay (adjustable 0.5 to 1.5 minutes) contact closures shall provide an input to the WTG controller and an input to enable an outdoor audible

3.11 INTRUSION ALARM (continued)

alarm. A time delay to disable the outdoor alarm (adjustable 5 to 30 minutes) shall be provided.

Provision for an exit delay (adjustable 0.5 to 1.5 minutes) is required to permit enabling the alarm system and exiting the building without activating the alarm.

Front panel indicators to indicate loop continuity status and alarm system ON/OFF, shall be provided.

3.12 WIRING INTERFACE

All input, output and power wiring for the system display panel shall enter the system display panel assembly from the top of the enclosure and terminate on terminal boards. Terminal board design shall be such that a pre-fabricated cable assembly can be installed in a minimum of time.

3.13 MECHANICAL

The system display panel shall be wall mountable. Capability of being mounted through a wall should be considered.

The maximum dimensions of the system display panel shall not exceed the dimensions shown in Figure 3.1

The system display panel shall provide a minimum of nine (9) square feet of front panel mounting space and accommodate standard nineteen (19) inch NEMA panels.

3.13.1 PANELS

All panels to be mounted in the system display panel shall be nineteen (19) inches wide and .187 inches thick having closed mounting slots. Mounting slot spacing shall be in accordance with E.I.A. standard RS-310.

3.14 THERMAL

Forced air circulation shall be used to limit the air temperature within the system display panel to 100°F maximum.

3.15 WEIGHT

The maximum weight of the system display panel shall not exceed 400 pounds.

3.16 MATERIALS

Materials used in the system display panel assembly shall be inherently corrosion resistant or protected from corrosion due to exposure to airborne moisture and salt in the operational environment. For corrosion analysis assume 0.005 PPM maximum salt content in environmental air after filtration for sea coast installation.

3.17 FINISH

All surfaces shall be chemically cleaned and treated to provide a bond between the primer paint and metal surfaces. The system display panel interior and exterior shall be painted. Color shall be in accordance with 47A380053.

3.18 MAINTAINABILITY

The lowest level of repair shall be at the component and circuit card level. With the assumption that properly trained personnel, replacement components, and circuit cards are available, the mean time to repair shall be less than 4 hours.

SECTION 4.0

VERIFICATION

4.1 GENERAL

The acceptance program for the system display panel shall be implemented by analysis and test of a prime design unit. Development tests will also be performed in advance of tests to support and confirm design and analytical tradeoffs. These tests are defined in this section.

4.1.1 RESPONSIBILITY FOR INSPECTION AND TESTS

GE/AEPD or its suppliers at GE/AEPD direction are responsible for conducting all tests and inspections to assure compliance with this specification and the documents referenced herein.

4.2 SPECIAL TESTS AND INSPECTIONS

4.2.1 ANALYSES

The following requirements of Section 3.0 shall be verified by review of analyses based on applicable specifications, applicable drawings, in-process test data, supplier component data, and operating experience with similar units.

Paragraph 3.1 - Environmental
Paragraph 3.6 - Analog Display
Paragraph 3.14 - Thermal
Paragraph 3.15 - Weight
Paragraph 3.16 - Materials
Paragraph 3.18 - Maintainability

4.2.2 ACCEPTANCE INSPECTIONS

The following requirements of Section 3.0 shall be verified by inspection of the hardware or review of manufacturing in-process inspection data or component supplier data.

Paragraph 3.5 - Operating time
Paragraph 3.6.1 - Scale
Paragraph 3.6.4 - Parameters
Paragraph 3.7 - Status display
Paragraph 3.8 - Video
Paragraph 3.8.1 - Video controls
Paragraph 3.9 - Test points
Paragraph 3.10 - Intercom
Paragraph 3.10.1 - Volume control
Paragraph 3.10.2 - Controls
Paragraph 3.12 - Wiring interface
Paragraph 3.13 - Mechanical
Paragraph 3.13.1 - Panels
Paragraph 3.17 - Finish

4.3 ACCEPTANCE TESTS

4.3.1 WIRING

All wiring shall be checked for loose connections.

4.3.2 FUNCTIONAL TESTS

4.3.2.1 ANALOG CIRCUITRY

Proper operation of each analog display circuit shall be verified.

4.3.2.2 INTRUSION ALARM

Proper operation of intrusion alarm electronics shall be verified.

4.4 TEST PROCEDURE

All tests shall be conducted using documented test procedures approved by quality assurance. All test procedures shall contain data sheets on which the results of the individual tests may be recorded.

4.5 TEST CONDITIONS

All tests shall be performed at room ambient conditions of temperature, humidity and atmospheric pressure unless other specified.

4.6 APPROVAL

Review and approval of all test results by a General Electric Quality Assurance representative is required prior to shipment of the system display panel assembly.

SECTION 5.0

PREPARATION FOR DELIVERY

The system display pa...l shall be prepared for shipment in accordance with Packaging Instructions, GE Drawing (later). Storage of the panel shall be consistant with the requirements of Paragraph 3.1 of this document and GE Drawing (later).

SECTION 6.0

NOTES

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Elevations: sea level to 7000 feet

3.2 SIGNAL REQUIREMENTS

3.2.1 ANALOG INPUT

4-20 milliamperes into a maximum load resistance of 250 ohms.

3.2.2 DISCRETE OUTPUT

120 VAC, 60 Hz. The phase line shall be switched to provide the output. Discrete outputs shall be capable of supplying a minimum of 2 amperes into a load with a 75% power factor.

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Normally open contacts capable of carrying 10 amperes, continuously @ 120 VAC, 60 Hz.

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The analog display for each parameter shall be displayed in engineering units. Multipliers such as (x10), (x100), etc. may be used.

3.6.2 SIGNAL GROUPING

A mutually exclusive switching arrangement shall be used whenever practical to minimize the number of digital panel meters required.

3.6.3 ACCURACY

Accuracy of conversion from 4-20 milliamperes to meter reading (engineering units) shall be within ±2%.

3.6.4 PARAMETERS

As a minimum the parameters listed in Table 3.1 shall be monitored and displayed in real time.

3.7 STATUS DISPLAY

As a minimum the status of the functions listed in Table 3.2 shall be included in the system display panel. Illuminated indicators shall be used to identify the status. Indicators shall provide wide angle visibility and be distinguishable to a distance of six (6) feet.

TABLE 3.1

REAL TIME PARAMETERS

PARAMETER	RANGE
Wind Velocity No. 1	0 to 150 MPH
Wind Velocity No. 2	0 to 150 MPH
Utility Voltage, Phase A-B	0 to 5.00 KV
Utility Voltage, Phase B-C	0 to 5.00 KV
Utility Voltage, Phase C-A	0 to 5.00 KV
Utility Power	-10.00 to +10.00 MW
Utility Reactive Power	-2.50 to +2.50 MVAR
Utility Current, Phase A	0 to +1500 Amps
Utility Current, Phase B	0 to +1500 Amps
Utility Current, Phase C	0 to +1500 Amps
Blade Tip No. 1 Position	-5.0 to +95.0 Deg.
Blade Tip No. 2 Position	-5.0 to +95.0 Deg.
Hub Position	-180.0 to +180 Deg.
Hub Speed	0 to 30.0 RPM
Yaw Position	-180.0 to +180.0 Deg.
Yaw Error No. 1	-180.0 to +180.0 Deg.
Yaw Error No. 2	-180.0 to +180.0 Deg.
Stator Voltage, Phase A-B	0 to 5.00 KV
Stator Voltage, Phase B-C	0 to 5.00 KV
Stator Voltage, Phase C-A	0 to 5.00 KV
Stator Current, Phase A	0 to 1500 Amps
Stator Current, Phase B	0 to 1500 Amps
Stator Current, Phase C	0 to 1500 Amps
Rotor Current, Phase A	0 to 1500 Amps
Rotor Current, Phase B	0 to 1500 Amps
Rotor Current, Phase C	0 to 1500 Amps
Generator Frequency	55 to 65 Hz
Generator Power	0 to 10 MW
Generator Reactive Power	-2.50 to +250 MVAR

TABLE 3.2

STATUS DISPLAY

FUNCTION	DISPLAY
Stator Breaker	Open/Closed
Rotor Breaker	Open/Closed
Starting Breaker	Open/Closed

3.8 VIDEO

The system display panel shall include a dual CCTV monitor as defined on GE Drawing 470381060P1.

3.8.1 VIDEO CONTROLS

Illuminated push button switches shall be used for control of the following functions as indicated on the video systems schematic (later).

- o Nacelle video camera ON/OFF control
- o Nacelle video camera panning ON/OFF control
- o Roof mounted video camera ON/OFF control
- o Roof mounted video camera windshield wiper ON/OFF control

Illuminated switches shall provide wide angle visibility and be distinguishable to a distance of six (6) feet.

3.9 TEST POINTS

Each parameter listed in Table 3.1 shall have a set of test jacks wired across the input load resistor for external monitoring.

To maintain measurement accuracy external mounitoring device must have a minimum input impedance of 500,000 ohms.

Test jacks shall be located on the front panel of the system display panel and accept a standard banana plug (4.44 MM/.175 diameter).

3.10 INTERCOM

The system display panel shall provide the capability of connecting a push to talk, hand-held microphone as part of the intercom system defined on schematic (later). In addition, a method for holding the microphone when not in use shall also be provided.

3.10.1 VOLUME CONTROL

A volume control for the office paging and communications speaker shall be mounted on the system display panel.

3.10.2 CONTROLS

Illuminated push button switches shall be used for control of the following intercom system controls.

- o Nacelle talk-back speaker control
- o Outdoor paging enable
- o Office speaker enable/disable

Illuminated switches shall provide wide angle visibility and be distinguishable to a distance of six (6) feet.

3.11 INTRUSION ALARM

Capability shall be provided to accept the loss of continuity of a series connected security loop as indication of an unauthorized intrusion. The response to the intrusion shall energize an audible alarm mounted on the front panel, with an entrance time delay to permit authorized personnel to enter and disable the alarm by way of a front panel mounted switch (key operated). After the entrance delay (adjustable 0.5 to 1.5 minutes) contact closures shall provide an input to the WTG controller and an input to enable an outdoor audible

3.11 INTRUSION ALARM (continued)

alarm. A time delay to disable the outdoor alarm (adjustable 5 to 30 minutes) shall be provided.

Provision for an exit delay (adjustable 0.5 to 1.5 minutes) is required to permit enabling the alarm system and exiting the building without activating the alarm.

Front panel indicators to indicate loop continuity status and alarm system ON/OFF, shall be provided.

3.12 WIRING INTERFACE

All input, output and power wiring for the system display panel shall enter the system display panel assembly from the top of the enclosure and terminate on terminal boards. Terminal board design shall be such that a pre-fabricated cable assembly can be installed in a minimum of time.

3.13 MECHANICAL

The system display panel shall be wall mountable. Capability of being mounted through a wall should be considered.

The maximum dimensions of the system display panel shall not exceed the dimensions shown in Figure 3.1

The system display panel shall provide a minimum of nine (9) square feet of front panel mounting space and accommodate standard nineteen (19) inch NEMA panels.

3.13.1 PANELS

All panels to be mounted in the system display panel shall be nineteen (19) inches wide and .187 inches thick having closed mounting slots. Mounting slot spacing shall be in accordance with E.I.A. standard RS-310.

3.14 THERMAL

Forced air circulation shall be used to limit the air temperature within the system display panel to 100°F maximum.

3.15 WEIGHT

The maximum weight of the system display panel shall not exceed 400 pounds.

3.16 MATERIALS

Materials used in the system display panel assembly shall be inherently corrosion resistant or protected from corrosion due to exposure to airborne moisture and salt in the operational environment. For corrosion analysis assume 0.005 PPM maximum salt content in environmental air after filtration for sea coast installation.

3.17 FINISH

All surfaces shall be chemically cleaned and treated to provide a bond between the primer paint and metal surfaces. The system display panel interior and exterior shall be painted. Color shall be in accordance with 47A380053.

3.18 MAINTAINABILITY

The lowest level of repair shall be at the component and circuit card level. With the assumption that properly trained personnel, replacement components, and circuit cards are available, the mean time to repair shall be less than 4 hours.

SECTION 4.0

VERIFICATION

4.1 GENERAL

The acceptance program for the system display panel shall be implemented by analysis and test of a prime design unit. Development tests will also be performed in advance of tests to support and confirm design and analytical tradeoffs. These tests are defined in this section.

4.1.1 RESPONSIBILITY FOR INSPECTION AND TESTS

GE/AEPD or its suppliers at GE/AEPD direction are responsible for conducting all tests and inspections to assure compliance with this specification and the documents referenced herein.

4.2 SPECIAL TESTS AND INSPECTIONS

4.2.1 ANALYSES

The following requirements of Section 3.0 shall be verified by review of analyses based on applicable specifications, applicable drawings, in-process test data, supplier component data, and operating experience with similar units.

Paragraph 3.1 - Environmental
Paragraph 3.6 - Analog Display
Paragraph 3.14 - Thermal
Paragraph 3.15 - Weight
Paragraph 3.16 - Materials
Paragraph 3.18 - Maintainability

4.2.2 ACCEPTANCE INSPECTIONS

The following requirements of Section 3.0 shall be verified by inspection of the hardware or review of manufacturing in-process inspection data or component supplier data.

Paragraph 3.5 - Operating time

Paragraph 3.6.1 - Scale

Paragraph 3.6.4 - Parameters

Paragraph 3.7 - Status display

Paragraph 3.8 - Video

Paragraph 3.8.1 - Video controls

Paragraph 3.9 - Test points

Paragraph 3.10 - Intercom

Paragraph 3.10.1 - Volume control

Paragraph 3.10.2 - Controls

Paragraph 3.12 - Wiring interface

Paragraph 3.13 - Mechanical

Paragraph 3.13.1 - Panels

Paragraph 3.17 - Finish

4.3 ACCEPTANCE TESTS

4.3.1 WIRING

All wiring shall be checked for loose connections.

4.3.2 FUNCTIONAL TESTS

4.3.2.1 ANALOG CIRCUITRY

Proper operation of each analog display circuit shall be verified.

4.3.2.2 INTRUSION ALARM

Proper operation of intrusion alarm electronics shall be verified.

4.4 TEST PROCEDURE

All tests shall be conducted using documented test procedures approved by quality assurance. All test procedures shall contain data sheets on which the results of the individual tests may be recorded.

4.5 TEST CONDITIONS

All tests shall be performed at room ambient conditions of temperature, humidity and atmospheric pressure unless other specified.

4.6 APPROVAL

Review and approval of all test results by a General Electric Quality Assurance representative is required prior to shipment of the system display panel assembly.

SECTION 5.0

PREPARATION FOR DELIVERY

The system display panel shall be prepared for shipment in accordance with Packaging Instructions, GE Drawing (later). Storage of the panel shall be consistant with the requirements of Paragraph 3.1 of this document and GE Drawing (later).

SECTION 6.0

NOTES

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16. Abstract

This report documents the design, development and analysis of the 7.3MW MOD-5A wind turbine generator covering work performed between July 1980 and June 1984. The report is divided into four volumes: Volume I summarizes the entire MOD-5A program, Volume II discusses the conceptual and preliminary design phases, Volume III describes the final design of the MOD-5A, and Volume IV contains the drawings and specifications developed for the final design.

Volume IV contains the drawings and specifications that were developed in preparation for building the MOD-5A wind turbine generator.

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