Malfunction Abatement Plan (MAP)

RIVERVIEW ENERGY SYSTEMS, LLC

20000 GRANGE ROAD

RIVERVIEW, MICHIGAN 48193

MALFUNCTION ABATEMENT PLAN

RIVERVIEW ENERGY SYSTEMS, LLC

TABLE OF CONTENTS

MALFUNCTION ABATEMENT PLAN
RIVERVIEW ENERGY SYSTEMS, LLC

1.0 INTRODUCTION

1.1 Background

The Riverview Energy Systems, LLC facility operates a treatment system, gas compressor skids, and two combustion turbine generators at the Riverview Land Preserve Landfill in Riverview, Michigan. The facility operates under authority received from the State of Michigan Department of Environment, Great Lakes, and Energy (EGLE) – Air Quality Division through Renewable Operating Permit MI-ROP-M4469-2015a and Permit to Install 250-00C. This Malfunction Abatement Plan (MAP) has been prepared to meet the requirements of Condition III. 2. of FGTURBINES of the permit. This MAP has been prepared by Riverview Energy Systems, LLC in accordance with Rule 911 of the Michigan Air Pollution Act (Part 55 of Michigan Act 451) and will be used as a method to detect and correct malfunctions or equipment failures. This document also describes the documentation and reporting requirements when a malfunction occurs.

1.2 Description of System

Conditions of the Renewable Operating Permit require the development of a Malfunction Abatement Plan for the operation of the landfill gas treatment system, turbines and associated pollution control equipment. This system produces electricity via landfill gas combustion in the two Solar combustion turbine generators, and also utilizes a sulfur removal system.

1.3 Included Components

The following items are included in the requirements of the Malfunction Abatement Plan (MAP):

- Fuel Gas Compressor
- H2S Treatment System
- Combustion Turbine Generators

1.4 Defining Malfunctions

Michigan Air Pollution Control Rule R 336.1113(a) defines a *malfunction* as:

> *…any sudden, infrequent and not reasonably preventable failure of a source, process, process equipment, or air pollution control equipment to operate in a normal or usual manner. Failures that are caused in part by poor maintenance or careless operations are not malfunctions.*

A true *malfunction* must have a reasonable potential to cause an exceedance in an established emission rate.

The turbines in FGTURBINES shall not operate "…unless the sulfur control system is installed, maintained, and operated…" per ROP condition IV.1. of FGTURBINES.

Following is a list of malfunction events covered by this Plan. For more information, please see Table 1.

1.5 Responsible Personnel

The Plant Manager is responsible for ensuring that the facility operates in compliance with all environmental and safety requirements and regulations. The Plant Manager is responsible for day-to-day operations and maintenance of the plant, compressor, H2S treatment system, and turbines.

Facility Contact:
Riverview Energy Systems, LLC
20000 Grange Road
Riverview, Wayne County, Michigan

Jeff Neumann, Plant Manager
Cell Phone: 734-216-6979

Owner Contact:
DTE Vantage – Biomass Energy
One Energy Plaza, 400 WCB
Detroit, MI 48226

Steve Berlinski, Regional Operations Manager

Cell: 269-217-1603

Corporate Environmental Contact:

DTE Vantage – Environmental Affairs

One Energy Plaza, 400 WCB

Detroit, MI 48226

Maureen Bennett, Environmental Engineer

Cell: 734-834-0005

2.0 SCHEDULED MAINTENANCE

The equipment manuals provide schedules of routine maintenance for the system. These manuals are kept in hard copy at the site. The schedules specify tasks that should be conducted on a routine basis. Riverview Energy Systems, LLC will perform routine maintenance in accordance with the manuals and integrated into the electronic maintenance system, eMaint. The elements of the routine maintenance program are contained in the manuals.

2.1 Inspections/Maintenance

Maintenance of the turbines and control equipment is required at established intervals. The recommended intervals are for nominal environmental and operating conditions.

Daily and Monthly Maintenance

Daily and monthly maintenance includes a walkaround inspection to ensure equipment is functioning properly and to detect leaks or obvious faults. Operating parameters should be recorded and analyzed for trends. This will help predict faults.

Daily

- Plant operator performs plant inspections.
- Record all panel readings.
- Visually inspect gages and indicators for proper operation (daily).
- Check oil tank level every 24 hours. Record oil consumption.
- Verify proper operation of oil makeup system, if installed.
- Record fuel pressure, adjust at off-skid regulator if necessary.
- Be alert for any unusual operating condition (vibration, noise, etc.).
- Inspect all lines and hoses for leaks, wear, chafing; correct as necessary.
- Inspect all mechanical linkages for wear, looseness; correct as necessary.
- Visually inspect entire package for fuel, oil, and air leaks
- Record fuel pressure, adjust at off-skid regulator if necessary.

Monthly

- Plant operator performs plant inspections.
- Plant manager performs plant inspections.
- Check battery electrolyte level on both turbine gensets.
- Take engine oil sample from both turbine gensets.
- Take skid oil sample on 500 and 600 gas compressor systems.
- Check wiring for absence of chafing and insulation damage
- Check lube oil system for leaks.

Semiannual Maintenance

Semiannual maintenance emphasizes protective systems checkout and ensures optimum equipment performance. Regardless of hours of operation, this maintenance should be performed semiannually.

- Perform water wash on both turbine gensets.
- Change inlet air filter Pre-Wraps on both turbine gensets.
- Apply corrosion inhibitor to variable guide vane system linkage.
- Change Engine LFG Coalescer Filters (5ea.)
- Solar Field Service Semi-Annual Inspection
- Perform oil filter change on both turbine gensets.
- Remove and inspect igniter cable. Inspect igniter plug for erosion and proper gap. Replace if necessary.
- Test speed and temperature topping system.
- Test and calibrate backup overspeed monitors.
- Verify calibration of temperature monitors.
- Check and calibrate as necessary all safety, warning, and shutdown devices.
- Check and calibrate Inlet Guide Vane activation system.
- Inspect and replace air inlet filters as needed.
- Inspect and replace lube oil and servo oil filters as needed.
- Lubricate oil cooler fan shaft bearings.
- Remove and inspect igniter torch housing for cracks, excessive erosion; inspect discharge tube for chafing wear.
- Inspect fuel injectors and clean if necessary.
- Conduct borescope inspection of turbine.
- Lubricate all electric motors equipped with grease fittings.
- Check all safety relief valves as required by local regulations.
- Clean entire package.
- Restart turbine and record acceleration time. Monitor control system for proper sequencing.
- Conduct vibration survey for trending.

Annual Maintenance

Annual maintenance involves disassembly of subsystem components for inspection. Problems noted in previous inspections should receive attention in annual maintenance whether or not they are listed in this manual. Detailed records help pinpoint malfunctions prior to performance impact.

- Perform LFG cooler tube cleaning/maintenance.
- Perform annual Howden 255 and 321 compressor overhaul.
- Inspect inlet air filters and replace if necessary (every 48 months).
- Test package vibration monitor and calibrate transducers.
- Change lithium battery in PLC, or controller.
- Disassemble, clean, inspect, and reassemble bleed valve.

- Rebuild solenoid valves as needed.
- Check gearbox to generator alignment; realign as necessary. Inspect and, as necessary, clean the generator with a high-dielectric cleaner recommended by the generator manufacturer.

2.2 Replacement Parts

Replacement parts (e.g. filters, seals, lines/hoses, solenoids, actuators, diaphragm assemblies, valves) may be ordered directly from the manufacturer. Most parts can be shipped within 24 hours of ordering. A complete list of all parts and catalog numbers is included in the equipment operating manuals.

The replacement part list of parts recommended to be kept onsite is below, containing part number, part description, installed quantity, and recommended quantity to be kept onsite.

Operational Consumable Parts

Part Number	Part Description	Installed Quantity	Recommended Quantity
1017897	GASKET,SPIRAL,4.0,RF,CL150,304	4	2
1017907	GASKET,SPIRAL,3.0,CL300,RF,304	6	2
1022447	SEAL,LIP	2	2
1043265-1	HOLDER,FUSE,600 V	56	3
1043265-3	FUSE,2.0 A,600 V	16	5
1043265-4	FUSE,5.0 A,600 V	20	5
1043265-5	FUSE,10 A,600 V	36	10
1043265-6	FUSE,15 A,600 V	10	3
1043265-7	FUSE,20 A,600 V	14	5
1043265-8	FUSE,25 A,600 V	10	3
1072904	SEAL,METALLIC,303 SS	4	8
1089034-3	ELEMENT,FLTR,AIR,BARR,CELL	4	16
112015-1	ADHESIVE,THREADLOCK,50 CC	12	2
120411-400	KIT,ELEMENT,PLEATED,LUBE OIL	16	16
120544-2	KIT,ELEMENT,PLEATED,FUEL	4	8
136633-4	GASKET,10.94 ID,15.19 OD	6	8
136845-1	GASKET,1.85 X .62IN,.032	24	24
172523-2	GASKET X 2.71IN,.062,BLUE-GARD	2	1
172567-1	GASKET,5.62 X 5.62IN,.030	2	3
173532-1	GASKET,5.895 ID,6.165 OD,0.032	4	16
173533-1	GASKET,3.4 ID,4.0 OD,0.015 IN	4	5
174653-1	GASKET,6.50 X 4.00IN,.031	2	2
183443-2	GASKET,31.09 ID,38.75 OD,0.125	2	1
190826-1	GASKET,4.38 ID,5.62 OD,0.020	4	1
196710-1	GASKET,3.824 ID,4.076 OD,0.15	2	1
304198-1	GASKET,2.75 OD,METALLIC,COPPER	2	1
903235C1	O-RING,SAE 114,VITON	12	25
903246C1	O-RING,SAE 227,VITON	2	10
903268C1	O-RING,SAE 908,VITON	4	25
903289C1	O-RING,SAE 158,VITON	2	6
903315C1	GASKET,0.77 ID,METALLIC,SPARK	4	25
903316C1	SPARK PLUG	2	4
903509C1	O-RING,SAE 219,VITON	6	18
903556C1	O-RING,SAE 166,VITON	2	4

903560C1	O-RING,SAE 117,VITON	4	25
903732C1	O-RING,SAE 225,VITON,1.859 ID	12	15
908056C1	O-RING,SAE 122,VITON	2	25
912358C1	BOLT,HEX,0.375-16 X 1.25 IN,B6	108	30
912642C1	O-RING,SAE 228,VITON	8	10
912755C1	SEAL,METALLIC,303 SS	2	4
917212C1	SEALANT,GLAND,SILICONE,POTTING	6	2
950463C1	O-RING,SAE 241,VITON	2	2
952248C1	SEAL,THREADED,0.375 ID,0.75 OD	8	10
953676C1	SEALANT,SILICONE,3.0 OZ	2	1
957968C1	O-RING,SAE 267,VITON	4	1
963859C1	GASKET,SPIRAL,3.0,CL600,RF,304	4	2
964686C1	LOCKWASHER,SPLIT,0.50 IN,316	30	25
967692C1	SEAL,METALLIC,303 SS	4	1
967923C1	GASKET 4'' 150# FULL FACE	8	2
969035C1	GASKET,SPIRAL,0.75,CL600,304	40	160
FT67073-100	KIT,TUBE FITTINGS,STD	2	1

Insurance Parts – Critical Items

Part Number	Part Description	Installed Quantity	Recommended Quantity
1034549-10	POWER SUPPLY,24 VDC	2	1
1034549-21	MODULE,VIB,SEISMIC,BN 1701	6	1
1034549-70	MODULE,VIB,AXIAL POSITION,BN	2	1
1034549-71	MODULE,VIB,VELOCITY,BN 1701	4	1
1051931-67	BASE,TERMINAL,SPRING,-20-+70 C	32	2
1051931-69	BASE,TEMPERATURE,SPRING	2	1
1051931-71	BASE,GENERIC,SPRING,-20-+70 C	8	1
1053834-3	MONITOR,CONTROL,BU OVERSPEED	2	1
1062883-301	VALVE ASSY,BALL,PNEU	4	1
1063325-1	PUMP/GEAR,PACKAGE LUBE OIL	2	1
1066431-300	THERMOCOUPLE,TYPE- K	4	2
1069178-3502	DRIVE,VAR FREQ,125 HP,380 VAC	2	1
1074392-1	PUMP, HYDRAULIC	2	1
1089240-10	MODULE,FLEX,FAST ANALOG,2 IN	4	2
1089240-11	MODULE,FLEX,FAST ANALOG,4 OUT	2	1
1089240-2	MODULE,FLEX,DISCRETE,16 IN	8	1
1089240-29	MODULE,FLEX,FAST COUNTER,2 IN	2	1
1089240-3	MODULE,FLEX,DISCRETE,10 IN/6	2	1
1089240-30	MODULE,FLEX,ADAPTER	10	2
1089240-31	MODULE,FLEX,FAST RTD/TC,8 IN	6	2
1089240-4	MODULE,FLEX,DISCRETE,8 OUT	6	1
1089240-5	MODULE,FLEX,DISCRETE,16 OUT	2	1
1089240-7	MODULE,FLEX,ANALOG,8 IN	6	2
1089240-9	MODULE,FLEX,FAST ANALOG,4 IN	4	1
1089241-28	POWER SUPPLY,42 W,24 VDC	2	1
1089241-30	MODULE,CONTROLLER	2	1
1089241-36	MODULE,COMMUNICATION,ETHERNET	2	1
1089241-4	MODULE,COMMUNICATION	6	1
1091605-100	VALVE,SOLENOID,3-WAY,0.5 IN,24	4	1
1100969-3	MOTOR,ELEC,1.5 HP,120 VDC	2	2
1110429-300	STARTER MOTOR ASSY,ELEC AC,60	2	1
1112178-2401	COMPUTER SYS,TT4000 SGL UNIT	2	1
1125181-1	SENSOR,SPEED,ACTIVE	2	1
120649-18	SENSOR,VEL,SELF-GENERATING	2	1

1286570-1	POWER SUPPLY,1260 W,28 VDC	2	1
130797-102	VALVE,BLEED,PNEU,4.0 IN	2	2
131146-101	INJECTOR,GAS,CONVENTIONAL	40	20
131230-6	DETECTOR,TEMP,RESISTANCE	4	1
186232-3300	VALVE ASSY,BALL,PNEU,3.0 IN	4	1
190430-1	SENSOR,SPEED,PASSIVE	2	1
190855-500	PUMP/MOTOR,LUBE OIL,2 HP,30	4	2
2018739-100	VALVE,CONTROL,MAIN,GAS FUEL	4	2
913739C2	VALVE,RELIEF,65 PSIG	2	1
915233C1	CYLINDER,HYDRAULIC	2	1
917560C2	EXCITER	2	1
918777C2	DETECTOR,TEMP,RESISTANCE	2	1
918801C1	DETECTOR,TEMP,RESISTANCE	4	1
919340C2	CABLE,IGNITION,59.0 IN	2	1
964192C1	DETECTOR,TEMP,RESISTANCE	2	1
E131148-306	TORCH,GAS	2	2

Insurance Parts – Non-critical Items

Part Number	Part Description	Installed Quantity	Recommended Quantity
1011018-2	VALVE,CHECK,1.25 IN	8	1
1016391-1	VALVE,SOLENOID,4-WAY,24 VDC	2	1
1020225	CONNECTOR,QUICK DISCONNECT	20	4
1020281-100	VALVE ASSY,PANCAKE DRAIN,0.5	4	4
1025156-1	COUNTER,DUAL-DSPLY,7-DIGIT	2	1
1030794-12	VALVE,CHECK,0.375 IN,2 PSIG	4	1
1039363-1	VALVE,HAND,0.50 IN,6000 PSIG	2	1
1039364-1	VALVE,HAND,0.50 IN,6000 PSIG	2	1
1043174	METAL FLEX HOSE 2''	2	1
1043380-1	REGULATOR,PRESS,0.50 IN,125	4	1
1046415-30	CONNECTOR	24	6
1047420	HOSE,M/FLEX,1.50 ID,X 28.25	2	1
1047421	HOSE ASSY,1.5 IN X 36.00 IN	2	1
1052120-1	TRANSMITTER,DP,25 IN-H2O	2	1
1052120-4	TRANSMITTER,DP,300 PSI,DIGITAL	2	1
1052168-2	TRANSMITTER,PRESS,150 PSI	4	1
1052168-23	TRANSMITTER,PRESS,800 PSI	8	2
1052168-3	TRANSMITTER,PRESS,800 PSI	8	2
1053194	VALVE,CHECK,0.375 IN	4	1
1053923-153	SWITCH,PRESSURE,12 PSI,DPDT	4	1
1053929-16	SWITCH,DP,2 PSIG,DPDT,AIR,GF	4	1
1059700-1	VALVE,CHECK,1.5 IN	4	1
1061185	HOSE ASSY,1.5 IN X 44.00 IN	2	2
1061240	HOSE,M/FLEX,1-1/2'' X 23.00''	2	2
1064851-1	SWITCH,PUSHBUTTON,3PST,BLACK	6	1
1064851-10	SWITCH,KEY,3-POSITION,NC/NO	2	1
1064851-2	SWITCH,SELECTOR,3-POSITION	4	1
1064851-4	SWITCH,PUSHBUTTON	6	1
1064851-5	SWITCH,PUSHBUTTON,RED,MUSHROOM	2	1
1065717-1200	METER,FLOW,ANALOG	2	1
1067311-1	VALVE,SOLENOID,3-WAY PSI	10	1
1071411-1	RELAY,TIMER,ADJUSTABLE	12	2
1071411-3	RELAY,TIMER,WATCHDOG,24 VDC,2	2	1
1101768-1	HEATER,LUBE OIL,4.5 KW,220 VAC	2	1
1103208-101	HORN,EP	2	1

1103977-3	TRANSMITTER,PRESS,1450 PSI	22	3
1114470-9	SWITCH,PRESSURE,1300 PSI,DPDT	10	2
116878-1	VALVE,RELIEF,200 PSI	2	1
136633-500	COUPLING,DRVN,4.5 INCH BORE	2	1
1502703-1	VALVE,THERMO CNTL,130 DEGF	4	1
1506773	HOSE ASSY,2.00 IN X 45.27 IN	2	1
154554-15	FAN,COOLING,HEAT EXCHANGER,4''	2	1
1752196	HOSE ASSY,1.25 IN X 20.32 IN	2	1
186094-1	VALVE,SOLENOID,2-WAY,24 VDC	2	1
186273-42	REGULATOR,PRESS,POPPET,0.25 IN	4	1
186273-43	REGULATOR,PRESS,POPPET,0.25 IN	4	1
186286-1	VALVE,SOLENOID,2-WAY,24 VDC	2	1
190392-3	VALVE,HAND,0.50 IN,6000 PSI	4	1
190537-303	VALVE ASSY,BALL,PNEU,0.25 IN	4	1
1969997-1200	KIT,INSTL,VALVE,SOLENOID	2	1
44676-7	VALVE,CHECK,1.125 IN,2 PSI	2	1
906484C2	THERMOMETER,-5-115 C	2	1
908579C1	DIODE,RECTIFIER	4	25
912137C1	RESISTOR,0.25 W,10000 OHM	4	25
915498C1	VALVE,CHECK,1 IN	2	1
918192C4	SWITCH,LEVEL,FLOAT,750 PSI	4	1
952571C1	FLEX HOSE METAL 1.5'' X 25.0''	2	1
957257C1	HOSE ASSY-ISOLATION	2	1
964282C1	VALVE,HAND,NEEDLE,0.25 IN,5000	4	1
967664C1	VALVE,RELIEF,0.375 IN,400 PSI	4	1
967952C1	HOSE,0.25 IN	2	1
981089C1	RESISTOR,1.0 W,1000 OHM,+/-1%	2	5
981090C1	RESISTOR,1.0 W,3010 OHM,+/-1%	2	4
T32A1200C00	HOSE ASSY,2 IN	2	1

Insurance Parts – Repair Kits/Components

Part Number	Part Description	Installed Quantity	Recommended Quantity
1034347-5	CABLE,ACCELEROMETER,8.0 FT	2	1
1060367-2	CONTROL BOARD,BATTERY CHARGER	2	1
1060367-3	CONTROL BOARD,BATTERY CHARGER	2	1
1060367-4	CONTROL BOARD,BATTERY CHARGER	2	1
1060367-5	BA BRIDGE MODULE,BATT,CHRG	2	1
1085271-1001	MODULE,VFD,INTERFACE	2	1
1085271-1002	CARD,VFD,I/O,POWERFLEX 700VC	2	1
1085271-1003	MODULE,VFD,INTERFACE	2	1
1085271-1004	CASSETTE,VFD	4	1
1098494	FUSE,12 A,600 V	4	1
1111070-1	SWITCH,ROTARY,2-POSITION,30 A	2	1
1119193-1	RELAY,4PST,10 A	2	1
136633-5	O-RING,SAE 448,BUNA-N	6	6
136635-2	BOLT,SHEAR	8	2
176873-100	KIT,REPAIR,PUMP	2	1
2165031-1	CONTACTOR,30 A,250 V,DC,AC	2	1
600165C1	KIT,REPAIR,REGULATOR	4	1
600571C1	AMMETER,0-15 A	2	1
602759C1	KIT,REPAIR,SEALS,VALVE	12	1
603017C1	RELAY,24 VDC	76	10
604532C1	KIT,REPAIR,1.5 IN VALVE	4	1
907791C1	SPRING,VALVE	2	1

912740C1	SEAL,METALLIC,303 SS	2	2
912851C1	SEAL,METALLIC,303 SS	18	2
949803C2	KIT,O-RING,RELIEF VALVE	2	1
951611C1	GASKET,BYPASS VALVE	4	8
953160C1	O-RING,SAE 235,VITON	4	3
960132C1	RING,PISTON	2	2
962297C1	GASKET,BUNA-N,2.0 PIPE JOINT	8	4
967942C1	GASKET,VITON,2.0 PIPE JOINT	4	1
969997C1	THERMOSTAT, LUBE OIL TANK HEAT	2	1
990287C1	KIT,REPAIR,VALVE,SOLENOID	2	1
990506C1	KIT,REPAIR,VALVE,SOLENOID	2	1
990905C1	SWITCH,ROCKER,10 A,250 V,DPST	2	1
991707C1	INDICATOR,LIGHTED,GREEN	2	1
991708C1	INDICATOR,LIGHTED,AMBER	2	1
991709C1	INDICATOR,LIGHTED,RED	8	1
992313C1	SET,BOLT,QTY,8,0.75-16UNF-2A	4	1
993619C1	METER,VOLT,0-200 VDC	2	1
993968C1	KIT,REPAIR,VALVE SEAL,VITON	2	1
995636C1	KIT,REPAIR,VALVE PLUG,FILTER	4	4
995969C1	REGULATOR,PRESS,BYPASS	2	1
997396C1	KIT,REPAIR,VALVE	4	1
997692C1	KIT,REPAIR,REGULATOR,PRESSURE	4	1
997697C1	KIT,REPAIR,RELIEF VALVE	4	1
997805C1	FUSE,7.0 A,600 V	4	2
998057C1	FUSE,17.5 A,600 V	4	1
998964C1	BREAKER,CIRCUIT,20 A,120 VDC	4	1
998965C1	BREAKER,CIRCUIT,40 A,120 VDC	2	1
998966C1	BREAKER,CIRCUIT,60 A,120 VDC	4	1
999453C1	KIT,REPAIR,VALVE,FILTER	2	1
999688C1	TRANSFORMER,VOLTAGE	2	1
999689C1	INDUCTOR,BATTERY CHARGER	2	1
999690C1	FILTER,ELECTRONIC,EMI	2	1
999979C1	BREAKER,CIRCUIT,20 A,240 VAC	2	1
999980C1	BREAKER,CIRCUIT,15 A,120 VDC	2	1

3.0 MONITORING REQUIREMENTS

Daily inspections of the system include an inspection of the control panel to check for failed or alarm conditions. The system is equipped with the following alarms, as well as others:

1. Fuel system temperature and pressure
2. Engine vibration
3. System vibration
4. Shaft bearing temperature
5. Lube system temperature and level
6. Generator system parameters

Riverview Energy Systems Operating Log

LIMITS

Turbine Generator

		Inlet Temp.	Inlet Filter	Gen. Amps	Gen Volts	kW	PF	High/Low TC Temp	Engine T5	PDC	Gen Winding Temps A	Gen Winding Temps B	Gen Winding Temps C	Eng Run Hours	120 Batt. Volts	120 Batt Amps
High		120	5”		4575	--		120	1170	160	150	150	150		132	
							.98									
Low		--			3745	800		-120			--	--	--		128	

Eng Vibe	Gear Box Vibe	Gen. Vibe Drive	Gen. Vibe Excite	Gen. Brg. Temp. Drive	Gen. Brg. Temp. Excite	Oil Supply Temp	Oil Cooler Temp	Oil Tank Temp	Oil Tank Press	Oil Filt Δ P	Gen. Brg. Press.	Oil Sump level	Fuel Supply Press	Fuel Supply Temp	Fuel Manifold Press	Air Supply Press
.4	20	.4	.4	200	200	165			5”	20	18		225	155		
											15					
--	--	--	--			100			--	--	12	Yellow	120	130		110

Gas Skid

		1st Stage Amps	2nd Stage Amps	Scrub Tank Level	Servo Tank Level	Sep. Tank Level	Oil Lev Sw Run Pos	2nd Stage Press.	Servo Valve Press.	1st Stage Press.	Lube Oil Press.	Skid Dish. Press.
High		38	60					215	220	26	350	215
Low		--	--	--	1/2	32”		120	150	--	215	120

1st Stage Δ P	2nd Stage Δ P	Servo Valve Δ P	Lube Oil Δ P	Final Filter Δ P	1st Stage Temp	2nd Stage Temp	Cool Gas Temp.	Lube Oil Temp.	Lube Oil Tank Temp.	Final Filter Level	Hour Meter	Vac. H2O	Skid Inlet Temp
80	80	40	20	20	200	220	155	165	240			-100”	120
40	50	--	--	--	180	212	130	100	80				

Weekly Checks

120V Batt levels	Inlet Nitrogen psi	Air Comp. Oil Level
	60	

Switchgear

Battery A Volts	Battery B Volts
30	30
24	24

4.0 CORRECTIVE ACTION PROCEDURES

If a malfunction or failure that may cause emissions in excess of a permit limit occurs and it cannot be corrected by an operator, then the affected portion of the facility shuts down until the malfunctioning equipment can be repaired or replaced.

Standard Operating Procedure: Malfunction:

1. Minimize/stop emission of landfill gas (if present).
2. Determine cause of malfunction.
3. Fix the malfunction.
4. Complete Section 1 and Section 2 of the SMM Form (see Appendix A). Duration is the time it takes from discovery of malfunction to Step 3 above.
5. Refer to the Maintenance Instructions or Systems Operator's Guide if necessary (see Appendices B and C).

All malfunctions must be fully documented by completion of the Malfunction Event Form contained in Appendix A. Completed forms are saved electronically on the Riverview Energy Systems, LLC shared drive under Environmental.

Attachment

Table 1

Table 1 Operating Malfunctions Riverview Energy Systems, LLC			
Malfunction	**Action**	**Response**	**Documentation (form in Appendix A)**
Engine Compressor Surge	All turbines are subject to engine compressor surge under certain conditions. Transient conditions in fuel or air systems can cause the engine to surge as described by the following sounds and conditions: 1. Surge in the lower speed range could be indicated by the engine failing to accelerate, coupled with increased exhaust temperatures, and a sound of buffeting or fluttering air. 2. Surge in the higher speed range could be indicated by a loud roar and/or popping noises, plus engine failure to accelerate to rated speed.	If surge occurs, shut down the engine immediately to prevent the rapid buildup of damaging temperatures. After the engine has coasted to a stop, attempt to restart as usual. If surge occurs a second time, contact Solar Turbines Customer Service.	Malfunction Event Form
Generator Overheating and Vibration	Certain operating conditions may cause the generator to overload. Normal temperature rise of the generator windings is listed on the generator nameplate. Monitor temperature reported by the control system with surface temperature measuring instruments. Never check temperature by placing a hand on the surface.	Overheating may be caused by excessive ambient temperatures, poor air circulation due to improper or restricted ventilation, overload, excessive field current, contaminated or low lube oil supply, or worn bearings. If excessive temperature persists, shut down the unit and investigate the cause.	Malfunction Event Form
Explosive Atmosphere	Accumulations of natural gas, fuel fumes, oil tank vent leakage, or solvent fumes can be explosive and must be avoided. This is accomplished by proper ventilation, elimination of leaks, and by confining the use of solvents to appropriate maintenance facilities.	At installation and during maintenance of station equipment, observe the following precautions: 1.) Check piping for structural soundness. Verify that piping is properly supported and all connections are made in accordance with the best standard practices. Avoid unconventional or makeshift plumbing at all times. 2.) Prior to admitting gas into lines or systems, test for leaks and inspect to ensure all connections are properly made and all unused ports are plugged. Ensure that all flanged connections include required gaskets and that bolts are tight. Verify that lines have been cleared before pressurizing. 3.) Ensure that vent systems which handle natural gas are properly installed before operation of the equipment. Check	Malfunction Event Form

		that vents terminate in an area far enough from equipment or building to prevent any possibility of gas being carried back into the work area. Check vent systems to ensure that all unused ports are plugged to prevent gas escaping into the package enclosure or building. Check vent lines for bird nests, insects, ice, or any other obstructions that would prevent proper venting. 4.) If gas detection equipment is installed in the package or in the building, confirm proper operation of this equipment before admitting gas into the systems. 5.) When admitting gas into a system for the first time, listen for gas leaks. (Do not place your ear or head where there are suspected leaks.) Use a gas sniffer. Never attempt to check gas leaks by feeling for the suspected area with the hands or fingers. This method can be very dangerous as gas pressures can exceed 150 psi (1034 kPa, 10 bar, or 11 kg/cm2). A pinhole leak of high-pressure gas can Amputate a finger or hand. Use a piece of cloth (streamer) attached to a stick to test for leaks. 6.) Once gas has been admitted to equipment, use a gas sniffer to ensure the absence of gas before opening any explosionproof enclosure for troubleshooting.	

Appendix A

Riverview Energy Systems, LLC

BLANK FORMS

Riverview Energy System
Startup/Shutdown/Malfunction Report Form

Section 1 - All Events

List effected piece(s) of equipment

Type of Event		Military Time				Duration (hours)	Event Code	SOP* Followed?	
		Date/Time Start		Date/Time End			(see back of form)	Yes	No**
	Startup								
	Shutdown								
	Malfunction							Complete Section 2 Below	

*Standard Operating Procedure (SOP) for Flare Startups (Manual & Automatic) and Shutdowns are provided in SSM Plan
If SOP in SSM Plan was not followed, **notify site engineer immediately.

Section 2 - Malfunction Events Only

☑ ***Check one of the following for each step:***

Step	Corrective Action Procedures for All Malfunctions	Procedure completed	Procedure Not Applicable
1.	Determine if landfill gas is being released to the air (can you smell landfill gas, or measure/detect gas flow?).	☐	
2.	If landfill gas is being released to the air, notify personnel on "Contact List".	☐	☐
3.	Determine if the malfunction is causing an unsafe operating condition (air entering landfill or piping, smoking, vibration, or other problem), which may harm people, the environment or the landfill gas control equipment.	☐	
4.	If unsafe operating condition exists, or landfill gas is being released to the air, **stop** (if possible) **landfill gas flow.**	☐	☐
5.	If Control device or other system component is shutdown due to Step 4, follow Shutdown SOP and Complete Section 1 - "Shutdown".	☐	☐
6.	Determine if other personnel/resource (qualified technician, electrician, consultant or other) are needed for malfunction diagnosis.	☐	
7.	If additional personnel needed, notify qualified personnel: a. Record contact name, date and time:_______________________________ b. Contact site representative with information recorded in #7.a.	☐	☐
8.	Start malfunction diagnosis.	☐	
9.	Determine if other resources are needed to fix the malfunction (qualified technician, electrician, contractor, on-site resources, manufacturer's representative, or other).	☐	
10.	If additional resources needed, contact qualified resource: a. Record contact name, date and time:________________________________ b. Contact site representative with information recorded in #10.a.	☐	☐
11.	Fix the malfunction.	☐	
12.	Once the malfunction is fixed, re-start the system per SOP if it had been shut down, and record start-up times and dates on this form.	☐	☐
13.	Record date that malfunction occurred, date that malfunction was repaired, and total time that system was out of service in boxes in Section 1 of this form.	☐	
14.	Sign this form, copy it, and place it in the Start-up, Shutdown, Malfunction file.	☐	
15.	If the procedures listed above were not followed, contact the site engineer immediately.	☐	☐

Date Form Filled Out: ______________________________ **Title:** ______________________________

EVENT CODES

For Start-ups and Shutdowns:

Startup: The setting in operation of an affected source or portion of an affects source for any purpose.

Shutdown: The cessation of operation of an affected source or portion of any source for any purpose.

<u>**Code**</u>	<u>**Event**</u>
1	Maintenance
2	Suspected Collection System Malfunction
3	Suspected Control Device Malfunction
4	Suspected Continuous Monitoring System Malfunction (Temperature/Flow/Other)
5	Training
6	Gas System Construction/Expansion
99	Other (Describe)Manual startup/shutdown. No power, Switchgear and breaker maintenance

For Malfunctions:

Malfunction: Any sudden, infrequent and not reasonably preventable failure of air pollution control equipment, process equipment, or a process to operate in a normal or usual manner. Failures that are caused in part by poor maintenance or careless operation are not malfunctions.

10	Automatic shutdown of control device by designed protective systems
11	Autodialer Callout
12	Shutdown alarms that result in the device not shutting down
13	Unalarmed shutdown
14	Control Device Smoking
15	Inspection identified malfunction
16	Loss of power - utility down
17	Loss of power - unknown
18	Damaged Well, Header or Lateral Piping
19	Leaks at wellheads, valves, flanges, test ports, seals, couplings, etc.
20	Condensate Knock-out Problems
21	Collection Piping Blockages
22	Problems due to Settlement
23	Loss of phase
24	Blower overload condition
25	Blower bearing failure
26	Broken belts (if belt-drive) or broken coupling (if drect-drive) in blower
27	Continuous Monitoring System Malfunction - Thermocouple
28	Continuous Monitoring System Malfunction - UV Scanner
29	Continuous Monitoring System Malfunction - Flow Monitor
30	Continuous Monitoring System Malfuction - Flow Recorder
31	Continuous Monitoring System Malfuction - Temperature Recorder
32	Act of God (i.e., lightening, wind, etc.)
99	Other (Describe)

Appendix B

Riverview Energy Systems, LLC

Maintenance Instructions

Refurbished Centaur 40 Turbine-Driven Generator Set

Volume II

Maintenance Instructions

Refurbished Centaur® 40 Gas Turbine-Driven Generator Set

RIVERVIEW ENERGY SYSTEMS
Riverview, MI
Unit 2

Solar® Turbines
A Caterpillar Company

Volume II

Maintenance Instructions

Refurbished Centaur® 40 Gas Turbine-Driven Generator Set

RIVERVIEW ENERGY SYSTEMS
Riverview, MI
Unit 2

SOLAR®
65171

Volume II

Maintenance Instructions

Refurbished Centaur® 40 Gas Turbine-Driven Generator Set

RIVERVIEW ENERGY SYSTEMS
Riverview, MI
Unit 2

Solar® Turbines
A Caterpillar Company

Solar Turbines Incorporated
P.O. Box 85376
San Diego, CA 92186–5376

PUBLICATION NUMBER: IMI 13–65171 02/13

RECORD OF CHANGES

This page may be used to record changes to the manual made by Publication changes, Service Bulletins, or local changes and corrections.

Change, Date or Bulletin Number	Description	Pages Affected	Date

FOREWORD

This technical manual covers the Refurbished Centaur® 40 Gas Turbine-Driven Generator Set designed and manufactured by Solar Turbines Incorporated at the Package Refurbishment Center in Mabank, Texas.

Procured under Solar Project Definition No. 6517 by RIVERVIEW ENERGY SYSTEMS, this equipment is designated for the Riverview installation site.

Training for this and other equipment is available. For the latest class and registration information, visit the Customer Support section of our home page at *www.solarturbines.com*.

EQUIPMENT IDENTIFICATION

This equipment is identified as follows:

Model Number(s)	Centaur® 40
Assembly Number(s)	8-65171
Serial Number(s)	CG87548

TECHNICAL MANUAL OVERVIEW

The technical manual is provided in a four-volume set. Part numbers referred to within the manual set are Solar part numbers unless otherwise specified. Each volume of the set stands alone and is described in the following paragraphs.

Volume I - Systems Operator's Guide

Volume I is for equipment operator use. Locations and descriptions for all operator controls and indicators are provided. Procedures for starting, stopping, and operating the equipment are also included.

Volume II - Maintenance Instructions

Volume II is for maintenance and field service personnel use. The functions of major systems and subsystems are described, and component descriptions are included. Maintenance instructions, and alignment and checkout procedures are provided. The introduction chapter provides maintenance schedules, torque tables and maintenance information for the mechanical systems on the package.

Volume III - Supplementary Data

Volume III is a collection of standard, copyrighted documents that cover supplier-provided components and assemblies. These documents, passed on by Solar Turbines from its suppliers, are only available in the English language; therefore, these documents cannot be translated into other languages. Documents in this volume are arranged and tabbed alphabetically by the names of the suppliers, as listed on the Supplementary Data sheet furnished in the front of this volume.

Volume IV - Illustrated Parts List

Volume IV lists part numbers, part names, quantities required, reference designators, and drawings to locate parts used in the turbine package. Various indices are provided to aid the user in locating piece parts within the package.

CONTENTS

Chapter **Page**

Chapter **Page**

Chapter **Page**

Chapter **Page**

Chapter **Page**

Chapter **Page**

Chapter **Page**

Chapter **Page**

Chapter **Page**

Chapter **Page**

LIST OF ILLUSTRATIONS

Figure		Page

Figure **Page**

LIST OF TABLES

Table **Page**

Table **Page**

SAFETY REQUIREMENTS

EQUIPMENT SAFETY LABELS

Safety labels attached to the equipment are described in this section.

Safety and warning labels are in categories as detailed in the following subsections.

Caution, Warning and Danger labels may be accompanied with a Prohibition symbol, as shown in the following figure. The use of the prohibition symbol indicates a potentially hazardous situation or practice which is not to be allowed.

35749

Caution and Warning labels may be accompanied with a Safety Alert symbol, as shown in the following figure. The use of the Safety Alert symbol with Caution and Warning labels increases the severity of the label.

35750

- Danger - On the package, label has a red border, with white lettering on black, as shown in the following figure. In the print version, colors are not shown.

45131

Danger is the most severe safety label. The signal word Danger indicates a potentially hazardous situation which, if not avoided, will result in death or serious injury. Danger labels identify the most serious hazards.

- Warning - On the package, label has an orange border, with white lettering on black, as shown in the following figure. In the print version, colors are not shown.

45132

The signal word Warning indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury. Hazards identified with the signal word Warning present a lesser degree of risk of injury than those identified by the signal word Danger.

- Caution - On the package, label has a yellow border, with white lettering on black, as shown in the following figure. In the print version, colors are not shown.

45133

The signal word Caution used with a safety alert symbol indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.

The signal word Caution used without a safety alert symbol indicates a potentially hazardous situation which, if not avoided, may result in property damage.

- Notice - On the package, label has a blue border with white lettering on black, as shown in the following figure. In the print version, colors are not shown.

45134

The signal word Notice indicates a statement of policy relating directly or indirectly to the safety of personnel or protection of property. The statement of policy is on the Notice label. A circle around the statement requires mandatory action. The Notice signal word is not to be associated directly with a hazard or hazardous situation, and may not be used in place of Danger, Warning or Caution labels.

GENERAL

Solar turbine-driven packages are designed for safe and reliable operation. The packages include features which protect the equipment from damaging malfunctions and unsafe operation.

Personnel must become familiar with the following safety requirements and must observe the safety requirements at all times. Maximum safety of personnel is of primary importance, followed by protection of equipment from damage. Careful adherence to these safety requirements will minimize hazards or injury to personnel and equipment.

Included are procedures for certain operating malfunctions and precautions for personnel working in special environments (such as in an explosive atmosphere, or where there are dangerous substances).

MANUAL SAFETY WARNINGS, CAUTIONS AND NOTES

Three types of safety notices are used in the manual to emphasize critical information: WARNINGS, CAUTIONS, and NOTES.

WARNINGS, CAUTIONS, and NOTES are explained in order of significance as follows:

WARNING

A WARNING identifies procedures, practices, conditions, or precautions, which if not heeded, could result in personal injury or loss of life.

CAUTION

A CAUTION identifies precautions, which if not observed, could result in damage or destruction of equipment.

NOTE

A NOTE highlights information necessary to understand or follow a procedure, practice, condition, or description.

SAFETY INSPECTION

Careful attention to the package is required. A walkaround visual safety inspection is recommended to ensure that no foreign objects are lying on, in, or around the package. Perform the safety inspection before start-up, once each day of operation, and after shutdown. It is especially important to inspect the package before and after maintenance or repair. Inspect the package for the following unsafe conditions:

- Inspect for fuel gas leaks and lube oil leaks in hot areas.
- Look for leaking gas, sour gas, or condensate in drip pans.
- Check drain lines for leaks.
- Inspect for frayed or skinned electrical wiring. Eliminate high voltages.
- Inspect for broken or cracked anchor bolts or structural members.

- Look for obstructions or loose material in air inlet and exhaust ducts. Check inlet and vent lines for rocks, paper, bird nests, or other foreign matter. Verify that package and its vicinity are clean and unobstructed.

Following is a list of actions to enhance safe operation:

- Know the location of shutoff valves, switches, and telephones.
- Note the location of the customer-furnished emergency shutoff valve that should be installed in the fuel line to the package.
- Know emergency shutdown procedures and other emergency equipment or systems.
- Know emergency procedures applicable to the specific installation.
- Know where the fire extinguishers are and how to use them.
- If other equipment is operating or being serviced nearby, determine if this will create a hazardous condition that could cause personal injury, or affect safe operation or servicing of Solar equipment. Do not operate the package if hazardous or unsafe conditions appear to be likely.

WARNINGS

The following warnings cover Solar turbine-driven packages. Failure to observe these warnings could result in personal injury or loss of life. The order of listing does not indicate the order of importance. Each item is important for personnel safety. These warnings (and others not listed below which may be applicable to the specific installation) must be observed during service and operation of the package.

⚠ WARNING

Operate the unit only when it is safe. Unsafe conditions are:

- Fuel gas leaks, lube oil leaks in hot areas

- Frayed or skinned electrical wiring

- Broken or cracked anchor bolts or structural members

Accumulations of natural gas, fuel fumes, oil tank vent leakage, or solvent fumes can be explosive and must be avoided. This is done by proper ventilation, elimination of leaks, and by confining the use of solvents to appropriate maintenance facilities.

Only qualified personnel may operate the unit. The operator must understand turbine and driven equipment operation and function, including controls, indicators, and operating limits.

⚠ WARNING

Hearing and eye protection, as well as hard hats, safety goggles, ear plugs, and protective clothing, must be used by personnel in the vicinity of the operating machine.

The unit complies with user-specified noise level requirements. Noise levels may be further reduced by the user with modifications to the user's building or equipment. Modifications shall not interfere with safe operation or efficiency of the unit.

Ensure other personnel are nearby. NEVER WORK ALONE.

Never wire around automatic shutdown devices, or bypass software alarms and shutdowns. They prevent personnel injury and damage to the equipment.

When working on a nonoperating package, lock out the start circuit by opening the control circuit breaker and rotating the OFF/LOCAL/REMOTE, OFF/LOCAL/AUXILIARY or OFF/LOCAL/AUX keyswitch to OFF. Attach temporary DO NOT START tag to control switch to warn against inadvertent closing of the switch.

Verify operation of the personal gas monitor (sniffer) and use the monitor to ensure a gasfree environment.

Check that operation of switches and valves cannot endanger personnel and/or equipment.

Do not allow any bare wiring on or in vicinity of package.

Do not step on electrical conduit or junction boxes or use them as supports.

Prevent tripping by stowing unnecessary tools and parts.

Smoking, open flame, or spark-producing devices (such as cigarette lighters) are NOT allowed in the package vicinity AT ANY TIME.

Handle battery electrolyte with care. The battery MUST be kept clean.

Avoid personal contact with hot sections of equipment.

Eliminate any fuel or oil leaks as soon as detected.

WARNING

Check to ensure there is no pressure in any system lines before disconnecting them. High pressure lines may be pressurized up to5000 psi (34 473 kPa, 345 bar, or 352 kg/cm^2).

Use care when performing high voltage ignition system checks. Stand on a rubber mat and wear shockproof gloves and protective eye equipment.

Stand clear of all pressure lines and fittings during start and operation.

Wear protective equipment (face shields, masks, goggles, gloves, or clothing) and observe fire precautions when using cleaning solvents or solutions. Avoid skin contact with solvents or solutions. DO NOT INHALE FUMES.

When welding or cutting package components, observe fire prevention requirements stipulated in National Fire Protection Association (NFPA) Standard No. 51B for cutting and welding procedures. This standard has been adopted by the Occupational Safety and Health Administration (OSHA) of the United States Government as a national standard.

Do not apply external voltages to generator package control systems. Feedback through control transformers to terminals could be lethal.

Do not open circuits to current transformers, ammeters, or watt-var meter current coils with the generator set in operation. Jumper secondary terminals of transformer if generator is to be operated with open current circuits.

Verify correct generator synchronization or phase rotation when paralleling generators, or paralleling a generator with the utility grid. Generator to gear unit coupling damage could result, causing a hazard to personnel and equipment.

Use care when troubleshooting or performing maintenance procedures. Voltages can be dangerously high. Never override interlocks. Verify all main circuit breakers are open (OFF), so that engine will not start unexpectedly while maintenance or inspection work on engine is in progress.

WARNING

When working in areas with a known or potential hydrogen sulfide (H_2S) hazard, wear masks, goggles, gloves, or other protective equipment. H_2S deadens the sense of smell in 2 to 15 minutes, making it difficult to detect. Exposure can cause severe poisoning and CAN BE FATAL.

Discharge all high-voltage circuits by using a heavy insulated cable. Short each phase to ground before working on or around equipment. Residual voltages which might remain stored for several hours after shutdown could be lethal.

Oil heater operation is automatically sequenced to ensure safe operation of the heater. Operating the oil tank heater when oil is not at the required level creates a fire hazard. To avoid injury to personnel or damage to equipment by fire, do not manually bypass lube oil heater interlocks.

CAUTIONS

The following cautions cover Solar turbine-driven packages. Failure to observe these cautions could result in damage to or destruction of equipment. The order of listing does not indicate order of importance. Each item is important to overall equipment safety. These cautions (and others which may be applicable to a specific installation site) must be observed during all service and operation of the package.

CAUTION

Prevent foreign matter (such as ice) from entering air inlet. Foreign objects in the air inlet will cause severe damage.

Protect air inlet from entry of contaminants such as moisture, dust, sand, and oil mist.

Bleed all air from fuel system prior to operating equipment. Air in fuel system could cause malfunction and/or shutdown.

Under severe environmental conditions, ensure that inlet air filtration system is free of restrictions that could reduce inlet air pressure. Use snow covers, de-icers, and sand/dust filters to protect the inlet air system.

Before operating equipment, ensure that covers are removed from air inlet, exhaust, and vents. These openings must remain unobstructed during operation.

CAUTION

Watch instruments and indicator lights closely, especially during start-up. Engine speed and turbine temperature are best indications of performance or impending malfunctions.

During the start cycle, monitor engine speed and temperature. Rapid rise of turbine temperature with no corresponding speed increase indicates engine compressor surge. If engine compressor surge occurs, do not wait for controls to actuate. PRESS STOP SWITCH IMMEDIATELY.

In the event of malfunction shutdown, do not attempt another start until the cause is determined and corrected.

Do not exceed starter motor crank cycle limits.

Do not allow the turbine to rotate in reverse-from-normal rotation. Reverse rotation can cause serious damage to the turbine.

Cap all open lines and fittings during maintenance to prevent entry of contaminants. Use caps and blanks specifically intended for closing lines or fittings. DO NOT USE TAPE.

Keep package and vicinity clean and unobstructed. Keep maintenance work areas clean to ensure clean assembly. Cleanliness is important due to high speeds and close tolerances of turbine parts.

Do not overfill the oil tank. Ensure that clearance is maintained over the oil tank vent, and vent exhaust is directed away from engine air inlet and exhaust ducts.

Do not flex cables unnecessarily. Repeated flexing of wiring connections contributes to early fatigue failure.

Keep covers, doors, and panels in place and explosionproof enclosures closed, with all fasteners installed and tightened, when package access is not required.

Do not pull on electrical cables to disconnect. Disconnect by grasping connectors only.

Do not add water to discharged battery. Electrolyte level rises considerably during charging.

Verify check valves and other flow devices are correctly installed relative to direction of flow.

CAUTION

When applicable, allow pre/post lube oil pump to complete the postlube cycle before shutting off service air/gas supply.

Ensure that any system unsafe to operate is locked out and controls and switches are tagged "DO NOT OPERATE."

Verify that exhaust collector drains are not connected to common drain manifolds. Common drain manifolds sometimes drain or vent flammable gases and/or fluids.

When using electrical welding procedures on package skid, ensure proper grounding of welding equipment to prevent damage to electrical components mounted on the package.

When connecting generator package high-voltage power cables, ensure that elbow connectors are properly seated (in safe-break bushings) to prevent arcing and subsequent damage at startup.

OPERATING MALFUNCTIONS

Certain operating conditions constitute abnormal turbine engine operation. Identification of the following malfunctions helps in determining package maintenance or repair requirements.

Engine Compressor Surge

CAUTION

If engine compressor surge occurs, do not wait for controls to actuate. PRESS STOP SWITCH IMMEDIATELY. Surge can cause serious engine damage.

All turbines are subject to engine compressor surge under certain conditions. Transient conditions in fuel or air systems can cause the engine to surge as described by the following sounds and conditions:

1. Surge in the lower speed range could be indicated by the engine failing to accelerate, coupled with increased exhaust temperatures, and a sound of buffeting or fluttering air.

2. Surge in the higher speed range could be indicated by a loud roar and/or popping noises, plus engine failure to accelerate to rated speed.

NOTE

If surge occurs, shut down the engine immediately to prevent the rapid buildup of damaging temperatures. After the engine has coasted to a stop, attempt to restart as usual. If surge occurs a second time, contact Solar Turbines Customer Service.

Generator Overheating And Vibration

Certain operating conditions may cause the generator to overload. Normal temperature rise of the generator windings is listed on the generator nameplate. Monitor temperature reported by the control system with surface temperature measuring instruments. Never check temperature by placing a hand on the surface.

NOTE

Overheating may be caused by excessive ambient temperatures, poor air circulation due to improper or restricted ventilation, overload, excessive field current, contaminated or low lube oil supply, or worn bearings. If excessive temperature persists, shut down the unit and investigate the cause.

CAUTION

An increase in generator vibration during operation should be checked immediately. Shut down unit and check for misalignment, bent shafts, or rubbing between stator and rotating elements.

Explosive Atmosphere

Accumulations of natural gas, fuel fumes, oil tank vent leakage, or solvent fumes can be explosive and must be avoided. This is accomplished by proper ventilation, elimination of leaks, and by confining the use of solvents to appropriate maintenance facilities.

WARNING

Relying on the sense of smell to determine the presence of natural gas is not reliable and can be dangerous. Natural gas has no odor unless an odorizer has been added. Pipeline gas usually has no odor because the odorizer is not added until gas reaches the distributor.

A gas detection device (sniffer) more accurately determines if and where gas leakage exists. The sniffer must be operating properly (refer to manufacturer's operating instructions) before

WARNING

making checks. Sniffers MUST be calibrated periodically. NEVER rely on a sniffer that is out of calibration, or one suspected of being out of calibration.

If there is any doubt regarding gas leakage, a sniffer must be used to ensure that there is no leakage. Using a sniffer is the primary method to determine the presence of an explosive atmosphere. A soap solution may be used to determine the source of a leakage.

Any hazardous condition must be corrected before continuing with checkout procedures. This is a mandatory requirement.

At installation and during maintenance of station equipment, observe the following precautions:

1. Check piping for structural soundness. Verify that piping is properly supported and all connections are made in accordance with the best standard practices. Avoid unconventional or makeshift plumbing at all times.

2. Prior to admitting gas into lines or systems, test for leaks and inspect to ensure all connections are properly made and all unused ports are plugged. Ensure that all flanged connections include required gaskets and that bolts are tight. Verify that lines have been cleared before pressurizing.

3. Ensure that vent systems which handle natural gas are properly installed before operation of the equipment. Check that vents terminate in an area far enough from equipment or building to prevent any possibility of gas being carried back into the work area. Check vent systems to ensure that all unused ports are plugged to prevent gas escaping into the package enclosure or building. Check vent lines for bird nests, insects, ice, or any other obstructions that would prevent proper venting.

4. If gas detection equipment is installed in the package or in the building, confirm proper operation of this equipment before admitting gas into the systems.

5. When admitting gas into a system for the first time, listen for gas leaks. (Do not place your ear or head where there are suspected leaks.) Use a gas sniffer. Never attempt to check gas leaks by feeling for the suspected area with the hands or fingers. This method can be very dangerous as gas pressures can exceed 150 psi (1034 kPa, 10 bar, or 11 kg/cm^2). A pinhole leak of high pressure gas can amputate a finger or hand. Use a piece of cloth (streamer) attached to a stick to test for leaks.

6. Once gas has been admitted to equipment, use a gas sniffer to ensure the absence of gas before opening any explosionproof enclosure for troubleshooting.

7. Battery connections are not enclosed in an explosionproof housing. Verify that battery, battery charger, and circuit breakers are in nonexplosive environments with an explosionproof interconnection to the package. Test with a gas sniffer to ensure absence of explosive atmosphere when maintaining battery connections.

FIRST AID

⚠ WARNING

Solar recommends that personnel working in the vicinity of the equipment described in these operating and maintenance instructions be trained in first aid, and specifically, to deal with injuries including the following:

- Electric shock
- Inhalation of toxic gases, natural gas, or CO_2
- Bleeding
- Broken bones
- Chemical burns
  - Sulfuric or other acid
  - Preservative powder (dicyclohexyl ammonium nitrate)
- Flame, heat, steam, or hot water burns
- Head, neck, or spinal injury

1 INTRODUCTION

1.1 INTRODUCTION

This publication is for maintenance and field service personnel use. Chapters of this manual include:

- Introduction - describes package, major components, subsystems, site and structure considerations, and provides general maintenance information
- Start System - includes general, functional and component descriptions, and maintenance procedures
- Fuel System - includes general, functional and component descriptions, and maintenance procedures
- Electrical Control System - contains general, functional and component descriptions, and maintenance procedures
- Lube Oil System - contains general, functional, and component descriptions, and maintenance procedures
- Ancillary Equipment - describes air inlet and exhaust systems
- Turbine Engine - contains general, functional, and turbine engine component descriptions, engine performance data, engine cleaning instructions, and engine maintenance procedures
- Driven Equipment - contains general and functional descriptions, electrical check, troubleshooting, and maintenance procedures

1.2 GENERAL PACKAGE DESCRIPTION

The gas turbine-driven generator set has an axial-flow turbine engine, a generator, and gear unit. These elements are installed in-line on a steel base frame, a steel weldment with beam sections and cross members forming a rigid foundation. Machined mounting surfaces on the base facilitate alignment of major components. The gear unit input shaft is connected with the engine compressor rotor nose cone hub with a splined sleeve coupling. A mating flange bolted to the engine air inlet housing attaches the assemblies.

The generator input shaft is aligned with the gear unit output shaft, and the shafts are connected with a flexible shear coupling in a protective cover.

Generator set accessories include start, fuel, electrical control, lube oil systems, and a pneumatically controlled air system.

1.3 MAJOR COMPONENTS AND SYSTEMS

WARNING

Additions and/or modifications to the turbine package control systems, or other package systems and subsystems, which are not reviewed and approved by Solar Turbines Engineering may cause serious malfunctions and may allow unsafe operation. Such malfunctions or unsafe operation could cause significant property damage, personnel injury, and/or loss of life. Do not modify package equipment, or add third party supplied systems or components without Solar Turbines Engineering approval.

1.3.1 Start System

The start system includes starter and control devices. The starter rotates the engine to self-sustaining speed, shuts down, the starter clutch overruns, and the engine accelerates under its own power to loading speed.

1.3.2 Fuel System

The fuel system regulates fuel pressure and fuel flow to control engine power.

1.3.3 Electrical Control System

The 24 Vdc electrical system monitors engine and driven equipment and controls shutdowns. In operation, the electrical control system protects equipment from hazards such as overspeed, high engine temperature, low lube oil pressure, excessive oil temperature, and other anomalies.

The control system is operated from control and monitoring junction boxes. A display with indicator lights and pushbutton switches displays engine operational status.

1.3.4 Lube Oil System

Supplied from the base frame reservoir, the lube oil system circulates pressurized oil to rotating equipment bearings. An oil reservoir heater, oil cooler, and a thermostatic oil control valve maintain oil temperature.

1.3.5 Turbine Engine

Air is drawn into the turbine's compressor section through the air inlet and is compressed. Fuel is added to the compressed air in the combustor and is ignited. After combustion, hot gases expand through turbine nozzles and drive turbine rotors. Air and combustion gases are then discharged into the atmosphere through the exhaust system.

Major engine subassemblies include:

- air inlet
- compressor
- compressor diffuser
- annular combustor
- turbine
- exhaust diffuser
- exhaust collector

1.3.6 Generator

The generator transforms mechanical energy to electrical energy. The generator is bolted to the raised mounting pads on the base, in alignment with the gear unit. The standard generator set has a two-bearing, revolving field-type, three-phase, ac generator, with damper windings and a direct-connected brushless exciter.

1.4 SITE AND STRUCTURE CONSIDERATIONS

The standard turbine-driven package operates from sea level to 8000 feet (2438 m) elevation, at temperatures ranging from -20°F to +115°F (-29°C to +46°C). Accessories are required for operation at higher elevations, extreme temperatures, or corrosive environments.

Lube oil may limit operation in extreme temperatures. The lube oil must comply with viscosity requirements for the ambient starting temperature.

1.4.1 Environmental Considerations

The turbine-driven package may be installed in a building or outdoors when fitted with a weatherproof enclosure. Acoustic enclosures are typically not required for inside installations, however, turbine noise should be considered if personnel are near the operating machinery. For specific package installation data, see the Mechanical Installation Drawing.

1.4.2 Ducting and Vents

WARNING

Vent lines can be dangerous. Vents containing combustible fluids shall not be interconnected with ducting, drain lines, or sumps, which are connected to the engine's “hot” side. These vents shall be terminated individually in a safe atmosphere as far as possible from exhaust stacks, air inlets, or other vents so that no interflow can occur. Oil demister drains are normally returned to the oil tank and shall not be connected to drain sumps connected to the engine. The use of check valves in interconnected vents and/or drain lines is not an acceptable substitute for individual lines.

CAUTION

Termination of turbine exhaust ducts, oil cooler, lube oil tank vents, and service gas vents must not allow recirculation of exhaust products to the turbine air inlet or oil-cooling radiator. Turbine and/or radiator damage will occur.

Plant layout for the turbine(s) must accommodate inlet and exhaust ducting systems. Relative positions of inlet and exhaust ducts of all units must be considered where multiple units are used.

1.4.3 Floor Layout

Floor layout should consider space required to move package(s) into position, and clearance for removal of components for servicing including provision for lifting equipment. See installation drawing for lift information. Normally the oil cooler is mounted outside of any building.

1.4.4 Sound Level

A sound-attenuating enclosure may be required, especially with multiple units in operation.

NOTE

The unit complies with user-specified noise level requirements. Noise levels may be reduced by modifying the acoustic environment where the turbine operates. Modifications must not interfere with turbine safety or efficiency.

1.4.5 Low Winter Temperatures

Where low temperatures are encountered, low pour point oils and/or heating shall be used to ensure lube oil viscosity at start up is not greater than minimums detailed in the Lube System chapter. This limit applies to the complete oil system including tank, pipe, cooler, and filters. Space heating may be required in addition to the optional immersed tank heaters. Cooler loop piping must be kept warm. Viscous-type air inlet filters will require heating.

1.4.6 Water Wash System Requirements

Units installed in a salt or dusty environment should have the optional water wash system for the engine compressor to minimize performance deterioration. Customer lines and tanks feeding the water wash system should be corrosion-resistant. Galvanized piping is not acceptable.

1.5 MAINTENANCE SCHEDULE

Maintenance of the engine and control equipment is required at established intervals. The recommended intervals are for nominal environmental and operating conditions. Severe environments and extreme conditions may require more frequent and extensive maintenance. The local environment, operating conditions and practices, and the availability of skilled technicians must be carefully considered in establishing a maintenance plan. Preventive maintenance at specific intervals minimizes corrective maintenance.

WARNING

Before doing maintenance, read all facility safety policies and procedures to make sure you protect personnel and equipment.

Before you work in any hazardous area, read the facility Permit to Work (PTW) policy and get a written PTW.

The permit to work must cover the following:

— Proper personal protective equipment,

— Proper procedures for using sniffers,

— Proper personnel monitoring and use of communication equipment,

— Proper ventilation,

— Physical hazards,

— Temperature hazards,

— Proper use of hearing protection,

— Evacuation procedures and routes.

Only qualified personnel may operate and maintain the package. The operator and maintenance personnel must understand turbine and driven equipment operation and function, and must also understand the controls, indicators, and operating limits.

Do not operate the package when conditions are unsafe. Unsafe conditions include:

— fuel leaks or lube oil leaks

— damaged electrical wiring

⚠ WARNING

— damaged anchor bolts or structural members

Obey the facility procedure to lock out the controls and attach warning tags to them. Turn the OFF/LOCAL/REMOTE, OFF/LOCAL/AUXILIARY or OFF/LOCAL/AUX keyswitch to OFF. Make sure the battery charger, control console, and switchgear circuit breakers are open at the package motor control center (MCC). Before you do any work, attach “DO NOT OPERATE” tags to the start buttons and controls. Do not rely on color-coding of wiring for identification when you remove and install electrical components. Refer to the wiring diagram.

Before you do maintenance on the package, inspect the alarm indications on the package display. If the package is equipped with an offskid display, contact the remote operator for alarms status. If the package has an onskid display, inspect the alarms status at the package. Identify alarms that might become a dangerous situation while you do maintenance, for example, an alarm for a gas leak that has reached the Lower Explosive Limit (LEL) can become a more serious leak during maintenance.

Set up signs and barriers that keep non-maintenance personnel and vehicles out of the work area. If the package has an enclosure, non-maintenance personnel can be injured or can cause damage to equipment when the enclosure is opened for maintenance.

If the package has an enclosure, do not block any enclosure door whether or not it has been opened for maintenance. In case of emergency, use the nearest door to get out of the enclosure.

If the package has an enclosure, make sure the enclosure has adequate light to safely work inside. If necessary, install reliable temporary lights in the enclosure before you do maintenance. Make sure maintenance personnel have hand lights immediately available to them in case primary lighting fails and the enclosure does not have automatic backup lighting.

WARNING

Prevent explosive accumulations of natural gas, liquid fuel, oil mist, or solvent fumes. Make sure ventilation is adequate and immediately repair leaks. Before you use solvents or cleaning solutions, read the applicable Material Safety Data Sheets. Use solvents in appropriate maintenance facilities.

Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

If the package has an enclosure, make sure the pressure between the enclosure and its environment is equal before you open the doors. The enclosure can have higher or lower internal pressure compared to its environment. Maintenance personnel can be injured if doors are forcibly thrown open by positive internal pressure or are forcibly pulled closed by negative internal pressure.

Before you attempt to enter the enclosure, use the negative-pressure door-jacking assembly, if installed, to make the internal and external pressure equal. You can damage the doors if you force them open.

If the package has an enclosure, make sure the doors are latched in place after they have been opened. Winds can suddenly and forcibly move unlatched doors.

Do not touch hot surfaces. Gas turbines create extremely high surface temperatures. Use insulated gloves and protective clothing/equipment when you do maintenance.

Gas turbines create extremely high exhaust and surface temperatures that can ignite the fuels and lubricants used in gas-turbine packages. Solar strongly urges that you work in only non-hazardous, gas-free conditions. If maintenance must be done under hazardous atmosphere conditions, before doing maintenance, review the facility-specific auto-ignition temperatures (AITs) of the fuels and lubricants used in the package. Allow the equipment to cool to 80% of the lowest AIT before you do maintenance. Use a hand-held, non-contact thermometer approved for use in hazardous atmospheres to measure surface temperatures.

Close all fuel supply valves to the package before servicing seal system components. Attach “DO NOT OPEN” tags to the valves. Make sure all pressure has completely dissipated.

WARNING

Before you disconnect any system line, check pressure indicator gages and transmitter displays to make sure there is no pressure in the lines. Open hand-operated pressure-release valves slowly to release any pressure that might remain.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you use cleaning solvents or cleaning solutions. Prevent skin contact with solvents, solutions, or other materials that can be health hazards. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you handle fuels, lube oils, and their residues. Prevent skin contact with fuels, lube oils, and their residues. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you drain, transfer, or store fuels, lube oils, and their residues, or any other materials that contain chemicals or compounds that can be health hazards.

If any seal system component was loosened or removed, test the component for leaks on start-up.

Refer to the Safety Requirements section located in the front of this manual for additional Warnings and Cautions.

1.5.1 Daily and Monthly Maintenance

Daily and monthly maintenance includes a walkaround inspection to ensure equipment is functioning properly and to detect leaks or obvious faults.

Operating parameters should be recorded and analyzed for trends. This will help predict faults.

1.5.2 Semiannual Maintenance

Semiannual maintenance emphasizes protective systems checkout and ensures optimum equipment performance. Regardless of hours of operation, this maintenance should be performed semiannually.

Semiannual maintenance requires equipment shutdown.

1.5.3 Annual Maintenance

Annual maintenance involves disassembly of subsystem components for inspection. Problems noted in previous inspections should receive attention in annual maintenance whether or not they are listed in this manual. Detailed records help pinpoint malfunctions prior to performance impact.

For annual maintenance, equipment must be shut down.

1.5.4 Special Maintenance (if package has a Gear Unit)

Special maintenance is required for the gear unit. The gear unit requires disassembly, gear contact pattern and bearing inspection after 30 000 hours of operation.

1.5.5 Scheduled Periodic Checks and Maintenance Tasks

Following tables (1.5.1 through 1.5.10) recommend general minimum maintenance intervals. Where Supplementary Data specify more frequent, or more extensive maintenance, or where operating conditions dictate, adhere to the more rigorous requirement.

- D (day)
- M (month)
- S (semiannual - 4000 operating hours)
- A (annual - 8000 operating hours)

Table 1.5.1 Maintenance - Electrical and Control Systems

System/Description	D	M	S	A
Periodic Checks				
Visually inspect gages and indicators for proper operation.	X			
Inspect control console electrical connections for cleanliness and security. Check wiring for absence of chafing and insulation damage.[1]		X		
If applicable, check fire detectors for sensitivity.[1]			X	
If applicable, clean fire detectors.[1]		X		
If applicable, check fire bottles for proper charge.			X	
Check battery charger for proper operation. For NiCad batteries, place charger to high rate for a few hours.[2]		X		
Check and record speed magnetic pickup output voltage. This must be done with engine running.			X	
Check condition of thermocouple harnesses. Check integrity of support grommets.[1]			X	
Periodic Maintenance Tasks				

Table 1.5.1 Maintenance - Electrical and Control Systems, Contd

System/Description	D	M	S	A
Remove and inspect igniter cable. Inspect igniter plug for erosion and proper gap. Replace plug if necessary.			X	
Test speed and temperature topping system.			X	
Test and calibrate backup overspeed monitor (OSM).[2]			X	
Verify calibration of temperature monitors.			X	
Check and calibrate all temperature and pressure gages/switches.			X	
Test and calibrate as necessary all safety, warning, and shutdown devices.			X	
Test package vibration monitor and calibrate transducers.				X
Change lithium battery in PLC, or controller.[2]				X

NOTES:

(1) Checks can only be performed with the unit shut down.

(2) See MAINTENANCE in Electrical Control System Chapter of this volume.

Table 1.5.2 Maintenance - Air Systems

System/Description	D	M	S	A
Periodic Checks				
Check air inlet system for obstructions and contamination.[1] Record differential pressure.[2]		X		
If air dryer installed, check its operation.[1]		X		
Inspect engine compressor variable guide vane mechanism for wear or corrosion. Check for bent lever arms, loose linkages or bushings, and seized guide vanes.[1]		X		
Inspect intake and exhaust systems for damage, leaks, and debris.[1]			X	
Periodic Maintenance Tasks				
Check and calibrate IGV (Inlet Guide Vane) activation system.			X	
Apply corrosion inhibitor to variable guide vane system linkage.[1, 3]		X		
Inspect and replace air inlet filters as needed.[2]			X	

Table 1.5.2 Maintenance - Air Systems, Contd

System/Description	D	M	S	A
If self-cleaning air filter installed, check supply pressure, manually cycle through cleaning operation.		X		
Disassemble, clean, inspect, and reassemble bleed valve.				X

(1) Checks can only be performed with the unit shut down.

(2) Air inlet filters should be replaced per manufacturer's recommendation. As a guide, barrier filters require service if differential pressure reaches the alarm setpoint, normally 5 in. water (12.7 cm water). Prefilters require service if the differential pressure increases 1.0 to 1.5 in. water (2.5 to 3.8 cm water) above baseline.

(3) Refer to Service Bulletin 8.6/112.

Table 1.5.3 Maintenance - Lube Oil and Servo Oil Systems

System/Description	D	M	S	A
Periodic Checks				
Check oil tank level every 24 hours. Record oil consumption.	X			
Verify proper operation of oil makeup system, if installed.	X			
If applicable, check oil cooler belt tension.[1]			X	
Check oil cooler louver operation as applicable.		X		
If applicable, check lube oil tank vent fan and mist precipitator for proper operation.		X		
Check and record lube oil filter differential pressure. Change filters if differential pressure limit exceeded.		X		
Check servo oil filter “pop-up” indicator, if so equipped; change filter if popped.	X			
Check oil cooler core; clean as necessary.			X	
Periodic Maintenance Tasks				
Take lube oil sample for laboratory analysis.[2], [3]		X		
Check lube oil system for leaks.		X		

Table 1.5.3 Maintenance - Lube Oil and Servo Oil Systems, Contd

System/Description	D	M	S	A
Inspect and replace lube oil and servo oil filters as needed.[4]			X	
Lubricate oil cooler fan shaft bearings.			X	

(1) Checks can only be performed with the unit shut down.

(2) All maintenance tasks except for these require the unit to be shut down.

(3) See Solar Engineering Specification 9-224 for oil replacement criteria.

(4) Lube oil and servo oil filter elements should be replaced when visible contamination is present, when differential pressure “pop-up” indicators are popped, or when differential pressure limits are exceeded. Filters should be replaced no less than annually.

Table 1.5.4 Maintenance - Gas Fuel System (if applicable)

System/Description	D	M	S	A
Periodic Checks				
Inspect fuel control system for security and leaks, and visually inspect linkages and connections.[1]			X	
Check gas fuel system for leaks.		X		
Inspect fuel valve(s); clean as necessary.[1]				X
Periodic Maintenance Tasks				
Record fuel pressure, adjust at off-skid regulator if necessary.	X			
Disassemble, clean, and rebuild gas valves as applicable.			X	
Remove and inspect igniter torch housing for cracks, excessive erosion; inspect discharge tube for chafing wear.			X	
Rebuild or replace solenoid valves and regulators including those for air assist.				X

(1) Checks can only be performed with the unit shut down.

Table 1.5.5 Maintenance - Liquid Fuel System (if applicable)

System/Description	D	M	S	A
Periodic Checks				
Check low-pressure fuel pump operation, if installed.		X		
Check high-pressure fuel pump for leaks and noise.		X		
Check liquid fuel system for leaks.		X		
Check high-pressure fuel filter. Clean or replace as necessary.[1]		X		
Observe fuel control performance (stability, start time, lightoff time during start).		X		

Table 1.5.5 Maintenance - Liquid Fuel System (if applicable), Contd

System/Description	D	M	S	A
Check operation of fuel control valve. Verify T5 temperatures during start; compare with original data if available.			X	
Periodic Maintenance Tasks				
Inspect and replace filters as needed.[2]				X
Disassemble and lubricate fuel shutoff valves; reassemble with new O-rings.			X	
Inspect air purge manifolds for discoloration, cracks, and signs of overheating.			X	
Remove and inspect fuel injectors. Clean as needed.			X	
Rebuild or replace solenoid valves and regulators including those for air assist.				X

(1) Checks can only be performed with the unit shut down.

(2) Fuel filter elements should be replaced when visible contamination is present, when differential pressure “pop-up” indicators are popped, or when differential pressure limits are exceeded. Filters should be replaced no less than annually.

Table 1.5.6 Maintenance - Dual Fuel System (if applicable)

System/Description	D	M	S	A
Periodic Checks and Maintenance Tasks				
Conduct fuel transfer during operation. Observe speed, temperature, and load readings for stability.			X	
Check fuel system for leaks.		X		

Table 1.5.7 Maintenance - Water Injection System (if applicable)

System/Description	D	M	S	A
Periodic Checks				
Check water pump belts for proper tension.[1]			X	
Periodic Maintenance Tasks				
Grease and tighten water pump seals.			X	
Change oil in water pump.			X	

(1) Checks can only be performed with the unit shut down.

Table 1.5.8 Maintenance - Start System and Auxiliary Motors

System/Description	D	M	S	A
Periodic Checks				
Inspect and test pre/post lube oil pump, seal oil pump, backup lube oil pump, and backup seal oil pump, as applicable.[1]			X	
Inspect starter clutch, if applicable, to ensure lock-up in one direction and free rotation in the other.[1]			X	
Visually inspect starter gas seals.[1]			X	
If electrohydraulic start system, check oil reservoir level.	X			
Periodic Maintenance Tasks				
For electrohydraulic start systems, obtain oil sample from starter system for laboratory analysis.[2]				X
For electrohydraulic start systems, change start system filters.				X
For pneumatic start systems, change lube oil.[3]				X

(1) Checks can only be performed with the unit shut down.

(2) See Solar Engineering Specification 9-347 for oil replacement criteria. Sample more frequently if greater than normal number of starts is performed.

(3) Lube oil should be replaced after each 500 starts.

Table 1.5.9 Maintenance - Generator

System/Description	D	M	S	A
Periodic Checks				
Verify governor load gain voltage.				X
Periodic Maintenance Tasks				
Disassemble, clean, and inspect coupling teeth and shear bolts for wear or damage. Repack with fresh Solar coupling grease. Reassemble using new gaskets.				X
Check gearbox to generator alignment; realign as necessary.				X
Inspect and, as necessary, clean the generator with a high-dielectric cleaner recommended by the generator manufacturer.				X

Table 1.5.10 Maintenance - General

System/Description	D	M	S	A
Periodic Checks				
Be alert for any unusual operating condition (vibration, noise, etc.).	X			
Inspect all lines and hoses for leaks, wear, chafing; correct as necessary.	X			
Inspect all mechanical linkages for wear, looseness; correct as necessary.	X			

Table 1.5.10 Maintenance - General, Contd

System/Description	D	M	S	A
Visually inspect entire package for fuel, oil, and air leaks.	X			
Visually inspect integrity of fasteners, auxiliary motor couplings, bleed valve, and fuel control linkages.		X		
Check condition and operation of solenoids and shutoff valves.[1]			X	
Inspect package for unusual noise, discoloration, cracks, and chafing lines.		X		
Visually inspect exhaust bellows for cracks or distortion.				X
Periodic Maintenance Tasks				
Record all panel readings, check that all oil-filled gages are filled.[2]		X		
Conduct engine performance analysis. Perform ingestive cleaning if necessary and at least semiannually.[2]		X		
Conduct borescope inspection of turbine.			X	
Lubricate all electric motors equipped with grease fittings.			X	
Check all safety relief valves as required by local regulations.			X	
Clean entire package.			X	
Remove seal oil pump from accessory drive (if installed). Inspect shaft splines for wear or evidence of seal leakage. Inspect accessory drive internally. Reinstall seal oil pump using new gasket.				X
If applicable, disassemble interconnect shafts and inspect splines for wear. Reassemble using new O-rings.				X
Check and adjust alignment of engine, gear unit, and compressor(s) as applicable.				X
Restart turbine and record acceleration time. Monitor control system for proper sequencing.			X	
Conduct vibration survey for trending.[2]			X	
Sample NOx water quality and record results.[3]	X			
Sample fuel(s) for specific gravity, lower heating value (LHV), dew point and composition, and record results.[3]				X
For marine applications, lubricate the gimbal bearings and the slider in the primary package support tie-downs with National Lubricating Grease Institute (NLGI) Grade 2, lithium-based grease with extreme pressure (EP) and molybdenum disulfide additives. Pump grease into the Zerk fittings until fresh grease is extruded from the bearing grooves. Wipe away excess surface grease.		X		

(1) Checks can only be performed with the unit shut down.

(2) Maintenance tasks, except for these, require machine shutdown.

(3) See Solar Engineering Specification 9-98 for NOx water quality and for fuel data.

1.6 GENERAL MAINTENANCE PROCEDURES

WARNING

Before doing maintenance, read all facility safety policies and procedures to make sure you protect personnel and equipment.

Before you work in any hazardous area, read the facility Permit to Work (PTW) policy and get a written PTW.

The permit to work must cover the following:

- Proper personal protective equipment,
- Proper procedures for using sniffers,
- Proper personnel monitoring and use of communication equipment,
- Proper ventilation,
- Physical hazards,
- Temperature hazards,
- Proper use of hearing protection,
- Evacuation procedures and routes.

Only qualified personnel may operate and maintain the package. The operator and maintenance personnel must understand turbine and driven equipment operation and function, and must also understand the controls, indicators, and operating limits.

Do not operate the package when conditions are unsafe. Unsafe conditions include:

- fuel leaks or lube oil leaks
- damaged electrical wiring
- damaged anchor bolts or structural members

Obey the facility procedure to lock out the controls and attach warning tags to them. Turn the OFF/LOCAL/REMOTE, OFF/LOCAL/AUXILIARY or OFF/LOCAL/AUX keyswitch to OFF. Make sure the battery charger, control console, and switchgear circuit breakers are open at the package motor control center (MCC). Before you do any work, attach “DO

WARNING

NOT OPERATE” tags to the start buttons and controls. Do not rely on color-coding of wiring for identification when you remove and install electrical components. Refer to the wiring diagram.

Before you do maintenance on the package, inspect the alarm indications on the package display. If the package is equipped with an offskid display, contact the remote operator for alarms status. If the package has an onskid display, inspect the alarms status at the package. Identify alarms that might become a dangerous situation while you do maintenance, for example, an alarm for a gas leak that has reached the Lower Explosive Limit (LEL) can become a more serious leak during maintenance.

Set up signs and barriers that keep non-maintenance personnel and vehicles out of the work area. If the package has an enclosure, non-maintenance personnel can be injured or can cause damage to equipment when the enclosure is opened for maintenance.

If the package has an enclosure, do not block any enclosure door whether or not it has been opened for maintenance. In case of emergency, use the nearest door to get out of the enclosure.

If the package has an enclosure, make sure the enclosure has adequate light to safely work inside. If necessary, install reliable temporary lights in the enclosure before you do maintenance. Make sure maintenance personnel have hand lights immediately available to them in case primary lighting fails and the enclosure does not have automatic backup lighting.

Prevent explosive accumulations of natural gas, liquid fuel, oil mist, or solvent fumes. Make sure ventilation is adequate and immediately repair leaks. Before you use solvents or cleaning solutions, read the applicable Material Safety Data Sheets. Use solvents in appropriate maintenance facilities.

Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

⚠ WARNING

If the package has an enclosure, make sure the pressure between the enclosure and its environment is equal before you open the doors. The enclosure can have higher or lower internal pressure compared to its environment. Maintenance personnel can be injured if doors are forcibly thrown open by positive internal pressure or are forcibly pulled closed by negative internal pressure.

Before you attempt to enter the enclosure, use the negative-pressure door-jacking assembly, if installed, to make the internal and external pressure equal. You can damage the doors if you force them open.

If the package has an enclosure, make sure the doors are latched in place after they have been opened. Winds can suddenly and forcibly move unlatched doors.

Do not touch hot surfaces. Gas turbines create extremely high surface temperatures. Use insulated gloves and protective clothing/equipment when you do maintenance.

Gas turbines create extremely high exhaust and surface temperatures that can ignite the fuels and lubricants used in gas-turbine packages. Solar strongly urges that you work in only non-hazardous, gas-free conditions. If maintenance must be done under hazardous atmosphere conditions, before doing maintenance, review the facility-specific auto-ignition temperatures (AITs) of the fuels and lubricants used in the package. Allow the equipment to cool to 80% of the lowest AIT before you do maintenance. Use a hand-held, non-contact thermometer approved for use in hazardous atmospheres to measure surface temperatures.

Close all fuel supply valves to the package before servicing seal system components. Attach “DO NOT OPEN” tags to the valves. Make sure all pressure has completely dissipated.

Before you disconnect any system line, check pressure indicator gages and transmitter displays to make sure there is no pressure in the lines. Open hand-operated pressure-release valves slowly to release any pressure that might remain.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you use cleaning solvents or cleaning solutions. Prevent skin contact with solvents, solutions, or other materials that can be health

WARNING

hazards. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you handle fuels, lube oils, and their residues. Prevent skin contact with fuels, lube oils, and their residues. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you drain, transfer, or store fuels, lube oils, and their residues, or any other materials that contain chemicals or compounds that can be health hazards.

If any seal system component was loosened or removed, test the component for leaks on start-up.

Refer to the Safety Requirements section located in the front of this manual for additional Warnings and Cautions.

CAUTION

When removing and installing electrical components, ensure wiring is tagged, and lockout procedures are used. Do not rely on color coding on wiring for identification. Refer to the wiring diagram.

1.6.1 Removal and Installation of Accessories

CAUTION

Work areas must be kept clean to ensure a clean assembly. This is vitally important because of the high speeds and close tolerances of turbine engine parts.

For removal and installation of accessories, plumbing, and electrical harnesses, use standard industrial maintenance and repair practices. No special tools are required. These items are attached with standard hardware. Discard old O-rings and gaskets and replace with identical new parts.

1.6.2 Cleaning/Degreasing/Decarbonizing

CLEANING

WARNING

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you handle fuels, lube oils, and their residues. Prevent skin contact with fuels, lube oils, and their residues. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you drain, transfer, or store fuels, lube oils, and their residues, or any other materials that contain chemicals or compounds that can be health hazards.

Emulsion-type cleaners using petroleum solvents as the carrier liquid are fire hazards. Obey fire precautions.

Obey manufacturer's precautions when using cleaning materials.

Thorough cleaning of parts is important for satisfactory operation. When considerable time might elapse between cleaning or inspection and reassembly, lubricate and place clean parts in clear plastic bags to prevent corrosion or contamination. Clean accessories in accordance with Table 1.6.1.

Table 1.6.1 Accessories Cleaning

Part	Cleaning Method	Cleaning Material
Gas Strainers Oil Cooler	Wash and flush.	Stoddard solvent or equivalent
Oil Pump Oil Pressure Switch[1]	Wipe with clean, lintfree cloth soaked in solvent.	Stoddard solvent or equivalent
Temperature Switches[1] Exciter[1] (ignition) Instrument Panel Gages Indicator Lights Switches and Relays	Wipe clean with lintfree, dry cloth.	None required
Fuel and Oil Lines Pcd-Line Filter Water Traps Gas Fuel Filters	Force flush thoroughly and dry with dry compressed air.	Stoddard solvent or equivalent
Igniter Plug Fuel Injectors	Clean with soft wire brush.	None required

(1) Cap electrical receptacles before cleaning to prevent contamination.

DEGREASING

⚠ WARNING

Petroleum solvents have low flash points. In a spray they are highly flammable. Fire precautions must be observed. Personnel must be protected from solvent vapor inhalation.

Degrease with petroleum-based solvents, emulsion-type solvents, isopropyl alcohol solvent or detergent-based cleaners, such as for petroleum-based solvent, Chemsearch's Yield®, or Loctite's ODC-Free Cleaner Degreaser, and for a detergent-based material, Chemtool's CT-108-GD. Dip, soak, and agitate parts, or pressure spray them until oil and grease are removed. Use a fiber bristle brush to remove caked grease or soft carbon deposits. Decarbonizing may be required to remove hard carbon.

⚠ WARNING

Petroleum solvents are fire hazards. Use approved, safe, fire-suppressor containers. Observe fire precautions.

Use emulsion-type solvents or equivalent, in agitator-equipped vats or tanks so that movement of the liquid loosens deposits of oil, grease, and soft carbon. Agitate parts until clean. Drain and thoroughly rinse in water from pressure spray. After rinsing, dry parts immediately using clean, dry, lintfree cloths. Parts not requiring decarbonizing for the removal of hard carbon, scale, or corrosion should be sprayed with a lubricating oil incorporating a corrosion preventative.

NOTE

Aluminum alloy parts or tubing must be submerged immediately after degreasing, in a bath of 5 percent chromic acid solution, rinsed in clear water at 180°F (82°C) for 20 minutes, and anodized to prevent corrosion. Do not anodize any aluminum parts which have steel inserts or aluminum tubing which has steel coupling nuts. An eroding electrolytic action may be started.

DECARBONIZING

⚠ WARNING

Masks, gloves, and goggles are required whenever performing vapor or softgrit blasting.

Decarbonize or remove hard carbon deposits by vapor blasting or softgrit blasting.

Vapor blasting may be used for removing hard carbon or lead deposits, corrosion, and scale. Prior to vapor blasting, parts must be degreased and thoroughly dried. Grit of a grade no coarser than 325 should be used with a nozzle air pressure of 100 psi (689 kPa) (6.9 bar 7.03 kg/cm^2). The nozzle must be kept in motion so that stream does not dwell in one spot on the part.

Softgrit blasting may be used for removing hard carbon or lead deposits, corrosion, and scale. A standard sandblasting cabinet may be used. Air pressure may range from 65 to 100 psi (448 to 689 kPa) (4.5 to 6.9 bar 4.6 to 7.03 kg/cm^2), depending on type of grit material and nozzle size. Prior to soft- grit blasting, degrease and dry parts thoroughly. During blasting, keep nozzle in motion so that blast does not dwell in one spot. After blasting, repeat degreasing operation on parts to be subjected to fluorescent penetrant inspection. Parts not to be so inspected may be degreased with solvent or rinsed in hot water and thoroughly dried. Protect parts by spraying with a lubricating oil incorporating a corrosion preventative.

1.6.3 Surface Treatment of Aluminum Parts

When nicks and scratches damage the anticorrosion surface coating of the aluminum parts, the parts must be recoated.

On aluminum alloy parts having anodized surfaces, rinse the part with fresh water. Treat the damaged area using a chromate conversion chemical film such as Iridite, Alodine, or Chem Film. Follow the instructions provided with the selected repair material. A five percent chromic acid solution may be used as an alternate.

1.7 STANDARD MANUFACTURING REFERENCES

1.7.1 Mechanical Fasteners

Mechanical fasteners, such as bolts and nuts, are manufactured from many different materials with significantly different fastener strength. Two fastener materials used by Solar Turbines are carbon steel and stainless steel.

The most common types of bolt used at Solar Turbines is carbon steel, often called Zinc or Zinc-Dichromate (Gold) because of their Zinc-based corrosion resistant coatings. Steel bolts are manufactured in three common strength ranges: Grade 2, Grade 5, and Grade 8. Grade 2 bolts and studs are not used at Solar Turbines.

Stainless steel bolts are alloyed with chromium to make them more corrosion resistant. Chromium and other alloying elements increases corrosion resistance but reduce strength which prevents most stainless steel bolts from being used as direct replacements for zinc-coated carbon steel bolts. Torque values for stainless steel bolts are usually lower than those for zinc bolts and must be read from the appropriate torque tables.

While many bolts look nearly identical, their strengths vary significantly. It is important to know how to identify the bolt types used at Solar Turbines to ensure the correct bolt is used for a particular application.

1.7.2 Head Markings

Bolts are identified by head marking, which consist of letters, numbers, radial lines, or a combination of all three. Grade levels of studs are stamped on one end of the stud. The following describe specific carbon steel and stainless steel bolt head markings and bolt applications.

CARBON STEEL BOLTS

Carbon steel bolts are commonly identified by radial lines on the bolt heads. Carbon steel-alloy bolts may be identified by a combination of letters and numbers on the bolt heads.

Grade 5 Carbon Steel Bolt

Grade 5 carbon steel bolts (Figure 1.7.1) are identified by three radial lines on the head and are acceptable for most structural applications.

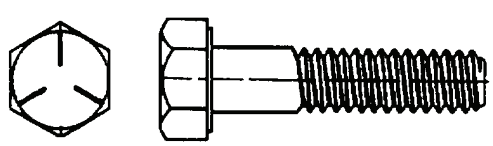


Figure 1.7.1 Grade 5 Carbon Steel Bolt

Grade B7 Carbon Steel Bolt/Stud

Grade B7 carbon steel bolts/studs (Figure 1.7.2) are identified by B7 on the head and are used in pressure and temperature applications.

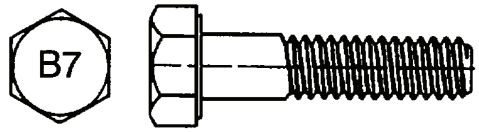


Figure 1.7.2 Grade B7 Carbon Steel Bolt/Stud

Grade B7M Steel Bolt/Stud

Grade B7M steel bolts/studs (Figure 1.7.3) are identified by B7M on the head and are used in National Association of Corrosion Engineers (NACE) (sour-gas) pressure and temperature applications.

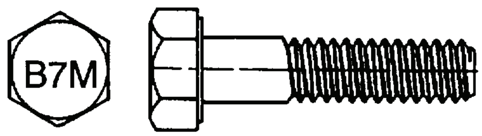


Figure 1.7.3 Grade B7M Steel Bolt/Stud

Grade 8 Carbon Steel Bolt

Grade 8 carbon steel bolts (Figure 1.7.4) are identified by six radial lines on the head and are used in applications that demand extra strength.

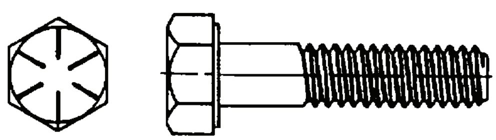


Figure 1.7.4 Grade 8 Steel Bolt

STAINLESS STEEL BOLTS

Stainless steel bolts are commonly identified by letters and numbers on the bolt heads.

Grade B6 Stainless Steel Bolt

Grade B6 stainless steel bolts (Figure 1.7.5) are identified by B6 on the head and are used in temperature and pressure applications.

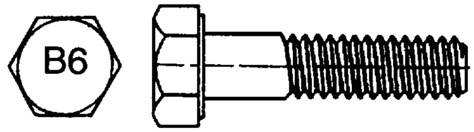


Figure 1.7.5 Grade B6 Stainless Steel Bolt

Grade B8 Stainless Steel Bolt

Grade B8 stainless steel bolts (Figure 1.7.6) are identified by B8 on the head and are used in pressure and temperature applications.

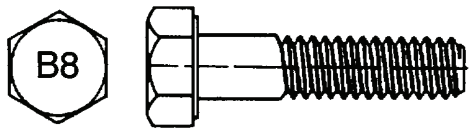


Figure 1.7.6 Grade B8 Stainless Steel Bolt

Grade B8M (Type 316) Stainless Steel Bolt/Stud

Grade B8M (Type 316) stainless steel bolts/studs (Figure 1.7.7) are identified by B8M on the head and are used in NACE (sour-gas) or non-NACE pressure and temperature applications.

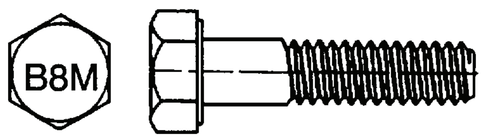


Figure 1.7.7 Grade B8M Stainless Steel Bolt/Stud

Grade 17-4PH, 17-4N, B8M, and B8M2 Stainless Steel Bolts/Studs

Grade 17-4PH stainless steel bolts/studs (Figure 1.7.8) are identified by 17-4 on the head and are used in pressure and temperature applications. Grade 17-4PH steel bolts and studs are a direct replacement for SAE Grade 5 carbon steel bolts and studs.

Bolts identified by 17-4N (Figure 1.7.8) on the head are used in NACE pressure and temperature applications, and are a direct replacement for SAE Grade 5 carbon steel bolts.

Bolts identified by B8M or B8M2 (Figure 1.7.8) on the head are similar to B8M (Type 316) stainless steel bolts except B8M or B8M2 bolts are stronger.

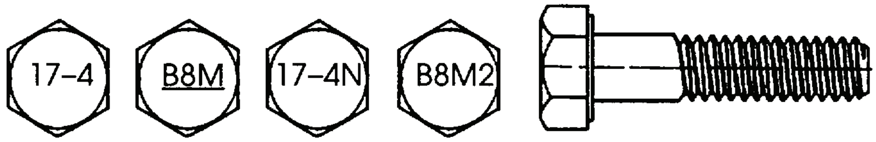


Figure 1.7.8 Grade 17-4PH Steel Bolt/Stud

WELD STUDS

Weld studs (Figure 1.7.9) have no head. They are welded directly to the base.

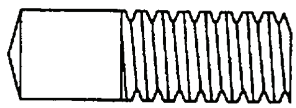


Figure 1.7.9 Weld Stud

1.7.3 Hex Nuts

Hex nuts are manufactured from materials with significant strength differences. Hex nut materials and their response to heat treatment influence fastener strength significantly.

Hex nuts should be selected for material strength comparable to that of the mating bolts. A Grade 5 steel bolt, for example, should be mated with at least a Grade 5 steel nut. It is permissible to substitute stronger fasteners, such as a Grade 8 steel nut on a Grade 5 steel bolt, although the torque applied is limited to the torque specified for the weaker fastener in the joint. Hex nuts are identified by their head markings. See Figure 1.7.10 for hex nut head markings.

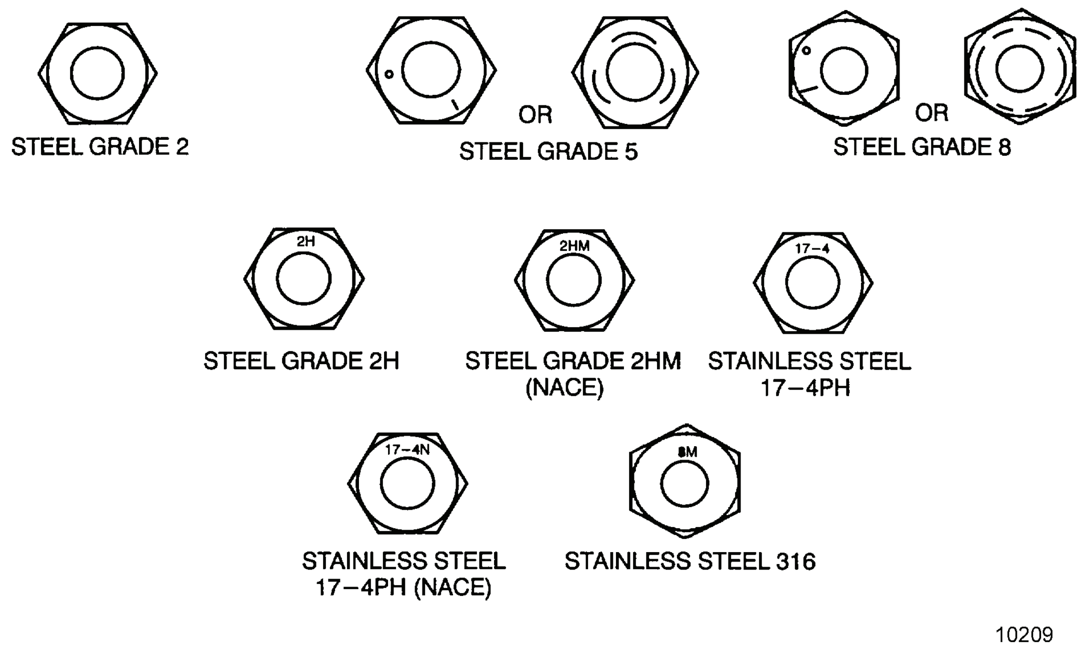


Figure 1.7.10 Hex Nut Head Markings

1.7.4 Thread Engagement

Steel, stainless steel, brass, and aluminum fasteners require thread engagement of at least one and one-half times the diameter of the fastener (Figure 1.7.11).

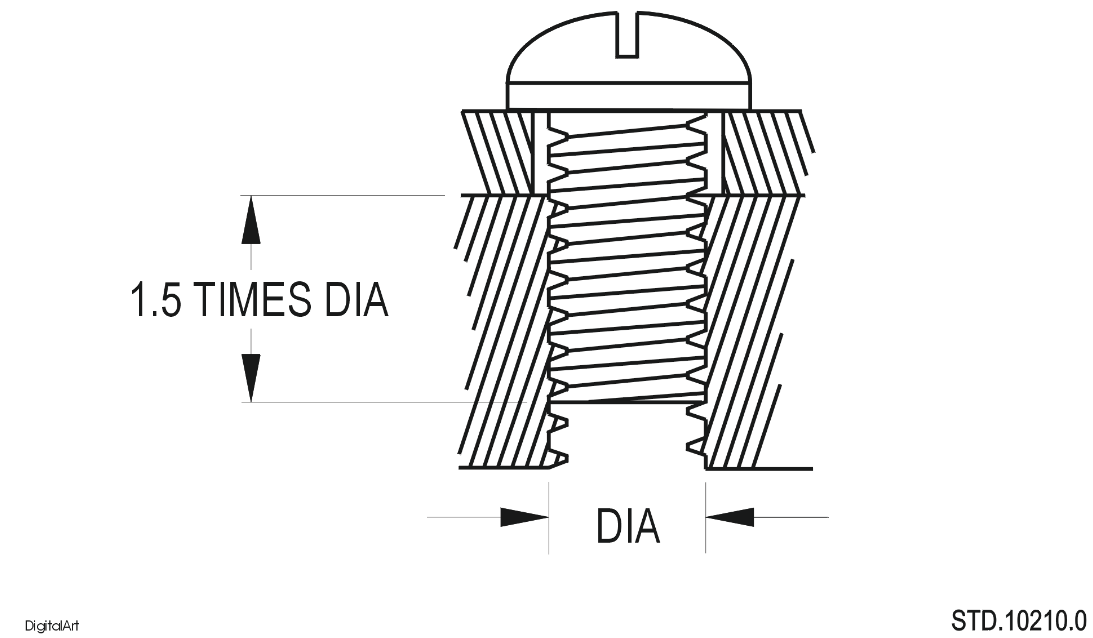


Figure 1.7.11 Metal Fastener Thread Engagement

Nonmetals, such as plastics, require thread engagement of at least the diameter of the fastener or three threads, whichever is greater (Figure 1.7.12).

Self-locking nuts must have at least three complete threads extending through the nut.

NOTE

Self-locking nuts are to be installed one time only. Once the assembly has been disassembled, discard locknuts and replace with new ones. Locknuts with nylon inserts are limited to 250°F (121°C).

Fasteners secured with lockwashers are torqued according to the fasteners' grade and size.

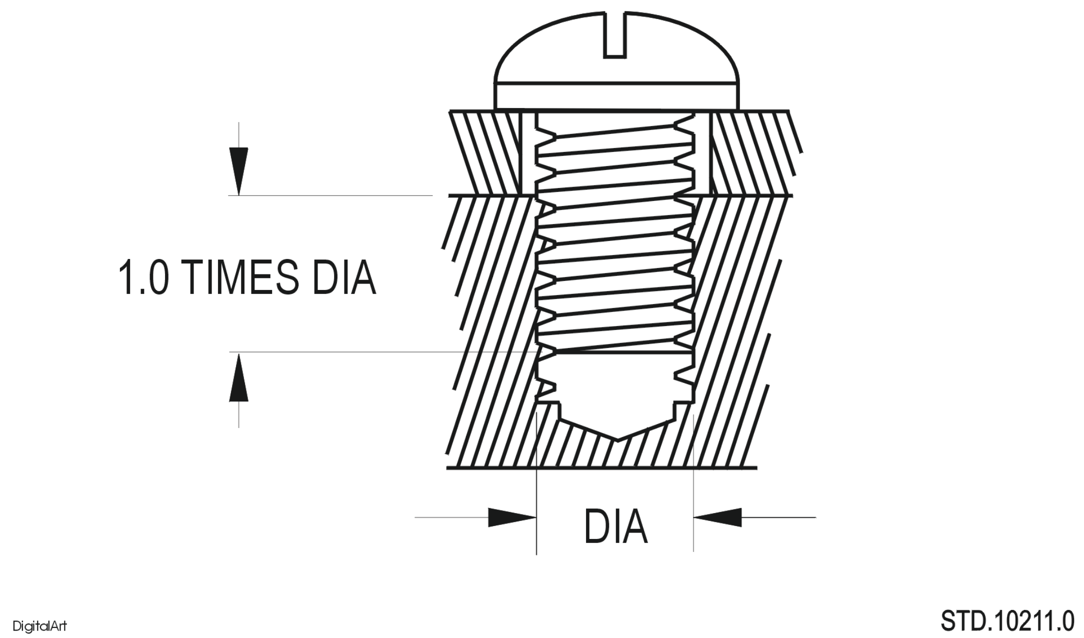


Figure 1.7.12 Nonmetal Fastener Thread Engagement

1.7.5 Thread Lubricants

Thread lubricant or anti-seize compound must be used when installing threaded fasteners. The relationship between applied torque and the resulting clamp load is directly affected by lubrication.

CAUTION

All bolts, capscrews, and studs with a thread diameter equal to or greater than 1/2 in. must be lubricated as specified in Solar Engineering Specification ES 9-54. Do not lubricate fasteners with a thread diameter smaller than 1/2 in.

Failure to lubricate threads can result in improper torque, substandard assembly, and/or seizure (cold welding) of fasteners.

Acceptable lubricants for threaded fasteners are listed in Table 1.7.1.

Table 1.7.1 Thread Lubricants

Name	Solar Part Number	Operating Temperature
Fel-Pro Nickel Anti-Seize Lubricant	917427C1	-95°F to 2400°F (-70.6°C to 1315.6°C)

Table 1.7.1 Thread Lubricants, Contd

Name	Solar Part Number	Operating Temperature
Dow Corning 321 Dry Film Lubricant Spray	980376C1	-325°F to 600°F (-198°C to 315.6°C)
Fougera White Petrolatum	915793C1	Ambient Temperatures Only

1.7.6 Critical Torque Areas and Assembly Hardware

Critical torque areas are identified as areas where fastener failure could cause harm to a system or operator. Fasteners used in critical torque areas are identified as assembly hardware. All assembly hardware is to be torqued to specifications with a torque wrench. The following indicates critical torque areas where assembly hardware must be used:

- Trunnions and engine mounts
- Pressure vessels, such as oil and fuel filters
- Driver and driven interfaces, such as couplings and guards
- Major components, such as start motor and all pumps and motors
- All vendor-supplied driven equipment, such as frame interface hardware, interface pipe assembly, hold-down hardware.
- All pipe assembly flanges, ASME/ANSI flanges, SAE/Caterpillar 4-bolt flanges
- Lubricating oil tank lids and other components with sealing surfaces
- Air inlet and exhaust collector ducting
- All base-to-base structural interfaces, all baseplate lifting members

1.7.7 Noncritical Torque Areas and Attaching Hardware

Noncritical torque areas are identified as areas where fasteners are used in noncritical applications and are nonstructural in their design intent. Fasteners used in noncritical torque areas are identified as attaching hardware. Attaching hardware, as a rule, must be firmly secured and wrench tight. The following indicates noncritical torque areas and applications where attaching hardware may be used:

- Mounting unistrut for conduit, tubing, and manifolds
- Mounting hardware for functional components such as switches, transmitters, gages, and solenoids
- The use of spring nuts
- Fine threaded or miniature fasteners, as used in control boxes

- Cushion clamps
- Serviceable hardware, that is, hardware that has to be removed to service or replace package components for maintenance in the field

1.7.8 Torque Sequences for Bolt Patterns

If one or more screws, bolts, or nuts of a series are tightened, as in a series of bolts around a flange or a half-shell, all of that series must be tightened equally to prevent distortion, damage, or leakage. See Figure 1.7.13 for torque sequences for bolt patterns.

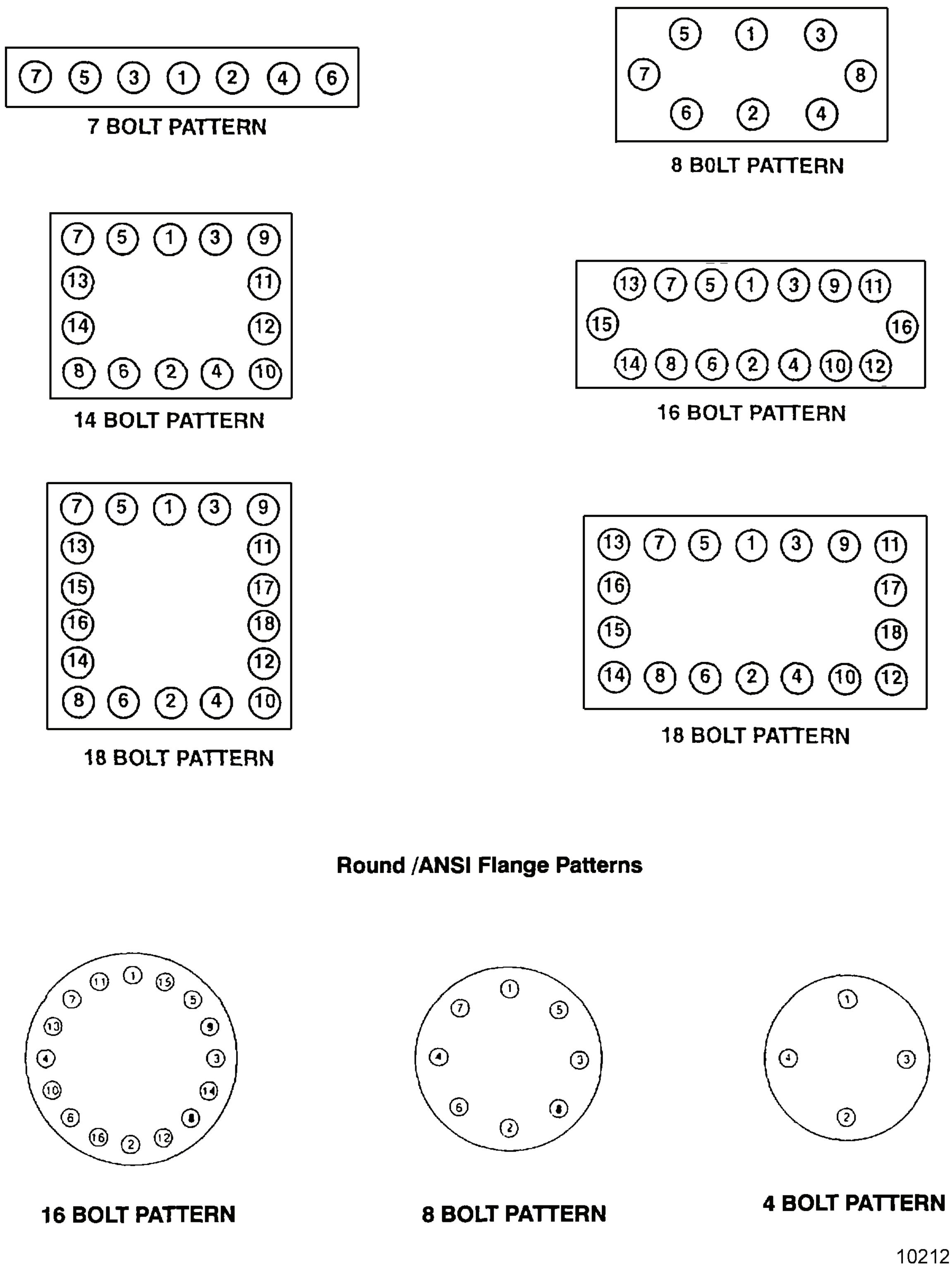


Figure 1.7.13 Torque Sequences for Bolt Patterns

1.7.9 Torque Sequences for Split Flange Clamps

See Figure 1.7.14 for torque sequences for low/high pressure, SAE 4-bolt, centerline split flanges. See Figure 1.7.15 for torque sequences for high pressure XT-5/6 4-bolt diagonal split flanges. Use SAE Steel Grade 8 or higher carbon steel bolts or Grade 17-4PH stainless steel bolts with according lengths and sizes on all 4-bolt, split-flange clamps. Refer to QAS 821 for hardware information.

NOTE

The maximum gap permitted after final tightening is cumulative, that is, 0.08 in. (2 mm) each side or 0.16 in. (4 mm) on one side with zero on opposite side or any combination equaling the 0.16 in. (4 mm) maximum gap.

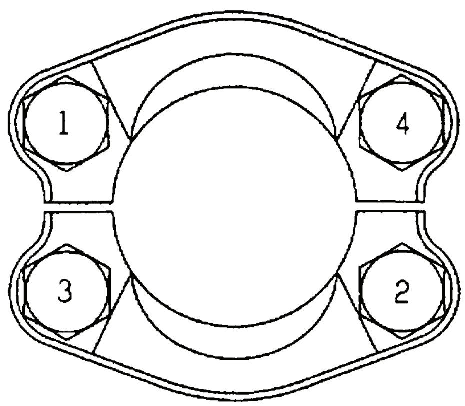


Figure 1.7.14 Torque Sequence for 4-Bolt Centerline Split Flange

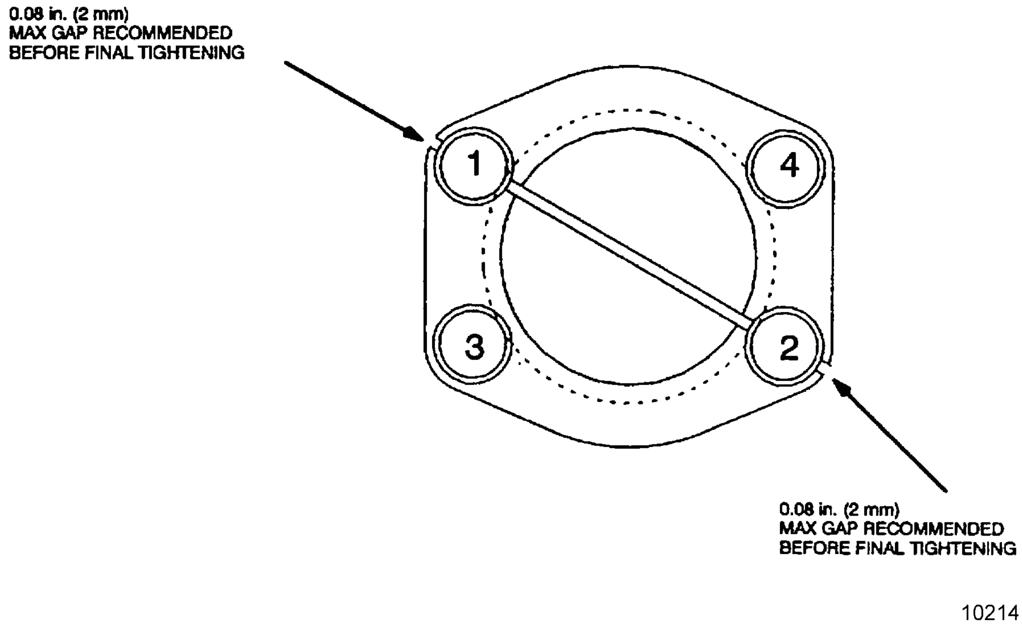


Figure 1.7.15 Torque Sequence for 4-Bolt Diagonal Split Flange

1.7.10 Torque Paint

Torque paint shall be applied such that breaks or unsealing may be readily identified. When torque paint is applied for the second time, all evidence of the first application must be removed. See Figure 1.7.16 for examples of torque paint acceptance standards.

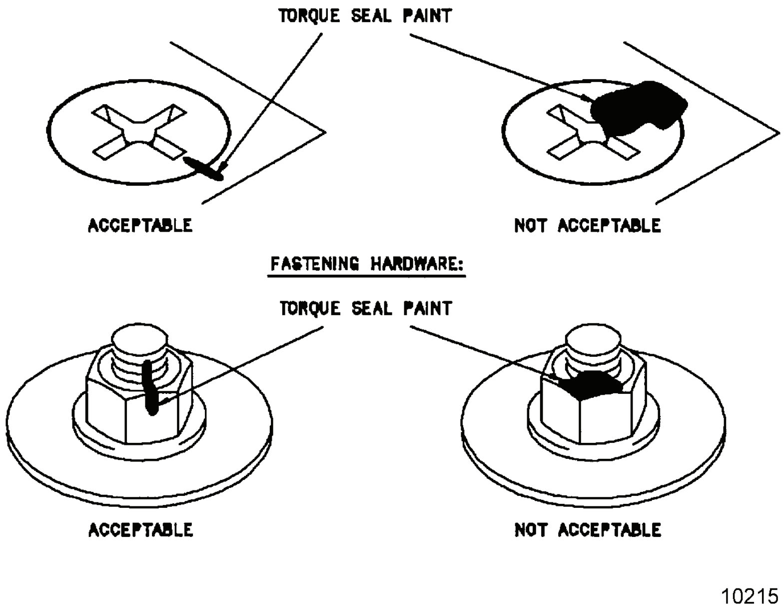


Figure 1.7.16 Torque Paint Acceptance Standards

1.7.11 Torque Values

CAUTION

Use standard torque values only when torque values are not specified for an application.

When tightening any screws, bolts, or nuts during inspection or during parts replacement or repair, tighten the item to the applicable torque listed in the following tables.

NOTE

Values in torque tables are based on bolts with thread sizes greater than or equal to 1/2 in. (12.7 mm) in diameter being lubricated with lubricants listed in Table 1.7.1. Bolts less than 1/2 in. (12.7 mm) in diameter are not to be lubricated.

Values in torque tables are given for UNF (Unified National Fine) and UNC (Unified National Coarse) bolt threads.

If one or more screw, bolt, or nut of a series is tightened, as in a series of bolts around a flange or a half-shell, all of that series must be tightened equally to prevent distortion, damage, or leakage.

INLET AND EXHAUST DUCTS

Torque values for inlet duct assembly hardware are 600 to 660 in-lb (68 to 75 N·m) or 50 to 55 ft-lb (68 to 75 N·m). Torque values for exhaust duct assembly hardware are 696 to 960 in-lb (79 to 109 N·m) or 58 to 80 ft-lb (79 to 109 N·m). Torque values apply to ducts in any orientation.

NOTE

A properly tightened fastener must be within ±5 percent of the prescribed or calculated torque value.

Torque values noted on mechanical installation drawing shall take precedence over torque values in this section, QAS 821, and ES 9-54.

GRADE 5 CARBON STEEL BOLTS

Table 1.7.2 provides torque values for Society of Automotive Engineers (SAE) Specification J429, Grade 5 carbon steel bolts.

Table 1.7.2 Torque Values for Grade 5 Carbon Steel Bolts

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	133 (15)	-	1/4-20	121 (14)	-
5/16-24	237 (27)	-	5/16-18	222 (25)	-
3/8-24	414 (47)	35 (47)	3/8-16	384 (43)	32 (43)
7/16-20	647 (73)	54 (73)	7/16-14	605 (68)	50 (68)
1/2-20	655 (74)	55 (74)	1/2-13	629 (71)	52 (71)
9/16-18	960 (109)	80 (109)	9/16-12	924 (104)	77 (104)
5/8-18	1340 (151)	112 (151)	5/8-11	1283 (145)	107 (145)
3/4-16	2325 (263)	194 (263)	3/4-10	2240 (253)	187 (253)
7/8-14	3696 (418)	308 (418)	7/8-9	3577 (404)	298 (404)
1-12	5042 (570)	420 (570)	1-8	4880 (551)	407 (551)
1 1/8 - 12	7226 (816)	602 (816)	1 1/8 - 7	6939 (784)	578 (784)
1 1/4 - 12	9960 (1125)	830 (1125)	1 1/4 - 7	9622 (1087)	802 (1087)
1 3/8 - 12	13 306 (1503)	1109 (1503)	1 3/8 - 6	12 733 (1439)	1061(1439)
1 1/2 - 12	17 330 (1958)	1444 (1958)	1 1/2 - 6	16 674 (1884)	1390 (1884)

GRADE B7 NICKEL-PLATED STEEL BOLTS/STUDS

Table 1.7.3 provides torque values for American Society for Testing Materials (ASTM) Specification A193, Grade B7 (Nickel-Plated) steel bolts/studs.

Table 1.7.3 Torque Values for Grade B7 Nickel-Plated Steel Bolts/Studs

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4 - 28	253 (29)	21 (29)	1/4 - 20	225 (25)	-
5/16 - 24	488 (55)	41 (55)	5/16 - 18	448 (51)	37 (51)
3/8 - 24	862 (97)	72 (97)	3/8 - 16	776 (88)	65 (88)
7/16 - 20	1343 (152)	112 (152)	7/16 - 14	1225 (138)	102 (138)
1/2 - 20	826 (93)	69 (93)	1/2 - 13	786 (89)	66 (89)
9/16 - 18	1165 (132)	97 (132)	9/16 - 12	1115 (126)	93 (126)
5/8 - 18	1628 (184)	136 (184)	5/8 - 11	1549 (175)	129 (175)
3/4 - 16	2825 (319)	235 (319)	3/4 - 10	2709 (306)	226 (306)
7/8 - 14	4492 (507)	374 (507)	7/8 - 9	4327 (489)	361 (489)
1 - 12	6699 (757)	558 (757)	1 - 8	6473 (731)	539 (731)
1 1/8 - 12	9604 (1085)	800 (1085)	1 1/8 - 7	9203 (1040)	767 (1040)
1 1/4 - 12	13 242 (1496)	1104 (1496)	1 1/4 - 7	12 786 (1445)	1066 (1445)
1 3/8 - 12	17 696 (1999)	1475 (1999)	1 3/8 - 6	16 892 (1909)	1408 (1909)
1 1/2 - 12	23 053 (2605)	1921 (2605)	1 1/2 - 6	22 128 (2500)	1844 (2500)
1 3/4 - 12	36 327 (4104)	3027 (4104)	1 3/4 - 5	35 050 (3960)	2921 (3960)
2 - 12	55 127 (6228)	4594 (6228)	2 - 4 1/2	52 470 (5928)	4373 (5928)
2 1/4 - 12	78 705 (8892)	6559 (8892)	2 1/4 - 4 1/2	75 481 (8528)	6290 (8528)
2 1/2 - 12	108 188 (12 223)	9016 (12 223)	2 1/2 - 4	103 447 (11 687)	8621 (11 687)

GRADE B7 ZINC-PLATED STEEL BOLTS/STUDS

Table 1.7.4 provides torque values for ASTM Specification A193, Grade B7 (Zinc-Plated) zinc-plated steel bolts/studs.

Table 1.7.4 Torque Values for Grade B7 Zinc-Plated Steel Bolts/Studs

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	163 (18)	-	1/4-20	149 (17)	-
5/16-24	315 (36)	26 (36)	5/16-18	294 (33)	25 (33)
3/8-24	553 (63)	46 (63)	3/8-16	508 (57)	42 (57)
7/16-20	863 (98)	72 (98)	7/16-14	800 (90)	67 (90)
1/2-20	894 (101)	75 (101)	1/2-13	846 (96)	71 (96)
9/16-18	1082 (122)	90 (122)	9/16-12	1042 (118)	87 (118)

Table 1.7.4 Torque Values for Grade B7 Zinc-Plated Steel Bolts/Studs, Contd

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
5/8-18	1510 (171)	126 (171)	5/8-11	1447 (164)	121 (164)
3/4-16	2619 (296)	218 (296)	3/4-10	2527 (286)	211 (286)
7/8-14	4163 (470)	347 (470)	7/8-9	4034 (456)	336 (456)
1-12	5152 (582)	429 (582)	1-8	5078 (574)	423 (574)
1 1/8 - 12	7351 (831)	613 (831)	1 1/8 - 7	7225 (816)	602 (816)
1 1/4 - 12	10 096 (1141)	841 (1141)	1 1/4 - 7	9667 (1092)	806 (1092)
1 3/8 - 12	13 448 (1519)	1121 (1519)	1 3/8 - 6	13 228 (1495)	1102 (1495)
1 1/2 - 12	17 470 (1974)	1456 (1974)	1 1/2 - 6	17 249 (1949)	1437 (1949)
1 3/4 - 12	27 417 (3098)	2285 (3098)	1 3/4 - 5	27 361 (3091)	2280 (3091)
2 - 12	41 447 (4683)	3454 (4683)	2 - 4 1/2	40 899 (4621)	3408 (4621)
2 1/4 - 12	59 013 (6667)	4918 (6667)	2 1/4-4 1/2	58 494 (6609)	4875 (6609)
2 1/2 - 12	80 940 (9145)	6745 (9145)	2 1/2 - 4	80 213 (9063)	6684 (9063)

GRADE B7M STEEL BOLTS/STUDS

Table 1.7.5 provides torque values for ASTM Specification A193, Grade B7M, steel bolts/studs.

Table 1.7.5 Torque Values for Grade B7M Steel Bolts/Studs

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	108 (12)	-	1/4-20	99 (11)	-
5/16-24	208 (23)	-	5/16-18	195 (22)	-
3/8-24	363 (41)	30 (41)	3/8-16	336 (38)	28 (38)
7/16-20	567 (64)	47 (64)	7/16-14	530 (60)	44 (60)
1/2-20	629 (71)	52 (71)	1/2-13	599 (68)	50 (68)
9/16-18	888 (100)	74 (100)	9/16-12	850 (96)	71 (96)
5/8-18	1240 (140)	103 (140)	5/8-11	1180 (133)	98 (133)
3/4-16	2152 (243)	179 (243)	3/4-10	2064 (233)	172 (233)
7/8-14	3422 (387)	285 (387)	7/8-9	3297 (373)	275 (373)
1-12	5104 (577)	425 (577)	1-8	4932 (557)	411 (557)
1 1/8 - 12	7317 (827)	610 (827)	1 1/8 - 7	7012 (792)	584 (792)
1 1/4 - 12	10 089 (1140)	841 (1140)	1 1/4 - 7	9728 (1099)	811 (1099)
1 3/8 - 12	13 483 (1523)	1124 (1523)	1 3/8 - 6	12 870 (1454)	1073 (1454)

Table 1.7.5 Torque Values for Grade B7M Steel Bolts/Studs, Contd

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1 1/2 - 12	17 564 (1984)	1464 (1984)	1 1/2 - 6	16 860 (1905)	1405 (1905)
1 3/4 - 12	27 678 (3127)	2307 (3127)	1 3/4 - 5	26 705 (3017)	2225 (3017)
2 - 12	42 001 (4745)	3500 (4745)	2 - 4 1/2	39 977 (4517)	3331 (4517)
2 1/4 - 12	59 966 (6775)	4997 (6775)	2 1/4-4 1/2	57 510 (6498)	4793 (6498)
2 1/2 - 12	82 429 (9313)	6869 (9313)	2 1/2 - 4	78 817 (8905)	6568 (8905)

GRADE 8 STEEL BOLTS

Table 1.7.6 provides torque values for SAE Specification J429, Grade 8, steel bolts.

Table 1.7.6 Torque Values for Grade 8 Steel Bolts

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	232 (26)	-	1/4-20	210 (24)	18 (24)
5/16-24	407 (46)	34 (46)	5/16-18	416 (47)	35 (47)
3/8-24	715 (81)	60 (81)	3/8-16	654 (74)	55 (74)
7/16-20	1114 (126)	93 (126)	7/16-14	1032 (117)	86 (117)
1/2-20	950 (107)	79 (107)	1/2-13	910 (103)	76 (103)
9/16-18	1374 (155)	115 (155)	9/16-12	1320 (149)	110 (149)
5/8-18	1918 (217)	160 (217)	5/8-11	1834 (207)	153 (207)
3/4-16	3327 (376)	277 (376)	3/4-10	3203 (362)	267 (362)
7/8-14	5290 (598)	441 (598)	7/8-9	5115 (578)	426 (578)
1-12	8193 (926)	683 (926)	1-8	7924 (895)	660 (895)
1 1/8 - 12	11 744 (1327)	979 (1327)	1 1/8 - 7	11 265 (1273)	939 (1273)
1 1/4 - 12	16 190 (1829)	1349 (1829)	1 1/4 - 7	15 625 (1765)	1302 (1765)
1 3/8 - 12	21 633 (2444)	1803 (2444)	1 3/8 - 6	20 675 (2336)	1723 (2336)
1 1/2 - 12	28 177 (3183)	2348 (3183)	1 1/2 - 6	27 079 (3059)	2257 (3059)

GRADE B6 STAINLESS STEEL BOLTS

Table 1.7.7 provides torque values for ASTM Specification A193, Grade B6, Type 410, stainless steel bolts.

Table 1.7.7 Torque Values for Grade B6 Stainless Steel Bolts

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	194 (22)	-	1/4-20	174 (20)	-
5/16-24	342 (39)	29 (39)	5/16-18	316 (36)	26 (36)
3/8-24	604 (68)	50 (68)	3/8-16	546 (62)	46 (62)
7/16-20	940 (106)	78 (106)	7/16-14	862 (97)	72 (97)
1/2-20	803 (91)	67 (91)	1/2-13	753 (85)	63 (85)
9/16-18	1133 (128)	94 (128)	9/16-12	1070 (121)	89 (121)
5/8-18	1587 (179)	132 (179)	5/8-11	1488 (168)	124 (168)
3/4-16	2759 (312)	230 (312)	3/4-10	2610 (295)	218 (295)
7/8-14	4390 (496)	366 (496)	7/8-9	4177 (472)	348 (472)
1-12	6544 (739)	545 (739)	1-8	6252 (706)	521 (706)
1 1/8 - 12	9407 (1063)	784 (1063)	1 1/8 - 7	8884 (1004)	740 (1004)
1 1/4 - 12	12 999 (1469)	1083 (1469)	1 1/4 - 7	12 366 (1397)	1031 (1397)
1 3/8 - 12	17 404 (1966)	1450 (1966)	1 3/8 - 6	16 331 (1845)	1361 (1845)
1 1/2 - 12	22 707 (2565)	1890 (2565)	1 1/2 - 6	21 450 (2423)	1788 (2423)
1 3/4 - 12	35 863 (4052)	2989 (4052)	1 3/4 - 5	33 948 (3835)	2828 (3835)
2 - 12	54 539 (6162)	4545 (6162)	2 - 4 1/2	50 863 (5747)	4239 (5747)
2 1/4 - 12	77 980 (8810)	6498 (8810)	2 1/4-4 1/2	73 416 (8295)	6118 (8295)
2 1/2 - 12	107 321 (12 125)	8943 (12 125)	2 1/2 - 4	100 583 (11 364)	8382 (11 364)

GRADE B8 STAINLESS STEEL BOLTS

Table 1.7.8 provides torque values for ASTM Specification A193, Grade B8, Type 304 stainless steel bolts.

Table 1.7.8 Torque Values for Grade B8 Bolts

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	57 (6)	5 (6)	1/4-20	51 (6)	4 (6)
5/16-24	107 (12)	9 (12)	5/16-18	99 (11)	8 (11)
3/8-24	188 (21)	16 (21)	3/8-16	171 (19)	14 (19)
7/16-20	293 (33)	24 (33)	7/16-14	270 (31)	23 (31)
1/2-20	216 (24)	18 (24)	1/2-13	208 (24)	17 (24)
9/16-18	412 (47)	34 (47)	9/16-12	388 (44)	32 (44)

Table 1.7.8 Torque Values for Grade B8 Bolts, Contd

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
5/8-18	577 (65)	48 (65)	5/8-11	540 (61)	45 (61)
3/4-16	1003 (113)	84 (113)	3/4-10	947 (107)	79 (107)
7/8-14	1596 (180)	133 (180)	7/8-9	1516 (171)	126 (171)
1-12	3008 (340)	251 (340)	1-8	2837 (321)	236 (321)
1 1/8 - 12	4338 (490)	362 (490)	1 1/8 - 7	4029 (455)	336 (455)
1 1/4 - 12	6008 (679)	501 (679)	1 1/4 - 7	5630 (636)	469 (636)
1 3/8 - 12	8261 (933)	688 (933)	1 3/8 - 6	7420 (838)	618 (838)
1 1/2 - 12	10 535 (1190)	878 (1190)	1 1/2 - 6	9776 (1105)	815 (1105)

GRADE B8M STAINLESS STEEL BOLTS/STUDS

Table 1.7.9 provides torque values for ASTM Specification A193, Grade B8M, Type 316 stainless steel bolts/studs.

Table 1.7.9 Torque Values for Grade B8M Stainless Steel Bolts/Studs

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	57 (6)	-	1/4-20	51 (6)	-
5/16-24	107 (12)	-	5/16-18	99 (11)	-
3/8-24	188 (21)	-	3/8-16	171 (19)	-
7/16-20	293 (33)	24 (33)	7/16-14	270 (31)	23 (31)
1/2-20	216 (24)	-	1/2-13	208 (23)	17 (23)
9/16-18	412 (46)	34 (46)	9/16-12	388 (44)	32 (44)
5/8-18	577 (65)	48 (65)	5/8-11	540 (61)	45 (61)
3/4-16	1003 (113)	84 (113)	3/4-10	947 (107)	79 (107)
7/8-14	1596 (180)	133 (180)	7/8-9	1516 (171)	126 (171)
1-12	3008 (340)	251 (340)	1-8	2837 (320)	236 (320)
1 1/8 - 12	4338 (490)	362 (490)	1 1/8 - 7	4029 (455)	336 (455)
1 1/4 - 12	6008 (679)	501 (679)	1 1/4 - 7	5630 (636)	469 (636)
1 3/8 - 12	8261 (933)	688 (933)	1 3/8 - 6	7420 (838)	618 (838)
1 1/2 - 12	10 535 (1190)	878 (1190)	1 1/2 - 6	9776 (1105)	815 (1105)
1 3/4 - 12	16 680 (1885)	1390 (1885)	1 3/4 - 5	15 456 (1746)	1288 (1746)
2 - 12	25 424 (2872)	2119 (2872)	2 - 4 1/2	23 180 (2619)	1932 (2619)

Table 1.7.9 Torque Values for Grade B8M Stainless Steel Bolts/Studs, Contd

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
2 1/4 - 12	36 411 (4114)	3034 (4114)	2 1/4 - 4 1/2	33 587 (3795)	2799 (3795)
2 1/2 - 12	50 176 (5669)	4181 (5669)	2 1/2 - 4	45 998 (5197)	3833 (5197)
2 3/4 - 12	67 107 (7582)	5592 (7582)	2 3/4 - 4	62 000 (7005)	5167 (7005)
3 - 12	87 389 (9873)	7282 (9873)	3 - 4	81 330 (9189)	6778 (9189)
3 1/4 - 12	111 391 (12 585)	9283 (12 585)	3 1/4 - 4	104 299 (11 784)	8692 (11 784)
3 1/2 - 12	139 353 (15 744)	11 613 (15 744)	3 1/2 - 4	131 224 (14 826)	10 935 (14 826)
3 3/4 - 12	171 181 (19 341)	14 265 (19 341)	3 3/4 - 4	162 412 (18 349)	13 534 (18 349)
4 - 12	208 859 (23 597)	17 405 (23 597)	4 - 4	198 185 (22 391)	16 515 (22 391)

GRADE 17-4PH STAINLESS STEEL BOLTS/STUDS

Table 1.7.10 provides torque values for AMS Specification 5643, Grade 17-4PH stainless steel bolts/studs.

Table 1.7.10 Torque Values for Grade 17-4PH Stainless Steel Bolts/Studs

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	151 (17)	13 (17)	1/4-20	138 (16)	12 (16)
5/16-24	270 (31)	23 (31)	5/16-18	253 (29)	21 (29)
3/8-24	472 (53)	39 (53)	3/8-16	438 (50)	37 (50)
7/16-20	738 (83)	61 (83)	7/16-14	690 (78)	58 (78)
1/2-20	747 (84)	62 (84)	1/2-13	718 (81)	60 (81)
9/16-18	1095 (124)	91 (124)	9/16-12	1055 (119)	88 (119)
5/8-18	1529 (172)	127 (172)	5/8-11	1465 (165)	122 (165)
3/4-16	2653 (300)	221 (300)	3/4-10	2557 (289)	213 (289)
7/8-14	4218 (477)	352 (477)	7/8-9	4082 (461)	340 (461)
1-12	5754 (650)	480 (650)	1-8	5569 (629)	464 (629)
1 1/8 - 12	8247 (932)	687 (932)	1 1/8 - 7	7919 (895)	660 (895)
1 1/4 - 12	11 367 (1284)	947 (1284)	1 1/4 - 7	10 981 (1241)	915 (1241)

Table 1.7.10 Torque Values for Grade 17-4PH Stainless Steel Bolts/Studs, Contd

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1 3/8 - 12	15 186 (1716)	1265 (1716)	1 3/8 - 6	14 532 (1642)	1211 (1642)
1 1/2 - 12	19 778 (2234)	1648 (2234)	1 1/2 - 6	19 030 (2150)	1586 (2150)

STAINLESS STEEL WELD STUDS

Refer to Table 1.7.11 for torque values for stainless steel weld studs made from annealed stainless steel - Specification Stud Welding, Stainless Steel, Type 18-8 and 316.

Table 1.7.11 Torque Values for Stainless Steel Weld Studs

UNF	Torque		UNC	Torque	
	in-lb (N·m)	ft-lb (N·m)		in-lb (N·m)	ft-lb (N·m)
1/4-28	76 (9)	6 (9)	1/4-20	68 (8)	6 (8)
5/16-24	143 (16)	12 (16)	5/16-18	132 (15)	11 (15)
3/8-24	251 (28)	21 (28)	3/8-16	228 (26)	19 (26)
7/16-20	391 (44)	33 (44)	7/16-14	360 (41)	30 (41)
1/2-20	288 (33)	24 (33)	1/2-13	277 (31)	23 (31)
9/16-18	549 (62)	46 (62)	9/16-12	517 (58)	43 (58)
5/8-18	769 (87)	64 (87)	5/8-11	720 (81)	60 (81)
3/4-16	1337 (151)	111 (151)	3/4-10	1263 (143)	105 (143)
7/8-14	2128 (240)	177 (240)	7/8-9	2021 (228)	168 (228)
1-14	4011 (453)	334 (453)	1-8	3783 (427)	315 (427)

1.7.12 Cotter Key Installation

Cotter keys are used to secure drilled bolts, clevis pins, and other fasteners that are subject to rotation. See Figure 1.7.17 for sample cotter key installation on a clevis pin. Key points for cotter key installation are:

- Cotter key ends are to be bent towards the center of the fastener being secured with excess length trimmed as shown in Figure 1.7.17.
- Do not deviate from listed torque values to bring cotter key holes into alignment. If fastener hole alignment cannot be obtained within specified torque limits, washers or fasteners should be changed until proper alignment is obtained within specified torque limits.

Refer to ES 9–54.

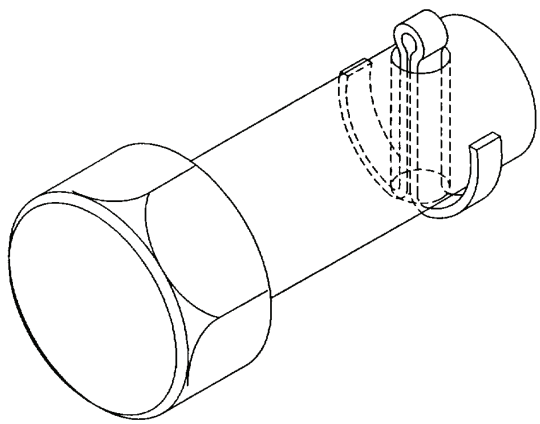


Figure 1.7.17 Cotter Key Installation, Clevis Pin

1.7.13 Safety Wire Installation

Use 0.032-in. (0.8-mm) diameter stainless steel safety wire for general applications in all locations accessible by routine servicing procedures. Use 0.020-in. (0.5-mm) diameter stainless steel safety wire for No. 8 or smaller screws, for electrical harness coupling nuts, and in other places where it is not practical to use 0.032-in. (0.8-mm) diameter wire.

Secure all drilled bolt heads, plugs, and screws, except those with self-locking nuts or lockwashers with safety wire. Bolts should be secured with safety wire in pairs, where possible. When reassembling, replace all removed safety wire with new safety wire. See Figure 1.7.18 for examples of safety wire installations. Key points for ensuring proper safety wire installation are:

- Safety wire must always tend to tighten.
- Safety wire ends are to be bent towards the center of the fastener being secured with excess length trimmed as shown.
- Do not tighten or loosen bolts outside of specified torque values to obtain hole alignment. If desired wire hole alignment cannot be obtained within specified torque limits, the fastener being secured with safety wire, or its washers, should be changed until proper alignment is obtained within torque limits.
- Safety wire must be tight enough to prevent rubbing against adjacent parts which may cause subsequent breakage due to fatigue.

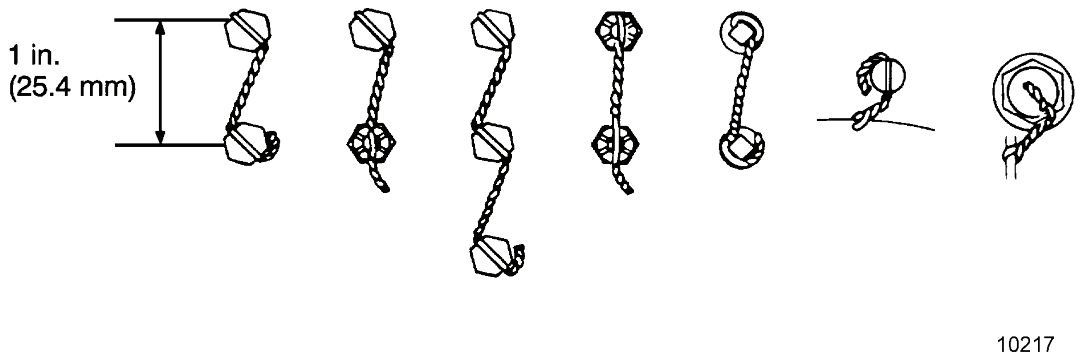


Figure 1.7.18 Safety Wire Installation

1.7.14 Fittings, Gaskets, Seals and O-Rings

Oil leaks are generally caused by improperly mated parts. Depending on connection type, oil leaks can be caused by failure of gaskets, seals, fittings, or O-rings. Repair requires disassembly. Take care to use correct replacement parts in re-assembly. Replace gaskets, O-rings, 37° flared tubing, pipe threads and Swagelok® fittings, using procedures detailed in this section.

NON GASKET

Surface Sealing with No Gasket

Gear unit cover plates, which are dimension sensitive, require a special sealing procedure which is included in the manufacturer's literature. If no manufacturer information is available, use the following procedure:

1. Clean and inspect sealing surfaces to ensure they are smooth. Remove nicks and scratches before proceeding.
2. Coat both surfaces with non-hardening Permatex #2™.
3. Assemble. Tighten evenly per Solar Turbines Specification ES9-54.
4. Allow time for sealant to set. Examine exposed edge to assure sealant is set.

GASKET

Surface Gaskets

1. Remove old gaskets completely from both seal surfaces.
2. Assure both surfaces are smooth and free from scratches or pits. Replace components where scratches and pits cannot be removed.

CAUTION

Prior to use of gasket sealant, surfaces must be oil-free.

3. Clean seal surfaces with gasket remover/cleaner (solvent) to completely remove oil.
4. Apply gasket sealant (RTV, Permatex #2™, or equivalent) to both surfaces.

CAUTION

Do not overtighten.

5. Assemble with a new gasket. Tighten bolts to torque per Solar Turbines Specification ES9-54.

CAUTION

Operation before sealant is dry will cause leaks.

6. Allow gasket sealant to set. Keep oil away from seal area. Refer to sealant manufacturer's instructions for drying time. Examine exposed sealant edges to assure sealant is dry.

Oil Tank Leaks

OIL TANK FILLER CAP

If oil leakage is detected from the oil tank filler cap, remove the gasket, clean both seal surfaces, and install a new gasket. Ensure new gasket is latest configuration, which has sufficient compliance to accommodate irregularities in cap and mating surfaces.

OIL TANK COVERS

If oil leakage is detected from the oil tank cover edges, replace the gasket material. A retrofit kit to create and install custom oil tank cover gaskets is available. This kit improves oil tank sealing in square tank lid Gore-Tex™ applications. Due to the variety of oil tank cover dimensions, custom gaskets are required for each individual tank lid. The kit contains material to custom make gaskets for five (5) tank covers. The Oil Tank Lid Leak Repair Retrofit Kit 1044515-1XX can be ordered from Solar Service Parts. Contact the local Solar District Field Office for information or assistance.

CURVED OIL TANK COVERS

For applications where the bolt holes are on curved oil tank lids, use Gore-Tex™ Joint Sealant Solar P/N 700673C1 (0.500" wide x 0.4").

1. Place Gore-Tex™ Joint Sealant on clean sealing surface inside of the bolt holes overlapping the ends at or near a bolt hole.
2. Install the bolts and tighten to required torque. For round bolt hole pattern torque bolts using the star pattern sequence in three successive steps.

FLANGE GASKETS

This section describes spirotallic-type gaskets used in raised-face flanges. On 150# and 300# systems, use an LS (Low Stress) series spirotallic gasket. Use this gasket or the extruded gasket listed in Table 1.7.12 for elimination of leaks in low pressure piping systems.

1. Raised face flanges should have a surface finish of 125-250 RMS (flange).
2. Flanges should be aligned as close as possible in the relaxed (unbolted) condition. Flange bores should align within 0.125”. Sealing surface faces should be parallel with 0.010".
3. Install the spirotallic gasket rated for the flange. Stagger tighten studs progressively to the required torque.

NOTE

If unsure of flange finish or the standard gasket continues to leak, install an extruded gasket with a RMS 190 rating. RMS 190 gasket part numbers (P/N) are shown in Table 1.7.12.

Table 1.7.12 Solar P/Ns for Extruded and LS Gasket Sizes

Size, inches	Extruded	Low Stress 150#	Low Stress 300#
1.5	190857-1 150#	1017892	1017904
2.0	190857-2 150#	1017893	1017905
1.0	190857-3 900/1500#	N/A	N/A
3.0	190857-4 150#	1017895	1017907
1.0	190857-5 150#	1017890	1017902
4.0	190857-6 150#	1017897	1017908
6.0	N/A	1017899	1017910

Table 1.7.12 Solar P/Ns for Extruded and LS Gasket Sizes, Contd

Size, inches	Extruded	Low Stress 150#	Low Stress 300#
8.0	N/A	1014794	1017911
10.0	N/A	1017900	1017912

SEALS

1. Lip seals are directional. A seal could be installed backwards and not initially leak, but after operating time, the seal could leak. Examine the seal orientation as it is removed. To seal oil in, the lip must face in.
2. Clean the seal mounting surface and examine the running (rotating) surface. Both should be smooth and free of scratches and pits.
3. Clean all surfaces with degreaser to remove any oil.
4. Lubricate the seal lip with a small amount of lube oil.
5. To assemble, use the proper size driver to press seals in place.

O-RINGS

1. Replace O-rings when components are removed.
2. Clean O-ring groove with solvent (not lacquer thinner or MEK). Check groove and flat surface for nicks or scratches. Remove any surface defects before proceeding.
3. Lubricate a new O-ring and groove with lube oil and assemble.

SWAGELOK® COMPRESSION FITTINGS

Swagelok compression fittings may be assembled or disassembled before use.

Leaking Swagelok Compression Fittings must be replaced. When replacing the Swagelok fitting, tubing with the recommended wall thickness must be used. Tube wall thickness for use with compression fittings is usually heavier than that used for flared fittings.

A new assembly can be made using the fitting body as a tool.

Use the following procedures to install Swagelok compression fittings.

NOTE
Do not use lubricant on Swagelok compression fittings.

1. Verify tube end is cut square with no burrs, filings, or chips.
2. Verify ferrules slide freely over tube end without binding.

3. Install nut and ferrules in proper sequence on tube. See Figure 1.7.19.
4. Install assembly on pre-swaging tool. If no tool is available, the fitting can be used for makeup, to form the flare. Limit use of fitting for makeup to once per fitting.
5. Finger tighten nut to seat components.
6. Turn nut an additional 1 1/4 turns.
7. Loosen nut and remove assembly from pre-swaging tool.
8. Insert tubing with pre-swaged ferrules into fitting until front ferrule seats in fitting.
9. Hand tighten nut.
10. With wrench, rotate nut about 1/4 turn for 1/4-inch to 3/4-inch diameter tubing, and for tubing 1-inch diameter and larger, rotate nut 1/2 turn, then snug slightly.

WARNING

Compression fittings and components from different manufacturers often appear identical. Do not mix components from different manufactures. Most manufacturers identify their individual components with micro-etching or casting logos.

CAUTION

Avoid overtightening. Overtightening may damage fitting.

NOTE

If gap-inspection gage fits between flareless nut and body hex of fitting, fitting has not been sufficiently tightened. If gap-inspection gage cannot be inserted between flareless nut and body hex of fitting, fitting has been sufficiently tightened.

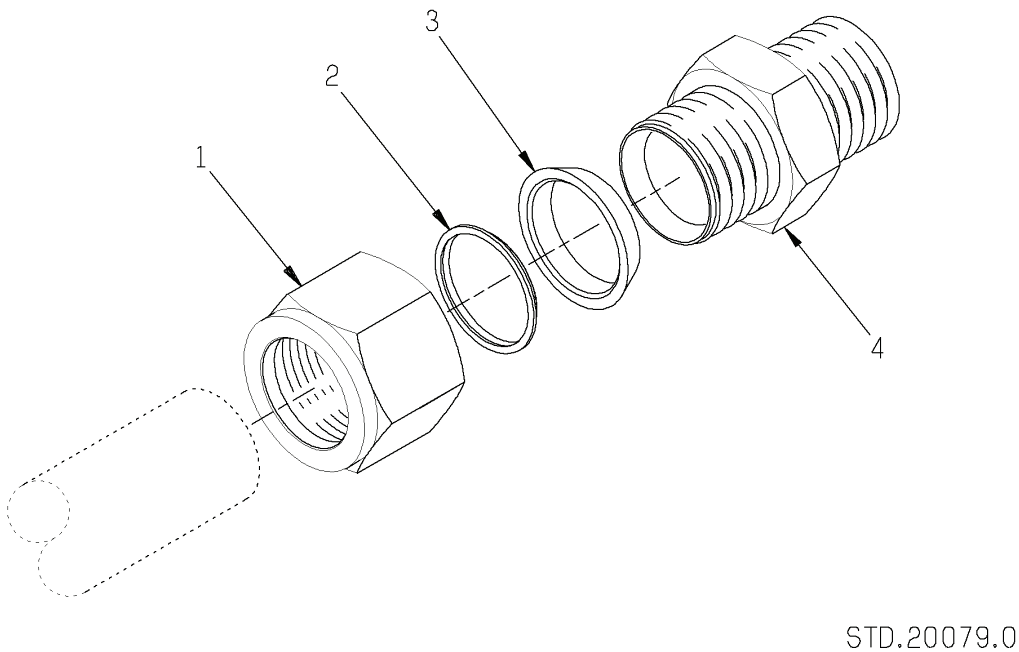


Figure 1.7.19 Assembly of Swagelok® Compression Fitting

Key for Figure 1.7.19			
1	Nut	2	Back Ferrule
3	Front Ferrule	4	Body

There is no reason to overtighten a properly installed compression fitting. Common errors in making up compression fittings are improper insertion when the fitting is originally swaged, and misalignment into the body when the tube assembly is connected on the package.

Refer to Supplier Data for other types of makeup instructions.

NPT FITTINGS

Proper sealing of NPT (National Pipe Thread) fittings is accomplished by cleaning threads and using sealant. Pipe fittings should not be assembled to a specific torque value.

Threads must be free of rust, paint, or other contaminants prior to installation. Remove contaminants with a wire brush.

Final clean the threads with Loctite 7070™ or alcohol. Clean internal and external threads and allow them to dry before applying sealant. Recommended sealant is SWAK™.

CAUTION

Do not use Teflon™ tape on threads.

Apply SWAK™ sealant to oil and fuel NPT pipe threads only. Do not apply SWAK™ to tubing or electrical conduit.

Apply a band of SWAK™ sealant to external threads of pipes under 2-inch (51 mm) diameter.

CAUTION

Keep the first two threads free of sealant.

Apply a band of SWAK™ sealant on internal and external threads of pipes 2- inch (51 mm) diameter and larger.

Sealant squeezes into gaps between roots and crests of mating threads during tightening. NPT threads rely on sealant for a seal. Do not back off fittings once installed. Tighten, but do not distort threads. Engage between 3-1/2 and 6 threads.

Use straight connectors and swivels where possible and plan for clocking, or final rotational positioning, when installing elbows.

FLARED FITTINGS

Flared fittings are used on 316L stainless steel mechanical and structural seamless tubing with a 37-degree flare angle. Procedures in this subsection are not for compression or other type connection.

Procedures in this subsection are not to be used on existing 37-degree tubing assembled with procedures other than flats-from-finger-tight (F.F.F.T.). Use of the F.F.F.T. method on fittings originally assembled with another method, or on overtightened fittings can cause leaks at the connection.

Preliminary Inspection

1. Inspect tubing to ensure tubing is formed and aligned to prevent stress on flare joints. Figure 1.7.20 illustrates correct and incorrect installation.

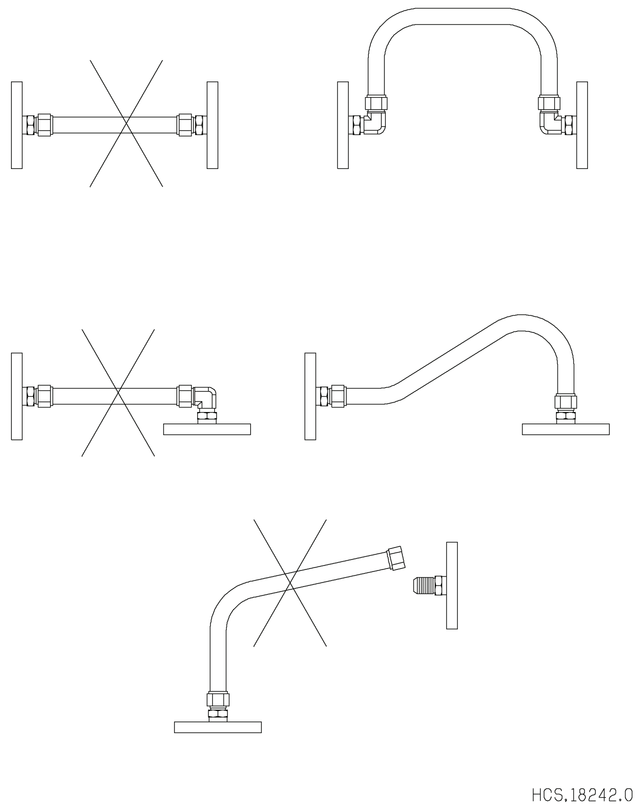


Figure 1.7.20 Tubing Installation

2. Inspect flare for correct flare size using a Tube Snap Gauge. If no gauge is available, use the sleeve as a gauge. See Figure 1.7.21.

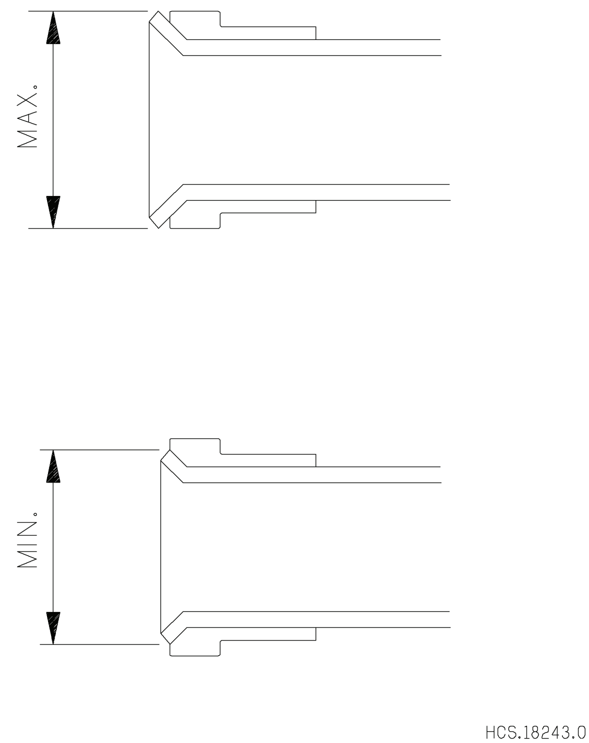


Figure 1.7.21 Flare Inspection

Flats from Finger Tight (F.F.F.T.) Method

The F.F.F.T. method for tightening a nut on a 37-degree flared tube body provides a consistent preload and prevents distortion on reinstallation.

INITIAL MAKEUP (ASSEMBLY)

Initial makeup is the first assembly of a tube to a fitting after tubing has been fabricated.

1. Apply a small amount of lubricant to sleeve back and body threads. Take care not to get lubricant on fitting nose or inside flared tube. See Figure 1.7.22.

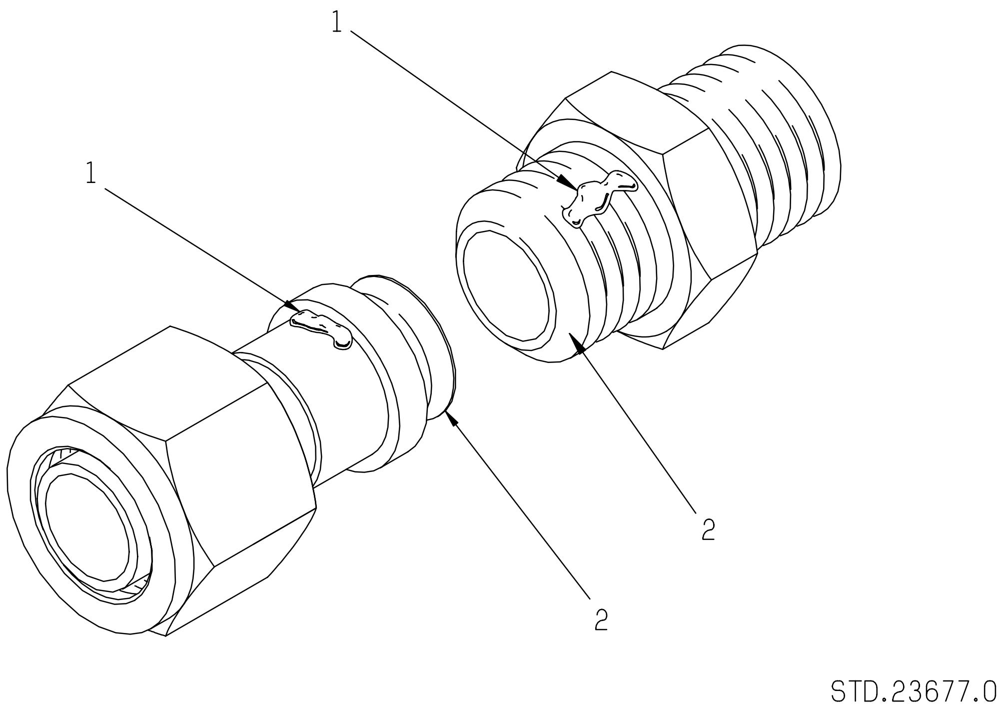


Figure 1.7.22 Flared Tube Fitting Lubrication

Key for Figure 1.7.22			
1	Lubricant	2	Flared Surface

CAUTION

Do not put lubricant on flared surfaces.

NOTE

For flare fitting lubrication, use Extreme Pressure Lube No. 3™ (Solar P/N FSL-740-001) or petroleum jelly.

2. Align tube and fitting. Thread nut onto body and tighten nut by hand, or very lightly with a wrench, to bring all surfaces in metal-to-metal contact.

3. Mark nut and body hex as shown in Figure 1.7.23, View A.

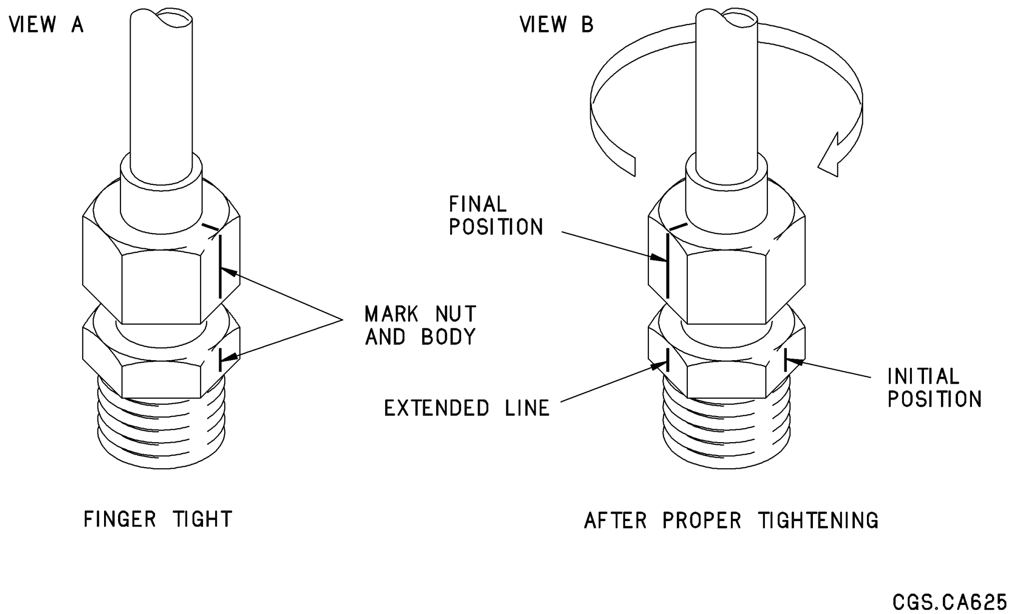


Figure 1.7.23 Flare Tube Fitting and Body Marking

4. Tighten nut to number of flats shown for Initial Installation in Table 1.7.13. See Figure 1.7.23. When tightening the nut, use a backup wrench on the body fitting.

Table 1.7.13 Initial Installation and Reinstallation Flat-Tightening Turns

Tube Size	Initial Installation F.F.F.T.	Reinstallation F.F.F.T.
1/4	2 to 2 1/2	3/4 to 1
3/8	2 to 2 1/4	1
1/2	1 1/2 to 1 3/4	1
5/8	1 1/2 to 1 3/4	3/4
3/4	1 1/2	3/4
1	1 1/4 to 1 1/2	3/4 to 1
1 1/4	1 to 1 1/2	3/4 to 1
1 1/2	1 1/4 to 1 1/2	1 to 1 1/4
2	1 to 1 1/4	3/4 to 1

5. After tightening, mark line on body to align with new nut position. See Figure 1.7.23, View B.

NOTE

After final tightening and marking, do not apply torque paint. Final marks are inspection and reference points if the fitting is loosened and remade. See Table 1.7.13 for remake (reinstallation) flat numbers.

A video tape for the F.F.F.T. Method is available (Solar P/N VC 2NO-549).

REMAKE PROCEDURE

The following procedure applies for all remakes, after initial installation.

1. Apply a small amount of lubricant to flare fitting and body threads. Take care not to get lubricant on the nose of the fitting or inside the flare tube. See Figure 1.7.22.

NOTE

As required for lubricating flare fittings, use Extreme Pressure Lube No. 3 (Solar P/N FSL-740-001) or, as an alternate, use petroleum jelly.

2. Align tube and fitting. Thread nut onto body and tighten nut finger tight.

   — The alignment mark on nut should lie somewhere between the initial and final position marks on body. See Figure 1.7.23

   — If using a new fitting with an original tube, use the foregoing procedure, INITIAL MAKEUP (ASSEMBLY), and Reinstallation column from Table 1.7.13

   — When tightening the nut to final position, always secure the body of fitting with a backup wrench

3. Using wrench, tighten nut the additional number of flats shown for remake (Reinstallation) in Table 1.7.13.

4. After tightening nut, extend line from nut to body, as shown in Figure 1.7.23.

NOTE

After final tightening and marking, do not apply torque paint. Final marks are inspection and reference points in the event the fitting is ever loosened and remade.

1.7.15 Hose Installation

The expected service life of hoses is directly related to proper installation. Since applications and pressure requirements determine hose selection, a variety of hoses are used with Solar turbomachinery. Typical packages include Teflon-lined stainless steel braided hose, Nomex braided hose, and rubber hose. Specific hose installation instructions are detailed in QAS 805 and the following general guidelines to minimize possible damage are applicable to all hose assemblies.

1. Union or floating flange should be used at one end of threaded hose assemblies.

2. Where flanges are used, fixed-flange end should be bolted into place before floating-flange end.

3. Where a threaded nipple and union are used, nipple end should be threaded into place and then union tightened into place using two wrenches. See Figure 1.7.24 for correct position of wrenches when tightening hose connections.

4. Install hose in an untwisted condition (Figure 1.7.25). Hose installed in twisted condition (Figure 1.7.26) will have built-in torsional stress (Figure 1.7.27) that tends to loosen fittings when hose assembly is pressurized or when motion takes place between connected components.

5. Adjust existing coupling elbow or line length to permit total length of flex hose to be on one plane. If assembly has been twisted so that it will not return unaided to its original configuration and corrugated metal tube has been damaged, install a new hose assembly.

6. Adjust hose and fittings so that flexing takes place in one plane only. Out-of-plane flexing movements (Figure 1.7.28) of a metal hose must originate in same plane as centerline of hose.

7. Out-of-line couplings and rotated fittings (Figure 1.7.29) cause unnatural bends in short metal hose assemblies. When installing hose assemblies, ensure couplings and fittings are in line (Figure 1.7.30).

8. Stretching hose assembly between fittings, as shown in Figure 1.7.31, is not acceptable. The free length of a flexible metal hose assembly should be slightly greater than the distance between the two package fittings. The package fittings must adjust to provide adequate slack in the metal hose assembly.

9. A flexible metal hose must make a gradual bend along its installed path. Sharp bends of radii less than listed in Table 1.7.14, and bends that start at end coupling (Figure 1.7.32) are not acceptable.

10. Clamping metal flexible hose assemblies with tubing, piping, or other hose assemblies (Figure 1.7.33) is not acceptable.

11. When possible, keep a one-inch clearance between flexible hose assemblies and other package components. In situations where a one-inch clearance is not possible, do not let installed flexible hose assemblies touch other hose assemblies, support structures, or engine and driven-equipment parts under any operating conditions. Conditions that could cause the hoses to touch are:

    - Vibration,

- Temperature changes,
- Pressure changes and pulsation,
- Movements caused by motion of the supporting vessel or structure, which can include roll, pitch, yaw, and heave,
- Permanent changes in orientation of the supporting vessel or structure, which can include list and trim,
- Movements caused by the deflection of the surface on which the package is mounted. These movements can include twisting, hogging, and sagging.

12. Install O-rings if required. Check for damage (nicks or gouges) to O-rings and mating surfaces. Lubricate with Extreme Pressure Lube No. 3 (Solar P/N FSL-740-001) or petroleum jelly (Solar P/N: FSP-400-0-01).

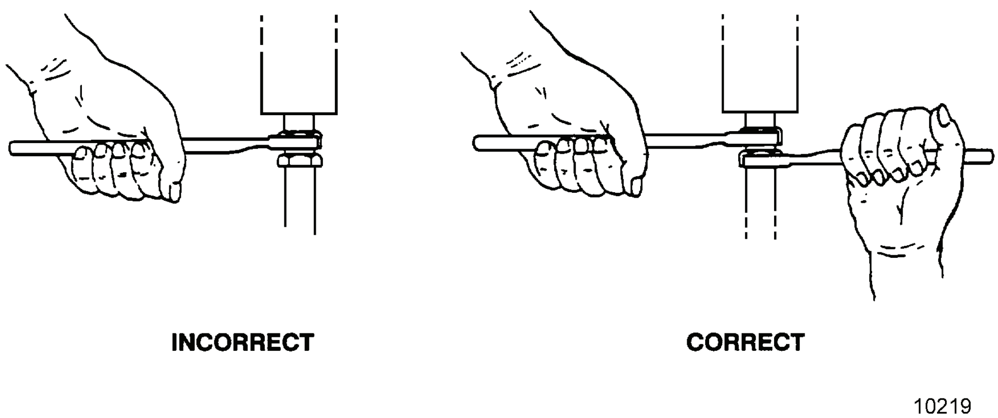


Figure 1.7.24 Tightening Hose Connections

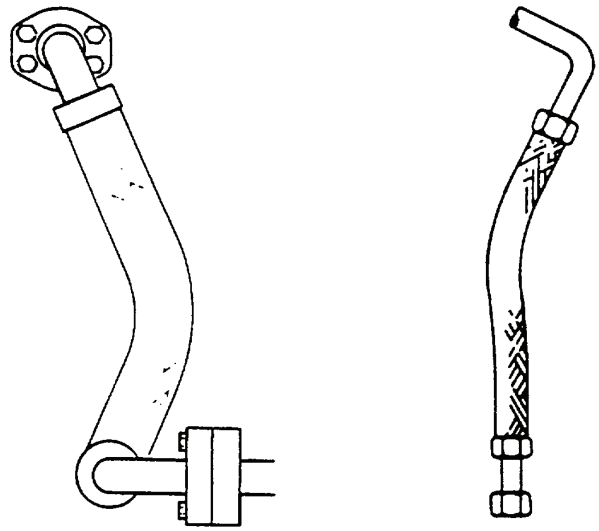


Figure 1.7.25 Untwisted Hose Positions

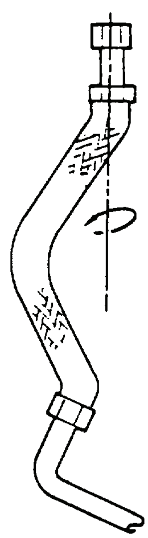


Figure 1.7.26 Twisted Hose Position

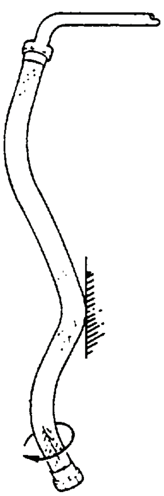


Figure 1.7.27 Hose with Torsional Twist

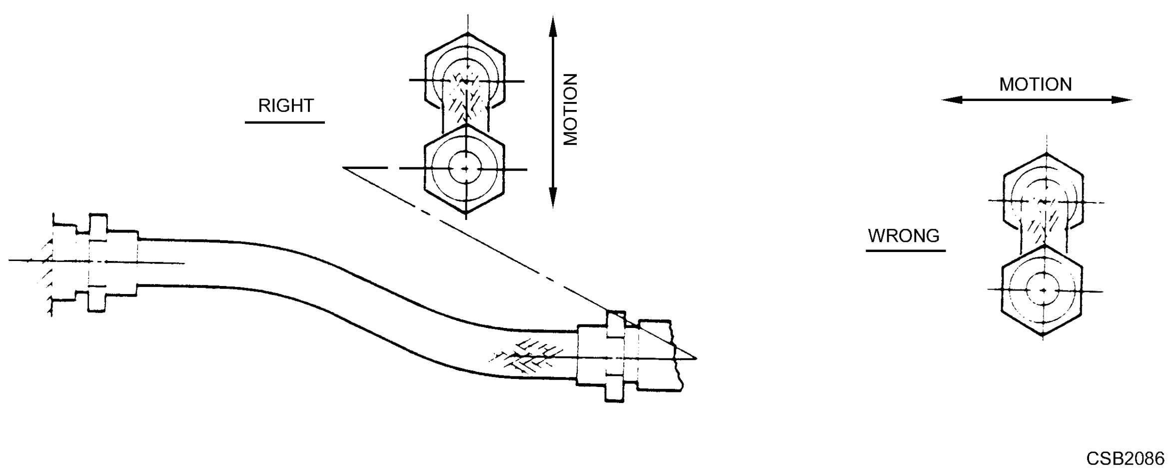


Figure 1.7.28 Flexing Movement

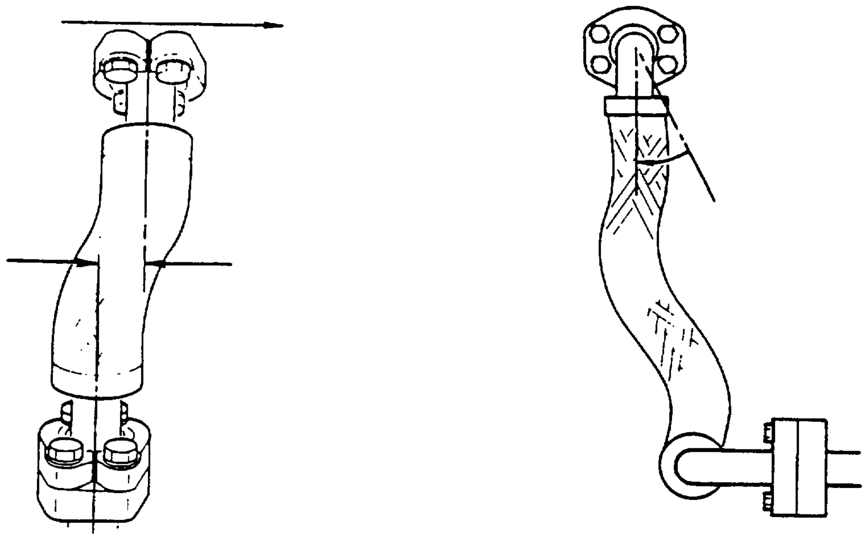


Figure 1.7.29 Out-of-Line Coupling Installation

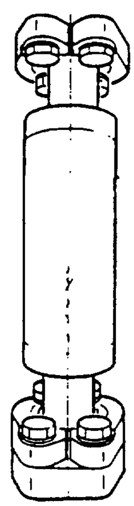


Figure 1.7.30 In-Line Coupling Installation

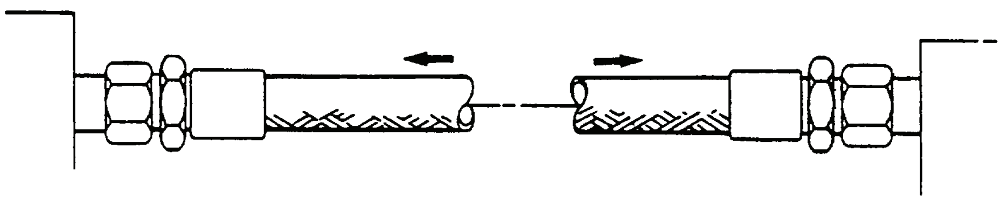


Figure 1.7.31 Unacceptable Stretching Hose Assembly

Table 1.7.14 Minimum Bend Radius Requirements for Stainless Steel Braided Hose

Nominal Hose Size	Minimum Bend Radius at Centerline
3/8 in. (9.5 mm)	8 in. (203.2 mm)
1/2 in. (12.7 mm)	10 in. (254 mm)
3/4 in. (19.1 mm)	12 in. (304.8 mm)
1 in. (25.4 mm)	14 in. (355.6 mm)
1 1/4 in. (31.8 mm)	16 in. (406.4 mm)
1 1/2 in. (38.1 mm)	18 in. (457.2 mm)
2 in. (50.8 mm)	19 in. (483 mm)
3 in. (76.2 mm)	20 in. (508 mm)
4 in. (101.6 mm)	22 in. (558.8 mm)

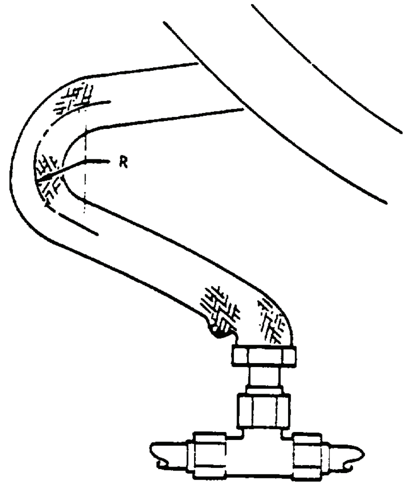


Figure 1.7.32 Unacceptable Hose Bending

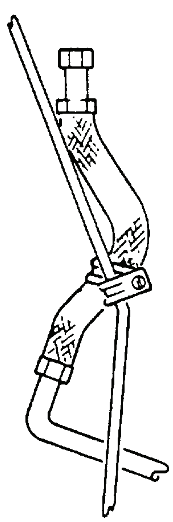


Figure 1.7.33 Unacceptable Hose Clamping

1.7.16 Protection of Ports

During maintenance or repair, cap or plug all open ports with a protective cover to ensure protection from contamination or damage. The design of the cap, plug, or cover shall prevent it from remaining in the port during reassembly.

1.7.17 References

Table 1.7.15 lists the references used to establish the criteria for the specifications in this section.

Table 1.7.15 References

Section	Publication
Mechanical Fasteners	ES 9-54
Thread Engagement	ES 9-54
Thread Lubricant	ES 9-54
Definition of Assembly and Attaching Hardware	PEDM 10051
Torque Values	ES 9-54
Torque Sequences	QAS 821
Cotter Key Installation	ES 9-54
Safety Wire Installation	QAS 814
Torque Paint	QAS 800
Electrical Installation - European	QAS 506
Electrical Installation - Domestic	QAS 503
Hydraulic Installation	QAS 829
Compression Fittings	QAS 816
NPT Fittings	QAS 815
Flared Fittings	QAS 817
Hose Installation	QAS 805
Protection of Ports	QAS 835
Counterfeit Bolts	SERVICE BULLETIN NO. 1.0/117

1.8 SOLAR TURBINES' TECHNICAL TRAINING

Solar Turbines recommends technical training for operators and maintenance personnel working on Solar turbomachinery. Solar Technical Training can be contacted at the following address:

Solar Turbines Incorporated

Technical Training, Mail Zone SP1A

9250A Sky Park Court

San Diego, CA 92123–5398, USA

Phone: (+1) 858–715–2060

E-mail: training_tech@solarturbines.com

Internet: www.solarturbines.com

1.9 DECOMMISSIONING AND DISPOSAL

Before you decommission and dispose of Solar turbomachinery, make the equipment inoperable. Isolate it from fuel supplies, pneumatic power supplies, and electrical power supplies. Read Material Safety Data Sheets before you remove any possibly toxic or hazardous materials, lubricants, or fuels from the equipment. Dispose of hazardous or toxic material in compliance with local environmental laws. Before shipment, prepare and preserve equipment and ancillary materials in accordance with Solar Product Information Letter (PIL) 097. For further assistance, contact Solar Turbines Local District Office.

2 START SYSTEM

2.1 GENERAL DESCRIPTION

The direct-drive ac start system provides the rotational power needed to rotate the compressor and turbine. The start system includes the following:

- Starter motor
- Line reactor
- Variable frequency drive

2.2 FUNCTIONAL DESCRIPTION

When the start/crank cycle is initiated, a timed prelube sequence is activated. As the prelube cycle times out, the control system directs power to the starter motor variable frequency drive which provides starting power to the starter motor.

Initially, the variable frequency drive provides a low-frequency ac voltage to the starter motor to begin rotation. The frequency and voltage to the starter motor are then ramped up to accelerate the engine to purging speed. When the purging cycle is completed, the fuel and ignition systems are activated. When lightoff is detected, the starter motor speed is increased until the engine reaches starter dropout speed. As the engine reaches starter dropout speed, the variable frequency drive is deactivated by the control system, cutting power to the starter motor, and the motor clutch disengages. The engine then accelerates to idle speed under its own power.

2.3 COMPONENT DESCRIPTIONS

The following are brief descriptions of components typically used in a direct ac start system. For reference designators, part numbers, component settings and operation values, refer to Direct AC Start Schematic (149457).

2.3.1 Component and Reference Designators Identification

Components are identified by reference designators. Reference designators are letter/number codes that link the electrical schematic, wiring diagram, and/or the hydromechanical schematics to the component. A reference designator legend is provided on the front sheet of electrical/hydromechanical schematics and the wiring diagram. The reference designator legend contains the letter/number code, symbol, and description for each type of component.

Each reference designator contains three elements: alpha character(s), a location number, and a two or three digit number. The reference designator form is as follows:

AANXXX, where

AA - alpha character(s) indicating component type and use in the system

N is a number indicating component location:

1. Control console front
2. Inside control console
3. On turbine package skid
4. Motor starter in the motor control center
5. Other remote location
6. Switchgear
7. Inlet air system
8. Reserved
9. Reserved for hydromechanical components

XXX is a two or three digit number.

2.3.2 Electric Motors

Reference Designator: BNXXX

Electric motors (starter motors) provide the breakaway torque required to start the engine, as well as accelerate the engine from a standstill to starter motor dropout speed. Some starter motors incorporate space heaters.

For maintenance requirements, refer to the maintenance section of this chapter.

2.3.3 Line Reactors

Reference Designator: **LR**NXXX

Line reactors prevent shutdown by isolating Variable Frequency Drives (VFDs) from external power disturbances (input) or improving voltage levels at the motor (output). The reactors also reduce operating temperature and noise in starter motors.

Line reactors do not require routine maintenance.

2.3.4 Variable Frequency Drives

Reference Designator: **VFD**NXXX

Variable Frequency Drives (VFDs) are used to control the rotational speed of the starter motor(s).

For maintenance requirements, refer to the maintenance section of this chapter.

2.4 MAINTENANCE

Maintenance is required on the start system at established intervals. For component maintenance, refer to the Supplementary Data referenced in Table 2.4.1.

2.4.1 Component Maintenance

The following table lists components that require maintenance. Refer to the table for Supplementary Data information. Refer to Maintenance Procedures Subsection 2.4.2 for maintenance procedures.

Table 2.4.1 Maintenance Requirements

Component	Maintenance	Supplementary Data
Starter Motor (B330)	Refer to instructions located in the Supplementary Data.	Reliance Electric
Variable Frequency Drive (VFD430)	Refer to instructions located in the Supplementary Data.	Allen Bradley

2.4.2 Maintenance Procedures

⚠ WARNING

Before doing maintenance, read all facility safety policies and procedures to make sure you protect personnel and equipment.

Before you work in any hazardous area, read the facility Permit to Work (PTW) policy and get a written PTW.

The permit to work must cover the following:

— Proper personal protective equipment,

— Proper procedures for using sniffers,

— Proper personnel monitoring and use of communication equipment,

— Proper ventilation,

— Physical hazards,

— Temperature hazards,

— Proper use of hearing protection,

— Evacuation procedures and routes.

WARNING

Only qualified personnel may operate and maintain the package. The operator and maintenance personnel must understand turbine and driven equipment operation and function, and must also understand the controls, indicators, and operating limits.

Do not operate the package when conditions are unsafe. Unsafe conditions include:

- fuel leaks or lube oil leaks
- damaged electrical wiring
- damaged anchor bolts or structural members

Obey the facility procedure to lock out the controls and attach warning tags to them. Turn the OFF/LOCAL/REMOTE, OFF/LOCAL/AUXILIARY or OFF/LOCAL/AUX keyswitch to OFF. Make sure the battery charger, control console, and switchgear circuit breakers are open at the package motor control center (MCC). Before you do any work, attach “DO NOT OPERATE” tags to the start buttons and controls. Do not rely on color-coding of wiring for identification when you remove and install electrical components. Refer to the wiring diagram.

Before you do maintenance on the package, inspect the alarm indications on the package display. If the package is equipped with an offskid display, contact the remote operator for alarms status. If the package has an onskid display, inspect the alarms status at the package. Identify alarms that might become a dangerous situation while you do maintenance, for example, an alarm for a gas leak that has reached the Lower Explosive Limit (LEL) can become a more serious leak during maintenance.

Set up signs and barriers that keep non-maintenance personnel and vehicles out of the work area. If the package has an enclosure, non-maintenance personnel can be injured or can cause damage to equipment when the enclosure is opened for maintenance.

If the package has an enclosure, do not block any enclosure door whether or not it has been opened for maintenance. In case of emergency, use the nearest door to get out of the enclosure.

WARNING

If the package has an enclosure, make sure the enclosure has adequate light to safely work inside. If necessary, install reliable temporary lights in the enclosure before you do maintenance. Make sure maintenance personnel have hand lights immediately available to them in case primary lighting fails and the enclosure does not have automatic backup lighting.

Prevent explosive accumulations of natural gas, liquid fuel, oil mist, or solvent fumes. Make sure ventilation is adequate and immediately repair leaks. Before you use solvents or cleaning solutions, read the applicable Material Safety Data Sheets. Use solvents in appropriate maintenance facilities.

Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

If the package has an enclosure, make sure the pressure between the enclosure and its environment is equal before you open the doors. The enclosure can have higher or lower internal pressure compared to its environment. Maintenance personnel can be injured if doors are forcibly thrown open by positive internal pressure or are forcibly pulled closed by negative internal pressure.

Before you attempt to enter the enclosure, use the negative-pressure door-jacking assembly, if installed, to make the internal and external pressure equal. You can damage the doors if you force them open.

If the package has an enclosure, make sure the doors are latched in place after they have been opened. Winds can suddenly and forcibly move unlatched doors.

Do not touch hot surfaces. Gas turbines create extremely high surface temperatures. Use insulated gloves and protective clothing/equipment when you do maintenance.

Gas turbines create extremely high exhaust and surface temperatures that can ignite the fuels and lubricants used in gas-turbine packages. Solar strongly urges that you work in only non-hazardous, gas-free conditions. If maintenance must be done under hazardous atmosphere conditions, before doing maintenance, review the facility-specific auto-ignition temperatures (AITs) of the fuels and lubricants used in the

⚠ WARNING

package. Allow the equipment to cool to 80% of the lowest AIT before you do maintenance. Use a hand-held, non-contact thermometer approved for use in hazardous atmospheres to measure surface temperatures.

Close all fuel supply valves to the package before servicing start system components. Attach “DO NOT OPEN” tags to the valves. Make sure all pressure has completely dissipated.

Before you disconnect any system line, check pressure indicator gages and transmitter displays to make sure there is no pressure in the lines. Open hand-operated pressure-release valves slowly to release any pressure that might remain.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you use cleaning solvents or cleaning solutions. Prevent skin contact with solvents, solutions, or other materials that can be health hazards. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you handle fuels, lube oils, and their residues. Prevent skin contact with fuels, lube oils, and their residues. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you drain, transfer, or store fuels, lube oils, and their residues, or any other materials that contain chemicals or compounds that can be health hazards.

Refer to the Safety Requirements section located in the front of this manual for additional Warnings and Cautions.

Where removal and installation procedures are obvious, such as disconnection of plumbing or wiring and removal of attaching parts and hardware, instructions are omitted.

Except where otherwise described, standard industrial maintenance and repair practices are acceptable. Always discard used O-rings, seals, and gaskets, and replace with new ones.

Refer to Illustrated Parts List for repair parts or repair kits available for maintenance on start system components.

For cleaning methods and materials, refer to INTRODUCTION Chapter, GENERAL MAINTENANCE PROCEDURES, Cleaning/Degreasing/Decarbonizing 1.6.2.

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fitting, Gaskets, Seals and O-Rings 1.7.14.

CAUTION

Keep work areas clean to prevent contamination of parts with dirt or grit. When removing parts for maintenance or repair, cover openings to prevent entry of foreign material.

2.4.3 Starter Motor

Use the following procedures for removal and installation of Starter Motor (B330).

WARNING

Turn off and tag out electrical power to motors prior to removal.

CAUTION

Keep work areas clean. When removing parts for maintenance or repair, cover openings to prevent entry of foreign material.

STARTER MOTOR REMOVAL

1. Turn off electrical power and tag to prevent electrical shock.
2. Disconnect input cables from terminals, identify, tag, and insulate cables.
3. Connect hoisting equipment to starter motor. Take up slack on hoist cable to carry weight of starter motor.

WARNING

Ensure hoisting equipment provides adequate support for the starter motor during removal.

4. If required, remove attaching hardware securing the starter motor to the starter motor support.
5. Remove attaching hardware securing starter motor to adapter.
6. Pull starter motor straight out from adapter. Starter motor must slide out freely.

SPLINED COUPLING INSTALLATION

If installing a new starter motor, it may be necessary to install the splined coupling on the starter motor shaft. Install the splined coupling on the starter motor shaft as follows:

NOTE

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fitting, Gaskets, Seals and O-Rings 1.7.14.

1. Degrease starter motor shaft, splined coupling, lockwasher, nut, key, and keyway with solvent and dry thoroughly.
2. Heat splined coupling to 250°F (121°C).
3. Cool starter motor shaft with dry ice or similar cooling agent. Do not freeze shaft.
4. Insert key in keyway and slide warmed splined coupling onto starter motor shaft until it bottoms on starter motor shaft shoulder.
5. Allow splined coupling to cool completely.
6. Liberally apply high temperature RTV sealant (Solar P/N 953676C1) around starter motor shaft and splined starter coupling interface, taking particular care to fill the keyway with the sealant.
7. Install locking tab, washer, and nut on starter motor shaft. Torque nut as required. Bend one tab of locking tab against one flat of nut.

INSTALLATION PREPARATION

If reinstalling the same starter motor, perform installation preparation as follows:

NOTE

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fitting, Gaskets, Seals and O-Rings 1.7.14.

1. Remove nut and washer attaching splined coupling to starter motor.
2. Clean starter motor shaft shoulder area, keyway area, and washer seating area with solvent. Dry thoroughly.

3. Liberally apply high temperature RTV sealant (Solar P/N 953676C1) around starter motor shaft and splined starter coupling interface, taking particular care to fill the keyway with the sealant.

4. Install locking tab, washer, and nut on starter motor shaft. Torque nut as required. Bend one tab of locking tab against one flat of nut.

STARTER MOTOR INSTALLATION

NOTE

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fitting, Gaskets, Seals and O-Rings 1.7.14.

1. Connect hoisting equipment to starter motor. Take up slack on hoist cable to carry weight of starter motor.

WARNING

Ensure hoisting equipment provides adequate support for the starter motor during installation.

2. Install starter motor onto adapter.

3. Install attaching hardware to secure starter motor to adapter. Tighten attaching hardware as required.

4. If required, install attaching hardware to secure the starter motor to the starter motor support. Torque attaching hardware as required.

5. Remove hoisting equipment from starter motor.

6. Connect input cables to correct terminals. Refer to tags installed during removal.

7. Remove tags and turn on electrical power.

(This page intentionally left blank)

3 FUEL SYSTEM

3.1 GENERAL DESCRIPTION

The gas fuel and air system, in conjunction with the control system, automatically schedules fuel flow during engine acceleration and load operation. The system also provides overtemperature and overspeed topping control of fuel flow and automatic shutdown in the event of malfunction.

3.1.1 Gas Fuel Requirements

The selection of a satisfactory fuel depends upon the physical and chemical composition of the fuel. Natural gas fuel requirements for engine gas fuel are given in Table 3.1.1. Gas supply must conform to Solar Specification ES 9-98.

Table 3.1.1 Gas Fuel Requirements

Nomenclature	Description
Lower Heating Value of Fuel	1098 to 1342 WI (WOBBE index) (43.2 to 52.8 MJ/m^3). WOBBE index is equal to the Lower Heating Value in Btu/Scf divided by the square root of the specific gravity of the fuel. A WOBBE index value outside this range is acceptable with the approval of Solar Engineering.
Composition	Gas fuel temperature shall be at least 50°F (27.7°C) above the dew point of fuel at operating pressure (no liquids are allowed in gas fuel) and shall not be higher or lower than 4°F (2.2°C) than the gas fuel temperature specified for the project fuel system.
Contaminants:	Total contaminants shall not exceed: 30 ppm x (lower heating value by weight Btu/lb ÷ 21 500 Btu/lb) or 30 ppm x (lower heating value by weight MJ/kg ÷ 50 MJ/kg).
	Particles shall not exceed 10 microns.
	No entrained water in the gas is allowed: that is, no water in excess of saturation at maximum operating pressure.
	The percent by weight total sulfur, including hydrogen sulfide, shall not exceed: 1% x (lower heating value by weight Btu/lb ÷ 21 500 Btu/lb) or 1% x (lower heating value by weight MJ/kg ÷ 50 MJ/kg).

Gas fuel should be free of contaminants, entrained water, and sulfur. The gas fuel system requires a constant supply of gas at the flow rate and pressure range specified on the Mechanical Interface Drawing (149063).

NOTE

Users are urged to consult local authorities for sulfur emission limitations. Limits in this section are based solely on design considerations, and much lower levels may be required by antipollution regulations.

3.1.2 Fuel Systems

The fuel system consists of the following interrelated systems.

- Fuel Metering System
- Pilot System
- Compressor Air System (Pcd)

FUEL METERING SYSTEM

The fuel metering system consists of shutoff valves, supply manifolds, flow control valves, and fuel injectors. The control system monitors the fuel metering system to regulate fuel flow to change engine speed (Ngp) and temperature (T5).

PILOT SYSTEM

Pilot system pressure is provided from a port on the main fuel supply manifold or from an external compressed air source. The pilot system supplies pressure to the pneumatically actuated fuel shutoff valves. Each pneumatically actuated shutoff valve is connected to a solenoid valve. When activated by the control system, the solenoid valve opens to allow pilot pressure to open the shutoff valve. When the solenoid valve closes, pilot pressure vents, and the shutoff valve closes. The pilot system is a fail safe fuel shutoff in the event of control system failure.

COMPRESSOR AIR SYSTEM

The engine compressor air system supplies compressor discharge air (Pcd) to various systems. Tubing is connected to ports on the engine compressor that distribute pneumatic pressure to system components. In the fuel system, Pcd is measured to determine fuel flow metering, to purge fuel lines and injectors and to close exhaust diffuser drain valves.

3.2 FUNCTIONAL DESCRIPTION

The following is a functional description of the gas fuel system. For settings and system normal or operating design values, refer to the Gas Fuel Schematic (149456) and Air/Drain Schematic (149459).

3.2.1 Valve Check Sequence

Before each startup, the control system tests the integrity of the shutoff valves. To verify operation, gas fuel pressure is applied to the primary and secondary shutoff valves. The valves must hold pressure and open and close when commanded. If either shutoff valve fails, the control system annunciates a valve check failure and aborts the start cycle.

3.2.2 Purge Crank Cycle

After the valve check sequence, the purge crank cycle is initiated to remove combustibles from the engine exhaust system. To purge, the start system cranks the engine to create air movement though the exhaust system until the timer times out. The purge crank cycle timer is programmed according to package exhaust system volume.

3.2.3 Ignition Sequence

After the purge crank cycle, the starter continues to crank the engine. The primary and secondary shutoff valves open to supply gas fuel to the metering system. Gas fuel flows through the torch and is ignited in the presence of combustion air. The torch flame flares into the airflow inside the engine combustor liner.

The fuel injectors, spaced equally around the combustor, mix fuel in the air stream inside the combustor liner. The torch ignites the fuel-air mixture and engine lightoff occurs.

3.2.4 Acceleration Sequence

Following lightoff, the starter continues to crank the engine. The control system increases the fuel flow to gradually elevate T5 temperature and engine speed (Ngp).

At approximately 65-70 percent Ngp, the start system is deenergized. As the engine continues to accelerate, the inlet variable vanes move toward maximum open position, while the compressor bleed valve closes, further increasing T5 temperature. The control system increases the rate of fuel supply until Ngp reaches 100 percent (synchronous idle). The engine is now ready for load.

During load transients (fluctuation of engine load), the control system continuously adjusts fuel flow, inlet variable vanes and compressor bleed valve positions, to maintain T5 temperature and Ngp.

If T5 temperature exceeds the preset limit, a 20-second delay timer is started. If T5 temperature remains above limit, the control system annunciates a high temperature alarm and shuts down the engine. The time delay allows for momentary overtemperature during load transients.

If the temperature shutdown timer fails, and the turbine engine temperature reaches a higher limit, the backup T5 high temperature circuit initiates engine shutdown.

CAUTION

Operating in an alarm state for extended periods may damage the turbine.

3.3 COMPONENT DESCRIPTIONS

The following are brief descriptions of components typically used in a fuel system. For reference designators, part numbers, component settings and operation values, refer to Gas Fuel Schematic (149456) and Air/Drain Schematic (149459).

3.3.1 Component and Reference Designators Identification

Components are identified by reference designators. Reference designators are letter/number codes that link the electrical schematic, wiring diagram, and/or the hydromechanical schematics to the component. A reference designator legend is provided on the front sheet of electrical/hydromechanical schematics and the wiring diagram. The reference designator legend contains the letter/number code, symbol, and description for each type of component.

Each reference designator contains three elements: alpha character(s), a location number, and a two or three digit number. The reference designator form is as follows:

AANXXX, where

AA - alpha character(s) indicating component type and use in the system

N is a number indicating component location:

1. Control console front
2. Inside control console
3. On turbine package skid
4. Motor starter in the motor control center
5. Other remote location
6. Switchgear
7. Inlet air system
8. Reserved
9. Reserved for hydromechanical components

XXX is a two or three digit number.

3.3.2 Electric Fuel Control Valves

Reference Designator: EGFNXXX

Electric fuel control valves meter the flow and volume of fuel to the fuel manifolds. The valves are electric motor driven and are positioned by the control system. In gas fuel systems, the valve can also function as the secondary fuel shutoff valve.

For maintenance requirements, refer to the maintenance section of this chapter.

3.3.3 Fuel Flow Meter

Reference Designator: FMNXXX

The fuel flow meter measures fuel flow in the fuel supply manifold. A transmitter is part of the flow meter and transmits fuel flow information to the control system for monitoring.

For maintenance requirements, refer to the maintenance section of this chapter.

3.3.4 Fixed Orifices

Reference Designator: FONXXX

Fixed orifices are placed in the fuel lines, purge water lines, or airlines, to control the rate and volume of the flow. The diameters of the orifices are not adjustable.

The fixed orifices do not require routine maintenance.

3.3.5 Filters/Strainers

Reference Designator: FSNXXX

Filters/strainers remove foreign particles and liquids from air, gas fuel, liquid fuel, and water supplies. Filters/strainers are put in the fluid flows to prevent blockage of orifices and damage to components.

For maintenance requirements, refer to the maintenance section of this chapter.

3.3.6 Solenoid Valves

Reference Designator: LNXXX

Solenoid valves are electrically activated to control the flow of gases or liquids. The solenoid valves are used as either a pilot or shutoff valve. If used as a pilot valve, the solenoid controls the pneumatic (pilot) pressure that is used to open or close a pneumatic actuated shutoff valve. The solenoid valve may also be placed directly in the flow as a shutoff valve.

Some solenoid valves require routine maintenance. Refer to the maintenance section of this chapter for more information.

3.3.7 Pressure Control Valves

Reference Designator: PCVNXXX

Pressure control valves are used to regulate fuel or pilot pressure to the range required for optimum system performance.

For maintenance requirements, refer to the maintenance section of this chapter.

3.3.8 Resistance Temperature Detectors

Reference Designator: RTNXXX

Resistance Temperature Detectors (RTDs) measure temperatures in various locations in the fuel system for control system monitoring. The control of temperature is critical to safe turbine engine operation.

RTDs do not require routine maintenance.

3.3.9 Differential Pressure Switch

Reference Designator: SNXXX

The differential pressure switch alerts the control system when a possible flameout condition exists in the combustor.

The differential pressure switch does not require routine maintenance.

3.3.10 Thermocouples

Reference Designator: TCNXXX

Thermocouples measure temperatures in various locations in the fuel system for control system monitoring. The control of temperature is critical to safe turbine engine operation.

Thermocouples do not require routine maintenance.

3.3.11 Gas Fuel Flow Transmitter

Reference Designator: TFNXXX

The gas fuel flow transmitter is part of the gas fuel flow meter. The transmitter sends fuel flow information to the control system for monitoring.

The gas fuel flow transmitters do not require routine maintenance.

3.3.12 Pressure Transmitters

Reference Designator: TPNXXX

Pressure transmitters are used to monitor pressures within the fuel system. During the start cycle, the transmitters verify the integrity of the shutoff valves. Pressure transmitters function as safety monitoring devices to prevent system overpressurization.

Pressure transmitters do not require routine maintenance.

3.3.13 Differential Pressure Transmitters

Reference Designator: TPDNXXX

Differential pressure transmitters are used to measure pressure changes across various components in the fuel system. The transmitters measure pressure at the inlet and outlet side of the component, and report the difference between the two measurements to the control system as the differential pressure. A high pressure may mean the component being monitored needs service.

Differential pressure transmitters do not require routine maintenance.

3.3.14 Thermowell

Reference Designator: TWNXXX

Thermowells are pressure tight receptacles designed to accept a temperature sensing element and provide a means to insert that element into a vessel or pipe.

Thermowells act as a barrier between a process medium and the sensing element of a temperature measuring device. They protect against corrosive process media, as well as a media contained under pressure or flowing at a high velocity. Thermowells allow sensing elements to be removed from the application while maintaining a closed system.

Thermowells do not require routine maintenance.

3.3.15 Pneumatically Actuated Valves

Reference Designator: V2PNXXX

Pneumatically actuated valves are used as shutoff valves in the fuel system. The valves are connected to a pilot solenoid valve that controls the pneumatic pressure that opens or closes the valve.

Pneumatically actuated valves do not require routine maintenance.

3.3.16 Check Valves

Reference Designators: VCS/VCHNXXX

Check valves allow system pressure to flow in one direction and prevent backflow pressure from damaging system components.

Fuel system check valves do not require routine maintenance.

3.3.17 Instrument Isolation Hand Valves

Reference Designator: VINXXX

Instrument isolation hand valves are used to isolate and relieve pressure from instruments to allow for maintenance, calibration or replacement.

Instrument isolation hand valves do not require routine maintenance.

3.3.18 Pressure Relief Valves

Reference Designator: VRNXXX

Pressure relief valves are backups to the pressure control valves. The relief valves prevent damage to components from system pressure when a pressure control valve fails.

Pressure relief valves do not require routine maintenance.

3.4 MAINTENANCE REQUIREMENTS

Maintenance is required on the fuel system at established intervals. There are two types of maintenance, *system maintenance* and *component maintenance*. For *system maintenance* intervals, refer to Table 3.4.1. For *component maintenance*, refer to the manufacturers' documentation provided in Table 3.4.2.

The recommended intervals are for nominal environmental and operating conditions. Severe environments and extreme conditions may require more frequent and extensive maintenance. The local environment, operating conditions and practices, and the availability of skilled technicians must be considered in establishing a maintenance plan. Preventive maintenance at specific intervals minimizes the need for corrective maintenance.

Maintenance intervals are defined as follows:

- D (day)
  Daily maintenance includes a walk-around inspection to ensure equipment is functioning properly and to detect leaks or obvious faults. Operating parameters should be recorded and analyzed for trends. This will help predict faults. Daily maintenance does not require equipment shutdown.

- M (month)
  Monthly maintenance includes a walk-around inspection to ensure equipment is functioning properly and to detect leaks or obvious faults. Operating parameters should be recorded and analyzed for trends. This will help predict faults. Monthly maintenance requires equipment shutdown.

- S (semiannual - 4000 operating hours)
  Semiannual maintenance emphasizes protective systems checkout and ensures optimum equipment performance. Regardless of hours of operation, this maintenance should be performed semiannually. Semiannual maintenance requires equipment shutdown.

- A (annual - 8000 operating hours)
  Annual maintenance involves disassembly of subsystem components for inspection. Problems noted in previous inspections should receive attention in annual maintenance whether or not they are listed in this manual. Detailed records help pinpoint malfunctions prior to performance impact. Annual maintenance requires equipment shutdown.

3.4.1 System Maintenance

WARNING

Before doing maintenance, read all facility safety policies and procedures to make sure you protect personnel and equipment.

WARNING

Before you work in any hazardous area, read the facility Permit to Work (PTW) policy and get a written PTW.

The permit to work must cover the following:

— Proper personal protective equipment,

— Proper procedures for using sniffers,

— Proper personnel monitoring and use of communication equipment,

— Proper ventilation,

— Physical hazards,

— Temperature hazards,

— Proper use of hearing protection,

— Evacuation procedures and routes.

Only qualified personnel may operate and maintain the package. The operator and maintenance personnel must understand turbine and driven equipment operation and function, and must also understand the controls, indicators, and operating limits.

Do not operate the package when conditions are unsafe. Unsafe conditions include:

— fuel leaks or lube oil leaks

— damaged electrical wiring

— damaged anchor bolts or structural members

Obey the facility procedure to lock out the controls and attach warning tags to them. Turn the OFF/LOCAL/REMOTE, OFF/LOCAL/AUXILIARY or OFF/LOCAL/AUX keyswitch to OFF. Make sure the battery charger, control console, and switchgear circuit breakers are open at the package motor control center (MCC). Before you do any work, attach “DO NOT OPERATE” tags to the start buttons and controls. Do not rely on color-coding of wiring for identification when you remove and install electrical components. Refer to the wiring diagram.

⚠ WARNING

Before you do maintenance on the package, inspect the alarm indications on the package display. If the package is equipped with an offskid display, contact the remote operator for alarms status. If the package has an onskid display, inspect the alarms status at the package. Identify alarms that might become a dangerous situation while you do maintenance, for example, an alarm for a gas leak that has reached the Lower Explosive Limit (LEL) can become a more serious leak during maintenance.

Set up signs and barriers that keep non-maintenance personnel and vehicles out of the work area. If the package has an enclosure, non-maintenance personnel can be injured or can cause damage to equipment when the enclosure is opened for maintenance.

If the package has an enclosure, do not block any enclosure door whether or not it has been opened for maintenance. In case of emergency, use the nearest door to get out of the enclosure.

If the package has an enclosure, make sure the enclosure has adequate light to safely work inside. If necessary, install reliable temporary lights in the enclosure before you do maintenance. Make sure maintenance personnel have hand lights immediately available to them in case primary lighting fails and the enclosure does not have automatic backup lighting.

Prevent explosive accumulations of natural gas, liquid fuel, oil mist, or solvent fumes. Make sure ventilation is adequate and immediately repair leaks. Before you use solvents or cleaning solutions, read the applicable Material Safety Data Sheets. Use solvents in appropriate maintenance facilities.

Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

If the package has an enclosure, make sure the pressure between the enclosure and its environment is equal before you open the doors. The enclosure can have higher or lower internal pressure compared to its environment. Maintenance personnel can be injured if doors are forcibly thrown open by positive internal pressure or are forcibly pulled closed by negative internal pressure.

WARNING

Before you attempt to enter the enclosure, use the negative-pressure door-jacking assembly, if installed, to make the internal and external pressure equal. You can damage the doors if you force them open.

If the package has an enclosure, make sure the doors are latched in place after they have been opened. Winds can suddenly and forcibly move unlatched doors.

Do not touch hot surfaces. Gas turbines create extremely high surface temperatures. Use insulated gloves and protective clothing/equipment when you do maintenance.

Gas turbines create extremely high exhaust and surface temperatures that can ignite the fuels and lubricants used in gas-turbine packages. Solar strongly urges that you work in only non-hazardous, gas-free conditions. If maintenance must be done under hazardous atmosphere conditions, before doing maintenance, review the facility-specific auto-ignition temperatures (AITs) of the fuels and lubricants used in the package. Allow the equipment to cool to 80% of the lowest AIT before you do maintenance. Use a hand-held, non-contact thermometer approved for use in hazardous atmospheres to measure surface temperatures.

Close all fuel supply valves to the package before servicing fuel system components. Attach “DO NOT OPEN” tags to the valves. Make sure all pressure has completely dissipated.

Before you disconnect any system line, check pressure indicator gages and transmitter displays to make sure there is no pressure in the lines. Open hand-operated pressure-release valves slowly to release any pressure that might remain.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you use cleaning solvents or cleaning solutions. Prevent skin contact with solvents, solutions, or other materials that can be health hazards. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

⚠ WARNING

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you handle fuels, lube oils, and their residues. Prevent skin contact with fuels, lube oils, and their residues. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you drain, transfer, or store fuels, lube oils, and their residues, or any other materials that contain chemicals or compounds that can be health hazards.

Do not disconnect, or otherwise make inoperable, any fuel valve or speed control device, whether the turbine engine is running or not. Loss of speed control could cause significant property damage, personal injury, and/or loss of life.

Prior to draining the liquid fuel purge tank, the collection tank must be grounded to the package frame and purge tank. Check the installation and integrity of the drain piping before draining the fuel.

If any fuel system component was loosened or removed, test the component for leaks on start-up.

Before you do maintenance, use the remote manual block and bleed valve to isolate and depressurize the package fuel system.

Refer to the Safety Requirements section located in the front of this manual for additional Warnings and Cautions.

Use following table for fuel system maintenance. The table represents the minimum maintenance intervals. If site conditions are severe, the system maintenance intervals will need to be modified.

Table 3.4.1 System Maintenance Intervals

System/Description	D	M	S	A
Using soapy water in a squirt bottle, check the pressurized gas fuel system for leaks. If bubbles are present, shutdown the package and repair immediately.		X		
Check the inlet fuel pressure and adjust as needed. The inlet fuel pressure requirements are listed on the Mechanical Interface Drawing (149063).		X		

3.4.2 Component Maintenance

⚠ WARNING

Before doing maintenance, read all facility safety policies and procedures to make sure you protect personnel and equipment.

Before you work in any hazardous area, read the facility Permit to Work (PTW) policy and get a written PTW.

The permit to work must cover the following:

— Proper personal protective equipment,

— Proper procedures for using sniffers,

— Proper personnel monitoring and use of communication equipment,

— Proper ventilation,

— Physical hazards,

— Temperature hazards,

— Proper use of hearing protection,

— Evacuation procedures and routes.

Only qualified personnel may operate and maintain the package. The operator and maintenance personnel must understand turbine and driven equipment operation and function, and must also understand the controls, indicators, and operating limits.

Do not operate the package when conditions are unsafe. Unsafe conditions include:

— fuel leaks or lube oil leaks

— damaged electrical wiring

— damaged anchor bolts or structural members

Obey the facility procedure to lock out the controls and attach warning tags to them. Turn the OFF/LOCAL/REMOTE, OFF/LOCAL/AUXILIARY or OFF/LOCAL/AUX keyswitch to OFF. Make sure the battery charger, control console, and switchgear circuit breakers are open at the package motor control center (MCC). Before you do any work, attach “DO

⚠ WARNING

NOT OPERATE" tags to the start buttons and controls. Do not rely on color-coding of wiring for identification when you remove and install electrical components. Refer to the wiring diagram.

Before you do maintenance on the package, inspect the alarm indications on the package display. If the package is equipped with an offskid display, contact the remote operator for alarms status. If the package has an onskid display, inspect the alarms status at the package. Identify alarms that might become a dangerous situation while you do maintenance, for example, an alarm for a gas leak that has reached the Lower Explosive Limit (LEL) can become a more serious leak during maintenance.

Set up signs and barriers that keep non-maintenance personnel and vehicles out of the work area. If the package has an enclosure, non-maintenance personnel can be injured or can cause damage to equipment when the enclosure is opened for maintenance.

If the package has an enclosure, do not block any enclosure door whether or not it has been opened for maintenance. In case of emergency, use the nearest door to get out of the enclosure.

If the package has an enclosure, make sure the enclosure has adequate light to safely work inside. If necessary, install reliable temporary lights in the enclosure before you do maintenance. Make sure maintenance personnel have hand lights immediately available to them in case primary lighting fails and the enclosure does not have automatic backup lighting.

Prevent explosive accumulations of natural gas, liquid fuel, oil mist, or solvent fumes. Make sure ventilation is adequate and immediately repair leaks. Before you use solvents or cleaning solutions, read the applicable Material Safety Data Sheets. Use solvents in appropriate maintenance facilities.

Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

WARNING

If the package has an enclosure, make sure the pressure between the enclosure and its environment is equal before you open the doors. The enclosure can have higher or lower internal pressure compared to its environment. Maintenance personnel can be injured if doors are forcibly thrown open by positive internal pressure or are forcibly pulled closed by negative internal pressure.

Before you attempt to enter the enclosure, use the negative-pressure door-jacking assembly, if installed, to make the internal and external pressure equal. You can damage the doors if you force them open.

If the package has an enclosure, make sure the doors are latched in place after they have been opened. Winds can suddenly and forcibly move unlatched doors.

Do not touch hot surfaces. Gas turbines create extremely high surface temperatures. Use insulated gloves and protective clothing/equipment when you do maintenance.

Gas turbines create extremely high exhaust and surface temperatures that can ignite the fuels and lubricants used in gas-turbine packages. Solar strongly urges that you work in only non-hazardous, gas-free conditions. If maintenance must be done under hazardous atmosphere conditions, before doing maintenance, review the facility-specific auto-ignition temperatures (AITs) of the fuels and lubricants used in the package. Allow the equipment to cool to 80% of the lowest AIT before you do maintenance. Use a hand-held, non-contact thermometer approved for use in hazardous atmospheres to measure surface temperatures.

Close all fuel supply valves to the package before servicing fuel system components. Attach “DO NOT OPEN” tags to the valves. Make sure all pressure has completely dissipated.

Before you disconnect any system line, check pressure indicator gages and transmitter displays to make sure there is no pressure in the lines. Open hand-operated pressure-release valves slowly to release any pressure that might remain.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you use cleaning solvents or cleaning solutions. Prevent skin contact with solvents, solutions, or other materials that can be health

WARNING

hazards. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you handle fuels, lube oils, and their residues. Prevent skin contact with fuels, lube oils, and their residues. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you drain, transfer, or store fuels, lube oils, and their residues, or any other materials that contain chemicals or compounds that can be health hazards.

Do not disconnect, or otherwise make inoperable, any fuel valve or speed control device, whether the turbine engine is running or not. Loss of speed control could cause significant property damage, personal injury, and/or loss of life.

Prior to draining the liquid fuel purge tank, the collection tank must be grounded to the package frame and purge tank. Check the installation and integrity of the drain piping before draining the fuel.

If any fuel system component was loosened or removed, test the component for leaks on start-up.

Before you do maintenance, use the remote manual block and bleed valve to isolate and depressurize the package fuel system.

Refer to the Safety Requirements section located in the front of this manual for additional Warnings and Cautions.

The following table lists components that require maintenance. Refer to the table for maintenance schedules and Supplementary Data information. Refer to Maintenance Procedures Subsection 3.4.3 for maintenance procedures.

Table 3.4.2 Component Maintenance

Component	Maintenance	Supplementary Data
Gas Fuel Control Valve (EGF388A)	Refer to instructions located in the Supplementary Data.	Precision
Gas Fuel Control Valve (EGF388B)	Refer to instructions located in the Supplementary Data.	Precision
Gas Fuel Flow Meter (FM586)	Refer to instructions located in the Supplementary Data.	bMicro Motion
Air Supply Filter (FS911-1)	Drain filter bowl every 4,000 hours or less as determined by site conditions. Replace element every 4,000 operating hours or when differential pressure reaches 10 psi (68.9 kPa, 0.68 bar, 0.70 kg/cm^2).	
Oncrank Water Wash Strainer (FS991-1)	Clean element semiannually (4,000 operating hours).	Armstrong
Pressure Control Valves (PCV930-1, PCV930-2)	Refer to instructions located in the Supplementary Data.	Welker Engineering
Pressure Control Valves (, PCV952)	Refer to instructions located in the Supplementary Data.	Wilkerson

3.4.3 Maintenance Procedures

WARNING

Before doing maintenance, read all facility safety policies and procedures to make sure you protect personnel and equipment.

Before you work in any hazardous area, read the facility Permit to Work (PTW) policy and get a written PTW.

The permit to work must cover the following:

— Proper personal protective equipment,

— Proper procedures for using sniffers,

— Proper personnel monitoring and use of communication equipment,

— Proper ventilation,

— Physical hazards,

WARNING

— Temperature hazards,

— Proper use of hearing protection,

— Evacuation procedures and routes.

Only qualified personnel may operate and maintain the package. The operator and maintenance personnel must understand turbine and driven equipment operation and function, and must also understand the controls, indicators, and operating limits.

Do not operate the package when conditions are unsafe. Unsafe conditions include:

— fuel leaks or lube oil leaks

— damaged electrical wiring

— damaged anchor bolts or structural members

Obey the facility procedure to lock out the controls and attach warning tags to them. Turn the OFF/LOCAL/REMOTE, OFF/LOCAL/AUXILIARY or OFF/LOCAL/AUX keyswitch to OFF. Make sure the battery charger, control console, and switchgear circuit breakers are open at the package motor control center (MCC). Before you do any work, attach "DO NOT OPERATE" tags to the start buttons and controls. Do not rely on color-coding of wiring for identification when you remove and install electrical components. Refer to the wiring diagram.

Before you do maintenance on the package, inspect the alarm indications on the package display. If the package is equipped with an offskid display, contact the remote operator for alarms status. If the package has an onskid display, inspect the alarms status at the package. Identify alarms that might become a dangerous situation while you do maintenance, for example, an alarm for a gas leak that has reached the Lower Explosive Limit (LEL) can become a more serious leak during maintenance.

Set up signs and barriers that keep non-maintenance personnel and vehicles out of the work area. If the package has an enclosure, non-maintenance personnel can be injured or can cause damage to equipment when the enclosure is opened for maintenance.

WARNING

If the package has an enclosure, do not block any enclosure door whether or not it has been opened for maintenance. In case of emergency, use the nearest door to get out of the enclosure.

If the package has an enclosure, make sure the enclosure has adequate light to safely work inside. If necessary, install reliable temporary lights in the enclosure before you do maintenance. Make sure maintenance personnel have hand lights immediately available to them in case primary lighting fails and the enclosure does not have automatic backup lighting.

Prevent explosive accumulations of natural gas, liquid fuel, oil mist, or solvent fumes. Make sure ventilation is adequate and immediately repair leaks. Before you use solvents or cleaning solutions, read the applicable Material Safety Data Sheets. Use solvents in appropriate maintenance facilities.

Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

If the package has an enclosure, make sure the pressure between the enclosure and its environment is equal before you open the doors. The enclosure can have higher or lower internal pressure compared to its environment. Maintenance personnel can be injured if doors are forcibly thrown open by positive internal pressure or are forcibly pulled closed by negative internal pressure.

Before you attempt to enter the enclosure, use the negative-pressure door-jacking assembly, if installed, to make the internal and external pressure equal. You can damage the doors if you force them open.

If the package has an enclosure, make sure the doors are latched in place after they have been opened. Winds can suddenly and forcibly move unlatched doors.

Do not touch hot surfaces. Gas turbines create extremely high surface temperatures. Use insulated gloves and protective clothing/equipment when you do maintenance.

⚠ WARNING

Gas turbines create extremely high exhaust and surface temperatures that can ignite the fuels and lubricants used in gas-turbine packages. Solar strongly urges that you work in only non-hazardous, gas-free conditions. If maintenance must be done under hazardous atmosphere conditions, before doing maintenance, review the facility-specific auto-ignition temperatures (AITs) of the fuels and lubricants used in the package. Allow the equipment to cool to 80% of the lowest AIT before you do maintenance. Use a hand-held, non-contact thermometer approved for use in hazardous atmospheres to measure surface temperatures.

Close all fuel supply valves to the package before servicing fuel system components. Attach "DO NOT OPEN" tags to the valves. Make sure all pressure has completely dissipated.

Before you disconnect any system line, check pressure indicator gages and transmitter displays to make sure there is no pressure in the lines. Open hand-operated pressure-release valves slowly to release any pressure that might remain.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you use cleaning solvents or cleaning solutions. Prevent skin contact with solvents, solutions, or other materials that can be health hazards. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you handle fuels, lube oils, and their residues. Prevent skin contact with fuels, lube oils, and their residues. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you drain, transfer, or store fuels, lube oils, and their residues, or any other materials that contain chemicals or compounds that can be health hazards.

Do not disconnect, or otherwise make inoperable, any fuel valve or speed control device, whether the turbine engine is running or not. Loss of speed control could cause significant property damage, personal injury, and/or loss of life.

WARNING

Prior to draining the liquid fuel purge tank, the collection tank must be grounded to the package frame and purge tank. Check the installation and integrity of the drain piping before draining the fuel.

If any fuel system component was loosened or removed, test the component for leaks on start-up.

Before you do maintenance, use the remote manual block and bleed valve to isolate and depressurize the package fuel system.

Refer to the Safety Requirements section located in the front of this manual for additional Warnings and Cautions.

Where removal and installation procedures are obvious, such as disconnection of plumbing or wiring and removal of attaching parts and hardware, instructions are omitted.

Except where otherwise described, standard industrial maintenance and repair practices are acceptable. Always discard old or used O-rings, seals, and gaskets, and replace with new ones.

Refer to Illustrated Parts List of this manual set for repair parts or repair kits available for maintenance on fuel system components.

For cleaning methods and materials, refer to INTRODUCTION Chapter, GENERAL MAINTENANCE PROCEDURES, Cleaning/Degreasing/Decarbonizing 1.6.2.

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fitting, Gaskets, Seals and O-Rings 1.7.14.

3.4.4 Air Supply Filter

Maintenance of the Air Supply Filter (FS911-1) is limited to draining accumulated liquid every 4,000 hours, or as determined by the unique conditions at your site, and replacing the filtration element every 4,000 hours or when the pressure drop across the filter reaches 10 psid.

Drain the bowl often enough to make sure liquid never reaches the bottom of the filtration element. The element removes particles from the air flowing through the filter. Air flows from the outside of the element to the inside.

The pressure transmitter in the airline downstream of the filter will send a signal to the control system to alert maintenance personnel that they need to remove and replace the element. Record the initial pressure reported by this transmitter after installing a clean element. If the pressure drop across the filter reaches 10 psid above the initial pressure measurement across the clean filter, remove and replace the element.

WARNING

Before you do service on the air supply filter, make sure pressure has completely dissipated. Close all shutoff valves and attach DO NOT OPEN tags.

Turn off electric power and attach DO NOT OPERATE tags to circuit breakers and start switches.

CAUTION

Keep work areas clean. When you remove parts for maintenance or repair, do not let dirt or foreign materials get into openings. Use caps and blanks to block open lines and fittings. Do not use tape.

NOTE

The filtration element cannot be cleaned. Discard it and replace it with a new element.

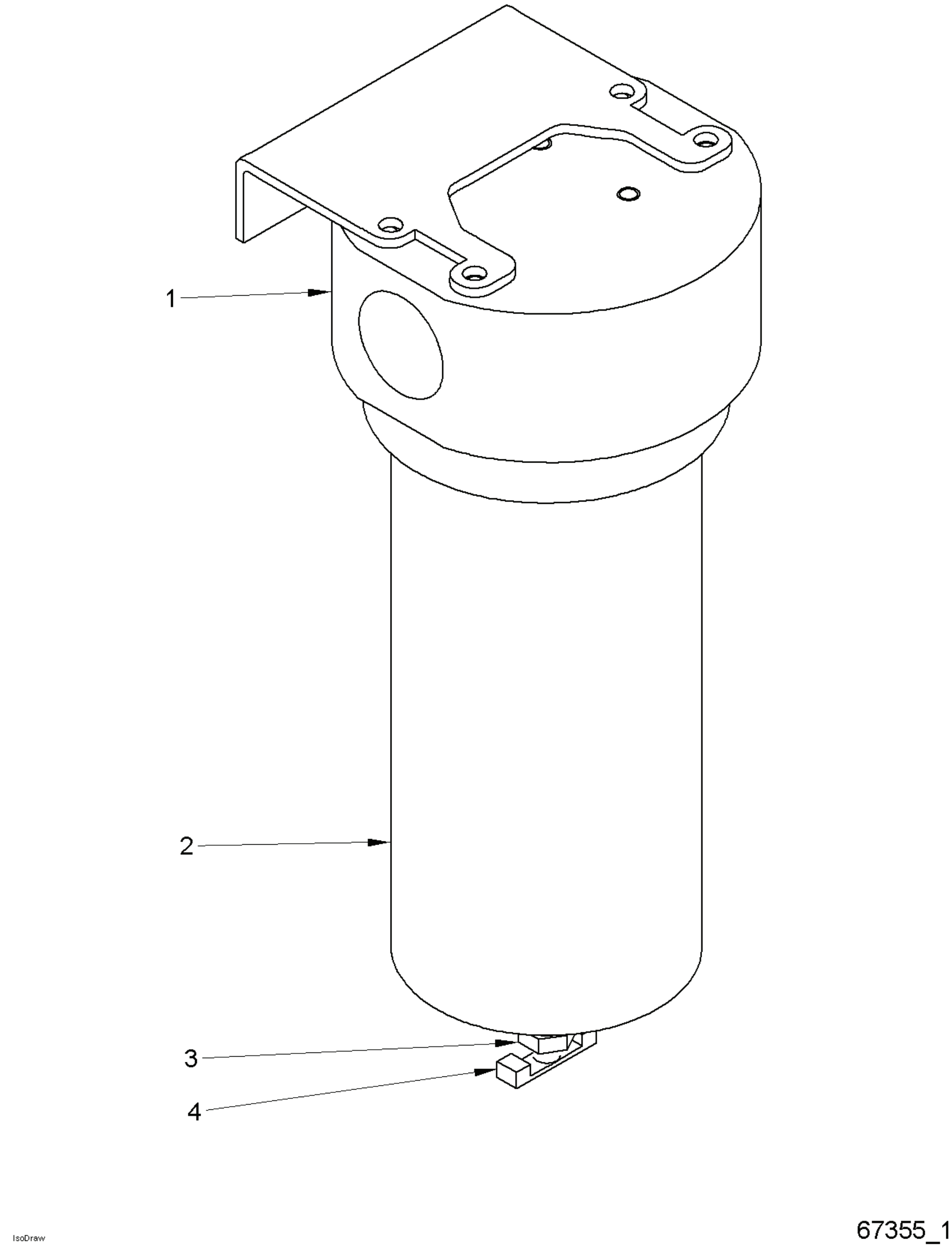


Figure 3.4.1 Air Supply Filter Element Replacement

Key for Figure 3.4.1			
1	Filter Head	2	Filter Bowl
3	Hex-shaped Fitting	4	Drain Valve

DRAIN FILTER BOWL

Use this procedure to drain the filter bowl.

1. Close the manually operated shutoff valve provided by the customer.
2. Put a container under the drain valve (4) to collect the liquid.
3. Slowly turn the drain valve (4) clockwise (from the bottom) to drain all liquid trapped inside the filter.
4. To close the drain valve (4), use only your fingers to turn the valve counterclockwise until it seals.

REMOVE ELEMENT

1. Close the manually operated shutoff valve provided by the customer.
2. Drain the filter bowl (2). Refer to the preceding procedure.
3. Loosen and remove the filter bowl (2) from the filter head (1).

CAUTION

When you loosen the filter bowl, put the wrench only on the hex-shaped fitting at the bottom of the bowl.

4. Loosen the bottom adapter from the filter element retaining rod.

NOTE

Keep the adapter.

5. Remove the element and discard.
6. Remove the O-ring from the filter head (1) and discard.

INSTALL ELEMENT

1. Use a soft, lint-free cloth to clean all threads and internal surfaces of the filter bowl (2) and the filter head (1).
2. Put the replacement O-ring onto the filter head (1).
3. Put the new filter element onto the filter head (1) and the retaining rod. Screw the bottom adapter to the retaining rod to secure the filter element to the filter head (1).
4. Tighten the filter bowl (2) onto the filter head (1) until it is secure.

CAUTION

When you tighten the filter bowl, put the wrench only on the hex-shaped fitting at the bottom of the bowl.

5. Use your fingers to tighten the drain valve (4).

6. Open the manually operated shutoff valve provided by the customer.

7. Do a leak check when the engine is started and, if necessary, retighten the filter bowl (2) to the filter head (1).

3.4.5 Oncrank Water Wash Strainer

Maintenance on Oncrank Water Wash Strainer (FS991-1) is limited to strainer cleaning.

WARNING

Before servicing fuel filters or strainers, ensure that all pressure has completely dissipated. All shutoff valves must be closed with a “DO NOT OPEN” tag attached.

Turn off and tag out electric power.

CAUTION

Keep work areas clean. When removing parts for maintenance or repair, cover openings to prevent entry of foreign material.

NOTE

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fitting, Gaskets, Seals and O-Rings 1.7.14.

1. Unscrew plug in lower branch of strainer housing to vent pressure. When pressure is relieved, remove strainer.

2. Remove all foreign particles remaining in strainer housing. Clean strainer with Stoddard solvent or equivalent.

3. Using a clean cloth, clean housing and install strainer.

4. Install plug and tighten.

3.4.6 Torch Pressure Coarse-Adjust Regulator

The torch coarse-adjust regulator (PCV930-1) reduces the fuel-system pressure to a stable pressure that can be used by the torch fine-adjust regulator (PCV930-2). The regulator taps pressure downstream of the off Secondary Gas Fuel Shutoff Valve (V2P932) and it must be set to 35 psig (241 kPa, 2.4 bar, or 2.46 kg/cm^2).

The regulator does not require regular maintenance but may require repair if its internal seals are leaking or if the regulator is not maintaining constant output pressure.

You can use Solar Turbines pressure regulator repair kit, P/N 997692C1, to repair the regulator. After you disconnect the regulator from the fuel system, you can remove it from its mount-bracket. Solar Turbines strongly recommends you take the regulator to a clean work area before you begin repair.

Use the following procedure to remove and install the regulator.

⚠ WARNING

Before you remove the regulator, make sure all fuel system pressure has completely dissipated.

Turn off electric power and attach *DO NOT OPERATE* tags to circuit breakers and start switches. Shut off service air/gas supply to pneumatically operated pump motors and attach *DO NOT OPEN* tags to hand-operated valves.

Do not touch hot surfaces. Gas turbines create extremely high surface temperatures. Use insulated gloves and protective clothing/equipment when you do maintenance. Solar Turbines strongly recommends you let the equipment cool down before you do maintenance.

⚠ CAUTION

Keep work areas clean. When you remove parts for maintenance or repair, do not let dirt or foreign materials get into openings. Use caps and blanks to block open lines and fittings. Do not use tape.

NOTE

You need a clean work area to repair the regulator, such as a work bench or a shop. If a new regulator is available, replace the defective regulator with a new one before you repair the defective regulator. Put the repaired regulator in storage until it is needed.

REMOVAL

1. Disconnect the inlet line that is attached to the regulator.
2. Disconnect the outlet line that is attached to the regulator.
3. Remove the 0.375-inch bolt and washer that holds the regulator's mount-bracket to the module.

NOTE
Keep the bolt and washer. They will be reinstalled.

4. Remove the 0.25-inch bolt and washer that holds the regulator body to the mount-bracket.

NOTE
Keep the bolt and washer. They will be reinstalled.

5. Take the regulator to a clean workbench or shop for repair.

INSTALLATION

1. Inspect the interior of the regulator. Make sure there are no blockages or debris from the damaged seals.
2. Follow the instructions in Solar Turbines pressure regulator repair kit, P/N 997692C1, to remove and replace the damaged seals.

CAUTION

Keep work and storage areas clean. When you put parts in storage or move them to or from the package, do not let dirt or foreign materials get into openings. Use caps and blanks to block openings and fittings. Do not use tape.

3. If you are not putting the repaired regulator in storage, take it to the turbine package you took it off of.
4. Use the 0.25-inch bolt and washer to attach the regulator body on its mount-bracket.
5. Use the 0.375-inch bolt and washer to attach the regulator mount-bracket to the module.
6. Connect the outlet line to the regulator.
7. Connect the inlet line to the regulator.
8. On initial start up, check for leaks.

9. Tighten the connections if necessary.

3.4.7 Torch Pressure Fine Adjust Regulator

The torch fine-adjust regulator (PCV930-2) further reduces the torch coarse-adjust regulator outlet pressure so that the torch receives the correct, constant, pressure needed for fuel-gas ignition. The regulator must be set to 5 psig (34.5 kPa, 0.34 bar, or 0.35 kg/cm^2).

The regulator does not require regular maintenance but may require repair if its internal seals are leaking or if the regulator is not maintaining constant output pressure.

You can use Solar Turbines pressure regulator repair kit, P/N 997692C1, to repair the regulator. After you disconnect the regulator from the fuel system, you can remove it from its mount-bracket. Solar Turbines strongly recommends you take the regulator to a clean work area before you begin repair.

Use the following procedure to remove and install the regulator.

WARNING

Before you remove the regulator, make sure all fuel system pressure has completely dissipated.

Turn off electric power and attach *DO NOT OPERATE* tags to circuit breakers and start switches. Shut off service air/gas supply to pneumatically operated pump motors and attach *DO NOT OPEN* tags to hand-operated valves.

Do not touch hot surfaces. Gas turbines create extremely high surface temperatures. Use insulated gloves and protective clothing/equipment when you do maintenance. Solar Turbines strongly recommends you let the equipment cool down before you do maintenance.

CAUTION

Keep work areas clean. When you remove parts for maintenance or repair, do not let dirt or foreign materials get into openings. Use caps and blanks to block open lines and fittings. Do not use tape.

NOTE

You need a clean work area to repair the regulator, such as a work bench or a shop. If a new regulator is available, replace the defective regulator with a new one before you repair the defective regulator. Put the repaired regulator in storage until it is needed.

REMOVAL

1. Disconnect the inlet line that is attached to the regulator.
2. Disconnect the outlet line that is attached to the regulator.
3. Remove the 0.375-inch bolt and washer that holds the regulator's mount-bracket to the module.

NOTE

Keep the bolt and washer. They will be reinstalled.

4. Remove the 0.25-inch bolt and washer that holds the regulator body to the mount-bracket.

NOTE

Keep the bolt and washer. They will be reinstalled.

5. Take the regulator to a clean workbench or shop for repair.

INSTALLATION

1. Inspect the interior of the regulator. Make sure there are no blockages or debris from the damaged seals.
2. Follow the instructions in Solar Turbines pressure regulator repair kit, P/N 997692C1, to remove and replace the damaged seals.

CAUTION

Keep work and storage areas clean. When you put parts in storage or move them to or from the package, do not let dirt or foreign materials get into openings. Use caps and blanks to block openings and fittings. Do not use tape.

3. If you are not putting the repaired regulator in storage, take it to the turbine package you took it off of.
4. Use the 0.25-inch bolt and washer to attach the regulator body on its mount-bracket.

5. Use the 0.375-inch bolt and washer to attach the regulator mount-bracket to the module.
6. Connect the outlet line to the regulator.
7. Connect the inlet line to the regulator.
8. On initial start up, check for leaks.
9. Tighten the connections if necessary.

3.4.8 Leak Check Procedure

For gas fuel, a squirt bottle with a soapy water solution can be used to locate leaks. With the fuel system pressurized, spray the component connections with the soapy water solution. If bubbles are present, perform shutdown procedures and ensure all system pressure is dissipated. Retighten the connections, and recheck for leaks. If the leak is persistent, the tube fittings, O-rings, or flange connection gaskets may need replacement.

WARNING

Do not resume package operation if fuel leaks are present.

3.4.9 Fuel Injector Assemblies

Refer to Turbine Engine, Chapter 7 for removal, inspection and cleaning, and installation of the fuel injector assemblies.

4 ELECTRICAL CONTROL SYSTEM

4.1 GENERAL DESCRIPTION

This chapter describes Solar Turbines' electrical control system.

Control of operating parameters such as temperatures, pressures, flow, speed and vibration is critical to prevent damage to turbine engine and driven equipment. Startup and shutdown require controlled sequenced processes.

A programmable logic controller, a computer adapted for control tasks, controls turbine engine package systems. The controller, which also may be called a processor, reads input device status such as control panel pushbuttons, makes decisions, and sets output devices such as indicators, positioners, or heating coils. Pressure and temperature sensors, speed and vibration pick-ups, and other sensors transfer measured data to the controller through analog input modules. Switch settings and other two-state inputs are sent, through discrete input modules, to the controller. The controller evaluates these inputs and sends commands, through output modules, to control devices such as positioners and solenoids. Communication modules accommodate data transmission between control system devices using dissimilar data formats, for example control data transmitted to the controller over the Ethernet or along data networks.

Control and support equipment are housed in junction boxes or other nonhazardous areas. Instrumentation and control devices are in and around the turbomachinery package.

WARNING

Additions and/or modifications to the turbine package control systems, or other package systems and subsystems, which are not reviewed and approved by Solar Turbines Engineering may cause serious malfunctions and may allow unsafe operation. Such malfunctions or unsafe operation could cause significant property damage, personnel injury, and/or loss of life. Do not modify package equipment, or add third party supplied systems or components without Solar Turbines Engineering approval.

This chapter includes sections:

- 4.2 - Functional Description
- 4.3 - Component Descriptions
- 4.4 - Maintenance

Reference drawings for use with this manual section include:

- Electrical Schematic (149450)
- Wiring Diagram (149451)
- Interface/Interconnect Drawing (149452)

4.2 FUNCTIONAL DESCRIPTION

This section provides an overview of the electrical control system's functions.

4.2.1 Controller Assembly

The Logix5000™ Controller:

- Controls engine startup, operation, and shutdown
- Uses stored software control programs
- Monitors operating conditions and requests for data
- Sends commands to regulate
  - Speed
  - Temperature
  - Load
  - Other conditions
- Sends operation and status data to display devices

The controller assembly includes:

- Chassis/power supply
- Controller module
- Communications modules

The controller assembly communicates with the turbomachinery and manual control devices through:

- Distributed Flex I/O modules

The controller receives input from:

- Turbine control panel through input modules
- Process measurement instrumentation through input modules
- The display computer through communication modules

Distributed input modules:

- Receive discrete, (two-state, ON or OFF), data
  - Typically from a switch
  - ON (closed, true, yes, or 1) indicated by +24 Vdc signal

 — OFF (open, false, no, or 0) indicated by 0 Vdc signal

- Receive analog (continuous-state variable signal) data
  - From thermocouples, pressure/temperature transmitters, magnetic speed pickups, proportional position transducers
- Convert data to digital data (a series of pulsed signals)
  - Discrete - binary logic values (1 or 0)
  - Analog - signed 16-bit integers
- Send data to controller through
  - Flex I/O adapter, ControlNet and ControlNet adapters

Distributed output modules:

- Receive digital data from controller through ControlNet and Flex I/O adapter
- Convert digital data to
  - Discrete data - for solenoid valves, indicator lights, and interposing relays for motor contacts and space heaters
  - Analog data - for actuators and servos to control the engine bleed valve, inlet guide vanes, fuel control and other valves, oil cooler motors, etc
- Send data to
  - Turbine control panel
  - Backup control circuitry
  - Package/system control devices

Communications modules:

- Typically receive operating condition change commands, or display requests
- Send Data Highway Plus (DH+) format data to processor
- Send digital data to operator terminal (usually operational or status information) in form received from processor

4.2.2 Generator Metering and Control

Generator metering and control system:

- Controls generator loading and operation mode
- Monitors generator performance

Generator metering and control system includes:

- Combination generator control module (CGCM)
- Voltage and current transformers
- AC/DC control power circuit breakers

Instruments and ac control devices operate from secondary windings of current and potential instrument transformers in generator switchgear.

4.2.3 Backup Control

Backup control:

- Is a group of instantaneous and time delay relays
- Activates in four conditions:
    - Turbine overspeed
    - Emergency stop manual switch activation
    - Controller failure
    - Fire indication
- Outputs relay logic
- Initiates emergency turbomachinery shutdown
- Controls postlube cycle

4.2.4 Instrumentation and Control Devices

Instrumentation:

- Measures physical systems
    - Liquid and gas pressures
    - Fluid and metal temperatures
    - Flow rates and levels
    - Vibration, speed and positions
- Delivers system data to I/O modules for communication to controller
- Delivers controller output, converted by I/O modules, to control devices

Control devices:

- Get input from the controller and backup systems
- Change physical system conditions
- Include
  - Electro/hydromechanical actuators
  - Solenoid valves
  - Motor starters

4.2.5 Control System Power

Control system power is provided by a battery/charger combination which is powered by a customer connection. When the customer input is interrupted, the batteries supply control power.

4.2.6 Vibration Monitoring System

A vibration monitor system uses proximitor probes, accelerometers and velocity transducers to monitor vibration and acceleration. Vibration and acceleration levels can be viewed on the operator terminal.

4.3 COMPONENT DESCRIPTIONS

For maintenance and updating, this section describes hardware components in terms of:

- Type
- Location
- Connection
- Function
- Power
- Status indicators
- Operation

Each component is identified by a reference designator on the electrical schematic and the wiring diagram. Reference designator form is as follows:

AANXXX, where

AA - alpha character(s) indicating component type and use in the system

N is a number indicating component location per the following:

1. Control console front
2. Inside control console
3. On turbine package skid
4. Motor starter in the motor control center
5. Other remote location
6. Switchgear
7. Inlet Air System

XXX is a two or three digit number.

4.3.1 ControlLogix-XT™ Controller Assembly

ControlLogix-XT™ is a trademark of Rockwell Automation Inc., Milwaukee, WI.

CONTROLLOGIX-XT CHASSIS

Reference Designator: CHNXXX

Figure 4.3.1 shows a typical chassis assembly with power supply, controller and communication interface modules.

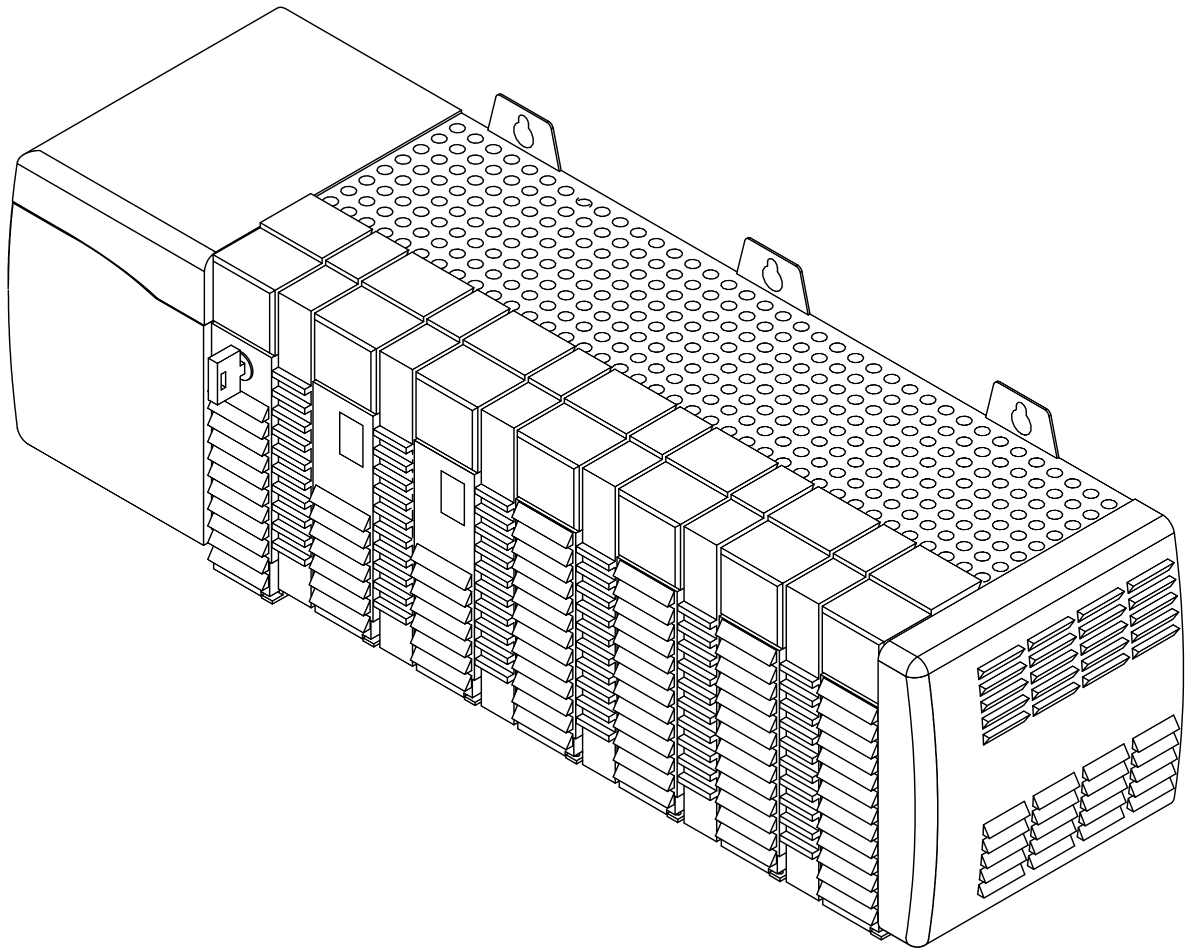


Figure 4.3.1 Typical ControlLogix-XT Chassis

Table 4.3.1 ControlLogix-XT Chassis

Type	Sheet metal housing with printed circuit backplane
Location	Chassis location is specified on the electrical schematic drawing
Connection	Components in chassis connect through printed backplane power and data buses
Function	Chassis has integral power supply and provides mounting locations for controller and communication modules
Power	The chassis backplane is powered by an internal power supply. The power supply requires 24 Vdc, which is provided from the electrical control system

Operation

The chassis is a connector that distributes power and data.

Refer to Supplementary Data.

IN-CHASSIS CONTROLLOGIX-XT POWER SUPPLY

Reference Designator: PSNXXX

See Figure 4.3.1.

Table 4.3.2 In-Chassis ControlLogix-XT Power Supply Module

Type	Electronic device which is integrated into a ControlLogix-XT chassis
Location	Mounted in a cabinet on the left side of the ControlLogix-XT chassis
Connection	Input power is to front-panel screw connectors (under a door). Power output is to chassis backplane
Function	Converts control system power to regulated power for the modules mounted in the chassis
Power	24 Vdc from electrical control system

Table 4.3.3 In-Chassis ControlLogix-XT Power Supply Module - Indicators

LED	Status	Indication
POWER	LIGHTED	Power supply system operating properly
	OFF	No power applied to power supply, or Power input not within limits, or Power loads in chassis exceed limits

Operation

The power supply module receives either 24 Vdc or 120/220 Vac from the electrical distribution system, converts the incoming power to the required regulated dc voltages, and provides up to 75 watts power for the modules mounted on the ControlLogix-XT chassis.

Refer to Supplementary Data.

CONTROLLOGIX-XT PROCESSOR MODULE

Reference Designator: UNXXX

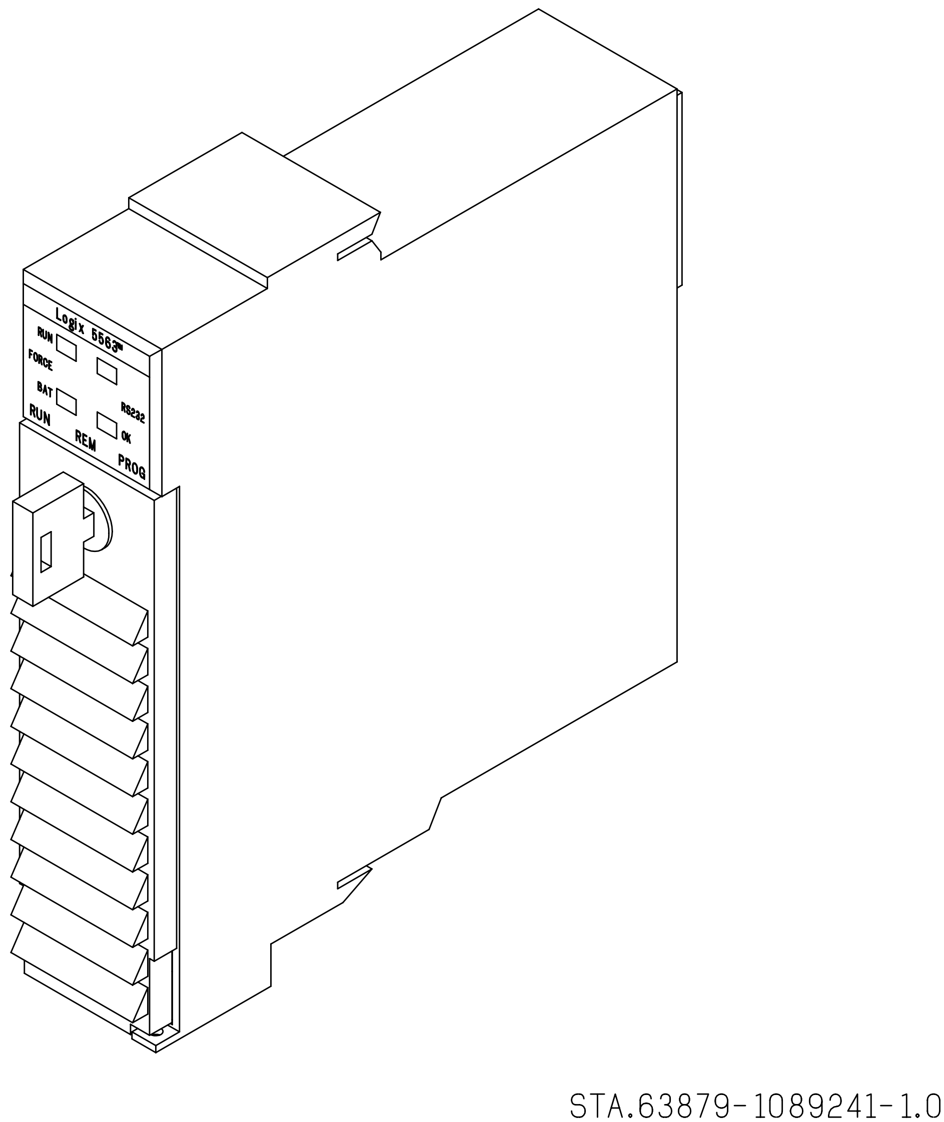


Figure 4.3.2 ControlLogix-XT Processor Module

Table 4.3.4 ControlLogix-XT Processor Module

Type	A single-slot-width computer adapted for control tasks.
Location	Locked in any slot in ControlLogix-XT chassis. Location is specified on electrical schematic drawing
Connection	Data and power connections are to the chassis backplane. An RS232 9-pin, serial port connector is under a front-panel door
Function	Controls system operation, runs the application program, analyzes measured data, issues commands, reports status, and activates alarms and shutdowns
Power	DC voltage is provided via the chassis backplane Backup AA lithium battery is behind front-panel door

Table 4.3.5 ControlLogix-XT Processor Module- Keyswitch Settings

Keyswitch setting	Function
PROG	Program is not scanned, discrete output is disabled, and inputs are not updated. Programs can be saved, modified, and restored. Operating mode cannot be changed at programming terminal
REM	Can select REM - Program, Run or Test. In Program operation same as PROG. In Run, online programming enabled, same as RUN. In Test, ladder logic executed, outputs disabled. Program files cannot be created or deleted
RUN	Programs run normally, I/O can be forced. Programs can be saved, but not modified online. Operating mode cannot be changed at programming terminal

Table 4.3.6 ControlLogix-XT Processor Module - Indicators

LED	Status	Indication
RUN	OFF	Controller is in Program or Test mode
	GREEN	Controller is in Run mode
I/O	OFF	Either: No I/O device is configured for use with the chassis, or The controller does not contain a project - memory is empty
	GREEN	Controller is communicating with all devices for which it is configured
	FLASHING GREEN	One or more I/O devices in the chassis I/O configuration are not responding
	FLASHING RED	Chassis is bad. Replace chassis
RS232	OFF	There is no activity
	GREEN FLASHING	Data are being received or transmitted
BAT	OFF	Battery will support memory
	RED	Either: Battery is not installed, or Battery is at least 95 percent discharged and must be replaced

Table 4.3.6 ControlLogix-XT Processor Module - Indicators, Contd

LED	Status	Indication
OK	OFF	No power is applied
	FLASHING RED	Recoverable fault
	RED	Non - recoverable fault. To correct: • Cycle chassis power • Download project into controller • Select Run mode
	GREEN	Controller is OK

Operation

The processor module is a digital microprocessor with programmable memory. The controller:

- Self diagnoses
- Executes application program
- Indicates status
- Uses programmable read only memory (PROM) to store operating system programs
- Uses volatile random access memory (RAM) to store transferred data
- Interfaces with in-chassis communication module to:
  - — Accept transferred input data
  - — Furnish transferred output data
  - — Validate transferred data

NOTE
Controller memory is volatile and needs power to maintain data. Power is supplied by system power or the backup battery.

Refer to Supplementary Data.

CONTROLLOGIX-XT CONTROLNET INTERFACE MODULE

Reference Designator: ZZNXXX

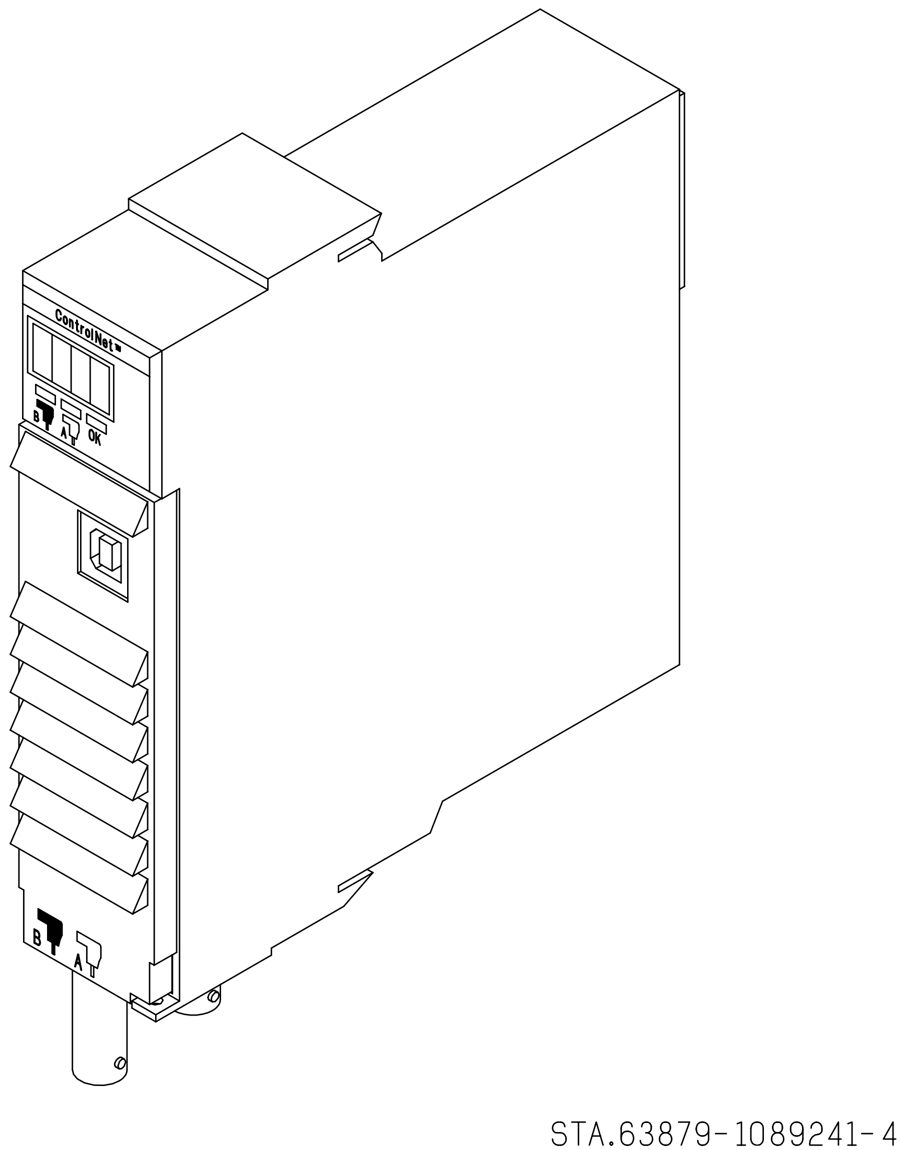


Figure 4.3.3 ControlLogix-XT ControlNet Interface Module

Table 4.3.7 ControlLogix-XT ControlNet Interface Module

Type	The module is a microprocessor-based, solid-state electronic device consisting of one single-width, rack-mounted module
Location	Any slot of the ControlLogix-XT chassis. Location is specified on electric schematic
Connection	Connects to I/O chassis through backplane. Connects to ControlNet network with redundant BNC connectors
Function	Interfaces between ControlLogix-XT chassis and ControlNet network
Power	DC voltage through chassis backplane

The module has LEDs and a module status display, which, together, can be used for troubleshooting. Table 4.3.8 explains the OK LED and the display indications which define module status.

Table 4.3.8 ControlLogix-XT ControlNet Interface Module-Indicator OK

OK LED	Display	Indication
RED	ADDR ERR	Module's network address is set to 00, which is an invalid ControlNet address
	RACK ERR	Module cannot read data stored in electronically erasable, programmable, read only memory (EEPROM) because EEPROM is uninitialized or invalid
	CNP2 ERR	Module has detected a firmware incompatibility
	BPIC ERR	There is a hardware fault in the module, or the module has detected improper backplane operation, which may indicate defective connections or bad module hardware
	CNIC ERR	There is a hardware fault in the module
FLASHING RED	ROM UPDT	Flash update is in progress
	DUPL NODE	Module's network address is the same as another module on the link
	BOOT	Module has invalid firmware
GREEN	OK	Normal operation
GREEN OR FLASHING GREEN	BPA# ERR	Module detected a different slot address than was latched-in at powerup. Excessive noise on the backplane can cause this error
	BPRX	Too many cyclic redundancy check (CRC) errors being generated by the multicast backplane receiver, so the backplane multicast receivers have been shut off
	KPR ERR	The module is unable to operate on the attached network
	BW XCED	Module is receiving too much network traffic and connections are timing out. Network bandwidth has been exceeded
	SW ERR	Module's network address has changed since powerup
FLASHING GREEN	NET ERR	Network cable error or no other nodes on network.

The module status indicators, A and B, are detailed in Table 4.3.9.

Table 4.3.9 ControlLogix-XT ControlNet Interface Module - Indicators (A and B)

Status	Indication
ALTERNATING RED/OFF	Incorrect node configuration
OFF	Channel disabled
STEADY GREEN	Normal operation
FLASHING GREEN/OFF	Temporary errors, or node is not configured to go online
FLASHING RED/OFF	Media fault, or no other nodes present on network
FLASHING RED/GREEN	Incorrect network configuration

Table 4.3.9 terms are defined:

- STEADY - Indicator is ON continuously
- ALTERNATING - Indicators alternate between the states defined in Table 4.3.9 at the same time. The two indicators are always in opposite states, out of phase.
- FLASHING - Indicator alternates between the two states defined in Table 4.3.9. If both indicators are flashing, they must flash together, in phase.

Operation

The module is an adapter that contains communication hardware and communication protocols that manage data traffic between the controller's I/O memory in RAM, and the ControlNet network. Network data include identified tags which represent analog and discrete data. Analog data include measured process variables such as speed, temperature and pressure. Discrete data include switch settings and indicator status. Tags are configured in the controller. Configuration establishes the electronic path to the tag.

The module places updated tags in a “tag table” in a portion in the controller's RAM for I/O, and retrieves them for communication to a display or control device.

Refer to Supplementary Data.

CONTROLLOGIX-XT ETHERNET COMMUNICATIONS MODULE

Reference Designator: ZZNXXX

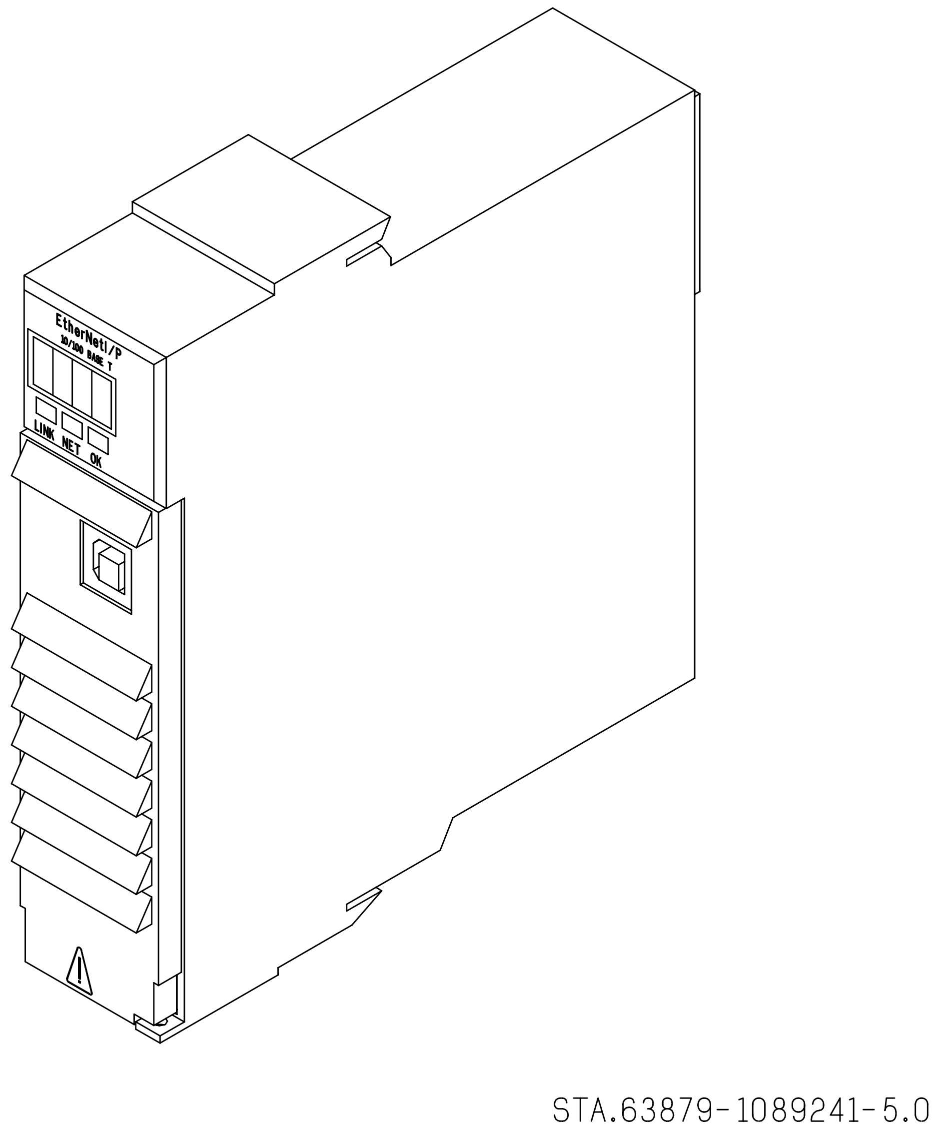


Figure 4.3.4 ControlLogix-XT Ethernet Communications Module

Table 4.3.10 ControlLogix-XT Ethernet Communications Module

Type	Single-slot module providing Ethernet/Controller connectivity
Location	In any slot in the ControlLogix-XT chassis. Location is specified on electrical schematic drawing
Connection	Connects to Ethernet with front-mounted autonomous unit interface (AUI) connector or 10BT Ethernet connector. Connects to chassis on backplane
Function	Communicates between controller and ControlNet network, and Ethernet (transmission control protocol/internet protocol ([TCP/IP])
Power	DC voltage through backplane

The module has an alphanumeric display, as well as LED status indicators. When power is applied, the alphanumeric display cycles through the following states:

- PASS
- OK
- REV YY, where YY is the module's firmware revision

In operation, the alphanumeric display alternates between OK and the module's address.

Table 4.3.11 ControlLogix-XT Ethernet Communications Module - LED Indicators

LED	Status	Indication
Link	OFF	There is no data communication: the module is not ready to communicate
	GREEN	Module is ready to communicate
	FLASHING GREEN	Module is communicating over the network
NET	OFF	The module is not powered, or does not have an internet protocol (IP) address
	FLASHING GREEN	Module has an IP address, but no connections established
	GREEN	Module has an IP address, and at least one connection established
	FLASHING RED	A connection has timed out
	RED	Module has detected its IP address is defective
OK	OFF	No power is applied to module
	FLASHING GREEN	Module is not configured
	GREEN	Module is operating correctly
	FLASHING RED	A recoverable fault has been detected
	RED	An unrecoverable fault has been detected
	FLASHING RED AND GREEN	Module is performing powerup selftest

Operation

The module is an adapter that contains communication hardware and communication protocols that manage data traffic between the controller's I/O memory in RAM, and the Ethernet network. Network data include identified tags which are analog and discrete data. Analog data include measured process variables such as speed, temperature and pressure. Discrete data include switch settings and indicator status. Tags are configured in the controller. Configuration establishes the electronic path to the tag.

Refer to Supplementary Data.

4.3.2 Flex I/O-XT™ Input/Output (I/O) System

Flex I/O-XT™ is a trademark of Allen Bradley Inc., Milwaukee, WI.

The Flex I/O-XT system is a distributed control system that connects I/O modules with a ControlNet processor, or programmable controller. Input/output (I/O) modules interface the controller with input devices such as switches and process measurement sensors, and, on the output side, with control devices such as motor contacts. Up to eight Flex I/O-XT modules are mounted on bases attached, on a DIN rail, to an adapter which connects to the controller. These module/base/adapter assemblies are placed in the Control Console and various junction boxes. The following describes adapters, bases, and modules.

FLEX I/O-XT™ TERMINAL BASE

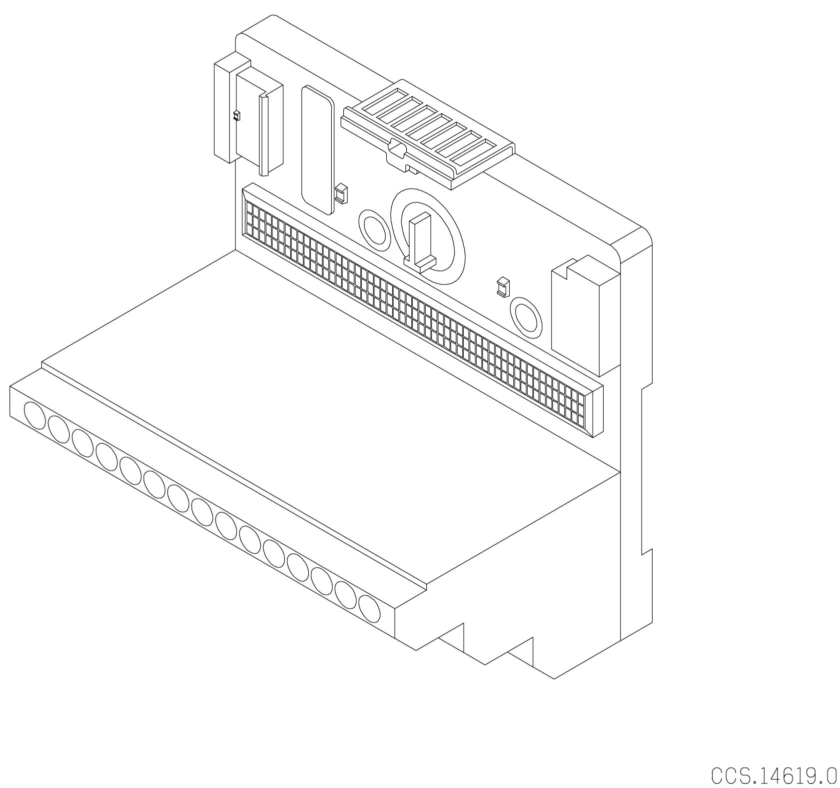


Figure 4.3.5 Flex I/O-XT™ Terminal Base

Table 4.3.12 Flex I/O-XT™ Terminal Base

Type	DIN rail-mounted inert connector.
Connection	Electrical system wiring, including data and power, connects to base terminals I/O modules mount on the terminal base Inputs to the PLC are through a Flexbus formed across the back panel of terminal bases
Function	Mounting platform and power and data connection for Flex I/O-XT module
Power	24 Vdc through Flex I/O-XT adapter and power bus

NOTE

Bases do not have separate reference designators. Flex I/O-XT module reference designators include the attached base.

Operation

The Flex I/O-XT terminal base is a connector.

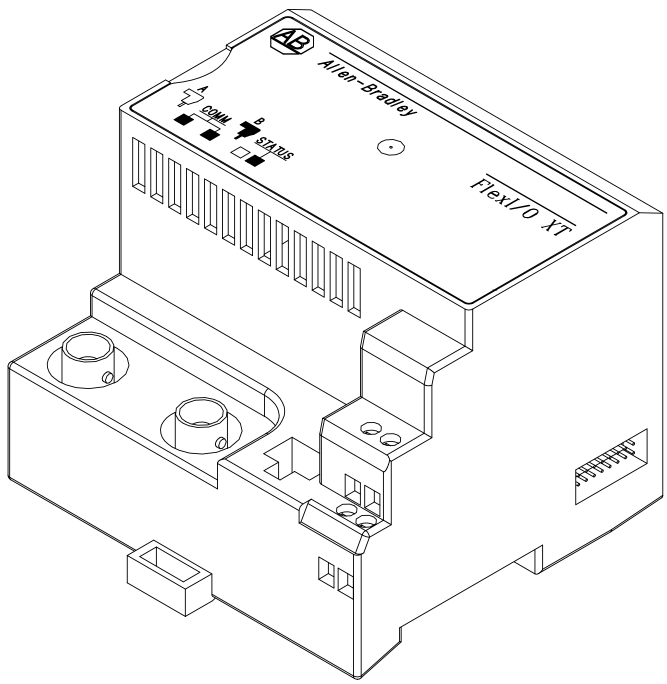
For spring-clamp terminal bases, refer to Supplementary Data.

For spring-clamp terminal bases used with temperature modules, refer to Supplementary Data.

For spring-clamp terminal bases, refer to Supplementary Data.

FLEX I/O-XT™ REDUNDANT CONTROLNET ADAPTER MODULE

Reference Designator: UFNXXX



STA.63880-1089240-1.0

Figure 4.3.6 Flex I/O-XT™ Redundant ControlNet Adapter Module

Table 4.3.13 Flex I/O-XT™ Redundant ControlNet Adapter Module

Type	Microprocessor-controllable, solid-state electronic device
Connection	24 Vdc system power input wiring connected to terminals on adapter base Two BNC connectors on base Connection to adjacent terminal bases (and modules) via 8-pin Flexbus connectors on module's bottom rear
Function	Interfaces between Flex I/O-XT terminal strip I/O modules and control processor
Power	24 Vdc from electrical control system power supply

Table 4.3.14 Flex I/O-XT™ Redundant ControlNet Adapter Module - Indicators

LED	Status	Indication
COMM A (left) and COMM B	RED	Module inoperative
	FLASHING RED/GREEN	Selftest
	FLASHING RED/OFF	Bad node configuration
	OFF	No power

Table 4.3.14 Flex I/O-XT™ Redundant ControlNet Adapter Module - Indicators, Contd

LED	Status	Indication
COMM A (left) or COMM B	GREEN	Channel operating normally
	FLASHING GREEN/OFF	Temporary network errors
	FLASHING RED/OFF	Redundancy warning, broken cable or cable fault
	FLASHING RED/GREEN	Bad network configuration
	OFF	Channel disabled
STATUS	FLASHING GREEN	Channel online, not connected
	GREEN	Channel online and link is OK
	FLASHING RED	Recoverable fault
	RED	Critical fault or adapter failure
	OFF	Channel disabled

Operation

The adapter is configured using a two-position switch located on the front of the module. The switch selects the ControlNet address. 00-02 is the proper address for the first I/O adapter, 00-03 for the next, etc.

Refer to Supplementary Data.

FLEX I/O-XT™ 16-CHANNEL DISCRETE INPUT MODULE

Reference Designator: ZFNXXX

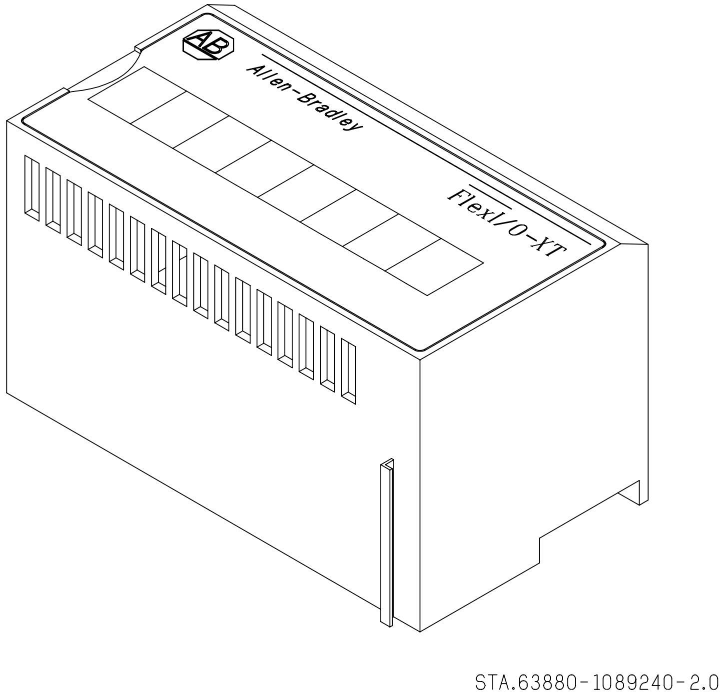


Figure 4.3.7 Flex I/O-XT™ 16-Channel Discrete Input Module

Table 4.3.15 Flex I/O-XT™ 16-Channel Discrete Input Module

Type	16-channel discrete input module
Connection	Connects to Flex I/O-XT base
Function	Converts discrete 24 Vdc signals from electrical system to low level digital data (1's or 0's) for controller
Power	24 Vdc through Flex I/O power bus

Table 4.3.16 Flex I/O-XT™ 16-Channel Discrete Input Module - Indicators

LED	Status	Indication
CHANNEL STATUS	LIGHTED	Channel is active (Channel numbers: 0-15)
	OFF	Channel inactive

Operation

The module is a sink-type module which receives a +24 Vdc signal and returns it to dc common (battery negative).

Refer to Supplementary Data.

FLEX I/O-XT™ 10/6-CHANNEL DISCRETE I/O MODULE

Reference Designator: ZFNXXX

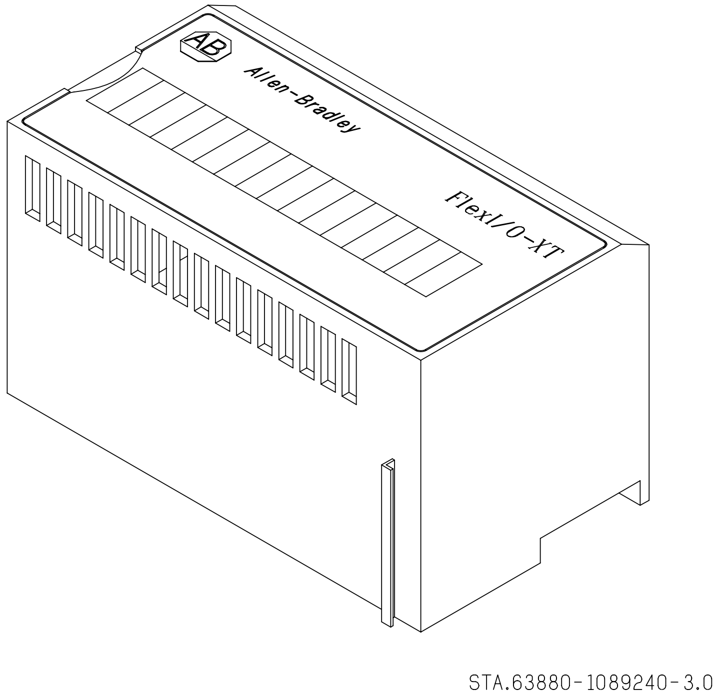


Figure 4.3.8 Flex I/O-XT™ 10/6-Channel Discrete I/O Module

Table 4.3.17 Flex I/O-XT™ 10/6-Channel Discrete I/O Module

Type	Ten input channel, six output channel, solid-state electronic device
Connection	Connects to Flex I/O-XT base
Function	Input channels convert ten discrete signals from electrical system to low level digital data for controller. Output channels convert digital data from controller to six discrete signals for electrical system
Power	24 Vdc through Flex I/O-XT power bus

Table 4.3.18 Flex I/O-XT™ 10/6-Channel Discrete I/O Module - Indicators

LED	Status	Indication
0-9	YELLOW	Input logic level high (1)
	OFF	Input logic level low (0)
0-5	YELLOW	Output logic level high (1)
	OFF	Output logic level low (0)

Operation

Discrete input channels are sink-type channels which receive 24 Vdc signals and return them to dc common (battery negative).

Refer to Supplementary Data.

FLEX I/O-XT™ 8-CHANNEL DISCRETE OUTPUT MODULE

Reference Designator: ZFNXXX

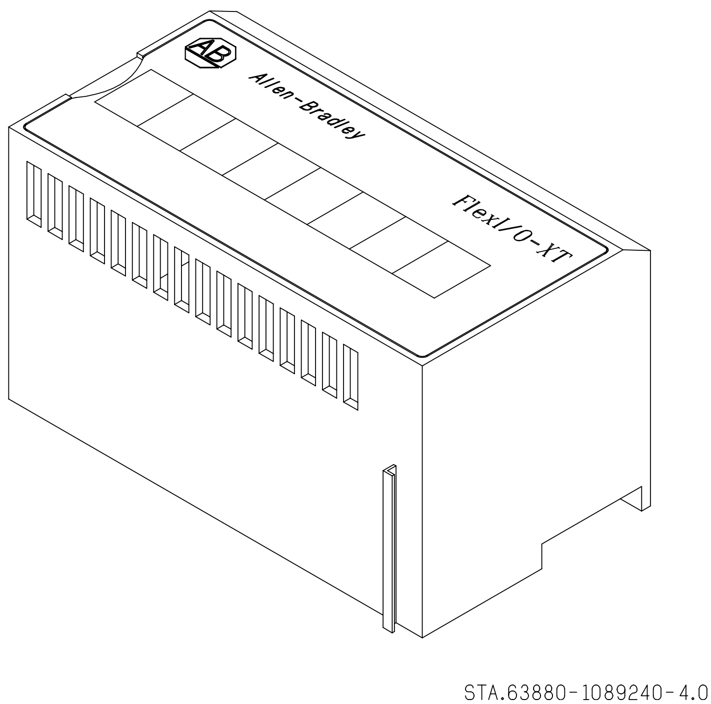


Figure 4.3.9 Flex I/O-XT™ 8-Channel Discrete Output Module

Table 4.3.19 Flex I/O-XT™ 8-Channel Discrete Output Module

Type	8-channel output module
Connection	Connects to Flex I/O-XT base
Function	Converts low level digital data (1's or 0's), from controller, to 8 discrete 24 Vdc signals, for electrical system
Power	24 Vdc through Flex I/O-XT power bus

Table 4.3.20 Flex I/O-XT™ 8-Channel Discrete Output Module - Indicators

LED	Status	Indication
LED O (per channel)	LIGHTED-YELLOW	status indication: channel active
	OFF	Channel inactive
LED D (per channel)	LIGHTED-RED	Diagnostic indication: fault
	OFF	No fault

Operation

Press reset button (RST) to reset fault. Refer to Supplementary Data.

FLEX I/O-XT™ 16-CHANNEL DISCRETE OUTPUT MODULE

Reference Designator: ZFNXXX

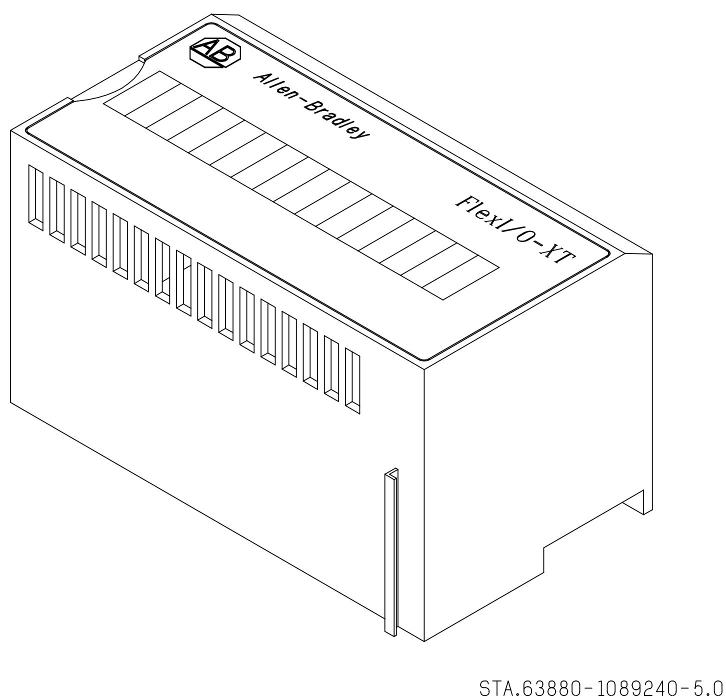


Figure 4.3.10 Flex I/O-XT™ 16-Channel Discrete Output Module

Table 4.3.21 Flex I/O-XT™ 16-Channel Discrete Output Module

Type	16 channel discrete output solid-state electronic module
Connection	Connects to Flex I/O-XT base

Table 4.3.21 Flex I/O-XT™ 16-Channel Discrete Output Module, Contd

Function	Converts low level digital signals from processor to 16 discrete signals for electrical system
Power	24 Vdc provided to terminal base connectors

Table 4.3.22 Flex I/O-XT™ 16-Channel Discrete Output Module - Indicators

LED	Status	Indication
0-15	Lighted	Channel communicating

Operation

Refer to Supplementary Data.

FLEX I/O-XT™ 8-CHANNEL ANALOG INPUT MODULE

Reference Designator: ZFNXXX

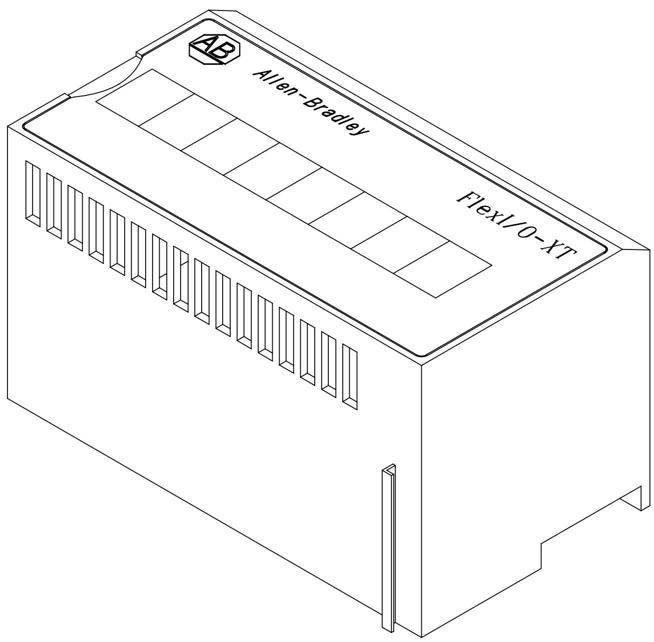


Figure 4.3.11 Flex I/O-XT™ 8-Channel Analog Input Module

Table 4.3.23 Flex I/O-XT™ 8-Channel Analog Input Module

Type	solid-state electronic module for 8 (nonisolated) analog input channels
Connection	Connects to Flex I/O-XT base

Table 4.3.23 Flex I/O-XT™ 8-Channel Analog Input Module, Contd

Function	Converts analog signals from electrical system to low level digital signals for controller
Power	24 Vdc through Flex I/O-XT power bus

Table 4.3.24 Flex I/O-XT™ Analog Input Module - Indicators

LED	Status	Indication
PWR	LIGHTED	Power ON
	OFF	Power OFF

Operation

The module is a schedule transfer module. Module is configured for either voltage or current input. The module is software configured for:

- Input range [(0 to 5V or 1 to 5V) or (0 to 20 mA or 4 to 20 mA)]
- Minimum and maximum scaling values for each input channel
- Realtime sample period, digital filtering, data format (binary)
- Input type (single-ended)

Refer to Supplementary Data.

FLEX I/O-XT™ 2/2–CHANNEL ANALOG I/O MODULE

Reference Designator: ZFNXXX

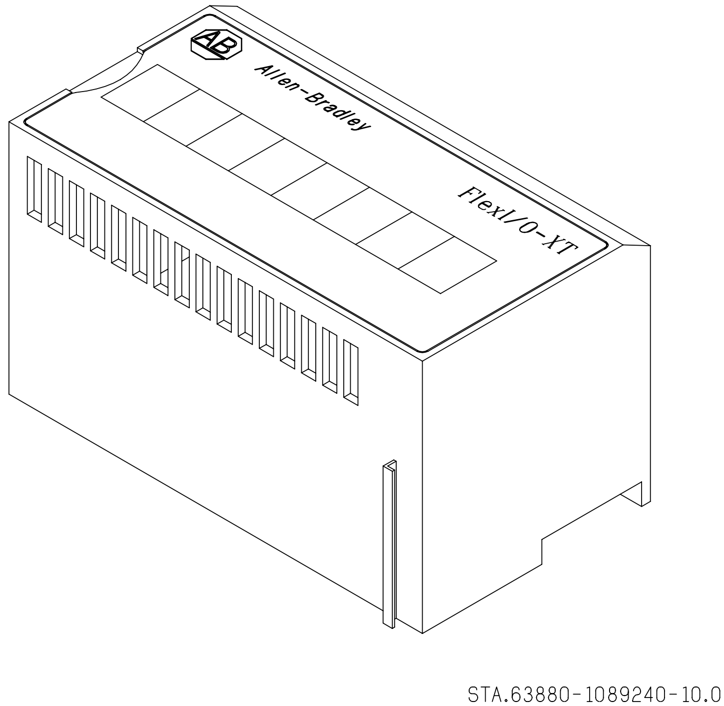


Figure 4.3.12 Flex I/O-XT™ 2/2-Channel Analog I/O Module

Table 4.3.25 Flex I/O-XT™ 2/2-Channel Analog I/O Module

Type	Solid-state electronic device with 2 isolated analog input and 2 isolated analog output channels
Connection	Connects to a Flex I/O-XT base
Function	Interface between controller and control devices Interface between sensors and controller Converts analog data to digital and digital data to analog
Power	24 Vdc power through terminal base connections

Table 4.3.26 Flex I/O-XT™ 2/2-Channel Analog I/O Module - Indicators

LED	Status	Indication
OK	LIGHTED	Power is ON
	FLASHING	Examine word status bit
	OFF	Power is OFF

Operation

The module receives positive dc voltage or current input from sensors and returns it to dc common. The module is configured for voltage or current input. The module is software configured for:

- Input range [(0 to 10V or ±10V) or (0 - 20 mA or 4 - 20 mA)]
- Minimum and maximum scaling values for each input channel
- Realtime sample period, digital filtering, data format (binary)
- Input type (single-ended)

On powerup, the controller transfers configuration data to the module using an instruction in the ladder logic program.

On receiving a data request, the module moves words of data from memory to the controller. Data transferred include diagnostic bits for module configuration status, over/underrange for each channel, and invalid scaling.

The module provides current output to control devices through the ControlNet system. The module is software configured for:

- Output Current Range [(0 - 20 mA) or (4 - 20 mA)]
- Output Voltage Range [(0 to 10V or ±10V) or (0 to 5V or ±5V)]
- Minimum and maximum scaling values for each input channel

As directed by the ladder diagram program, the controller sends up to thirteen 16-bit data and configuration words to analog output modules. The transmission includes:

- Four data words.
- A configuration word specifying polarity and scaling factors for each channel and data format (binary).
- Eight words which allow setting minimum and maximum scaling values for each channel (when used).

The module converts digital values to analog values for each output.

Refer to Supplementary Data.

FLEX I/O-XT™ 4-CHANNEL ANALOG OUTPUT MODULE

Reference Designator: ZFNXXX

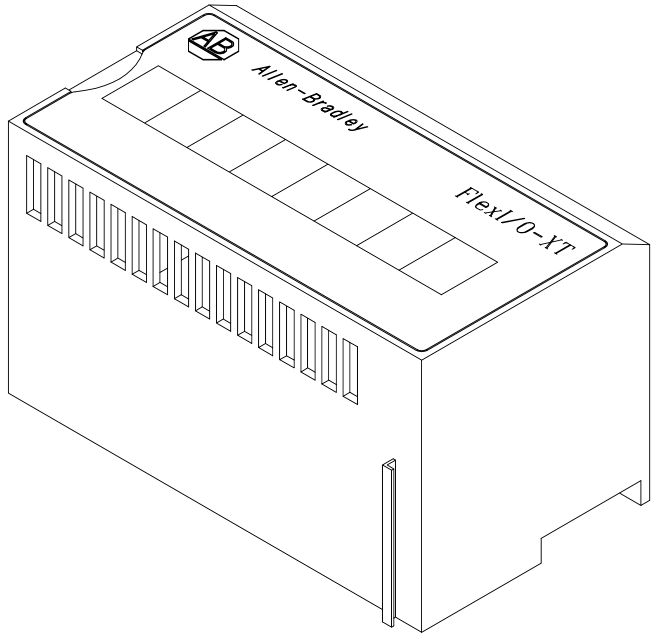


Figure 4.3.13 Flex I/O-XT™ 4-Channel Analog Output Module

Table 4.3.27 Flex I/O-XT™ 4-Channel Analog Output Module

Type	Solid-state electronic device with 4 isolated channels
Connection	Connects to a Flex I/O-XT base
Function	Interface between controller and process measurement instrument. Converts four single-ended analog signals from controller to digital values for electrical system
Power	24 Vdc power through terminal base connections

Table 4.3.28 Flex I/O-XT™ 4-Channel Analog Output Module - Indicators

LED	Status	Indication
OK	LIGHTED	Power is ON
	FLASHING	Examine module status word
	OFF	No power

Operation

The module moves data by schedule transfer, providing a 4 to 20 mA current output to control devices.

As directed by the ladder diagram program, the processor performs a schedule transfer to send 16-bit data and configuration words to an analog output module. The transmission includes:

- Four data words.
- A configuration word specifying polarity, scaling factors and data format (binary) for each channel.
- Eight more words which set minimum and maximum scaling values for each channel (when used).

The module converts digitized data to analog values for each output.

Refer to Supplementary Data.

FLEX I/O-XT™ 8-CHANNEL THERMOCOUPLE/RTD INPUT MODULE

Reference Designator: ZFNXXX

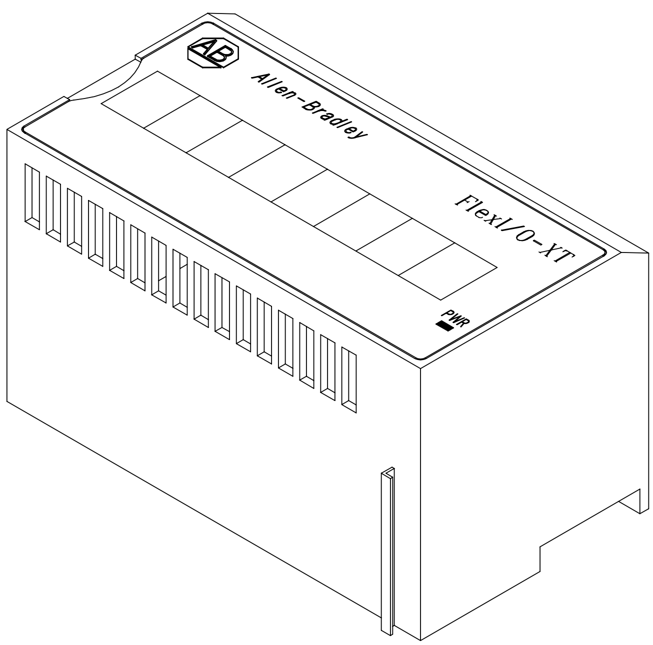


Figure 4.3.14 Flex I/O-XT™ 8-Channel Thermocouple/RTD Input Module

Table 4.3.29 Flex I/O-XT™ 8-Channel Thermocouple/RTD Input Module

Type	Microprocessor-based, solid-state electronic device with 8 isolated channels
Connection	Connects to a Flex I/O-XT base

Table 4.3.29 Flex I/O-XT™ 8-Channel Thermocouple/RTD Input Module, Contd

Function	Interface between T5/T7 thermocouple/RTD instrumentation and controller Module converts eight analog signals from electrical system to digital values for controller
Power	24 Vdc power for the logic circuitry is provided through terminal base

Table 4.3.30 Flex I/O-XT™ 8-Channel Thermocouple/RTD Input Module - Indicators

LED	Status	Indication
FAULT (per channel)	RED	LED lights at power up until internal diagnostics are complete. After diagnostics, illuminated LED indicates a critical fault
	OFF	No faults
	BLINKING RED	Non-critical fault, such as an open sensor
PWR	ON	Module powered
	OFF	Module not powered

Operation

THERMOCOUPLE - Module receives a low level dc voltage from thermocouples.

Module is configured by the software for data format (binary), digital filtering options, realtime sampling, and minimum and maximum scaling values for each input.

Engine T5/T7 thermocouples send the module signals. The module converts signals, analog-to-digital (A/D), optoelectrically isolates them, and stores the binary values until the ControlNet initiates data transfer.

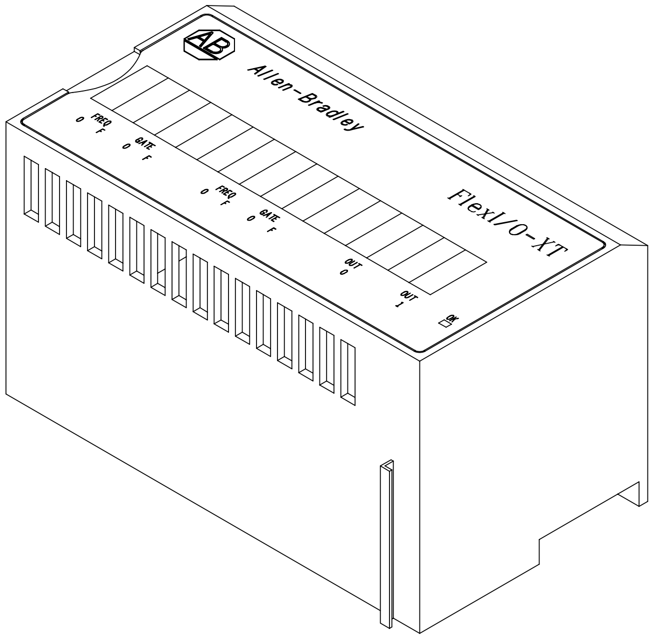
RTD - RTDs send a 1 mA current through RTDs and read (temperature dependent) resistance to the current flow.

The module is software configured for the type of resistive device (platinum), data format (2's complement binary), units of measure (°F or °C), input conditioning information (bias), and module calibration information (offset and gain).

Refer to Supplementary Data.

FLEX I/O-XT™ FAST-SPEED INPUT MODULE

Reference Designator: ZFNXXX



STA.63880-1089240-12

Figure 4.3.15 Flex I/O-XT™ Fast-Speed Input Module

Table 4.3.31 Flex I/O-XT™ 2-Channel Fast Speed Input Module

Type	2-channel fast analog input microprocessor based, solid-state module
Connection	Connects to a Flex I/O-XT base
Function	Interfaces between engine speed magnetic pickup instrumentation and controller Converts frequency data signals from electrical system to digital values for controller
Power	24 Vdc power through terminal base connections

Table 4.3.32 Flex I/O-XT™ 2-Channel Fast Speed Input Module - Indicators

LED	Status	Indication
GATE or FREQUENCY Channel 0 or 1	YELLOW	Input ON
	OFF	Channel not used or wire disconnected
GATE or FREQUENCY - F -	FLASHING RED	Fault
	OFF	Normal operation

Table 4.3.32 Flex I/O-XT™ 2-Channel Fast Speed Input Module - Indicators, Contd

LED	Status	Indication
OUT Channel 0, 1	YELLOW	Output (logic drive) is ON
	OFF	Input turned OFF
OK	GREEN	Normal operation
	RED	Module fault
	OFF	24 Vdc power OFF, or 5 Vdc power problem

Operation

The module receives high level ac input from engine speed magnetic pickup instrumentation. The module is configured for this use by the manufacturer and requires no hardware or software setup.

The module conditions the frequency input signal, optoelectrically isolates it and derives a frequency from the waveform periods. It converts frequency to a digital value.

Refer to Supplementary Data.

4.3.3 Turbine Control and Interface

The following subsections of this manual describe the system hardware components, which provide operation information and allow control of the turbomachinery.

See Controls and Indicators in the Systems Operator's Guide for more detail.

TURBINE CONTROL PANEL

Table 4.3.33 Turbine Control Panel

Type	The turbine control panel is the primary operator control device
Connection	Individual control components of the turbine control panel are wired to Flex I/O modules that are connected through the ControlNet wiring to the system processor in the control console
Function	The turbine control panel allows input commands and indicates operational status
Power	24 Vdc power is provided from the control system

Operation

Turbine control panel switches provide +24 Vdc output when they are closed. Output is directed to Flex I/O modules and the ControlNet. Controller switches are normally closed (NC) contact type. Other switches typically are normally open (NO).

Indicators are illuminated by +24 Vdc from Flex I/O output modules as directed by the system processor over the ControlNet. System status is annunciated by the indicator illumination.

DIGITAL DISPLAY COMPUTER

Computer hardware establishes an interface between operator and the turbine package control system.

The display computer includes a touchscreen, Ethernet card and internal modem. The computer uses Windows XP and TT4000 Version 5 software.

Refer to Supplementary Data.

DISPLAY COMPUTER

Computer hardware establishes an interface between operator and the turbine package control system.

The display computer typically includes screen, keypad, keyboard, hard drives and CD-ROM. An Ethernet card and internal modem are typically included. The computer uses Windows XP, Office 2000, Internet Explorer, and TT4000 Version 5 software.

The TT4000 allows operator communication with the control system, and enables the operator to view instantaneous and historical process parameters. The system allows further analysis of historical process parameters.

The computer is connected to system-provided operating power. A printer can be connected.

Refer to Supplementary Data.

4.3.4 Electric Actuator Controllers

FUEL CONTROLLER

Electric linear actuator controllers (Reference Designators EGFNXXX) control the fuel metering valve position. The fuel controllers receive analog input from the system controller and positions controlled device in response to system controller commands. Fuel controllers report controlled device position to the system controller.

Refer to Supplementary Data.

4.3.5 Generator Control Components

COMBINATION GENERATOR CONTROL MODULE (CGCM)

Reference Designator: ZNXXX

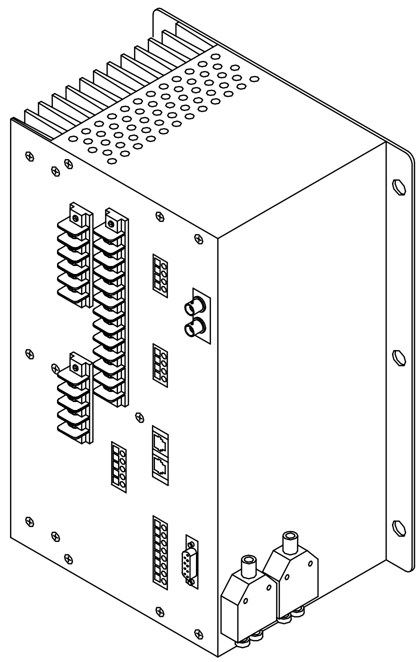


Figure 4.3.16 Combination Generator Control Module (CGCM)

Table 4.3.34 Combination Generator Control Module (CGCM)

Type	Programmable automatic generator controller
Location	Location is specified on the electrical schematic drawing
Connection	Seven front-panel terminal blocks connect to: • permanent magnet generator (PMG) • generator field • current transformers • potential transformers • 24 Vdc power • loadshare circuit • fault indication BNC connectors provide connection to the control system ControlNet. Two RS232 ports allow connection for factory test, and a redundant connection

Table 4.3.34 Combination Generator Control Module (CGCM), Contd

Function	Matches synchronizing bus phasing to reference bus phasing Adjusts load sharing output voltage Decreases or increases synchronizing bus output power to appropriate portion of total system load Regulates either exciter field current, or generator voltage, or generator volt-ampere-reactive (VAR) output, or generator power factor (PF) Provides over/under excitation limiting Provides generator protection
Power	The CGCM receives PMG ac voltage, or a portion of the ac terminal voltage from the generator. The CGCM also receives 24 Vdc power

The CGCM has an indicator for each of the two ControlNet channels. Status indications are explained in Table 4.3.35.

Table 4.3.35 Combination Generator Control Module (CGCM) - Indicators

LED	Status	Indication
CN A and CN B	RED	Module inoperative
	FLASHING RED/GREEN	Selftest
	FLASHING RED/OFF	Bad node configuration
	OFF	No power
CN A or CN B	GREEN	Channel operating normally
	FLASHING GREEN/OFF	Temporary network errors
	FLASHING RED/OFF	Redundancy warning, broken cable or cable fault
	FLASHING RED/GREEN	Bad network configuration
	OFF	Channel disabled
STATUS Check This	FLASHING GREEN	Channel online, not connected
	GREEN	Channel online and link is OK
	FLASHING RED	Recoverable fault
	RED	Critical fault or adapter failure
	OFF	Channel disabled

Operation

The CGCM, with synchronization, performs voltage regulation via control of exciter field current provided to the generator's stator field windings. The CGCM does parameter metering, line synchronization, protective relaying, and, when operating in parallel with other generators, load share control. The CGCM incorporates system and internal protection functions and fault indication.

The CGCM supports ControlNet communication.

Refer to Supplementary Data.

SYNCHRONIZING CHECK RELAY

Reference Designator: ZNXXX

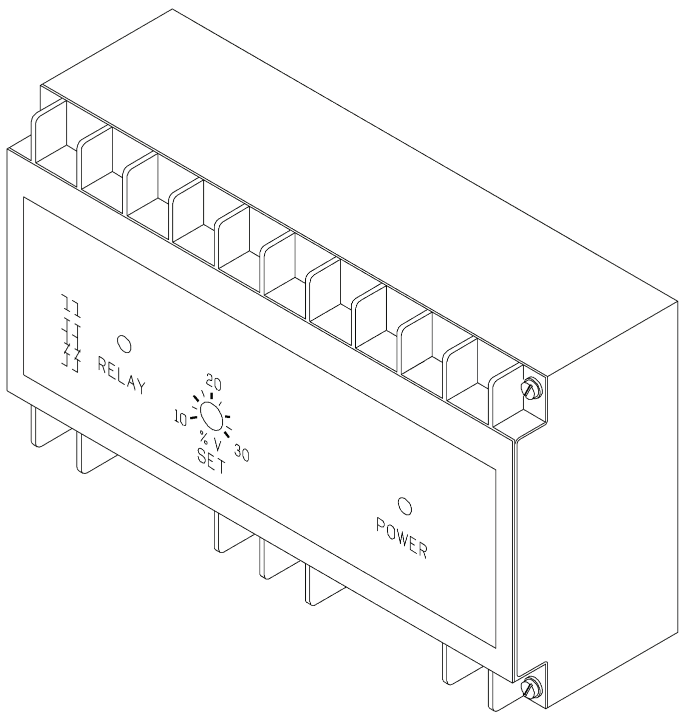


Figure 4.3.17 Synchronizing Check Relay

Table 4.3.36 Synchronizing Check Relay

Type	solid-state electronic device consisting of frequency-sensing circuits that operate relay contacts.
Location	Generator Control Junction Box

Table 4.3.36 Synchronizing Check Relay, Contd

Connection	Relay is connected to a discrete I/O module Relay is connected to generator and power bus
Function	Relay contacts prevent closure of the power circuit breaker main contacts if synchronization of the oncoming generator and live bus is not within the limits established by the synchronizing relay setpoints.

Operation

The synchronizing check relay normally closed contacts control the permissive close relay, assuming ready to load conditions are achieved. The synchronizing check relay contacts remain open if the difference in frequency of the two circuits to be paralleled exceeds the synchronizing check relay setpoints.

Since the permissive close relay normally open contacts are in series with the power circuit breaker close control circuit, the circuit breaker main contacts cannot be closed until proper frequency matching allows relay contacts to close and energize the permissive close relay.

The synchronizing check relay includes an additional dead bus sensing circuit in which a set of normally closed contacts overrides the frequency sensors to permit closure of the power circuit breaker, regardless of generator frequency, when starting to a dead bus.

Refer to Supplementary Data.

CURRENT TRANSFORMERS

The generator control system incorporates several current transformers, some of which may be customer-furnished or supplied by others. The current transformer is basically an instrument-type transformer of high thermal rating, designed to produce, in its secondary winding a relatively small current proportional to the actual load current in the primary winding. Typical step-down ratios are 400:5, 600:5, and 800:5, for use with instruments or modules having a requirement of 5 amperes.

POTENTIAL TRANSFORMERS

The generator control system also incorporates potential transformers, some of which may be customer-furnished or supplied by others. Potential transformers are usually step-down transformers, which proportionally reduce system voltage to permit connection of devices such as control modules, load synchronizers, voltmeters, wattmeters, etc. to its secondary windings.

4.3.6 Backup Control

BACKUP CONTROL RELAYS

Table 4.3.37 Backup Control Relays

Type	A group of timing and instantaneous relays and switches that control the system when controller is bypassed or deactivated
Connection	Components are hard wired to the controller and control components
Function	Control relays manage orderly unloading of driven equipment, turbine shutdown, and postlube operation when controller failure, overspeed or fast stop shutdown occurs
Power	Relays operate on 24 Vdc backup system power

Operation

Backup control relays are maintained in a fail-safe (energized) condition by a series of relay and switch contacts from the backup overspeed monitor, local and remote manual fast stop switches, and microprocessor fail relay. When any one of these contacts in the series circuit open, the relays are deenergized and the backup shutdown sequence is initiated.

The shutdown sequence deenergizes fuel valve solenoids to cut off the engine fuel supply, activates driven equipment unloading devices, and operates postlube system to protect engine and driven equipment. During shutdown sequence, the backup system active indicator illuminates.

Backup control locks out main control system until backup control system is reset. Resetting the backup control system rearms backup control circuits, extinguishes backup system active indicator, and (providing that the engine has decelerated to a safe speed) resets backup overspeed monitor contacts.

BACKUP OVERSPEED MONITOR (OSM)

Reference Designator: ZMNXXX

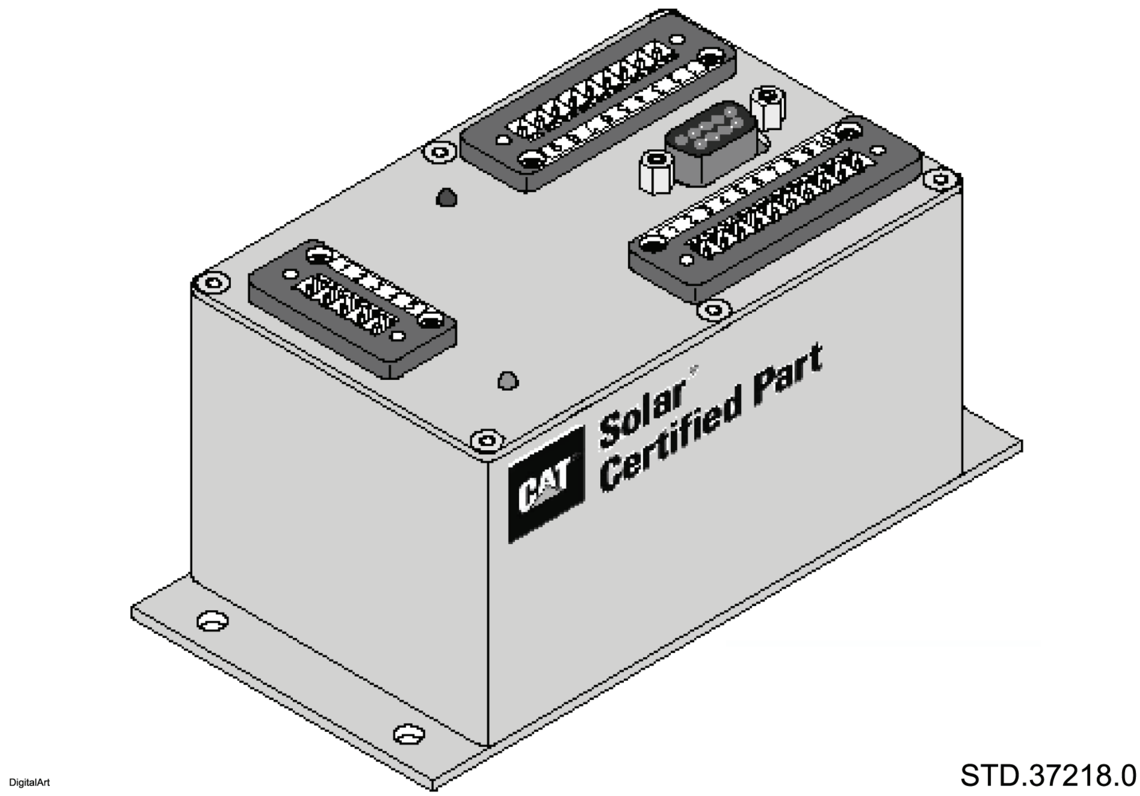


Figure 4.3.18 Backup Overspeed Monitor

Table 4.3.38 Backup Overspeed Monitor

Type	Solid-state electronic device which operates switch contacts in control system to shut down engine
Connection	Front panel connectors attach to: • speed sensor (input) • relays (output) • control and power inputs and outputs • diagnostics and communication

Table 4.3.38 Backup Overspeed Monitor, Contd

Function	• Responds to an overspeed condition by issuing a shutdown command via relay • Provides excitation to and accepts frequency input from a speed sensor • Provides a 4 to 20 mA analog output of the speed signal • Provides a programmable Health Monitor Set Point via an RS-232 port • Allows user diagnostics and setpoint review via an RS-232 port • Provides system test capability • Provides self-diagnostics to determine the OSM is properly functioning and reports fault conditions
Power	24 Vdc from power supply

Table 4.3.39 Backup Overspeed Monitor - Indicator

LED	Status	Indication
GREEN	ILLUMINATED	Indicates a speed signal greater than the Health Indicator Set Point, the relay is energized, and the normally open contact is closed
RED	ILLUMINATED	Indicates an overspeed monitor fault condition

The Backup Overspeed System shuts down the turbine, independent of other monitoring or control devices, by closing the fuel valve and therefore interrupting fuel flow to the turbine engine. Fuel valves are enabled by two separate discrete output modules, which are placed in different control nodes of the PLC/Controller. A set of trip chain relay contacts are interposed in each control node. Opening any of the trip chain relay contacts immediately disables and closes the fuel valves, shutting down the turbine.

The interposing relay contacts placed between PLC/Controller discrete contacts and each fuel valve are dependent upon the trip chain circuit; the OSM overspeed relay is placed as the first set of contacts within the trip chain. In an overspeed condition, the OSM is opened, deenergizing the trip chain relays. This opens the trip chain relay contacts, and closes the fuel valves.

Refer to Supplementary Data for additional information on the Backup Overspeed Monitor.

4.3.7 Instrumentation and Control Devices

Instrumentation and control devices include sensors, signal conditioners (if applicable), safety barriers, valves, actuators, and control devices used in package systems. The following describes instrumentation and control devices used for specific types of control:

T5 TEMPERATURE

Table 4.3.40 T5 Instrumentation

Type	T5 temperature instrumentation includes thermocouples and thermistors. Thermocouples - type K (Chromel-Alumel). Thermistors - temperature sensitive resistor assemblies embedded in plastic
Connection	Measuring tips of thermocouples extend into power turbine nozzle gas path. Chromel-alumel thermocouple leads attach to TC/RTD input module terminal base. Thermistors attach to input module base
Function	T5 instrumentation measures critical gas temperatures at power turbine inlet in turbine engine

Operation

The thermocouple has a measuring junction at the thermocouple tip where two dissimilar metals (Chromel and Alumel) are joined. At this junction a voltage proportional to temperature is produced. This voltage is delivered to the input module. Reference temperature data in current form is delivered to the input module from thermistors located with the TC/RTD module. From the two inputs the TC/RTD input module computes and delivers a digital signal representing measured temperature to the controller.

GAS PRODUCER SPEED

Gas producer speed is sensed with a magnetic pickup. The magnetic pickup is in the forward gas producer bearing housing. The pickup extends to the interconnect shaft cover cavity and senses splines on the interconnect shaft hub.

The magnetic pickups provide an ac signal (5 to 70 volts) with a frequency indicating shaft speed.

Magnetic pickups have a coil of copper wire wrapped around a magnetic core in the tip. The magnetic tip is very close (0.05 inch/1.27 mm) to the ferrous metal splines on the shaft hub. When the hub rotates, the splines pass by the magnetic tip causing a change in the flux field. The change in flux field causes a current to flow in the coil of wire and develops a voltage between the connection leads.

Voltage amplitude varies almost proportionally to the speed and inversely to the magnetic tip gap. The signal is essentially a sine wave with one cycle produced by each spline.

FLUID AND METAL TEMPERATURE

Fluid and most metal temperatures are measured with single element RTDs. RTDs are used to measure temperature in the inlet air duct, package enclosure, lube oil and start systems, engine and driven equipment bearings.

The RTD provides a resistance value [100 ohms at 32°F (0°C)] that directly relates to the temperature being sensed.

The RTD consists of a small coil of platinum or nickel wire protected by a sheath of stainless steel. The RTD is immersed in the fluid or placed in contact with the metal of the temperature to be measured.

A 1 mA current is passed through the RTD and the resulting voltage drop across it is measured. The voltage drop changes in proportion to the temperature and resistance change. The temperature is calculated from the voltage using conversion constants.

4.3.8 Control System Power

The system consists of an ac power source powering a battery/charger in a cabinet with circuit breakers. The battery/charger combination powers the control system when ac power is available. When ac power is not available, the battery powers the backup control system.

BATTERY CHARGER

Reference Designator: BCNXXX

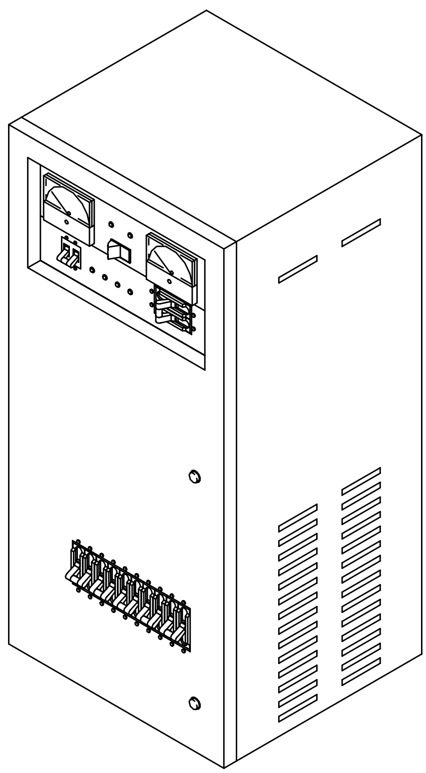


Figure 4.3.19 Battery Charger

Table 4.3.41 Battery Charger

Type	An assembly of battery charging rectifiers designed to supply a constant voltage to standby and online batteries at two load rates: “float” and “high rate”
Connection	The charger is connected to supply power. Through internal circuit breakers the charger connects to the battery pack
Function	Battery charger provides power to maintain battery charge, and through the battery pack, provides control system power. The charger is designed to work with a battery
Power	Input power is typically ac. Chargers will accept input power +/- 10 per cent from specified input voltage. See schematic for input voltage

Operation

Refer to Supplementary Data.

4.3.9 Vibration Monitor System

The vibration monitor system is a subsystem of the controller. The vibration monitor system uses probes to measure displacement. From these measurements, radial and thrust vibration data are developed. The probes are energized and measure gap dc voltage between probe and a moving surface. Probes measure high frequency displacement. The vibration system uses seismic sensors to measure velocity or acceleration. Seismic devices, also called accelerometers, measure lower frequency displacements. Seismic measurements are based on elastic deformation of a piezo-electric element mounted to a relatively high inertia mass.

The system checks for errors and OK status. The vibration system communicates status data and vibration data to the controller via a communication adapter module.

The system includes a chassis with a backplane, a power supply, monitor modules and input modules which are called proximitor or transducer and internal transducer modules. On schematics and/or wiring diagrams these I/O module may be named for the vibration data they transmit, such as radial or seismic input. See Figure 4.3.20.

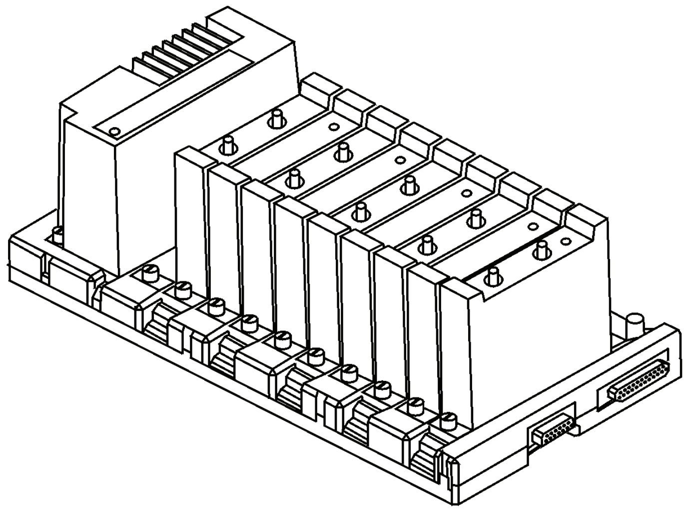


Figure 4.3.20 Typical Vibration Monitor System

MONITOR MODULE

Reference Designator: ZZNXX

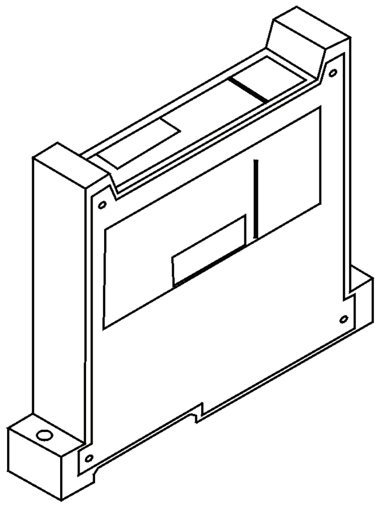


Figure 4.3.21 Monitor Module

Table 4.3.42 Monitor - General

Type	A single-width two-channel module in the vibration chassis. Monitor modules are paired with transducer input modules. Monitors are high frequency-type for radial and thrust vibration, and low frequency, or seismic-type, for acceleration and velocity
Connection	Receives input data from its paired transducer module, or transducer's isolator on the chassis backplane. Outputs, via the vibration chassis backplane, to the controller, through a communication adapter
Function	Converts measured displacement data from probes or sensors, to vibration or acceleration data that is communicated to the controller
Power	DC voltage is provided from a power supply through the chassis backplane

Table 4.3.43 Monitor Module - Indicators

LED	Status	Indication
LED	OFF	Power is OFF, or some component is defective
	GREEN FLASHING	Monitor is not configured
	GREEN STEADY	Monitor is configured and components are OK
	RED/GREEN FLASHING	One or both channels are in alarm

Table 4.3.43 Monitor Module - Indicators, Contd

LED	Status	Indication
	RED FLASHING	There is a recoverable fault condition, such as transducer channels are not OK, monitor is not OK, or configuration is invalid
	RED STEADY	Controller communication failed for one second

Operation

Monitor modules accept input signals, through transducer, or proximitor, input modules, from probes and seismic sensors. These input signals are displacement measurements. The module converts the input signals to digital format, and scales the signals into a range. The module checks errors and OK status, and process alarms. The electrical system controller sends configuration data and setpoints to the monitor. The monitor sends vibration data and system status data to the controller. Communication between controller and monitor modules is through the ControlNet network, the ControlNet adapter mounted with each vibration chassis, and the vibration chassis backplane.

The electrical system controller is the vibration system host. The controller sends vibration data to display devices.

Refer to Supplementary Data.

I/O MODULE

May also be called Internal Dual Proximitor® Module, Dual Proximitor®/Accelerometer I/O Module, Dual Velocity I/O Module, Dual Velomitor® I/O Module, Velomitor®A and Velocity B I/O Module, or Dual -18 Volt Proximitor® I/O Module.

Reference Designator: ZZNXX

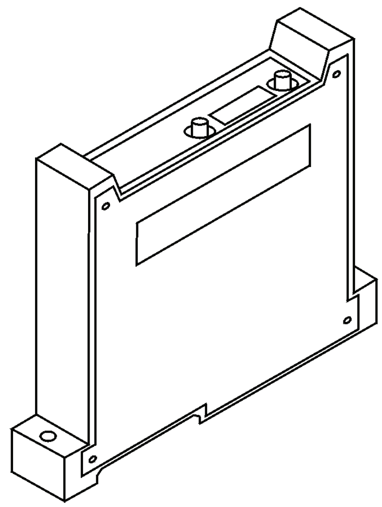


Figure 4.3.22 I/O Module

Table 4.3.44 Module - General

Type	A two-channel single-width module in the vibration chassis
Connection	Module has two front-panel BNC connectors for displacement input. Communication with paired isolator module, or monitor module is via the vibration chassis backplane
Function	The proximitor/accelerometer module is an I/O device communicating displacement probe data to an isolator module. The transducer transfers power from the vibration chassis backplane to the proximitor probes
Power	DC voltage is provided from a power supply through the chassis backplane

Operation

Refer to Supplementary Data.

4.3.10 Electrical Schematic

The electrical schematic includes information in the following approximate order:

- Symbols table showing electrical device and connection symbols used in the schematic.
- Index table identifying sheet numbers and information on them.

- Reference designator location table identifying the reference designation series and their location in the electrical system.
- Tables of engine gas turbine speed and T5 temperature topping and shutdown setpoint values and conversions.
- Notes explaining general and specific requirements and limitations within the electrical system.
- System switch setting table identifying hardware components switch and jumper configuration settings
- DC power distribution showing battery and charger arrangement and power and distribution circuit breakers.
- Backup control showing relay logic used in the backup control system.
- Controller I/O modules showing components and logic of power flow to/from the controller for instrumentation, controls, indicators, and switches. Included are terminal number assignments for chassis and input/output modules. Module configuration switch settings are shown.
- Motor, heater and lighting control showing connections, power requirements, and size and type ratings for motors, heaters, controllers, lights and motor starters.
- Vibration monitoring showing components, interconnects, and sensor locations for the vibration monitoring system.

4.4 MAINTENANCE

⚠ WARNING

Guard against electric shock. Perform removal and/or replacement of electrical components with power off, except where there is a clear direction in Supplementary Data to perform maintenance work with power on, such as controller backup battery replacement.

4.4.1 Control Consoles

⚠ WARNING

Control consoles have a high center of gravity and may tip over. Control consoles falling on individuals can cause serious injury or death. Prior to performing any work on or near a control console, ensure that the console is secured to the package, floor/pad or other stabilizing support structure.

- Before opening any console door, perform a visual inspection to ensure that the control console is secured and stable.
- Verify that any control console is properly secured and safe prior to beginning work on it.
- Post warning signs and limit access to any area containing an unsecured control console.

Control consoles not permanently installed must be temporarily secured in one of the following manners:

- Attach a properly rated crane to the lift points on the top of the console and remove all slack from the cabling.
- Attach a properly rated hoist to the lift points on the top of the console and remove all slack from the cabling.
- Attach the console to a temporary stand properly designed to secure the console, with adequate safety margins when all doors are opened.
- Place the console in a safe horizontal position. Even in the horizontal position, the console doors are hazardous. Remove the console doors prior to performing work on the horizontal console.

4.4.2 Electrostatic Discharge

Guard against electrostatic discharge during electrical control system repair or maintenance.

Electrostatic discharge can degrade control system performance, or permanently damage the system. Observe the following cautions to guard against electrostatic damage:

CAUTION

Remain in contact with an approved grounded point while handling modules or other components.

When handling electronic components, wear a properly grounded wrist strap for electrostatic discharge.

Do not touch the backplane connector or connector pins.

Use a static-safe work station when configuring or replacing internal components.

Keep modules and other equipment in a static-shielded bag when not in use.

4.4.3 Electrical Control System Components

Repair and maintenance of the electrical control system typically involves component replacement. The requirement for power on, or power off, varies with the component. For example, the controller processor battery must be replaced with the controller powered, or the stored program will be lost. Modules in chassis slots can only be removed and replaced with no power. Flex I/O modules are designed to be removed under backplane power, but with field power removed, while the bases for I/O module mounting can be removed from their DIN rail mountings only with power off.

Prior to any work on the electrical control system, review the electrical schematic for location of circuit breakers. Review Supplementary Data for definition of power status for safe module removal and replacement. Supplementary Data references are in the descriptions of electrical system components.

4.4.4 Grounding

GROUNDING TERMINOLOGY

Bonding

Electrical bonding refers to the process of electrically connecting equipment by means of a low resistance conductor. The purpose is to make the structure homogenous with respect to the flow of currents to avoid potential differences that can produce electromagnetic interference (EMI) or circulating ground currents and allow fault currents to flow to ground.

Shielding

Shielding of wires and cables is required to prevent the equipment from propagating interference and to protect the equipment from the effects of interference propagated by other devices. Shielding is typically floating on the device end, tied to Instrument Earth (IE) at the Unit Control Panel, and is never daisy chained.

Earth Ground Electrode

The Earth Ground Electrode is part of the earth grounding system. The Earth Ground Electrode is an electrical conductor that is buried in the earth to which all electrical return lines must attach. It is used to maintain the conductors connected to it at ground potential and dissipate current conducted to it into the earth. The Earth Ground Electrode must conform to the specifications listed in Solar Specification ES 2648.

Frame Ground (FG)

The Frame Ground (FG), also referred to as Protective Earth ground, refers to the interconnection of instrument chassis, instrument panels, doors, and control panels to a common skid frame ground. The package skid is used as the frame ground. The frame ground reduces the possibility of electrical hazard to personnel and provides a protective path to ground to eliminate shock hazards. The FG must be tied in the most direct possible path to an Earth Ground Electrode to which all electrical return lines attach, or for marine applications, to the Marine Platform Grounding Point. The FG conductor must be a 4-gauge American Wire Gauge (AWG) conductor wire, or larger.

Power Earth (PE) Ground

The Power Earth (PE) bus ground provides a route to dissipate the power line transients to earth potential. PE provides a clean return path and must be tied in the most direct possible path to an Earth Ground Electrode, or for marine applications, to the Marine Platform Grounding Point. The PE ground conductor must be a 4-gauge AWG conductor wire, or larger.

Instrument Earth (IE) Ground

The Instrument Earth (IE) ground protects sensitive electrical and electronic devices, circuits, and wiring from electromagnetic interference and radio frequency interference (RFI). IE is a quiet ground which is free from transient voltages and electromagnetic noise. The IE ground must be isolated from the PE ground. The IE ground must be tied in the most direct possible path to an Earth Ground Electrode, or to the Marine Platform Grounding Point. The IE ground conductor must be a 4-gauge AWG conductor wire, or larger.

Hazardous Area Instrument Earth (HAIE) Ground (Used in Intrinsically Safe Control Systems)

The Hazardous Area Instrument Earth (HAIE) ground is a dedicated ground that is required for intrinsically safe vibration systems. The HAIE ground bus is a copper bar inside of a control box that is isolated from the FG, PE, IE, and Intrinsic Safe (IS) buses. The HAIE ground bus must be connected in the most direct possible path to an Earth Ground Electrode, or to the Marine Platform Grounding Point. The HAIE ground conductor must be a 4-gauge AWG conductor wire, or larger.

The measured impedance between the HAIE bus and earth electrode must be one ohm or less.

The *Bently Nevada*™ vibration system power supply is grounded to the IE bus and modules are grounded to the HAIE bus.

Intrinsic Safe (IS) Earth Ground (Used in Intrinsically Safe Control Systems)

The Intrinsic Safe (IS) Earth ground is a dedicated ground that is required for intrinsically safe controls. The IS ground bus is isolated from FG, PE, IE, and HAIE buses and must be connected in the most direct possible path to an Earth Ground Electrode, or to the Marine Platform Grounding Point. The IS ground bus must have two separate, 12-gauge AWG or larger conductor wires, that are connected to one common ground point on the Earth Ground Electrode, or on the Marine Platform Grounding Point.

GROUNDING PRACTICES

⚠ WARNING

Grounding practices must comply with Solar Engineering Specification ES2648. Local codes prevail where conflicts arise with the required grounding practices listed in Solar Engineering Specification ES2648.

Grounding practices must be followed at all times to:

- ensure reliable operation

- reduce electrical-noise interference-causing signals in the control system

Grounding protects electronic equipment against line disturbances introduced by adjacent electrical equipment and line transients traveling on the power distribution system.

Building or Marine/Platform Earth Requirements

Grounding systems that customers use may vary. Because of this, Solar Turbines Incorporated assumes that the customer will provide a reference point/points or plane, through approved, industry-recognized distribution and bonding practices that ultimately tie FG, PE, IE, HAIE and IS to the same ground reference. Refer to Solar Engineering Specification ES2648 for the minimum grounding system requirements.

Control System Grounding Practices

If additional components are installed after initial commissioning, the following control system grounding practices must be obeyed:

- **Daisy Chains** - Daisy chaining of grounds is prohibited. Where there are multiple IE bus bars, one shall be selected as the marshaling bus and the customer's station ground termination made on that bus.
- **Ground Electrodes** - All local grounds such as PE bus, FG stud, IE bus, HAIE bus, and IS bus must be connected separately to the final station grounding electrodes.
- **Routing of Ground Leads** - All grounds must be routed by the most direct path to the station grounding electrodes. Solar Turbines Incorporated requires a minimum of 4-gauge AWG conductor wire, or larger for these grounds.

Ground Connection Bonding

To maintain a high-integrity grounding system, all grounding connections must be bonded properly. The three primary requirements of proper ground connection bonding are given below:

- **Surface Condition** - A clean, conductive surface free of all paint, anodic film, grease, and lacquer.
- **Protective Coating** - The clean grounding surface must be coated with an approved lubricating compound to prevent corrosion.
- **Fasteners** - The ground lug must be connected to the clean surface directly or with an approved star washer. Lugs and washers material must be similar in electrical properties to the conductive surface material.

Ground System (On-Shore Applications)

Figure 4.4.1 and Table 4.4.1 provide an overview of the entire ground system that is used on all on-shore generator sets, and gas turbine compressor sets where the gas pipeline is isolated from earth and from the compressor set. Ground system connections must be maintained annually.

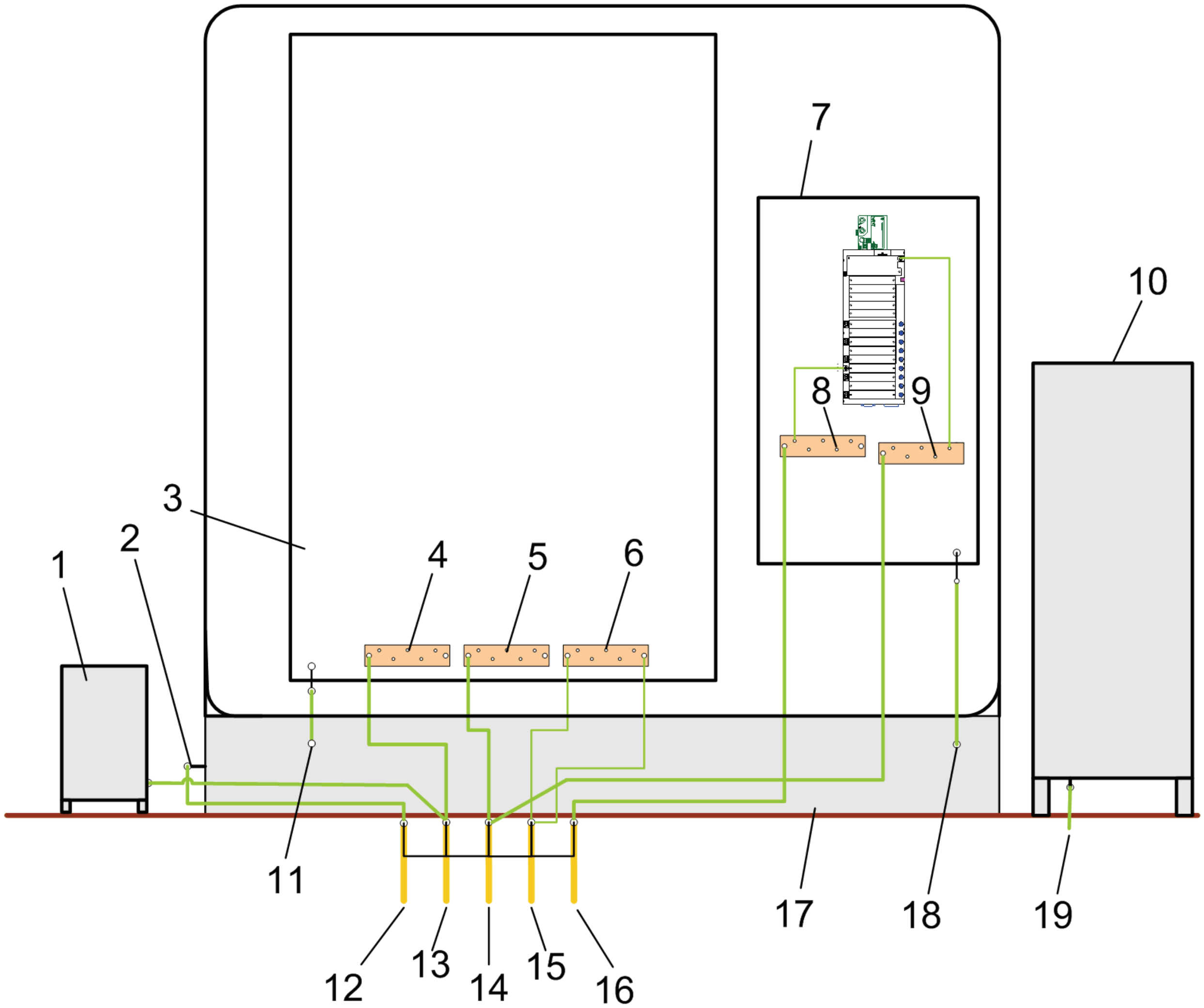


Figure 4.4.1 Ground System (On-Shore Applications)

Table 4.4.1 Ground System (On-Shore Applications)

Index No.	Description
1	Battery charger and batteries, if applicable; connected to the PE ground.
2	Skid ground connections.

Table 4.4.1 Ground System (On-Shore Applications), Contd

Index No.	Description
3	Control boxes; connected to the FG ground. Control boxes contain PE, IE, IS bus bars. **NOTE** All PE, IE, and IS bus bars grounds within the control box must be independently routed to the Earth Ground Electrode to which all electrical return lines attach.
4	Power Earth (PE) bus bar.
5	Instrument Earth (IE) bus bar. **NOTE** The IE bus must be free from transient voltages and electromagnetic noise. Therefore, the IE bus bar grounding conductor wire must be routed separately to the Instrument Earth (IE) ground connection (14).
6	Intrinsic Safe Earth (IS) bus bar. **NOTE** The IS bus must have two separate, 12-gauge AWG or larger conductor wires, that are connected to one common ground point on the Intrinsic Safe Earth (IS) ground connection (15).
7	If applicable, Intrinsic Safe (IS) control box contains HAIE and IE bus bars.
8	If applicable, Hazardous Area Instrument Earth (HAIE) bus; connected to the HAIE ground.
9	Instrument Earth (IE) bus bar; connected to the IE ground.
10	Variable Frequency Drive, if applicable; connected to FG connection (19).
11	Frame Ground (FG) connection; from control box (3) to gas-turbine package skid (17).
12	Frame Ground (FG) connection, shown on the illustration in the color gold, must be bonded to the Earth Ground Electrode to which all electrical return lines attach. [1] **WARNING** The purpose of the frame ground (FG) is to reduce hazards to personnel. The FG must be tied in the most direct possible path to the earth electrodes. The earth electrodes grounding connection is provided by the customer.
13	Power Earth (PE) ground connection, shown on the illustration in the color gold, must be bonded to the Earth Ground Electrode to which all electrical return lines attach. [1]
14	Instrument Earth (IE) ground connection, shown on the illustration in the color gold, must be bonded to the Earth Ground Electrode to which all electrical return lines attach. [1]

Table 4.4.1 Ground System (On-Shore Applications), Contd

Index No.	Description
15	If applicable, Intrinsic Safe Earth (IS) ground connection, shown on the illustration in the color gold, must be bonded to the Earth Ground Electrode to which all electrical return lines attach. [1]
16	If applicable, Hazardous Area Instrument Earth (HAIE) connection, shown on the illustration in the color gold, must be bonded to the Earth Ground Electrode to which all electrical return lines attach. [1]
17	Gas-turbine package skid.
18	Frame Ground (FG) connection from IS control box (7), if applicable, to gas-turbine package skid (17).
19	If applicable, Frame Ground (FG) connection; from variable frequency drive (10) to FG connection (12).

(1) Some installations may have a grid or ring ground.

GROUND SYSTEM MAINTENANCE

Electric signals from electric actuators, variable frequency drives (VFDs), electric fuel-control valves and other devices provide essential feedback signals to the Safety Critical Control Systems (SCCS). However, electromagnetic interference (EMI) and radio frequency interference (RFI) can violate the integrity of these feedback signals. To reduce the effects of EMI and RFI, the unit and control boxes must be properly grounded.

Regular inspections of the grounding system can help identify potential sources of electrical and electromagnetic interference.

Annual Ground System Inspection

Do the following procedures once a year:

1. Visually inspect all wiring connections to each ground bus. Make sure that the connections are tight, dry, clean, and free of corrosion.
2. Visually inspect each grounding system to make sure that the ground bus bars are isolated and run to an Earth Ground Electrode, or to a Marine Platform Grounding Point.

Annual Ground System Connections And Connection Path Inspection

Do the following procedures once a year:

1. Check that analog signal wires are shielded and appropriately connected per the Grounding Practices Subsection.

2. Make sure that noise sensitive signal wires are routed separately away from cables with high noise potential.

3. Review the installation against these grounding practice guidelines to determine where corrections could be made.

Annual Ground System Checks

Use a multimeter to do the following procedures once a year:

1. Measure from the 24 Vdc terminal to the 0 Vdc terminal of output of power supply or inverter. This should read between 24 and 28 Vdc.

2. For compressor sets and electric motor drives, measure from the 24 Vdc terminals to IE ground. This should read between 12 and 14 Vdc.

3. For compressor sets and electric motor drives, measure from the 24 Vdc terminals to PE ground. This should read between 12 and 14 Vdc.

4. For compressor sets and electric motor drives, measure from the 24 Vdc terminals to FG ground. This should read between 12 and 14 Vdc.

5. For generator sets, measure from the 24 Vdc terminals to IE ground. This should read between 24 and 28 Vdc.

6. For generator sets, measure from the 24 Vdc terminals to PE ground. This should read between 24 and 28 Vdc.

7. For generator sets, measure from the 24 Vdc terminals to FG ground. This should read between 24 and 28 Vdc.

8. Measure in Vac from the 24 Vdc terminal to 0 Vdc terminal. This should read less than 250 mVac.

9. Measure in Vac from 24 Vdc to IE ground. This should read less than 250 mVac.

10. Measure in Vac from 24 Vdc to PE ground. This should read less than 250 mVac.

11. Measure in Vac from 24 Vdc to FG ground. This should read less than 250 mVac.

12. Measure the frequency (Hz) from the 24 Vdc terminal to the 0 Vdc terminal. This should read less than 120 Hz.

13. Measure the frequency (Hz) from 24 Vdc to IE ground. This should read less than 120 Hz.

14. Measure the frequency (Hz) from 24 Vdc to PE ground. This should read less than 120 Hz.

15. Measure the frequency (Hz) from 24 Vdc to FG ground. This should read less than 120 Hz.

16. If noise problems are present or Vac measured greater than 250 mVac, perform Ground System Troubleshooting listed in Subsection below.

GROUND SYSTEM TROUBLESHOOTING

This subsection describes the procedures used to troubleshoot the ground system when noise problems are present or Vac measured greater than 250 mVa.

PE, IE, IS, and HAIE ISOLATION TEST

WARNING

Before you disconnect the ground connections, make sure that all the electrical power sources are turned off.

NOTE

In the following procedure, not all packages have IS or HAIE buses.

Figure 4.4.2 and Table 4.4.2 give the grounding resistance test setup.

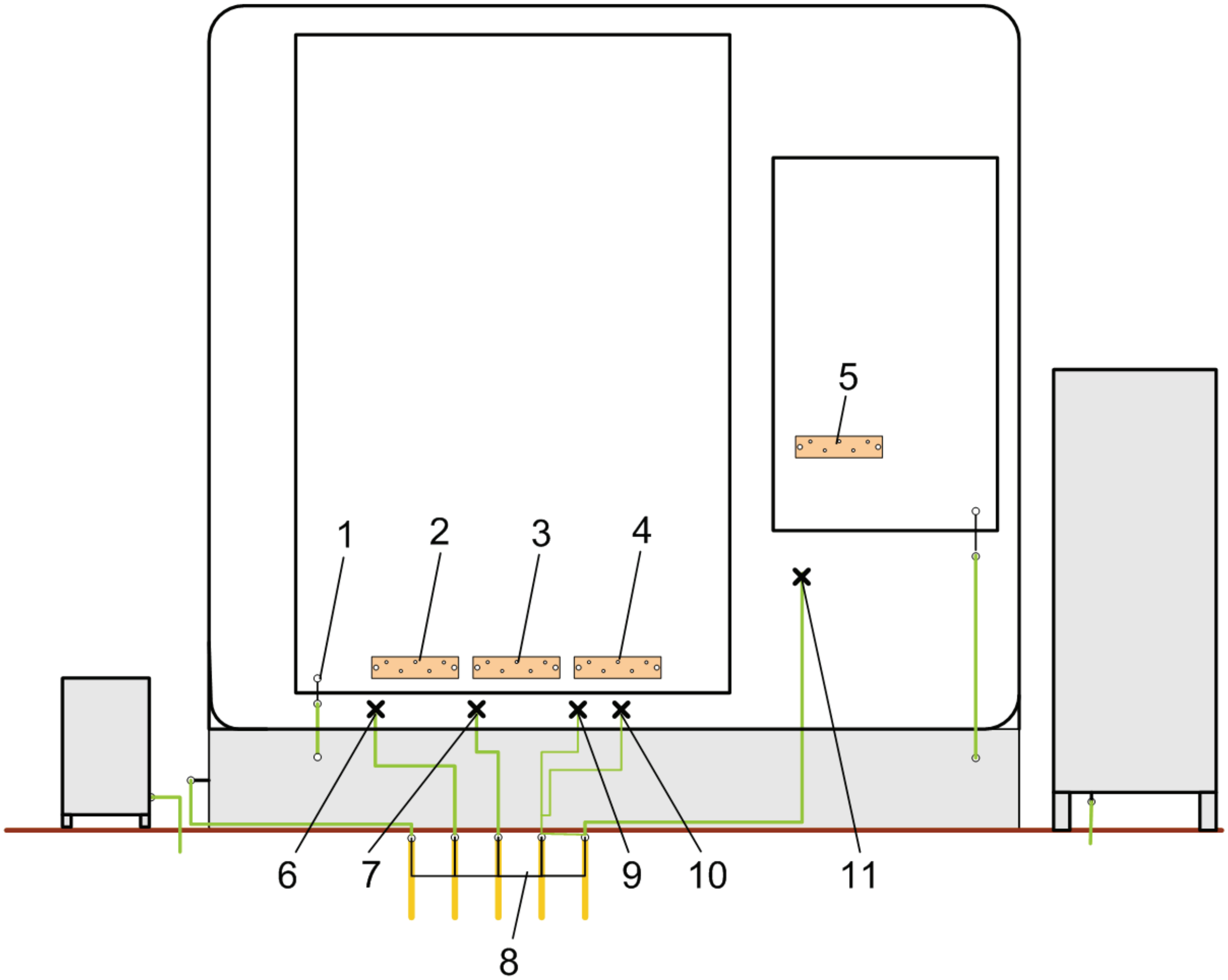


Figure 4.4.2 Grounding Resistance Test Illustration

Table 4.4.2 Grounding Resistance Test Illustration

Index No.	Description and/or Instructions
1	Frame Ground (FG) connection; from control box to gas-turbine package skid. The FG must be tied in the most direct possible path to the Earth Ground Electrode or Marine Platform Grounding Point. **WARNING** Do not disconnect Frame Ground (FG) connections from any control box to gas-turbine package skid. The purpose of the frame ground is to reduce hazards to personnel.
2	Power Earth (PE) Bus Bar **NOTE** On generator sets, the 0 Vdc wire conductor, branded as "0V", must be removed from the Power Earth (PE) Bus Bar.
3	Instrument Earth (IE) Bus Bar

Table 4.4.2 Grounding Resistance Test Illustration, Contd

Index No.	Description and/or Instructions
4	If applicable, Intrinsic Safe Earth (IS) bus bar
5	If applicable, Hazardous Area Instrument Earth (HAIE) bus bar
6	Power Earth (PE) 4-gauge AWG conductor, or larger, wire. This wire must be removed from the PE Bus Bar (2).
7	Instrument Earth (IE) 4-gauge AWG conductor, or larger, wire. This wire must be removed from IE Bus Bar (3).
8	Earth Ground Electrode or Marine Platform Grounding Point
9	If applicable, Intrinsic Safe Earth (IS) 12-gauge AWG or larger conductor wire. This wire must be removed from the IS Bus Bar (4).
10	If applicable, Intrinsic Safe Earth (IS) 12-gauge AWG or larger conductor wire. This wire must be removed from the IS Bus Bar (4).
11	Hazardous Area Instrument Earth (HAIE) 4-gauge AWG conductor, or larger, wire This wire must be removed from the HAIE Bus Bar (5).

Do the following procedure to make sure buses are isolated from each other.

1. Make sure all power sources are turned off before proceeding.

2. Obey the following WARNING:

⚠ WARNING

Do not disconnect Frame Ground (FG) connections from any control box to gas-turbine package skid. The purpose of the frame ground is to reduce hazards to personnel.

3. Make sure that PE, IE, IS, and HAIE buses (2,3,4) are not connected; buses must be isolated.

4. At the PE, IE, IS, and HAIE buses (Figure 4.4.2, Index Numbers: 2, 3, 4, 5) disconnect the ground conductors cables (Index Numbers: 6, 7, 9, 10, and 11) that are connected to the Earth Ground Electrode or Marine Platform Grounding Point (8).

5. Due to the 1-megohm-resistor network in the ControlNet™ adapters, connections between the following buses must be removed:

   a. On a generator set, the 0 Vdc wire conductor, branded as "0V", must be removed from the Power Earth (PE) Bus Bar.

   b. The frame ground (FG) connection to the PE bus;

6. Check resistance between each of the bus connections (2, 3, 4, 5). None should be less than one megohm.

7. After the isolation checks are completed, reconnect the grounding conductors to their respective ground points.

Grounding Resistance Test

NOTE

If noise problems are present or Vac measured greater than 250 mVac, do the following procedure.

Determine that the resistance levels between the grounds listed in the following are within the limits specified, or are within the limits specified on the General Arrangement engineering drawing.

1. Make sure the resistance between grounds is within the levels given below:

   a. Measure the FG connection (1, Figure 4.4.2).

   NOTE

   The resistance between the FG connection and the Earth Ground Electrode or Marine Platform Grounding Point (8) must be less than one ohm. If FG resistance exceeds five ohms, make sure that connections are tight, dry, clean, and free of corrosion. Also make sure that the ground conductors are the proper sizes in accordance with the General Arrangement engineering drawing.

   b. Measure the PE connection (2, Figure 4.4.2).

   NOTE

   The resistance between the PE connection and the Earth Ground Electrode or Marine Platform Grounding Point (8) must be less than one ohm. If PE bus resistance exceeds five ohms, make sure connections are tight, dry, clean, and free of corrosion. Also make sure that the ground conductors are the proper sizes in accordance with the General Arrangement engineering drawing.

   c. Measure the IE connection (3, Figure 4.4.2).

NOTE

The resistance between the IE connection and the Earth Ground Electrode or Marine Platform Grounding Point (8) must be less than one ohm. However, the resistance from any *Bently Nevada*™ 1701 Field Monitor Machinery Protection System grounding HAIE terminal must not exceed one ohm to the Earth Ground Electrode or Marine Platform Grounding Point.

d. If intrinsically safe equipment is used, measure the IS connection (4, Figure 4.4.2).

NOTE

The resistance between the IS connection and the Earth Ground Electrode or Marine Platform Grounding Point (8) must be less than one ohm. If the IS resistance exceeds one ohm, check to make sure that the connections are tight, dry, clean, and free of corrosion. Make sure the ground conductors are the sizes required by the General Arrangement engineering drawing, wiring diagram, electrical schematic, and any other electrical specification.

Advanced Grounding Test Troubleshooting (Using An Oscilloscope)

NOTE

If noise problems are present or Vac measured greater than 250 mVa, do the following procedure.

1. Use an oscilloscope to measure any existing AC ripple. The maximum allowed value is 250 mV RMS.
2. Make sure analog signal wires are shielded and appropriately connected.
3. Make sure that noise-sensitive signal wires are routed separately from cables that have high noise potential.

4.4.5 Controller Battery Replacement

⚠ WARNING

Failure to follow the lithium battery handling guidelines in Supplementary Data may result in damaged equipment and/or injury to personnel.

CAUTION

The controller should be powered up when replacing the internal lithium battery. The program stored in the controller's memory will be lost if the backup battery is removed with the unit powered down.

The controller's lithium battery should be replaced every year. The battery must be replaced when the BATT status indicator is red. Refer to Supplementary Data for important battery replacement information and safety guidelines for proper transportation, disposal, storage, and handling of lithium batteries.

4.4.6 Correcting ControlNet Network Noise

CABLES

Acceptable cables are listed in Table 4.4.3. Use of other cables could cause communication problems with the ControlNet system.

CAUTION

Do not subject cables to sharp bend radii. This can cause coaxial cable damage. Minimum bend radius for Allen Bradley 1786-RG6 cable is 3 inches. Minimum bend radius for gray drop cables is 1.5 inches.

Table 4.4.3 Acceptable ControlNet Cables

Solar Part Number	Cable Type	Manufacturer Part Number
1060181	Standard PVC	Allen Bradley: 1786-RG6 Belden: 3092A CommScope: 5060
1060182	Flooded Burial	Allen Bradley: N/A Belden: 1190A CommScope: 5060B
1060183	High Flex	Allen Bradley: 1786-RG6F/B Belden: 3092F CommScope: 5060F
1060184	Armored	Allen Bradley: N/A Belden: 123092A CommScope: 5060A

CONNECTORS

Use either of the following connectors:

- Allen Bradley 1786-BNC/B
- Amphenol 31-71000-RFX

Both of these connectors are stocked under Solar Part Number 1020225.

CAUTION

Ensure that correct connectors are used. Use of other connectors can cause ControlNet system communication problems.

CRIMPING AND CUTTING TOOL

Use Allen Bradley ControlNet Coaxial Tool Kit 1786-CTK/B for crimping or cutting cables. This is stocked under Solar part number 1025013-100. When newly installed on a cable end, a BNC connector must be tested with either a 60 lb pull or, where measured testing is not practical, by using a strong hand pull.

DIAGNOSTIC TESTS

Five types of diagnostic tests can be used to check the health of the ControlNet network:

- View the RSLinx diagnostic screen
- NetChecker test
- Node troubleshooting
- Cross-wiring test
- Multimeter test for shorts and open circuits

RSLinx Screen Diagnostic Tool

To troubleshoot the system when a noise problem is suspected on the network, monitor the RSLinx diagnostic screen and error counters for each ControlNet node. In general, the number of errors, or counts, is not as important as how often they change or adjust. The purpose of the diagnostic tool is to detect abnormal occurrences of errors, as distinguished from some normal baseline. If an error counter has accumulated a count of 10 over 24 hours, this is regarded as a normal level of noise on the network. Even if the counter accumulates 150 counts over 24 hours, without changing, this is considered a normal level of noise. If the error counter has a large number of errors (e.g. 250) reported over 24 hours, but is constant, at a lower level, when observed, it is likely that some major activity near the network caused a burst of noise to be recorded.

If the error counter changes frequently (e.g. one increment every 1 to 60 minutes), this is an abnormal level of noise on the network. Correct the noise problem immediately if the error counter increments on the RSLinx diagnostic screen. Such noise is not intermittent and could cause network problems. When this condition is noted, the NetChecker test must be performed to determine the source of the noise.

NetChecker Test

The Allen Bradley ControlNet NetChecker is used to test the ControlNet network. Part number for the NetChecker is 1788-CNCHKR. Use the tester as follows:

1. Follow the test procedure outlined in the instruction manual provided with the ControlNet NetChecker for initial testing.

   NOTE
   The instruction manual can also be found on the Rockwell Automation web site.

2. Draw a block diagram of the ControlNet network prior to testing.

   NOTE
   A line resistor is required at the beginning and the end of the line. The network must be a single line run of cable from tap to tap, with no loops.

3. Add a test connection in the form of a drop line. Refer to Figure 4.4.3 for basic wiring requirements.

   NOTE
   The test must be run from one end of the network.

4. Test the system for faults, noise, signal level, and proper wave shape.

   NOTE
   If all results of the NetChecker test are green LEDs, no fault LEDs, no buzzer, and the barograph indicator is within the range of 2 to 6, then the overall health of the network is acceptable, and no additional testing is required.

5. Perform the following troubleshooting procedure if the NetChecker indicates a problem.

Node Troubleshooting

If a communication problem is indicated with the NetChecker connected as shown in Figure 4.4.3 and the NetChecker set to global test position 00, select one node at a time (using the system network block diagram for guidance) until the problem node has been identified. The problem node can be determined as follows:

1. Disconnect the cable on the node just prior to the suspected problem node.
2. Replace the cable with an end-of-line resistor (point 4 in Figure 4.4.3). Retain the NetChecker in global test position 00.
3. Reconnect the removed cable if the communication problem clears.
4. Disconnect the cable on the next node (point 5 in Figure 4.4.3) and connect the end-of-line resistor. Repeat the global test with the NetChecker. If the communication problem returns, this is the problem node.
5. Remove the drop cable from the ACNR module (point 6 in Figure 4.4.3) and repeat the global test with the NetChecker. If the communication problem clears, replace the ACNR module. If the problem persists, check cables and BNC connectors on the Y tap for shorts, cuts, poor connections, or sharp bend radii.
6. Replace the Y tap with its drop cord, if necessary.

NOTE

There may be more than one problem node and additional testing may be needed.

7. Repeat test for any additional problems.
8. If necessary, repeat this test for the B communication link.

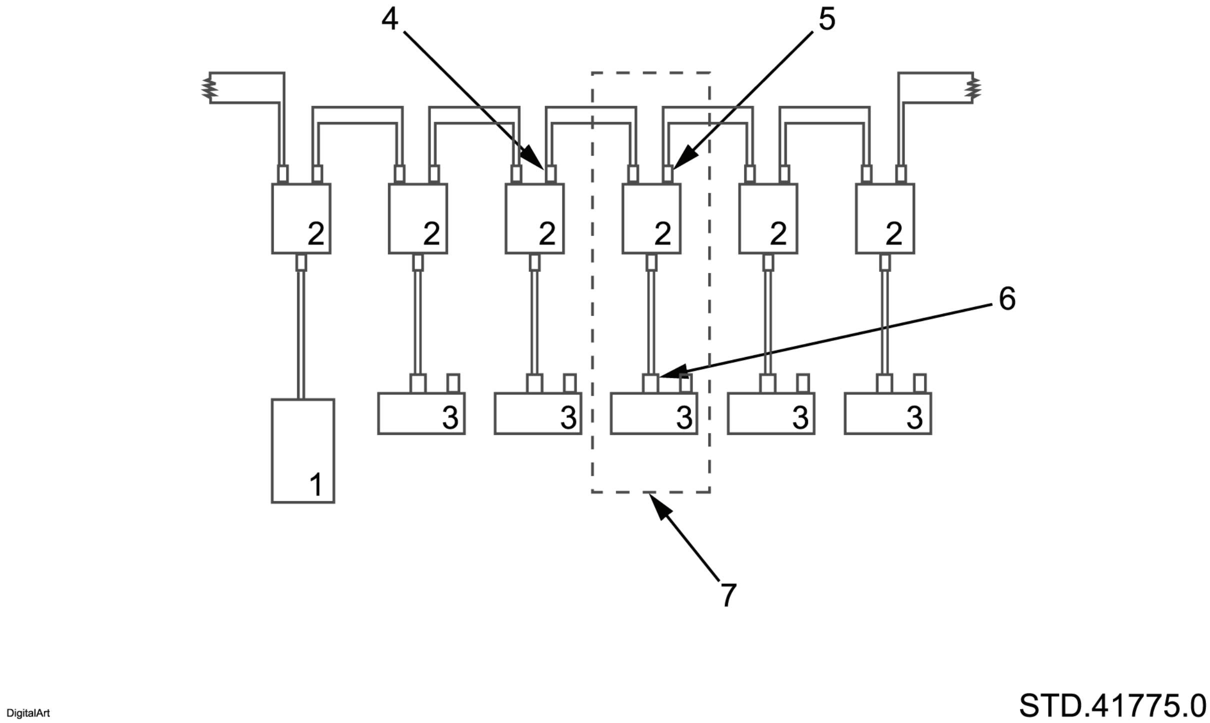


Figure 4.4.3 NetChecker Test Setup

Key for Figure 4.4.3			
1	NetChecker	2	Y Tap
3	Node XX	4	First disconnection point
5	Second disconnection point	6	Third disconnection point
7	Problem node		

Cross-Wiring Test

Test for cross-wiring between the A-channel communication link and the B-channel communication link as follows:

1. Disconnect the A link from the CNBR module at the PLC chassis.
2. Ensure that the A-light on each of the ACNR modules is blinking red.

NOTE
If any of the B-lights blink red, there is a crossover connection just prior to that module.

3. Refer to ControlNet block diagram to determine which module is just prior to the crossover connection.

Shorts and Open Circuits Multimeter Testing

Use a multimeter to test for shorts and open circuits as follows:

1. In the console, identify channels A and B of the dual media ControlNet architecture. Check for end-of-line resistors and make sure that the run of cable is from tap to tap with no additional loops.
2. Disconnect all of the ControlNet drop cables on one channel at their BNC connectors, but leave the connection at the Y tap connected.
3. Connect an ohmmeter to one of the BNC connectors at the end of the disconnected drop cables. See Figure 4.4.4.

NOTE

The ohmmeter should read between 37-45 ohms.

- If the resistance reading is below 37 ohms, a short circuit is indicated.
- If the resistance is between 75-85 ohms, one or more open connections are indicated. In this instance, the open circuit is between the ohmmeter and the point at which the end-of-line resistor has been removed.
- If the resistance reading is greater than 85 ohms, there are multiple open circuits, or the end-of-line resistors are missing. If the end-of-line resistors are present, remove one of them.
- If the ohmmeter reading is still greater than 85 ohms, the open circuit is between the remaining end-of-line resistor and the ohmmeter.

4. Reconnect the end-of-line resistor and remove the other end-of-line resistor.
5. Move the ohmmeter closer to the end-of-line resistor until the ohmmeter reads 75-85 ohms. This will allow you to locate the open circuit.
6. Reconnect both end-of-line resistors. The ohmmeter should read between 37-45 ohms.
7. It may be necessary to repeat this test for the other communication link.

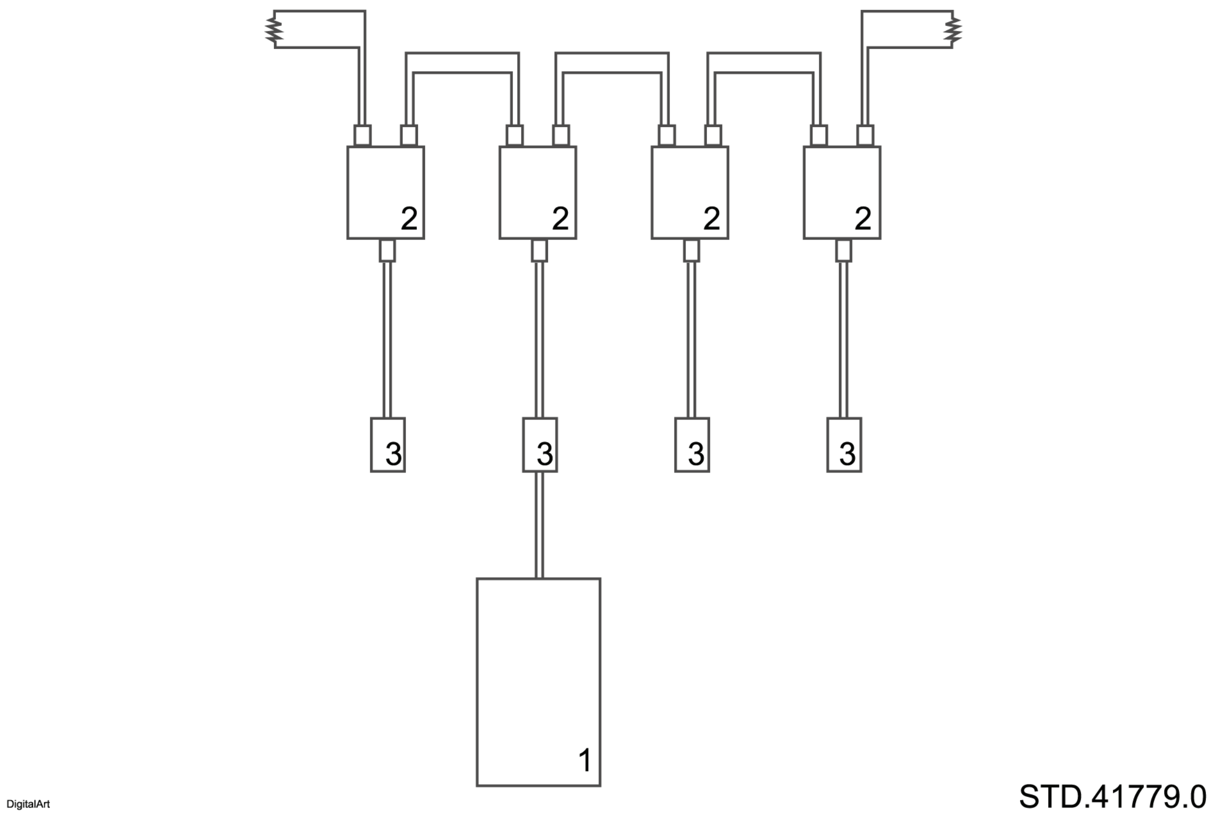


Figure 4.4.4 Multimeter Test Setup

Key for Figure 4.4.4			
1	Ohmmeter	2	Y Tap
3	BNC connector		

4.4.7 Fuse Replacement

WARNING

When working on a nonoperating package, always disable the power circuit by opening the control circuit breaker and placing the OFF/LOCAL/REMOTE, or OFF/LOCAL/AUXILIARY, keyswitch to OFF. To prevent system activation, remove the key from the keyswitch while work is underway. If the control circuit is protected with a fuse, open the battery circuit breaker. Attach a DO NOT START tag to the keyswitch, and to the opened circuit breaker to warn against the breaker being inadvertently closed.

WARNING

Do not start the package, or turn on any power if any DO NOT START, or other tags, which may indicate work is being performed, are attached to the package, control console, or battery charger. Tags may identify open circuit breakers or fuse holders. Check with maintenance personnel if any tags are discovered.

Prior to performing work on a circuit, use a voltmeter to ensure the circuit on which work will be done is not energized.

Fuse holders may protect 24-volt and 120-volt circuits. When replacing the fuses, follow tag and lockout safety procedures.

WARNING

Do not replace fuses that are under electric load, that is, that have electric power applied.

- Do not open a fuse holder which is under electric load.
- Install only fuses matching the amperage rating of the fuse being replaced. Do not install higher-rated amperage fuses in a fuse holder.

4.4.8 Backup Overspeed Monitor Test

Test the Backup Overspeed Monitor (OSM) semiannually. The OSM system is tested from the Maintenance screen of the display system.

WARNING

The Backup Overspeed Monitor is a primary safety system for the turbine package. Do not operate the turbine package without a properly functioning Backup Overspeed Monitor (OSM).

The OSM test is a system test that tests all components involved in overspeed detection and engine shutdown, including relays, fuel shutoff valve(s), controller and controller inputs/outputs.

To perform the test, the engine must be unloaded and for single-shaft engines, speed must be 100%.

Once the test is initiated, the control system reduces the overspeed setpoint at 1% per second until the engine is shut down. The time to reach engine shutdown initiation, and the engine speed at shutdown are measured, compared to the overspeed setpoint and an error valve is calculated.

Allowable error rate is +/- 0.5%.

TT4000 VERSION 5 DISPLAY SYSTEM

For the TT4000 system, test the OSM as follows:

1. On the Maintenance or Engine Details screen, touch the BACKUP OVERSPEED SYSTEM then press Start button .

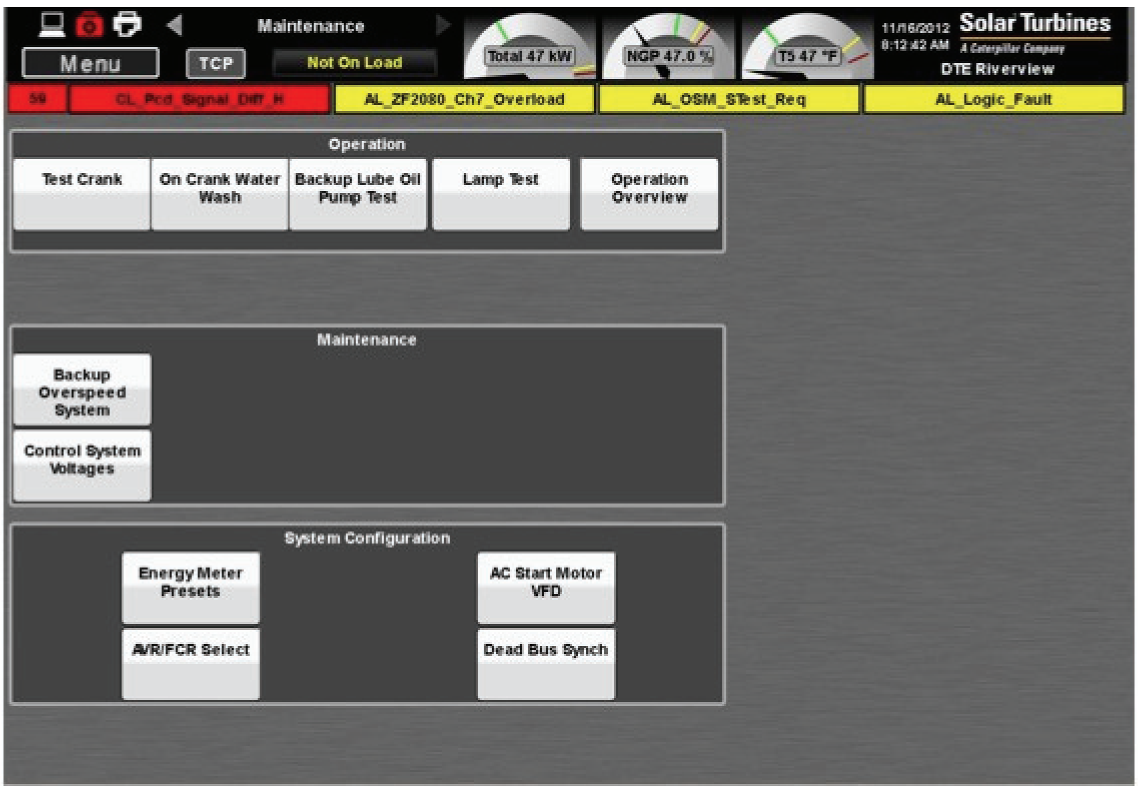


Figure 4.4.5 Maintenance Screen

NOTE

A popup screen will appear.

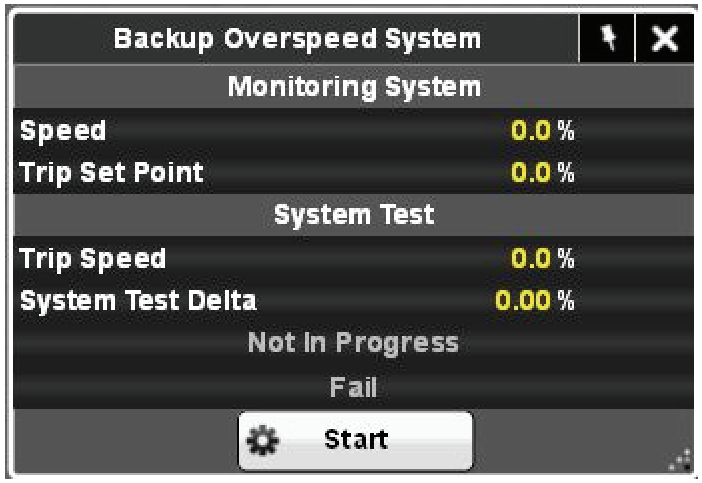


Figure 4.4.6 Backup Overspeed System Pop-Up Window

2. Touch the Start button.

NOTE

A successful test will be indicated by illumination of the Pass bar. Test values will be reported in indicated boxes

3. In the event of test failure inspect all system components. Correct as required.

4. Retest by repeating steps 1 and 2.

4.4.9 Nickel Cadmium Battery Maintenance

WARNING

The fluid, paste, or gel in batteries will severely burn human skin and eyes. Avoid contact with battery acid. Use protective gloves, face shields and protective clothing when working with battery acid. Do not take any acid into the mouth, or use transfer methods which can cause skin, mouth, or eye contact.

Nickel cadmium (NiCd) batteries are shipped wet and fully charged, or dry-discharged. When shipped dry-discharged, they require the addition of potassium hydroxide (KOH) electrolyte with lithium hydroxide (LiOH) additive, and a special First Charge before being put in service.

ACTIVATING NICKEL CADMIUM BATTERIES

CAUTION

Sulfuric acid, used as electrolyte in lead acid batteries, will ruin nickel cadmium batteries. Hydrometers, filler bulbs, or tools, that have been used with lead acid batteries must not be used, as they may be contaminated with acid, which can destroy a nickel cadmium battery.

1. Place battery to be filled on work bench. Never activate batteries in their operating position. Remove filler caps.
2. If dry electrolyte is available, make liquid as follows:
   - Specific gravity 1.20 - 1 US gallon distilled or deionized water to approximately 3.0 pounds dry KOH/LiOH mix (most applications)
3. Liquid electrolyte must conform to specific gravity requirements.
4. Check each cell, and add KOH liquid electrolyte to a level 1.5 to 2.0 in. (38.1 to 50.8 mm) above plates, or about midway between minimum and maximum marks. Check level after about 30 minutes, and add electrolyte to replace liquid absorbed. Specific gravity of the electrolyte in the battery should be 1.18 - 1.20. The specific gravity of potassium hydroxide/water solution does not change with the state of charge of the battery, as it does with electrolyte in lead acid batteries.
5. Replace filler caps.
6. Remove grease, electrolyte, or other substance from battery tops, and keep exterior dry and clean at all times.
7. Place battery cells in their operating position and secure them in battery rack.
8. Make electrical connections as required by wiring diagram. Most 24 Vdc systems consist of 20 series-connected cells. Most 120 Vdc systems consist of 96 series-connected cells.

NOTE

If a battery is shipped dry, a special First Charge is required.

First Charging

NiCd batteries must be given a special first charge, which is described in this subsection.

1. Close vents during charging.

2. First charging must be made at a constant current. Recommended current is 0.2 times C amperes, where C is the rated capacity of the battery in ampere-hours. (For example, a 256 ampere-hour battery should be charged at 0.2 times 256 = 51.2 amperes.) A ten-hour charging period will yield the recommended charge of 2 times C ampere hours. (In the 256 ampere-hour battery example, total charge is 512 ampere-hours.)

3. Alternative charging rates between 50% and 150% of recommended charging current may be used if the charger time period is adjusted to provide a total charge of 2 times C ampere-hours. In most cases, the high-rate or boost charger current capability is not sufficient to maintain current for the required time period. Most chargers provided are limited to 110% of nameplate ampere-hour rating. Where chargers are limited, connect the charge to half the cells provided, and maintain the recommended charging rate and time. Repeat the process for the second half of the cells. (For example, a 256 ampere-hour battery requires 2 times C, or 512 ampere-hours of charge. This may be accomplished by charging each battery half 10 hours at 51 amperes, and by charging the complete battery 20 hours at 51 amperes, or any combination using current between 50% and 150%, 25.6 amperes to 76.8 amperes, for sufficient time to yield approximately 512 ampere-hours.
A generous first charging is important to obtain maximum battery performance.

4. Wait at least two hours after charging before adjusting electrolyte level. After two hours add electrolyte to bring the liquid level to the maximum level line.

NOTE

Saft NiCd batteries are supplied with a nominal 0.2 inch (5 mm) layer, or blanket, of mineral oil on top of the electrolyte liquid in each cell. The mineral oil is inert relative to battery processes, and is used to reduce evaporation of water in the electrolyte.

CHARGING NICKEL CADMIUM BATTERIES

The battery charger supplies a constant voltage output for any load within its rating. Beyond approximately 110 percent of the rated charger output, the output voltage will drop rapidly, protecting the rectifier and the battery. The charger supplies a constant current to a discharged battery.

1. When connecting dc output leads to batteries, ensure that positive terminal of charger is connected to positive terminal of battery, and charger's negative terminal is connected to battery's negative terminal.

2. Before connecting ac input to charger, measure ac line voltage with an ac voltmeter. Ensure that line voltage is within limits specified on unit nameplate. Ensure measurement and nameplate limits are compatible.

NOTE

Some chargers operate on dual voltages such as 240 and 480 Vac. Refer to charger manual to determine correct terminal connections. Jumpers may need to be changed at the charger T1 power transformer if the available ac voltage differs from the as-shipped factory connections. Some chargers operate on a range of closely related voltages such as 208/220/230/240 ac. A change from the as-shipped factory connection requires a simple reconfiguration to a different T1 transformer tap in the charger. Refer to charger manual.

Battery chargers may have either dc output fuse protection or a main dc output circuit breaker, which is generally a two-pole device identified as DCB. This output circuit breaker should be closed prior to closing the ac power switch (or ACB circuit breaker, if so equipped). This startup method provides a soft-start output rather than a voltage surge, which could damage any directly connected loads.

3. Batteries are charged when ac power is on. Charge rate is determined by the state of charge of the batteries and will diminish to a trickle or float charge as batteries approach full charge.

4. Chargers float charge nickel cadmium batteries at approximately 1.4 volts per cell, or 28 volts total for a 20-cell battery, and 135 volts for a 96-cell 120-volt battery. High rate charging is approximately 1.57 volts per cell or 31 volts for a 20-cell battery and 150 V for a 96-cell battery.

NOTE

It is impossible to determine the state of charge of a nickel cadmium battery by measuring the open circuit voltage. It is always approximately 1.3 volts per cell regardless of state of charge.

USING NICKEL CADMIUM BATTERIES

CAUTION

Tools or metal objects must be kept off the cell tops and from between the cells. Short circuits may be caused by such objects and can seriously damage battery.

1. Maintain electrolyte level above top of plates as previously specified. Do not allow level to drop below top of plates. When level is low, add distilled water to restore level. Addition of water should not be required more than once or twice a year. If water is required more often, check charging rate, which may be too high.

2. Keep battery clean at all times. Even though salt formation (potassium carbonate - from potassium in electrolyte, and carbon dioxide in air) on top of the cells is not corrosive and does not damage the battery, excessive salt formation is an indication that the battery may be charged more than necessary.

NOTE

Specific gravity readings do not indicate the state of charge of a nickel cadmium battery. Float charging at the specified voltage ensures that the battery is maintained in a charged condition.

Ensure battery specific gravity readings are taken from samples of clear electrolyte free of the mineral oil blanket.

STORING NICKEL CADMIUM BATTERIES

1. When out of service for a prolonged period, disconnect battery from charger and turbine control circuits. If prolonged storage near the turbine package is detrimental due to environmental conditions, battery should be removed, cleaned, and stored in a cool dry place.

2. If storage is to be six months or more, remove intercell connectors to prevent the loss of charge due to creeping currents.

3. Do not store a filled and charged battery for more than 12 months before using it. Storing a filled and charged battery above 86°F (30°C) can cause it lose capacity. Capacity loss can be as much 5% per 18°F (10°C) above 86°F (30°C) per year.

NOTE

When a battery has been discharged or allowed to stand unused for a long period of time, some of the electrolyte becomes absorbed into the plates. Charging the battery will release the electrolyte and cause the liquid level to rise. After battery charging is completed, the liquid level should be checked and electrolyte and/or distilled water added as necessary.

4. A freshening charge after storage is recommended. Overcharging does not damage the battery. However, should the battery temperature rise to 115°F (46°C), stop the charge until the battery has cooled.

4.4.10 Monthly Battery And Charger Maintenance

WARNING

Prior to work on batteries and/or battery charger, the charger must be off and battery circuit breakers open. See the electrical schematic.

For maintenance, batteries must be in a passive condition, that is, neither being charged nor discharged. The turbine must be stopped, postlube cycle completed, and control system shut down. The battery charger must be off, and any battery circuit breakers open.

⚠ WARNING

Prior to start of work, follow proper lock out and tagging procedure to isolate hazardous energy sources.

Manufacturers must send a Material Safety Data Sheet (MSDS) with batteries. Read and understand the MSDS and the hazards of working with battery electrolyte/acid.

Batteries generate hydrogen gas that is highly flammable. To avoid fire and explosion, keep sparks and other ignition sources away from batteries.

The battery is electrically live at all times and cannot be isolated in the conventional sense. However, the voltage at any point can be reduced by the removal of inter-unit connectors.

Take care that short circuits are not caused by dropping or touching metal objects onto the cellblock terminals.

When working with batteries, wear protective equipment including, but not limited to, rubber gloves, chemical goggles, full face shield, rubber boots, rubber apron, and long sleeved clothing. Remove all jewelry such as watches, rings, bracelets, or other metal jewelry. Use only insulated tools.

Never work alone on 120-volt batteries, unless the high-voltage danger is minimized by first removing an intercell cable so that the battery assembly temporarily consists of two 60 volt subassemblies. Be certain that all loads are first disconnected and be certain that the battery charger is off at both its ac input and dc output.

PROCEDURE

⚠ WARNING

Never use a hydrometer for both lead acid (including lead calcium) and nickel cadmium (NiCd) cells. Mixing small amounts of electrolyte between battery types can cause battery failure.

NOTE

If there are discrepancies in the voltages and/or specific gravities of a few cells, examine these cells for case deformation, discoloration or deformation of the internal plates, excessive shedding, or flaking of the plates, electrolyte leakage at the terminal posts, etc. These conditions may indicate impending cell failure.

If a single lead acid calcium cell, or up to three NiCd cells, are questionable in a 120-volt assembly, they may be temporarily disconnected and bypassed with a jumper cable. However, the battery charger must be adjusted for the reduced cells. Similarly, one NiCd cell may be removed from a 20–cell 24-volt array.

1. Inspect battery rack for stability, and check that all bolts are tightened.

2. Inspect the battery and rack for dirt, moisture and corrosion. Clean as required. Do not use solvents on battery cells. Clean battery cells using only a clean cotton cloth moistened with clean water.

3. Where applicable, check the electrolyte level in all battery cells. If required, add distilled or deionized water to achieve desired electrolyte level.

4. Measure voltage of the two 60 volt subassemblies. Measure the voltage of individual cells (or multicell blocks if individual cells cannot be measured). Record voltages for comparison with future annual voltage measurements.

5. If the voltage of any cell is significantly lower than the other cells, measure the specific gravity of all cells. Do not measure sealed cells. Cell voltages should be within three percent of the average; a four percent variation is acceptable if the battery has been in service less than six months.

NOTE

Low specific gravity for a lead acid cell usually indicates the cell is not charged. Low specific gravity for a NiCd cell indicates an erroneous mixture or excessive water dilution.

6. If the tests indicate the battery is within acceptable tolerances, coat battery terminal connections with non-oxide grease. Do not allow grease on plastic components or cell covers. For automotive/truck batteries (usually in 12-volt block arrays), a petroleum jelly such as Vaseline may be used. Reconnect the cable used to isolate the two sections of the 120-volt battery assembly.

7. Verify that the charger is operating satisfactorily. Check battery output current with a voltmeter accurate to +/- 0.5%. Verify charger output at Float and High-Rate setting per Table 4.4.4.

Table 4.4.4 Battery Charger Settings

Battery Type	Number of Cells	Float Setting, volts	High-Rate Setting, volts
120 Vdc NiCd	96	135	150

8. If annual tests of the postlube motor are to be performed right away, proceed to them. If the postlube motor tests are not going to be performed immediately, close the battery circuit breakers, if applicable, and turn on the battery charger.

4.4.11 Annual Postlube System Test

Verify the integrity of the backup lube system and the available battery capacity at least once per year. With engine shut down and the postlube timer timed out, lock out the normal postlube pump and operate the backup lube oil system for the Pump Test Time specified in Table 4.4.5.

Test conditions are summarized:

Table 4.4.5 Test Requirements

Turbine	Minimum Pressure	Maximum Pressure	Pump Test Time
Centaur	4 psig (27.6 kPa), (0.28 bar), (0.28 kg/cm^2)	25 psig (172.4 kPa), (1.72 bar), (1.76 kg/cm^2)	55 minutes

Monitor system operation and battery voltage during the test time.

Batteries should be fully charged prior to performing tests. Full charge requires that batteries be float charged for a minimum 72-hour continuous period with no loads, which exceed battery charger output current capability. (If there are no loads on battery at the end of the 72 hours charge period, battery charger output current will be less than two amperes.)

Select a test time when the engine is not used for eight hours, and the station is manned for the first two hours.

PROCEDURE

WARNING

Read this procedure completely prior to starting test. To prevent injury to personnel and/or damage to equipment, observe voltage limits and other warnings detailed in the procedure.

1. Connect a voltmeter or a strip chart recorder to the battery terminals. Discontinue test if battery charger does not correspond to voltages specified in latest revision of Service Bulletin 5.9/103: Battery Charger Adjustments.

2. Install a dc clamp-on meter in the supply lines and monitor the current. Some systems have a shunt in the supply lines to facilitate this connection.

3. Turn off battery charger.

4. Monitor backup lube oil pump pressure. Run the pump for a minimum time per Table 4.4.5

5. Monitor lube oil header pressure. The postlube pressure must be in the range specified in Table 4.4.5. If pressure cannot be maintained in the specified range, stop the test and repair the system. Refer to Lube Oil Chapter 5.

6. Monitor backup dc motor current. Current should not exceed dc motor nameplate reading, regardless of oil temperature.

7. Check dc motor starter contactor and its thermal overload setting.

WARNING

Do not allow motor to trip.

Provide ample margin when setting the thermal overload. This is an emergency lube oil pump, and its purpose is to protect the turbine engine. Electric motor protection is secondary.

8. Monitor lube oil temperature and corresponding current draw. Compare records on primary lube oil temperature in winter and summer. Higher thermal overload settings may be required for operation in extreme winter conditions.

9. Measure and record battery voltage shortly after starting postlube cycle test, after test mid-point, before test is completed, and after test completion. These readings provide important information about the condition and capacity of the battery system. Correct system and/or replace batteries if problems are found. (In some cases battery problems may be caused by errors in charger settings, low battery electrolyte levels in one or more cells, or inadequate torque on battery terminal or downstream electrical connections.)
Minimum acceptable battery voltages are provided in Table 4.4.6

Table 4.4.6 Minimum Battery Voltages

System Voltage	Minimum Volts, Pump Running	Minimum Volts, After Pump Stops
120	104	114

WARNING

Do not allow 120 Vdc battery to operate below 96 Vdc.

10. At completion of backup postlube test, restore primary pre/postlube system and activate battery charger. Let batteries charge six hours minimum. Confirm battery charge by observing dc ammeter on charger. The ammeter should indicate a high current immediately after operating the backup lube pump. When the battery is nearing full recharge, the ammeter current will be less than two amps.

11. The engine is ready to return to service. Record and retain data for future reference.

5 LUBE OIL SYSTEM

5.1 GENERAL DESCRIPTION

The lube oil system supplies filtered lubricating oil to turbine engine bearings and various package components within operating pressure and temperature limits. The lube oil system is monitored by the package control system and incorporates a lube oil reservoir, oil cooling system, pumps, filters, pressure control devices, and temperature control valves.

5.1.1 General Lubricating Oil Requirements

Lubricating oil containing suitable additives must meet physical and chemical requirements in Table 5.1.1. Lubricating oil shall not contain additives that are degradable below 284°F (140°C) or water separable. Additives shall remain uniformly distributed throughout the oil at all temperatures above pour point up to 284°F (140°C).

Table 5.1.1 General Lubricating Oil Physical and Chemical Requirements

ASTM Std.	Oil Properties	Minimum Requirements For New Oil
D130	Copper Corrosion at 212 °F (100°C), three hours	Class 1b
D665	Rust Prevention, Procedure B	Pass
D892	Foam Limits, Milliliters Maximum Sequence 1 Sequence 2 Sequence 3	 50/0 50/0 50/0
D943	Oxidation Resistance, Minimum Number of Hours to 2.0 Neutralization Number	2000
D1401	Emulsion Test	40-40-0 (30)
D4628	Zinc, Weight %, Maximum	0.005
D1744	Water, Weight, Parts Per Million, Maximum	200 (0.02 wt. %)
D1947	Load Carrying Capacity, lb/in., Minimum	1000
D4172	Wear Preventative Characteristic, Scar Diameter, Millimeters Maximum (167°F [75°C] 1200 rpm, 88.1 lb [40kg], 1 hour)	0.90
D2273	Sediment Volume % Maximum	0.005

5.1.2 Petroleum Lubricating Oil

Petroleum lubricating oil ISO VG 32 (S150) is used on this installation. Refer to Solar Specification ES 9-224 for other qualified oils that can be used.

CAUTION

Before changing from one lubricating oil type to another, contact Solar Turbines Customer Services.

Petroleum oil consists of refined paraffinic basestock oil with suitable additives to meet general physical and chemical requirements in Table 5.1.1 and unique physical and chemical requirements in Table 5.1.2. ISO VG 32 (S150) oil is recommended for use in cold to moderate climates.

Table 5.1.2 Unique Petroleum Oil ISO VG 32 (S150) Physical and Chemical Requirements

ASTM Std.	Oil Properties	Minimum Requirements For New Oil
D445	Viscosity at +104°F (+40°C) SSU (cSt - mm^2/s) Maximum	165 (35.2)
D445	Viscosity at +212°F (+100°C) SSU (cSt - mm^2/s) Minimum	43.0 (5.09)
D92	Flash Point, COC, °F (°C) Minimum	+390 (+199)
D92	Fire Point, COC, °F (°C) Minimum	+440 (+227)
D97	Pour Point, °F (°C) Maximum	+15 (-9.5)
D664	Neutralization (Total Acid) Number, mgKOH/g Maximum	0.20
D1298	Specific Gravity, 60/60°F (15/15°C)	0.86-0.88
E659	Auto Ignition Temperature °F (°C) Minimum	+590 (+310)
D2270	Viscosity Index, Minimum	90

Petroleum oil operating temperature limits for ISO VG 32 (S150) oil are as follows:

- Oil pour point shall be 11°F (6°C) below minimum ambient temperature limit.
- Operating oil temperature limits into engine, after a minimum of 30-minutes engine operation, are +110°F to +165°F (+43°C to +74°C).

NOTE

Petroleum oil is suitable for preservation of the engine and components for a period of up to 90 days. Contact Solar Turbines Customer Services for special instructions for preservation if storage, shipping, or downtime longer than 90 days is expected.

5.1.3 Lube Oil Systems

The lube oil system is comprised of three interrelated systems.

- Pre/Post Lube Oil System
- Main Lube Oil System

- Backup Postlube System

PRE/POST LUBE OIL SYSTEM

The pre/post lube oil system supplies lube oil to the engine bearings and driven equipment before engine start up and after engine shutdown. The pre/post lube oil system operates independent of the main lube oil pump. The pre/post lube oil system can be activated by the control system to provide temporary lube oil in the event of failure of the main lube oil pump.

MAIN LUBE OIL SYSTEM

The main lube oil system provides lube oil to the engine bearing while the engine is running. The system is comprised of a reservoir pump or pumps, pressure and temperature control valves, filters, lube oil cooling system, supply manifolds and return lines.

BACKUP POSTLUBE SYSTEM

The backup postlube system supplies lube oil to the engine bearings if the pre/post system fails.

5.2 FUNCTIONAL DESCRIPTION

The following is a functional description of the lube oil system. For settings and system normal or operating design values, refer to the Lube Oil Schematic (149455).

5.2.1 Prelube Lube Oil Pump Check

When a cold engine start or test crank is initiated, the control system tests the backup postlube oil pump and the pre/post lube oil pump.

The control system energizes the backup postlube oil pump. Once the backup postlube oil pump has achieved the minimum pressure setpoint, the pump is deenergized. If the backup postlube oil pump fails to achieve the minimum pressure setpoint, a backup postlube oil pump failure shutdown is annunciated and the control system aborts the prelube lube oil pump check. If lube oil pressure fails to drop after the backup postlube oil pump is deenergized, a shutdown is annunciated and the control system aborts the prelube lube oil pump check.

After the lube oil pressure drops, the control system energizes the pre/post lube oil pump. If the pre/post lube oil pump discharge pressure reaches the minimum pressure setpoint, the prelube lube oil pump check is complete. The pre/post lube oil pump remains energized for the duration of the package prelube. If the pre/post lube oil pump fails to reach the minimum pressure setpoint and/or the pressure signal is lost, a pre/post lube oil pump failure shutdown is annunciated. The control system aborts the prelube lube oil pump check. Refer to Figure 5.2.1 for the prelube oil pump check sequence.

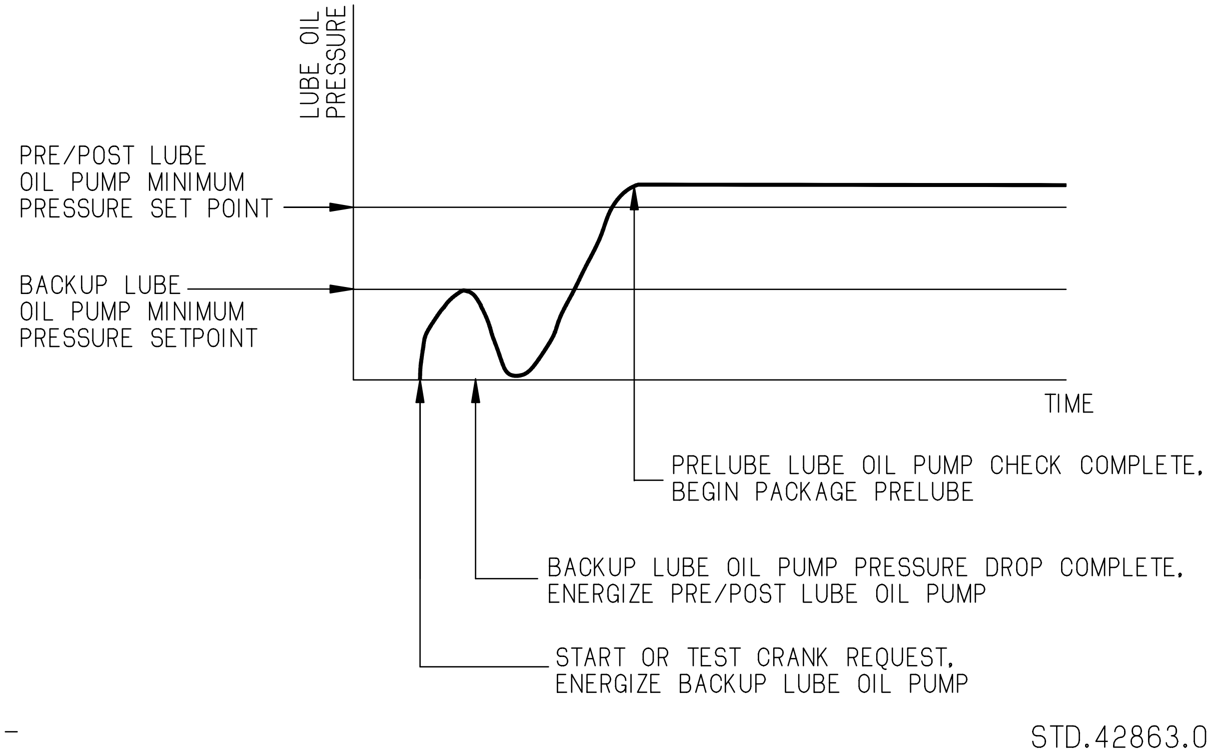


Figure 5.2.1 Prelube Lube Oil Pump Check Sequence

NOTE

If the pre/post lube oil pump is energized due to engine rundown, post lube or driven equipment lube oil requirements, the control system bypasses the prelube lube oil pump check when a start or test crank is initiated. For all restarts, the control system performs a backup postlube oil pump check even when the pre/post lube oil pump is energized.

5.2.2 Prelube

Upon completion of the prelube lube oil pump check, the control system starts the prelube oil timer. During prelube, lube oil header pressure must remain above the minimum pressure setpoint for 30 seconds. After 30 seconds of prelube, the control system permits start motor operation. If lube oil header pressure falls below the minimum pressure setpoint during the 30 second prelube, a pre/post lube oil pump fail shutdown is annunciated. The control system aborts the start or test crank attempt.

5.2.3 Engine Operation

During the start cycle the pre/post lube oil pump is deenergized when the engine speed (Ngp) is greater than the starter dropout setpoint and the engine-driven lube oil pump is providing sufficient pressure. Once engine speed is greater than 5% Ngp and lightoff temperature is achieved, the backup relay system is enabled. The backup relay system conducts postlube if the programmable logic controller (PLC) fails.

If the engine-driven lube oil pump fails to provide sufficient pressure after starter dropout, a low lube oil pressure alarm is annunciated and the pre/post lube oil pump is energized. If the minimum pressure is not reached and/or the pressure continues to drop, a low lube oil pressure shutdown is annunciated; fuel is shut off to the engine, the backup postlube oil pump is energized. The backup postlube oil pump remains energized for 30 seconds minimum to prevent pump cycling as the lube oil header pressure fluctuates.

During a test or purge crank the pre/post lube oil pump is energized to supply package lube oil. If the pre/post lube oil pump fails to supply minimum pressure, a pre/post lube oil pump failure shutdown is annunciated; the control system aborts the test or purge crank, the backup postlube oil pump is energized. The backup postlube oil pump remains energized for 30 seconds minimum to prevent pump cycling as the lube oil header pressure fluctuates.

NOTE

If the lube oil header pressure signal is lost, a shutdown is annunciated, fuel is shut-off to the engine and the pre/post lube oil pump is energized.

5.2.4 Engine Shutdown

If a shutdown is initiated after the engine has achieved starter motor dropout speed, the pre/post lube oil pump is energized when the engine-driven lube oil pump discharge pressure falls below the minimum setpoint. After the fuel is shut off to the engine, the control system starts the postlube timer. Once engine speed has decreased below 5% Ngp, the control system starts the rundown timer.

The rundown timer ensures lube oil header pressure is maintained until the engine and driven equipment stops rotating. Below 5% Ngp, the engine speed sensors are unable to accurately determine engine speed. To determine engine rundown time, the control system estimates the time required for the engine and driven equipment to stop rotating. During alarm conditions such as a fire, the control system limits postlube time. If a shutdown has been initiated due to a programmable logic controller (PLC) failure, the backup relay system operates engine rundown and postlube.

When a shutdown is initiated during a test crank, the pre/post lube oil pump supplies lube oil for engine and driven equipment rolldown. After engine speed decreases below 5% Ngp, the control system starts the rundown timer.

NOTE

If the lube oil header pressure signal is lost at any time during shutdown, an alarm is annunciated and the pre/post lube oil pump is energized. If the pre/post lube oil pump fails to provide sufficient pressure during rundown, a low lube oil pressure shutdown is annunciated and the backup postlube oil pump is energized. If the backup postlube oil pump is energized, it remains energized for 30 seconds minimum to prevent pump cycling as the lube oil header pressure fluctuates.

5.2.5 Postlube

⚠ WARNING

When a fast stop shutdown has been initiated due to fire detection, the pre/post lube oil pump remains energized for a preset rundown period. After the preset rundown period expires, the pre/post lube oil pump is deenergized for 20 minutes. After the 20-minute time period expires, the pre/post lube oil pump cycles on and off for a preset postlube period. If unsafe conditions still exist, the operator must manually abort the post lube cycle by opening the facility breakers for the pre/post lube oil pump and backup postlube oil pump.

After engine operation, a postlube is required to cool the engine bearings and driven equipment bearings. The pre/post lube oil pump is energized during rundown and continues to operate for the duration of the postlube timer. If the pre/post lube oil pump fails to maintain the minimum pressure setpoint during postlube, the backup postlube oil pump is energized.

If a fire occurs during postlube, the control system stops the postlube for a preset time period. After the time period expires, the postlube is resumed. An alarm is annunciated to indicate that postlube has resumed with a fire detected.

If the postlube is stopped for an extended period, heat soak can damage the engine bearings. If the maximum postlube interruption time period is exceeded, a bearing failure is annunciated and the postlube timer is reset. The control system prevents the start motor from energizing until the engine lockout timer expires or the postlube is resumed and completed.

NOTE

Upon control system power-up, a postlube is automatically initiated.

The backup relay system conducts postlube if the programmable logic controller (PLC) fails.

5.2.6 Backup Postlube Oil Pump Check

A backup postlube oil pump check is automatically performed once every 24 hours at 12:00 pm. The operator can also manually perform a backup postlube oil pump check by following the instructions on the Lube Details screen. Refer to the Systems Operator's Guide manual for more information.

When a backup postlube oil pump check is initiated, the control system energizes the pump to verify discharge pressure. The backup postlube oil pump is energized for the duration of the pump check. If the backup postlube oil pump fails to produce required pressure before the pump check timer times out, a backup postlube oil pump test fail alarm is annunciated. If the backup postlube oil pump discharge switch or transmitter indicate the pump is still producing pressure after the pump is deenergized, a backup postlube oil pump discharge switch or transmitter fail is annunciated.

5.3 COMPONENT DESCRIPTIONS

The following are brief descriptions of components typically used in a lube oil system. For reference designators, part numbers, component settings and operation values, refer to Lube Oil Schematic (149455).

5.3.1 Component and Reference Designators Identification

Components are identified by reference designators. Reference designators are letter/number codes that link the electrical schematic, wiring diagram, and/or the hydromechanical schematics to the component. A reference designator legend is provided on the front sheet of electrical/hydromechanical schematics and the wiring diagram. The reference designator legend contains the letter/number code, symbol, and description for each type of component.

Each reference designator contains three elements: alpha character(s), a location number, and a two or three digit number. The reference designator form is as follows:

AANXXX, where

AA - alpha character(s) indicating component type and use in the system

N is a number indicating component location:

1. Control console front
2. Inside control console
3. On turbine package skid
4. Motor starter in the motor control center
5. Other remote location
6. Switchgear
7. Inlet air system
8. Reserved
9. Reserved for hydromechanical components

XXX is a two or three digit number.

5.3.2 Electric Motors

Reference Designator: BNXXX

Electric motors are used to drive lube oil pumps and lube oil cooler fan motors. The type of motor may be alternating or direct current.

For maintenance requirements, refer to the maintenance section of this chapter.

5.3.3 Pump/Motor Assembly

Reference Designator: BPNXXX

The pump/motor assembly consists of a pump coupled to an electric motor installed on a mounting plate. The assembly is used to pump lube oil from the lube oil reservoir.

For maintenance requirements, refer to the maintenance section of this chapter.

5.3.4 Flow Sight Glasses

Reference Designator: FGNXXX

Flow sight glasses are mounted in the lube oil manifold drain lines and provide a visual indication of oil flow.

Flow sight glasses do not require routine maintenance.

5.3.5 Fixed Orifices

Reference Designator: FONXXX

Fixed orifices are placed in the lube oil system to control the rate and volume of the flow. The orifices diameter is not adjustable.

Fixed orifices do not require routine maintenance.

5.3.6 Filters/Strainers

Reference Designator: FSNXXX

Filters/strainers are positioned in the lube oil flow to prevent blockage of orifices and damage to components. Filters remove small particle contaminants from the lube oil. Strainers remove large particle contaminants from the lube oil.

For maintenance requirements, refer to the maintenance section of this chapter.

5.3.7 Lube Oil Heater

Reference Designator: HNXXX

The lube oil heater warms the lube oil in the reservoir and/or main lube oil manifold. The heater uses electric elements in direct contact with the lube oil. The heater is thermostatically controlled.

For maintenance requirements, refer to the maintenance section of this chapter.

5.3.8 Solenoid Valves

Reference Designator: LNXXX

Solenoid valves are electrically activated to control the direction of lube oil flow to the hydraulic actuators. Solenoid valves receive 24 Vdc signals from discrete output modules.

Solenoid valves do not require routine maintenance.

5.3.9 Level Indicator

Reference Designator: LINXXX

The level indicator visually indicates the level of lube oil in the lube oil reservoir.

Level indicators do not require routine maintenance.

5.3.10 Pumps

Reference Designator: PNXXX

Pumps supply lube oil from the lube oil reservoir to the engine and driven equipment. Pumps may be connected directly to the engine or connected to an electric motor. Pumps may also be driven by pneumatic pressure.

For maintenance requirements, refer to the maintenance section of this chapter.

5.3.11 Pressure Control Valve

Reference Designator: PCVNXXX

The pressure control valve regulates lube oil system pressure to prevent component damage.

For maintenance requirements, refer to the maintenance section of this chapter.

5.3.12 Resistance Temperature Detectors

Reference Designator: RTNXXX

RTDs measure temperatures in various locations in the lube oil system for control system monitoring. Temperature control is critical to safe turbine engine operation.

RTDs do not require routine maintenance.

5.3.13 Pressure Switches

Reference Designator: SNXXX

Pressure switches are used in various locations to monitor pressure within the lube oil system. Pressure switches verify the operation of the lube oil pumps.

Pressure switches do not require routine maintenance.

5.3.14 Level Switch

Reference Designator: SNXXX

The level switch monitors the level of lube oil in the lube oil reservoir and activates alarms when oil reaches certain levels.

Level switches do not require routine maintenance.

5.3.15 Vibration Switch

Reference Designator: SNXXX

The vibration switch monitors the vibration level of the lube oil cooler fan. The switch prevents the lube oil cooler fan from reaching excessive vibration levels.

Vibration switches do not require routine maintenance.

5.3.16 Temperature Control Valve

Reference Designator: TCVNXXX

The temperature control valve controls the flow of lube oil to the lube oil cooler. The control valve bypasses the cooler when the oil temperature is low. The valve is thermally activated.

Temperature control valves do not require routine maintenance.

5.3.17 Temperature Indicators

Reference Designator: TINXXX

Temperature indicators indicate the temperatures in various locations in the lube oil system. The indicators are not connected to the control system.

Temperature indicators do not require routine maintenance.

5.3.18 Pressure Transmitters

Reference Designator: TPNXXX

Pressure transmitters are used to monitor pressures within the lube oil system. The transmitters are connected to the control system.

Pressure transmitters do not require routine maintenance.

5.3.19 Differential Pressure Transmitter

Reference Designator: TPDNXXX

Differential pressure transmitters are used to measure pressure changes across various components in the lube system. The transmitters measure pressure at the inlet and outlet side of the component, and report the difference between the two measurements to the control system as the differential pressure. A high pressure may mean the component being monitored needs service.

Differential pressure transmitters do not require routine maintenance.

5.3.20 Thermowells

Reference Designator: TWNXXX

Thermowells are pressure tight receptacles designed to accept a temperature sensing element and provide a means to insert that element into a vessel or pipe.

Thermowells act as a barrier between the lube oil and the sensing element of a temperature measuring device.

Thermowells do not require routine maintenance.

5.3.21 Check Valves

Reference Designators: VCS/VCHNXXX

Check valves allow lube oil pressure to flow in one direction to prevent backflow in the system.

For maintenance requirements, refer to the maintenance section of this chapter.

5.3.22 Hand Valves

Reference Designator: VHNXXX

Hand valves are used to shutoff system pressure for component or filter maintenance.

Hand valves do not require routine maintenance.

5.3.23 Instrument Isolation Hand Valves

Reference Designator: VINXXX

Instrument isolation hand valves are used to isolate and relieve pressure from instruments to allow for maintenance, calibration or replacement.

Instrument isolation hand valves do not require routine maintenance.

5.3.24 Pressure Relief Valves

Reference Designator: VRNXXX

Pressure relief valves are backups to the pressure control valves. The relief valves prevent damage to components from system pressure if a pressure control valve fails.

Pressure relief valves do not require routine maintenance.

5.3.25 Transfer Hand Valve

Reference Designator: VTNXXX

The transfer hand valve manually controls the flow of lube oil to either of the lube oil filters. This allows for one lube oil filter to be in service while isolating the second filter for maintenance.

Transfer hand valves do not require routine maintenance.

5.4 MAINTENANCE REQUIREMENTS

Maintenance is required on the lube oil system at established intervals. There are two types of maintenance, *system maintenance* and *component maintenance*. For *system maintenance* intervals, refer to Table 5.4.1. For *component maintenance*, refer to the manufacturers' documentation provided in Table 5.4.2.

The recommended intervals are for nominal environmental and operating conditions. Severe environments and extreme conditions may require more frequent and extensive maintenance. The local environment, operating conditions and practices, and the availability of skilled technicians must be considered in establishing a maintenance plan. Preventive maintenance at specific intervals minimizes the need for corrective maintenance.

Maintenance intervals are defined as follows:

- D (day)
  Daily maintenance includes a walk-around inspection to ensure equipment is functioning properly and to detect leaks or obvious faults. Operating parameters should be recorded and analyzed for trends. This will help predict faults. Daily maintenance does not require equipment shutdown.

- M (month)
  Monthly maintenance includes a walk-around inspection to ensure equipment is functioning properly and to detect leaks or obvious faults. Operating parameters should be recorded and analyzed for trends. This will help predict faults. Monthly maintenance requires equipment shutdown.

- S (semiannual - 4000 operating hours)
  Semiannual maintenance emphasizes protective systems checkout and ensures optimum equipment performance. Regardless of hours of operation, this maintenance should be performed semiannually. Semiannual maintenance requires equipment shutdown.

- A (annual - 8000 operating hours)
  Annual maintenance involves disassembly of subsystem components for inspection. Problems noted in previous inspections should receive attention in annual maintenance whether or not they are listed in this manual. Detailed records help pinpoint malfunctions prior to performance impact. Annual maintenance requires equipment shutdown.

5.4.1 System Maintenance

WARNING

Before doing maintenance, read all facility safety policies and procedures to make sure you protect personnel and equipment.

WARNING

Before you work in any hazardous area, read the facility Permit to Work (PTW) policy and get a written PTW.

The permit to work must cover the following:

— Proper personal protective equipment,

— Proper procedures for using sniffers,

— Proper personnel monitoring and use of communication equipment,

— Proper ventilation,

— Physical hazards,

— Temperature hazards,

— Proper use of hearing protection,

— Evacuation procedures and routes.

Only qualified personnel may operate and maintain the package. The operator and maintenance personnel must understand turbine and driven equipment operation and function, and must also understand the controls, indicators, and operating limits.

Do not operate the package when conditions are unsafe. Unsafe conditions include:

— fuel leaks or lube oil leaks

— damaged electrical wiring

— damaged anchor bolts or structural members

Obey the facility procedure to lock out the controls and attach warning tags to them. Turn the OFF/LOCAL/REMOTE, OFF/LOCAL/AUXILIARY or OFF/LOCAL/AUX keyswitch to OFF. Make sure the battery charger, control console, and switchgear circuit breakers are open at the package motor control center (MCC). Before you do any work, attach “DO NOT OPERATE” tags to the start buttons and controls. Do not rely on color-coding of wiring for identification when you remove and install electrical components. Refer to the wiring diagram.

WARNING

Before you do maintenance on the package, inspect the alarm indications on the package display. If the package is equipped with an offskid display, contact the remote operator for alarms status. If the package has an onskid display, inspect the alarms status at the package. Identify alarms that might become a dangerous situation while you do maintenance, for example, an alarm for a gas leak that has reached the Lower Explosive Limit (LEL) can become a more serious leak during maintenance.

Set up signs and barriers that keep non-maintenance personnel and vehicles out of the work area. If the package has an enclosure, non-maintenance personnel can be injured or can cause damage to equipment when the enclosure is opened for maintenance.

If the package has an enclosure, do not block any enclosure door whether or not it has been opened for maintenance. In case of emergency, use the nearest door to get out of the enclosure.

If the package has an enclosure, make sure the enclosure has adequate light to safely work inside. If necessary, install reliable temporary lights in the enclosure before you do maintenance. Make sure maintenance personnel have hand lights immediately available to them in case primary lighting fails and the enclosure does not have automatic backup lighting.

Prevent explosive accumulations of natural gas, liquid fuel, oil mist, or solvent fumes. Make sure ventilation is adequate and immediately repair leaks. Before you use solvents or cleaning solutions, read the applicable Material Safety Data Sheets. Use solvents in appropriate maintenance facilities.

Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

If the package has an enclosure, make sure the pressure between the enclosure and its environment is equal before you open the doors. The enclosure can have higher or lower internal pressure compared to its environment. Maintenance personnel can be injured if doors are forcibly thrown open by positive internal pressure or are forcibly pulled closed by negative internal pressure.

WARNING

Before you attempt to enter the enclosure, use the negative-pressure door-jacking assembly, if installed, to make the internal and external pressure equal. You can damage the doors if you force them open.

If the package has an enclosure, make sure the doors are latched in place after they have been opened. Winds can suddenly and forcibly move unlatched doors.

Do not touch hot surfaces. Gas turbines create extremely high surface temperatures. Use insulated gloves and protective clothing/equipment when you do maintenance.

Gas turbines create extremely high exhaust and surface temperatures that can ignite the fuels and lubricants used in gas-turbine packages. Solar strongly urges that you work in only non-hazardous, gas-free conditions. If maintenance must be done under hazardous atmosphere conditions, before doing maintenance, review the facility-specific auto-ignition temperatures (AITs) of the fuels and lubricants used in the package. Allow the equipment to cool to 80% of the lowest AIT before you do maintenance. Use a hand-held, non-contact thermometer approved for use in hazardous atmospheres to measure surface temperatures.

Close all fuel supply valves to the package before servicing lube oil system components. Attach “DO NOT OPEN” tags to the valves. Make sure all pressure has completely dissipated.

Before you disconnect any system line, check pressure indicator gages and transmitter displays to make sure there is no pressure in the lines. Open hand-operated pressure-release valves slowly to release any pressure that might remain.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you use cleaning solvents or cleaning solutions. Prevent skin contact with solvents, solutions, or other materials that can be health hazards. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

WARNING

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you handle fuels, lube oils, and their residues. Prevent skin contact with fuels, lube oils, and their residues. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you drain, transfer, or store fuels, lube oils, and their residues, or any other materials that contain chemicals or compounds that can be health hazards.

If any lube oil system component was loosened or removed, test the component for leaks on start-up.

Refer to the Safety Requirements section located in the front of this manual for additional Warnings and Cautions.

Use following table for lube oil system maintenance. The table represents the minimum maintenance intervals. If site conditions are severe, the system maintenance intervals will need to be modified.

Table 5.4.1 System Maintenance Intervals

System/Description	D	M	S	A
Check the entire lube oil system for leaks. If leaks are present, shutdown the package and repair immediately.	X			
Check lube oil reservoir level indicator. Make a record of oil consumption rate. A spike in oil consumptions may indicate bearing seal failure.	X			
Verify proper operation of the lube oil auto fill system.	X			
Check oil cooler operation. Remove any debris blocking the air flow. Check for oil leaks. Checks can only be performed with the unit shut down. Refer to the Component Maintenance Table 5.4.2 for cooler information.		X		
Check the lube oil system pump hoses for pump pulsing. Pump pulsing may be caused by aerated oil or check valve failure. Pump pulsing can result in flex hose failures. Refer to the Component Maintenance Table 5.4.2 for check valve information. Refer to the Pump Pulsing Subsection 5.4.5 of this chapter for more information.	X			
Take a lube oil sample for laboratory analysis. Refer to the Lube Oil Analysis Subsection 5.4.4 of this chapter for instructions. For standby units, samples should be taken every 6 months. Make a record of the analysis results.		X		

5.4.2 Component Maintenance

⚠ WARNING

Before doing maintenance, read all facility safety policies and procedures to make sure you protect personnel and equipment.

Before you work in any hazardous area, read the facility Permit to Work (PTW) policy and get a written PTW.

The permit to work must cover the following:

— Proper personal protective equipment,

— Proper procedures for using sniffers,

— Proper personnel monitoring and use of communication equipment,

— Proper ventilation,

— Physical hazards,

— Temperature hazards,

— Proper use of hearing protection,

— Evacuation procedures and routes.

Only qualified personnel may operate and maintain the package. The operator and maintenance personnel must understand turbine and driven equipment operation and function, and must also understand the controls, indicators, and operating limits.

Do not operate the package when conditions are unsafe. Unsafe conditions include:

— fuel leaks or lube oil leaks

— damaged electrical wiring

— damaged anchor bolts or structural members

Obey the facility procedure to lock out the controls and attach warning tags to them. Turn the OFF/LOCAL/REMOTE, OFF/LOCAL/AUXILIARY or OFF/LOCAL/AUX keyswitch to OFF. Make sure the battery charger, control console, and switchgear circuit breakers are open at the package motor control center (MCC). Before you do any work, attach “DO

WARNING

NOT OPERATE" tags to the start buttons and controls. Do not rely on color-coding of wiring for identification when you remove and install electrical components. Refer to the wiring diagram.

Before you do maintenance on the package, inspect the alarm indications on the package display. If the package is equipped with an offskid display, contact the remote operator for alarms status. If the package has an onskid display, inspect the alarms status at the package. Identify alarms that might become a dangerous situation while you do maintenance, for example, an alarm for a gas leak that has reached the Lower Explosive Limit (LEL) can become a more serious leak during maintenance.

Set up signs and barriers that keep non-maintenance personnel and vehicles out of the work area. If the package has an enclosure, non-maintenance personnel can be injured or can cause damage to equipment when the enclosure is opened for maintenance.

If the package has an enclosure, do not block any enclosure door whether or not it has been opened for maintenance. In case of emergency, use the nearest door to get out of the enclosure.

If the package has an enclosure, make sure the enclosure has adequate light to safely work inside. If necessary, install reliable temporary lights in the enclosure before you do maintenance. Make sure maintenance personnel have hand lights immediately available to them in case primary lighting fails and the enclosure does not have automatic backup lighting.

Prevent explosive accumulations of natural gas, liquid fuel, oil mist, or solvent fumes. Make sure ventilation is adequate and immediately repair leaks. Before you use solvents or cleaning solutions, read the applicable Material Safety Data Sheets. Use solvents in appropriate maintenance facilities.

Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

WARNING

If the package has an enclosure, make sure the pressure between the enclosure and its environment is equal before you open the doors. The enclosure can have higher or lower internal pressure compared to its environment. Maintenance personnel can be injured if doors are forcibly thrown open by positive internal pressure or are forcibly pulled closed by negative internal pressure.

Before you attempt to enter the enclosure, use the negative-pressure door-jacking assembly, if installed, to make the internal and external pressure equal. You can damage the doors if you force them open.

If the package has an enclosure, make sure the doors are latched in place after they have been opened. Winds can suddenly and forcibly move unlatched doors.

Do not touch hot surfaces. Gas turbines create extremely high surface temperatures. Use insulated gloves and protective clothing/equipment when you do maintenance.

Gas turbines create extremely high exhaust and surface temperatures that can ignite the fuels and lubricants used in gas-turbine packages. Solar strongly urges that you work in only non-hazardous, gas-free conditions. If maintenance must be done under hazardous atmosphere conditions, before doing maintenance, review the facility-specific auto-ignition temperatures (AITs) of the fuels and lubricants used in the package. Allow the equipment to cool to 80% of the lowest AIT before you do maintenance. Use a hand-held, non-contact thermometer approved for use in hazardous atmospheres to measure surface temperatures.

Close all fuel supply valves to the package before servicing lube oil system components. Attach “DO NOT OPEN” tags to the valves. Make sure all pressure has completely dissipated.

Before you disconnect any system line, check pressure indicator gages and transmitter displays to make sure there is no pressure in the lines. Open hand-operated pressure-release valves slowly to release any pressure that might remain.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you use cleaning solvents or cleaning solutions. Prevent skin contact with solvents, solutions, or other materials that can be health

WARNING

hazards. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you handle fuels, lube oils, and their residues. Prevent skin contact with fuels, lube oils, and their residues. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you drain, transfer, or store fuels, lube oils, and their residues, or any other materials that contain chemicals or compounds that can be health hazards.

If any lube oil system component was loosened or removed, test the component for leaks on start-up.

Refer to the Safety Requirements section located in the front of this manual for additional Warnings and Cautions.

The following table lists components that require maintenance. Refer to the table for maintenance schedules and Supplementary Data information. Refer to Maintenance Procedures Subsection 5.4.3 for maintenance procedures.

Table 5.4.2 Component Maintenance

Component	Maintenance	Supplementary Data
Backup Postlube Pump Motor (B322)	Refer to instructions in Supplementary Data.	US Energy
Pre/Post Lube Oil Pump/Motor Assembly (BP902)	Refer to instructions in Supplementary Data.	Viking Pump
Lube Oil Heater (H390-1)	Refer to instructions in Supplementary Data.	Chromalox
Main Lube Oil Pump (P901)	Refer to instructions in Supplementary Data	Commercial Intertech
Backup Lube Oil Pump (P903)	Refer to instructions in Supplementary Data	Viking Pump
Pressure Control Valve (PCV901)	Refer to instructions in Supplementary Data.	Rivett
Lube Oil Check Valves (VCS904, VCS904-2)	Inspect valve every 16,000 hours. If valve shows wear, replace. Replace the valve at 32,000 hours.	PCC Valves and Controls

5.4.3 Maintenance Procedures

WARNING

Before doing maintenance, read all facility safety policies and procedures to make sure you protect personnel and equipment.

Before you work in any hazardous area, read the facility Permit to Work (PTW) policy and get a written PTW.

The permit to work must cover the following:

— Proper personal protective equipment,

— Proper procedures for using sniffers,

— Proper personnel monitoring and use of communication equipment,

— Proper ventilation,

— Physical hazards,

— Temperature hazards,

— Proper use of hearing protection,

— Evacuation procedures and routes.

Only qualified personnel may operate and maintain the package. The operator and maintenance personnel must understand turbine and driven equipment operation and function, and must also understand the controls, indicators, and operating limits.

Do not operate the package when conditions are unsafe. Unsafe conditions include:

— fuel leaks or lube oil leaks

— damaged electrical wiring

— damaged anchor bolts or structural members

Obey the facility procedure to lock out the controls and attach warning tags to them. Turn the OFF/LOCAL/REMOTE, OFF/LOCAL/AUXILIARY or OFF/LOCAL/AUX keyswitch to OFF. Make sure the battery charger, control console, and switchgear circuit breakers are open at the package motor control center (MCC). Before you do any work, attach “DO

WARNING

NOT OPERATE" tags to the start buttons and controls. Do not rely on color-coding of wiring for identification when you remove and install electrical components. Refer to the wiring diagram.

Before you do maintenance on the package, inspect the alarm indications on the package display. If the package is equipped with an offskid display, contact the remote operator for alarms status. If the package has an onskid display, inspect the alarms status at the package. Identify alarms that might become a dangerous situation while you do maintenance, for example, an alarm for a gas leak that has reached the Lower Explosive Limit (LEL) can become a more serious leak during maintenance.

Set up signs and barriers that keep non-maintenance personnel and vehicles out of the work area. If the package has an enclosure, non-maintenance personnel can be injured or can cause damage to equipment when the enclosure is opened for maintenance.

If the package has an enclosure, do not block any enclosure door whether or not it has been opened for maintenance. In case of emergency, use the nearest door to get out of the enclosure.

If the package has an enclosure, make sure the enclosure has adequate light to safely work inside. If necessary, install reliable temporary lights in the enclosure before you do maintenance. Make sure maintenance personnel have hand lights immediately available to them in case primary lighting fails and the enclosure does not have automatic backup lighting.

Prevent explosive accumulations of natural gas, liquid fuel, oil mist, or solvent fumes. Make sure ventilation is adequate and immediately repair leaks. Before you use solvents or cleaning solutions, read the applicable Material Safety Data Sheets. Use solvents in appropriate maintenance facilities.

Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

WARNING

If the package has an enclosure, make sure the pressure between the enclosure and its environment is equal before you open the doors. The enclosure can have higher or lower internal pressure compared to its environment. Maintenance personnel can be injured if doors are forcibly thrown open by positive internal pressure or are forcibly pulled closed by negative internal pressure.

Before you attempt to enter the enclosure, use the negative-pressure door-jacking assembly, if installed, to make the internal and external pressure equal. You can damage the doors if you force them open.

If the package has an enclosure, make sure the doors are latched in place after they have been opened. Winds can suddenly and forcibly move unlatched doors.

Do not touch hot surfaces. Gas turbines create extremely high surface temperatures. Use insulated gloves and protective clothing/equipment when you do maintenance.

Gas turbines create extremely high exhaust and surface temperatures that can ignite the fuels and lubricants used in gas-turbine packages. Solar strongly urges that you work in only non-hazardous, gas-free conditions. If maintenance must be done under hazardous atmosphere conditions, before doing maintenance, review the facility-specific auto-ignition temperatures (AITs) of the fuels and lubricants used in the package. Allow the equipment to cool to 80% of the lowest AIT before you do maintenance. Use a hand-held, non-contact thermometer approved for use in hazardous atmospheres to measure surface temperatures.

Close all fuel supply valves to the package before servicing lube oil system components. Attach “DO NOT OPEN” tags to the valves. Make sure all pressure has completely dissipated.

Before you disconnect any system line, check pressure indicator gages and transmitter displays to make sure there is no pressure in the lines. Open hand-operated pressure-release valves slowly to release any pressure that might remain.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you use cleaning solvents or cleaning solutions. Prevent skin contact with solvents, solutions, or other materials that can be health

WARNING

hazards. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you use any solvents, cleaning solutions, adhesives, sealants, lubricants, battery electrolytes, or any other materials that contain chemicals or compounds that can be health hazards.

Use protective equipment (face shields, masks, goggles, gloves, or clothing) and obey fire precautions when you handle fuels, lube oils, and their residues. Prevent skin contact with fuels, lube oils, and their residues. Do not inhale fumes. Read the applicable Material Safety Data Sheets before you drain, transfer, or store fuels, lube oils, and their residues, or any other materials that contain chemicals or compounds that can be health hazards.

If any lube oil system component was loosened or removed, test the component for leaks on start-up.

Refer to the Safety Requirements section located in the front of this manual for additional Warnings and Cautions.

Where removal and installation procedures are obvious, such as disconnecting plumbing or wiring and removal of attaching parts and hardware, instructions are omitted.

Except where otherwise described, standard industrial maintenance and repair practices are acceptable. Always discard old or used O-rings, seals, and gaskets, and replace with new ones.

Refer to Illustrated Parts List for repair parts or repair kits available on lube oil system components.

For cleaning methods and materials, refer to INTRODUCTION Chapter, GENERAL MAINTENANCE PROCEDURES, Cleaning/Degreasing/Decarbonizing 1.6.2.

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fitting, Gaskets, Seals and O-Rings 1.7.14.

BACKUP POSTLUBE PUMP AND MOTOR

Use the following procedures for removal and installation of Backup Postlube Pump Motor (B322) and Backup Postlube Pump (P903).

⚠ WARNING

Turn off and tag out electrical power to motor prior to removal.

⚠ CAUTION

Keep work areas clean. When removing parts for maintenance or repair, cover openings to prevent entry of foreign material.

Removal

1. Disconnect ground wire and electrical leads from pump motor B322. Tag disconnected electrical leads.
2. Remove inlet and discharge pipes and tubing from pump P903.

⚠ WARNING

Ensure the hoisting equipment provides adequate support for the pump and motor during removal.

3. If required, attach hoist to motor and pump P903. Take up slack.
4. Remove hardware attaching motor to mounting bracket.
5. Hoist motor and pump P903 clear of package skid.

Installation

NOTE

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fitting, Gaskets, Seals and O-Rings 1.7.14.

⚠ WARNING

Ensure the hoisting equipment provides adequate support for the pump and motor during installation.

1. Hoist motor B322 and pump P903 on mounting bracket and secure with attaching hardware.
2. Torque attaching hardware as required.

3. Disconnect hoist.

4. Connect discharge and inlet pipes and tubing to pump P903.

5. Torque discharge and inlet pipes and tube fittings as required.

6. Reconnect electrical leads to motor B322. Refer to the wiring diagram for proper connection. Reconnect ground wire. Remove tags.

WARNING

If any lube system component was loosened or removed, the component must be checked for oil leaks upon start-up. If lube oil leaks are present, immediately shut down the engine and repair the oil leak.

PRE/POST LUBE OIL PUMP/MOTOR ASSEMBLY

Use the following procedures for removal and installation of Pre/Post Lube Oil Pump/Motor Assembly (BP902).

WARNING

Turn off and tag out electrical power to motor prior to removal.

CAUTION

Keep work areas clean. When removing parts for maintenance or repair, cover openings to prevent entry of foreign material.

Removal

1. Disconnect ground wire and electrical leads from the pump/motor assembly. Tag disconnected electrical leads.

2. Remove inlet and discharge pipes and tubing from pump/motor assembly.

WARNING

Ensure the hoisting equipment provides adequate support for the pump and motor during removal.

3. If required, attach hoist to pump/motor assembly. Take up slack.

4. Remove hardware attaching pump/motor assembly to mounting bracket.

5. Hoist pump/motor assembly clear of package skid.

Installation

NOTE

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fitting, Gaskets, Seals and O-Rings 1.7.14.

⚠ WARNING

Ensure the hoisting equipment provides adequate support for the pump and motor during installation.

1. Position pump/motor assembly on mounting bracket and secure with attaching hardware.
2. Torque nuts as required.
3. Disconnect hoist.
4. Connect discharge and inlet pipes and tubing to pump/motor assembly.
5. Torque discharge and inlet pipes attaching hardware and tubing as required.
6. Reconnect electrical leads to pump/motor assembly. Refer to the wiring diagram for proper connection. Reconnect ground wire. Remove tags.

⚠ WARNING

If any lube system component was loosened or removed, the component must be checked for oil leaks upon start-up. If lube oil leaks are present, immediately shut down the engine and repair the oil leak.

MAIN LUBE OIL PUMP

Use the following procedures for removal and installation of Main Lube Oil Pump (P901).

⚠ WARNING

Turn off and tag out electric power.

CAUTION

Keep work areas clean. When removing parts for maintenance or repair, cover openings to prevent entry of foreign material.

Removal

1. If required, install eyebolts into lube oil pump housing.
2. Remove attaching hardware, discharge pipe, and gasket from pump.
3. Remove attaching hardware, suction pipe, and gasket from pump.
4. Attach hoist to eyebolts. Take up slack.

NOTE

The pump shaft is driven through a splined interconnect sleeve.

5. Remove hardware attaching pump to mounting pad.

WARNING

Ensure the hoisting equipment provides adequate support for the pump during removal.

6. Hoist pump clear of engine and skid.
7. Remove gasket from either pump or mounting pad flange.

Installation

NOTE

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fitting, Gaskets, Seals and O-Rings 1.7.14.

1. Clean inlet and discharge flanges on pump housing and piping.
2. Position gasket on pump.
   Ensure the hoisting equipment provides adequate support for the pump during installation.
3. Install pump to mounting pad. Secure with attaching hardware.

4. Torque attaching as required.
5. Disconnect hoist.
6. Install gasket and suction pipe to pump. Secure with attaching hardware.
7. Install gasket and discharge pipe to pump. Secure with attaching hardware.
8. Torque suction and discharge pipe attaching hardware as required.
9. If required, remove eyebolts.
10. Remove lock out tags.

⚠ WARNING

If any lube system component was loosened or removed, the component must be checked for oil leaks upon start-up. If lube oil leaks are present, immediately shut down the engine and repair the oil leak.

5.4.4 Lube Oil Analysis

Lube oil analysis is a useful tool in trending the wear that occurs within an engine. It allows for early detection of problems and ensures the lubricating quality of the oil. Samples must be taken at regular intervals. The most effective way to determine the condition of the lube oil is by conducting a spectrochemical analysis and a physical properties test. A spectrochemical analysis measures the amount of wear metals and other contaminants. The physical properties test checks the lube oil quality. Other tests that should be conducted are oil foaming and optical particle count.

Determining the quality of lube oil is more than the wear metal concentration levels. The overall trend (increasing, decreasing or stable) of the metals must be considered. The other factors are the physical properties of the oil and external sources of contamination.

SPECTROCHEMICAL ANALYSIS

Spectrochemical analysis measures the quantity of various elements in a lube oil sample. The elements listed in Table 5.4.3 are identified and measured by the spectrometer.

Wear Metals

Over extended time periods, metal-to-metal contact will result in surface wear and debris in the oil. The key to effective oil analysis is tracking the level of wear metals over time. The composition and concentration of wear metal debris depends on the equipment materials and the volume of oil. Because of the large volume of oil used in turbine engines, the ratio of wear debris to oil volume is low. With the start-up of new equipment, a certain level of wear debris is generated as rotation clearances are established. Iron, lead, copper, chromium, aluminum, nickel, silver, antimony, and tin are elements that indicate wear. In monitoring wear metal concentrations, gradual or abrupt increases indicate excessive wear. Refer to Table 5.4.3 for wear metals sources.

Table 5.4.3 Wear Metals and Potential Sources

Wear Metals	Potential Sources
Iron	Accessory drive gearbox gears and bearings. Generator set reduction gearboxes. Compressor set speed increasing and decreasing gearboxes.
Copper	Engine bearing and seals, thrust bearings, bearing cases (bronze), accessory drive gearbox bearings, gas compressor bearings and seals, Babbit material, reduction gearbox bearings, accessories (pumps), and oil coolers.
Tin	Engine bearings and seals, thrust bearings, reduction gearbox bearings, speed increasing and decreasing gearboxes, gas compressor bearings and seals.
Silver	Engine bearing overlays and seal overlays.
Antimony	Reduction gearbox bearings and radial bearing Babbit material.
Aluminum	Present in labyrinth seal of gas compressors and in buffer gas seals.
Lead	Engine bearings and seals, thrust bearings, reduction gearbox bearings, speed increasing and decreasing gearboxes, gas compressor bearings and seals.

Contaminants

Contamination is associated with substances entering the lube oil system from an outside source. The most common probable cause of contaminants is sample contamination or incorrect oil replenishment procedures. Silicon in the form of silicon dioxide is one of the most common contaminants and is the element that indicates the presence of dirt, sand, or dust in the oil. Other sources of silicon include seals, grease, antifoam and coolant additives. Any silicone level greater than 5 ppm should be considered abnormal. Wear metals are also a form of abrasive contaminants.

Oil Additives

Oil additives are chemical compounds added to oils to create new fluid properties, enhance properties already present, and reduce the rate at which undesirable changes take place in the oil during service life. Zinc, phosphorus, calcium, barium, and magnesium are the elements that could be blended into the various lubricants by the manufacturers. Phosphorus and zinc act as anti wear elements by coating the wetted parts and reducing friction. Calcium, barium, and magnesium are dispersants and detergents that flow through the system, pick up wear and contaminant particles, and carry them to the filter for removal from the oil. Potassium compounds are used as corrosion inhibitors, but may also be found as a mineral salt in sea water. Some anticorrosion additives can have adverse effects on other oil properties. The additives must be properly formulated.

Zinc

Solar Engineering Specification 9-224 calls for less than 50 ppm in new oil, that is, 50 ppm as an oil additive (not a contaminant or residue). Typically, oils containing zinc additive will have as much as 600 ppm zinc. Zinc causes sludge formation and galvanic attack of silver plating. These oils should not be used.

Coolant Additives

Sodium and boron are used as corrosion inhibitors and anti oxidants in reciprocating engines and will not generally show up with gas turbines. Sodium, however, may also enter the system as a contaminant from salt water or sea air.

PHYSICAL PROPERTIES TEST

Physical properties tests consist of a series of related tests to determine the classification, contamination, and degradation of a lubricant. The following paragraphs describe what is measured by the physical properties test:

Fuel Dilution

Fuel dilution is a measurement of the amount of unburned liquid fuel present in the lubricant and is determined by a distillation or flash test. This test will indicate such problems as fuel pump leakage into the accessory gear housing.

Water

Water present in the lube oil system is abnormal. The water test, when run in conjunction with other related tests, indicates emulsification of the lubricant from an outside source of contamination or condensation. When water is present in concentrations of 2000 ppm or more, the oil is condemned unless the concentration can be reduced below that limit by centrifuging or other methods.

Viscosity

Viscosity is the measure of the flow rate of a lubricant at a given temperature in relation to time. This test is indicative of a lubricant classification by grade, oxidation, and contamination. Solar Engineering Specification 9-224 lists the viscosity requirements for new oil. Lube oil must be replaced if the viscosity increases or decreases from the original viscosity by more than the percentages shown in Table 5.4.4.

Neutralization Number

Neutralization number is a number expressed in milligrams of a substance required to neutralize ten grams of lubricant. This test is used to show the relative changes in a lubricant. The neutralization number is reported as a Total Acid Number (TAN). A high TAN usually means overheated or oxidized oil. If the TAN test shows a significant increase in acidity since the last test, a Rotary Bomb Oxidation Test (RBOT) should be performed. Total Base Number (TBN) is a measurement of the reserve alkalinity remaining in the lubricant and is typically used with engine and hydraulic oils, not with turbine oils.

FOAMING TEST

Foaming is the formation of a layer of bubbles on the surface of the oil. Foaming becomes a problem when it is capable of hindering the normal drainage of oil back to the lube oil reservoir. Oil foaming can be reduced by the addition of antifoam compounds to the lube oil, however, all possible mechanical contributions should be investigated and eliminated first. The improper addition of antifoamant can cause air entrainment in the oil. The test used to measure foaming tendencies and the stability of the foam is described in ASTM D-892.

OPTICAL PARTICLE TEST

The optical particle test determines oil cleanliness. Solar uses a modified ISO 4406:1999 standard to establish the relationship between particle counts and cleanliness. This standard provides a three part code to specify the number of particles per milliliter of oil that is greater than or equal to 2 micrometers (μm), 5 μm, and 15 μm respectively. Each code number correlates to a particle concentration range and can be found in ISO 4406:1999. Solar specifies a cleanliness standard code of 16/14/12.

AIR ENTRAPMENT

Air entrainment (aeration) consists of small bubbles trapped beneath the surface of the oil. Air trapped within the oil will reduce the film strength of the oil causing problems with physical contact between the shafts and bearings and the meshing of gear teeth. Entrained air in the lube oil can also cause hose vibration and pump cavitation. The main cause of air entrainment is the misuse of antifoamant.

SAMPLING PROCEDURES

A sample is collected in a clean sample bottle from a valve located in a flowing bearing supply line or is drawn from the middle of the oil reservoir (tank) after the oil has been thoroughly mixed. It is then sent to a laboratory for analysis. A spectrochemical analysis is conducted to measure the amount of various wear metals in the oil, and physical properties tests are done to monitor oil quality. The key to effective oil analysis lies in the determination of changes over time. Samples must be taken at regular periodic intervals for the program to function properly.

Correct labeling of an oil sample is extremely important. An improperly labeled oil sample is useless if its analysis results cannot be matched to a particular package.

The label should show the following information:

- Sampling date

- Name of the company
- Solar package serial number
- Engine hours since last overhaul
- Hours since last oil change
- Amount of oil added since last sampling
- Type of oil used
- Type of fuel used

For generator sets, samples should be taken while the engine is operating and after oil has attained normal operating temperature. This will ensure that particle concentrations have achieved a uniform distribution throughout oil. It is also preferable to have a load on the engine during this time to ensure highest equilibrium level of wear-metal concentration.

For compressor and mechanical drive sets, samples must be taken only after engine shutdown. Prior to shutdown, the engine should attain normal operating temperature, preferably under loaded conditions.

⚠ WARNING

All gas compressor sets may contain potentially explosive gas mixture in the lube oil tanks during engine operation and after shutdown. Strict compliance with Solar Service Bulletin 13.2/101 is required.

NOTE

Do not insert sampling tube so deep as to pick up sediment or debris from the bottom of reservoir R901. Even small amounts of sediment will significantly affect analytical results of the sample.

TEST RESOURCES

Variances in the sampling and measurement techniques used by different labs can yield different results. Using a consistent sampling method and reliable lab are important if valid trends are to be established. For any questions regarding lube oil testing or problems, contact the closest Solar District Office. Oil testing for other purposes should be conducted independently.

OIL REPLACEMENT CRITERIA

Solar Engineering Specification 9-224 establishes the requirements for new oil and lists specific oil replacement criteria for used oil. The criteria requiring maintenance and/or oil replacement are listed in Table 5.4.4. Whenever a spectrochemical analysis is done, the sample should also be tested for color, odor, viscosity, water content, and particle contamination.

Table 5.4.4 Lube Oil In-Service Limits

Property	Limits (compared to new oil)
Water	Maximum 2,000 ppmw
Viscosity	+20% or -10%
Total Acid Number (TAN)	Increase of 0.4 mgKOH/g (for all oil types) or: 0.8 mg KOH/g maximum for synthesized hydrocarbon oils (Class I oils) 0.6 mg KOH/g maximum for petroleum oils (Class II oils) 2.0 mg KOH/g maximum for synthetic ester oils (Class III oils) 0.2 mg KOH/g maximum for phosphate ester oils (Class IV oils)
Rotary Bomb Oxidation Test (RBOT)	25% of original (new oil) value
Foaming Characteristics	Sequence I - 300/10 Sequence II- 300/10 (Guideline only, refer to Section 4.3.3 of ES-9-224).
Air Release at 122°F (50°C)	10 minutes maximum (Guideline only, refer to Section 4.3.4 of ES-9-224).

OIL FLUSHING GENERAL INFORMATION

Turbine package lube oil system flushing is performed at the factory and is not required at the installation site. Off skid interconnect piping, lube oil vents, and the reservoir auto fill system requires flushing. Refer to the installation drawings for the procedure. The lube oil cooler may also require flushing. Refer to the manufacture's documentation for information. In the event of a catastrophic failure, the entire lube oil system may require flushing. Contact Solar Turbines Customer Services Department for more information and flushing procedures.

5.4.5 Pump Pulsing

Pump pulsing or cavitation causes the flexible lube oil hoses to pulsate or vibrate leading to hose failure. If pump pulsing is a persistent problem, contact Solar Turbines Service Department.

Possible sources of pump pulsing/flexible hose failure are:

- The antifoaming and air entrainment properties of the lube oil used do not meet Solar’s minimum requirements.

- Restriction, blockage, or air leak in the lube oil pump suction line.
- Small oil sump volume does not provide sufficient time for air release.
- Marginal or missing baffles in the reservoir.
- Flex hoses are installed incorrectly or are damaged.

AERATED OIL

Lube oil pump cavitation and system pulsation are aggravated by aerated oil. For information on the causes of aerated oil, refer to the Lube Oil Analysis Subsection of this chapter.

LUBE OIL SYSTEM BLOCKAGE

The main cause of lube oil system blockage is check valve failure. When a check valve fails, debris from the valve can block the suction side of the pump. The main lube oil pump check valve or valves should be inspected for wear and damage.

AIR LEAKS

If the pump suction line is not completely tight, air is sucked into the line interior, forming air bubbles. Even a small leak can add a lot of air to the lube oil. Due to the vacuum inside the line, no external oil leak will be visible. If an air leak is present, replace the pump suction line gaskets. If the suction line is damaged, replace immediately.

6 ANCILLARY EQUIPMENT

6.1 GENERAL DESCRIPTION

The following subsections describe the ancillary equipment provided for this installation.

6.1.1 Exhaust System

CAUTION

If multiple turbines are using common exhaust ducting, ensure that each nonoperating turbine is protected from exhaust backflow. Exhaust backflow will damage the bearings in an idle turbine and impair reliable starting.

The exhaust system typically consists of all components downstream of the turbine engine exhaust flexible section that are necessary to ensure a smooth flow of exhaust from the turbine engine. The exhaust system handles gas flow as specified on the Mechanical Interface Drawing (149063). Pressure losses should not exceed specified limits. Excessive backpressure decreases turbine horsepower.

EXHAUST BELLOWS

The exhaust bellows connects the turbine exhaust diffuser to the exhaust silencer. The bellows is flexible and compensates for the expansion and contraction of the exhaust system.

NOTE

During any engine removal and installation, inspect the exhaust bellows for excessive corrosion, cracks or other damage. It is recommended to replace the exhaust bellows after 60,000 hours of operation.

EXHAUST SILENCER

The exhaust silencer, using sound-deadening material, reduces the noise from engine exhaust. The exhaust silencer and ducting are supported independently of the skid and do not impose excessive loads on the engine exhaust connection. Thermal expansion loads are avoided by proper location of the muffler and ducting and the use of flexible connections.

EXHAUST DRAIN

The exhaust drain allows the moisture, from snow or rain, to drain from the exhaust ducting. The use of an exhaust exit cap or hinged cover is not recommended because of the risk of backpressure causing turbine damage.

(This page intentionally left blank)

7 TURBINE ENGINE

7.1 GENERAL DESCRIPTION

The Centaur 40-4701 gas turbine engine (Figure 7.1.1) is a single-shaft, axial-flow design consisting of the following major assemblies/components:

- Reduction Drive
- Air Inlet
- Axial-Flow Compressor
- Annular Combustor With Fuel Injectors
- Turbine
- Exhaust Diffuser and Bellows

The major components of the engine are maintained in accurate alignment by mating flanges with pilot surfaces and are bolted together to form a rigid assembly.

The engine develops output power by converting the energy of expanding combustion gases to rotating mechanical power. The energy of the expanding gases drives the turbine and the single shaft through the engine. The single shaft drives the engine compressor rotor and reduction drive assembly which is attached to the air inlet. The reduction drive assembly contains the main output drive shaft, oil pump drive pad, and starter drive pad. The generator is connected to the main output drive shaft through a coupling assembly. The main oil pump and starter motor are connected directly to their drive pads. During start, the starter motor turns the reduction drive assembly which turns the engine.

Refer to Table for Centaur 40-4701 gas turbine engine specifications.

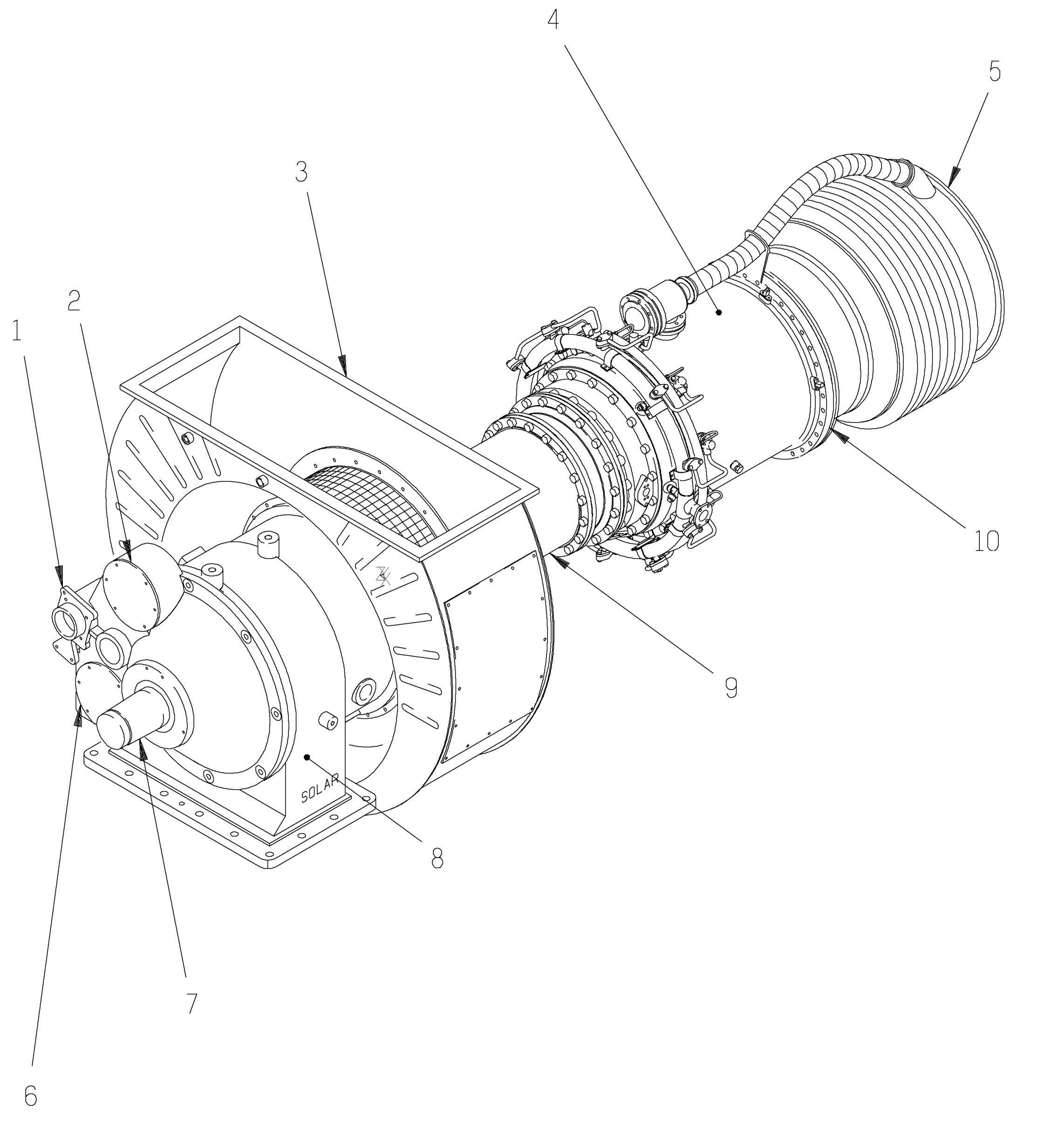


Figure 7.1.1 Centaur 40-4701

Key for Figure 7.1.1

1	Starter Drive Pad	2	Accessory Drive Pad
3	Air Inlet Duct	4	Combustor Assembly
5	Turbine Exhaust Diffuser and Bellows Assembly	6	Oil Pump Drive Pad
7	Output Drive Shaft	8	Reduction Drive Assembly
9	Engine Compressor Assembly	10	Turbine Assembly

Table 7.1.1 Centaur 40-4701 Gas Turbine Engine Specifications

Description	Data
COMPRESSOR	
Type	Axial
Number of Stages	11
Compression Ratio	10:1
Speed	14 944 rpm
COMBUSTION CHAMBER	
Type	Annular
Ignition	Torch
Number of Fuel Injectors	10
TURBINE	
Type	Reaction
Number of Stages	3
BEARINGS	
Journal	Tilt-Pad
Thrust	Fixed Tapered Land

7.2 ORIENTATION

Directional references (Figure 7.2.1) to the gas turbine package (left side, right side, forward, and aft) are established by viewing the package from the centerline of the turbine exhaust (aft), and looking toward the air inlet (forward).

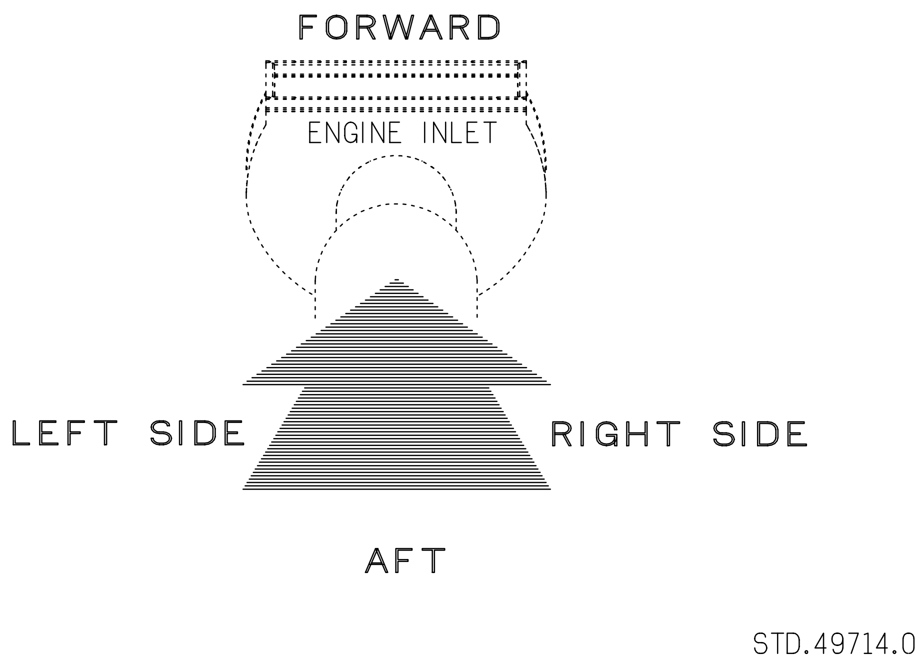


Figure 7.2.1 "Aft Looking Forward" Package Orientation

7.3 FUNCTIONAL DESCRIPTION

7.3.1 Gas Turbine Operation

Air is drawn into the engine air inlet, is compressed, fuel is mixed with this air and burned, and various parts of the engine work together to change the fuel energy (exhaust gas energy) to mechanical energy (shaft horsepower).

Upon gas turbine engine start initiation, the engine requires starter assistance until reaching a self-sustaining speed. Ambient air is drawn into the air inlet of the gas turbine and is compressed by the multi-stage axial-flow compressor. The compressed air is directed into the combustion chamber in a steady flow. A torch igniter, aimed into the combustion chamber and fed by a separate fuel line, is ignited by an igniter plug. Fuel is injected through the fuel injectors into the pressurized air within the combustor. The torch ignites the fuel/air mixture entering the combustor. At the end of the start cycle, the torch is extinguished, the starter motor drops out, and the engine continues to accelerate under its own power to idle speed.

Bootstrapping (continuous flame propagation) is maintained as long as there is adequate flow of pressurized air and fuel. The hot, pressurized gas from the combustion chamber expands through and drives the turbine, dropping in pressure and temperature as it exits the turbine.

The gas turbine requires approximately one-fourth of the total air it compresses to completely burn the supplied fuel. The excess air is used to cool the combustion chamber and mixes with the combustion products to reduce the gas temperature at the inlet to the first-stage turbine.

7.3.2 Oil Seal Pressurization Air

The engine incorporates three air-pressurized labyrinth seals to prevent leakage of lube oil from the bearings. Compressor discharge pressure is routed by external air lines through orifices to the compressor rotor forward oil seal. Compressor diffuser air is metered through internal passages to the compressor rotor aft oil seal and gas producer turbine oil seal.

7.3.3 Turbine Cooling Air

There are two principal sources of turbine cooling air. The first source of cooling air is from leakage between the aft compressor hub and compressor diffuser; the second source is from the compressor diffuser. The path of cooling air from the diffuser is split between the duct assembly (inner liner) and the convector (outer liner).

The cooling air duct assembly creates three separate concentric passages that surround the No. 3 bearing housing. Cooling air for the duct assembly, combustor, rotor disc and blades is directed from the compressor diffuser and flows through the duct assembly to the preswirler. The cooling air from the preswirler cools the leading edge of the first-stage turbine rotor disc and the first-stage rotor blades.

Leakage from the aft compressor hub (eleventh-stage) is the cooling air that is directed under the duct assembly. This air cools the No. 3 compressor bearing support housing, gas producer center-bolt, and rotor disc. The air that flows through passages in the gas producer turbine shaft is directed to the gas producer turbine rotor discs and center-bolt. The cooling air path is split between the radial holes in the aft hub of the first-stage and second-stage disc and the center bolt. The cooling air path in the rotor disc is metered to the forward face of the rotor discs by a labyrinth seal in the hub of each interstage nozzle diaphragm.

Cooling air supplied from the area surrounding the convector (outer liner) passes through the nozzle support housing screen and is directed by an annular duct to the first-stage turbine nozzle. Cooling air that enters the hollow first-stage nozzles passes through the outer impingement plate installed on each nozzle segment, and exits through a number of metering holes in the trailing edges of each first-stage nozzle vane.

7.3.4 Bleed Air System

The compressor bleed air system is designed to prevent engine surge by reducing backpressure imposed on the engine compressor during acceleration and low-speed operation. Compressed air (bleed air) is vented from the combustor housing to the turbine exhaust.

During acceleration, the bleed valve closes when the compressor discharge pressure reaches 72 psig (496 kPa), (5 bar), (5 kg/cm^2) (approximately 83% corrected Ngp) or above. During deceleration the bleed valve opens when the compressor discharge pressure reaches 38 psig (262 kPa), (2.6 bar), (2.6 kg/cm^2) or below.

7.3.5 Variable Vane System

The variable vane system is provided to avoid compressor surge and to maintain maximum engine performance over the entire turbine engine operating range. The variable vane system is designed to aerodynamically match the low pressure stages of the compressor with the high-pressure stages. This change of vane position varies the effective volume of air which enters the compressor rotor. The blade angle determines the compression characteristics for any particular compression stage. By changing the position of the variable vanes, the critical low-pressure stages are realigned to maintain a balanced airflow and compressor performance.

The variable vane system consists of a single row of variable Inlet Guide Vanes (IGVs) and two rows of Variable Stator Vanes (VSVs).

The variable vanes are opened as a function of Gas Producer Speed (Ngp) corrected to 59°F (15°C). Below 65% corrected Ngp, the variable vanes are in the closed position. At 65% increasing corrected Ngp, they begin to move toward the maximum open position and are fully open within 10 seconds. The vanes close immediately when corrected Ngp decreases below 90% or the engine receives a shutdown signal.

Movement of the variable vanes to closed or open position is achieved by means of a hydraulic cylinder-type actuator that operates on engine lube oil pressure, with the oil supply to (and return from) the actuator cylinder controlled by a four-way, pilot-operated control valve. The pilot valve is solenoid-actuated and responds to signals from the engine electrical control system.

7.4 COMPONENT DESCRIPTIONS

7.4.1 Reduction Drive Assembly

Since the required input speed of the generator is lower than the output speed of the turbine, a reduction drive assembly (Figure 7.4.1) is necessary.

The reduction drive assembly is an epicyclic, high-speed, star-gear design used to reduce the drive speed from the turbine engine to the generator. The reduction drive assembly is designed for an output speed of 1800 rpm for 60 Hz service.

The reduction drive assembly is located between the engine and the generator. It is bolted directly to the air inlet housing and the oil tank to provide a rigid support. For this reason, the reduction drive assembly does not require alignment with the engine. The firm attachment of the housing provides support to the forward end of the turbine engine.

The reduction drive assembly case consists of a large housing, attached to the air inlet housing, and a smaller output shaft case.

Mounted on the reduction drive assembly is a magnetic pickup which counts the speed of the gear teeth and transmits a signal to the speed monitor control box in the control panel. Another magnetic pickup device directs a signal to the governor to control turbine speed.

The reduction drive assembly gear train is a compound star arrangement with three equally spaced star clusters. The power flows through the input pinion (sun gear) (5) into three first-stage star gears (6), through three second-stage pinion gears (7), and to the second-stage ring gear (4) on the output shaft (9).

The input pinion assembly (5) is supported at one end by a ramp bearing mounted on an adapter on the gear carrier. The other end is supported by the three first-stage star gears (6). Pinion thrust loads are taken by a tapered land thrust bearing. The gear clusters have two sleeve bearings mounted inside their bores. The journal bearing is stationary and is mounted in the carrier to support the gear clusters.

The second-stage ring gear (4) is mounted on a hub with a loose fitting spline, which allows the ring to center itself on the output shaft (9) through a fixed spline.

A sprag-type one-way clutch is mounted on the starter gear shaft. The starter drives through the clutch. When the starter disengages, the sprags lift off the shaft and the clutch overruns continuously.

Each of the first-stage meshes in the power train is cooled and lubricated by three sets of two oil jets directed toward the sun gear between each pair of meshes. Each pinion in the second-stage is cooled and lubricated by two jets on the inboard side. Centrifugal force drives this oil into the ring gear teeth. It is then flung out at the open end of the ring and through holes at the inner end.

Additional oil jets cool and lubricate the accessory pinion gear mesh, the output ball bearing, and the one-way clutch on the starter shaft. All other accessory gear meshes and bearings are lubricated by air-oil mist generated in the housing by the high speed meshes.

The hydrodynamic ramp bearing and thrust bearing on the input pinion assembly and the sleeve bearings on the countershafts are pressure-fed with oil. Pressurized oil is provided by the externally mounted main lube oil pump.

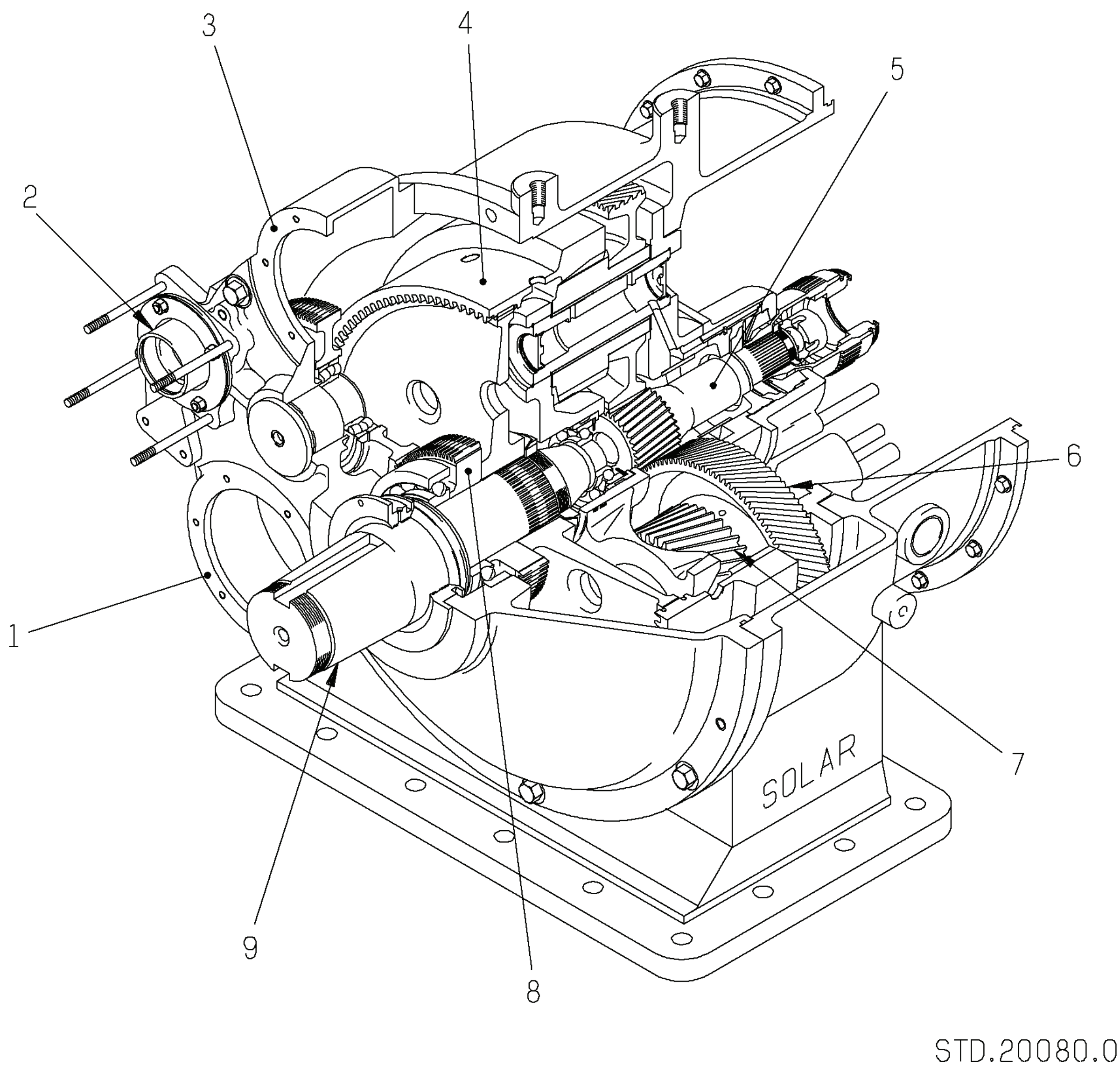


Figure 7.4.1 Cutaway View Reduction Drive Assembly

Key for Figure 7.4.1			
1	Lube Oil Pump Drive Pad	2	Starter Drive Pad
3	Accessory Drive Pad	4	Second-Stage Ring Gear

Key for Figure 7.4.1, Contd			
5	Input Pinion Assembly	6	First-Stage Star Gear
7	Second-Stage Pinion Gear	8	Accessory Drive Gear
9	Output Shaft		

7.4.2 Air Inlet Assembly

The air inlet assembly, located aft of the reduction drive assembly, is attached to the reduction drive assembly and the compressor case.

Air drawn through the air inlet filters and ducting follows an axial flow path to the air inlet duct. The air inlet duct provides a radial flow path for air drawn through the air inlet assembly into the engine compressor assembly. The air inlet duct contains bosses for water wash plumbing, temperature sensor, and a drain.

An annular opening in the air inlet assembly redirects the radial flow path to an axial flow path. The opening is covered with a heavy mesh screen to prevent the entry of solid foreign material into the gas producer air inlet. This screen is not to be considered an air filtration device. Included in the air inlet assembly are supports for the forward bearing housing assembly containing the No. 1 tilt-pad bearing and labyrinth seals.

7.4.3 Engine Compressor Assembly

The engine compressor assembly is an eleven-stage, axial-flow type. It includes an air inlet assembly, compressor variable and fixed vanes, compressor rotor assembly, compressor case assembly, diffuser assembly, and compressor bearing support housing.

The compressor case assembly is bolted to the air inlet assembly. The stator rows are as follows: one row of variable Inlet Guide Vanes (IGVs), two rows of Variable Stator Vanes (VSVs), nine fixed vane rows, and one fixed outlet guide vane row. The variable IGVs and VSVs are pneumatically controlled and hydraulically actuated.

The aft end of the compressor case is bolted to the diffuser assembly. The diffuser assembly contains the gas producer bearing assembly, the oil inlet and two oil drains, the compressor discharge pressure taps, turbine cooling air pressure tap and borescope access. The gas producer bearing assembly contains the No. 2 radial bearing, the thrust bearing and the No. 3 radial bearing. The No. 2 bearing is the tilting-pad type and it supports the aft end of the compressor rotor. The thrust bearing is adjacent to the No. 2 bearing and it is the fixed-ramp type. The No. 3 bearing is the tilting-pad type and it supports the turbine rotor.

7.4.4 Variable Vane System

The variable vane system (Figure 7.4.2) is a hydromechanical system. The actuator rod of the Variable Vane Control Actuator is connected by a turnbuckle to an actuating lever. Three turnbuckles are connected to the lever and to the three vane rings. Each ring contains the mechanisms that connect to the long vane shaft of each variable vane.

Each vane ring rotates its corresponding set of variable vanes through a range that is preadjusted at the factory. These vane adjustments are exacting and the resulting setpoints, in degrees, are unique to each individual engine. The setpoint is stenciled on the variable vane support.

Adjustment to the setpoint is controlled by the turnbuckles that interconnect the mechanical linkage components.

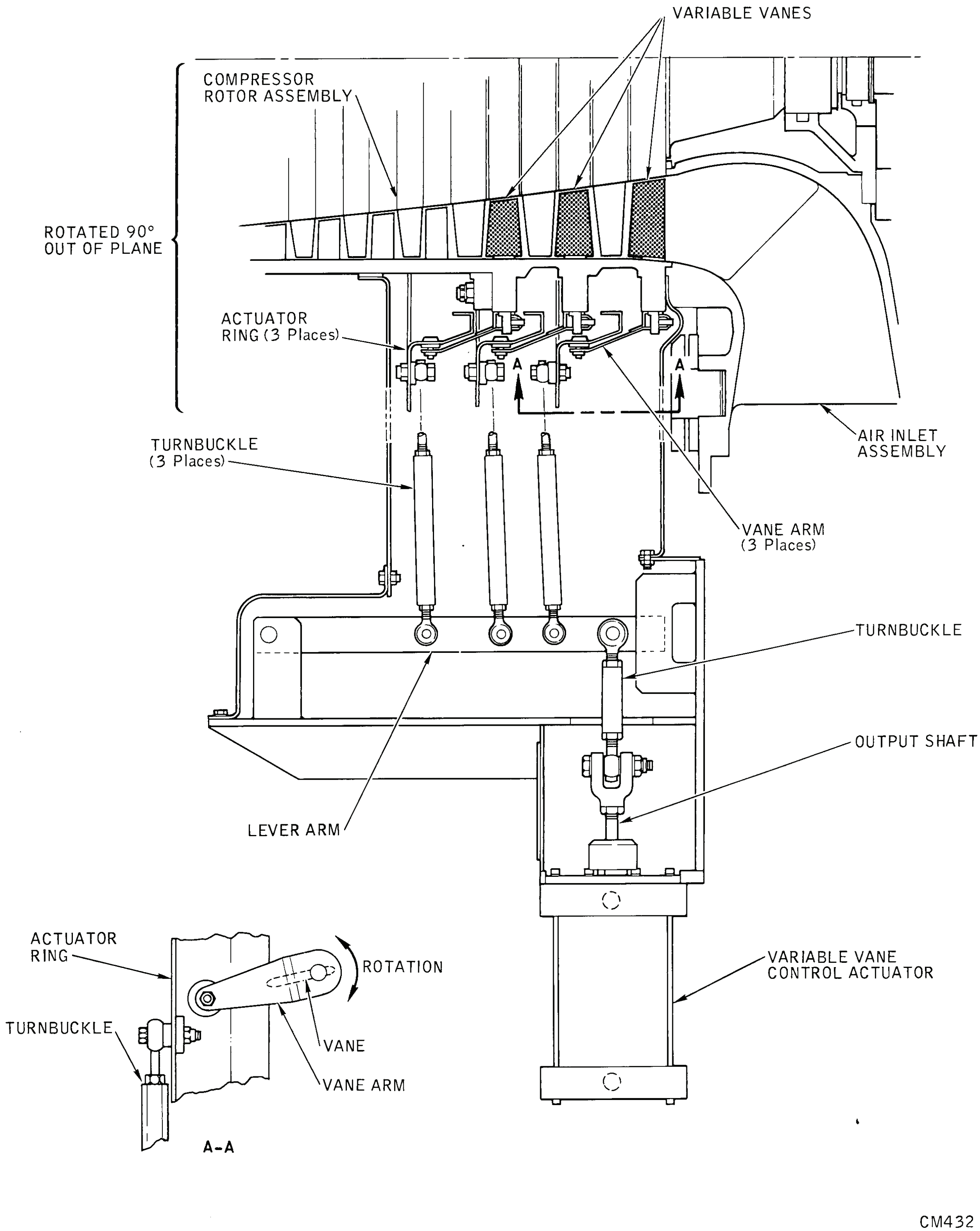


Figure 7.4.2 Variable Vane System

VARIABLE VANE CONTROL ACTUATOR

The Variable Vane Control Actuator is a hydraulic cylinder with actuator piston and actuator rod. Engine lubricating oil at nominal operating pressure is supplied, by way of a solenoid-operated control valve, to either side of the actuator piston to extend or retract the actuator rod and thus move the variable vanes to the maximum or minimum open position.

VARIABLE VANE SOLENOID VALVE

The variable vane solenoid valve is a two-position, four-way, spool-type valve, equipped with a three-way solenoid-actuated pilot valve. When the solenoid is de-energized, the piston chamber of the control spool valve is vented to the return to tank line. The spool valve return spring then acts to move the spool to direct engine lube oil supply pressure to the top side of the actuator piston while the lower side is vented to oil return. As a result, the actuator rod retracts, fully moving the vanes to the minimum open position. When the pilot solenoid is energized, the pilot valve vent closes and engine lube oil supply pressure is directed to the control valve piston chamber. Oil pressure on the control valve piston moves the valve spool against the return spring to direct engine lube oil pressure to the lower side of the actuator rod. The actuator rod extends fully and moves the variable vanes to the maximum open position.

MECHANICAL LINKAGE

The actuator rod of the variable vane control actuator is connected by a turnbuckle to an actuating lever. Three turnbuckles connect the lever to the three vane rings. Each ring contains the mechanisms that connect to the outboard ends of each variable vane.

Each vane ring rotates its corresponding set of vanes through a range that is preadjusted at the factory. These vane adjustments are exacting and the resulting setpoints in degrees, which are unique to each individual engine, are therefore stenciled on the variable vane support.

The approximate range of vane rotation from the minimum open to the maximum open position, respectively, are -35 degrees to +5 degrees for the inlet guide vanes, -29 degrees to 0 degree for the first-stage vanes, and -24 degrees to 0 degree for the second-stage vanes.

Adjustment of these settings is controlled by the turnbuckles that interconnect the mechanical linkage components.

7.4.5 Compressor Diffuser Assembly

The forward end of the compressor diffuser assembly is bolted to the aft end of the compressor case. The diffuser assembly supports the No. 2 and No. 3 bearing support housings and thrust balance diaphragm. The diffuser housing incorporates the oil inlet, two oil drain ports, compressor discharge pressure taps, turbine cooling air pressure tap, and borescope access. The No. 2 bearing support housing incorporates the No. 2 tilt-pad bearing, thrust bearing, thrust balance diaphragm and the stationary components of the thrust balance seal. The No. 2 bearing supports the aft end of the compressor rotor. The thrust bearing is adjacent to the No. 2 bearing and it is the fixed-ramp type. The No. 3 bearing support housing incorporates the No. 3 tilt-pad bearing and supports the turbine rotor shaft.

7.4.6 Combustor and Gas Producer Turbine Assembly

The combustor and gas producer turbine assembly includes the combustor assembly, fuel manifold assemblies, fuel injectors, bleed valve assembly, T5 thermocouples, and the gas producer turbine assembly.

The combustor assembly includes an outer housing which bolts to the aft flange of the compressor diffuser assembly. The annular-type combustor liner is supported in the combustor housing by six combustor support pins located between the 10 fuel injectors. The torch igniter assembly, used only at combustion lightoff, has its own interruptible fuel supply and igniter plug and also contains the forward combustor drain. The bleed valve mounts to a combustor housing flange and is electrically controlled and hydraulically actuated. The combustor housing has an insulation blanket aft of the fuel injectors.

Borescope access is through six ports near the forward end of the combustor housing which is used to inspect fuel injectors, combustor liner, and turbine section. One borescope access port, near the aft end of the combustor housing, enters into the second-stage nozzle and is used to inspect the first-stage and second-stage turbine rotor blades and second-stage nozzles. The T5 thermocouple ports are used to inspect the second-stage and third-stage turbine rotor blades and nozzles.

The fuel manifold assemblies include fuel injectors, fuel manifolds for gas fuel, liquid fuel, air assist, or water, as applicable, and the interconnecting lines. The fuel injectors mount radially in the combustor housing with the injector tips fitted into the combustor dome.

BLEED VALVE ASSEMBLY

The compressor bleed valve, mounted on the combustor housing assembly, is a normally-open, spring-loaded piston valve. The valve reduces backpressure imposed on the engine compressor during starting and part-speed operation by venting bleed air to the atmosphere through the exhaust collector.

Compressor air from the combustor housing is connected directly to the piston cylinder. The piston operates as a sleeve valve to close eight radial ports in the base of the inner walls of the bleed valve housing. When the engine start cycle begins, the piston spring holds the valve open. As engine speed increases, compressor discharge pressure begins to move the piston, overcoming the spring force and closing the valve. The valve is fully closed when compressor discharge pressure has attained approximately 72 psig (496 kPa), (5 bar), (5 kg/cm^2) and the engine has attained approximately 83% speed. This provides full compressor airflow for normal operation. During deceleration the bleed valve opens when the compressor discharge pressure reaches 38 psig (262 kPa), (2.6 bar), (2.6 kg/cm^2) or below.

To compensate for the variation in ambient air pressure at different altitude locations, shims are used as required, between the bleed valve piston spring seat and spring. The valve is factory calibrated for conditions at sea level, and final altitude adjustment is normally performed at the installation site.

T5 THERMOCOUPLES

The T5 thermocouples are mounted around the combustor aft housing. The thermocouples protrude into the turbine nozzle area, where they sense the temperature of the third-stage turbine inlet (T5).

GAS PRODUCER TURBINE ASSEMBLY

The turbine assembly consists of the turbine rotor assembly and turbine nozzle assembly. The stationary and rotating components of the turbine assembly are stacked and shimmed to maintain axial clearances. The turbine rotor shaft engages the keyed aft compressor hub with taper-type coupling.

Turbine Rotor Assembly

The turbine rotor assembly consists of the turbine rotor shaft and three disc assemblies. The discs and turbine rotor shaft engage each other by radial face splines which transmit torque and keep the discs concentric to the center of the shaft. Radial face splines allow the disc to thermally expand radially. The entire assembly is secured by a thermo-stretched throughbolt.

The first-stage turbine rotor blades are cooled by compressor air and fed at a controlled rate through the first-stage turbine nozzle support assembly to an annular slot (preswirler) that discharges onto the rotating blade roots. The air makes two passes through an internal passage in each blade and is discharged from a third chamber through a series of passages in the trailing edge and tip.

Turbine Nozzle Assembly

The turbine nozzle assembly consists of the nozzle support housing, first-stage, second-stage, and third-stage turbine nozzle assemblies.

The mounting flange of the nozzle support housing is pinned to the aft flange of the combustor housing for alignment and is cantilevered forward. The nozzle support housing is compressed between the aft flange of the combustor housing and the forward flange of the exhaust diffuser for rigid support. The nozzle support housing contains one borescope port hole and six T5 thermocouple ports. The housing supports the screen assembly and three stages of turbine nozzles.

The first-stage nozzle assembly contains the first-stage nozzle segments and first-stage diaphragm assembly, which includes the preswirler, and the nozzle clamp ring. The first-stage nozzle segments are secured to the first-stage diaphragm assembly by a nozzle clamp ring. Each first-stage nozzle segment contains two aerodynamic vane segments and inserts. The throat of the nozzle segment directs hot exhaust gasses toward the first-stage disc assembly. Cooling air, which enters each aerodynamic vane segment, is directed by flow control inserts to internally cool the leading edge and air foil surfaces, and is then discharged through the trailing edge.

The second- and third-stage turbine nozzles segments are pinned to their respective diaphragm assemblies which form a seal against the second- and third-stage disc assemblies to direct cooling air and control the exhaust gas path.

7.4.7 Turbine Exhaust Diffuser and Bellows Assembly

The turbine exhaust diffuser and bellows assembly includes an inner and outer diffusing wall, seven radial struts supporting the center cylinder, and a bellows connected to the outlet V-band clamp. This assembly is bolted to the combustor housing aft flange. It is provided with a liquid drain. A flexible bellows section is incorporated in the turbine exhaust diffuser assembly as a standard feature. This bellows is designed to accommodate the engine thermal growth and up to 0.5 in. (12.7 mm) of external thermal growth when optional equipment such as an exhaust silencer, a heat recovery system, or other special exhaust ducting is used.

7.4.8 Exhaust Duct Connector

The exhaust duct connector, terminating in a heavy plate flange, is installed between the exhaust bellows and the external ducting. The forward end of the spool piece is V-band clamped to the exhaust bellows assembly. The plate flange is bolted to the exhaust ducting for easy removal of the engine during major maintenance. The exhaust duct connector has three 1/8-in. (3.17-mm) pipe tap bosses evenly distributed around the circumference for test instrumentation. They are normally plugged. External areas of the diffuser, bellows, and connector are covered with an insulating stainless steel blanket for protection of personnel and to prevent fire.

7.4.9 Engine Support

The turbine engine is cantilevered aft from the forward flange of the air inlet housing, which is bolted to the reduction drive assembly. Additional rear support is provided by a steel pedestal attached to the combustor housing aft flange. The pedestal base rests on a vibration isolating pad located on the steel base crossmember below the combustor housing.

The vibration pad is provided with load springs, adjustment bolts, and spacers, that in addition to serving as a resilient rear mount, also permit vertical and horizontal adjustments of the engine for purposes of alignment.

7.5 PERFORMANCE EVALUATION

7.5.1 General

Engine performance evaluation is initiated in the field by recording the baseline condition of the as-installed package. Performance evaluation is a comparison of the baseline condition to routinely kept records of the normal operating condition of the engine.

The most important thing to watch for in performance testing is not the absolute values of performance, but a change or trend of engine performance indicating degradation of power, efficiency, etc.

The parameters which affect gas turbine performance are inlet air temperature, barometric pressure of inlet air (i.e. elevation), inlet and exhaust pressure losses, and, to a lesser degree, inlet air humidity.

7.5.2 Engine Condition Monitoring

Engine condition monitoring is accomplished by the video display computer, the monitoring and operating interface with the control system. It is used to display historical trending and real-time performance mapping of the gas turbine engine.

NOTE

The video display computer should be used to monitor trends in engine performance, not to verify absolute engine performance levels

Historical monitoring provides past, present, and predicted conditions of engine performance. Prediction of deteriorating trends in engine performance allows the timing at an off-peak or other convenient time to schedule correction of a problem before it leads to an undesirable shutdown. Information gained from this feature can point to corrective and diagnostic action required, such as washing the compressor and borescoping the hot gas path.

A navigation screen provides access to all video display computer screens. Information on the use and features use of the TT4000 application and display screens is contained in the on-line help instructions included with the software package. Help can be selected from any display screen.

Digital values for the engine performance parameters are displayed on the Engine Performance screen. Input parameters, which are based on real-time package instrumentation readings, are used to calculate the engine's corrected (standard conditions) performance. A key performance indicator is the trend of corrected engine performance parameters from predicted values of the gas turbine performance map. The trend of these parameters provides a true indication of performance degradation since the data are standardized for the actual operating point and not just optimum.

It should be noted that for a compressor or pump drive, actual horsepower is not being measured, but is calculated from parameters such as flow, discharge pressure and temperature and, therefore is an estimate only. For generators, however, kilowatt output is normally measured, so actual kW from the generator is displayed.

NOTE

The engine performance data is designed to address only the general engine performance issues. The overall system performance of a given installation is a function of many factors, including: site conditions, driven equipment used, fuel type, power extraction, and parasitic loads. For specific information regarding site performance, contact Solar Turbines Customer Services Department.

7.5.3 Effects of Turbine Cleaning

Turbine engines require occasional cleaning to maintain peak efficiency. Performance degradation can be categorized into two types: recoverable and nonrecoverable. Recoverable performance is an amount of degradation that can be recovered with engine cleaning. Refer to ENGINE COMPRESSOR INGESTIVE CLEANING, Section 7.6 in this chapter. Nonrecoverable degradation is that amount of performance degradation that can be recovered only with major in-shop inspection and maintenance. Between engine cleanings, performance degradation may be calculated as the sum of the recoverable degradation and nonrecoverable degradation (Figure 7.5.1).

The recoverable performance degradation is affected primarily by the amount of contamination that enters the turbine through the inlet air, fuel, and water supplies, and the frequency and thoroughness of engine cleaning. Each site has unique operating conditions. Unusual conditions such as exhaust ingestion, soiled inlet filters, and locally generated contaminants will accelerate the rate of contamination and adversely influence turbine performance. Site-specific experience will determine when engine cleaning is necessary.

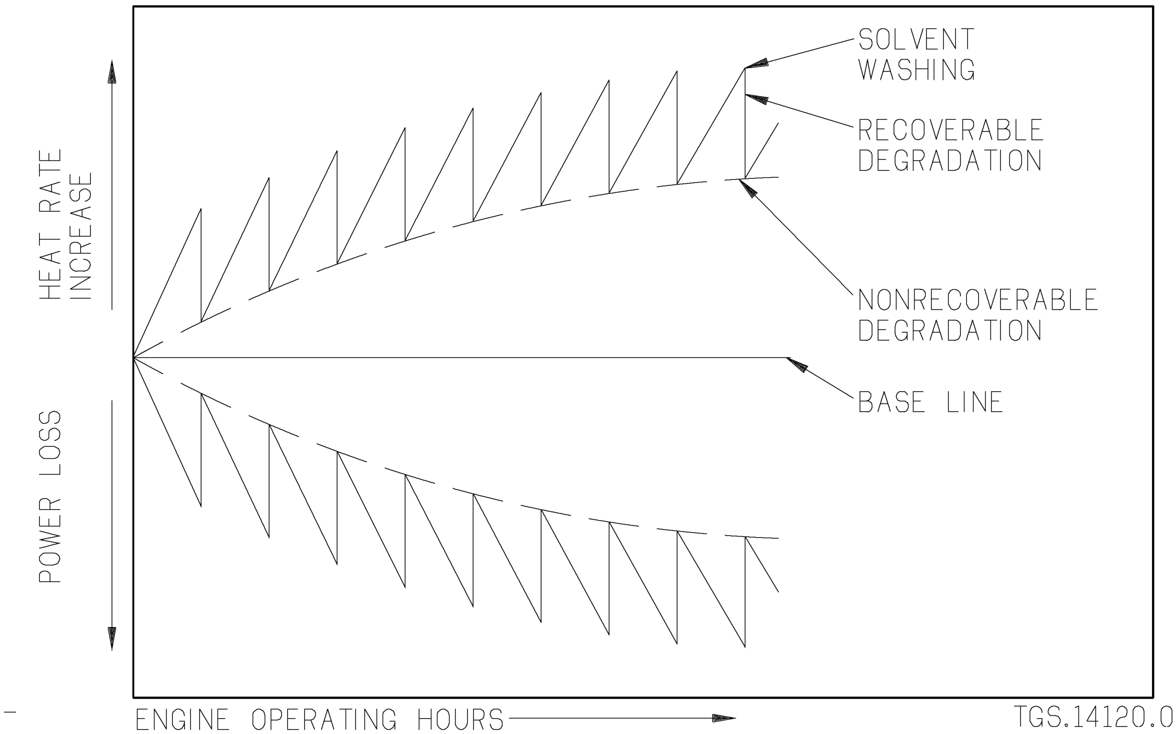


Figure 7.5.1 Total Performance Degradation

7.6 ENGINE COMPRESSOR INGESTIVE CLEANING

This section pertains to all Solar Turbines engine models.

WARNING

Operation of the unit may be performed only when conditions indicate it is safe to proceed. Dangerously explosive accumulations of natural gas, fuel fumes, oil tank vent leakage, or solvent fumes must be avoided at all times. This is done by proper ventilation, elimination of leaks, and by confining the use of solvents to appropriate maintenance facilities.

Operation of the unit may be performed only by qualified personnel. The operator must understand turbine and driven equipment operation, function, and systems and also know and understand all controls, indicators, normal indications, and operating limits.

Appropriate hearing and eye protection must be used by operating and maintenance personnel in the vicinity of the operating machine.

7.6.1 Definitions of Compressor Ingestive Cleaning Terminology

The following list of definitions will help the user better understand the procedure.

- Ingestive Cleaning - process of engine compressor cleaning where cleaning product is introduced through the air inlet
- Cleaning System - an appropriate combination of cleaning equipment, cleaning product, and a compressor ingestive cleaning procedure to be used
- Cleaning Equipment - accessory equipment used to properly introduce cleaning product into the air inlet
- Cleaning Mode - the mode of operation of the engine (either on-crank or on-line) while compressor cleaning is performed
- On-Crank - engine operation at maximum speed obtainable on starter alone with fuel and ignition de-activated
- On-Line - engine fired and operating at any power level ranging from idle (no load) to full rated power and load
- Cleaning Cycle - a cycle constitutes completion of an on-crank or on-line compressor cleaning procedure

- **Cleaning Fluid** - the fluid (water or cleaning product) used during the ingestive cleaning procedure
- **Cleaning Product** - a mixture of water and cleaning solution used during certain ingestive cleaning procedures
- **Cleaning Solution** - a concentrate of detergent and/or solvent that, when mixed with water, produces the cleaning product (some are available premixed, or "Ready-To-Use")
- **Detergent** - cleaning solution that dissolves contamination by surface interaction (surfactant)
- **Solvent** - cleaning solution that dissolves contamination through reaction at molecular bonds
- **Freeze Point Depressant** - additive used to reduce the freezing point of the cleaning product
- **Rinse Water** - water (not mixed with any cleaning solution) that is used to rinse the engine during an on-line or on-crank cleaning procedure
- **Water Wash** - a compressor ingestive cleaning procedure in which water (not mixed with any cleaning solution) is used as the cleaning fluid

7.6.2 Purpose of Cleaning

When contaminants such as dust, salt, and oil-laden air pass through the engine air filters, they adhere to components in the engine compressor air path and decrease engine performance. Engine compressor ingestive cleaning may eliminate the following engine performance-related problems:

- Failure to accelerate to full speed
- General lack of acceleration
- Compressor surge
- Loss of output power
- Loss of compressor discharge pressure

In some cases, the need for compressor on-crank cleaning is indicated when contamination is visible at the air inlet and/or through the compressor borescope ports.

Before cleaning the engine compressor, eliminate any sources of contamination, including poor air filtration, oily mist from the oil tank vent, and exhaust from nearby equipment.

7.6.3 Recording Pre/Post Cleaning Performance Data

In order to accurately measure the performance of the compressor cleaning system and determine necessary changes to cleaning frequency and dosage, the essential engine operating parameters should be recorded prior to and following each cleaning. If this data is recorded carefully, a trend will soon be established to show how the cleaning system is performing.

It is recommended that ingestive cleaning be repeated until compressor IGVs are clean, no further improvement in engine performance can be measured, and until a clean waste stream is noted in the engine drains. The best reference for optimum engine performance baseline data obtained when the engine was commissioned.

7.6.4 Cleaning Modes

The engine compressor can be cleaned while the engine is cranking (on-crank mode) or while the engine is operating in the simple cycle mode (on-line mode).

NOTE

On-line cleaning is an optional feature and may not be applicable to this package.

The Solar on-crank and on-line compressor cleaning system is specifically designed for maintenance of the engine compressor. Its effectiveness will depend on proper use and monitoring of engine performance parameters on a regular basis. Monitoring of engine overall performance can give some indication of the effectiveness of on-crank and on-line engine cleaning. However, degradation of engine output is not necessarily related to engine compressor degradation only and therefore should not be the sole basis of evaluating the effectiveness of on-crank or on-line engine cleaning.

ON-CRANK MODE

In the on-crank mode, the engine operates at the maximum speed obtainable by the starter alone, with the fuel and ignition systems de-activated.

On-crank cleaning is more effective than on-line cleaning. The waste stream produced during the on-crank cleaning procedure is discharged through the drain ports. On-line cleaning may be used between on-crank cleaning cycles to extend the time between on-crank cleanings and to minimize further contamination of the engine compressor.

ON-LINE MODE

In the on-line mode, the engine operates at any power level ranging from idle (no load) to full rated power with engine temperature stabilized at operating speed.

In on-line mode an engine compressor can be cleaned with the engine operating normally within minutes. Cleaning does not affect engine operation and should be performed on a scheduled basis. This allows the operator to avoid engine downtime while minimizing fouling of the engine compressor.

CAUTION

On-line cleaning is permitted only at ambient temperatures above 39°F (4°C).

On-line cleaning in a salt-laden environment is not recommended.

Adequate air treatment must be employed to remove the bulk of airborne constituents such as dried salt particles. Table 7.6.1 lists the air requirements.

Airborne salts removed during the cleaning process can cause serious damage to the hot section of the turbine. Please contact your local Solar Turbines representative for support in this matter.

NOTE

On-line cleaning is intended as a supplement to on-crank cleaning, not as a substitute. It is imperative that the compressor be cleaned in the on-crank mode on a regular basis.

Table 7.6.1 Requirements for Air Entering Compressor Air Inlet

Airborne Contaminants	Maximum Allowable Limit (measured at air inlet)
Total solid particles (including sea salt)	≤ 0.010 ppmw (ASTM D3365)[1]
Maximum particle size	≤ 10 microns
Total combustibles	≤ 5 ppmw (ASTM D2820)

(1) This limit complies with ES 9–98 even in the worst-case scenario, i.e., particles entering the gas turbine are 100% sea salt. Under these circumstances (deemed the most corrosive of airborne contaminants), sodium + potassium present in 0.010 ppmw of sea salt is calculated to be less than 0.004 ppmw in air; on this basis, the maximum concentration of airborne contaminants at a maximum particle loading rate of 0.010 ppmw would be as follows:

```
Na + K  ≤ 0.004 ppmw
Ca + Mg ≤ 0.008 ppmw
S       ≤ 43    ppmw
F       ≤ 0.004 ppmw
```

7.6.5 Intervals Between Engine Cleaning Cycles

Appropriate intervals for both on-crank and on-line cleaning cycles should be determined by recording and trending engine performance degradation. Cleaning should not be delayed so long that contamination becomes impossible to remove completely by on-crank cleaning.

ON-CRANK CLEANING INTERVALS

On-crank cleaning is recommended at maximum intervals of every 4,000 hours of operation, and before full load power degrades more than 5%. For two-shaft turbines operating at full load on T5 topping, this typically corresponds to a 2.5% drop in Pcd. For two-shaft turbines operating at full load on Ngp topping, degree of compressor fouling is more difficult to quantify. As the compressor fouls, T5 will increase with little change in power or Pcd until T5 topping is achieved.

Recommended minimum intervals between on-crank cleaning operations to avoid excessive ingress of cleaning product into the oil system is at least 96 hours between each on-crank cleaning cycle.

ON-LINE CLEANING INTERVALS

On-line cleaning intervals should be determined by observing the effectiveness in restoring performance. On-line cleaning is best suited to remove the initial buildup of contamination from already clean airfoils. If the airfoils become significantly fouled between on-line cleaning intervals, cleaning will be less effective.

Initial on-line cleaning interval should be at most 48 hours of operation. Performance should then be evaluated to determine the effect of each cleaning operation, and overall rate of performance degradation. After completing an on-crank cleaning, on-line cleaning interval can be increased to 72 hours of operation. If no significant difference in on-line cleaning effectiveness is observed, the interval may be increased again by 24 hours. Typically, the maximum interval for an effective on-line cleaning program is no more than 96 hours of operation.

Recommended minimum intervals between on-line cleaning operations to avoid excessive ingress of cleaning product into the oil system is at least 24 hours between each on-line cleaning cycle.

7.6.6 Cleaning Fluids

Three cleaning fluids can be used in engine compressor ingestive cleaning: water, cleaning product, or emulsified solutions (water mixed with kerosene or diesel fuel).

Water and cleaning product can be used in either cleaning mode (on-crank or on-line). Cleaning product concentrations will vary depending on the cleaning mode selected. Using either cleaning mode, the cleaning fluid volume and flow rates must comply with the requirements defined in Solar ES 9-62. For water and cleaning product requirements, refer to Solar ES 9-62.

CAUTION

Because the engine is firing during on-line cleaning, the cleaning fluid (either water or cleaning product) ingested must meet the more stringent requirements defined in Solar ES 9-62 to minimize introduction of corrosive/fouling contaminants.

CAUTION

The use of abrasive cleaners (such as Carboblast, walnut shells, pecan shells or rice) are not recommended in any model of Solar Turbines engine. Use of abrasive cleaners can cause blockage of cooling air passages in nozzles and blades, resulting in loss of cooling air and thermal degradation of the component. Abrasive cleaners may also have a detrimental effect on compressor blade coatings.

WATER

Water (without concentrate) can be used to remove water-soluble contaminants such as salt, chemicals, dust, or other non-oily, non-waxy substances from the compressor air path. Water is also used during the rinse portion of all engine compressor ingestive cleaning procedures, as well as in standard ambient-temperature water wash and low ambient-temperature water wash procedures. Refer to Solar ES 9-62 for water requirements. A recommended device for measuring water purity would be a conductivity meter. Acceptable values should be 4 megaohms resistance or 25 micromhos conductance.

CAUTION

Low-ambient temperature water wash may be done only in the on-crank mode. Refer to Solar ES 9-62 for on-crank low ambient temperature water wash specifications.

CLEANING SOLUTIONS

WARNING

Avoid direct and prolonged inhalation of cleaning solution vapors. DO NOT INGEST CLEANING SOLUTIONS. After accidental ingestion, do not induce vomiting, seek medical attention. In the event of direct contact of cleaning solution with eyes, rinse the eyes copiously with clean water. If prolonged direct contact with skin occurs, wash with soap and water.

Solar Turbines cleaning solutions should not be used for on-line cleaning, unless a properly designed and installed injection system is fitted. Solar Turbines cleaning solutions can be used with any on-crank cleaning system.

Solar-recommended cleaning products may be used in the on-crank and on-line cleaning system. Other cleaners may not work effectively or may fail to meet Solar Specification ES 9-62 (Ingestive Cleaning Solar Turbine Engines) requirements and possibly damage the engine. Solar Turbines does not accept any liability for damage or injury caused by misuse of its cleaners or cleaning system.

Cleaning solutions are detergent and/or solvent concentrates that are mixed with water to produce the cleaning product. Cleaning solutions available through Solar Turbines are listed in Table 7.6.2. Prior to use, mix the applicable concentrates with water. The premixed or "Ready-To-Use" cleaners do not need to be diluted with water. Solar Turbines cleaning solutions will not chemically attack the special blade coatings.

Table 7.6.2 Solar-Recommended Cleaning Solutions

Solar Part Number	Solar Product Name/Description	Maximum Strength Volume Ratio (Water : Cleaning Solution)
701690C2 (6.5 gal) 701691C2 (55 gal)	Solar Gas Turbine Cleaner No. 1 (Petroleum Solvent-based) concentrate	4:1
701696C2 (6.5 gal) 701697C2 (55 gal)	Solar Gas Turbine Cleaner No. 1 (Petroleum Solvent-based) premixed (Ready-To-Use)	Full Strength
701688C2 (6.5 gal) 701689C2 (55 gal)	Solar Gas Turbine Cleaner No. 2 (Natural Solvent-based) concentrate	4:1
701694C2 (6.5 gal) 701695C2 (55 gal)	Solar Gas Turbine Cleaner No. 2 (Natural Solvent Water-based) premixed (Ready-To-Use)	Full Strength

Table 7.6.2 Solar-Recommended Cleaning Solutions, Contd

Solar Part Number	Solar Product Name/Description	Maximum Strength Volume Ratio (Water : Cleaning Solution)
1011634 (6.5 gal) 1011635 (55 gal)	Solar Gas Turbine Cleaner No. 3 (Non-Solvent Water-based) concentrate[1]	4:1
1011636 (6.5 gal) 1011637 (55 gal)	Solar Gas Turbine Cleaner No. 3 (Non-Solvent Water-based) premixed (Ready-To-Use)[1]	Full Strength

(1) This biodegradeable type of solution is formulated with natural detergents and is generally less effective than solutions containing solvents. Warming solution to approximately 86°F (30°C), and allowing longer soak time can improve effectiveness.

EMULSIFIED SOLUTIONS

CAUTION

The use of emulsified mixtures for on-line cleaning could cause turbine to overfire/overfuel and shutdown. Emulsified solutions used in ingestive cleaning may be applied only in the on-crank cleaning mode.

An emulsified mixture of kerosene and water or diesel fuel and water may be used for on-crank cleaning only. This mixture must be formulated by mixing diesel fuel (per MIL-F-16884) and water (per Solar ES 9-62) with an emulsifier (per MIL-D-16791 [Type II]). The solution must be homogenous and sprayable. The mixing ratio must be according to that recommended by the emulsifier manufacturer. The emulsifier must not exceed 10 percent (by volume) of the final mixture.

7.6.7 Ambient Temperature During Engine Cleaning

On-crank and on-line engine compressor cleaning is permitted at the ambient temperatures as stated in the following Subsections.

ON-CRANK

On-crank engine cleaning is permitted only at temperatures above -4°F (-20°C). When the ambient temperature is between -4°F (-20°C) and 39°F (4°C), a mixture of water or cleaning solution and freeze point depressants must be used. Examples of the relative stability of solutions when mixed with various freeze point depressants are listed in Table 7.6.3. The ratio of water/freeze point depressant mix depends upon the type of freeze depressant used.

CAUTION

Automotive or commercial antifreeze products are not acceptable. Use of such products may cause severe turbine damage.

NOTE

The water and freeze point depressant must be pre-mixed before adding the cleaning solution concentrate.

CAUTION

Low-ambient temperature water wash may be done only in the on-crank mode. Refer to Solar Engineering Specification ES 9-62 for on-crank low ambient temperature water wash requirements.

Table 7.6.3 On-Crank Requirements for Freeze Point Depressants used in Cold Ambient Temperatures

Ambient Temperature Range	Freeze Point Depressant	Volume Ratio Freeze Point Depressant : Water or Cleaning Solution	Stability
-4°F to +39°F (-20°C to 4°C)	Methanol	2:3	Over 3 hours
-4°F to +39°F (-20°C to 4°C)	Mono-ethylene glycol (per MIL-E-9500)	2:3	Over 3 hours
-14°F to +39°F (-10°C to 4°C)	Isopropyl Alcohol (per ASTM D770)	1:1	Over 1 hour

It is extremely important that the cleaning product/freeze point depressant be a homogenous mixture during injection. If the cleaning product/freeze point depressant mixture is allowed to sit for an extended period of time, it should be re-agitated to regain homogeneity.

NOTE

Agitation is automatic when a Rochem wash cart skid is used.

ON-LINE

On-line engine cleaning is permitted only at ambient temperatures above 39°F (4°C).

7.6.8 Package (On-Skid) Components

The package is equipped with two separate skid edge connections; one for on-line cleaning and one for on-crank cleaning. Each connection is plumbed to the respective manifold with the following components:

- Inlet strainer
- Shutoff solenoid
- Triple stage filter
- Three-way hand valve (on-crank only)

The package includes hose quick-disconnect couplings for use with the mobile tank. This hardware is installed at the skid edge connections.

The on-crank circuit three-way hand valve is located downstream from the shutoff solenoid with a quick-disconnect coupling for the hand-held wand. The control system logic prevents the on-crank solenoid from opening when T5 temperatures are above 150°F (66°C) and/or above 60 percent Ngp.

CAUTION

The on-crank manifold should not be used for on-line cleaning.

7.6.9 Engine Compressor Cleaning Spraying Mechanisms

ON-CRANK MANIFOLD AND ON-LINE MANIFOLD

The on-crank manifold and on-line manifold are two separate tubular assemblies located on the air inlet duct. Evenly spaced atomizing nozzles in the assemblies supply a fine mist into the turbulent airstream prior to its change of state to laminar flow. This mist does not interfere with the aerodynamics of the compressor.

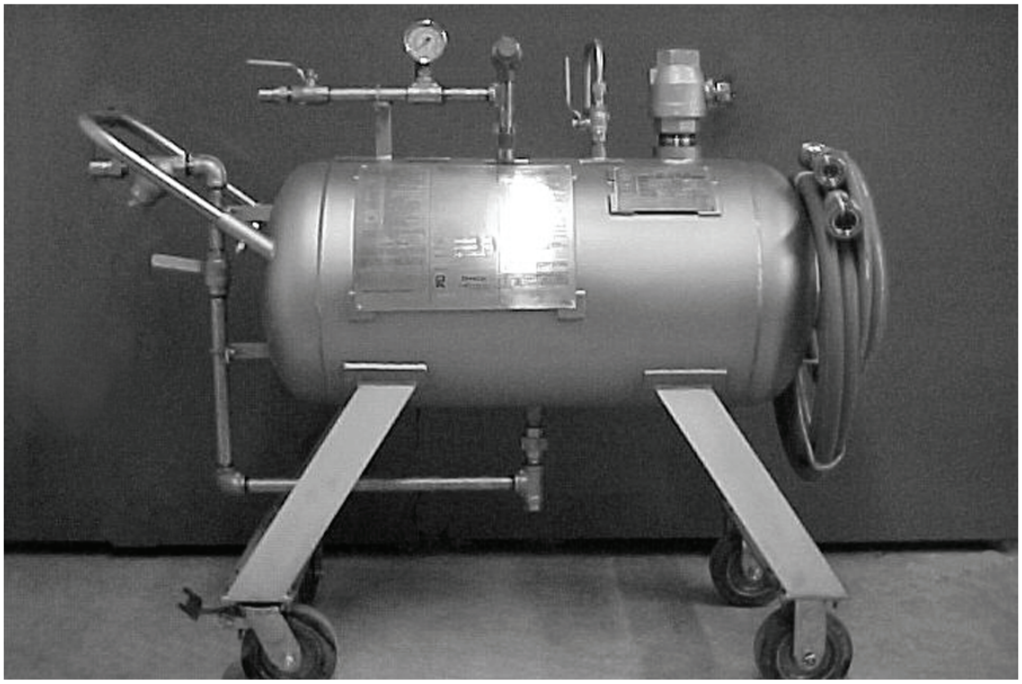
HAND-HELD SPRAYING WAND

The hand-held spraying wand is provided so cleaning fluids can be admitted to the engine compressor air path through the air inlet duct side panels. The spraying wand may also be used for on-crank water washing when no water wash manifold is installed in the air inlet duct.

7.6.10 Mobile Injection Tank (Rochem)

The mobile injection tank is an optional feature and may not be applicable to this package. The mobile injection tank (Figure 7.6.1) is a stainless steel, pressure injection vessel. The tank is designed and constructed to ASME Code VIII Specifications for a normal working pressure of 100 psig (689 kPa, 6.9 bar, 7.0 kg/cm^2). The 26 gal (100L) tank includes four heavy duty wheels mounted to the tank legs. (For stationary operation, the wheels can be removed.) The tank is complete with the following hardware:

- CE stamped pressure relief valve (for PED [Pressure Equipment Directive] units) set at 130 psig (896 kPa, 9.0 bar, 9.1 kg/cm^2)
- Auxiliary fill port with 2 in. ball valve (for gravity filling of tank with water and/or chemical)
- Tank inlet (water, chemical, and air) connection with 1/2 in. ball valve
- Tank fluid outlet 3/4 in. ball valve
- Tank fluid outlet filter “Y” strainer with 100 micron filter insert
- Drain plug
- Vent with 1/2 in. ball valve
- Magnetic level gage with dial face
- Hand hole for inspection and cleaning
- Plaque with engraved operating instructions
- ASME “UV” stamp; National Board registered
- Heavy duty, 3/4 in. chemical-resistant 15 ft (4.6 m) fluid delivery hose with female quick-disconnect coupling on each end. Used for connection between injection tank and engine on-line and on-crank manifold rings.
- Heavy duty, 1/2 in. chemical-resistant 15 ft (4.6 m) tank supply hose with female quick-disconnect coupling at each end. Used for connection between injection tank and air, water, and chemical sources.
- Male quick-disconnect couplings for air, water, and chemical sources; for tank inlet; for tank fluid outlet and manifold inlets (on-line and on-crank)
- Hand-held spraying wand



DigitalArt STD.37258.0

Figure 7.6.1 Mobile Injection Tank

7.6.11 Mobile Cleaning System Operation

Use of the mobile cleaning system is designed to be as simple to operate as possible. All interfaces between mobile tank air, water, and solution sources is through a 1/2 in. chemical-resistant 15 ft (4.6 m) tank supply hose with female quick-disconnect couplings on each end. Male quick-disconnect couplings are also provided with the package and are shipped loose. The couplings are to be connected as follows:

1. Two stainless steel male quick-disconnect couplings must be connected to the on-skid, on-line cleaning manifold and on-crank cleaning manifold inlets.
2. Two stainless steel male quick-disconnect couplings must be connected to the customer-supplied water and chemical sources.
3. A stainless steel male quick-disconnect coupler must be connected to the customer-supplied 100 psig (689 kPa, 6.9 bar, 7.0 kg/cm^2) air source.

PLACEMENT OF THE MOBILE INJECTION TANK

The mobile injection tank does not require permanent placement or installation. The following should be observed when selecting the mobile tank location:

1. During system operation, the mobile tank must be located within ten feet (3.1 m) of the on-skid, on-line manifold inlet or the on-skid, on-crank manifold inlet, depending on applicable operation.

2. During system operation, the mobile tank must be located within ten feet (3.1 m) of the 100 psig (689 kPa, 6.9 bar, 7.0 kg/cm^2) air source.

3. The chemical and water sources can be at any appropriate location accessible to the mobile tank. Chemical and water sources must be within ten feet (3.1 m) of the tank during filling.

TESTING OF MOBILE CLEANING SYSTEM

Prior to use, the entire mobile cleaning system should be flushed out, to ensure removal of any debris that could cause nozzle blockage, and pressure-tested for leaks. Flush out and pressure test the injection tank as follows:

NOTE

For the stationary tank cleaning system, follow the same procedures as stated below, except that the interface piping is rigid with no hoses provided.

1. For mobile tank cleaning system, connect tank supply hose between water source and tank inlet. Open tank vent valve and tank inlet valve; fill injection tank with water until water begins to flow out of the tank vent valve. Close tank inlet valve and disconnect tank supply hose.

2. Close the tank vent valve. Connect tank supply hose between air source and tank inlet. Open the tank inlet valve to pressurize the tank to normal working air pressure of 100 psig (689 kPa, 6.9 bar, 7.0 kg/cm^2), then close the tank inlet valve.

3. Leave tank under pressure for ten minutes. There should be no pressure drop or leakage at any fittings.

4. Slowly open the tank drain valve and allow the water to run safely to a drain until tank pressure is zero. Close the tank drain valve. Remove and clean the tank fluid outlet strainer, and reinstall.

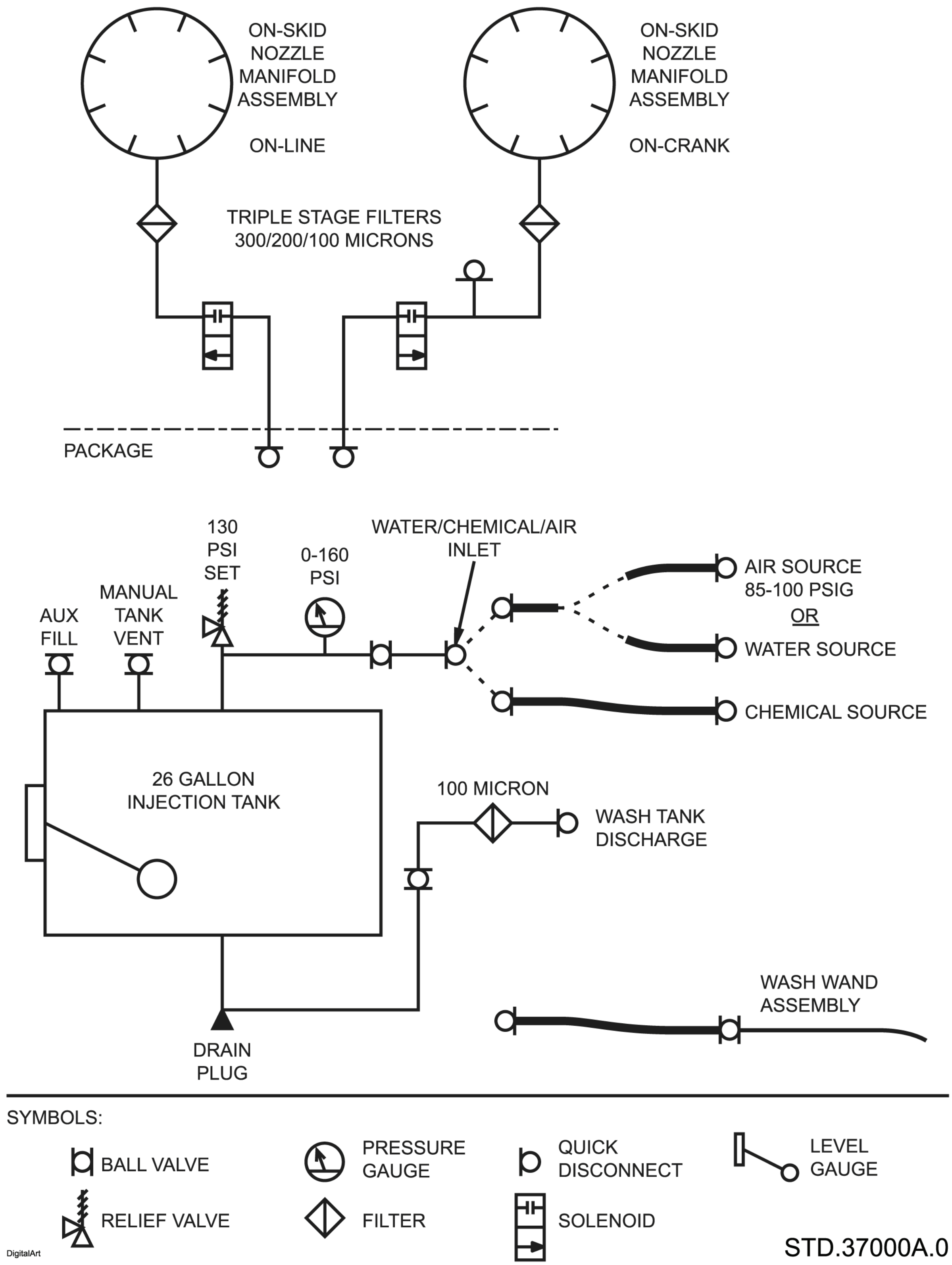


Figure 7.6.2 Engine Cleaning System Flow Diagram (Typical)

Pressure test the engine on-crank or on-line wash manifold ring assembly as follows:

1. Connect tank supply hose between water source and tank inlet. Open tank inlet valve, vent valve; and fill tank approximately half full with water. Close tank inlet and vent valves. Disconnect the tank supply hose.

2. Connect tank supply hose between air source and tank inlet. Open the tank inlet valve to pressurize the tank to 30 psig (207 kPa, 2.1 bar, 2.1 kg/cm^2). Connect fluid delivery hose between tank fluid outlet and on-crank or on-line wash manifold inlet and slowly open tank fluid outlet valve. Any major connector leaks will be immediately visible. If leaks are present, close tank fluid outlet valve and tighten the union fittings. Repeat this procedure by slowly increasing pressure until full working pressure of 100 psig (689 kPa, 6.9 bar, 7.0 kg/cm^2) is attained without leakage.

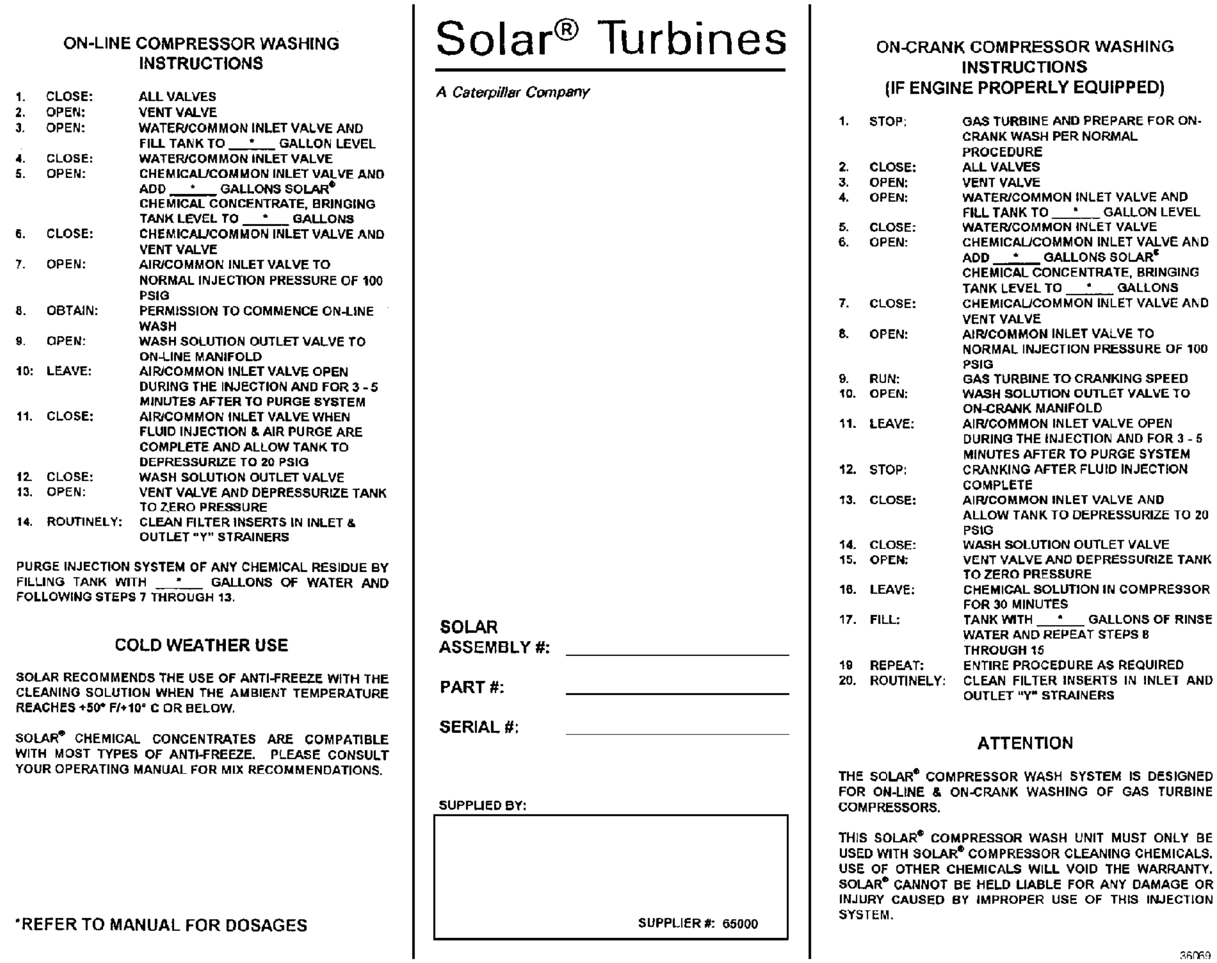
3. Pressure-test atomizing nozzles to verify proper spray pattern. If any nozzles appear to be blocked or partially blocked, disconnect nozzle from manifold and backflush nozzle tip through orifice with a commercial electrical-instrument cleaner, followed by high-pressure air or water.

7.6.12 Engine Compressor Cleaning Procedures

The following subsections describe the on-crank and on-line engine compressor cleaning procedures.

NOTE

The mobile injection tank has an “Operating Instructions” plaque (Figure 7.6.3) permanently attached to it. The procedures found in this document take precedence over any conflicting information that may be encountered from the instructions on the plaque.



ON-LINE COMPRESSOR WASHING INSTRUCTIONS

1. CLOSE: ALL VALVES
2. OPEN: VENT VALVE
3. OPEN: WATER/COMMON INLET VALVE AND FILL TANK TO ___*___ GALLON LEVEL
4. CLOSE: WATER/COMMON INLET VALVE
5. OPEN: CHEMICAL/COMMON INLET VALVE AND ADD ___*___ GALLONS SOLAR® CHEMICAL CONCENTRATE, BRINGING TANK LEVEL TO ___*___ GALLONS
6. CLOSE: CHEMICAL/COMMON INLET VALVE AND VENT VALVE
7. OPEN: AIR/COMMON INLET VALVE TO NORMAL INJECTION PRESSURE OF 100 PSIG
8. OBTAIN: PERMISSION TO COMMENCE ON-LINE WASH
9. OPEN: WASH SOLUTION OUTLET VALVE TO ON-LINE MANIFOLD
10: LEAVE: AIR/COMMON INLET VALVE OPEN DURING THE INJECTION AND FOR 3 - 5 MINUTES AFTER TO PURGE SYSTEM
11. CLOSE: AIR/COMMON INLET VALVE WHEN FLUID INJECTION & AIR PURGE ARE COMPLETE AND ALLOW TANK TO DEPRESSURIZE TO 20 PSIG
12. CLOSE: WASH SOLUTION OUTLET VALVE
13. OPEN: VENT VALVE AND DEPRESSURIZE TANK TO ZERO PRESSURE
14. ROUTINELY: CLEAN FILTER INSERTS IN INLET & OUTLET "Y" STRAINERS

PURGE INJECTION SYSTEM OF ANY CHEMICAL RESIDUE BY FILLING TANK WITH ___*___ GALLONS OF WATER AND FOLLOWING STEPS 7 THROUGH 13.

COLD WEATHER USE

SOLAR RECOMMENDS THE USE OF ANTI-FREEZE WITH THE CLEANING SOLUTION WHEN THE AMBIENT TEMPERATURE REACHES +50° F/+10° C OR BELOW.

SOLAR® CHEMICAL CONCENTRATES ARE COMPATIBLE WITH MOST TYPES OF ANTI-FREEZE. PLEASE CONSULT YOUR OPERATING MANUAL FOR MIX RECOMMENDATIONS.

*REFER TO MANUAL FOR DOSAGES

Solar® Turbines

A Caterpillar Company

SOLAR ASSEMBLY #: ____________

PART #: ____________

SERIAL #: ____________

SUPPLIED BY:

SUPPLIER #: 65000

ON-CRANK COMPRESSOR WASHING INSTRUCTIONS (IF ENGINE PROPERLY EQUIPPED)

1. STOP: GAS TURBINE AND PREPARE FOR ON-CRANK WASH PER NORMAL PROCEDURE
2. CLOSE: ALL VALVES
3. OPEN: VENT VALVE
4. OPEN: WATER/COMMON INLET VALVE AND FILL TANK TO ___*___ GALLON LEVEL
5. CLOSE: WATER/COMMON INLET VALVE
6. OPEN: CHEMICAL/COMMON INLET VALVE AND ADD ___*___ GALLONS SOLAR® CHEMICAL CONCENTRATE, BRINGING TANK LEVEL TO ___*___ GALLONS
7. CLOSE: CHEMICAL/COMMON INLET VALVE AND VENT VALVE
8. OPEN: AIR/COMMON INLET VALVE TO NORMAL INJECTION PRESSURE OF 100 PSIG
9. RUN: GAS TURBINE TO CRANKING SPEED
10. OPEN: WASH SOLUTION OUTLET VALVE TO ON-CRANK MANIFOLD
11. LEAVE: AIR/COMMON INLET VALVE OPEN DURING THE INJECTION AND FOR 3 - 5 MINUTES AFTER TO PURGE SYSTEM
12. STOP: CRANKING AFTER FLUID INJECTION COMPLETE
13. CLOSE: AIR/COMMON INLET VALVE AND ALLOW TANK TO DEPRESSURIZE TO 20 PSIG
14. CLOSE: WASH SOLUTION OUTLET VALVE
15. OPEN: VENT VALVE AND DEPRESSURIZE TANK TO ZERO PRESSURE
16. LEAVE: CHEMICAL SOLUTION IN COMPRESSOR FOR 30 MINUTES
17. FILL: TANK WITH ___*___ GALLONS OF RINSE WATER AND REPEAT STEPS 8 THROUGH 15
19 REPEAT: ENTIRE PROCEDURE AS REQUIRED
20. ROUTINELY: CLEAN FILTER INSERTS IN INLET AND OUTLET "Y" STRAINERS

ATTENTION

THE SOLAR® COMPRESSOR WASH SYSTEM IS DESIGNED FOR ON-LINE & ON-CRANK WASHING OF GAS TURBINE COMPRESSORS.

THIS SOLAR® COMPRESSOR WASH UNIT MUST ONLY BE USED WITH SOLAR® COMPRESSOR CLEANING CHEMICALS. USE OF OTHER CHEMICALS WILL VOID THE WARRANTY. SOLAR® CANNOT BE HELD LIABLE FOR ANY DAMAGE OR INJURY CAUSED BY IMPROPER USE OF THIS INJECTION SYSTEM.

36069

Figure 7.6.3 Mobile Tank Cleaning System "Operating Instructions" Plaque (Typical)

ON-CRANK ENGINE COMPRESSOR CLEANING

On-crank engine compressor cleaning is performed when the engine compressor is rotated by the start system. The engine must be shut down and allowed to cool prior to starting preparation procedures. Applicable methods and specifications for on-crank cleaning are listed in Table 7.6.4. Observe the following items pertaining to on-crank cleaning:

- Compressor fouling is a combination of water-soluble and non-water-soluble foulants. Unknowns are the degree to which each of these contaminants is present, and the rate at which they accumulate in the engine compressor.
- In general, on-crank cleaning tends to be the most effective method of removing deposits in the compressor air path. Waste stream produced by the cleaning procedure is discharged mainly through the drain ports.
- On-crank cleaning can be performed as often as needed.
- Engine cleaning is not recommended at temperatures below -4°F (-20°C).

- Do not exceed recommended duty cycle for electric starter system.

NOTE

For cold-weather operation, below 39°F (4°C), refer to Subsection 7.6.7.

Table 7.6.4 On-Crank Cleaning Methods and Specifications

Turbine Model	Cleaning Method	Cleaning Product (Volume / Dosage) Gallons	Water to Solution Ratio	Flow GPM	Air Pressure Psig[1]	Air Flow SCFM
Saturn 20	Cleaning Product	8-10	4:1	1.5-2.5	85-100	2.2
Saturn 20	Rinse Water	10-20[2]	n/a	1.5-2.5	85-100	2.2
Centaur 40	Cleaning Product	12-17	4:1	2.4-3.4	85-100	3.0
Centaur 40	Rinse Water	17-34[2]	n/a	2.4-3.4	85-100	3.0
Centaur 50	Cleaning Product	12-17	4:1	2.4-3.4	85-100	3.0
Centaur 50	Rinse Water	17-34[2]	n/a	2.4-3.4	85-100	3.0
Taurus 60	Cleaning Product	12-17	4:1	2.4-3.4	85-100	3.0
Taurus 60	Rinse Water	17-34[2]	n/a	2.4-3.4	85-100	3.0
Taurus 65	Cleaning Product	12-17	4:1	2.4-3.4	85-100	3.0
Taurus 65	Rinse Water	17-34[2]	n/a	2.4-3.4	85-100	3.0
Taurus 70	Cleaning Product	15-20	4:1	4.0-5.0	85-100	4.6
Taurus 70	Rinse Water	20-40[2]	n/a	4.0-5.0	85-100	4.6
Mars 90/100	Cleaning Product	15-20	4:1	4.0-5.0	85-100	4.6
Mars 90/100	Rinse Water	20-40[2]	n/a	4.0-5.0	85-100	4.6
Titan 130	Cleaning Product	20-25	4:1	4.5-5.5	85-100	5.3
Titan 130	Rinse Water	25-50[2]	n/a	4.5-5.5	85-100	5.3

(1) The optimal pressure at the injectors is between 90-100 psig (621-689 kPa, 6.2-6.9 bar, 6.3-7.0 kg/cm^2) measured at the skid edge connection. Attaining optimal pressure may require pressurizing the tank higher than specified, but limited to the relief valve setting for the tank.

(2) This is the recommended dosage. Compressor should be rinsed until a clean waste stream is noted in engine drains.

NOTE

On-crank cleaning methods and specifications listed in this table are subject to change. Refer to Solar Specification ES 9-62 for updates.

Preparation For On-Crank Cleaning Procedure

The following procedures are applicable for all Solar Turbines engine models. Where required additional steps are included with appropriate engine model noted.

CAUTION

Engine must be shut down and allowed to cool. Before cleaning, engine case temperature should not exceed 149°F (65°C). A minimum of eight hours is required to allow the engine to sufficiently cool prior to performing the cleaning procedure. Quicker cooling may be obtained by cranking the engine.

CAUTION

Taurus 70 only, a crank wash should not be conducted without ensuring that seals are pressurized.

1. Shut down engine and allow engine to cool.
2. Remove bracket holding eleventh-stage bleed lines together under engine (Mars only).
3. Loosen eleventh-stage bleed line bolts at diffuser case bosses and remove bolts from compressor case bosses. Slide bleed lines away from compressor case (Mars only).
4. Loosen seventh-stage bleed line bolts at diffuser fittings and remove bolts from compressor case bosses. Slide bleed lines away from compressor case (Titan only).
5. Install blanking plates FT30222-1 between bleed line flanges and compressor case bosses (Mars, Titan only).
6. Retighten bolts on all bleed line bosses.
7. Disconnect compressor discharge pressure line to fuel control (if applicable).
8. On engines using gas fuel only, disconnect torch drain line, then remove torch drain plug from torch body. On dual-fuel engines, remove torch drain plug from torch body, then disconnect drain line upstream of torch drain solenoid valve.

CAUTION

On engines using burner acoustic monitor (BAM) system, wash water can flow through the transfer tube and flood the acoustic monitor coil assembly during cleaning procedure. A flooded coil assembly could produce false alarms.

9. Disconnect transfer tube from either the acoustic monitor coil assembly or torch side pressure tap (PT) port.

10. Disconnect combustor, exhaust collector, and air inlet duct drain lines at check valve connections.

11. Disconnect 1/2 in. PCD supply to front and rear seal air at the engine (Taurus 70 only).

12. Connect 1/2 in. Shop air supply, approximately 40 psig (276 kPa, 2.8 bar, 2.8 kg/cm^2) to front and rear seal air lines (Taurus 70 only).

13. Connect flexible drain hose and container to each of the drain lines.

14. Position OFF/LOCAL/AUXILIARY keyswitch to LOCAL.

15. Remove air inlet assembly side panels.

16. Clean throat of engine and the first stage IGVs with water using solution wand.

17. Prepare engine for TEST CRANK CYCLE by first verifying that all appropriate circuit breakers are closed. At either the digital display junction box or turbine control panel (depending on your control system), momentarily press RESET switch. If there are no system malfunctions, shutdown and alarm summary lights will be extinguished and there will be no annunciation messages on display screen.

On-Crank Cleaning Procedure

1. Close all valves on tank.

2. Connect tank supply hose between water source and tank inlet.

3. Open tank vent valve and tank inlet valve.

4. Fill tank with required amount of water per Table 7.6.4. Refer to Subsection 7.6.7 for cold-weather washing.

5. Close tank inlet valve. Disconnect the tank supply hose.

6. Reconnect tank supply hose between chemical source and tank inlet.

7. Open tank inlet valve and fill tank with required amount of Solar Turbines cleaning concentrate per Table 7.6.4.

NOTE

The solution supplied to the injection tank should be pumped through the tank supply hose. Positive pressure from source is required to overcome the restriction caused by the inlet fittings.

8. Close tank inlet valve. Disconnect tank supply hose.

9. Connect tank supply hose between compressed air source and tank inlet. Ensure that the regulator at the tank inlet is set at range specified in Table 7.6.4.

10. Connect fluid delivery hose between tank fluid outlet and the on-crank manifold inlet, located on the skid.

11. Close tank vent valve.

12. Open tank inlet valve and pressurize tank to normal working pressure specified in Table 7.6.4. Leave tank inlet valve open for duration of on-crank cleaning to maintain steady injection pressure and flow.

CAUTION

Check the engine compressor section casing temperature. It should not exceed 149°F (65°C). Engine failure will result if the preparation procedures are not completed.

13. Verify preparation procedures are completed before on-crank fluid cleaning.

CAUTION

For inlet plenum temperatures below -4°F (-20°C), engine cleaning is not recommended.

14. Check inlet plenum temperature. Cold weather below 39°F (4°C), refer to Subsection 7.6.7.

15. Crank engine. Access MAINTENANCE display screen and press appropriate CRANK-ON function key.

16. Verify that prelube oil pressure reaches preset value determined by control system. Refer to hydromechanical schematic for value.

17. Verify that engine has increased to normal cranking speed.

18. Open tank fluid outlet valve and commence on-crank engine cleaning.

19. After completing on-crank cleaner injection:

    a. Stop cranking engine. Access MAINTENANCE display screen and press appropriate CRANK-OFF function key.

b. Leave tank inlet valve open for two to three minutes to allow air purge of line.

c. Close tank inlet valve, keep tank fluid outlet valve open, and allow tank pressure to drop to between 10 and 20 psig (69 and 138 kPa, 0.7 and 1.4 bar, 0.7 and 1.4 kg/cm^2).

d. Close tank fluid outlet valve.

e. Slowly open tank vent valve and release all pressure.

NOTE

Based on the recommended volume of cleaning solution and rinse water, it should take approximately four to ten minutes to complete each on-crank cleaning cycle (cleaning solution injection or rinse water injection) at a steady injection pressure specified in Table 7.6.4. If it takes appreciably longer, check the tank fluid outlet filter or injection nozzles for possible blockage. If it takes appreciably less time, check all connections for possible leaks.

20. Approximately 15 to 30 minutes after completion of on-crank chemical cleaning, it is recommended to perform a water rinse as follows:

    a. Reconnect tank supply hose between water source and tank inlet valve.

    b. Open tank vent valve and inlet valve; and fill tank with required amount of water per Table 7.6.4.

    c. Close tank water inlet valve and vent valve. Disconnect tank supply hose.

    d. Repeat steps 10 through 20.

    e. Repeat as necessary to ensure clean water at drains.

21. Disconnect tank supply hose, coil it, and hang it on tank hose rack.

22. Inspect inlet guide vanes (IGVs) and first-stage compressor blades for evidence of contamination.

    a. If compressor is clean, proceed with postcleaning engine preparation procedure.

    b. If contamination is still present; repeat steps 2 through 22 above.

On-Crank Postcleaning Procedure

NOTE

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fittings, Gaskets, Seals and O-Rings 1.7.14.

On engines that have Burner Acoustic Monitor Assembly, if liquid was detected, refer to Fuel System Chapter 3, Acoustic Monitor Coil Assembly, INSPECTING FOR LIQUID BUILDUP: ENGINE NOT OPERATING.

1. Turn Shop air supply to seals off and disconnect Shop air supply (Taurus 70 only).
2. Reconnect PCD line to front and rear seals (Taurus 70 only).
3. Disconnect flexible drain hose and container from each of the drain lines.
4. Reconnect air inlet duct, combustor, and exhaust collector drain lines at check valve connections.
5. Torque as required.
6. Install torch drain plug into torch body.
7. Connect torch drain line. For dual-fuel engines, connect drain line upstream of torch drain solenoid valve.
8. Torque as required.
9. Connect transfer tube to the acoustic monitor coil assembly and torch side pressure tap (PT) port.
10. Connect compressor discharge pressure line to fuel control (if applicable).
11. Torque as required.
12. Loosen seventh-stage bleed line bolts at diffuser fittings and remove bolts from compressor case bosses. Slide bleed lines away from compressor case (Titan only).
13. Loosen eleventh-stage bleed line bolts at diffuser case boss and remove bolts from compressor case bosses. Slide bleed lines away from compressor case (Mars only).

CAUTION

CATASTROPHIC ENGINE FAILURE will result if blanking plates from the seventh (Titan only) or eleventh-stage (Mars only) bleed bosses are not removed prior to engine restart.

CAUTION

CATASTROPHIC ENGINE FAILURE will result if the PCD supply to the front and rear bearing seal is not correctly re-instated (Taurus 70 only).

14. Remove blanking plates FT30222-1 between bleed line flanges and compressor case bosses (Mars, Titan only).
15. Move bleed lines toward compressor case (Mars, Titan only).
16. Install bolts on compressor bleed line bosses (Mars, Titan only).
17. Torque as required. (Mars, Titan only).
18. Torque all bleed line boss bolts at diffuser fittings as required (Titan only).
19. Torque all bleed line boss bolts at diffuser case boss as required. (Mars only).
20. Install bracket that ties eleventh-stage bleed lines together under engine (Mars only).
21. Inspect igniter plug for signs of contamination from cleaning solution. Clean as required and reinstall.
22. Install air inlet assembly side panels.
23. Check engine to ensure that it is ready to start. Refer to Systems Operator's Guide, Chapter 3, Operating Instructions, of this manual set.

CAUTION

Before starting the engine, ensure positive draining or venting in areas where the exhaust system forms a long horizontal run; where an exhaust heat recovery system is installed; or where there is any situation in which kerosene liquids or vapors can be trapped.

24. Start engine, allow engine temperature to stabilize for one hour at full load (or maximum allowable running condition).
25. If performance has not improved between successive cleaning operations, borescope engine compressor section.

NOTE

If excessive contamination is confirmed by the borescope inspection, manual cleaning of the compressor rotor and stator blades may be required. Manual cleaning of the compressor rotor and stator blades exceeds the maintenance limits of this manual. Contact Solar Turbines Customer Services for assistance.

ON-LINE ENGINE COMPRESSOR CLEANING

The cleaning fluid (either water or cleaning product) ingested must meet the requirements defined in Solar ES 9-62, for on-line cleaning, to minimize introduction of corrosive contaminants. Refer to Table 7.6.5 for quantities of solution required for solution wash and water rinse cycles. Observe the following items pertaining to on-line cleaning:

- The objective of using the on-line cleaning system is to clean the engine compressor on a regular basis in order to reduce the build-up of deposits in the compressor. The cleanliness of the compressor is maintained rather than allowing it to become fouled and then attempting to clean it.
- Incorrect use of the on-line cleaning system can induce compressor fouling.
- Due to the various factors which affect the operating efficiency of the compressor, such as operating environment and filtration, it is difficult to make specific recommendations on the chemical cleaning frequency for a particular engine. An initial trial run period is suggested to determine which solution washing frequency best maintains the engine compressor at or near base-line efficiency, at the most economical cost to the operator.

NOTE

On-line cleaning should not be viewed as a replacement for on-crank washing. With the site specific nature of engine compressor fouling, on-line cleaning may provide a significant performance benefit in extending the operating time between crank washes, reducing unnecessary downtime.

On-Line Cleaning Procedure

1. Ensure engine is stabilized at operating speed.
2. Close all valves on tank.
3. Connect tank supply hose between water source and tank inlet.
4. Open tank vent valve and tank inlet valve.
5. Fill tank with required amounts of water per Table 7.6.5. Refer to Subsection 7.6.7 for cold-weather washing.
6. Close tank inlet valve. Disconnect tank supply hose.

7. Reconnect tank supply hose between chemical source and tank inlet.

8. Open tank inlet valve and fill tank with required amounts of Solar Turbines cleaning concentrate per Table 7.6.5.

NOTE

Chemical feed to the injection tank should be pumped through the tank supply hose. Positive pressure from source is required to overcome restrictions in inlet fittings.

9. Close tank inlet valve. Disconnect the tank supply hose.

10. Connect tank supply hose between compressed air source and tank inlet.

11. Connect fluid delivery hose between tank fluid outlet and the on-line wash manifold inlet, located on the skid.

12. Close tank vent valve.

13. Open tank inlet valve and pressurize tank to normal working pressure specified in Table 7.6.5. Leave tank inlet valve open for duration of on-line wash to maintain steady injection pressure and flow.

14. Check inlet plenum temperature, for cold weather below 39°F (4°C), on-line engine cleaning is not recommended.

15. Access MAINTENANCE display screen and press appropriate on-line wash on function key.

16. Open tank fluid outlet valve and commence on-line engine cleaning.

17. Use all fluid in tank.

18. After completing on-line cleaning fluid injection:

    a. Leave inlet valve open for two to three minutes to allow air purge of line.

    b. Close tank inlet valve, keep tank fluid outlet valve open and allow tank pressure to drop to between 20 and 30 psig (138 and 207 kPa, 1.4 and 2.1 bar, 1.4 and 2.1 kg/cm^2).

    c. Access MAINTENANCE display screen and press appropriate on-line wash off function key.

    d. Close tank fluid outlet valve. Disconnect fluid delivery hose.

    e. Slowly open tank vent valve and release all pressure.

NOTE

Based on the recommended volume of cleaning solution, it should take approximately six to fifteen minutes to complete the on-line cleaning cycle at a steady injection pressure specified in Table 7.6.5. If it takes appreciably longer, check the tank fluid outlet filter or injection nozzles for possible blockage. If it takes appreciably less time, check all connections for possible leaks.

19. Approximately 20 minutes after completion of on-line solution wash it is recommended to perform a water rinse as follows:

    a. Reconnect tank supply hose between water source and tank inlet.

    b. Open tank inlet valve and fill tank with required amount of water per Table 7.6.5.

    c. Close tank inlet valve. Disconnect the tank supply hose.

    d. Repeat steps 10 through 18.

NOTE

Based on the recommended volume of rinse water, it should take approximately three to eight minutes to complete the on-line cleaning water rinse cycle at a steady injection pressure of 100 psig (689 kPa, 6.9 bar, 7.0 kg/cm^2).

20. Disconnect fluid delivery hose, coil it, and hang it on tank hose rack.

21. Disconnect tank supply hose, coil it, and hang it on tank hose rack.

22. Compare engine performance figures with those recorded before washing. Verify that contamination factor has decreased below value of 5 percent.

Table 7.6.5 On-Line Cleaning Methods and Specifications

Turbine Model	Cleaning Method	Cleaning Solution (Volume / Dosage) Gallons	Water to Solution Ratio	Flow GPM	Air Pressure Psig [1]	Air Flow SCFM
Saturn 20	Solution	8-10	4:1	0.4-1.0	85-100	0.7
Saturn 20	Rinse	10-20	n/a	0.4-1.0	85-100	0.7
Centaur 40	Solution	12-17	4:1	0.6–1.2	85-100	.98
Centaur 40	Rinse	17-34	n/a	0.6–1.2	85-100	.98
Centaur 50	Solution	12-17	4:1	0.6–1.2	85-100	.98
Centaur 50	Rinse	17-34	n/a	0.6–1.2	85-100	.98
Taurus 60	Solution	12-17	4:1	0.6–1.2	85-100	.98
Taurus 60	Rinse	17-34	n/a	0.6–1.2	85-100	.98

Table 7.6.5 On-Line Cleaning Methods and Specifications, Contd

Turbine Model	Cleaning Method	Cleaning Solution (Volume / Dosage) Gallons	Water to Solution Ratio	Flow GPM	Air Pressure Psig [1]	Air Flow SCFM
Taurus 65	Solution	12-17	4:1	0.6–1.2	85-100	.98
Taurus 65	Rinse	17-34	n/a	0.6–1.2	85-100	.98
Taurus 70	Solution	15-20	4:1	1.4-2.0	85-100	1.8
Taurus 70	Rinse	20-40	n/a	1.4-2.0	85-100	1.8
Mars 90/100	Solution	15-20	4:1	2.2-2.8	85-100	2.6
Mars 90/100	Rinse	20-40	n/a	2.2-2.8	85-100	2.6
Titan 130	Solution	20-25	4:1	3.0-3.6	85-100	3.5
Titan 130	Rinse	25-50	n/a	3.0-3.6	85-100	3.5

(1) The optimum pressure at the injectors is between 90-100 psig (621-689 kPa, 6.2-6.9 bar, 6.3-7.0 kg/cm^2) measured at the skid edge connection. Optimum pressure may require pressurizing the tank higher than specified but limited to the relief valve setting for the tank.

NOTE

On-line cleaning methods and specifications listed in this table are subject to change. Refer to Solar Specification ES 9-62 for updates.

7.6.13 Mobile Cleaning System Maintenance

Maintenance requirements for the on-crank/on-line cleaning system are minimal since the majority of the components in the cleaning system are stainless steel. Also, there are no moving parts in the system. The following in-service and annual maintenance checks are recommended to keep the system in good working order.

IN-SERVICE CHECKS AND MAINTENANCE

1. Periodically blow down the filter insert in the injection tank fluid outlet “Y” strainer.
2. Remove, clean, and inspect in-line triple-stage filter at on-line and on-crank wash manifold inlets.

During each on-crank or on-line wash, take note of the time it takes to inject the wash fluid. The time required for each wash should be fairly constant assuming there are no variations in injection pressure. If the injection time becomes appreciably longer, a fouled tank fluid outlet filter, fouled on-line wash or on-crank wash in-line triple stage filter, or blocked nozzles are possible causes. If the wash fluid injection time decreases, but no other parameters have changed, check the on-line and on-crank wash manifolds for fitting leaks.

ANNUAL CHECKS

1. Inspect each atomizing nozzle for damage.
2. Inspect manifold ring assemblies and couplings for security and tightness.
3. Pressure test the injection tank for leaks on all fittings.
4. Internally inspect the injection tank and clean if necessary.
5. Calibrate pressure gage.
6. Inspect the float and actuating mechanism of the magnetic level gage for any sign of damage. Calibrate magnetic level gage if necessary. Magnetic level gage accuracy can be verified by filling tank with an exact known quantity of water.
7. Check that pressure relief valve is lifting at approximately 30 psig (207 kPa, 2.1 bar, 2.1 kg/cm^2) above normal working pressure of 100 psig (689 kPa, 6.9 bar, 7.0 kg/cm^2).
8. Perform spray test on the on-line wash system to ensure all nozzles are spraying correctly.
9. Perform spray test on the on-crank wash system to ensure correct spray pattern.
10. Remove, clean in water, and inspect tank fluid outlet “Y” strainer.
11. Remove, clean, and inspect on-line and on-crank in-line triple stage filter at manifold inlet “T”.

Contact Solar Turbines Customer Services for all questions regarding the use or maintenance of the Solar Turbines engine compressor cleaning system.

7.6.14 Service Parts

Recommended service parts for the Solar Turbines on-crank and on-line engine cleaning system are listed in Table 7.6.6. Part numbers are subject to change due to product and design improvement.

Table 7.6.6 Service Parts

Solar Part Number	Description	Quantity
1027105-23	Hose, Chemical, 1/2 in. x 15 ft.	1
1027105-25	Hose, Chemical, 3/4 in. x 15 ft.	1
1027105-4	Gage, Pressure, 0 to 160 psig (0 to 11 bar), 1/4 in. NPT, Liquid Filled[1]	1
1027105-35	Valve, Pressure Relief, CE Stamped, 1/2 in. NPT, set at 130 psig (896 kPa, 9.0 bar, 9.1 kg/cm^2).	1
1027105-5	Gage, Level, 26 Gal (100 L)	1

Table 7.6.6 Service Parts, Contd

Solar Part Number	Description	Quantity
1027105-15	Insert, Filter, SS, 100 Micron for 3/4 in. NPT "Y" Strainer	1
1027105-18	Coupling, Female, Quick Disconnect, 3/4 in.	1
1027105-19	Coupling, Female, Quick Disconnect, 1/2 in.	1
1027105-26	Coupling, Male, Quick Disconnect, 3/4 in.	1
1027105-20	Coupling, Male, Quick Disconnect, 1/2 in.	1
1027105-21	Caster, Swivel Plate w/ brake, 6 in. diameter	1
1027105-22	Caster, Fixed, 6 in. diameter	1

(1) Pressure Gage is available in increments of psig and bar only.

7.7 BORESCOPE

Please contact your Solar District Service Office for assistance in performing borescope inspection.

7.8 MAINTENANCE

⚠ WARNING

Wear hard hats, safety goggles, ear plugs, and protective clothing when applicable.

Ensure other personnel are nearby. NEVER WORK ALONE.

Before working on a nonoperating package, always lock out start circuit by opening the control circuit breaker and rotate OFF/LOCAL/AUXILIARY keyswitch to OFF. Attach temporary DO NOT START tag to control switch to warn against inadvertent closing of the switch.

Turn off fuel supply and shut off service air/gas supply to pneumatic-operated pump motors when turbine is shut down for maintenance. This will prevent possible injury to personnel working on the unit.

Check for zero system pressure before disconnecting any system lines. High pressure lines may carry to 5000 psi, (34 473 kPa), (345 bar), (352 kg/cm^2) pressure.

Avoid personal contact with hot sections of equipment.

The variable vane actuator and variable vane assemblies may move without warning. Avoid pinch points when working on or near the variable vane system.

Eliminate any fuel or oil leaks as soon as detected.

Use care when troubleshooting or performing maintenance procedures. Voltages can be dangerously high. Never override interlocks. Verify all main circuit breakers are open (OFF), so that engine will not start unexpectedly while maintenance or inspection work on engine is in progress.

Use care when performing high voltage ignition system checks. Stand on a rubber mat and wear shockproof gloves and protective eye equipment.

Operation of the unit may be performed only when conditions indicate it is safe to proceed. Dangerously explosive accumulations of natural gas, fuel fumes, oil tank vent leakage, or solvent fumes must be avoided at all times. This is done by proper ventilation, elimination of leaks, and by confining the use of solvents to appropriate maintenance facilities.

WARNING

Operation of the unit may be performed only by qualified personnel. The operator must understand turbine and driven equipment operation, function, and systems and also know and understand all controls, indicators, normal indications, and operating limits.

Appropriate hearing and eye protection must be used by operating and maintenance personnel in the vicinity of the operating machine.

Refer to the Safety Requirements Chapter, located in the front of this manual, for additional Warnings and Cautions.

CAUTION

When removing and installing electrical components, ensure wiring is tagged for identification. Do not rely on color coding on wiring for component installation. If in doubt, refer to the wiring diagram for proper electrical connections.

Cap all open lines and fittings during maintenance to prevent entry of contaminants. Use caps and blanks specifically intended for closing lines or fittings. DO NOT USE TAPE.

Do not step on variable vane system assembly components.

Where removal and installation procedures are obvious, such as disconnection of plumbing or wiring and removal of attaching parts and hardware, instructions are omitted.

Except where otherwise described, standard industrial maintenance and repair practices are acceptable. Always discard old or used O-rings, seals, and gaskets, and replace with new ones.

Refer to Illustrated Parts List of this manual set for repair parts or repair kits available for maintenance on engine components.

For cleaning methods and materials, refer to INTRODUCTION Chapter, GENERAL MAINTENANCE PROCEDURES, Cleaning/Degreasing/Decarbonizing 1.6.2.

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fittings, Gaskets, Seals and O-Rings 1.7.14.

7.8.1 Ignition Exciter

The ignition exciter (5, Figure 7.8.1), located on the engine rear support in an explosionproof junction box, supplies the high voltage required for the torch igniter plug. If ignition troubles arise and the torch igniter plug or the ignition exciter is suspect, it should be tested by qualified personnel. The ignition exciter is removed, inspected, tested, and installed using the following procedures:

REMOVAL

1. Remove cover to ignition exciter junction box (7, Figure 7.8.1).
2. Remove input and output connectors (6, 4) from ignition exciter (5).
3. Remove two mounting screws, lockwashers, and nuts securing exciter to junction box. Remove exciter from junction box.

INSPECTION

1. Visually inspect exciter (5, Figure 7.8.1) for damage and corrosion. Clean as required.
2. Visually inspect 24 Vdc input connectors (6) for damage or corrosion. Clean and/or straighten pins as required.

NOTE

Pin A is negative (-), pin B positive (+) polarity.

3. Visually inspect ignition exciter output connectors (4) for damage, corrosion, and any signs of arcing or discharge to ground. Clean as required.
4. Disconnect ignition exciter cable (3) from torch igniter plug (1).
5. Inspect ignition exciter cable and porcelain tip for damage and breaks in insulation and for any signs of high voltage shorts or discharges to ground.

TESTING

⚠ CAUTION

Unless an explosive atmosphere is present, removal of the ignition exciter is not required to perform the test. If the exciter is removed, the mounting foot should be on a grounded surface.

1. Remove torch igniter plug (1, Figure 7.8.1) and gasket from torch igniter and lay on grounded surface where the electrode can be seen.

WARNING

Do not test ignition exciter and torch igniter plug in an explosive atmosphere.

2. Connect ignition exciter (5), ignition exciter cable (3) and electrical connectors (4, 6) to ignition exciter output and torch igniter plug.

CAUTION

Ignition exciter terminal “A” must be connected to negative terminal of a 24 Vdc power source.

3. Connect 24 Vdc source to ignition exciter input pins.

4. The electrode of torch igniter plug should emit a series of strong sparks at a rate of approximately two per second.

5. If torch igniter plug fails to emit a series of strong sparks and the exciter is producing audible an audible hum, replace torch igniter plug and repeat test.

6. If replacement torch igniter plug does not emit a series of strong sparks, ignition exciter is defective and should be replaced.

NOTE

If replacement torch igniter plug functions normally, first torch igniter plug is defective and should be replaced.

7. Disconnect power source from exciter.

INSTALLATION

NOTE

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fittings, Gaskets, Seals and O-Rings 1.7.14.

1. Install torch igniter plug (1, Figure 7.8.1) with new gasket in torch igniter housing.

2. Connect ignition exciter cable (3) to torch igniter plug.

3. Reinstall ignition exciter (5) in junction box (7) and secure with two retaining screws, lockwashers, and nuts. Tighten screws 35 to 50 in-lb (3.9 to 5.6 N·m) of torque.

4. Connect input and output connectors (6, 4) to ignition exciter.

5. Reinstall junction box cover.

6. Torque as required.

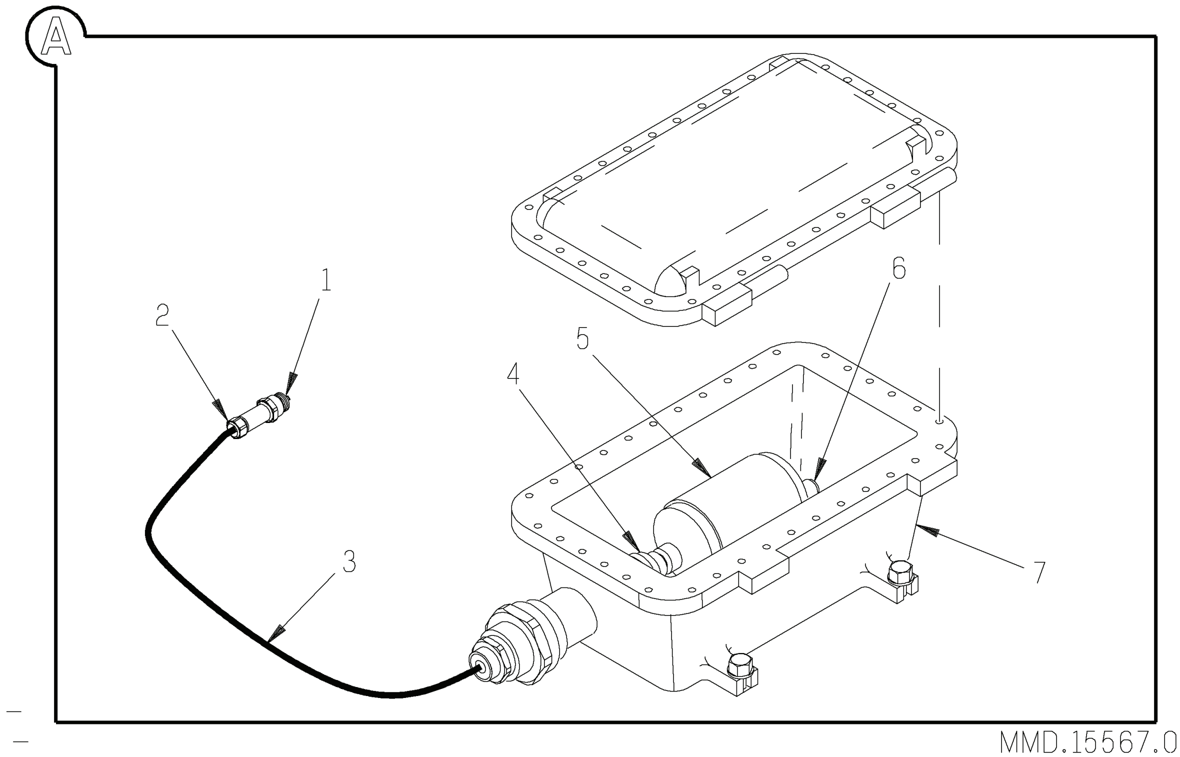


Figure 7.8.1 Ignition Exciter and Torch Igniter Plug

Key for Figure 7.8.1

1	Torch Igniter Plug	2	Exciter Cable Connector
3	Ignition Exciter Cable	4	Output Connector
5	Ignition Exciter	6	Input Connector
7	Junction Box		

7.8.2 Torch Igniter Plug

The torch igniter plug (1, Figure 7.8.1) should be inspected periodically for carbon buildup and wear. Prior to maintenance, the engine must be shut down, the fuel supply valve closed, and all systems depressurized. The torch igniter plug is removed, inspected, tested, and installed using the following procedures:

REMOVAL

1. Disconnect ignition exciter cable (3, Figure 7.8.1) from torch igniter plug (1).

2. Remove torch igniter plug from igniter housing.

3. Remove and discard gasket.

INSPECTION AND CLEANING

1. Inspect torch igniter plug (1, Figure 7.8.1) for carbon buildup and wear.
2. As necessary, replace, or clean using soft stainless steel wire brush.
3. Verify that the torch igniter plug gap is 0.090 ±0.01 in. (2.29 ±0.3 mm). Adjust as required.
4. Clean and inspect ignition exciter cable (3) for continuity and chaffing.

TESTING

WARNING

Do not test the ignition exciter and torch igniter plug in an explosive atmosphere.

1. Locate ignition exciter junction box (7, Figure 7.8.1) on rear engine mount base. Remove cover.
2. Verify that the torch igniter plug gap is 0.090 ±0.01 in. (2.29 ±0.3 mm). Adjust as required.
3. Connect exciter cable connector (2) to torch igniter plug. Ground torch igniter plug to metal surface of engine so that torch igniter plug electrode can be seen.

CAUTION

Ignition exciter terminal A must be connected to negative terminal of a 24 Vdc power source.

4. Remove ignition exciter input lead and connect separate 24 Vdc power source to ignition exciter.
5. Inspect for series of strong sparks in rapid succession when exciter is energized. If no spark is visible and exciter is producing audible hum, replace torch igniter plug.

INSTALLATION

1. Install new gasket on torch igniter plug (1, Figure 7.8.1).
2. Lubricate torch igniter plug threads with Fel-Pro Nickel Ease (Solar P/N 917427C1).

3. Install torch igniter plug in torch igniter housing. Torque plug to 25 to 30 ft-lb (33.8 to 40.6 N·m).

4. Connect exciter cable connector (2) to torch igniter plug.

7.8.3 Torch Igniter Assembly

The torch igniter assembly (Figure 7.8.2) is mounted near the bottom of the forward combustor housing. It should be inspected periodically for carbon buildup and wear.

WARNING

Prior to maintenance, the engine must be shut down, the fuel supply valve closed, and all systems depressurized.

NOTE

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fittings, Gaskets, Seals and O-Rings 1.7.14.

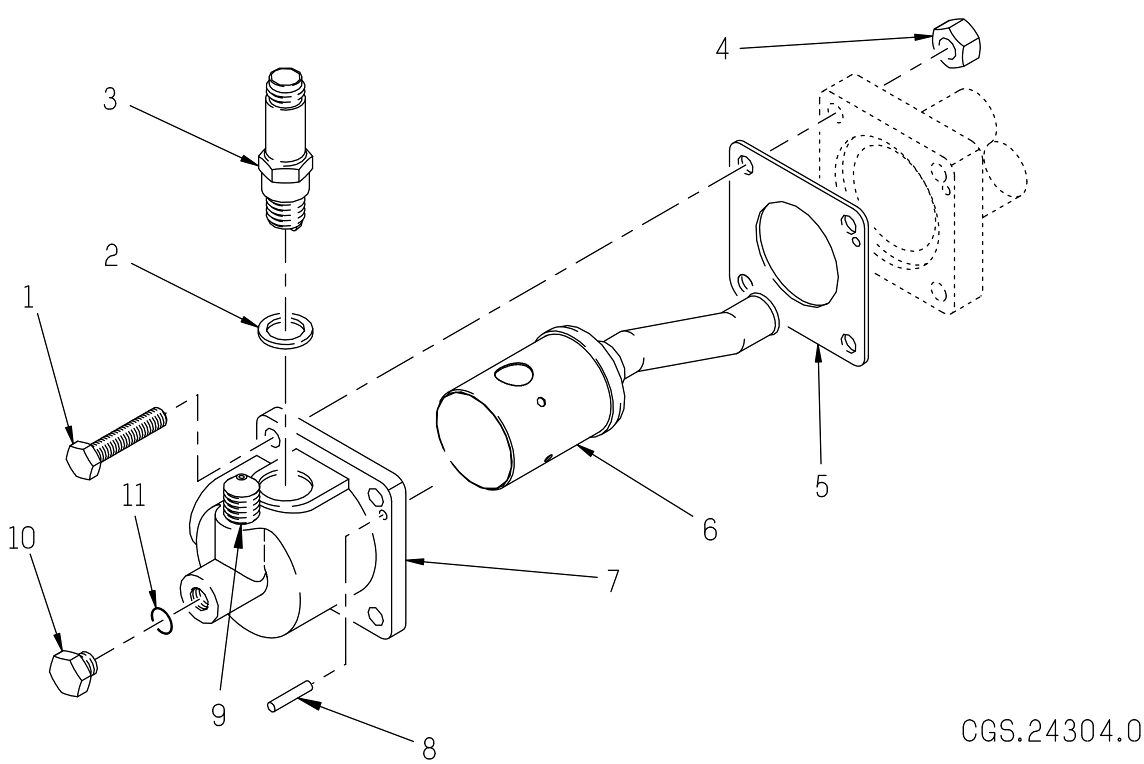


Figure 7.8.2 Torch Igniter Assembly

Key for Figure 7.8.2

1	Bolt	2	Gasket
3	Torch Igniter Plug	4	Nut
5	Gasket	6	Torch Igniter Tube
7	Igniter Housing	8	Dowel Pin
9	Gas Fuel Connection Union	10	Plug
11	Metallic Seal		

REMOVAL

Remove the torch igniter assembly using the following procedures:

1. Disconnect torch fuel supply line from gas fuel connection union (9, Figure 7.8.2).
2. Disconnect torch igniter plug cable from torch igniter plug (3).
3. Remove four bolts (1) and nuts (4) from torch mounting flange.
4. Remove torch and gasket (5) from combustor housing torch mounting flange.

DISASSEMBLY

Disassemble the torch igniter assembly on a clean work surface using the following procedures:

1. Remove torch igniter plug (3, Figure 7.8.2) and gasket (2) from igniter housing (7).
2. Remove torch igniter tube (6) from igniter housing (7).
3. Remove gas fuel connection union (9) and metallic seal from igniter housing (7). Separate metallic seal from fuel connection union.
4. Remove plug (10) and metallic seal (11) from igniter housing (7).

INSPECTION PARAMETERS

Inspect each component for the following types of contamination and damage. Determine the severity of the damage on an individual basis. Damage which cannot be repaired within applicable tolerance levels will require replacement of the component.

Distortion

Distortion is a structural change, such as heavy scoring, a bend or fold. A component being viewed on a concave surface could show signs of convexity or flatness, buckling and crumpling.

Buildup

Buildup is a deposit of foreign material on a component surface. Different types of buildup are: oil, carbon, and crystal.

Erosion and Corrosion

Erosion is caused by wear or corrosion from metal-to-metal contact or oxidation. Corrosion appears as flaking, creating a depression in the surface plane. Inspect for flaking, which appears as a terracing depression in the surface plane and for pieces missing, which would cause a hole or gap.

Burns

The normal background color of heated surfaces is light gray. Burned areas will appear as darker gray, holes will appear as black rings, and cracks will appear as black grooves.

Crack Pattern

Inspect for crack patterns. Crack lines will appear as narrow dark lines. Openings will appear as a gap or wide line. Converging cracks will appear as two or more crack lines converging. Pieces missing will show up as a missing piece of the surface plane.

CLEANING AND INSPECTION

Inspect the torch igniter using the above parameters. Damaged parts must be replaced. Parts which are clogged with grease or carbon deposits are cleaned using procedures found in INTRODUCTION Chapter, GENERAL MAINTENANCE PROCEDURES, Cleaning/Degreasing/Decarbonizing 1.6.2.

1. Clean torch igniter tube (6, Figure 7.8.2). Inspect for burns, cracks, distortions, erosion and open welds. If evidence of any of these conditions is found, replace tube.
2. Clean gasket (5). Inspect for buildup, cracks, and distortion. If evidence of any of these conditions is found, replace gasket.
3. Clean torch igniter plug (3). Inspect for buildup, cracks, and erosion. If evidence of any of these conditions is found, replace torch igniter plug.
4. Clean gasket (2). Inspect for buildup, cracks, and distortion. If evidence of any of these conditions is found, replace gasket.
5. Clean igniter housing (7). Inspect for cracks and distortion. If any cracks or distortion are found, replace housing.
6. Clean and inspect metallic seal (11) for cracks and distortion. If any evidence of these conditions is found, replace seal.

ASSEMBLY

1. Install fuel connection union (9, Figure 7.8.2) and metallic seal into igniter housing (7).
2. Torque as required.
3. Verify that the torch igniter plug gap is 0.090 ±0.01 in. (2.29 ±0.3 mm). Adjust as required.
4. Install torch igniter plug (3) and gasket (2) into igniter housing (7).
5. Torque to 25 to 30 ft-lb (33.9 to 40.68 N·m).
6. Install metallic seal (11) and plug (10) into igniter housing (7).
7. Torque as required.

INSTALLATION

1. Lubricate bolts (1, Figure 7.8.2) with Fel-Pro Nickel Ease (Solar P/N 917427C1).
2. Install igniter housing (7) and gasket (5) on forward combustor housing torch mounting boss with four bolts (1) and nuts (4).

NOTE

Carefully insert the torch tube tip into the grommet on the combustor liner outer plate.

3. Torque bolts as required.
4. Connect igniter cable to torch igniter plug.
5. Connect fuel line to torch igniter.
6. Torque fuel line connection fittings as required.

7.8.4 Bleed Air System

The following procedures provide removal, disassembly, cleaning and inspection, assembly, and installation instructions for the compressor bleed valve (Figure 7.8.3).

REMOVAL

1. Remove the V-band clamps and bleed air duct.
2. Remove nuts and washers from six studs (13, Figure 7.8.3). Remove bleed valve from mounting flange.
3. Remove gasket from mounting flange and discard.

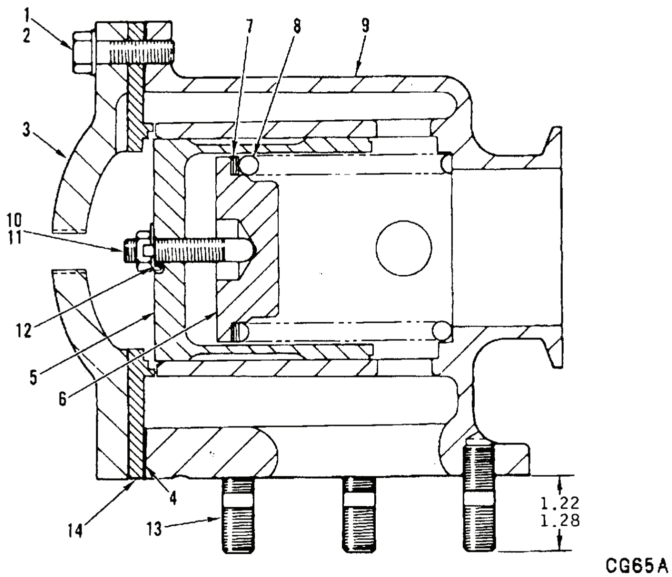


Figure 7.8.3 Typical Bleed Valve

Key for Figure 7.8.3

1	Bolt	2	Lockwasher
3	Cover	4	Cover Gasket
5	Piston	6	Spring Seat
7	Shim	8	Spring
9	Housing	10	Adjusting Screw
11	Jam Nut	12	Tab Washer
13	Stud	14	Spacer

DISASSEMBLY

1. Remove bolts (1, Figure 7.8.3) and lockwashers (2). Remove cover (3) and gasket (4).
2. Remove piston (5), spring seat (6), shims (7) and spring (8) from valve housing (9).

NOTE

Spring tension is factory-adjusted and the adjusting screw is locked in proper position. The only field adjustment necessary is the final altitude setting which is made prior to the first start-up by verifying that the correct number of shims are in the valve. DO NOT LOOSEN OR READJUST THE ADJUSTING SCREW.

3. Verify that correct number of 0.048±0.003-in. (1.2±0.08-mm) thick shims for given altitude ranges is installed as follows:

• 0 to 2000 feet (0 to 610 meters)	3 shims
• 2000 to 4000 feet (610 to 1219 meters)	2 shims
• 4000 to 6000 feet (1219 to 1829 meters)	1 shim
• 6000 to 8000 feet (1829 to 2438 meters)	0 shims

INSPECTION AND CLEANING

1. Visually inspect valve and components for damage (nicks, cracks, scoring), and piston for evidence of binding or excessive wear. Inspect adjusting screw (10, 7.8.3) and jam nut (11) for tightness, and end of screw for wear where it seats in spring seat (6).

2. Clean parts by wiping with clean, lintfree cloth dampened in Stoddard solvent or equivalent.

3. If parts are defective, replace valve. Valve must be calibrated at factory or overhaul center.

ASSEMBLY

1. Install spring (8, 7.8.3), shims (7), and spring seat (6) in housing (9).

2. Install piston (5) in housing (9) over spring (8) and spring seat (6).

3. Install new cover gasket (4) on housing (9). Then install cover (3), bolts (1), and lockwashers (2).

4. Torque bolts to 18 to 22 ft-lb (24 to 30 N·m).

INSTALLATION

NOTE

If the replacement of studs is necessary, reinstall the studs so the length of studs measures 1.20 to 1.28 in. (30 to 33 mm) from the valve housing surface to the end of studs.

NOTE

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fittings, Gaskets, Seals and O-Rings 1.7.14.

1. Install new gasket on mounting flange.
2. Install bleed valve on mounting flange and secure with six retaining nuts and washers.

NOTE

Position the bleed valve on the mounting flange so that the valve outlet faces the exhaust duct.

3. Torque nuts to 420 to 600 in-lb (47 to 68 N·m).
4. Position bleed valve duct between bleed valve and exhaust duct.
5. Attach bleed valve to bleed valve duct and exhaust duct with V-band clamps.
6. Start engine and check for smooth acceleration and satisfactory temperature stabilization.

7.8.5 Fuel Injector Assemblies

Use the following procedures for disassembly, inspection and cleaning, and installation of the fuel injector assemblies:

WARNING

Carefully inspect all fittings and fuel port bosses for leaks following any fuel injector maintenance work.

NOTE

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fittings, Gaskets, Seals and O-Rings 1.7.14.

REMOVAL

1. Disconnect fuel manifold-to-injector tube assemblies at fuel manifold and injector port connections.
2. Apply a penetrating oil, such as Aero-Kroil or Liquid Wrench, to the injector bolt heads/threads.
3. Remove bolts and washers from each injector flange.

CAUTION

To prevent galling and breaking of fuel injector bolts, allow engine to cool to touch prior to fuel injector bolt removal.

Use caution when achieving break-away torque of injector bolts.

NOTE

Should a bolt break off, refer to Technical Letter TL 8.0/110 for broken bolt removal procedure.

4. Mark the location of each fuel injector (using a permanent marker) prior to removal. Do not use a lead pencil.
5. Remove fuel injectors and gaskets from combustor housing flanges. Discard gaskets.

INSPECTION AND CLEANING

1. Inspect each fuel injector for wear or distortion.
2. Replace injector if excessively damaged or distorted.
3. Use soft wire brush to clean outside, and soft wire bottle brush to clean inside fuel injectors.

INSTALLATION

1. Install new gaskets and mount fuel injectors on combustor housing flanges.
2. Lubricate threads of bolts with Fel-Pro Nickel Ease (Solar P/N 917427C1).
3. Install bolts and washers. Torque bolts as required.
4. Lubricate threads of injector fuel port bosses and the outside of flare fitting sleeves with a small amount of Clear Petroleum Base Lubricant (Solar P/N 915793C1).

NOTE

Do not lubricate sealing surfaces of flare.

5. Reinstall all tube assemblies removed during disassembly. Torque tube fittings as required.

CAUTION

To avoid excessive stress and possible damage to fuel port bosses, use a backup wrench on the bosses when tightening tube fittings.

7.8.6 Variable Vane System

The following procedure is used to check the variable vanes for proper operation and adjustment using guide vane positioning gage FT20500 (Figure 7.8.4):

WARNING

The variable vane actuator and variable vane assemblies may move without warning. Avoid pinch points when working on or near the variable vane system.

CAUTION

Do not step on variable vane system assembly components.

1. Remove inlet guide vane sheet metal enclosure. Install gage FT20500 and locate gage so that two dowel pins are resting firmly on outside diameter of air inlet housing. Ensure that the index arm (machined surface) of gage is in line with center of inlet guide vane pivot shaft (Figure 7.8.4).

2. Check inlet guide assembly for loose hardware or obvious mechanical damage. If hardware is secure and there is no mechanical damage, minimum and maximum open positions may be checked as outlined in Step 3 below. If linkage or hardware is loose, then full repositioning should be made as described in Step 4.

3. Start engine and observe guide vane positioning gage and inlet guide vane scale. When starter begins to crank engine during start sequence, verify that vane control actuator is fully retracted. Verify that the machined surface of gage FT20500 is in approximate alignment with mark indicating -35 degrees or “C” on inlet guide vane scale. Marks indicating -29 degrees and -24 degrees on first- and second-stage vane assemblies indicate that vanes are in minimum open position.

4. As engine attains approximately 66 percent speed, vane control actuator should begin to extend, moving vanes to maximum open position. Degree of opening indicated on inlet guide vane scale should then agree with number of degrees stenciled on inlet guide vane support.

5. Stop engine and again observe vane positioning gage and inlet guide vane scale. As engine speed decreases below approximately 90 percent, vane control actuator should retract fully, moving vanes to minimum open position. Machined surface of positioning gage should then be in approximate alignment with mark indicating -35 degrees on inlet guide vane scale, and marks indicating -29 degrees and -24 degrees on first- and second-stage vane assemblies. If any adjustments are necessary, maximum open position may be changed by adjusting actuator to lever turnbuckle assembly. Minimum open position is determined by actuator piston travel and no adjustment of turnbuckle assembly should be attempted.

6. If full repositioning is required, disconnect plumbing to vane control actuator, and connect external source of oil pressure, 55 psi (55 psig (379 kPa), (3.8 bar), (3.9 kg/cm^2), to actuator top oil in port.

7. Apply oil pressure to fully retract actuator. Adjust inlet guide vane turnbuckle and rod ends so that machined surface of positioning gage FT20500 is in exact alignment with mark indicating -35 degrees on inlet guide vane scale. Readjust first- and second-stage vanes in similar manner, to marks indicating -29 degrees and -24 degrees. Tighten all turnbuckles, locknuts, and other attaching hardware.

Disconnect external oil supply from actuator top port and connect it to bottom oil in port. Apply oil pressure to fully extend actuator and move vanes to maximum open position.

Degree of opening indicated on inlet guide vane scale must agree with number of degrees stenciled on inlet guide vane support. If it is not same, adjust actuator to lever turnbuckle assembly to obtain correct setting on inlet guide vane scale.

Disconnect external oil supply from actuator bottom port and reconnect it to top port. Apply oil pressure to fully retract actuator and verify that vanes return to approximately the -35 degree mark on inlet guide vane scale.

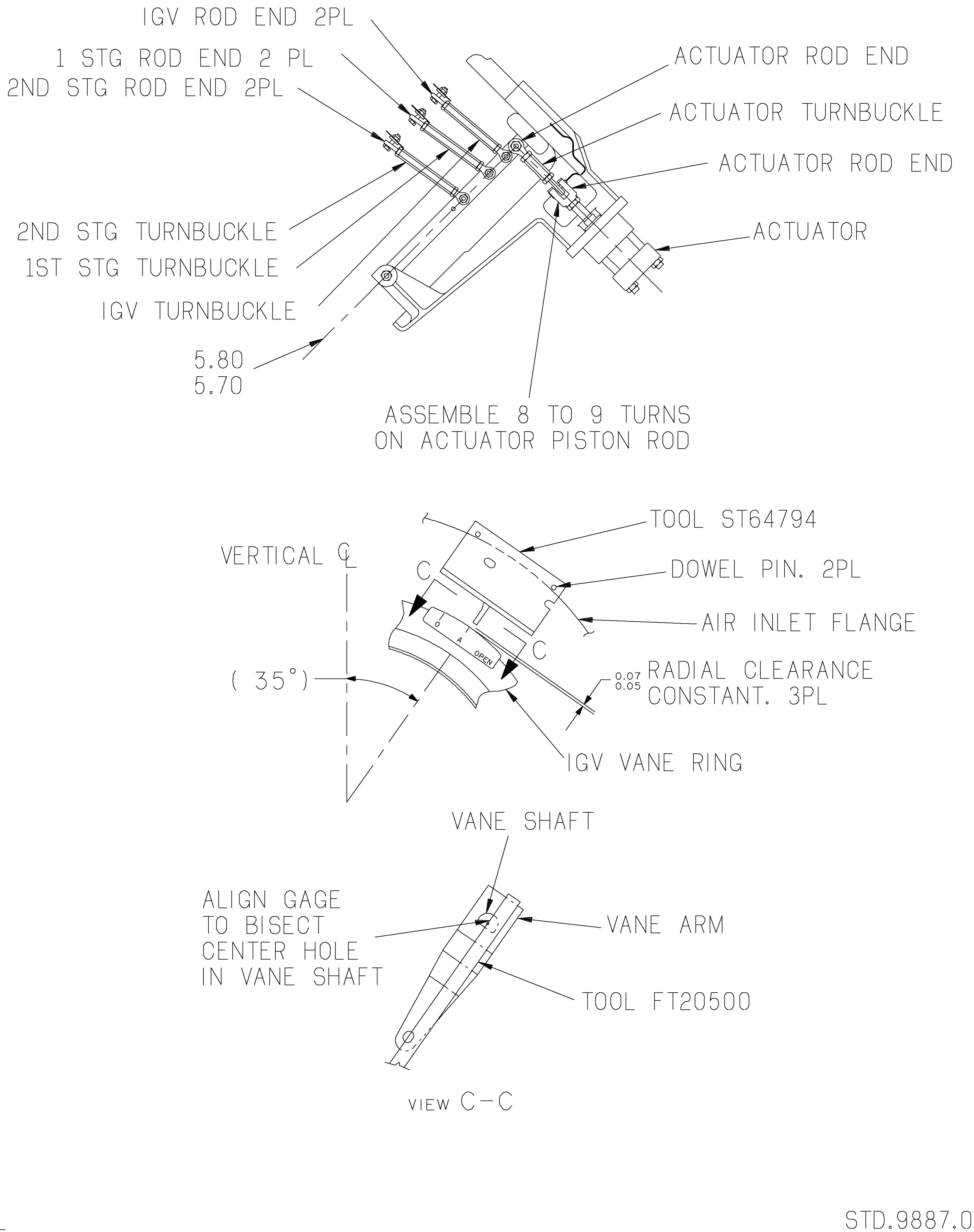


Figure 7.8.4 Guide Vane Positioning Gage, FT20500, Installed

7.8.7 Variable Vane Corrosion Inspection

Perform regular (monthly or more frequent) inspection of the variable guide vane system as follows:

WARNING

Always remove motive force (electric or hydraulic) to guide vane actuators before servicing the vanes or working in adjacent areas. Follow appropriate lock out procedure for the entire turbomachinery package, ancillaries, and associated equipment and attach "DO NOT OPERATE" tags.

CAUTION

Do not operate the unit with seized guide vanes or bent lever arms. Engine compressor blade failure may result.

1. Remove variable guide vane covers if applicable.
2. Inspect for bent lever arms.
3. Inspect for grommets that have worked out of position on the unison rings.
4. Inspect for corrosion around the guide vanes. Pay special attention to the guide vanes at the bottom of the compressor case.
5. If corrosion is evident, remove the turnbuckle from each variable guide vane ring, one at a time, and rotate by hand to verify free movement of the system.

NOTE

If one or more stages of variable guide vanes are difficult to rotate but still have some freedom, the unit can be operated; however, inspection of the lever arms must be carried out more frequently. Contact your local Solar District Office to schedule an evaluation and to obtain recommended corrective actions. After an inspection, an external preservation is recommended as described in Subsection 7.8.8.

7.8.8 Variable Vane External Preservation

Periodically apply a corrosion inhibitor to the external guide vane system linkages and rotating contact surfaces. Ideally, this should be done after the inspection described in Subsection 7.8.7. Use one of the corrosion inhibitors listed in Table 7.8.1 for variable guide vane external preservation.

Table 7.8.1 Materials and Equipment

Item	Description	Remarks
Handheld pump sprayer	3 pints to 1 gallon (1.4 to 3.8 liters)	Used to apply corrosion inhibitor
Corrosion inhibitor	Cor-Ban™ D-5010NS aerosol	Available from Zip-Chem® Aviation Products
Corrosion inhibitor	Cor-Ban™ ZC-010 bulk liquid	Available from Zip-Chem® Aviation Products
Corrosion inhibitor	RPX 2354B	Available from Chemtool Incorporated®

WARNING

Do not apply corrosion inhibitor to an engine that is operating or to an engine that has not cooled below the corrosion inhibitor manufacturer's maximum recommended application temperature. To do so can leave a residue, create noxious vapors, or ignite the corrosion inhibitor and/or corrosion inhibitor vapors.

1. Remove all guide vane covers.
2. Fill a suitable handheld, pump-pressurized, general-purpose sprayer with corrosion inhibitor.
3. Apply corrosion inhibitor underneath each guide vane actuating lever and around the guide vane stems and bushings where they penetrate the compressor case.

NOTE

Apply enough corrosion inhibitor to fully wet all guide vane component surfaces.

4. Allow the corrosion inhibitor to penetrate the bushings for a few minutes then wipe off any excess corrosion inhibitor from the compressor case, actuating levers, and unison rings.

WARNING

On units with exposed guide vane lever arms, exercising the guide vanes creates a pinch hazard. Do not exercise guide vanes on an engine having exposed lever arms unless the package is enclosed.

NOTE

To minimize heating of the corrosion inhibitor, crank the engine the minimum amount of time to cycle the guide vane system to full open, then stop immediately and allow the engine to coast down.

5. Test crank the engine.

NOTE

Test crank will bring the unit to approximately 20% Ngp and will send a 20 mA signal to the actuator to fully open the guide vanes. For engines with hydraulic guide vane actuators, the lube oil header pressure must be 20 psig (138 kPa, 1.4 bar, 1.4 kg/cm^2) to cycle the guide vanes during test crank.

6. Repeat the crank cycle five times. Observe the guide vane actuation process to ensure there is smooth and complete travel from fully opened to fully closed.

7. Install the guide vane covers.

7.8.9 Variable Vane and Compressor Flow Path Internal Preservation

If an engine is scheduled for a period of non-operation or standby of two weeks or more in adverse conditions, apply corrosion inhibitor to the gas path for short-term corrosion protection. Refer to Service Bulletin 8.6/112.

7.8.10 T5 Thermocouples

The T5 thermocouples are mounted around the combustor aft housing. Remove, inspect, test, and install the T5 thermocouples using the following procedures.

REMOVAL

1. Remove cover from T5 junction box.
2. Identify and tag T5 thermocouple leads in T5 junction box.
3. Disconnect thermocouple leads from Flex I/O™ module.
4. Disconnect thermocouple harness assembly conduit union nuts on T5 junction box.
5. Pull conduit unions and thermocouple leads out of T5 junction box.
6. Disconnect thermocouple harness assembly clamps where necessary.
7. Remove two bolts from thermocouple flange.

CAUTION

Thermocouple assembly must be pulled straight out slowly. Take extreme care not to damage thermocouple tip.

8. Pull thermocouple assembly straight out of port.

9. Remove gasket from flange and discard.

INSPECTION AND FUNCTIONAL TEST

1. Inspect thermocouples, harness assemblies, and output leads for signs of erosion, broken or bent wires, nicked, dented, or punctured insulating tubing, or other visible damage. Replace all damaged thermocouple assemblies.

2. Connect ohmmeter to thermocouple leads. Thermocouple resistance should be no more than a few ohms. Replace thermocouple assembly if faulty.

3. Temporarily connect thermocouple output lead wires to Flex I/O module. Rotate OFF/LOCAL/AUXILIARY keyswitch to LOCAL. Use an appropriate calibrated, thermalwell-style temperature source to apply heat to each thermocouple while observing the temperature readings. Select a series of temperature points across the thermocouples operating range to ensure thermocouple, harness assembly, Flex I/O module, output coaxial cable and PLC module are working correctly.

NOTE

If a calibrated temperature source is unavailable, a heat gun may be used to apply heat to thermocouple tip. Using this technique, you will only be able to determine thermocouple response, not accuracy.

4. If temperature readings do not track temperature input correctly, remove thermocouple from heat source. Disconnect thermocouple output lead wires from Flex I/O module.

5. Connect type-K thermocouple simulator to the Flex I/O module input connections. If a simulator is not available, a calibrated millivolt source can be used. Select a series of temperature (or millivolt) inputs while observing the temperature output readings.

NOTE

Refer to Table 7.8.2 for type-K thermocouple temperature/millivolt conversions.

Table 7.8.2 Type-K Thermocouple Temperature/Millivolt Conversions

°F/°C	Millivolts	°F/°C	Millivolts
50/10.0	0.40	1050/565.6	23.44
100/37.8	1.52	1100/593.3	24.62
150/65.6	2.67	1150/621.1	25.80
200/93.3	3.82	1200/648.9	26.98
250/121.1	4.96	1250/676.7	28.20
300/148.9	6.10	1300/704.4	29.31
350/176.7	7.21	1350/732.2	30.47
400/204.4	8.32	1400/760.0	31.62
450/232.2	9.43	1450/787.8	32.77
500/260.0	10.56	1500/815.6	33.91
550/287.8	11.70	1550/843.3	35.04
600/315.6	12.85	1600/871.1	36.17
650/343.3	14.01	1650/898.9	37.28
700/371.1	15.18	1700/926.7	38.39
750/398.9	16.35	1750/954.4	39.49
800/426.7	17.53	1800/982.2	40.58
850/454.4	18.70	1850/1010.0	41.66
900/482.2	19.89	1900/1037.8	42.74
950/510.0	21.07	1950/1065.6	43.81
1000/537.8	22.25	2000/1093.3	44.87

6. If temperature tracks correctly, replace the thermocouple and harness assembly. If temperature does not track correctly, troubleshoot the Flex I/O module, output coaxial cable and PLC module circuit.

7. Rotate OFF/LOCAL/AUXILIARY keyswitch to OFF.

INSTALLATION

NOTE

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fittings, Gaskets, Seals and O-Rings 1.7.14.

1. Install new gasket onto thermocouple port flange.

2. Insert thermocouple into port.
3. Lubricate threads of bolts with Fel-Pro Nickel Ease (Solar P/N 917427C1).
4. Install two bolts on thermocouple flange.
5. Torque as required.
6. Install thermocouple harness assembly clamps.
7. Insert thermocouple leads and harness assembly conduit union into T5 junction box.
8. Install thermocouple harness assembly conduit union nut on T5 junction box.
9. Torque as required.
10. Connect thermocouple leads to Flex I/O module.
11. Remove tags from thermocouple leads.
12. Install cover on T5 junction box.

7.9 ENGINE REMOVAL AND INSTALLATION

WARNING

Avoid physical contact with the hot sections of equipment.

Perform a site hazard assessment and a job safety analysis prior to starting any work.

Prior to working on a nonoperating package, always lock out the start circuit by opening the control circuit breaker and rotating the OFF/LOCAL/AUXILIARY keyswitch to OFF. Attach a temporary DO NOT START tag to the circuit breaker to warn against inadvertent closing of the breaker.

Depressurize the system before disconnecting any system lines. High-pressure lines may carry up to 5000 psi (34 474 kPa), (345 bar), (350 kg/cm^2).

Turn off the fuel supply and shut off the service air/gas supply to pneumatic-operated pump motors when turbine is shut down for maintenance.

For offshore installations, confirm that no inclement weather is forecast for the planned working days prior to proceeding with turbine engine removal/installation. For limits on the use of engine handling equipment, refer to the appropriate section of Solar Turbines Engineering Specification ES 2335 – Lifting Equipment for Solar Turbines Packages and Package Equipment.

The engine handling equipment is load tested and certified by a classification society prior to shipment. However, it is the responsibility of the equipment owner to inspect and/or recertify the equipment before use as required by the classification society or the Authority Having Jurisdiction (AHJ) in the country of registration or use. Typically, the classification societies and the AHJ require lifting equipment to be inspected every six months and to be recertified every four years.

CAUTION

When removing and installing electrical components, verify that the wiring is tagged for identification. Do not rely on the color coding on the wiring for component installation. If in doubt, refer to the wiring diagram for proper electrical connections.

CAUTION

When disassembling or assembling the various systems, use the lifting lugs provided to handle each component individually. Employ industry-accepted lifting techniques when lifting lugs are not provided.

Removed O-ring seals and gaskets should be replaced with new seals and gaskets at assembly or installation. Lubricate new O-ring seals with petroleum jelly or equivalent before installation.

Cap all open lines and fittings during the engine disconnect procedure to prevent entry of contaminants. Use caps and blanks intended for closing lines or fittings. DO NOT USE TAPE.

Where removal and installation procedures are obvious, such as in the connection/disconnection of plumbing or wiring, and in the removal/installation of attaching parts and hardware, instructions are omitted.

Except where otherwise described, standard industrial maintenance and repair practices are acceptable. Always discard old or used O-rings, seals, and gaskets, and replace with new ones.

For cleaning methods and materials, refer to INTRODUCTION Chapter, GENERAL MAINTENANCE PROCEDURES, Cleaning/Degreasing/Decarbonizing 1.6.2.

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fittings, Gaskets, Seals and O-Rings 1.7.14.

7.9.1 Scope

This section is used by customer/field service personnel to remove and install the Centaur 40 (C40) single-shaft engines. It is used with the site-specific package drawings and Solar Turbines specifications. Subsections of this section are described in the following paragraphs.

Unenclosed/Enclosed packages (Subection 7.9.2) — Describes the primary differences between removing an engine from an unenclosed package and an enclosed package.

Configuration of C40 Engines Returned to Solar Turbines Overhaul Facilities (Subsection 7.9.3) - Includes the list of engine components to be removed and a list of components to be left attached to the engine for return to a Solar Turbines overhaul facility.

Tools and Materials (Subsection 7.9.4) - Includes tables that list tools and materials used in the engine removal and installation procedures.

General Information (Subsection 7.9.5) - Includes an illustration showing the engine with the lift tools installed.

Engine Connection Points (Subsection 7.9.6) - Includes a check list of the engine components to be disconnected for engine removal and reconnected for engine installation.

Engine Removal (Subsection 7.9.7) - Includes step-by-step instructions for engine removal.

Engine Installation (Subsection 7.9.8) - Includes step-by-step instructions for engine installation.

7.9.2 Unenclosed/Enclosed Packages

The engine is disconnected from the package at the same points for both unenclosed and enclosed packages. The primary differences in the engine removal are:

- Unenclosed packages require the use of customer-provided hoists or cranes capable of safely lifting the weight of the engine.
- Enclosed packages require removing crossbars, panels, and doors from the enclosure before engine-removal equipment can be set up.
- Enclosed packages require using or installing trolley beams, trolley beam extensions, and trolley beam hoist to lift and remove the engine.

Both customer-provided lifting equipment and package-installed lifting equipment will be attached to the single-point lift tool shown in General Information (Subsection 7.9.5).

7.9.3 Configuration of C40 Engines Returned to Solar Turbines Overhaul Facilities

NOTE

Some external engine parts must be returned to Solar overhaul facilities along with the engine. Solar evaluates these external parts and reconditions or replaces the parts as appropriate. Failure to return these parts with the engine may result in delays in the overhaul process and/or increased overhaul costs.

Refer to Solar Turbines Service Bulletin 8.0/126 (C40) for current return configuration requirements. Information presented below is for reference only.

EXTERNAL ENGINE PARTS TO BE RETURNED

The following external engine parts must be left on the engine for return to a Solar Turbines overhaul facility:

- Fuel injectors and fuel manifold components
- Bleed valve and actuator
- Compressor coupling hub
- Variable vane actuator
- Variable vane actuator covers
- Air inlet screens
- Torch ignitor assembly
- Lube oil transfer tube
- T-5 thermocouple harness assembly
- Borescope plugs
- Lube oil drain adapters
- Clamp ring
- Starter sprag clutch assembly and quill sleeve (if reduction drive gearbox is returned)
- Bearing housing fittings (C40)
- T5 compensator (C40)

EXTERNAL ENGINE PARTS NOT TO BE RETURNED

The following external parts are not to be returned with the engine:

- Engine mounts
- External junction boxes
- Special fittings
- Air inlet collector
- Exhaust collector
- Starter
- Lube oil pump

7.9.4 Tools and Materials

Engine removal tool kits and external A-frame kits (enclosed packages) required for removal and installation of the engine are listed in Table 7.9.1. Miscellaneous tools and consumable materials required are listed in Table 7.9.2.

Table 7.9.1 Centaur 40 Engine Handling Equipment

Engine Type	Landbased Engine Removal Tool Kits[1 2 3]	Landbased External A-Frame Kits[2 4]	Offshore Engine Removal Tool Kits[1 2 3]	Offshore External A-Frame Kits[2 4]
C40 One Shaft	70-47405-100 1081998-100	1036654-100 1060192-101 1075716-100	1037843-100 1081999-100	1050167-100 1060829-100 1075716-200
C40S One Shaft	1055192-200 1082000-100	1036654-100 1060192-101 1075716-100	1037843-200 1082001-100	1050167-100 1060829-100 1075716-200

(1) Includes engine single-point lift tool and trolley hoist.

(2) One required.

(3) Guide beam 1077099-100 required for trolley hoist installation.

(4) Includes external trolley beam extension and A-frame assembly.

Table 7.9.2 Tools and Consumable Materials

Nomenclature	Range/Part No.	Quantity/Remarks
FIELD TOOLS		
C40 Single-Shaft Engine Shipping/Storage Container (recommended)	FT20865	(1 each) Consists of one metal container that will hold engine (without inlet and exhaust ducts).
C40 Single-Shaft Engine Cart	FT20870	(1 each) Consists of one wheeled cart that will hold engine (without inlet and exhaust ducts).
Guide Pins (recommended)	FT20059-2	(1 set) Consists of two 12 in. long guide pins. Used to guide engine into gearbox during engine installation.

Table 7.9.2 Tools and Consumable Materials, Contd

Nomenclature	Range/Part No.	Quantity/Remarks
Jack Screws (recommended)	FT20059-3	(1 set) Consists of four 12 in. long jack screws. Used to separate engine from gearbox during engine removal.
Gearbox Lift Tool	FT20060	(1 each) Used to lift gearbox with or without starter adapter and/or hub.
Nylon Slings (recommended)	FT61096	(1 set) Consists of nine nylon slings of various sizes. Used in many engine component and subassembly lifting and handling operations.
Winch Sling (recommended)	FT61027	(1 each) Consists of one winch sling. Used in many engine component and subassembly lifting and handling operations.
Ropes and guy wires	-	(As required) Used to steady the load during engine or component removal and installation.
MECHANICS TOOLS		
Allen Wrench	1/8 to 3/4 in.	(1 set)
Flare Wrench	1/2 to 1 in.	(1 set)
Torque Wrench	15 to 100 ft-lb (20 to 140 N·m)	(1 each)
Heat Gun	300°F to 500°F (149°C to 260°C)	(1 each)
Caulking Gun	70-30171-1	(1 each)
CONSUMABLE MATERIALS		
Safety Wire	0.032 dia 917345C1	As required
Fel-Pro Nickel Ease	917427C1	As required
RTV Adhesive	917212C1	As required
Butyl Rubber Sealant	980739C1	As required

Table 7.9.2 Tools and Consumable Materials, Contd

Nomenclature	Range/Part No.	Quantity/Remarks
Synthetic Rubber Sealant	952095C1	As required
3M Hi-Tack 76 (or equivalent) Spray Adhesive	-	As required

7.9.5 General Information

WARNING

All equipment used for lifting and hoisting must be capable of handling the load without exceeding safety margins.

Figure 7.9.1 depicts Single-Point Lift Tool (FT20617-100) mounted on the engine. Figure 7.9.2 depicts Single-Point Lift Tool (FT21607-107) mounted on the engine. Figure 7.9.3 depicts Single-Point Lift Tools (FT21609-105 / -202) mounted on the engine. Table 7.9.3 lists the weights of the various engine models, as well as major engine components.

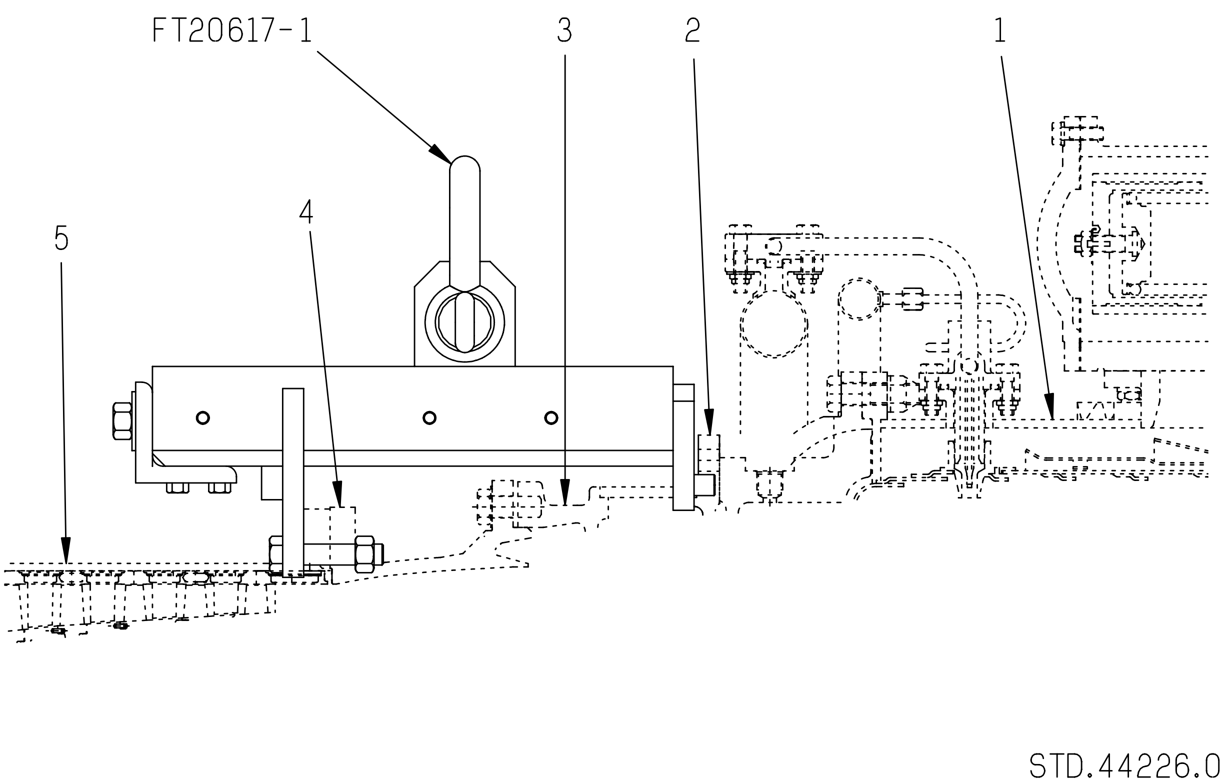


Figure 7.9.1 Lift Tool FT20617-100

Key for Figure 7.9.1

1	Combustor Housing	2	GP Outer Bearing Support
3	Aft Diffuser Housing Section	4	Compressor Housing
5	Diffuser Housing		

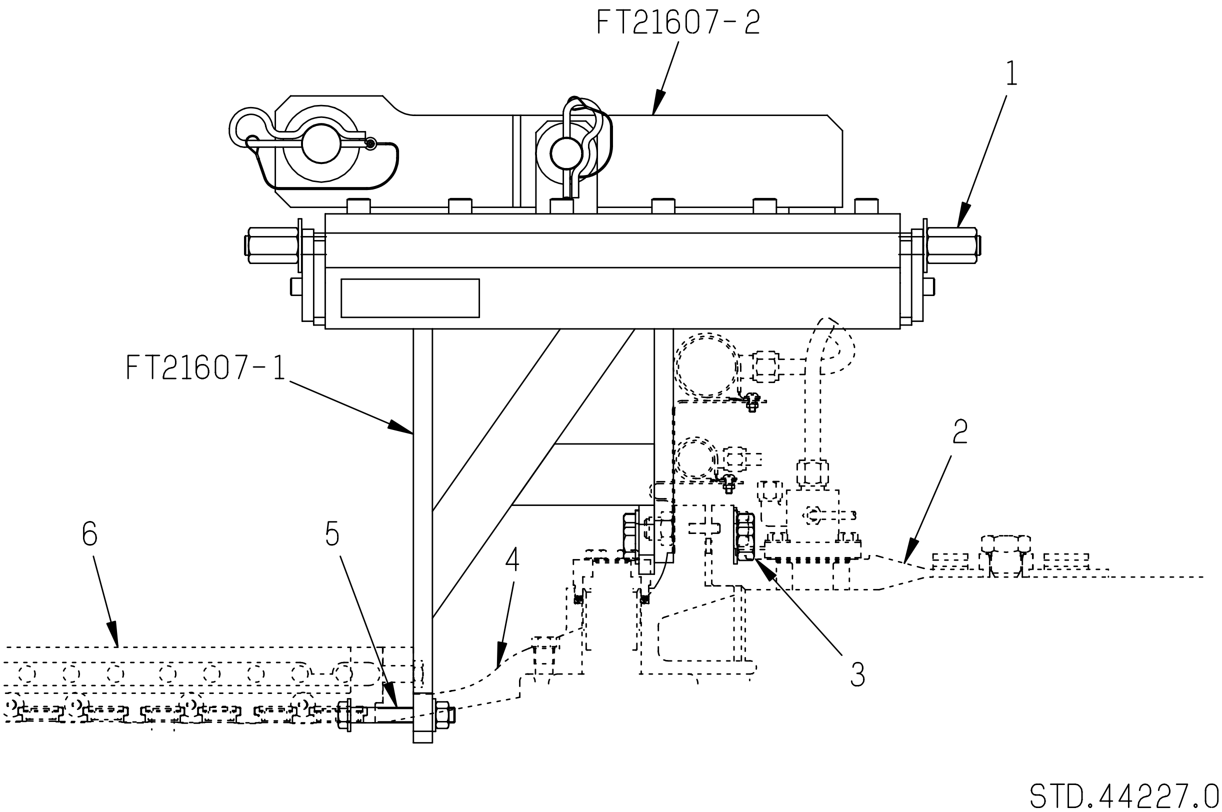


Figure 7.9.2 Lift Tool FT21607-107

Key for Figure 7.9.2

1	C/G Adjustment Nut	2	Combustor Housing
3	Bolt, Nut, and Washer	4	Diffuser Housing
5	Bolt, Nut, and Washer	6	Compressor Housing

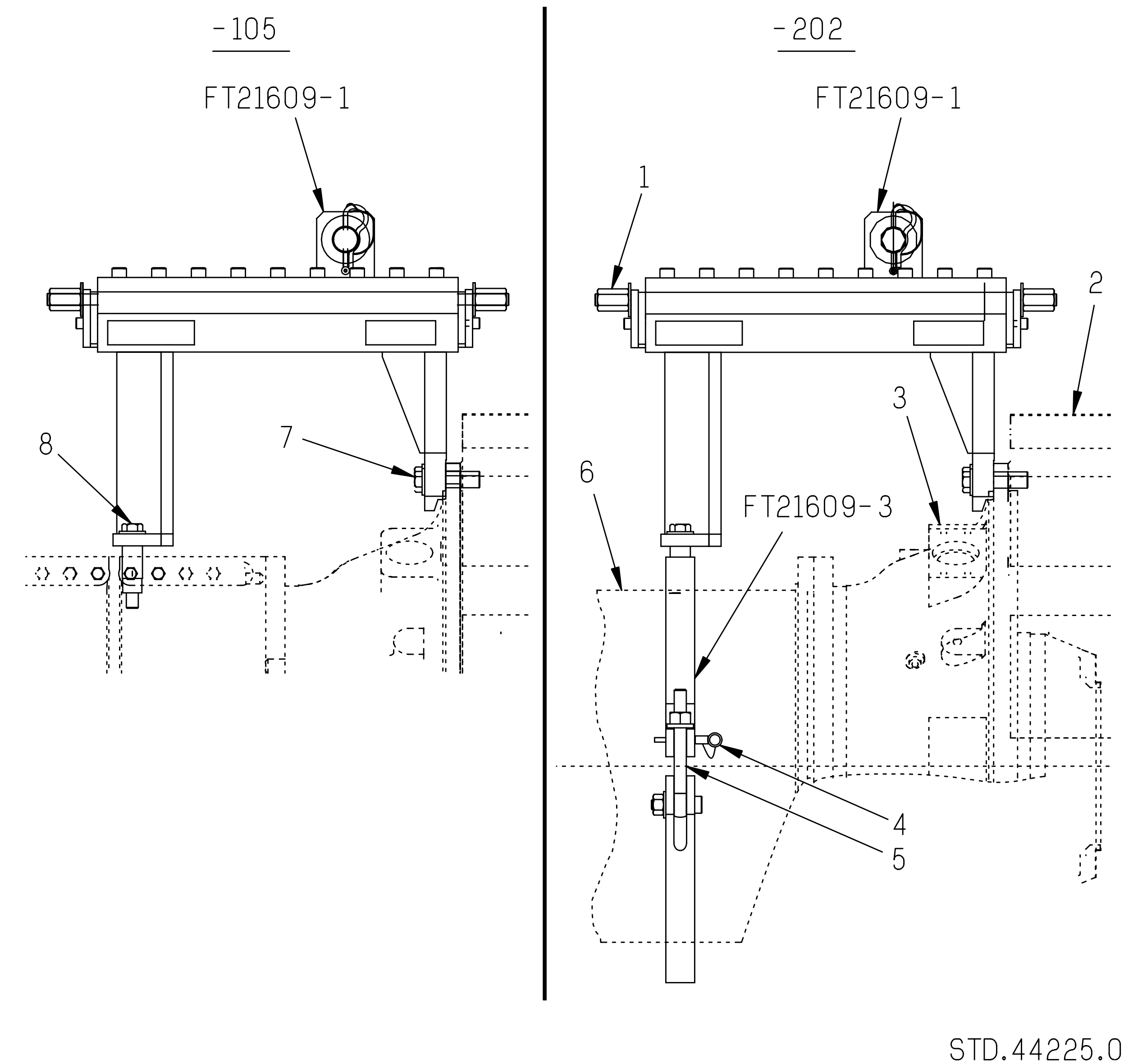


Figure 7.9.3 Lift Tool FT21609-105 / -202

Key for Figure 7.9.3			
1	C/G Adjustment Nut	2	Combustor Housing
3	Diffuser Housing	4	Ball Lock Pin
5	Eye Bolt	6	Compressor Housing
7	Cap Screw	8	Cap Screw

Table 7.9.3 Engine and Component Weights

Item	Approximate Weight
C40 Engine (with air inlet duct and exhaust duct)	4 050 lb (1 837 kg)
C40S Engine (with air inlet duct and exhaust duct)	5 270 lb (2 390 kg)
Air inlet duct	280 lb (127 kg)
Exhaust diffuser	300 lb (136 kg)

7.9.6 Engine Connection Points

The engine connection points are the locations on the engine where fittings/components must be disconnected before engine removal and reconnected during engine installation. Refer to the ENGINE CONNECTION POINTS CHECKLIST on the following pages.

NOTE

The ENGINE CONNECTION POINTS CHECKLISTS do not list the actual order of operations for items to be disconnected for engine removal, or reconnected for engine installation. For proper order of operation, refer to Subsection 7.9.7 for engine removal, and Subsection 7.9.8 for engine installation.

SINGLE-SHAFT ENGINE

The CED engine connection points are grouped by engine area as follows:

- Combustor and turbine exhaust diffuser area (Figure 7.9.4)
- Compressor area (Figure 7.9.4)
- Air inlet duct area (Figure 7.9.5)

SINGLE-SHAFT ENGINE CONNECTION POINTS CHECKLIST
Combustor and Turbine Exhaust Diffuser Area

- Bleed valve exhaust duct (1, Figure 7.9.4)
- Bleed valve assembly hydraulic supply lines (2, 3)
- Combustor case drain line (7)
- Turbine exhaust diffuser drain line (5)
- Igniter torch (8), fuel supply line(s), drain line, and igniter cable
- T5 thermocouples junction box (4)
- Turbine exhaust diffuser and bellows assembly (6)

Compressor Area

- Fuel supply lines (1, 2, Figure 7.9.4)
- Compressor discharge pressure (Pcd) lines (3, 9, and 11)
- C40 Engines - gas producer velocity transducer cable leads
- Variable vane actuator pressure (PRESS) oil supply line (5), return (RTN) oil drain line (6), and control cable leads, located inside of pullbox (10)
- Lube oil drain lines (7)
- Lube oil supply line (8)

Air Inlet Duct Area

- Air inlet temperature (T1) RTD cable leads pullbox (1, Figure 7.9.5)
- Seal air (Pcd) supply line (4)
- Speed sensor and gas producer backup overspeed cable leads pullbox (8)
- On-crank water wash supply line (9)
- Air inlet duct drain line
- Lube oil supply line (7)
- On-line water wash supply line (10)

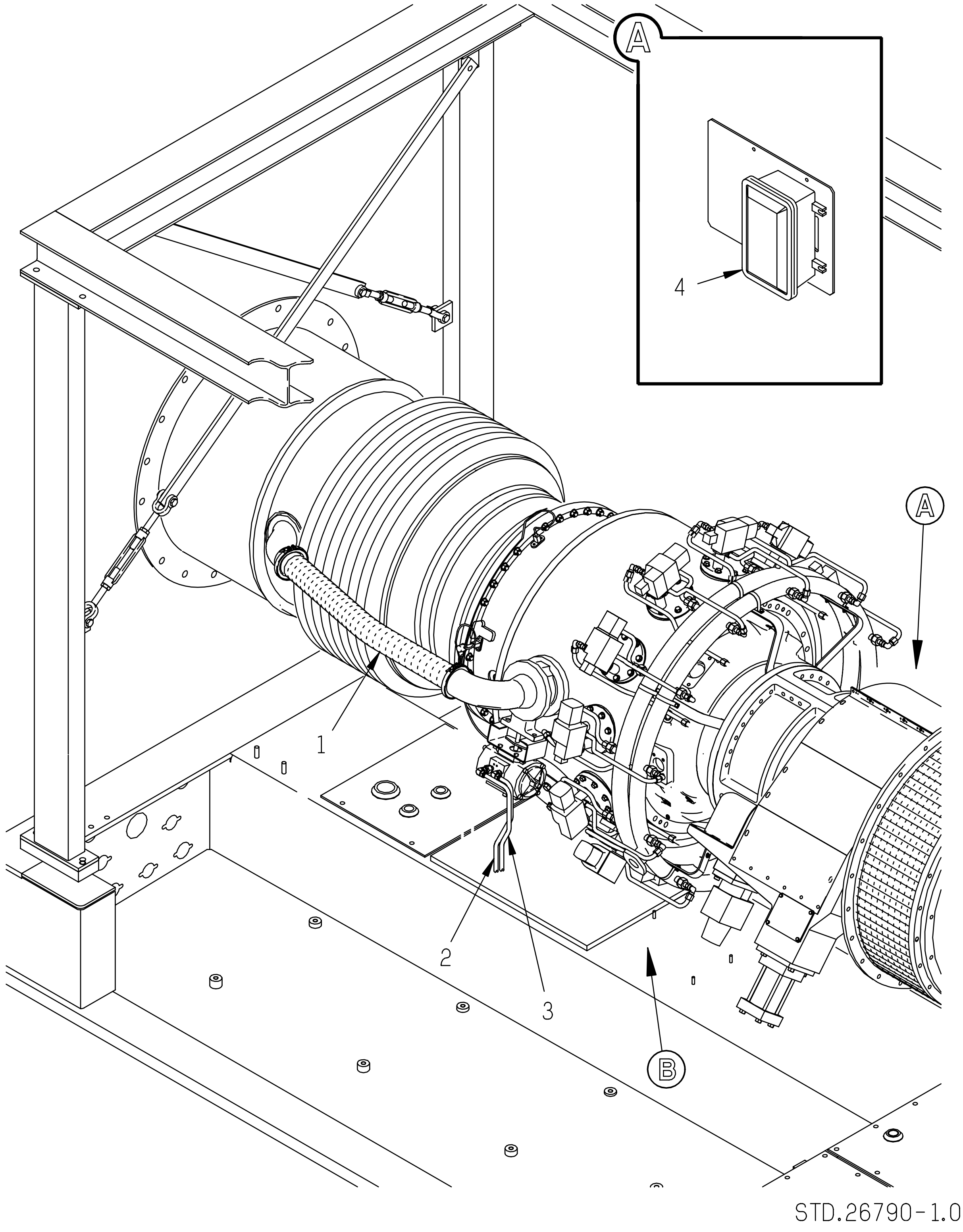


Figure 7.9.4 Combustor and Turbine Exhaust Diffuser Area Connection Points (Typical)

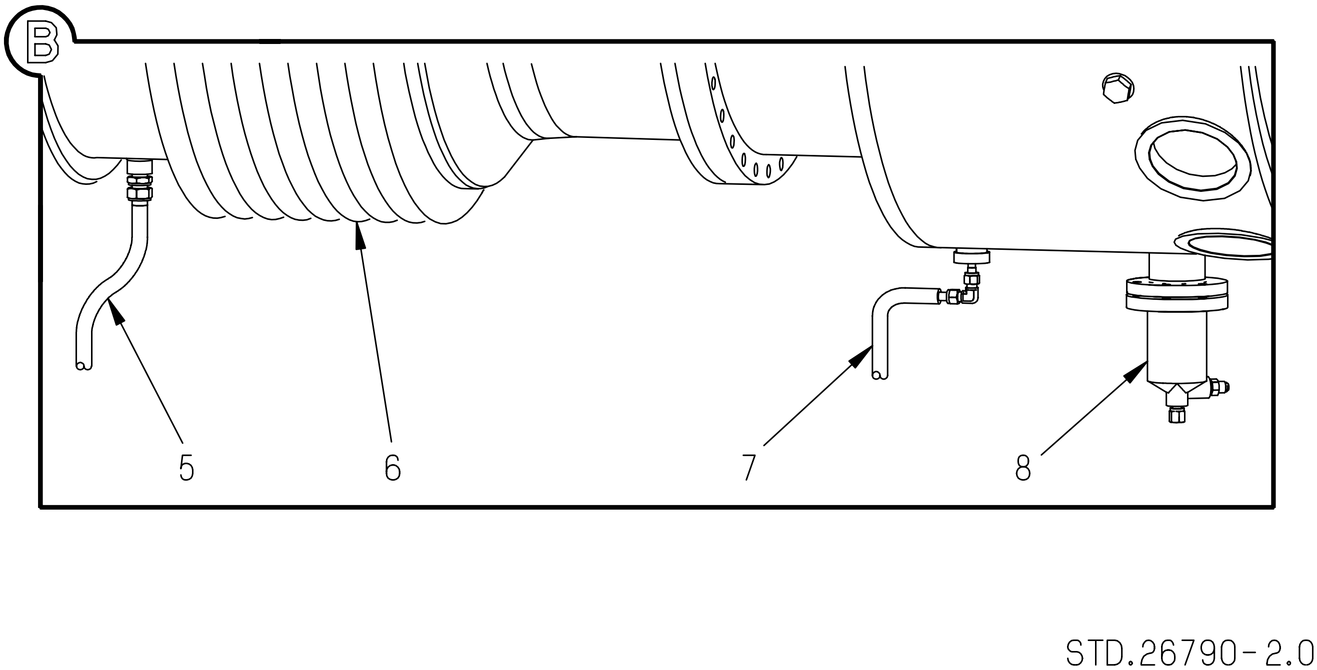


Figure 7.9.4 Combustor and Turbine Exhaust Diffuser Area Connection Points (Typical), Contd

Key for Figure 7.9.4

1	Bleed Valve Exhaust Duct	2	Bleed Valve Actuator Hydraulic Supply Line
3	Bleed Valve Actuator Hydraulic Supply Line	4	Junction Box
5	Turbine Exhaust Diffuser Drain Line	6	Turbine Exhaust Diffuser and Bellows Assembly
7	Combustor Case Drain Line	8	Igniter Torch

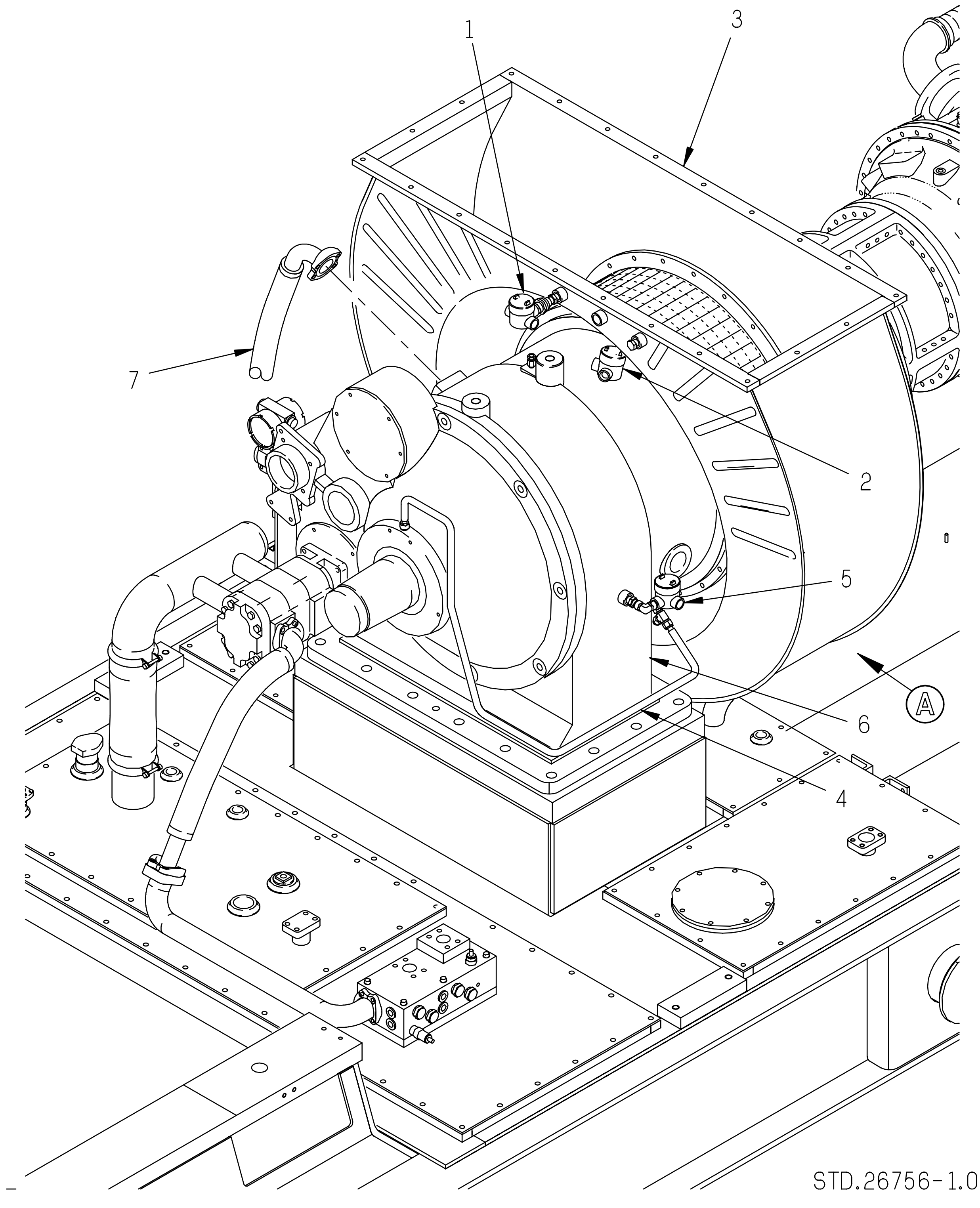


Figure 7.9.5 Air Inlet Duct Area Connection Points (Typical)

Figure 7.9.5 Air Inlet Duct Area Connection Points (Typical), Contd

Key for Figure 7.9.5

1	Air Inlet Temperature (T1) RTD Pullbox	2	Engine Bearing No. 1Y Displacement Probe Pullbox
3	Air Inlet Duct	4	Seal Air Supply Line
5	Pullbox	6	Reduction Gearbox
7	Lube Oil Supply Line	8	Gas Producer Backup Overspeed Speed Sensor Pullbox
9	On-crank Water Wash Supply Line	10	On-line Water Wash Supply Line

7.9.7 Engine Removal

The following subsections provide guidelines for removing the engine from the package base frame. Access to the engine is from either side. Typically, the engine is removed from the right side.

ENGINE DISCONNECT

Disconnect the engine components at the locations listed in Engine Connection Points, Subsection 7.9.6.

Cable Disconnect (Typical)

1. Remove cover from pullbox closest to component to be disconnected.
2. Disconnect cable from terminal strip, or in-line splice connectors.
3. Disconnect grounding strap fitting from pullbox conduit union fitting as applicable.
4. Disconnect conduit union fitting from pullbox.
5. Pull sensor cables out of pullbox.

⚠ CAUTION

Do not twist or crimp the cables. The minimum bend radius of sensor cable is 0.25 in. (6.4 mm).

6. Coil the sensor cable and attach it to the flex conduit using cable-ties. Secure the sensor cable and flex conduit away from the engine using cable-ties.
7. Install cover on pullbox.

ENGINE REMOVAL LIFT TOOL INSTALLATION

Install engine removal tool as follows:

1. Inspect the single-point lift tool for integrity.
2. Attach hoist to lift tool.
3. Lift and position lift tool over engine.
4. Using hardware included in the engine removal tool kit, attach lift tool to engine.
5. Adjust hoist to carry load of engine.

PREPARATION OF ENGINE SHIPPING CONTAINER (FT20865 / FT20868) / ENGINE CART (FT20870)

Prepare the Engine Shipping Container (FT20865/FT20868) for engine installation by opening the engine shipping/storage container relief valve, and removing the container cover. Position the container/cart under the proper side of the skid, and lock the casters in place.

SINGLE-SHAFT, SEPARATION OF ENGINE FROM REDUCTION GEARBOX AND ENGINE AFT SUPPORT ASSEMBLY

Use the following procedures to separate the engine from the reduction gearbox and the engine aft support assembly:

1. Install ropes, guy wires, and/or winch sling as necessary to steady the engine when removed.
2. Remove hardware attaching flexible transition duct to engine air inlet duct. Separate flexible transition duct from engine.
3. Using safety wire, tie corners of flexible transition duct (if applicable) up to a convenient bracket.
4. Position lifting equipment over engine lift point. Install hoist onto lifting equipment (if applicable).
5. Attach hoist to engine lift tool. Adjust hoist to support weight of engine.
6. Loosen all bolts securing reduction gearbox to engine except for two: one at the three o'clock, and one at the nine o'clock position.
7. Remove bolts (1, Figure 7.9.6) and nuts (4) securing the upper support plate (5) to the combustor flange.
8. Remove all bolts securing reduction gearbox to engine except for two: one at the three o'clock, and one at the nine o'clock position.
9. Install two guide pins (FT20059-2) in open bolt holes at the four o'clock and ten o'clock positions.
10. Remove last two bolts at three o'clock and nine o'clock positions securing reduction gearbox to engine.
11. Install four jack screws (FT20059-3), spaced 90 degrees apart, into reduction gearbox.
12. Evenly tighten jacking bolts to separate engine from reduction gear unit.
13. Support engine-to-gearbox coupling when engine is pulled back from reduction gear unit. Remove coupling when clearance allows.
14. Carefully move engine aft on movable trolley beam while feeding instrumentation wiring out through reduction gear unit.
15. Install trolley beam extension assembly. Ensure that all attaching hardware is tight. Refer to ENCLOSURE AND ANCILLARY EQUIPMENT, Chapter 6 of this manual.
16. Using trolley hoists, raise the engine several inches and check for vertical clearances. Verify that all connections are disconnected.
17. Roll engine out of enclosure onto external trolley beams.
18. Lower engine onto shipping/handling skid and remove lift tools.

NOTE

Before returning the engine, verify that the proper components were left on the engine during disconnection. Refer to Configuration of C40/C50/T60 Engines Returned to Solar Turbines Overhaul Facilities, Subsection 7.9.3.

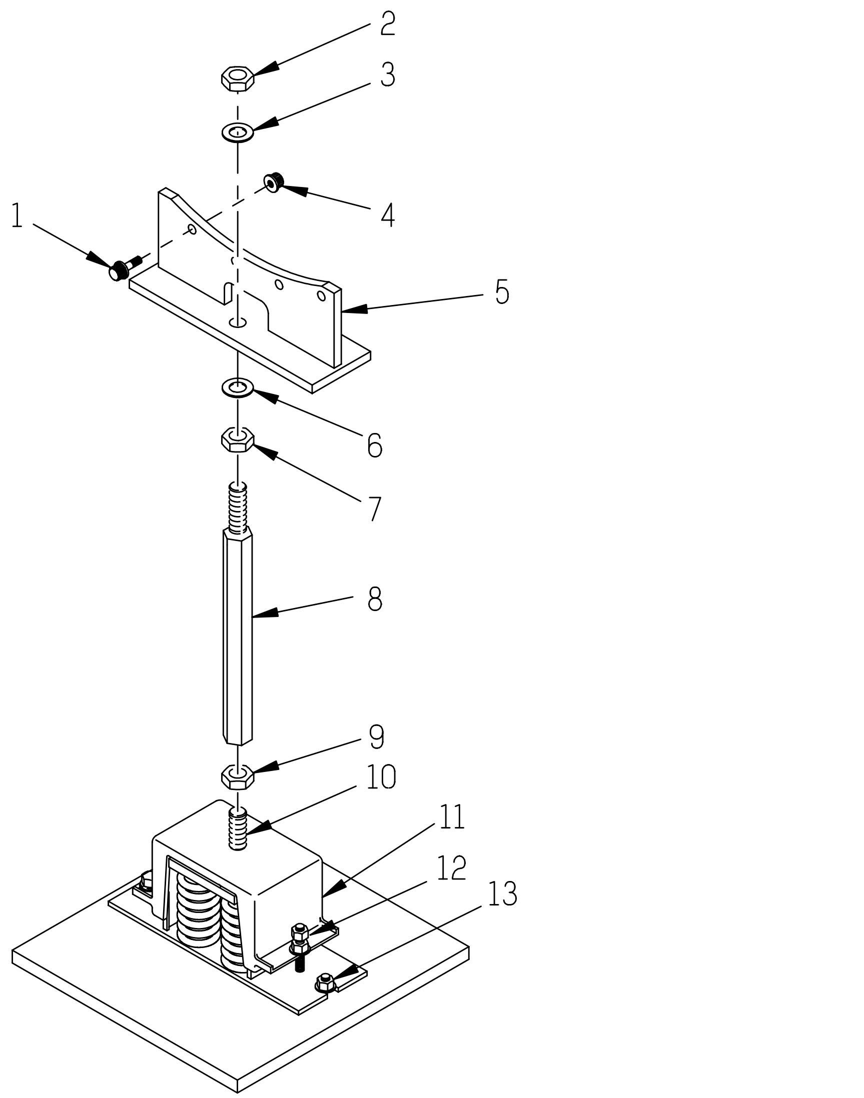


Figure 7.9.6 Engine Aft Support Assembly

Key for Figure 7.9.6			
1	Combustor Flange Bolt	2	Nut
3	Washer	4	Combustor Flange Nut
5	Upper Support Plate	6	Washer
7	Nut	8	Support Rod

Key for Figure 7.9.6, Contd			
9	Jam Nut	10	Stud
11	Spring Mount	12	Locknut
13	Bolt, Lockwasher, Washer		

7.9.8 Engine Installation

The following subsections provide guidelines for installing an engine onto the package base frame. Access to the engine is from either side. Typically, the engine installed from the right side.

NOTE

Discard removed O-ring seals and gaskets, and replace with new O-ring seals and gaskets at assembly or installation. Lubricate new O-ring seals with petroleum jelly or equivalent before installation.

Coat all bolt/stud threads that will be subjected to high temperatures with Fel-Pro Nickel Ease (Solar P/N 917427C1) before component installation.

After each phase of engine component reconnection, remove all temporary tags.

For nut/bolt torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Torque Values 1.7.11.

For tube fitting torque requirements, refer to INTRODUCTION Chapter, STANDARD MANUFACTURING REFERENCES, Fittings, Gaskets, Seals and O-Rings 1.7.14.

PREPARATION OF ENGINE SHIPPING CONTAINER (FT20865 / FT20868) / ENGINE CART (FT20870)

Prepare the Engine Shipping Container (FT20865/FT20868) for engine installation by opening the engine shipping/storage container relief valve, and removing the container cover. Position the container/cart under the proper side of the skid, and lock the casters in place.

ENGINE REMOVAL LIFT TOOL INSTALLATION

Install engine removal tool as follows:

1. Inspect the single-point lift tool for integrity.
2. Attach hoist to lift tool.

3. Lift and position lift tool over engine.

4. Using hardware included in the engine removal tool kit, attach lift tool to engine.

5. Adjust hoist to carry load of engine.

ENGINE REMOUNTING

Single-Shaft Engine

CAUTION

Before remounting the engine on the package, insert the Number 1Y engine bearing displacement probe cable into conduit attached to reduction gearbox. Ensure the interconnect coupling shaft has aligned itself into reduction gearbox.

1. Install guide pins (FT20059-2) on gearbox.

2. Install gearbox-to-engine coupling on gearbox input shaft.

NOTE

Verify that speed pickup teeth on the coupling are oriented towards the speed pickup.

3. Attach upper support plate (5, Figure 7.9.6) to combustor housing aft flange, using four bolts (1) and nuts (4).

4. Torque bolts as required.

5. On engine rear support assembly, assemble stud (10), spring mount (11), and spring pack.

NOTE

Remove and discard any elastomer mounting pad that may be attached to the bottom of the spring pack.

   a. Install stud (10) through hole in top of spring mount (11) and into hole in top of spring pack. Secure stud with jam nut (9).

   b. Install nut (7) on stud end of support rod (8) until approximately 1.75 in. (44.5 mm) of thread shows between the nut and threaded end of rod.

   c. Screw support rod (8) onto stud (10) as far as it will go.

   d. Install spring pack and support rod (8) with threaded end of support rod protruding through hole in upper support plate (5).

e. Install washer (6) on top of nut (7), and insert support rod (8) stud end into the upper support plate (5). Secure with nut (2) and washer (3).

6. Install ropes, guy wires, and/or winch sling as necessary to steady the engine when installing.

7. Adjust hoist to support engine weight and balance the engine. Raise the engine to installation height.

8. Lower engine into installation position on package skid.

9. Mate engine to reduction gearbox.

CAUTION

Take up all cable slack as the engine is moved towards the gearbox to avoid damage to the instrumentation cables.

Carefully position the engine so that the oil transfer tubes line up with the reduction gearbox transfer tube ports.

Rotate the engine shaft as required to mesh the gearbox-to-engine coupling on the gearbox input shaft with the engine output shaft.

10. Loosely install all reduction gearbox bolts, lockwashers, and washers.

11. Remove guide pins (FT20059-2) from gearbox.

12. Install remaining reduction gearbox bolts, lockwashers, and washers.

13. Torque as required.

14. Install bolts, lockwashers, and washers (13, Figure 7.9.6) to secure spring pack to skid frame.

NOTE

Locknuts (12) on each side of the spring pack can be used to compress springs temporarily to facilitate this operation.

15. Torque as required.

16. Back off locknuts (12) (far enough to free the springs). Measure and record overall height of spring pack. Turn support rod (8) until nut contacts bottom surface of upper support plate (5).

17. While keeping the support rod from rotating, turn nut (7) at stud end of support rod until spring pack has been compressed 0.50 in. (12.7 mm). Lock support assembly in this position with nut (2) on top side of upper support plate (5).

18. Ensure the weight of the engine has been removed from the hoist.
19. Reset single-point lift tool to center of gravity.
20. Remove single-point lift tool from the engine.
21. Install the engine bolts and nuts to the engine compressor and diffuser flanges.
22. Torque as required.

ENGINE RECONNECTION

Connect the engine components/fittings at engine connection points listed in Subsection 7.9.6. Torque all tubing nuts, split-flange clamp bolts, and other connection hardware as required. Install all miscellaneous non-engine system equipment that has been removed per MISCELLANEOUS ITEMS REMOVAL, Engine Removal Subsection 7.9.7.

Cable Reconnect (Typical)

1. Remove cover from pullbox.

CAUTION

Do not twist or crimp the sensor cable. The minimum bend radius of the cable is 0.25 in. (6.4 mm).

2. Carefully remove cable tie and uncoil sensor cable.
3. Route sensor cable into pullbox.
4. Connect conduit union fitting to pullbox.
5. Identify tagged cable leads and connect them to terminal strip or to in-line splice connector(s) located inside pullbox.
6. Install cover on pullbox.
7. Connect grounding strap to conduit union fitting on pullbox as required.

8 DRIVEN EQUIPMENT

8.1 GENERAL DESCRIPTION

The gas turbine-driven generator set is designed to accept a wide range of generators for maximum flexibility. Generator selection is based on the concept whereby the generator, exciter, voltage regulator, and critical input transformers are all specified to ensure an overall system engineered for optimum performance.

The generator (Figure 8.1.1) is built to meet or exceed the National Electrical Manufacturer's Association (NEMA) construction and performance requirements.

The insulation conforms to NEMA Class F and is suitable for the environmental conditions of high humidity, sand, dust, fungus, and salt air. This insulation allows a temperature rise of 198°F (110°C) for generators rated less than 7000 volts and 189°F (105°C) rise for generators rated over 7000 volts (in accordance with NEMA continuous duty temperature rise requirements, measured by embedded detectors on the stator), and a temperature rise of 189°F (105°C) (as measured by resistance of the rotor with a maximum ambient temperature of 104°F (40°C)).

Temperature rise for standby service is in accordance with NEMA specifications for such service. This allows temperature rises up to 45°F (25°C) above those for continuous duty operation.

The generator, exciter, and regulator package provide steady state voltage regulation within 0.5 percent of rated voltage when the load is varied from no-load to rated kVa and all transients have decayed to zero.

Sudden application of up to 25 percent of the generator NEMA rating when the generator, exciter, and regulator are operating at no-load, and rated voltage and frequency, results in less than 25 percent excursion from rated voltage. Recovery is to within 5 percent of rated voltage, with no more than one undershoot or one overshoot in less than 1-second.

With generator initially operating at rated voltage, and with a constant load between zero and 100 percent of rated power factor, the change in the regulated output will not exceed 1 percent of rated voltage for any 30-minute period at a constant ambient temperature.

Multiple units are capable, through the droop, crosscurrent compensation system, of reactive loadsharing within 5 percent of nameplate rating.

The combined generator, exciter, and regulator efficiency at full-load, is 96 percent or better.

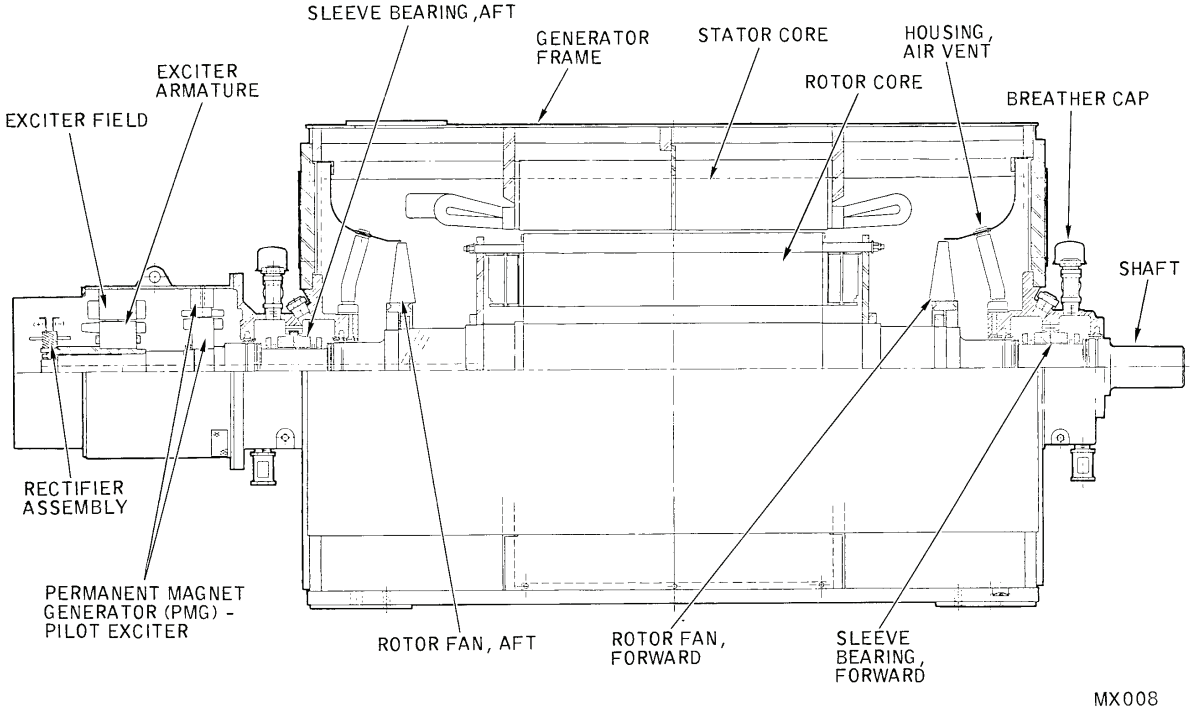


Figure 8.1.1 Typical Generator

8.2 FUNCTIONAL DESCRIPTION

During generator set operation, the three-phase ac power, generated in the exciter armature (Figure 8.2.1) is applied to the rectifier where it is converted to direct current power. The dc output from the rotating rectifier is then applied as field excitation current to the generator rotating field coils.

It should be noted that, with this arrangement, the main generator field coils rotate and its armature is stationary, while the exciter field is stationary but its armature rotates with the main generator rotor shaft. As a result, a single rotating assembly, consisting of exciter armature, exciter rectifier, and main generator field coils is formed, which greatly simplifies all electrical connections within the generator assembly.

A sensing transformer supplies the bus potential signal to the regulator. The main generator output is controlled by the generator field current. The generator field current is in turn controlled by the brushless exciter circuit. The power transformer, through the regulator, furnishes the excitation to the exciter field. Variations in bus potential will be sensed and subsequently corrected by this circuit.

As indicated in the foregoing, all ac generators require that direct current (excitation) be applied to the rotor windings (field coils) in order to set up the magnetic flux necessary for generator operation. Because the amount of dc current going into the field of the exciter will determine the output voltage of the exciter, the exciter output, being applied to the generator field, will therefore control the output voltage of the main generator.

Upon proper voltage buildup, the generator accelerates to 100 percent speed and excitation and voltage control is assumed by the voltage regulator.

A crosscurrent-compensating transformer provides the proper signals to the regulator to accommodate reactive loadsharing between multiple units in parallel.

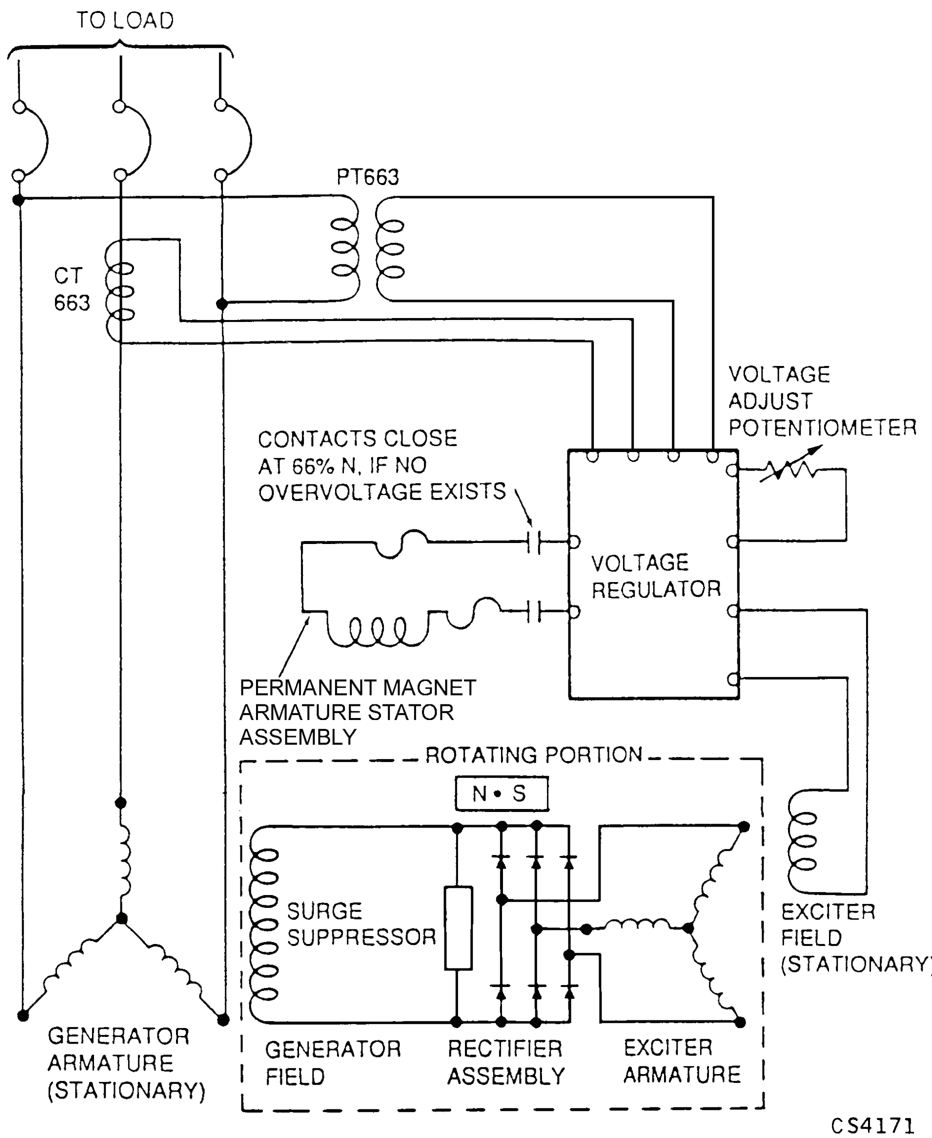


Figure 8.2.1 Typical Generator, Exciter, and Regulator System

8.3 COMPONENT DESCRIPTIONS

8.3.1 Rotor

The rotor is dynamically balanced so that the degree of dynamic imbalance provides minimum vibration. Efficient rotor fans move air through the generator and around the rotor for cooling. The rotors have layer-wound field windings, which are then cemented with a high-strength resin and baked. The rotor is in electrical and mechanical balance at all speeds, up to 125 percent of rated speed.

8.3.2 Stator

The stator is built with high-grade silicon steel laminations, which are precision-punched and individually insulated. Windings, form-wound in lined slots, are repeatedly treated with thermosetting synthetic varnish and baked for maximum moisture resistance, high dielectric strength, and high bonding qualities. The windings are also braced to withstand shock loads such as motor starting and short circuits. Space heaters can be supplied to minimize condensation during shutdowns.

8.3.3 Shaft

The shaft diameter is sufficient to provide the stiffness necessary to preclude torsional problems. Every turbine-driven generator system is given a complete torsional analysis.

8.3.4 Frame

The frame is heavy-duty steel, fabricated with deep welds and internal reinforcing for extra rigidity and strength. Lifting lugs are provided.

8.3.5 Exciter

Excitation current for the generator field coils is provided by a brushless rotating exciter unit with Permanent Magnet Generator (PMG) pilot exciter. The generator is a synchronous, three-phase, alternating current generator with rotating field coils, and the exciter unit is mounted directly on the generator rotor shaft.

The exciter unit consists of two basic parts, a small three-phase, ac generator with rotating armature, and a three-phase, full-wave, diode-type bridge rectifier portion that rotates together with the armature. The pilot exciter is a PMG that rotates with the main generator rotor shaft. It feeds the exciter field windings with excitation current through the voltage regulator.

Since the exciter unit itself also requires dc current for excitation of its own stationary field coils, it is furnished by a pilot exciter which is simply a PMG that is mounted on and rotates together with the main rotor shaft.

It will be apparent when starting the generator set, that little or no direct current will be available for excitation of either the main generator or the exciter fields, were it not for the action of the PMG pilot exciter.

8.4 GENERATOR ELECTRICAL CHECK

The following subsections describe instructions for Solar-furnished equipment. Customer-furnished generator metering equipment may differ from that described below.

WARNING

Some high voltage devices can store and maintain a residual voltage for several hours after the unit has been stopped. A lethal electrical shock can result. Before working on or around the equipment, discharge all high voltage circuits by using a heavy insulated cable and shorting each phase to ground.

8.4.1 Startup Check

WARNING

Ensure that all loose items such as nuts, washers, and spare wiring are removed from generator set before starting.

Prepare the generator for preoperation startup check by disconnecting the power circuit breakers or disconnecting the main bus from the circuit breaker. This isolates the generator, voltage regulator, and meters for electrical check. After the startup check is complete, shut down the unit and reconnect the bus and circuit breakers.

Start engine following Start Procedure, located in Systems Operator's Guide of this manual set. Speed should stabilize at 100 percent.

Rated voltage should be developed at approximately 80 percent speed. Set the specified voltage with the voltage adjust control. If the voltage can be adjusted and controlled, this indicates that the generator and voltage regulator are operating properly. If the voltage cannot be adjusted or controlled, shut down the unit and check for open circuits to the voltage regulator. If the generator fails to build up voltage, check for the following:

- Excitation voltage to generator, including PMG circuit
- Sensing voltage relay and speed switch
- Polarity reversal in exciter voltage leads or PMG circuit
- Faulty voltage regulator

When the turbine generator set is operating at 100 percent engine speed, a frequency meter should indicate the frequency stamped on the generator nameplate. If the frequency meter is indicating incorrectly, check the connections.

NOTE

Frequency meters are not adjustable.

Since the generator is operating at a no-load condition, a kW/kVAR meter or an ammeter will not indicate. If used, a power factor meter may rotate freely. These meters can be checked or read only during a load test.

8.4.2 Load Test

⚠ WARNING

Never open the circuit to current transformers, ammeters, or kW/kVAR meter current coils with the generator in operation. Possible personal injury and transformer damage could result. If the generator is to be operated with open current circuits, jumper the secondary terminals of the current transformer.

In most cases it will be necessary to remove all load and power from the bus before applying the initial generator load. Check the manual and electrical trip circuits of all circuit breakers concerned. Check the phase rotation before operating the generator in parallel.

When connecting to resistive load banks, or building loads (isolated from commercial power) a small load should be applied to check the wattmeter and ammeter. Power factor meter will indicate 1.0 due to lack of inductive current. At low load, meter may not indicate, or indication will be sluggish.

The wattmeter can be checked by using the following formulas:

$$kW = \frac{Volts \times Amps \times Power \times 1.73}{1000}$$

$$kVA = \frac{Volts \times Amps \times 1.73}{1000}$$

If wattmeter fails to indicate, check current and potential transformers for polarity connections.

8.4.3 Phase Rotation

Before operating two or more generators in parallel, phase rotation on each unit must be the same. The following method of checking phase rotation is recommended (Figure 8.4.1).

Open circuit breakers A, B, and C to isolate generators and bus for phase check.

Connect phase meter to bus, either direct or through a potential transformer, depending on voltage. Do not move phase meter during phase check.

Close circuit breaker C and observe phase meter indication. Open circuit breaker C.

Start engine following procedures in Systems Operator's Guide of this manual set.

With generators operating at rated speed, set specified no-load frequency and voltage on units being checked.

Close circuit breaker A and observe phase meter indicator. Open circuit breaker A. Close circuit breaker B and observe phase meter indication. Open circuit breaker B. All phase meter indications must be the same. If a different indication was obtained, check and correct wiring, then repeat phase check.

When check is complete, shut down engine following procedures in Systems Operator's Guide of this manual set.

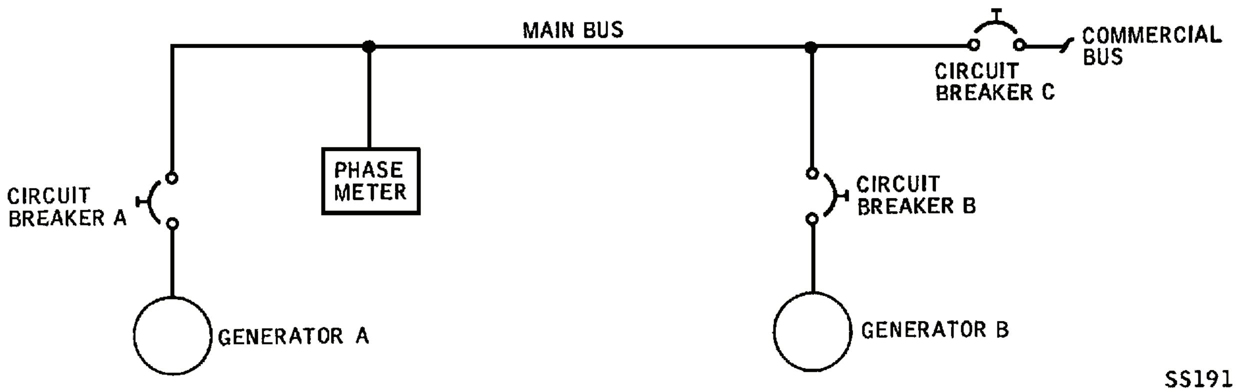


Figure 8.4.1 Phase Rotation Check Diagram

8.5 MAINTENANCE

Maintenance on the generator is limited to qualified personnel, using approved special tools, in a clean facility. Instructions for the maintenance of the generator are provided in Supplementary Data of this manual set.

The following subsections provide instructions for removal and installation of the generator, instructions for shear coupling maintenance, and guidelines for generator troubleshooting.

Before performing any troubleshooting or corrective action procedures, refer to the Safety Requirements at the beginning of this manual and the following warnings and cautions.

WARNING

Operation of the unit may be performed only by qualified personnel. The operator must understand turbine and driven equipment operation, function, and systems and also know and understand all controls, indicators, normal indications, and operating limits.

The unit has been designed to comply with the noise level requirements as specified by the user. Noise reduction is a function of noise source, installation considerations, equipment in close proximity, and the acoustical characteristics of the existing building and barriers. Noise levels may be further reduced by the user with modifications to their building or equipment. Modifications shall not interfere with safe operation or efficiency of the unit.

Before work is started on the generator, the package must be shut down and the postlube cycle completed. All controls shall have warning signs attached advising: DO NOT OPERATE. MAINTENANCE IN PROGRESS.

Some high voltage devices can store and maintain a residual voltage for several hours after the unit has been stopped. A lethal electrical shock can result. Before working on or around the equipment, discharge all high voltage circuits by using a heavy insulated cable and shorting each phase to ground.

CAUTION

When removing and installing electrical components, ensure wiring is tagged for identification. Do not rely on color coding on wiring for identification during component installation. If in doubt, refer to the wiring diagram for proper electrical connections.

CAUTION

Work areas must be kept clean to prevent contamination of parts with dirt or grit. When removing parts, immediately cover up access holes and mounting ports with suitable material to eliminate the entry of foreign material.

8.5.1 Shear Coupling Shear Bolt Replacement

NOTE

The coupling shear bolts will shear if an overload occurs. If this happens, the shear bolts must be replaced. The shear bolts can be replaced without removal of the shear coupling assembly.

If shear bolts (10, Figure 8.5.1) are sheared or suspected of being stressed, replace as follows:

1. Remove coupling guard and attaching hardware.
2. Remove shear bolts (10), flat washers (11), and nuts (20).

CAUTION

Shear bolts (10) must be installed from gear unit side of shear coupling. Ensure matchmarks are aligned.

Do not install more than four shear bolts. Use of more than four shear bolts can cause significant damage to gear unit.

3. Align shear coupling matchmarks and install flat washers (11), shear bolts (10), and nuts (20).
4. Torque nuts (20) to 200 to 220 ft-lb (271 to 298 N·m) above self locking torque.

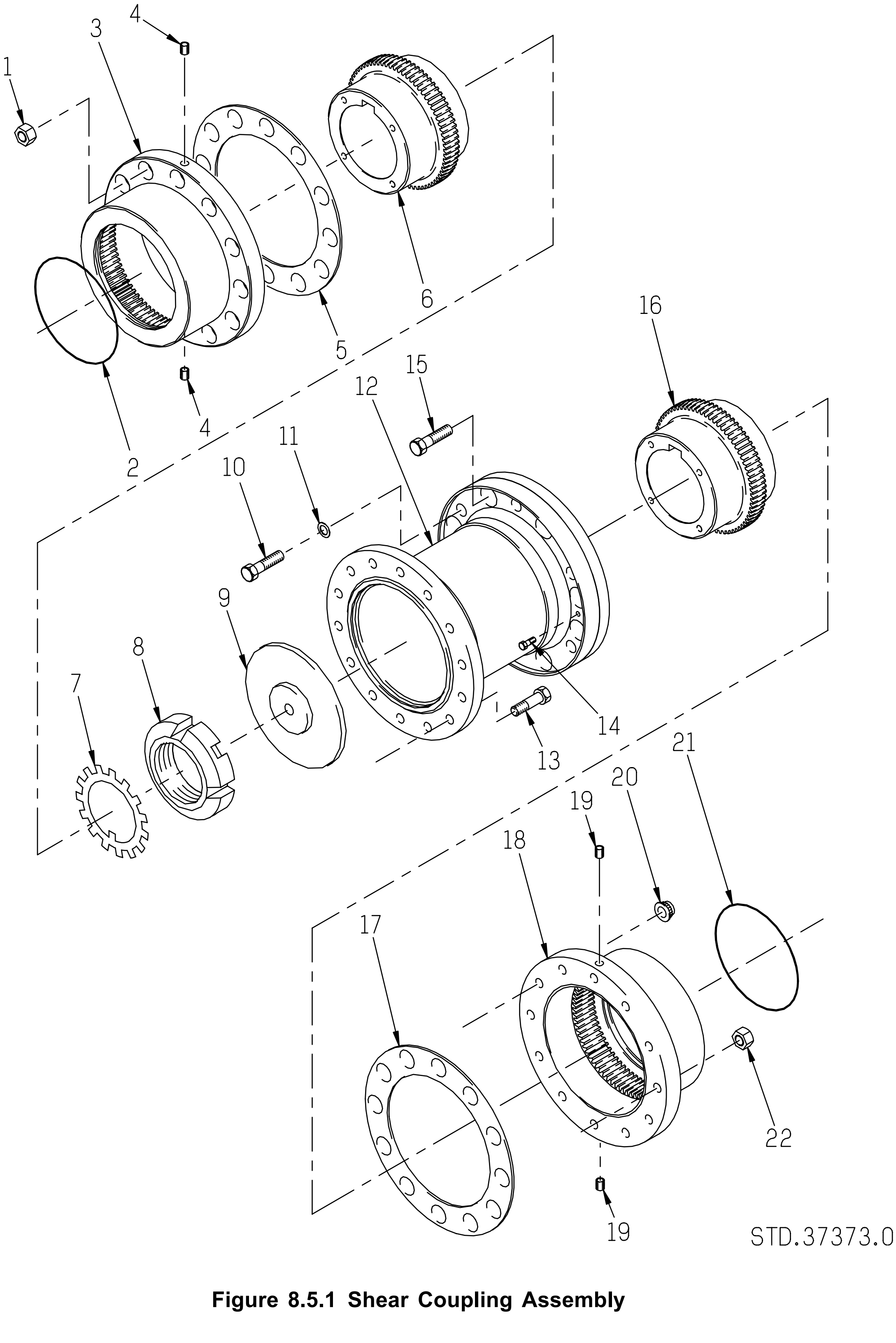


Figure 8.5.1 Shear Coupling Assembly

Key for Figure 8.5.1			
1	Nut	2	O-Ring Seal
3	Gear Unit Sleeve	4	Grease Plug
5	Gasket	6	Gear Unit Hub
7	Lockwasher	8	Locknut
9	Limited End Float Plate	10	Shear Bolt
11	Flat Washer	12	Shear Spacer
13	Hex Head Bolt	14	Installation Bolt
15	Hex Head Bolt	16	Generator Hub
17	Gasket	18	Generator Sleeve
19	Grease Plug	20	Nut
21	O-Ring Seal	22	Nut

8.5.2 Shear Coupling Removal and Installation

The following paragraphs provide procedures for removal and installation of the gear unit to generator shear coupling.

MATERIALS AND EQUIPMENT

The materials and equipment that are required to install gear unit and generator hubs are listed in Table 8.5.1.

Table 8.5.1 Materials and Equipment

Item	Description	Remarks
Metal Can	7 gal (26 L)	Used for hot oil bath
Turbine Oil	Approximately 3 gal (11 L)	Fill can to 8 in. (203 mm) depth
Grease	P/N 1013623	For lubricating the shear coupling
Thermometer	500°F (260°C)	Used to monitor temperature of hot oil bath
Metal Basket	-	To hold couplings in during hot oil bath
Hot Plate	-	Temperature controlled
Insulated Gloves	-	For handling hot components
Fire Extinguisher	-	Follow fire protection procedures

REMOVAL

Remove shear coupling as follows:

1. Remove coupling guard and attaching hardware.

2. Install installation bolts (14, Figure 8.5.1) in shear spacer (12). Torque installation bolts (14) to a maximum of 40 ft-lb (54 N·m).

3. Remove shear bolts (10), flat washers (11), and nuts (20).

4. Support shear spacer (12) using sling attached to a suitable hoist.

CAUTION

Shear coupling components are matchmarked and balanced as a matched assembly. Observe and note matchmarks prior to disassembly. If matchmarks are not visible, mark components using a permanent type marker.

5. Remove hex head bolts (15) and nuts (22) from shear spacer (12) and generator sleeve (18).

6. Position generator shaft towards generator until it bottoms.

7. Remove hex head bolts (13) and nuts (1) from shear spacer (12) and gear unit sleeve (3).

8. Remove shear spacer (12) and gaskets (5, 17). Remove hoist and slings.

9. If required, remove gear unit hub (6) and generator hub (16) as follows:

    a. Unstake locknut (8) by bending down tabs of lockwasher (7).

    b. Remove locknut (8) and lockwasher (7) from gear unit shaft.

    c. Remove gear unit hub (6) and gear unit sleeve (3) from gear unit shaft using heavy-duty puller attached to hub puller holes.

    d. Remove keys from gear unit shaft. Remove and discard O-ring seal (2).

    e. Remove generator hub (16) and generator sleeve (18) from generator shaft using heavy-duty puller attached to hub puller holes.

    f. Remove key from generator shaft. Remove and discard O-ring seal (21).

INSTALLATION

Install shear coupling as follows:

1. If required, install gear unit hub (6, Figure 8.5.1) and gear unit sleeve (3) as follows:

CAUTION

The gear unit output shaft is tapered. To ensure proper shaft/hub interference fit, the hub pull-up (axial draw) must be monitored during installation.

a. Clean mating surfaces of gear unit hub (6) and gear unit output shaft and wipe with lint-free towels.

CAUTION

Do not overdress the shear coupling components. The shaft is dynamically balanced and may require rebalancing if too much material is removed.

b. Inspect shaft and hub for nicks or burrs. Dress as required.

c. Lightly lubricate gear unit shaft and threads.

d. Install gear unit hub (6) on the shaft without the keys and tap lightly with a soft hammer to ensure a metal-to-metal fit. This is the starting point for the axial draw.

e. Using a depth gage, measure the distance from the gear unit hub (6) to the end of the shaft. Record this dimension to be used to verify correct hub advance at final installation. Remove hub from shaft.

CAUTION

The keys must be precisely fitted to keyways in the gear unit shaft and hub. The keys should have a tight fit on the sides with a slight clearance on top. To maintain dynamic balance, the keys should fill the keyways exactly and not be too long or too short.

f. Install keys in gear unit output shaft.

g. Lubricate and install O-ring seal (2) in groove of gear unit sleeve (3).

h. Install gear unit sleeve (3) on gear unit shaft.

WARNING

To avoid injury to personnel, wear suitable protective equipment (faceshield, gloves or clothing) while heating and handling hot parts and assemblies. Avoid skin contact with heated parts, assemblies and oil.

CAUTION

Do not heat gear unit hub (6) to more than 350°F (177°C) or use an open flame to heat any part. Distortion may occur.

i. Heat gear unit hub (6) in an oven or hot oil bath to 350°F (177°C) maximum. If using hot oil bath, ensure hub is fully submerged while heating.

NOTE

The hub pull-up (axial draw) must be monitored during installation. This may be accomplished by mounting a dial indicator on the equipment housing and zeroing it against the hub.

j. Position heated gear unit hub (6) on the gear unit shaft in the start position noted in step e. Advance the hub on the shaft an additional 0.040 ±0.008 in. (1.02 ±0.20 mm) to obtain the correct hub/shaft interference.

k. Allow gear unit hub (6) to cool to ambient temperature.

l. Using a depth gage, measure the distance from the gear unit hub (6) to the end of the shaft. Compare this distance to the dimension recorded in step e. The difference should be 0.040 ±0.008 in. (1.02 ±0.20 mm) which is the distance the hub was advanced on the shaft.

m. Install lockwasher (7) and locknut (8). Torque locknut (8) to 1000 to 1230 ft-lb (1356 to 1668 N·m).

n. Stake locknut (8) by bending down tabs of lockwasher (7).

2. If required, install generator hub (16) and generator sleeve (18) as follows:

a. Clean mating surfaces of generator sleeve (18) and generator hub (16), and wipe with lint-free towels.

CAUTION

The key must be precisely fitted to keyway in the gear unit shaft and hub. The key should have a tight fit on the sides with a slight clearance on top. To maintain dynamic balance, the key should fill the keyway exactly and not be too long or too short.

b. Install key in generator shaft.

WARNING

To avoid injury to personnel, wear suitable protective equipment (faceshield, gloves or clothing) while heating and handling hot parts and assemblies. Avoid skin contact with heated parts, assemblies and oil.

CAUTION

Do not heat generator hub (16) to more than 350°F (177°C) or use an open flame to heat any part. Distortion may occur.

c. Heat generator hub (16) in an oven or hot oil bath to 350°F (177°C) maximum. If using hot oil bath, ensure hub is fully submerged while heating.

d. Lightly lubricate generator shaft.

e. Lubricate and install O-ring seal (21) in groove of generator sleeve (18).

f. Install generator sleeve (18) on generator shaft.

g. Press heated generator hub (16) onto generator shaft and into generator sleeve (18). Hub should be flush with shaft end.

CAUTION

Equipment alignment must be performed prior to installing the shear spacer if any change has been made in the relative position of the driving to driven equipment.

Do not overdress coupling assembly components. The coupling is dynamically balanced and may require rebalancing if too much material is removed.

3. Inspect faces and pilots of shear spacer (12), gear unit sleeve (3), and generator sleeve (18) for nicks and burrs. Dress as required.

4. Ensure that coupling guard support ring is installed on gear unit housing.

5. Position generator shaft in direction of generator until it bottoms. Scribed mark on shaft (magnetic center) should be inside bearing housing and not visible.

6. Verify that two installation bolts (14) are installed in shear spacer (12).

7. Using a sling attached to a suitable hoist, lower shear spacer (12) with limited end float plate (9) installed into position between gear unit sleeve (3) and generator sleeve (18). Ensure matchmarks are aligned.

8. Install gasket (5), hex head bolts (13), and nuts (1). Torque nuts (1) to 209 to 231 ft-lb (283 to 313 N·m).

9. Install shear bolts (10), and flat washers (11) in shear spacer (12) to maintain hole alignment.

10. Install hex head bolts (15), gasket (17), and nuts (22). Torque nuts (22) to 209 to 231 ft-lb (283 to 313 N·m).

11. Install nuts (20) on shear bolts (10). Torque nuts (20) to 200 to 220 ft-lb (271 to 298 N·m) above self locking torque.

12. As coupling bolts are tightened, the generator shaft will be pulled toward gear unit. When all bolts are torqued to specifications, the generator shaft will have moved toward the gear unit but the magnetic center scribe mark will still be positioned inside the generator housing. Using a pry bar, move the generator shaft towards the gear unit until the gear unit shaft contacts the limited end float plate inside the shear coupling. The magnetic center scribe mark will now be visible. The distance from the scribe mark to generator housing is one half of the coupling end float. The generator shaft magnetic center mark should be able to move into the generator housing the same approximate distance that it moved out of the housing. This is verification of proper limited end float of the coupling. If mark on generator shaft is aligned with housing anywhere up to 0.120 in. (3.5 mm) outside housing, it is considered acceptable.

13. Remove two installation bolts (14) from shear spacer (12).

14. Lubricate shear coupling using grease, P/N 1013623 as described in Subsection 8.5.3.

8.5.3 Shear Coupling Lubrication

Shear coupling lubrication is critical. The use of proper and sufficient lubrication is required as part of shear coupling installation and must be accomplished prior to equipment operation. The shear coupling lubricant should be checked every 12 months to ensure that the proper level is maintained and that the lubricant is free of contaminates.

CAUTION

Do not use oil to lubricate the shear coupling. Use only grease P/N 1013623 or equivalent.

Do not attempt to fill the shear coupling with grease without venting the interior by removing all grease plugs. An air lock may result which can cause incomplete filling or damage to O-ring seals.

Lubricate the shear coupling as follows:

1. Remove two grease plugs (4, Figure 8.5.1) from gear unit sleeve (3).
2. Remove two grease plugs (19) from generator sleeve (18).
3. Rotate the coupling to place the bottom holes 45 degrees off horizontal.
4. Pump 2.25 lb (1.02 kg) of grease P/N 1013623 into the top hole of each coupling half. Any excess will appear at the bottom hole.
5. Install grease plugs (4, 19). Torque grease plugs (4, 19) to 50 ft-lb (68 N·m).
6. Install coupling guard and attaching hardware.

8.5.4 Equipment Alignment

CAUTION

The majority of vibration and bearing problems can be traced directly to improper alignment. Therefore, after transporting package or repositioning the engine or generator, the equipment alignment must be checked.

Prior to package shipment, the generator is aligned to the engine at the factory. The shear coupling assembly is shipped with the respective hubs mounted on the reduction drive assembly output shaft and generator input shaft. On sleeve bearing generators, the generator shaft is locked in position by a shipping brace that must be removed before alignment and installation of the coupling. Subsequent field alignment is accomplished by repositioning the generator as necessary to achieve alignment with the fixed position of the reduction drive assembly.

Alignment of the generator to reduction drive assembly consists of setting up the generator rotational axis with respect to the reduction drive assembly rotational axis. This is achieved by first establishing the distance between the generator and the reduction drive assembly, then checking the face and rim measurements on the reduction drive assembly hub. The necessary corrections are accomplished by adjusting the generator vertically, laterally, and longitudinally by means of the jacking bolts provided at the generator base (Figure 8.5.2).

Dimensions between the facing ends of the reduction drive assembly output and generator input hubs, and all vertical and horizontal indicator readings, must be brought to within the limits specified. Any reliable dial indicator, graduated to 0.001 in. is suitable for the required face and rim readings.

The face measurement establishes the angular alignment of the generator shaft centerline with respect to the rotational plane of the reduction drive assembly shaft, which is represented by the face of the reduction drive assembly hub, surface "B" (Figure 8.5.3). The concentricity of the alignment of the generator shaft centerline with the reduction drive assembly shaft centerline is established by the rim measurement, surface "A" (Figure 8.5.3).

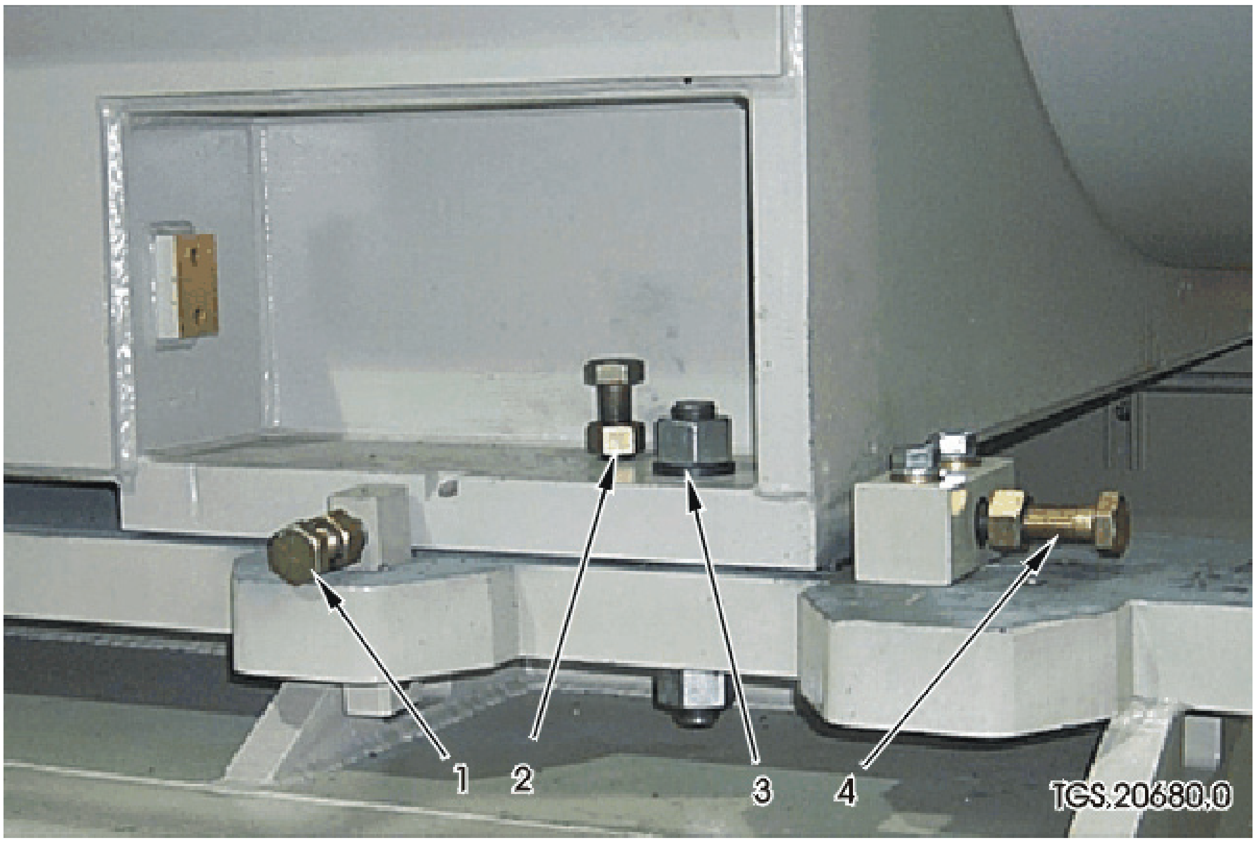


Figure 8.5.2 Typical Generator Alignment Adjustments

Key for Figure 8.5.2

1	Lateral Jacking Bolts (4 places)	2	Vertical Jacking Bolts (4 places)
3	Generator Mounting Bolts (4 places)	4	Longitudinal Jacking Bolts (4 places)

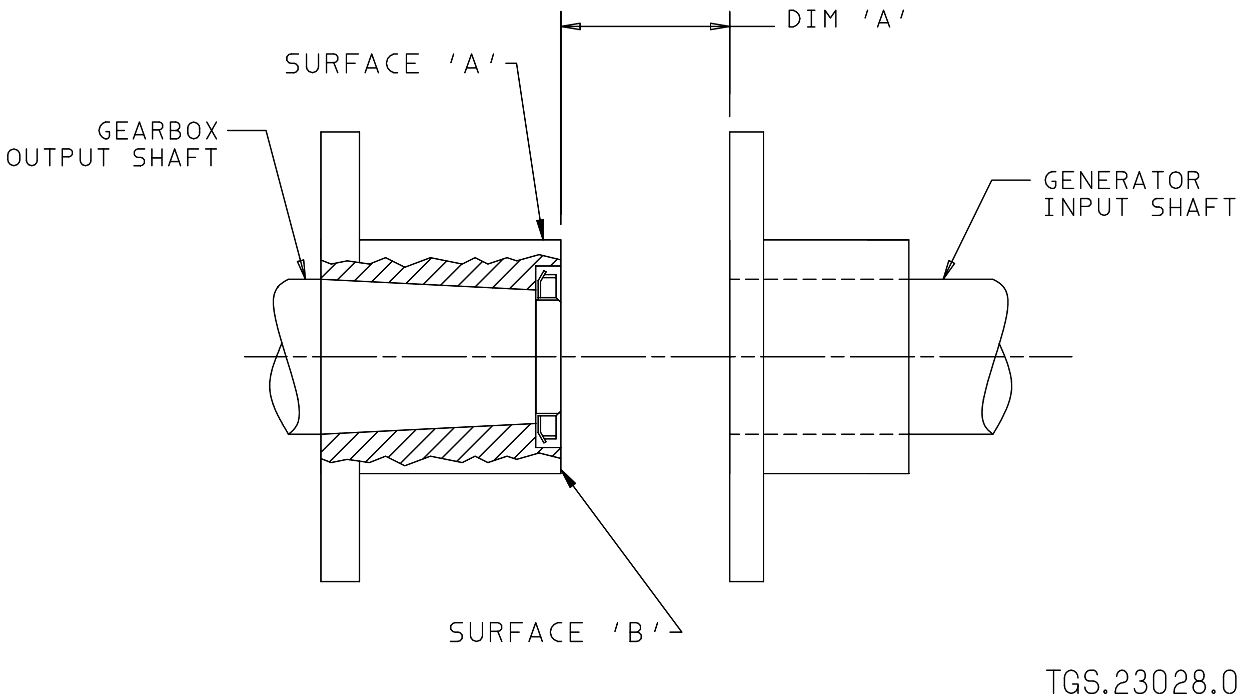


Figure 8.5.3 Hub-to-Hub Distance

PREALIGNMENT REQUIREMENTS

Prior to shipment, the engine rear support assembly is locked in position by a preload turnbuckle and shipping brackets at the spring mount and aft engine mount assembly.

1. Remove shipping turnbuckle and brackets from engine rear mount, if installed.
2. Remove shipping brace from generator input shaft, if installed.
3. Check that generator hold-down cap screws are properly installed and secure.
4. Verify that all generator mounting and adjustment jacking bolts are lubricated with a suitable anti-seize lubricant.
5. Ensure that lube oil tank is filled to operating level.
6. Turn off generator space heater and lube oil tank heater.
7. Ensure equipment has been allowed to cool for 12 to 24 hours.
8. Remove the shear coupling guard and shear spacer if installed.
9. Position generator shaft at magnetic center (not required for generators with a thrust bearing).

FIELD TOOLS

The following field tools are required to perform generator-to-reduction drive assembly alignment.

- FT21005 - Alignment Tool Kit
- FT67001 - Dial Indicator Kit
- FT21010 - Generator Rotating Arm

ALIGNMENT PROCEDURE

1. Remove generator shaft shipping brace, if installed.

NOTE

To permit movement of the generator for alignment purposes, the vertical, lateral, and longitudinal jacking bolts, in addition to the generator mounting bolts, must be fully loosened prior to making adjustments. Generator mounting bolts must be tight while taking measurements.

The vertical jacking bolts must be loosened after inserting or removing shims for height adjustment. To prevent damage to the jacking bolts and their mounts, the front, rear, and side jacking bolts should also be loosened after each adjustment of the generator. Ensure shims are clean and free of foreign material.

2. Measure axial distance between generator and reduction drive assembly hub (dimension "A" Figure 8.5.3). Refer to the Mechanical Interface Drawing for correct dimension. Take measurements in four places at 90-degree intervals. Move generator with jacking bolts, as necessary, to obtain required dimension.

3. Move generator shaft to position of fully extended or completely bottomed internally. Either position is acceptable. However, generator shaft must remain in chosen position during entire alignment procedure.

4. Measure this distance and maintain it while alignment is in progress. This is only a reference dimension for alignment purposes.

5. Install alignment tool on generator shaft as shown in (Figure 8.5.4). Adjust dial indicators to sweep reduction drive assembly hub rim and face (surface A and B, Figure 8.5.3).

6. Align generator to reduction drive assembly as shown on the Mechanical Interface Drawing. During alignment procedure, monitor shaft-to-shaft distance determined in Step 5 above to ensure that it does not change as other adjustments are made.

7. Tighten generator mounting bolts. Bring jacking bolts into contact with generator base and tighten jam nuts provided. Do not overtighten jacking bolts.

8. Install shear coupling as described in Subsection 8.5.2.

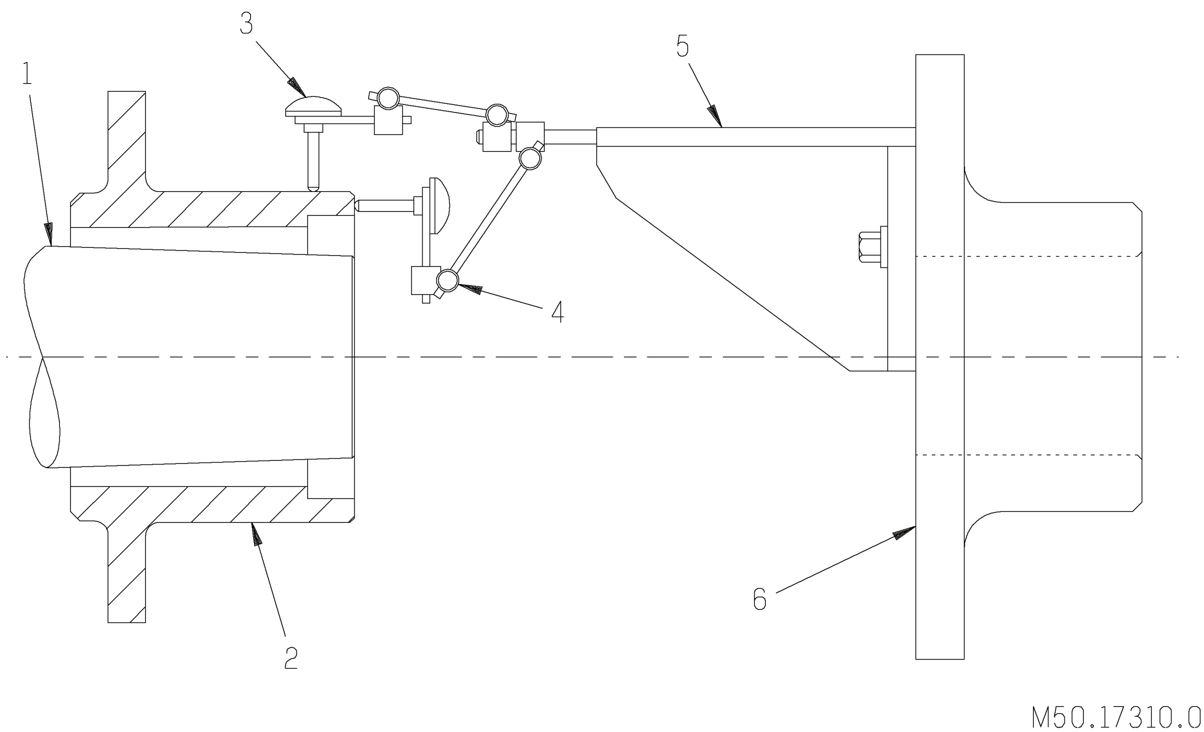


Figure 8.5.4 Generator-to-Reduction Drive Assembly Alignment

Key for Figure 8.5.4			
1	Reduction Drive Assembly Output Shaft	2	Reduction Drive Assembly Hub
3	Bore Indicator (Part of Dial Indicator Kit FT67001)	4	Face Indicator (Part of Dial Indicator Kit FT67001)
5	Alignment Tool	6	Generator Hub

Appendix C

Riverview Energy Systems, LLC

System Operator's Guide

Refurbished Centaur 40 Turbine-Driven Generator Set

Volume I

Systems Operator's Guide

Refurbished Centaur® 40 Gas Turbine-Driven Generator Set

RIVERVIEW ENERGY SYSTEMS
Riverview, MI
Unit 2

Solar® Turbines
A Caterpillar Company

Volume I

Systems Operator's Guide

Refurbished Centaur® 40 Gas Turbine-Driven Generator Set

RIVERVIEW ENERGY SYSTEMS
Riverview, MI
Unit 2

SOLAR®
65171

Volume I

Systems Operator's Guide

Refurbished Centaur® 40 Gas Turbine-Driven Generator Set

RIVERVIEW ENERGY SYSTEMS
Riverview, MI
Unit 2

Solar® Turbines
A Caterpillar Company

Solar Turbines Incorporated
P.O. Box 85376
San Diego, CA 92186–5376

PUBLICATION NUMBER: SOG 13–65171 02/13

PROPRIETARY NOTICE

RECORD OF CHANGES

This page may be used to record changes to the manual made by Publication changes, Service Bulletins, or local changes and corrections.

Change, Date or Bulletin Number	Description	Pages Affected	Date

FOREWORD

This technical manual covers the Refurbished Centaur® 40 Gas Turbine-Driven Generator Set designed and manufactured by Solar Turbines Incorporated at the Package Refurbishment Center in Mabank, Texas.

Procured under Solar Project Definition No. 6517 by RIVERVIEW ENERGY SYSTEMS, this equipment is designated for the Riverview installation site.

Training for this and other equipment is available. For the latest class and registration information, visit the Customer Support section of our home page at *www.solarturbines.com*.

EQUIPMENT IDENTIFICATION

This equipment is identified as follows:

Model Number(s)	Centaur® 40
Assembly Number(s)	8-65171
Serial Number(s)	CG87548

TECHNICAL MANUAL OVERVIEW

The technical manual is provided in a four-volume set. Part numbers referred to within the manual set are Solar part numbers unless otherwise specified. Each volume of the set stands alone and is described in the following paragraphs.

Volume I - Systems Operator's Guide

Volume I is for equipment operator use. Locations and descriptions for all operator controls and indicators are provided. Procedures for starting, stopping, and operating the equipment are also included.

Volume II - Maintenance Instructions

Volume II is for maintenance and field service personnel use. The functions of major systems and subsystems are described, and component descriptions are included. Maintenance instructions, and alignment and checkout procedures are provided. The introduction chapter provides maintenance schedules, torque tables and maintenance information for the mechanical systems on the package.

Volume III - Supplementary Data

Volume III is a collection of standard, copyrighted documents that cover supplier-provided components and assemblies. These documents, passed on by Solar Turbines from its suppliers, are only available in the English language; therefore, these documents cannot be translated into other languages. Documents in this volume are arranged and tabbed alphabetically by the names of the suppliers, as listed on the Supplementary Data sheet furnished in the front of this volume.

Volume IV - Illustrated Parts List

Volume IV lists part numbers, part names, quantities required, reference designators, and drawings to locate parts used in the turbine package. Various indices are provided to aid the user in locating piece parts within the package.

CONTENTS

Chapter **Page**

Chapter **Page**

Chapter **Page**

LIST OF ILLUSTRATIONS

Figure **Page**

Figure **Page**

LIST OF TABLES

SAFETY REQUIREMENTS

EQUIPMENT SAFETY LABELS

Safety labels attached to the equipment are described in this section.

Safety and warning labels are in categories as detailed in the following subsections.

Caution, Warning and Danger labels may be accompanied with a Prohibition symbol, as shown in the following figure. The use of the prohibition symbol indicates a potentially hazardous situation or practice which is not to be allowed.

35749

Caution and Warning labels may be accompanied with a Safety Alert symbol, as shown in the following figure. The use of the Safety Alert symbol with Caution and Warning labels increases the severity of the label.

35750

- Danger - On the package, label has a red border, with white lettering on black, as shown in the following figure. In the print version, colors are not shown.

45131

Danger is the most severe safety label. The signal word Danger indicates a potentially hazardous situation which, if not avoided, will result in death or serious injury. Danger labels identify the most serious hazards.

- Warning - On the package, label has an orange border, with white lettering on black, as shown in the following figure. In the print version, colors are not shown.

45132

The signal word Warning indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury. Hazards identified with the signal word Warning present a lesser degree of risk of injury than those identified by the signal word Danger.

- Caution - On the package, label has a yellow border, with white lettering on black, as shown in the following figure. In the print version, colors are not shown.

45133

The signal word Caution used with a safety alert symbol indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.

The signal word Caution used without a safety alert symbol indicates a potentially hazardous situation which, if not avoided, may result in property damage.

- Notice - On the package, label has a blue border with white lettering on black, as shown in the following figure. In the print version, colors are not shown.

45134

The signal word Notice indicates a statement of policy relating directly or indirectly to the safety of personnel or protection of property. The statement of policy is on the Notice label. A circle around the statement requires mandatory action. The Notice signal word is not to be associated directly with a hazard or hazardous situation, and may not be used in place of Danger, Warning or Caution labels.

GENERAL

Solar turbine-driven packages are designed for safe and reliable operation. The packages include features which protect the equipment from damaging malfunctions and unsafe operation.

Personnel must become familiar with the following safety requirements and must observe the safety requirements at all times. Maximum safety of personnel is of primary importance, followed by protection of equipment from damage. Careful adherence to these safety requirements will minimize hazards or injury to personnel and equipment.

Included are procedures for certain operating malfunctions and precautions for personnel working in special environments (such as in an explosive atmosphere, or where there are dangerous substances).

MANUAL SAFETY WARNINGS, CAUTIONS AND NOTES

Three types of safety notices are used in the manual to emphasize critical information: WARNINGS, CAUTIONS, and NOTES.

WARNINGS, CAUTIONS, and NOTES are explained in order of significance as follows:

WARNING

A WARNING identifies procedures, practices, conditions, or precautions, which if not heeded, could result in personal injury or loss of life.

CAUTION

A CAUTION identifies precautions, which if not observed, could result in damage or destruction of equipment.

NOTE

A NOTE highlights information necessary to understand or follow a procedure, practice, condition, or description.

SAFETY INSPECTION

Careful attention to the package is required. A walkaround visual safety inspection is recommended to ensure that no foreign objects are lying on, in, or around the package. Perform the safety inspection before start-up, once each day of operation, and after shutdown. It is especially important to inspect the package before and after maintenance or repair. Inspect the package for the following unsafe conditions:

- Inspect for fuel gas leaks and lube oil leaks in hot areas.
- Look for leaking gas, sour gas, or condensate in drip pans.
- Check drain lines for leaks.
- Inspect for frayed or skinned electrical wiring. Eliminate high voltages.
- Inspect for broken or cracked anchor bolts or structural members.

- Look for obstructions or loose material in air inlet and exhaust ducts. Check inlet and vent lines for rocks, paper, bird nests, or other foreign matter. Verify that package and its vicinity are clean and unobstructed.

Following is a list of actions to enhance safe operation:

- Know the location of shutoff valves, switches, and telephones.
- Note the location of the customer-furnished emergency shutoff valve that should be installed in the fuel line to the package.
- Know emergency shutdown procedures and other emergency equipment or systems.
- Know emergency procedures applicable to the specific installation.
- Know where the fire extinguishers are and how to use them.
- If other equipment is operating or being serviced nearby, determine if this will create a hazardous condition that could cause personal injury, or affect safe operation or servicing of Solar equipment. Do not operate the package if hazardous or unsafe conditions appear to be likely.

WARNINGS

The following warnings cover Solar turbine-driven packages. Failure to observe these warnings could result in personal injury or loss of life. The order of listing does not indicate the order of importance. Each item is important for personnel safety. These warnings (and others not listed below which may be applicable to the specific installation) must be observed during service and operation of the package.

⚠ WARNING

Operate the unit only when it is safe. Unsafe conditions are:

- Fuel gas leaks, lube oil leaks in hot areas

- Frayed or skinned electrical wiring

- Broken or cracked anchor bolts or structural members

Accumulations of natural gas, fuel fumes, oil tank vent leakage, or solvent fumes can be explosive and must be avoided. This is done by proper ventilation, elimination of leaks, and by confining the use of solvents to appropriate maintenance facilities.

Only qualified personnel may operate the unit. The operator must understand turbine and driven equipment operation and function, including controls, indicators, and operating limits.

⚠ WARNING

Hearing and eye protection, as well as hard hats, safety goggles, ear plugs, and protective clothing, must be used by personnel in the vicinity of the operating machine.

The unit complies with user-specified noise level requirements. Noise levels may be further reduced by the user with modifications to the user's building or equipment. Modifications shall not interfere with safe operation or efficiency of the unit.

Ensure other personnel are nearby. NEVER WORK ALONE.

Never wire around automatic shutdown devices, or bypass software alarms and shutdowns. They prevent personnel injury and damage to the equipment.

When working on a nonoperating package, lock out the start circuit by opening the control circuit breaker and rotating the OFF/LOCAL/REMOTE, OFF/LOCAL/AUXILIARY or OFF/LOCAL/AUX keyswitch to OFF. Attach temporary DO NOT START tag to control switch to warn against inadvertent closing of the switch.

Verify operation of the personal gas monitor (sniffer) and use the monitor to ensure a gasfree environment.

Check that operation of switches and valves cannot endanger personnel and/or equipment.

Do not allow any bare wiring on or in vicinity of package.

Do not step on electrical conduit or junction boxes or use them as supports.

Prevent tripping by stowing unnecessary tools and parts.

Smoking, open flame, or spark-producing devices (such as cigarette lighters) are NOT allowed in the package vicinity AT ANY TIME.

Handle battery electrolyte with care. The battery MUST be kept clean.

Avoid personal contact with hot sections of equipment.

Eliminate any fuel or oil leaks as soon as detected.

WARNING

Check to ensure there is no pressure in any system lines before disconnecting them. High pressure lines may be pressurized up to5000 psi (34 473 kPa, 345 bar, or 352 kg/cm^2).

Use care when performing high voltage ignition system checks. Stand on a rubber mat and wear shockproof gloves and protective eye equipment.

Stand clear of all pressure lines and fittings during start and operation.

Wear protective equipment (face shields, masks, goggles, gloves, or clothing) and observe fire precautions when using cleaning solvents or solutions. Avoid skin contact with solvents or solutions. DO NOT INHALE FUMES.

When welding or cutting package components, observe fire prevention requirements stipulated in National Fire Protection Association (NFPA) Standard No. 51B for cutting and welding procedures. This standard has been adopted by the Occupational Safety and Health Administration (OSHA) of the United States Government as a national standard.

Do not apply external voltages to generator package control systems. Feedback through control transformers to terminals could be lethal.

Do not open circuits to current transformers, ammeters, or watt-var meter current coils with the generator set in operation. Jumper secondary terminals of transformer if generator is to be operated with open current circuits.

Verify correct generator synchronization or phase rotation when paralleling generators, or paralleling a generator with the utility grid. Generator to gear unit coupling damage could result, causing a hazard to personnel and equipment.

Use care when troubleshooting or performing maintenance procedures. Voltages can be dangerously high. Never override interlocks. Verify all main circuit breakers are open (OFF), so that engine will not start unexpectedly while maintenance or inspection work on engine is in progress.

WARNING

When working in areas with a known or potential hydrogen sulfide (H_2S) hazard, wear masks, goggles, gloves, or other protective equipment. H_2S deadens the sense of smell in 2 to 15 minutes, making it difficult to detect. Exposure can cause severe poisoning and CAN BE FATAL.

Discharge all high-voltage circuits by using a heavy insulated cable. Short each phase to ground before working on or around equipment. Residual voltages which might remain stored for several hours after shutdown could be lethal.

Oil heater operation is automatically sequenced to ensure safe operation of the heater. Operating the oil tank heater when oil is not at the required level creates a fire hazard. To avoid injury to personnel or damage to equipment by fire, do not manually bypass lube oil heater interlocks.

CAUTIONS

The following cautions cover Solar turbine-driven packages. Failure to observe these cautions could result in damage to or destruction of equipment. The order of listing does not indicate order of importance. Each item is important to overall equipment safety. These cautions (and others which may be applicable to a specific installation site) must be observed during all service and operation of the package.

CAUTION

Prevent foreign matter (such as ice) from entering air inlet. Foreign objects in the air inlet will cause severe damage.

Protect air inlet from entry of contaminants such as moisture, dust, sand, and oil mist.

Bleed all air from fuel system prior to operating equipment. Air in fuel system could cause malfunction and/or shutdown.

Under severe environmental conditions, ensure that inlet air filtration system is free of restrictions that could reduce inlet air pressure. Use snow covers, de-icers, and sand/dust filters to protect the inlet air system.

Before operating equipment, ensure that covers are removed from air inlet, exhaust, and vents. These openings must remain unobstructed during operation.

CAUTION

Watch instruments and indicator lights closely, especially during start-up. Engine speed and turbine temperature are best indications of performance or impending malfunctions.

During the start cycle, monitor engine speed and temperature. Rapid rise of turbine temperature with no corresponding speed increase indicates engine compressor surge. If engine compressor surge occurs, do not wait for controls to actuate. PRESS STOP SWITCH IMMEDIATELY.

In the event of malfunction shutdown, do not attempt another start until the cause is determined and corrected.

Do not exceed starter motor crank cycle limits.

Do not allow the turbine to rotate in reverse-from-normal rotation. Reverse rotation can cause serious damage to the turbine.

Cap all open lines and fittings during maintenance to prevent entry of contaminants. Use caps and blanks specifically intended for closing lines or fittings. DO NOT USE TAPE.

Keep package and vicinity clean and unobstructed. Keep maintenance work areas clean to ensure clean assembly. Cleanliness is important due to high speeds and close tolerances of turbine parts.

Do not overfill the oil tank. Ensure that clearance is maintained over the oil tank vent, and vent exhaust is directed away from engine air inlet and exhaust ducts.

Do not flex cables unnecessarily. Repeated flexing of wiring connections contributes to early fatigue failure.

Keep covers, doors, and panels in place and explosionproof enclosures closed, with all fasteners installed and tightened, when package access is not required.

Do not pull on electrical cables to disconnect. Disconnect by grasping connectors only.

Do not add water to discharged battery. Electrolyte level rises considerably during charging.

Verify check valves and other flow devices are correctly installed relative to direction of flow.

CAUTION

When applicable, allow pre/post lube oil pump to complete the postlube cycle before shutting off service air/gas supply.

Ensure that any system unsafe to operate is locked out and controls and switches are tagged "DO NOT OPERATE."

Verify that exhaust collector drains are not connected to common drain manifolds. Common drain manifolds sometimes drain or vent flammable gases and/or fluids.

When using electrical welding procedures on package skid, ensure proper grounding of welding equipment to prevent damage to electrical components mounted on the package.

When connecting generator package high-voltage power cables, ensure that elbow connectors are properly seated (in safe-break bushings) to prevent arcing and subsequent damage at startup.

OPERATING MALFUNCTIONS

Certain operating conditions constitute abnormal turbine engine operation. Identification of the following malfunctions helps in determining package maintenance or repair requirements.

Engine Compressor Surge

CAUTION

If engine compressor surge occurs, do not wait for controls to actuate. PRESS STOP SWITCH IMMEDIATELY. Surge can cause serious engine damage.

All turbines are subject to engine compressor surge under certain conditions. Transient conditions in fuel or air systems can cause the engine to surge as described by the following sounds and conditions:

1. Surge in the lower speed range could be indicated by the engine failing to accelerate, coupled with increased exhaust temperatures, and a sound of buffeting or fluttering air.

2. Surge in the higher speed range could be indicated by a loud roar and/or popping noises, plus engine failure to accelerate to rated speed.

NOTE

If surge occurs, shut down the engine immediately to prevent the rapid buildup of damaging temperatures. After the engine has coasted to a stop, attempt to restart as usual. If surge occurs a second time, contact Solar Turbines Customer Service.

Generator Overheating And Vibration

Certain operating conditions may cause the generator to overload. Normal temperature rise of the generator windings is listed on the generator nameplate. Monitor temperature reported by the control system with surface temperature measuring instruments. Never check temperature by placing a hand on the surface.

NOTE

Overheating may be caused by excessive ambient temperatures, poor air circulation due to improper or restricted ventilation, overload, excessive field current, contaminated or low lube oil supply, or worn bearings. If excessive temperature persists, shut down the unit and investigate the cause.

CAUTION

An increase in generator vibration during operation should be checked immediately. Shut down unit and check for misalignment, bent shafts, or rubbing between stator and rotating elements.

Explosive Atmosphere

Accumulations of natural gas, fuel fumes, oil tank vent leakage, or solvent fumes can be explosive and must be avoided. This is accomplished by proper ventilation, elimination of leaks, and by confining the use of solvents to appropriate maintenance facilities.

WARNING

Relying on the sense of smell to determine the presence of natural gas is not reliable and can be dangerous. Natural gas has no odor unless an odorizer has been added. Pipeline gas usually has no odor because the odorizer is not added until gas reaches the distributor.

A gas detection device (sniffer) more accurately determines if and where gas leakage exists. The sniffer must be operating properly (refer to manufacturer's operating instructions) before

⚠ WARNING

making checks. Sniffers MUST be calibrated periodically. NEVER rely on a sniffer that is out of calibration, or one suspected of being out of calibration.

If there is any doubt regarding gas leakage, a sniffer must be used to ensure that there is no leakage. Using a sniffer is the primary method to determine the presence of an explosive atmosphere. A soap solution may be used to determine the source of a leakage.

Any hazardous condition must be corrected before continuing with checkout procedures. This is a mandatory requirement.

At installation and during maintenance of station equipment, observe the following precautions:

1. Check piping for structural soundness. Verify that piping is properly supported and all connections are made in accordance with the best standard practices. Avoid unconventional or makeshift plumbing at all times.

2. Prior to admitting gas into lines or systems, test for leaks and inspect to ensure all connections are properly made and all unused ports are plugged. Ensure that all flanged connections include required gaskets and that bolts are tight. Verify that lines have been cleared before pressurizing.

3. Ensure that vent systems which handle natural gas are properly installed before operation of the equipment. Check that vents terminate in an area far enough from equipment or building to prevent any possibility of gas being carried back into the work area. Check vent systems to ensure that all unused ports are plugged to prevent gas escaping into the package enclosure or building. Check vent lines for bird nests, insects, ice, or any other obstructions that would prevent proper venting.

4. If gas detection equipment is installed in the package or in the building, confirm proper operation of this equipment before admitting gas into the systems.

5. When admitting gas into a system for the first time, listen for gas leaks. (Do not place your ear or head where there are suspected leaks.) Use a gas sniffer. Never attempt to check gas leaks by feeling for the suspected area with the hands or fingers. This method can be very dangerous as gas pressures can exceed 150 psi (1034 kPa, 10 bar, or 11 kg/cm^2). A pinhole leak of high pressure gas can amputate a finger or hand. Use a piece of cloth (streamer) attached to a stick to test for leaks.

6. Once gas has been admitted to equipment, use a gas sniffer to ensure the absence of gas before opening any explosionproof enclosure for troubleshooting.

7. Battery connections are not enclosed in an explosionproof housing. Verify that battery, battery charger, and circuit breakers are in nonexplosive environments with an explosionproof interconnection to the package. Test with a gas sniffer to ensure absence of explosive atmosphere when maintaining battery connections.

FIRST AID

WARNING

Solar recommends that personnel working in the vicinity of the equipment described in these operating and maintenance instructions be trained in first aid, and specifically, to deal with injuries including the following:

- Electric shock
- Inhalation of toxic gases, natural gas, or CO_2
- Bleeding
- Broken bones
- Chemical burns
  - Sulfuric or other acid
  - Preservative powder (dicyclohexyl ammonium nitrate)
- Flame, heat, steam, or hot water burns
- Head, neck, or spinal injury

1 INTRODUCTION

1.1 GENERAL

This publication is for equipment operator use. Only qualified personnel may operate the unit. The operator must understand package equipment, systems, operation, operating limits, and controls and indicators prior to package operation. Refer to the Safety Requirements in the front of this manual prior to package operation. Chapters of this manual are described in the following paragraphs.

Chapter 1, Introduction, describes the contents of this volume.

Chapter 2, Controls and Indicators, provides illustrations and corresponding tables that describe package controls and indicators. Sections are arranged by component location relative to the package. Table information includes:

Index No. (Index Number): The number that corresponds to the number referencing an item on the illustration. A dash (-) in the Index No. column indicates the part is not illustrated.

Nomenclature: The as-labeled component name and description of the type of component, such as ALARM SUMMARY Light, ENGINE HOURS/START COUNTER Meter, or EMERGENCY STOP Switch.

Ref. Desig. (Reference Designator): The alphanumeric designator used on the electrical schematic, such as DS110, Z101, or S112.

Description: A brief physical and/or functional summary of the component.

Chapter 3, Enhanced Display Software, contains customer specific screens and information.

Chapter 4, Operating Instructions, contains step-by-step procedures for starting, operating and stopping the equipment from the unit control panel, auxiliary unit control panel (if applicable), and remote unit control panel (if applicable).

1.2 SOLAR TURBINES' TECHNICAL TRAINING

Solar Turbines recommends technical training for operators and maintenance personnel working on Solar turbomachinery. Solar Technical Training can be contacted at the following address:

Solar Turbines Incorporated

Technical Training, Mail Zone SP1A

9250A Sky Park Court

San Diego, CA 92123–5398, USA

Phone: (+1) 858–715–2060

E-mail: training_tech@solarturbines.com

Internet: www.solarturbines.com

2 CONTROLS AND INDICATORS

2.1 GENERAL

This chapter includes illustrations and tables that describe operator controls and indicators. Each illustration is accompanied by a corresponding table which lists the items referenced in the illustration. The illustration shows location of components, while the table lists their physical and functional characteristics. Installation drawings, mechanical drawings, and the electrical schematic provided with the package are project specific, have more detailed information, and should be used with this chapter.

The following illustrations and tables are arranged by systems to allow the operator to check the controls and indicators of each system to assure the package is set up correctly for operation. The systems incorporated in this chapter include the following:

- Unit control panel controls and indicators
  - TT4000S display screens
- Auxiliary unit control panel controls and indicators
  - Turbine control panel
  - Video display computer

2.2 UNIT CONTROL PANEL CONTROLS AND INDICATORS

The controls and indicators for the unit control panel are shown in Figure 2.2.1 and are listed in Table 2.2.1.

NOTE

Only index numbers for operator controls and indicators are listed in the following table.

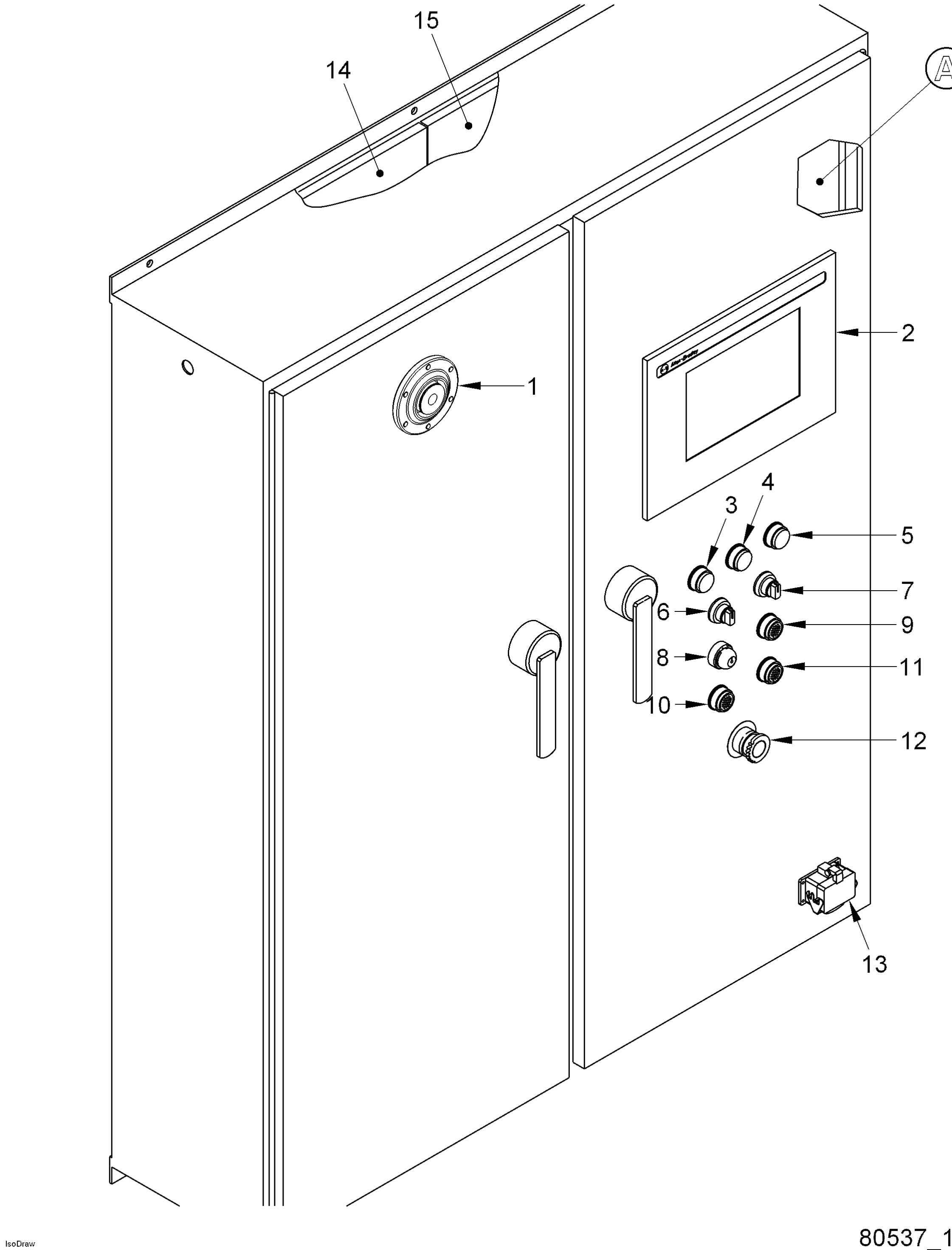


Figure 2.2.1 Unit Control Panel Controls and Indicators

Table 2.2.1 Unit Control Panel Controls and Indicators

Index No.	Nomenclature	Ref. Desig.	Description
1	CONTROL SYSTEM ALARM Horn	AH172	Horn sounds alarm to alert operator of control system alarm or shutdown condition. Alarm is silenced by pressing HORN SILENCE Switch (S172) or ACKNOWLEDGE Switch (S117).
2	DIGITAL DISPLAY Terminal	Z1100	Terminal used for controlling and monitoring turbine package. Refer to Supplementary Data for controls and indicators of digital display terminal. Refer to Chapter 3for a description of display software and screens. **NOTE** For a list of alarms and shutdowns, refer to the Software Cause and Effect Drawing that is provided in the RSLogix/9000_999/Reports folder of the Project CD-ROM.
3	HORN SILENCE Switch	S172	**CAUTION** **Pressing HORN SILENCE Switch does not clear malfunction condition.** Pushbutton switch pressed to silence Control System Alarm Horn (AH172) after an alarm or shutdown has occurred. Additional alarm or shutdown will reactivate alarm horn. HORN SILENCE Switch or ACKNOWLEDGE Switch (S117) must be pressed again to silence alarm horn.

Table 2.2.1 Unit Control Panel Controls and Indicators, Contd

Index No.	Nomenclature	Ref. Desig.	Description
4	ACKNOWLEDGE Switch	S117	**CAUTION** **Pressing ACKNOWLEDGE Switch does not clear malfunction condition.** Pushbutton switch pressed to acknowledge alarm or shutdown. Pressing ACKNOWLEDGE Switch enables RESET Switch (S114), which allows system to be reset when alarm or shutdown becomes inactive. Pressing ACKNOWLEDGE Switch also silences Control System Alarm Horn (AH172) after an alarm or shutdown has occurred. Additional alarm or shutdown will reactivate alarm horn. ACKNOWLEDGE Switch or HORN SILENCE Switch (S172) must be pressed again to silence alarm horn. **NOTE** OFF/LOCAL/AUXILIARY Keyswitch (S101) must be in LOCAL position prior to switch operation.
5	RESET Switch	S114	Pushbutton switch pressed to clear alarm or shutdown indication and reset control system. **NOTE** OFF/LOCAL/AUXILIARY Keyswitch (S101) must be in LOCAL position prior to switch operation.

Table 2.2.1 Unit Control Panel Controls and Indicators, Contd

Index No.	Nomenclature	Ref. Desig.	Description
6	SPEED DECREASE INCREASE Switch	S154	Three-position (DECREASE, spring return-to-center, INCREASE) switch rotated and held to decrease or increase setpoint selected on Gen Set Points display screen. While switch is held in DECREASE position, selected setpoint gradually decreases until minimum setpoint is reached. While switch is held in INCREASE position, selected setpoint gradually increases until maximum setpoint is reached. **NOTE** OFF/LOCAL/AUXILIARY Keyswitch (S101) must be in LOCAL position prior to switch operation.
7	VOLTAGE DECREASE/INCREASE Switch	S152	Three-position (DECREASE, spring return-to-neutral-center, INCREASE) switch rotated to control generator output voltage within ±10 percent. In DECREASE position, generator output voltage gradually decreases until minimum voltage setpoint is reached. In INCREASE position, generator output voltage gradually increases until maximum voltage setpoint is reached. **NOTE** OFF/LOCAL/AUXILIARY Keyswitch (S101) must be in LOCAL position prior to switch operation.

Table 2.2.1 Unit Control Panel Controls and Indicators, Contd

Index No.	Nomenclature	Ref. Desig.	Description
8	OFF / LOCAL / AUXILIARY Keyswitch	S101	**CAUTION** **Rotating the keyswitch to the OFF position, when the unit is operating, will initiate a control system stop of the engine with no cooldown cycle.** Three-position (OFF, LOCAL, AUXILIARY) rotary-selector keyswitch. In OFF position, start sequence is inhibited. In LOCAL position, package operation is controlled from unit control panel. In AUXILIARY position, package operation is controlled from auxiliary unit control panel. Normal and emergency stop functions remain active regardless of LOCAL or AUXILIARY selection.
9	START/STARTING Switch/Light	S/DS110	Pushbutton switch pressed to initiate start sequence. Light flashes until start cycle is completed. **NOTE** OFF/LOCAL/AUXILIARY Keyswitch (S101) must be in LOCAL position prior to switch operation.
10	STOP/STOPPING Switch/Light	S/DS111	Pushbutton switch pressed to initiate cooldown stop sequence. **NOTE** The generator circuit breaker opens and engine speed reduces to idle. Idle speed is maintained for a preselected cooldown cycle before the fuel is shut off and the engine shuts down. Light illuminates when normal, emergency, or control system stop is initiated. Light extinguishes when restart timer has timed out after engine shutdown.

Table 2.2.1 Unit Control Panel Controls and Indicators, Contd

Index No.	Nomenclature	Ref. Desig.	Description
11	BACKUP SYSTEM ACTIVE/RESET Switch/Light	S/DS124	Light illuminates to indicate backup relay system is activated by one of following events: • Failure of microprocessor • Detection of fire • Detection of engine overspeed by backup overspeed monitor • Pressing of emergency stop switch **NOTE** The backup relay system will maintain lube oil pump operation to avoid possible damage to the engine or driven equipment. Switch pressed to reset backup relay system. **NOTE** The backup relay system cannot be reset until after the ACKNOWLEDGE and RESET switches are pressed. Light extinguishes when backup relay system has been reset.

Table 2.2.1 Unit Control Panel Controls and Indicators, Contd

Index No.	Nomenclature	Ref. Desig.	Description
12	EMERGENCY STOP Switch	S112	Pushbutton switch pressed to initiate immediate engine shutdown with no cooldown cycle. **NOTE** The generator circuit breaker opens, the fuel is shut off, and the engine shuts down. STOP/STOPPING Switch/Light (S/DS111) illuminates. Pull switch to reset circuit.
-	ENGINE HOURS/START COUNTER Meter	M210	Dual-function (engine starts counter and engine operating hours) meter assembly. ENGINE STARTS meter increments when engine T5 reaches lightoff temperature. Logs cumulative number of starts. ENGINE HOURS meter begins to log cumulative engine operating time at starter dropout setpoint. Logs time in hundredths of an hour, up to 99999.99 hours.

2.2.1 TT4000S Display Screens

Refer to Chapter 3 for a description of all standard display software and screens.

NOTE

For a list of alarms and shutdowns, refer to the Software Cause and Effect Drawing that is provided in the RSLogix/9000_999/Reports folder of the Project CD-ROM.

2.3 AUXILIARY UNIT CONTROL PANEL CONTROLS AND INDICATORS

The controls and indicators for the auxiliary unit control panel are shown in Figure 2.3.1 and are listed in Table 2.3.1.

NOTE

Only index numbers for operator controls and indicators are listed in the following table.

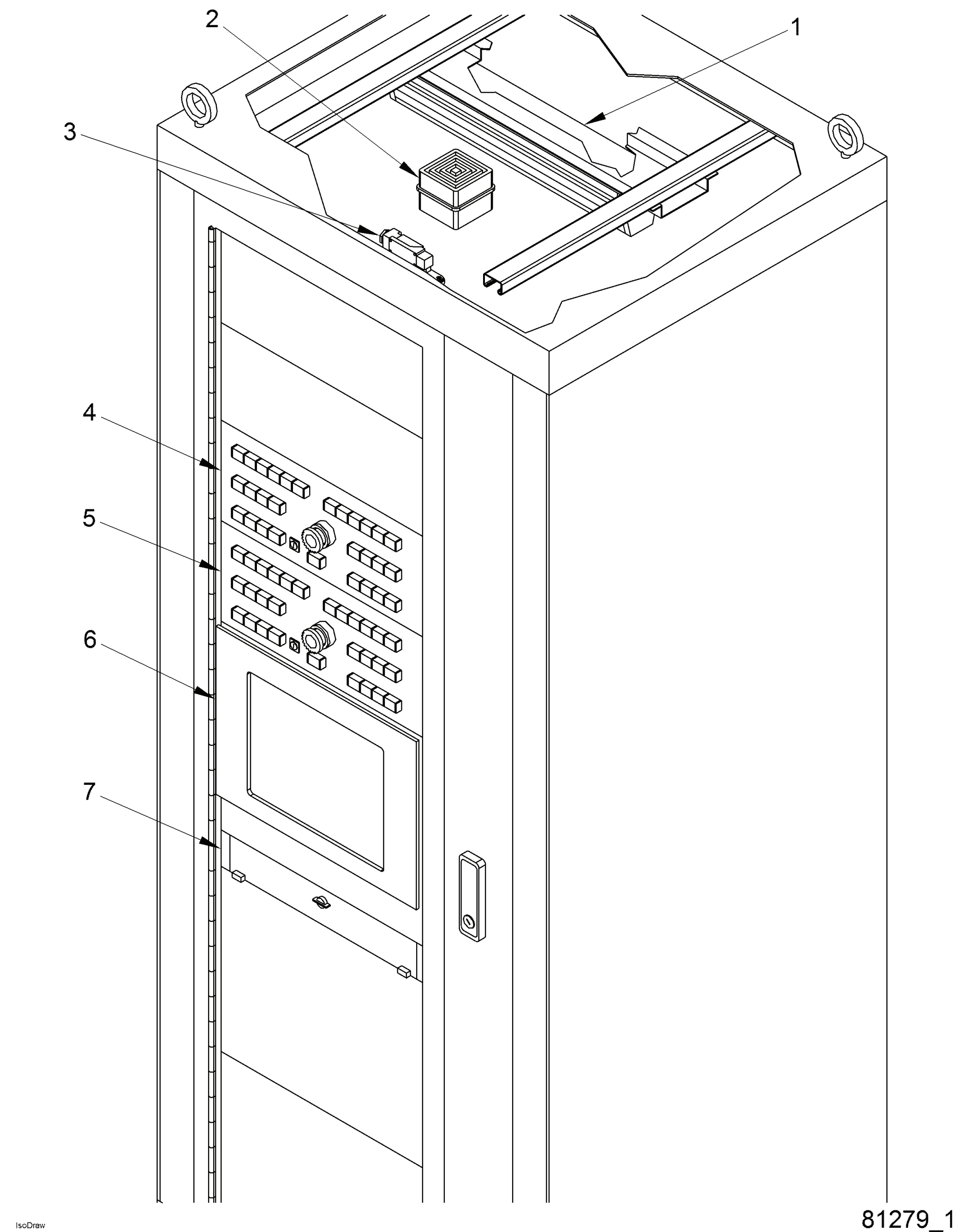


Figure 2.3.1 Auxiliary Unit Control Panel Controls and Indicators

Table 2.3.1 Auxiliary Unit Control Panel Controls and Indicators

Index No.	Nomenclature	Ref. Desig.	Description
2	CONTROL SYSTEM ALARM Horn	AH272	Horn sounds alarm to alert operator of control system alarm or shutdown condition. Alarm is silenced by pressing HORN SILENCE Switch (S1072) or ACKNOWLEDGE Switch (S1017).
4-5	TURBINE CONTROL Panel	-	Refer to Subsection 2.3.1.
6	VIDEO DISPLAY Computer	Z1190	Refer to Subsection 2.3.2.
7	Keyboard	ZZ1192	Refer to Subsection 2.3.2.

2.3.1 Turbine Control Panel

The controls and indicators for the turbine control panel are shown in Figure 2.3.2 and are listed in Table 2.3.2.

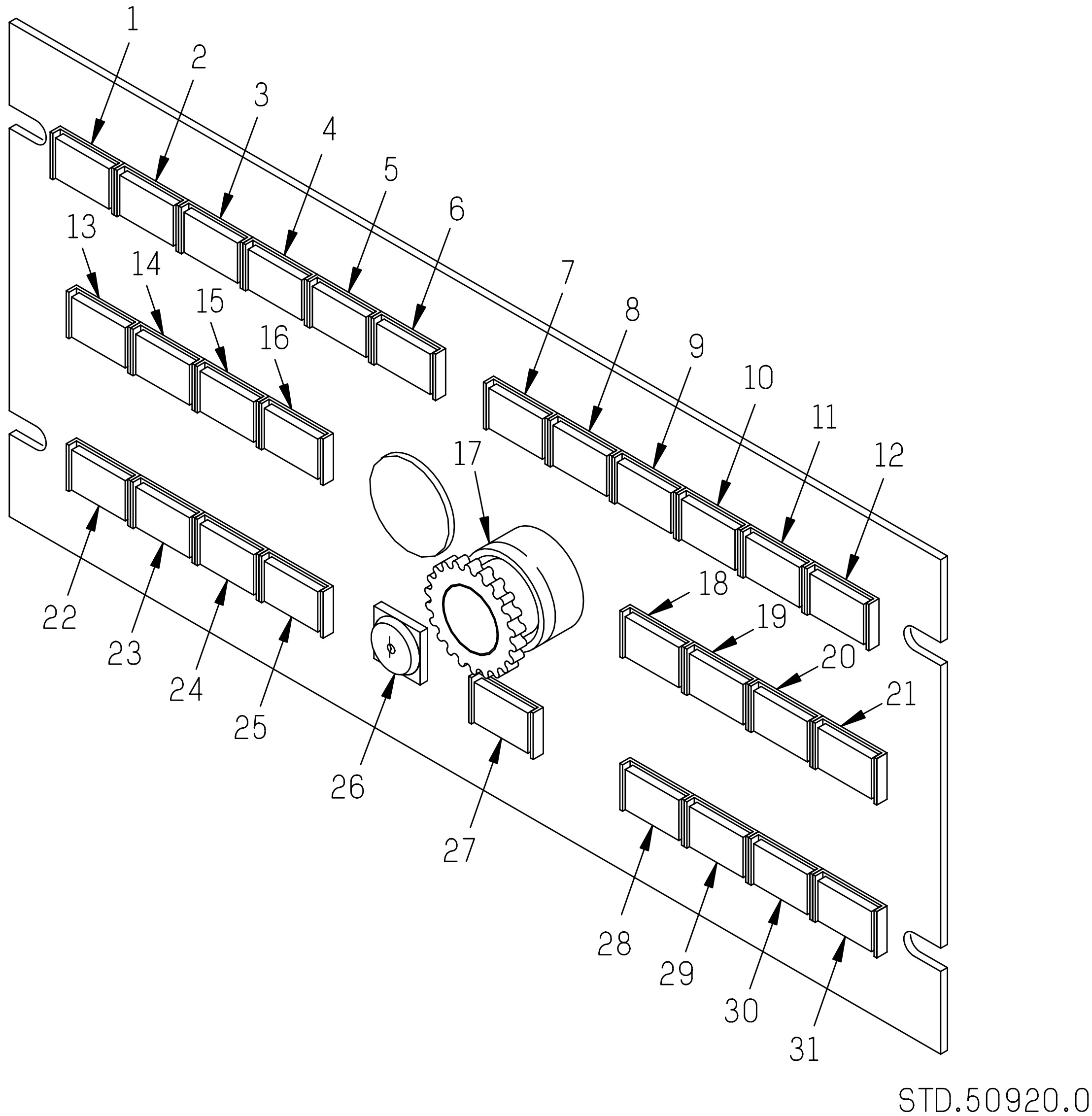


Figure 2.3.2 Turbine Control Panel Controls and Indicators

Table 2.3.2 Turbine Control Panel Controls and Indicators

Index No.	Nomenclature	Ref. Desig.	Description
1	READY Light	DS1077	Light illuminates to indicate system is ready to start, no active shutdown indications exist, and OFF/LOCAL/AUXILIARY Keyswitch (S101) is in any other position but OFF. Light extinguishes when START Switch (S1010) is pressed.

Table 2.3.2 Turbine Control Panel Controls and Indicators, Contd

Index No.	Nomenclature	Ref. Desig.	Description
2	STARTING Light	DS1014	Light illuminates when START Switch (S1010) is pressed. STARTING Light will flash and continue flashing until starter dropout speed is reached.
3	READY TO LOAD Light	DS1086	Light illuminates 20 seconds after Ngp speed (for single-shaft engines) or Npt speed (for two-shaft engines) reaches 90 percent. Light remains illuminated until ON LOAD Light (DS1059) illuminates.
4	ON LOAD Light	DS1059	Light illuminates when generator circuit breaker is closed, and engine assumes generator load. **NOTE** Generator circuit breaker can only be closed while READY TO LOAD Light DS1086 is illuminated.
5	Spare	DSP05	
6	LOCAL/AUX Light	DS1001	Split-type, (LOCAL, AUX) dual-function indicator light illuminates to indicate selected mode. Mode is selected by rotating OFF/LOCAL/AUXILIARY Keyswitch (S101), located on unit control panel.
7	Spare	DSP07	
8	COOLDOWN Light	DS1013	Light illuminates when NORMAL STOP Switch (S1011) is pressed and system begins cooldown cycle. Light extinguishes when cooldown cycle times out and engine shuts down.
9	STOPPING Light	DS1011	Light illuminates when normal, emergency, or control system stop is initiated. Light extinguishes when restart timer has timed out after engine shutdown.
10	ALARM SUMMARY Light	DS1073	Light illuminates to indicate an alarm condition. Light remains illuminated until condition is cleared and system is reset.

Table 2.3.2 Turbine Control Panel Controls and Indicators, Contd

Index No.	Nomenclature	Ref. Desig.	Description
11	BACKUP ACTIVE Light	DS1024	Light illuminates to indicate backup relay system is activated by one of following events: • Failure of microprocessor • Detection of fire • Detection of engine overspeed by backup overspeed monitor • Pressing of emergency stop switch **NOTE** The backup relay system will maintain lube oil pump operation to avoid possible damage to the engine or driven equipment. Rotate BACKUP RESET Keyswitch (S1024) clockwise to reset backup relay system. **NOTE** The backup relay system cannot be reset until after the ACKNOWLEDGE and RESET switches are pressed. Light extinguishes when backup relay system has been reset.
12	SHUTDOWN SUMMARY Light	DS1075	Light illuminates if shutdown is initiated manually or automatically. Light remains illuminated until control system is reset.
13	Spare	S/DSP13	
14	Spare	S/DSP14	
15	Spare	S/DSP15	

Table 2.3.2 Turbine Control Panel Controls and Indicators, Contd

Index No.	Nomenclature	Ref. Desig.	Description
16	SPD ISOCH/SPD DROOP Switch/Light	S/DS1091	Pushbutton switch pressed to select SPEED ISOCH or SPEED DROOP operation. Light illuminates to indicate if SPEED ISOCH or SPEED DROOP operation is active. **NOTE** Selecting SPEED ISOCH operation will automatically deselect SPEED DROOP operation. Selecting SPEED DROOP operation will automatically deselect SPEED ISOCH operation.
17	EMERGENCY STOP Switch	S1012	Pushbutton switch pressed to initiate immediate engine shutdown with no cooldown cycle. **NOTE** The generator circuit breaker opens, the fuel is shut off, and the engine shuts down. STOPPING Light (DS1011) illuminates. Pull switch to reset circuit.
18	Spare	S/DSP19	
19	Spare	S/DSP20	
20	VOLTAGE DECREASE Switch	S/DSP1053	Pushbutton switch pressed to decrease generator voltage. Generator voltage gradually decreases until minimum voltage setpoint has been reached for duration in which switch is pressed. **NOTE** OFF/LOCAL/AUXILIARY Keyswitch (S101) must be in AUXILIARY position prior to switch operation.
21	VOLTAGE INCREASE Switch	S/DSP1052	Pushbutton switch pressed to increase generator voltage. Generator voltage gradually increases until maximum voltage setpoint has been reached for duration in which switch is pressed. **NOTE** OFF/LOCAL/AUXILIARY Keyswitch (S101) must be in AUXILIARY position prior to switch operation.

Table 2.3.2 Turbine Control Panel Controls and Indicators, Contd

Index No.	Nomenclature	Ref. Desig.	Description
22	HORN SILENCE Switch	S1072	**CAUTION** **Pressing HORN SILENCE Switch does not clear malfunction condition.** Pushbutton switch pressed to silence Control System Alarm Horn (AH272) after an alarm or shutdown has occurred. Additional alarm or shutdown will reactivate alarm horn. HORN SILENCE Switch or ACKNOWLEDGE Switch (S1017) must be pressed again to silence alarm horn.
23	ACKNOWLEDGE Switch	S1017	**CAUTION** **Pressing ACKNOWLEDGE Switch does not clear malfunction condition.** Pushbutton switch pressed to acknowledge alarm or shutdown. Pressing ACKNOWLEDGE Switch enables RESET Switch (S1014), which allows system to be reset when alarm or shutdown becomes inactive. Pressing ACKNOWLEDGE Switch also silences Control System Alarm Horn (AH272) after an alarm or shutdown has occurred. Additional alarm or shutdown will reactivate alarm horn. ACKNOWLEDGE Switch or HORN SILENCE Switch (S1072) must be pressed again to silence alarm horn. **NOTE** OFF/LOCAL/AUXILIARY Keyswitch (S101) must be in AUXILIARY position prior to switch operation.

Table 2.3.2 Turbine Control Panel Controls and Indicators, Contd

Index No.	Nomenclature	Ref. Desig.	Description
24	RESET Switch	S1014	Pushbutton switch pressed to clear alarm or shutdown indication and reset control system. **NOTE** Start is permitted only if shutdowns are inactive and control system has been reset. OFF/LOCAL/AUXILIARY Keyswitch (S101) must be in AUXILIARY position prior to switch operation.
25	LAMP TEST Switch	S1013	Pushbutton switch pressed to illuminate all indicator lights. **NOTE** All lights illuminated indicate all light circuits are intact.
26	BACKUP RESET Keyswitch	S1024	Rotary, two-position (OFF, ON) keyswitch rotated clockwise to reset backup relay system. **NOTE** The backup relay system cannot be reset until after the ACKNOWLEDGE and RESET switches are pressed. BACKUP ACTIVE Light (DS1024) extinguishes when backup relay system has been reset.
27	NORMAL STOP Switch	S1011	Pushbutton switch pressed to initiate cooldown stop sequence. **NOTE** The generator circuit breaker opens and engine speed reduces to idle. Idle speed is maintained for a preselected cooldown cycle before the fuel is shut off and the engine shuts down.

Table 2.3.2 Turbine Control Panel Controls and Indicators, Contd

Index No.	Nomenclature	Ref. Desig.	Description
28	START Switch	S1010	Pushbutton switch pressed to initiate start sequence. **NOTE** OFF/LOCAL/AUXILIARY Keyswitch (S101) must be in AUXILIARY position with READY Light (DS1077) illuminated before a start can be initiated.
29	Spare	S/DSP30	
30	DECREASE (Down Arrow) Switch	S1055	Pushbutton switch pressed to decrease engine speed. Engine speed gradually decreases until minimum speed setpoint has been reached for duration in which switch is pressed. **NOTE** OFF/LOCAL/AUXILIARY Keyswitch (S101) must be in AUXILIARY position prior to switch operation.
31	INCREASE (Up Arrow) Switch	S1054	Pushbutton switch pressed to increase engine speed. Engine speed gradually increases until maximum speed setpoint has been reached for duration in which switch is pressed. **NOTE** OFF/LOCAL/AUXILIARY Keyswitch (S101) must be in AUXILIARY position prior to switch operation.

2.3.2 Video Display Computer

The video display computer is the operator's main monitoring and secondary operating interface with the control system. The display computer is an industrial personal computer with a color video monitor and software. It collects data from the programmable logic controller (PLC), processes and stores the computational results, and generates formatted display screens.

Video display computer display screens provide graphic and tabular presentation of real-time and stored data. Using the display screens, the operator monitors package operating conditions, changes device operating modes (pumps ON or OFF), changes programming constants, and selects printer functions.

KEYBOARD CONTROL KEYS

Tab Key

The TAB key is used to highlight display screen titles on the menu tree or onscreen buttons.

NOTE

Highlighted display screen titles or onscreen buttons are selected (activated) by the ENTER key.

Cursor Control

The cursor is controlled by the up, down, left, and right arrow keys on the numeric/control keypad. These keys are used to move the arrow cursor up and down on the Alarm Summary and Event Log display screens.

Enter

The ENTER key is used to select (activate) a highlighted display screen title on the menu tree or onscreen button.

NOTE

Display screen titles on the menu tree or onscreen buttons are highlighted by the TAB key.

Escape

The ESC (Escape) key is used to cancel an operation in progress.

Function Keys

The function keys are used to activate features prompted by the display.

Numeric Keys

The numeric keys are used to input numerical data.

Alpha Keys

The alpha keys are used to input scripted data.

Home and End Keys

The HOME key is used to select the first parameter on the first page of the display screen. The END key is used to select the last parameter on the last page of the display screen.

Page Up and Page Down Keys

The PAGE UP and PAGE DOWN keys are used to scroll through multiple page display screens.

Print Screen Key

The PRINT SCREEN key is used to print the current display screen.

ELECTRONIC POINTERS

Electronic pointers, such as a trackball or mouse, are used to access display screens or to activate onscreen functions. Use the trackball or mouse to position the cursor to the desired position and click the left trackball or mouse button to access the desired display screen or to activate the desired onscreen function.

NOTE

Any operation that can be performed with a mouse can be performed with the trackball.

(This page intentionally left blank)

3 ENHANCED DISPLAY SOFTWARE

3.1 TT4000 OVERVIEW

The operator uses the TT4000S screens to monitor and operate the equipment.

3.1.1 Screen Header

The screen header, Figures 3.1.1and 3.1.2, is the same for all screens and consists of the Banner and the Alarm Bar.

Figure 3.1.1 Screen Header

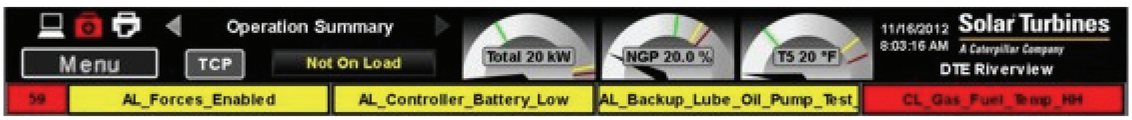


Figure 3.1.1 Screen Header, Contd

Figure 3.1.2 Screen Header (Multi-Unit)

Figure 3.1.2 Screen Header (Multi-Unit), Contd

You can switch between two screen header views, *Gauges* and *Text*, through the Display Settings window, Figure 3.1.5 accessible from the Menu window, Figure 3.1.3.

BANNER

The banner has icons that show you the status of the equipment, and it has gages that show you the current operating conditions of the package. Text-based information can be selected instead of the gages. The banner also has buttons that will open windows that take you to additional screens or give you basic operating control of the turbine.

HMI Connection Icon: When you move the cursor over this icon, an indicator appears that shows you your auxiliary or local connection status and, depending on your log-in properties, whether you have read-only permission for the screens, or you have permission to change the screens.

HMI PC Health Icon: When you move the cursor over this icon, it will show you the health of the Human Machine Interface (HMI) Personal Computer (PC). If the icon is white, the HMI PC has no problems. The icon will change to yellow and then to red to warn you about increasingly serious problems.

Printer Icon: Click this button to print the screen.

Menu Button: Move the cursor over this button to open the menu window, Figures 3.1.3 and 3.1.4. Click the Views button to show all TT4000 screens. To open a screen, click its title. Click the Display Settings button to open a window, Figures 3.1.5 and 3.1.6, that lets you select screen language, gauges or text-based information in the banner, and a theme for the background of the screens.

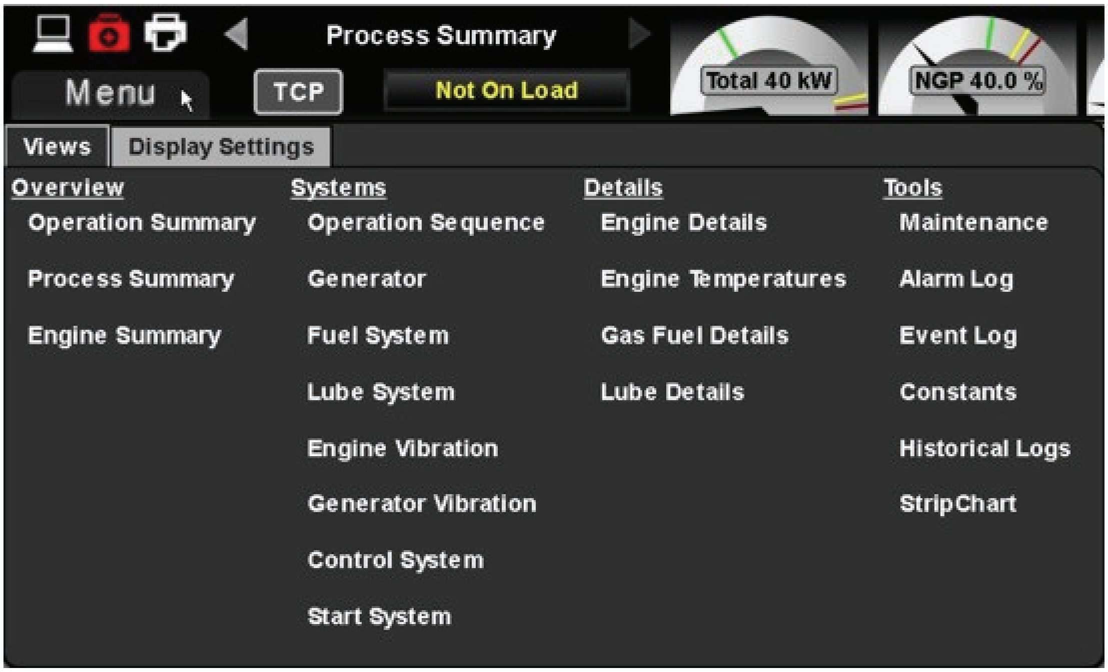


Figure 3.1.3 Menu Window

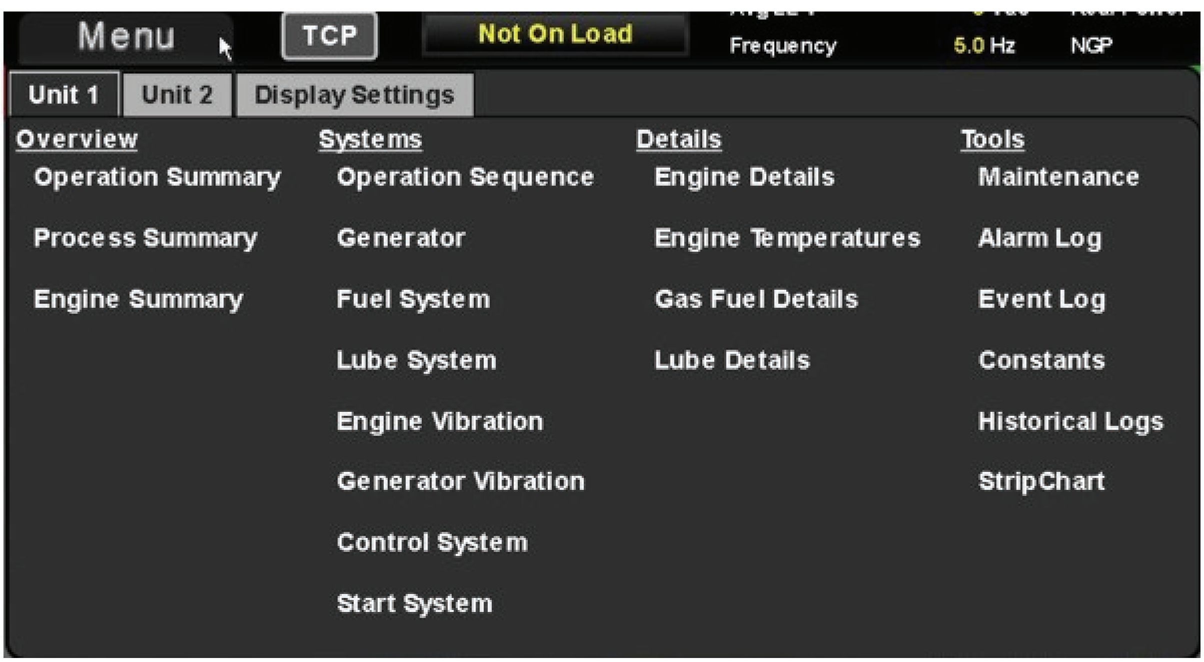


Figure 3.1.4 Menu Window (Multi-Unit)

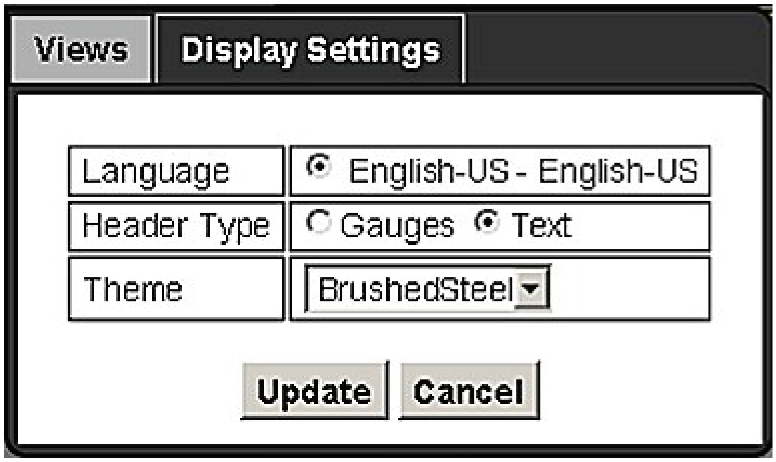


Figure 3.1.5 Display Settings Window

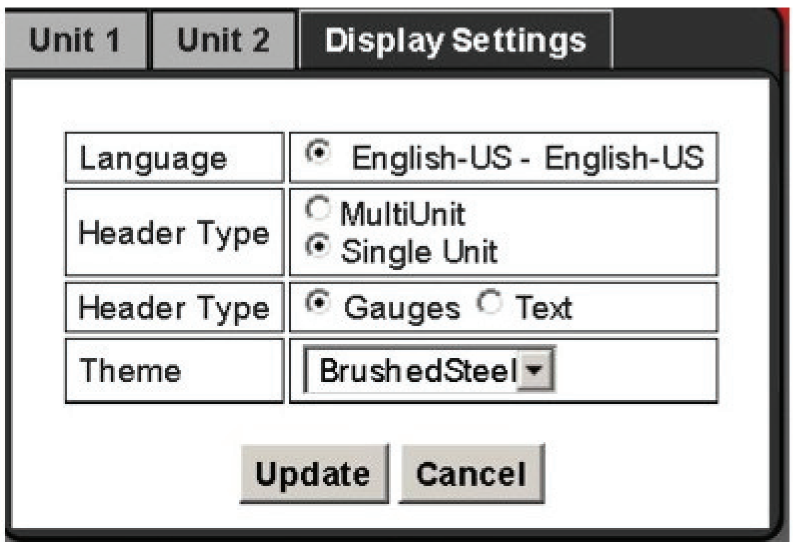


Figure 3.1.6 Display Settings Window (Multi-Unit)

TCP Button: Click this button to open the onscreen Turbine Control Panel (TCP), Figure 3.1.7. You can use the panel to start the package, do a normal stop, reset alarms and shutdowns, silence the horn, and acknowledge alarms and shutdowns.

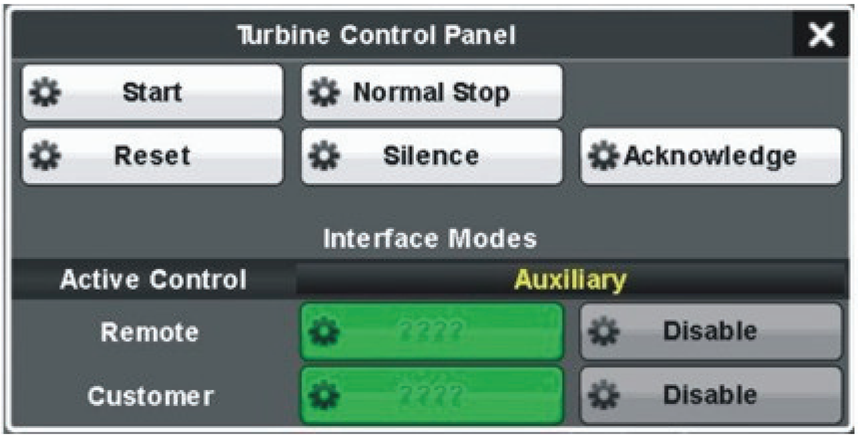


Figure 3.1.7 Onscreen Turbine Control Panel

ALARM BAR

The Alarm Bar, directly below the banner, shows active alarms and shutdowns. To make sure the operator always understands the order in which the alarms and shutdowns happened, the operator cannot change the alarm bar. The oldest unacknowledged shutdown or alarm (if there are no unacknowledged shutdowns) is shown at the far left of the bar. For a single-unit screen, the bar shows a combination of four alarms and shutdowns. When there are no active alarms or shutdowns, the boxes in the bar turn gray.

The alarm/shutdown counter at the far left of the bar shows the current quantity of unacknowledged alarms and shutdowns. Click on the counter to open a summary window that shows all the alarms and shutdowns.

3.1.2 Legend Window

The Legend window, Figure 3.1.8, defines color codes for animated objects such as fans and pumps. Screens that have color based animation will have a legend window.

Figure 3.1.8 Typical Legend Window

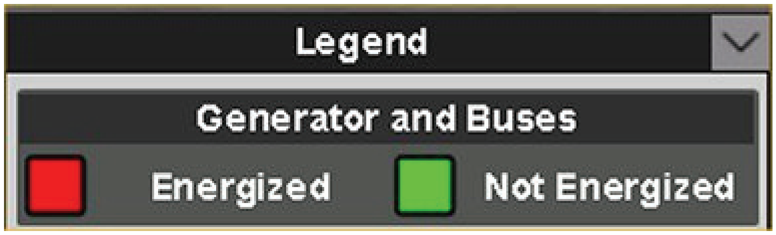


Figure 3.1.8 Typical Legend Window, Contd

3.1.3 Custom Tag Dock Window

The Custom Tag Dock window, Figure 3.1.9, lets you customize the screen that is currently open. You can add up to eight selections that show operation values or status data. Add selections by using the Tag Picker window Figure 3.1.10. Remove selections by using the Custom Tag Dock window.

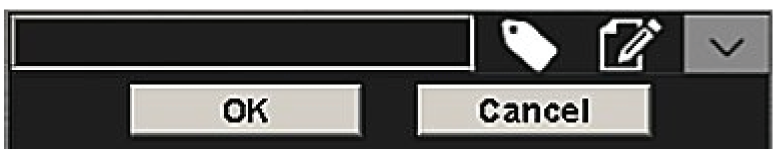


Figure 3.1.9 Custom Tag Dock Window

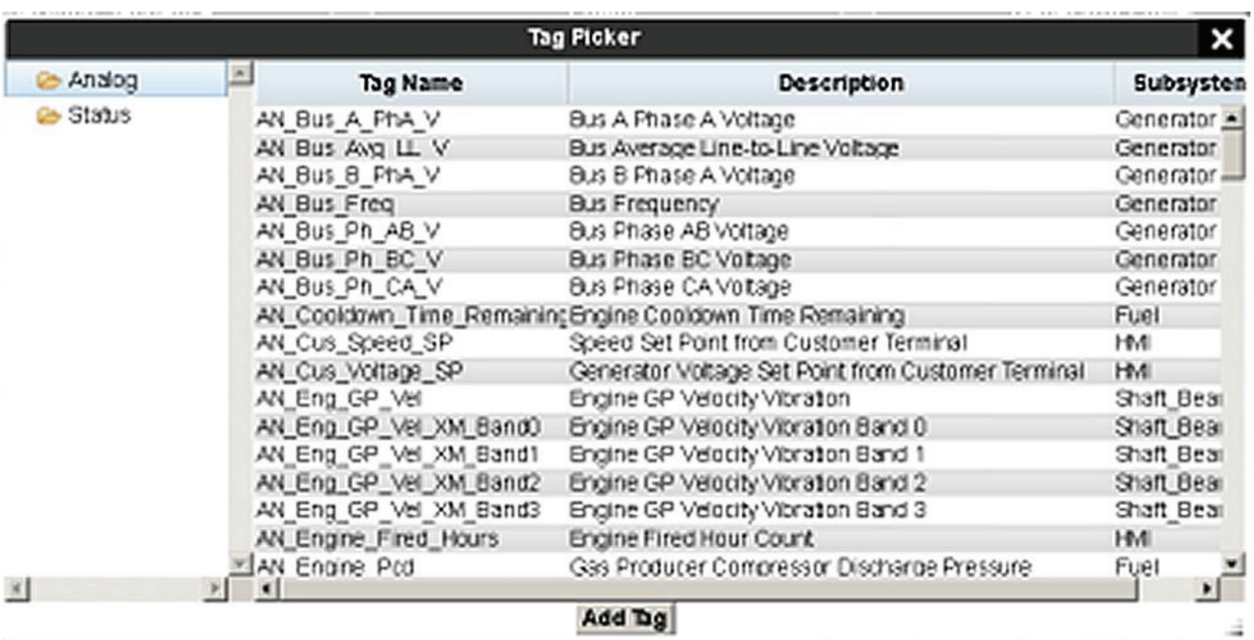


Figure 3.1.10 Tag Picker Window

NOTE

Put the cursor on an icon to show its function.

ADDING TAGS

1. Click the Edit Mode icon to open the Custom Tag Dock window, Figure 3.1.9.
2. On the Custom Tag Dock window, click the Add Tag icon to open the Tag Picker window, Figure 3.1.10.
3. From the Tag Picker window, select the tag you want, and click the Add Tag button. You can add up to eight selections to the Custom Tag Dock window.
4. Click the OK button on the Custom Tag Dock window.
5. You can use the Open Dock or Close Dock icon to maximize or minimize the Custom Tag Dock window .

REMOVING TAGS

1. Click the Edit Mode icon on Custom Tag Dock window, Figure 3.1.9.
2. Click the Remove Tag icon to the right of each unwanted tag.
3. Click OK on the Custom Tag Dock window when finished.
4. You can use the Open Dock or Close Dock icon to maximize or minimize the Custom Tag Dock window .

3.2 OVERVIEW SCREENS

NOTE

Operator selectable buttons may be available on the *Overview Screens* to access additional windows and screens.

3.2.1 Overview Screens

OPERATION SUMMARY SCREEN

The Operation Summary screen, Figure 3.2.1, shows a summary of engine and generator operating values. Data is shown in real time.

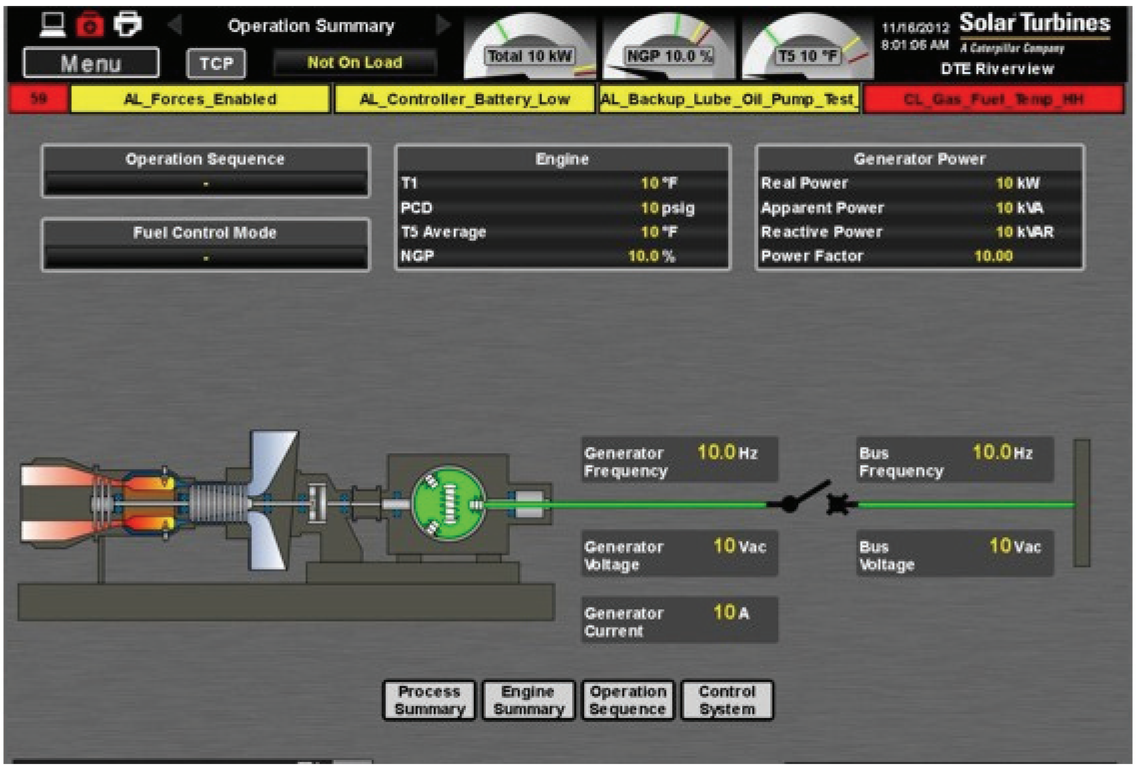


Figure 3.2.1 Operation Summary Screen

PROCESS SUMMARY SCREEN

The Process Summary screen shows a summary of generator power, voltage control modes, and speed/kW control modes. The set points window permits the operator to adjust the setpoints for Speed, Voltage, Real Power, Import Power, Reactive Power, and Power Factor. The set points window also permits the operator to enable or disable speed or voltage setpoint control from an external setpoint source.

Figure 3.2.2 Process Summary Screen

ENGINE SUMMARY SCREEN

The Engine Summary screen, Figure 3.2.3, shows a summary of all monitored engine temperatures, engine operating values, fuel pressure, lube oil temperatures and pressures, status indications, timer status, backup lube oil pump and fuel control operating modes. Data is shown in real time.

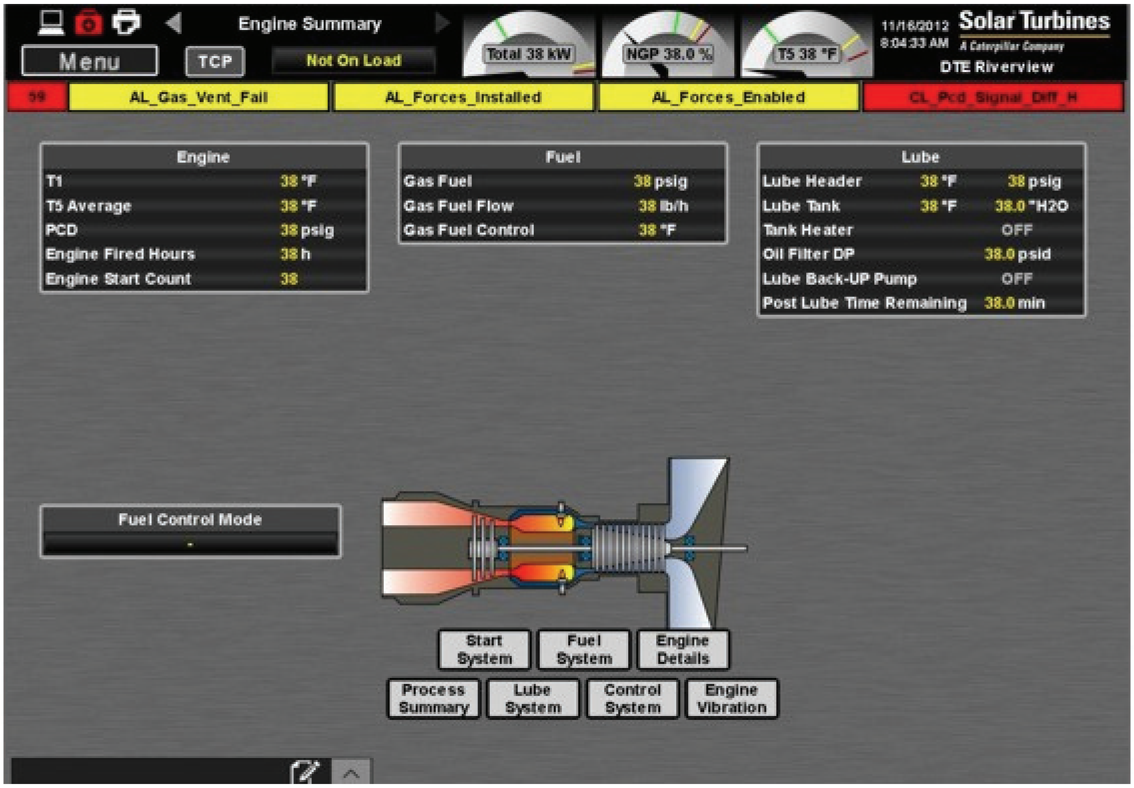


Figure 3.2.3 Engine Summary Screen

3.3 SYSTEM SCREENS

NOTE

The System Screens are the same for the Local and Multi-Unit control panels.

NOTE

Operator selectable buttons may be available on the *System Screens* to access additional windows and screens.

3.3.1 System Screens

OPERATION SEQUENCE SCREEN

The Operation Sequence screen, Figure 3.3.1 shows a summary of start sequence and stop sequence events as they progress. Some start and stop events have additional windows that open and show specific information for that event. Data is shown in real time.

The following start sequence events have onscreen windows that open when the event begins and then close after the event is done:

- Shutdown Not Ready To Start
- Lube Pump Check
- Enclosure Purge
- Gas Valve Check
- Purge Crank
- Ignition
- Acceleration To Load Speed

The following stop sequence events have onscreen windows that open when the event begins and then close after the event is done:

- Stopping
- Cooldown
- Post Lube

Figure 3.3.1 Operation Sequence Screen

GENERATOR SCREEN

The Generator screen, Figure 3.3.2, shows a summary of generator, bus, excitation, and power operating values. Generator winding and bearing temperatures, generator breaker synchronization status, and control modes are also shown. Colors show the status of the Generator and Buses. The Legend window gives the meaning of each color.

Figure 3.3.2 Generator Screen

FUEL SYSTEM SCREEN

The Fuel System screen, Figure 3.3.3, shows fuel pressure, flow, temperature operating values, and actuator percentage. Colors show the status of valves. The Legend window gives the meaning of each color.

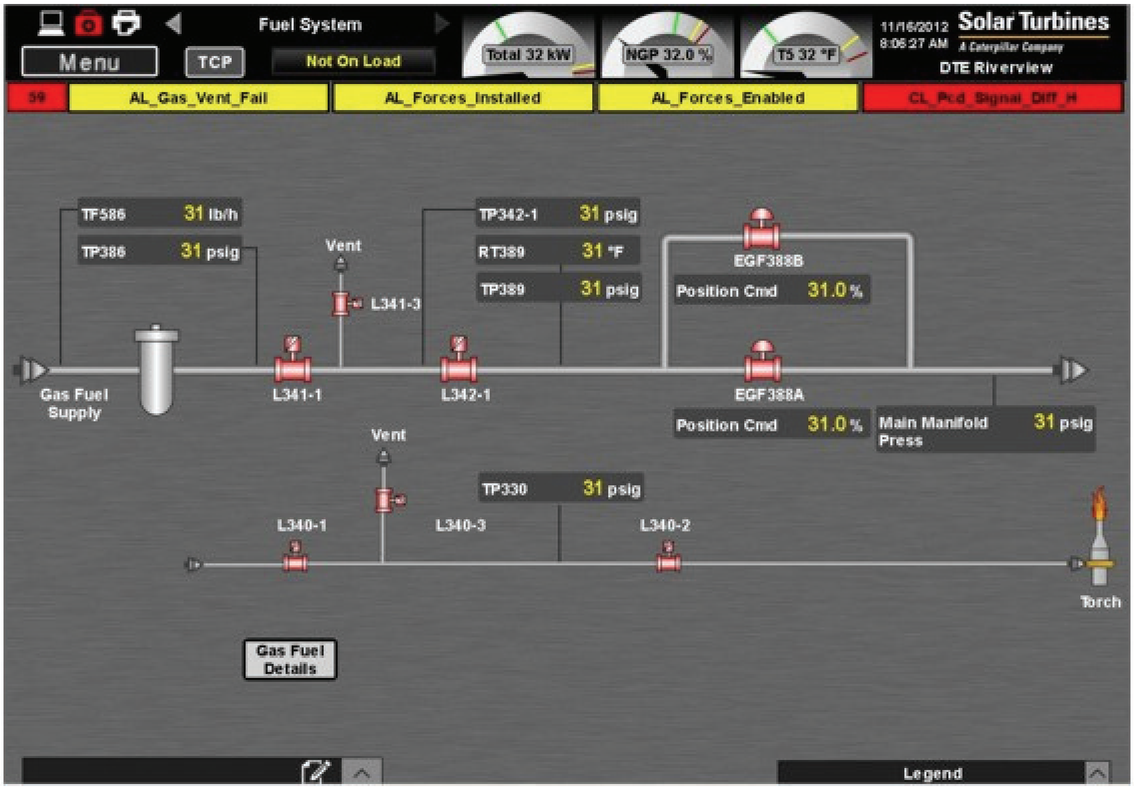


Figure 3.3.3 Fuel System Screen

LUBE SYSTEM SCREEN

The Lube System screen, Figure 3.3.4, shows a line diagram of the lube oil system. The screen provides lube-oil pump operating mode, lube-oil header pressure and temperature, lube-oil filter differential pressure, lube oil cooler fan status, and heater status. Data is presented in real time and is continually updated. Colors show the status of generator, pumps, and fans. The Legend window gives the meaning of each color.

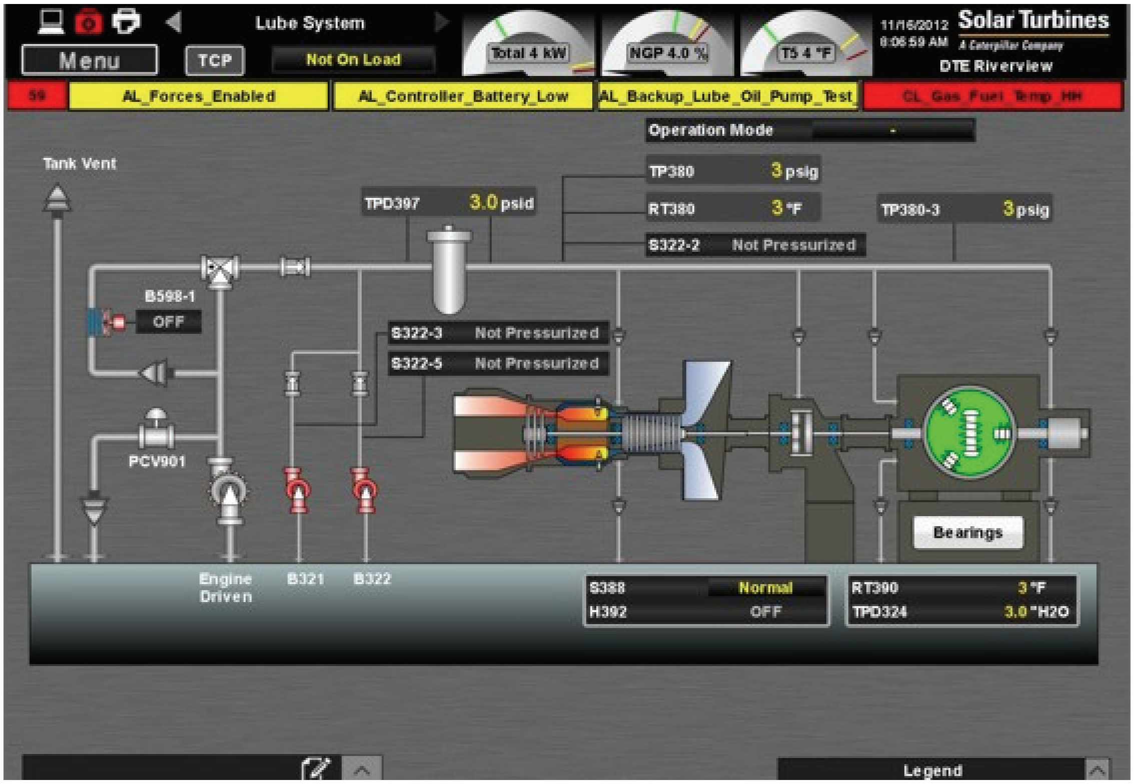


Figure 3.3.4 Lube System Screen

ENGINE VIBRATION SCREEN

CAUTION

Do not operate the unit in an alarm-state for an extended period.

The Engine Vibration screen, Figure 3.3.5, shows a summary of radial vibration amplitudes and proximity probe gap voltages measured at the bearings of the gas-turbine engine. Gap voltage is the negative direct current voltage (Vdc) output signal of the proximity probe. The strength of the signal is proportional to the distance between the probe and the surface of the rotating shaft. The lube oil header operating values are shown.

Gas producer and power turbine bearings radial vibration amplitudes, measured in mils peak-to-peak (mil pp), are shown on three vertical bar graphs.

Vibration readings indicate the mechanical condition of the gas-turbine engine. The yellow line on each bar graph indicates the vibration alarm limit. The red line on each bar graph indicates the vibration shutdown limit. The bar graph shows a green highlight to indicate vibration readings are in the normal range, flashes yellow when the vibration alarm limit has been exceeded, and flashes red when the vibration shutdown limit has been exceeded. For troubleshooting support, or assessing the mechanical condition of the gas-turbine engine, contact the Solar District Service Office.

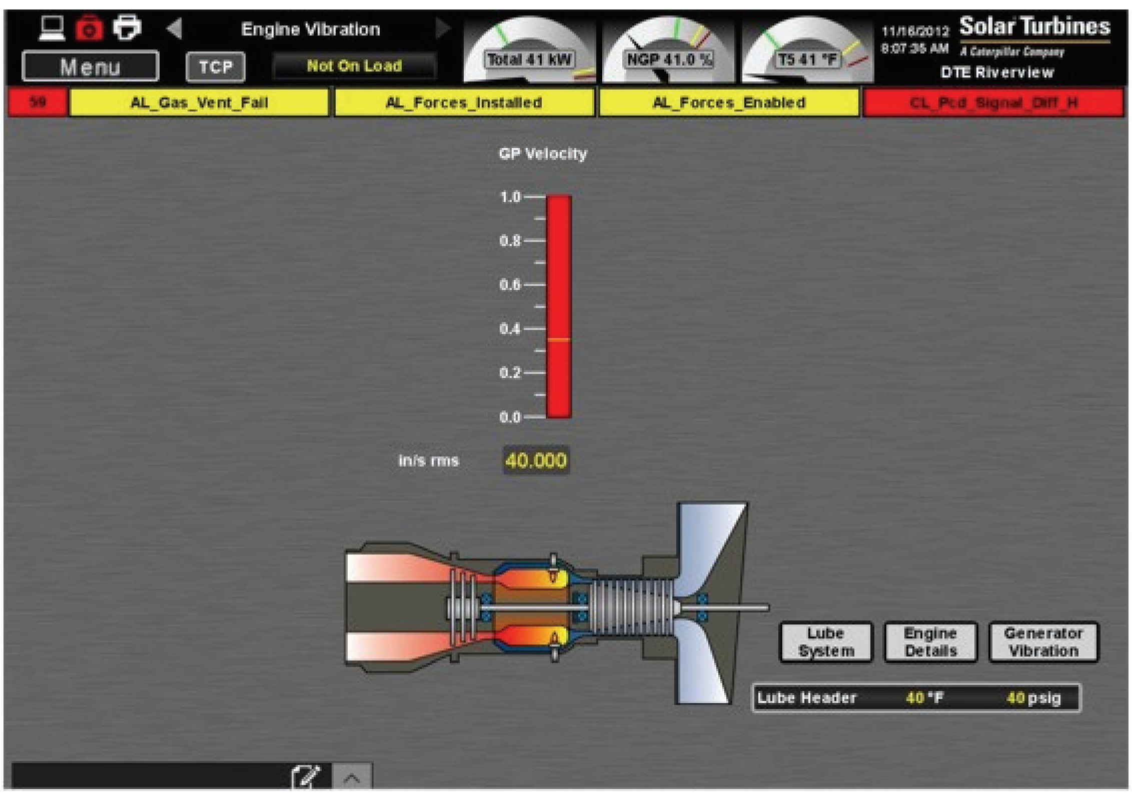


Figure 3.3.5 Engine Vibration Screen

GENERATOR VIBRATION SCREEN

CAUTION

Do not operate the unit in an alarm-state for an extended period.

The Generator Vibration screen, Figure 3.3.6, shows a summary of vibration amplitudes measured at the bearings of the generator, and shows the gearbox acceleration vibration amplitudes measured at a specific location on top of the gearbox.

Generator radial vibration readings, measured in inches per second root mean square (in/s rms), are displayed on two vertical bar graphs. The gearbox acceleration vibration reading, measured in g-force root mean square (g rms), is displayed on a single vertical bar graph.

Vibration readings indicate the mechanical condition of the gearbox and generator. The yellow line on each bar graph indicates the vibration alarm limit. The red line on each bar graph indicates the vibration shutdown limit. The bar graph shows a green highlight to indicate vibration readings are in the normal range, flashes yellow when the vibration alarm limit has been exceeded, and flashes red when the vibration shutdown limit has been exceeded. For troubleshooting support, or assessing the mechanical condition of the gearbox or generator, contact the Solar District Service Office.

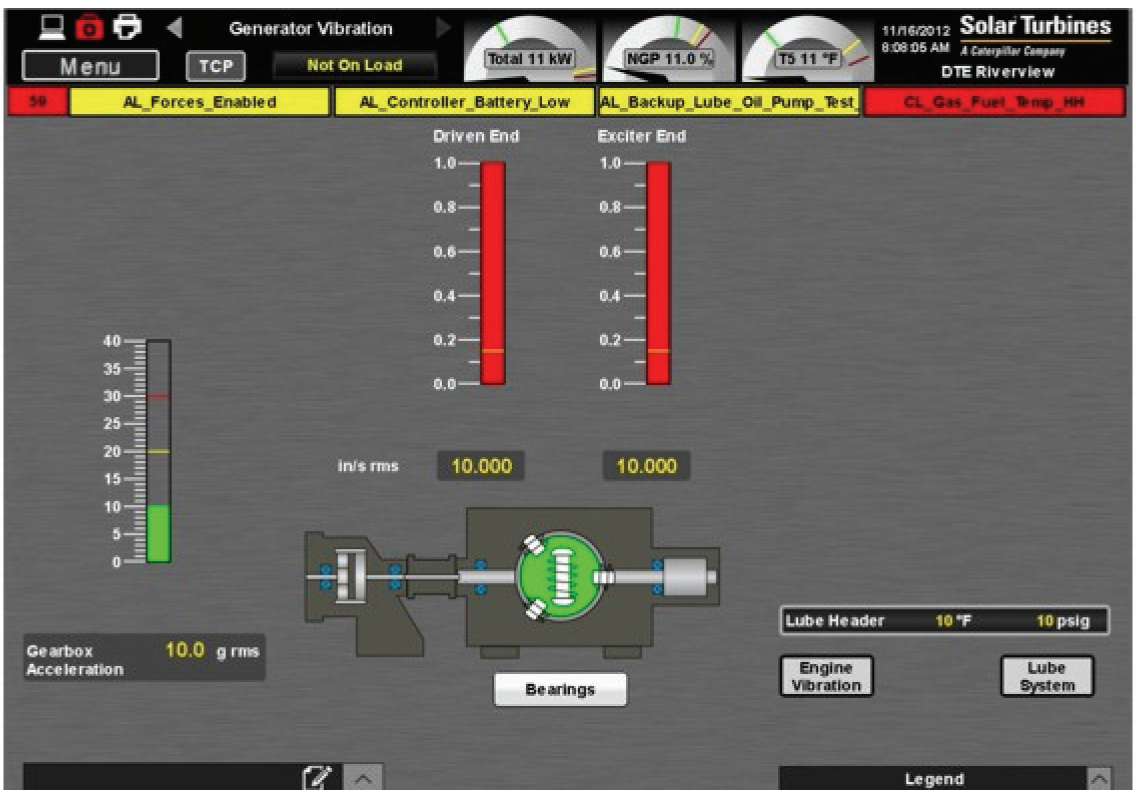


Figure 3.3.6 Generator Vibration Screen

CONTROL SYSTEM SCREEN

The Control System screen, Figure 3.3.7, summarizes the status of all major control loops including set points and generator control modes of operation. Data is presented in real time.

Figure 3.3.7 Control System Screen

START SYSTEM SCREEN

The Start System screen, Figure 3.3.8, gives the operator onscreen buttons to activate a test crank, water wash, and to configure the variable frequency drive (VFD).

NOTE

Variable frequency drive cannot be configured when it is in operation.

Figure 3.3.8 Start System Screen

3.4 DETAIL SCREENS

NOTE

The Detail Screens are the same for the Local and Multi-Unit control panels.

NOTE

Operator selectable buttons may be available on the *Details Screens* to access additional windows and screens.

3.4.1 Detail Screens

ENGINE DETAILS SCREEN

The Engine Details screen, Figure 3.4.1, shows engine information, timers and the amount of time left, actuator operating percentages, engine operating temperatures and the number of active T5 thermocouples, pressures for turbine air inlet, gas producer compressor discharge pressure, and gas producer compressor discharge pressure number 1 and 2.

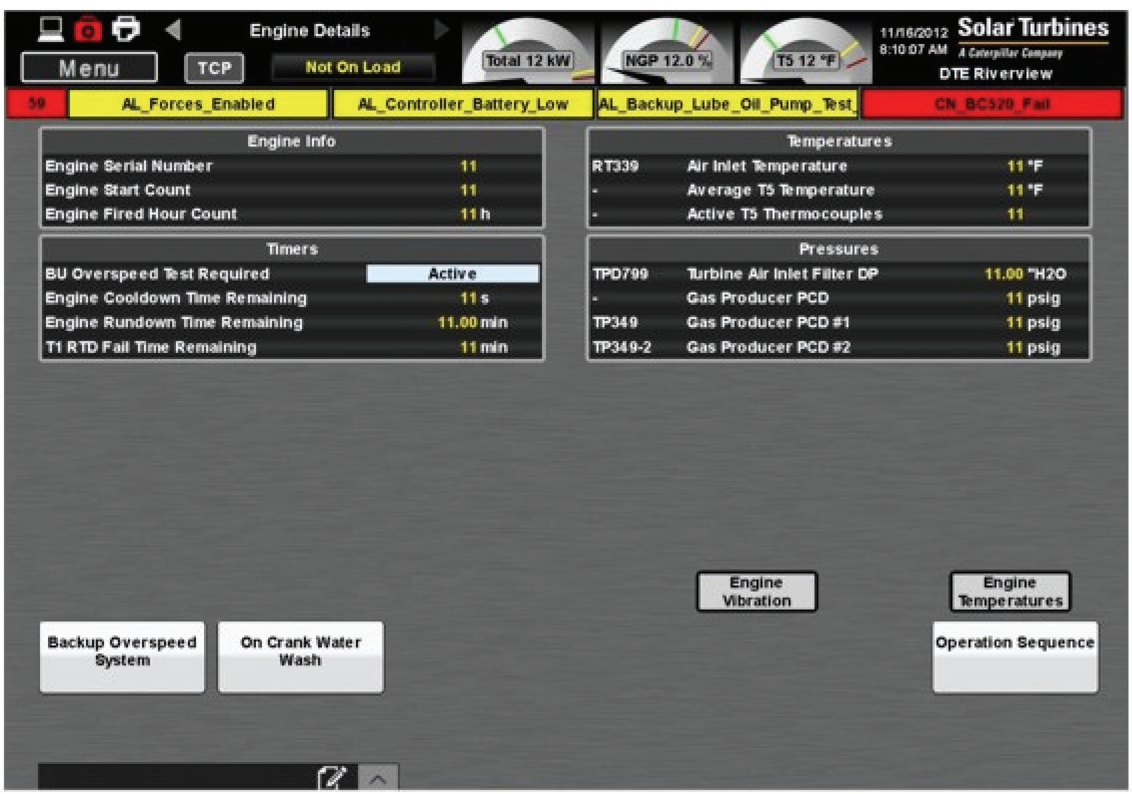


Figure 3.4.1 Engine Details Screen

ENGINE TEMPERATURES SCREEN

The Engine Temperature screen, Figure 3.4.2, shows temperature readings for engine thermocouples, T5 average, T5 Radial Plot Figure 3.4.3, T5 Bar Plot Figure 3.4.4, T5 Delta Bar Plot Figure 3.4.5, and number of active T5 thermocouples. Data is shown in real time.

NOTE

Inactive thermocouples are excluded from the temperature average calculation.

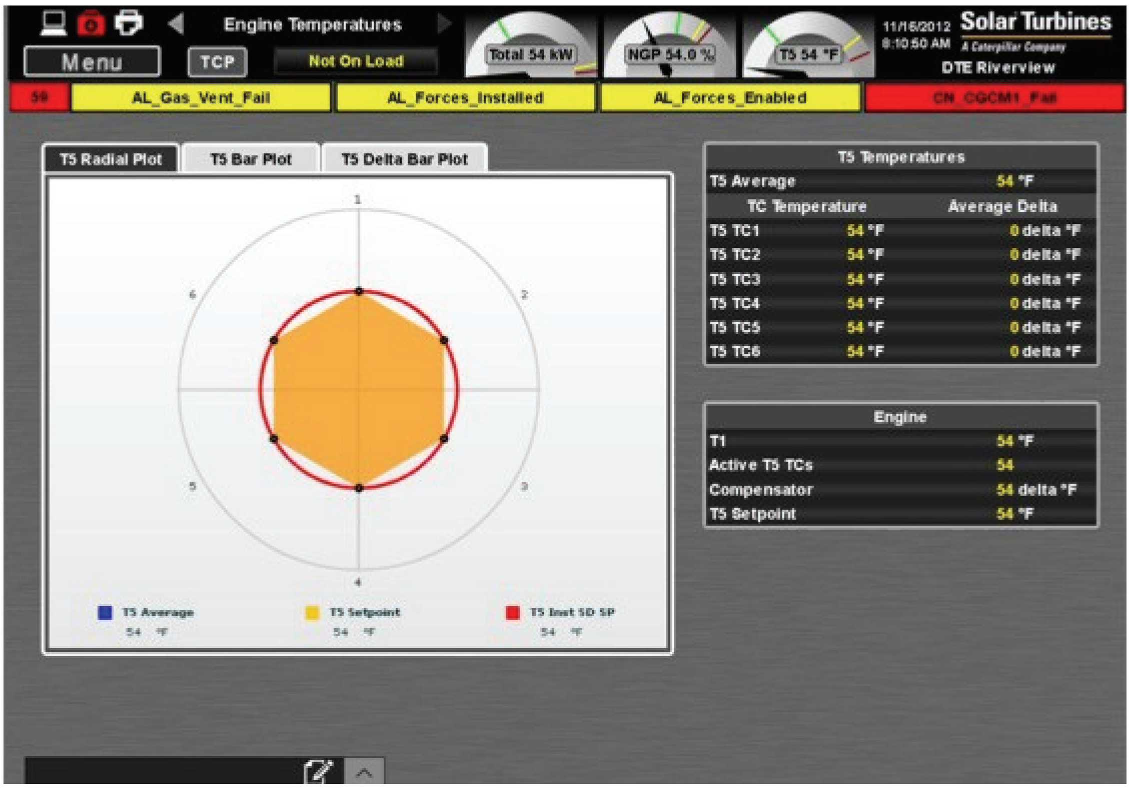


Figure 3.4.2 Engine Temperatures Screen

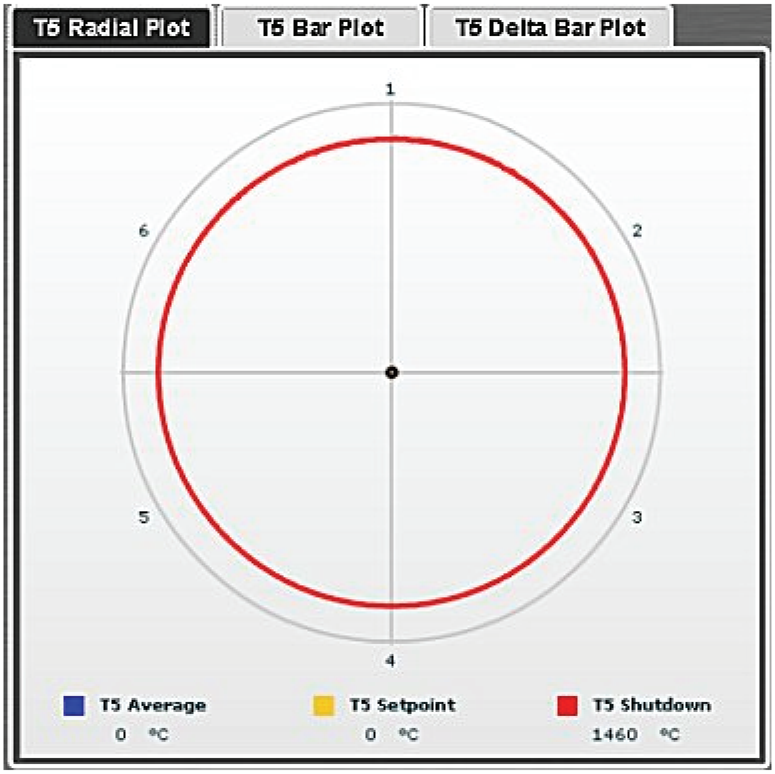


Figure 3.4.3 T5 Radial Plot Window

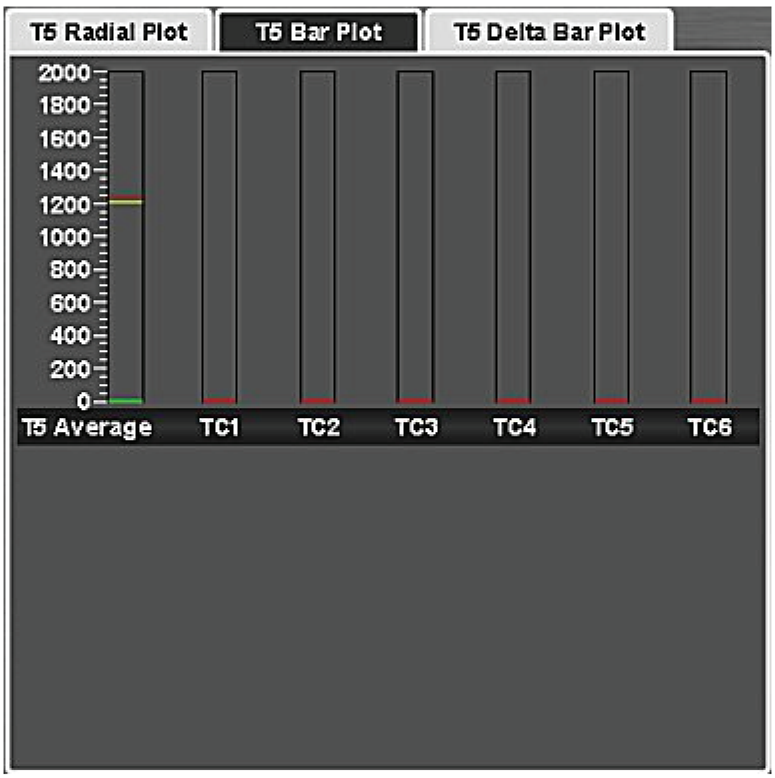


Figure 3.4.4 T5 Bar Plot Window

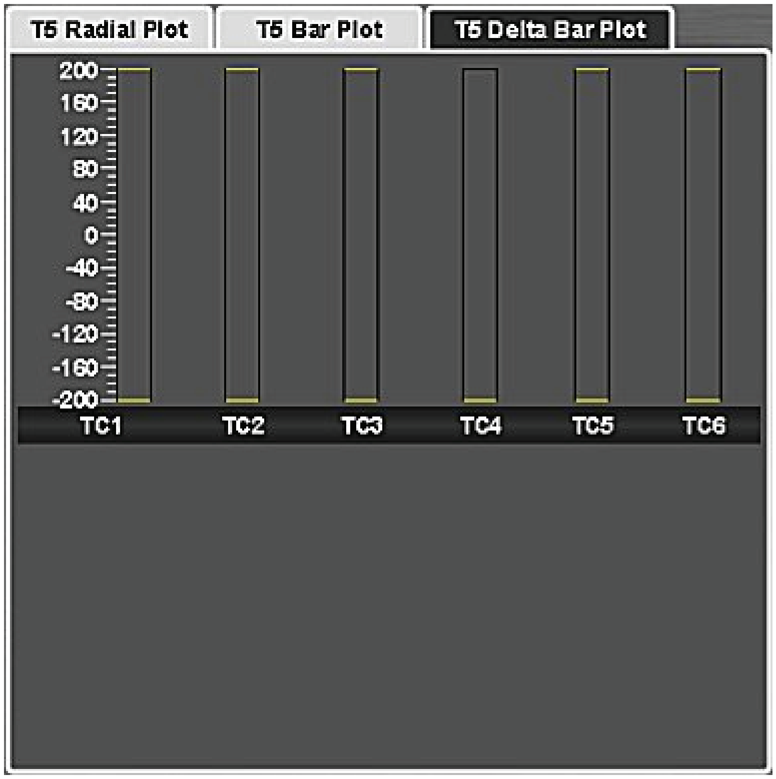


Figure 3.4.5 T5 Delta Bar Plot Window

GAS FUEL DETAILS SCREEN

The Gas Fuel Details screen, Figure 3.4.6, shows fuel pressures, operating values, actuator status, and engine operating values.

Figure 3.4.6 Gas Fuel Details Screen

LUBE DETAILS SCREEN

The Lube Details screen, Figure 3.4.7, shows lube oil system temperatures, pressures, status indications, timer status, pump and cooler operating modes. A backup lube oil pump check can be initiated from this screen.

Figure 3.4.7 Lube Details Screen

3.5 TOOLS SCREENS

NOTE

The Tools Screens are the same for the Local and Multi-Unit control panels.

NOTE

Operator selectable buttons may be available on the *Tools Screens* to access additional windows and screens.

3.5.1 Tools Screens

MAINTENANCE SCREEN

The Maintenance screen, Figure 3.5.1, provides the operator with onscreen buttons for operation options, to perform routine maintenance, and to access turbine system configuration.

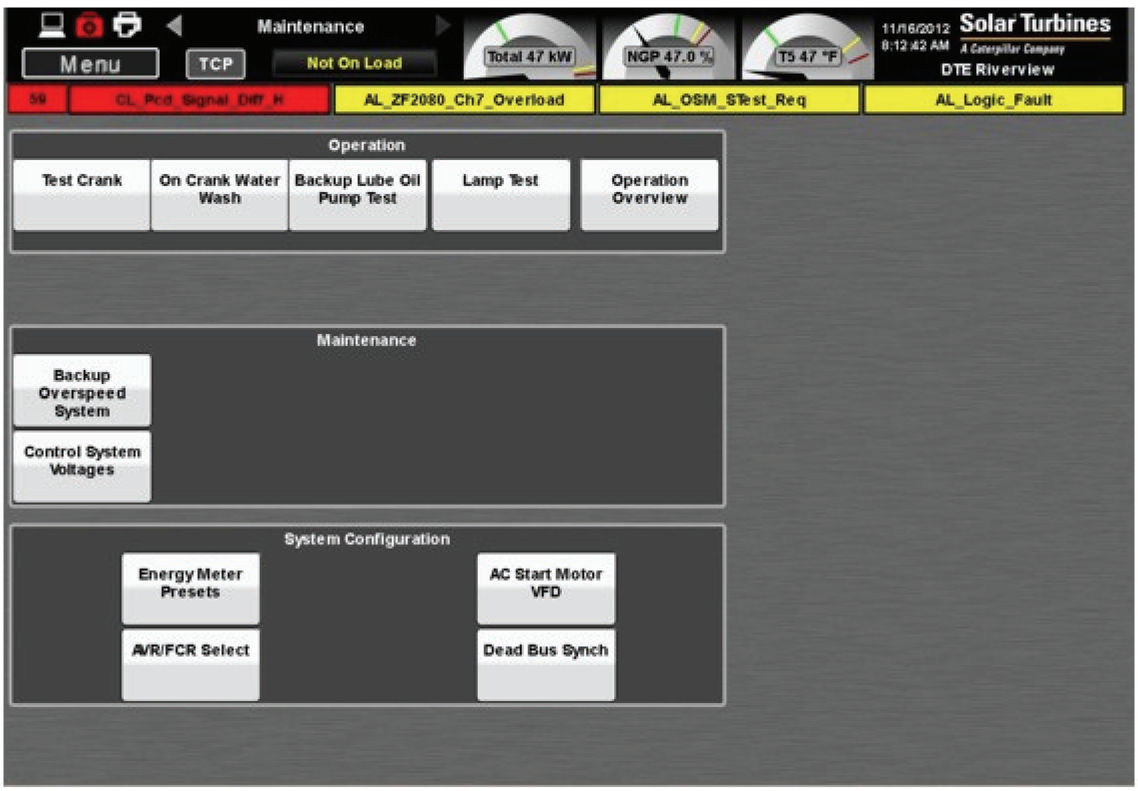


Figure 3.5.1 Maintenance Screen

ALARM LOG SCREEN

The Alarm Log screen, Figure 3.5.2, is selected from the Menu screen by touching the onscreen Alarm Log button. The Alarm Log screen shows a log of alarm and shutdowns in the order detected by the controller. The alarms and shutdowns are listed in chronological order with the most recent alarm or shutdown at the top. Each alarm and shutdown appears, with a brief description, along with the date and time the alarm or shutdown occurred. This screen is helpful for troubleshooting and should be used as a supplement to the Alarm Summary screens. If more alarms have been logged than can fit on one page, touch the scroll bar to the right of the list of alarms and shutdowns.

When new alarms are generated, the first place they should be viewed is from the Alarm Summary screen. The Alarm Summary screen lists alarms in the order received by the HMI, and includes a time/date stamp of when the display recorded the alarm.

To update the current list, select another screen and then reselect the Alarm Log screen.

Alarms and shutdowns that are inactive appear in gray. Unacknowledged alarms and shutdowns appear with black lettering on a colored background. Acknowledged alarms and shutdowns appear with colored lettering on a black background.

If more events have occurred than can be seen on one page, the additional events can be viewed by pressing the PAGE UP/PAGE DOWN keys on the keypad or using the cursor to move the scroll bar at the right of the screen.

NOTE

1. Double-clicking the column heading will sort the column alphabetically. To sort in reverse alphabetical order, double-click the column heading a second time.

2. While opened, the ALARM LOG screen is not updated to reflect new events. To view the most current list of discrete events, select another screen and then reselect the ALARM LOG screen, or press the Retrieve button.

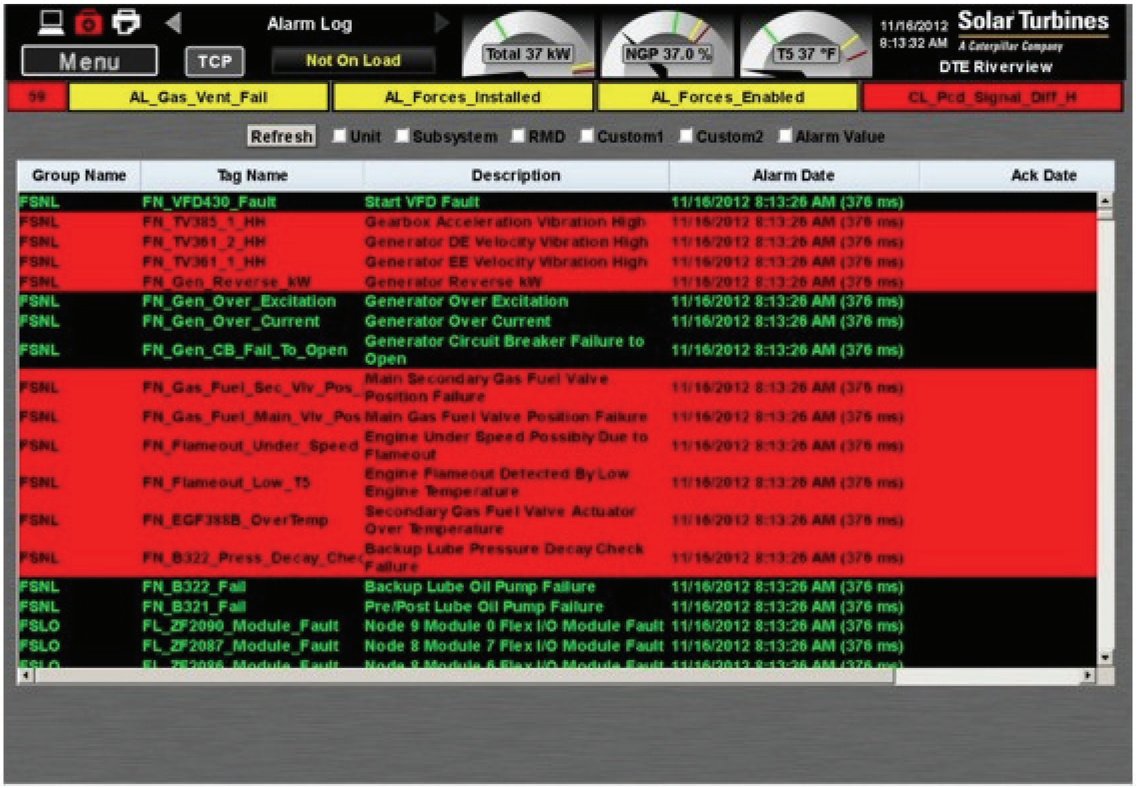


Figure 3.5.2 Alarm Log Screen

EVENT LOG SCREEN

The Event Log screen, Figure 3.5.3, is selected from the Menu screen by touching the onscreen Event Log button. The Event Log screen shows data captured whenever a discrete parameter changes state or an alarm or shutdown occurs. For example, a pump turns on, a valve closes, or an alarm limit has been reached. This screen is useful for troubleshooting and should be used as a supplement to the Alarm Summary and Alarm Log screens.

When new alarms are generated, the first place they should be viewed is from the Alarm Summary screen. The Alarm Summary screen lists alarms in the order received by the HMI, and includes a time/date stamp of when the HMI recorded the alarm.

Events are listed in chronological order with the most recent event appearing at the top. Each event appears with a brief description and the date and time the event occurred. Active status events appear with green or white text on a black background. Inactive status events will appear with black text on a white or green background. Alarms are yellow in color, and shutdowns are red. Inactive alarms and shutdowns are gray in color. Unacknowledged alarms and shutdowns appear with black lettering on a colored background. Acknowledged alarms and shutdowns appear with colored lettering on a black background. Acknowledged alarms and shutdowns remain on the screen until reset.

If more events have occurred than can be seen on one page, the additional events can be viewed by pressing the PAGE UP/PAGE DOWN keys on the keypad or using the cursor to move the scroll bar at the right of the screen.

NOTE

1. Double-clicking the column heading will sort the column alphabetically. To sort in reverse alphabetical order, double-click the column heading a second time.

2. While opened, the EVENT LOG screen is not updated to reflect new events. To view the most current list of discrete events, select another screen and then reselect the EVENT LOG screen, or press the Retrieve button.

Figure 3.5.3 Event Log Screen

CONSTANTS SCREEN

The Constants screen, Figure 3.5.4, lists the first 250 control system programming constants. This screen lets the operator change the first 250 control system programming constant values.

Use the following procedure to select and change programming constant values.

1. Put the cursor on the desired programming constant and double click the left mouse key to select it. To select a parameter not shown on the list, use the PAGE UP/PAGE DOWN keys on the numeric/control keypad or use the cursor to move the scroll bar at the right of the screen.

2. When a parameter is selected, the Set Value window, Figure 3.5.5, will appear. The Set Value window requires a user name and password to be entered before a constant value can be changed.

3. Enter new programming constant value within displayed allowable range. The program will reject values outside the range

4. In Remote mode, the operator can only look at Constants screen.

⚠ WARNING

The ranges displayed for programming constants cover all possible operating conditions. Just because a value is within the range displayed, does not necessarily make it a safe value for all operating conditions. In other words, just because it can be changed to a particular value does not mean that it should be changed. Injury to personnel or damage to equipment could occur if any value is changed improperly.

NOTE

Double-clicking the column heading will sort the column alphabetically. To sort in reverse alphabetical order, double-click the column heading a second time.

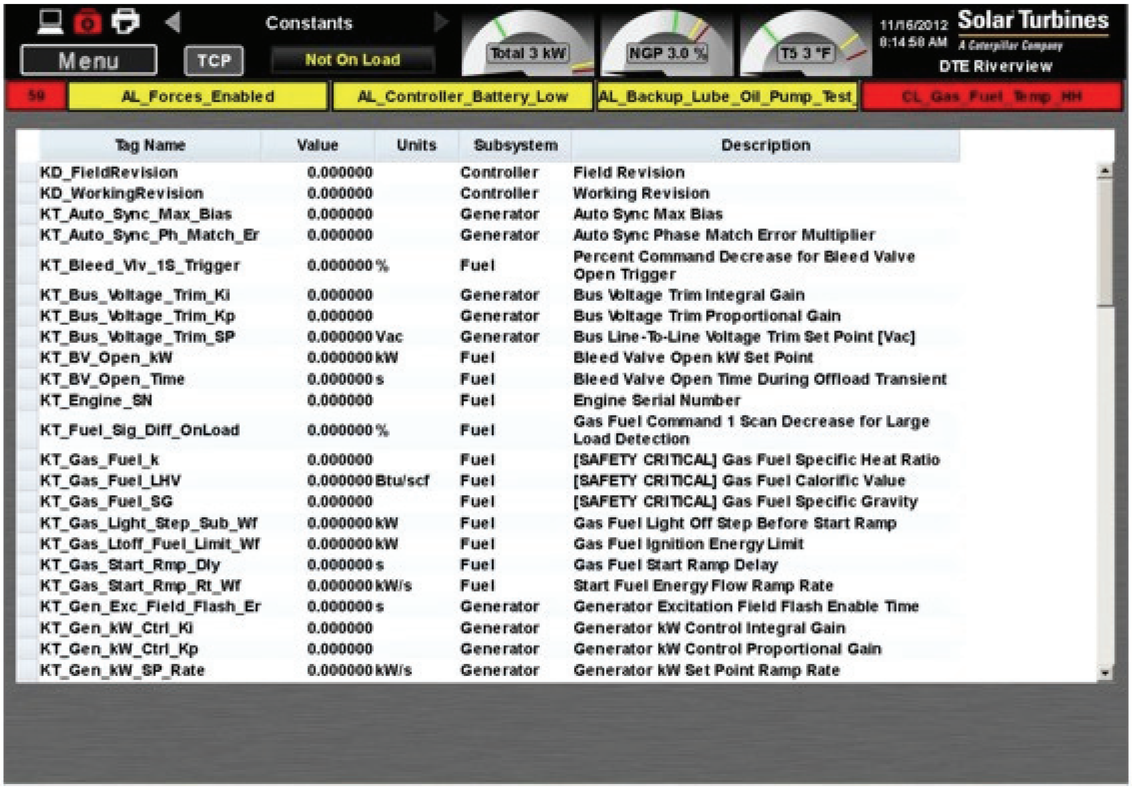


Figure 3.5.4 Constants Screen

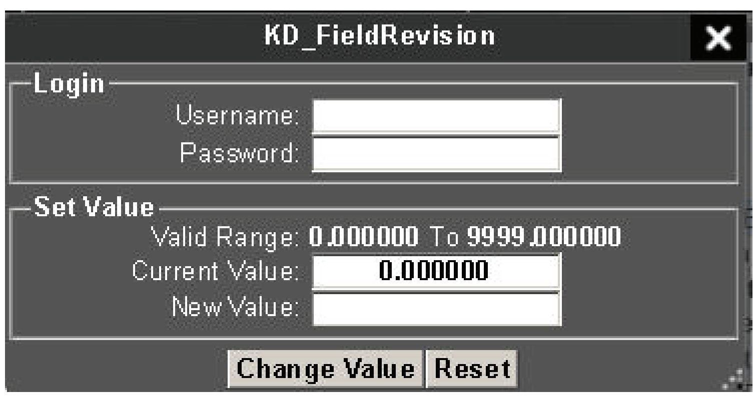


Figure 3.5.5 Set Value Window

STRIP CHART SCREEN

The Strip Chart screen, Figure 3.5.6, shows an emulation of a strip-chart recorder with a number of pens that can be configured, to monitor analog variables. Pens are lines and/or symbols used to represent values. The values can be monitored tags or constant values. Pens can be different colors with different weights and symbols to help easily distinguish between multiple pens.

The strip chart shows raw, real time data. To change the scale on the strip chart to match the desired variable (Npt, Ngp, and T5 Avg for example), touch the variable in the legend below the chart. The legends located at the bottom of the screen continually shows the pens or tags used and their values.

Time Range is located below the plot area.

Legend, located at the bottom of the screen, is a display of the selected pen(s) and their values.

Y-Axis Scale, located at the right of the plot area, is the pen minimum and maximum range values selected in the legend.

Vertical (Y-Axis) Zoom In and Zoom Out scroll bars are located at the bottom and right side of the screen.

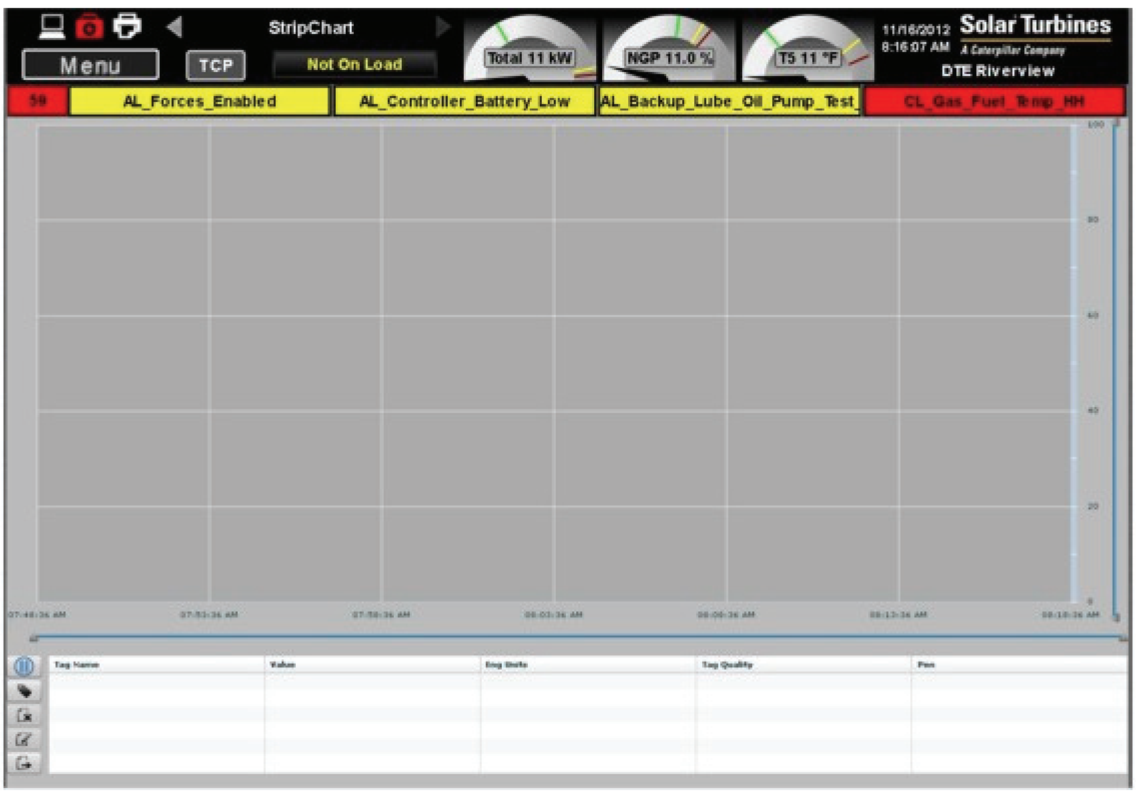


Figure 3.5.6 Strip Chart Screen

Figure 3.5.7 Strip Chart Icons

Strip Chart Options

Other Strip Chart screen options can be accessed from the Tag Picker window, Figure 3.5.8. To open the Tag Picker window, double click the left mouse button in the Strip Chart screen plot area.

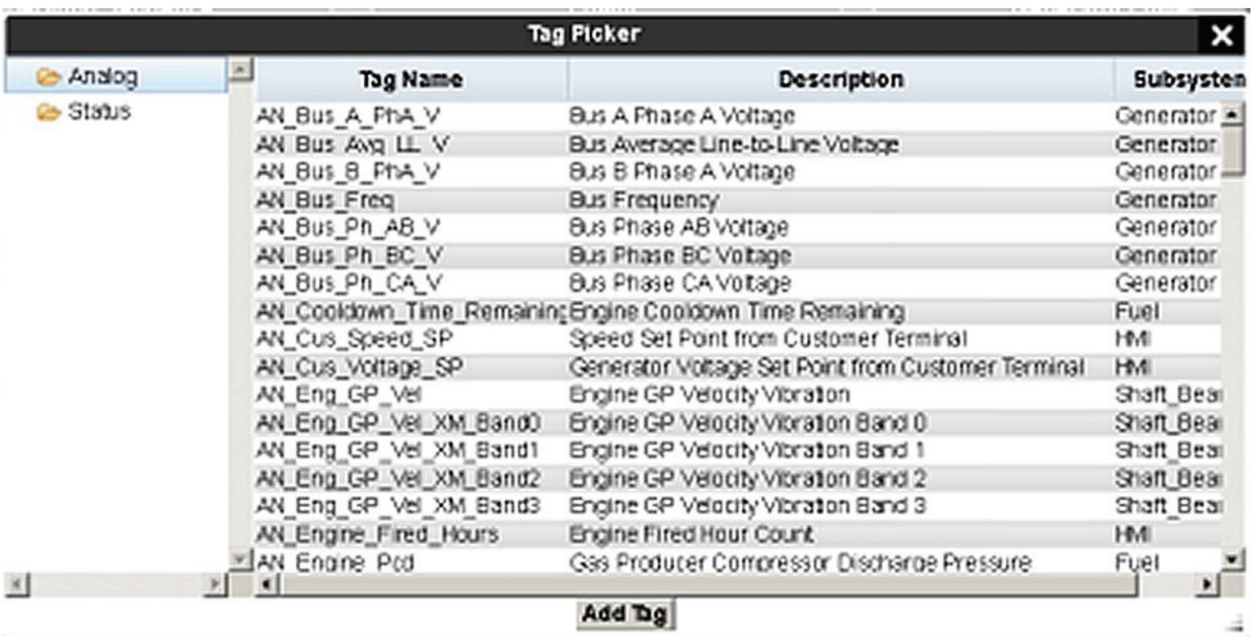


Figure 3.5.8 Tag Picker Window

- **Add Tag** - enters the selected tag into the strip chart.
- **Remove Tag** - removes the selected tag from the strip chart
- **Edit Pen** - opens Edit Pen window, Figure 3.5.9.

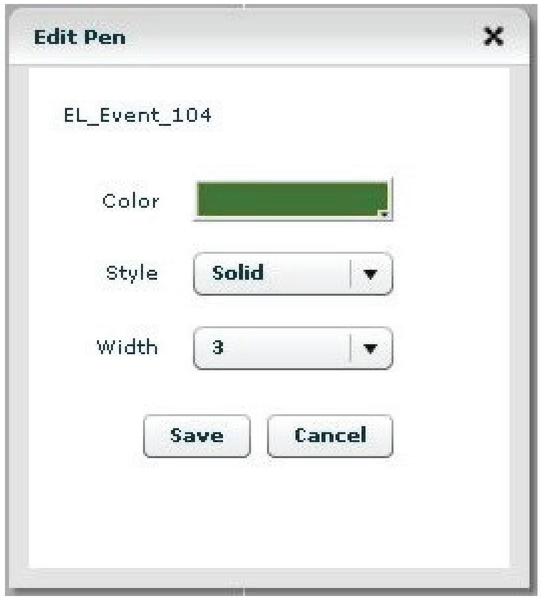


Figure 3.5.9 Edit Pen Window

- **Generate CSV List** - creates a historical log file, Figure 3.5.10.

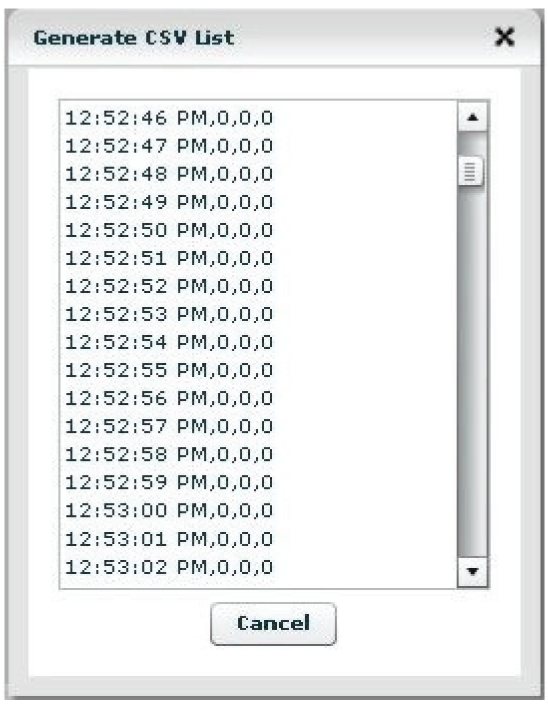


Figure 3.5.10 Generate CSV List Window

Add or Update Tag

1. Double click on the plot area of the strip chart screen, the Tag Picker window, Figure 3.5.8, will open.
2. From the Tag Picker window, double-click required Tag name or click Add Tag button.

3. Click the added tag to highlight. While tag is highlighted click the Edit Pen icon.

4. On the Edit Pen window select required Color, Style, and Width.

Remove Tag

From the plot area of the strip chart screen, click Tag name to be removed, then click the Remove Tag icon, refer to Figure 3.5.7. The selected tag will be removed from the strip chart.

HISTORICAL LOG SCREEN

The TT4000 Historical Log Screen, Figure 3.5.11, permits users to review historical data collected by the computer. The historical data are listed in chronological order with the most recent log at the top. Each historical log appears, with a brief description, along with the date and time the log occurred.

NOTE
Operator can download selected files and view.

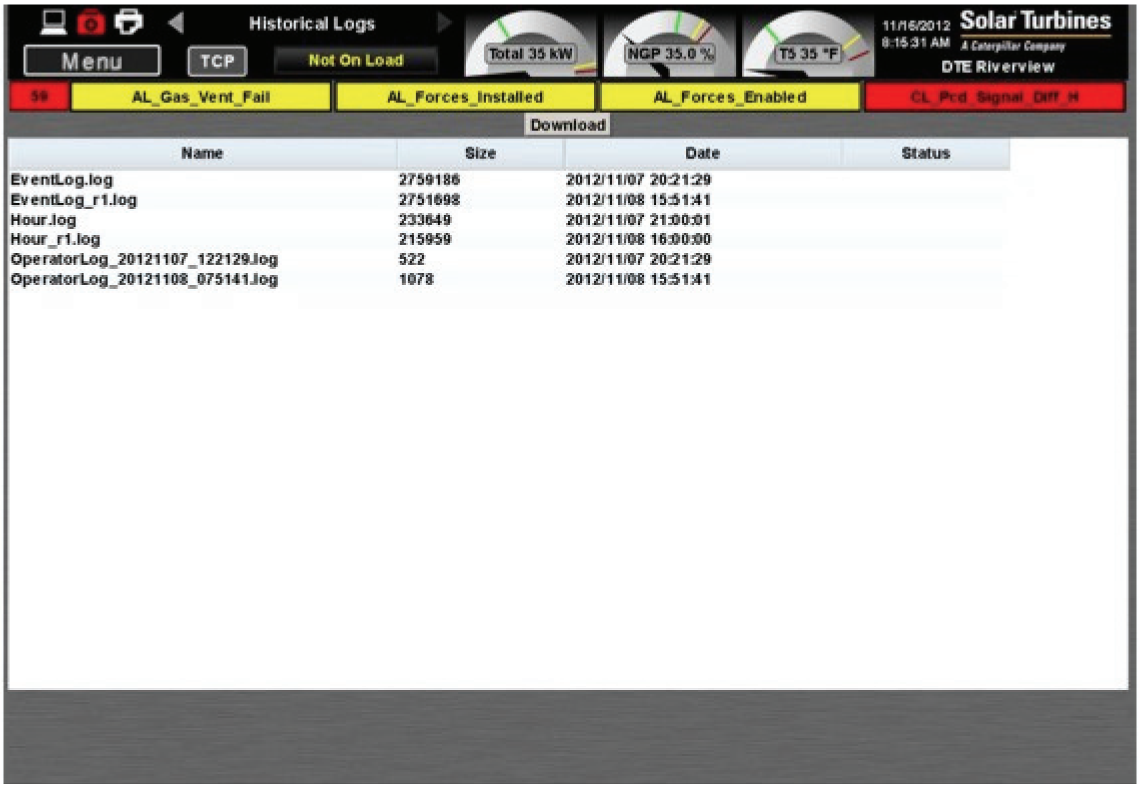


Figure 3.5.11 Historical Log Screen

3.6 CUSTOM SCREEN BUILDER (OPTIONAL)

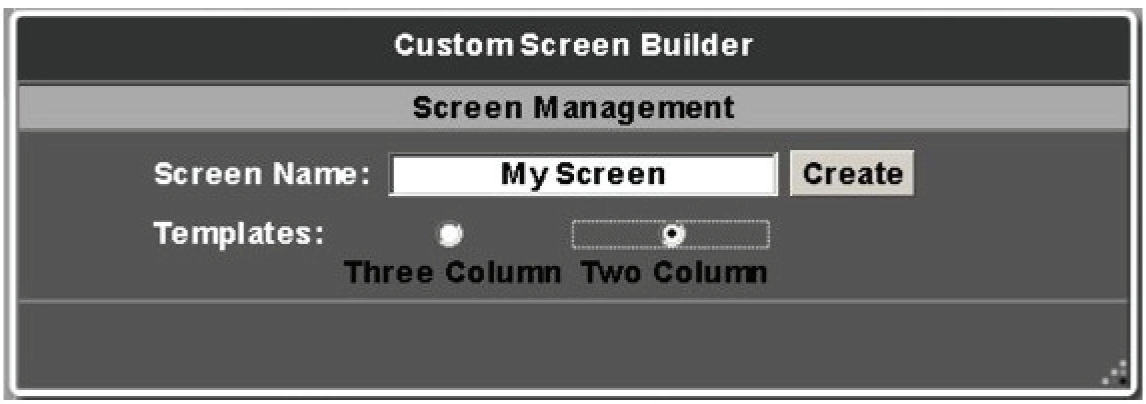
NOTE

The Custom Screen Builder process is the same for both the Generator and Compressor set.

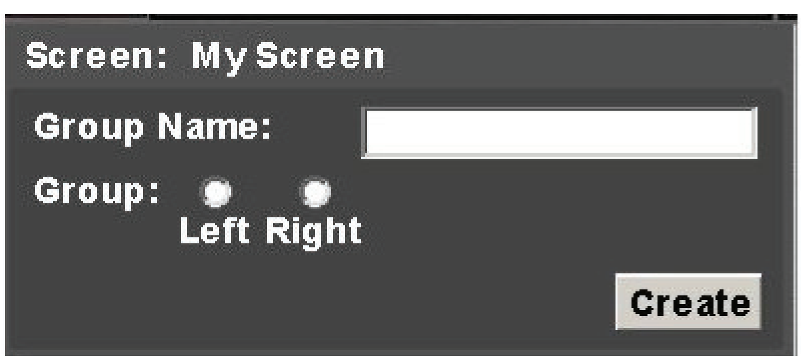
The Custom Screen Builder is provided for users to create custom screens at run-time without having to exit production mode. Different templates are provided based on existing screen layouts. Once a template is selected, the user can add or remove groups through the group options provided. The user can populate each group by selecting tags and dragging them onto the designated group.

To build a custom screen, follow these steps:

1. Click the Menu button at the top of the header.
2. Select Custom Screen Builder from the menu.
3. The Custom Screen Builder, screen management window will be shown.



4. Type a name for the custom screen in the Screen Name window and select one of the available templates.
5. Click the Create button.
6. In the Group section type in a group name and choose the required layout position for that group.



7. Click the Create button to create the Group block.

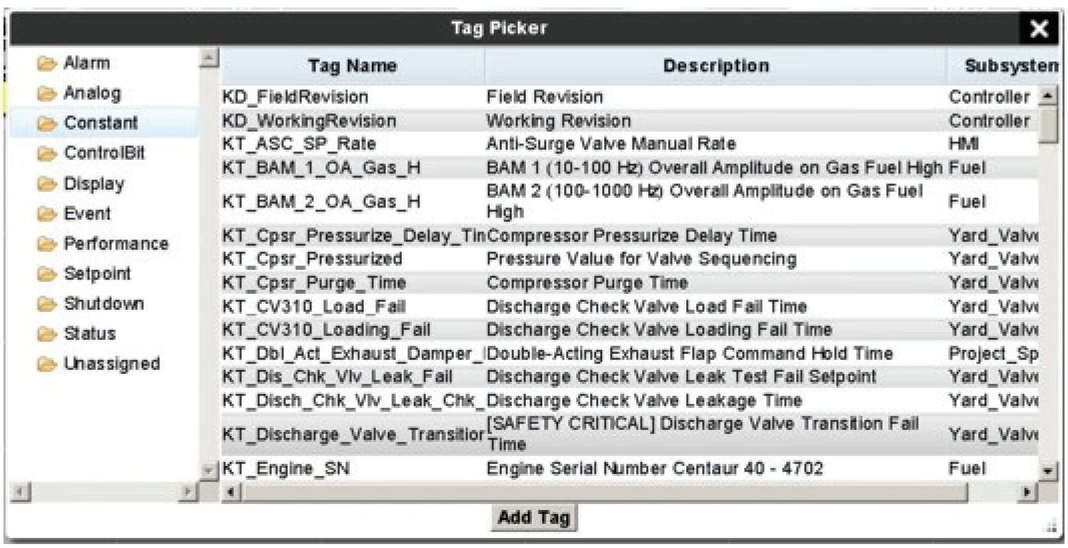
NOTE

Based on your choice of a 2 or 3 column template, add groups as required.

8. The group name will appear as a column heading at the top segment of the empty screen area.

9. Click the **Available Tags** icon.

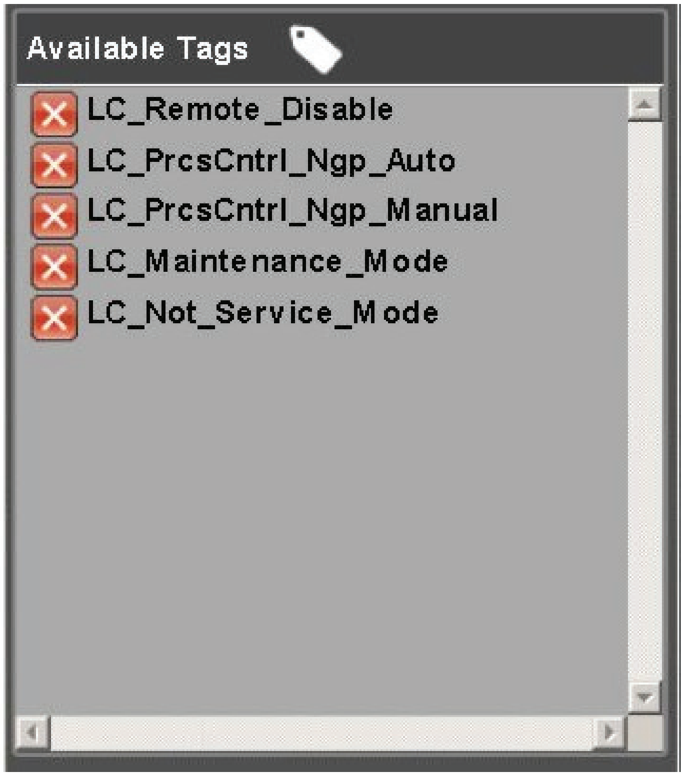
- The **Tag Picker** screen will appear.



NOTE

All tags associated with the Package are displayed. They can be seen by scrolling up and down.

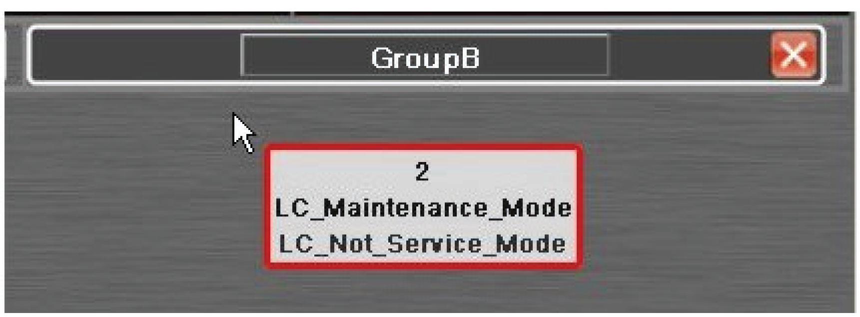
- Double click mouse button and the tag will appear in the **Available Tags** area.



NOTE

You can also single-click the tag and then click the **Add Tag** icon. The tag will appear in the **Available Tags** area.

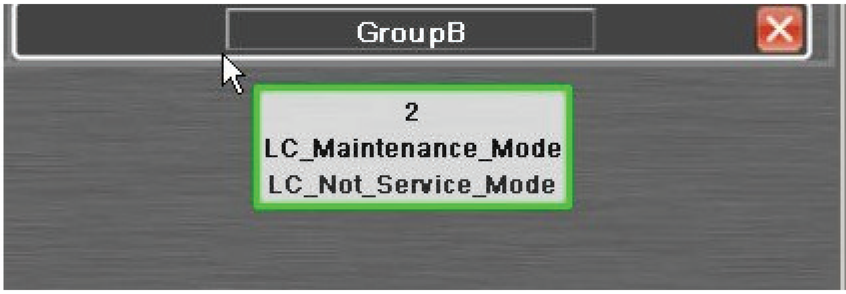
- From the **Available Tags** area, click the required tag and hold down the left mouse button to drag it to the group name.



NOTE

The tag will be contained in a red bordered box.

- Release the left mouse button to drop the tag when the red border changes to green.

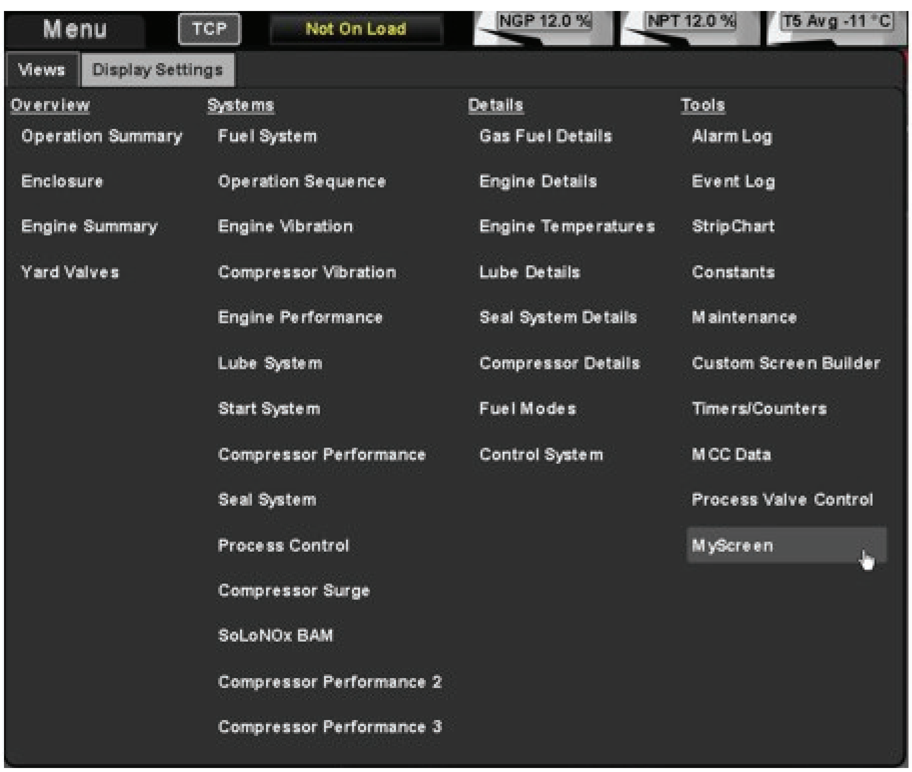


NOTE

To close the **Tag Picker** window, click the “X” at its top right corner.

10. When all required tags have been dragged into the selected group, click the **Build** button and then click the **Save** button. "Custom Screen Saved!" will appear below the save button.

11. When completed, click on the Menu tab to see the newly listed Custom Screen. Click on the screen name to open.

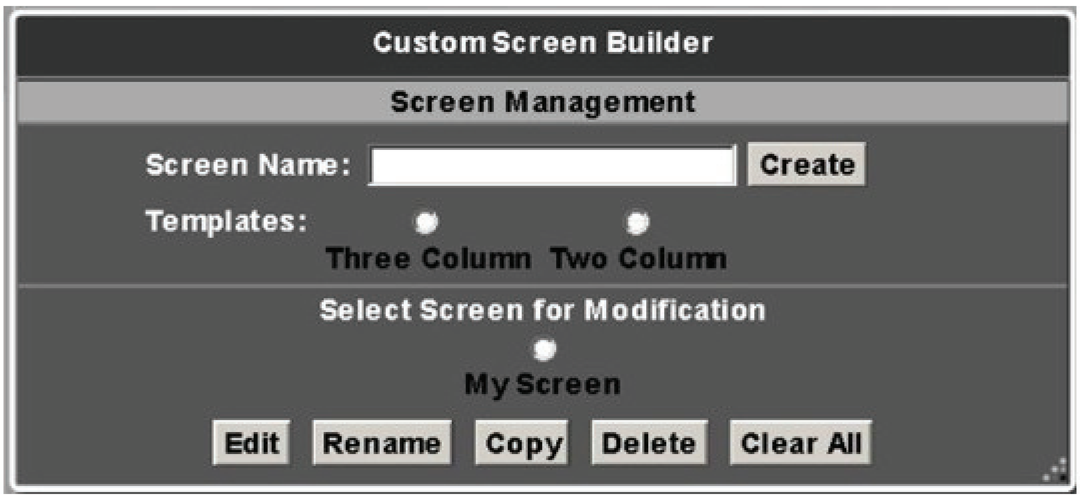


NOTE

Up to eighteen custom screens can be created. More than eighteen is not permitted.

To edit or delete an existing custom screen, follow these steps:

1. Click the Menu button at the top of the header.
2. Select Custom Screen Builder from the menu.
3. The Custom Screen Builder, screen management window will be shown.
4. Under Select Screen for Modification, click the radio button for the screen you want to modify.



NOTE

The following options are available

- Edit- Takes the user back to the screen builder area.
- Rename - Opens a window to allow the user change the existing screen name.
- Copy - Will make a copy of the selected screen and opens a window to allow the user to name the new screen.
- Delete - Will delete the selected screen.
- Clear All - Will delete all custom screens.

(This page intentionally left blank)

4 OPERATING INSTRUCTIONS

4.1 GENERAL

This chapter provides operating instructions for the gas-turbine engine and driven equipment. The following sections are arranged to provide the best methods for startup and shutdown. Instructions are to be performed in the order given, and all safety WARNINGS, CAUTIONS, and NOTES must be observed. Sections provided within this chapter include:

- Engine operation using unit control panel
- Engine operation using remote control panel
- Functional description of generator control modes
- Generator control mode selection
- Generator control setpoint adjustment
- Generator synchronization
- Manual trip of generator circuit breaker

4.2 ENGINE OPERATION USING UNIT CONTROL PANEL

WARNING

Operate the gas-turbine engine and driven equipment only when it is safe. Unsafe conditions include: fuel leaks, process gas leaks, oil leaks in hot areas, frayed or skinned electrical wiring, or loose or cracked anchor bolt nuts or structural members.

Explosive accumulations of natural gas, fuel fumes, oil tank vent leakage, or solvent fumes must be avoided at all times. This is done by proper ventilation, elimination of leaks, and confining the use of solvents within appropriate maintenance facilities.

Only qualified personnel may operate the gas-turbine engine and driven equipment. The operator must understand gas-turbine engine and driven equipment operation, function, and systems and controls, indicators, and operating limits.

Hearing and eye protection must be used by personnel in the vicinity of operating turbomachinery.

Gas-turbine engine and driven equipment operation is inherently safe and reliable. The control system protects against damaging malfunctions. Refer to the Safety Requirements in the front of this manual and observe the following to ensure proper operation.

- Operate, service, and maintain gas-turbine engine and driven equipment as described in this manual set.
- Understand gas-turbine engine and driven equipment operations, functions, and systems.
- Understand controls, indicators, indications, and operating limits.
- Rely on the instruments provided. Record and compare readings to detect developing problems.
- Learn the significance of possible malfunctions before operating the gas-turbine engine and driven equipment. Be prepared to take appropriate actions in the event of any malfunction.
- Contact Solar Turbines Customer Services for assistance in resolving unique or persistent problems.

4.2.1 Unit Control Panel Activation

Perform the following procedures to activate the unit control panel.

NOTE

In the following procedure display screen indications shown in brackets [ ].

1. At the unit control panel, rotate OFF/LOCAL/AUXILIARY Keyswitch (S101) to LOCAL position.

NOTE

Perform the following step, if [Remote] or [Customer] is highlighted on the *Turbine Control Panel (TCP)* window for ACTIVE CONTROL.

2. Select the *TCP* button located on the screen header. This will open the Turbine Control Panel window

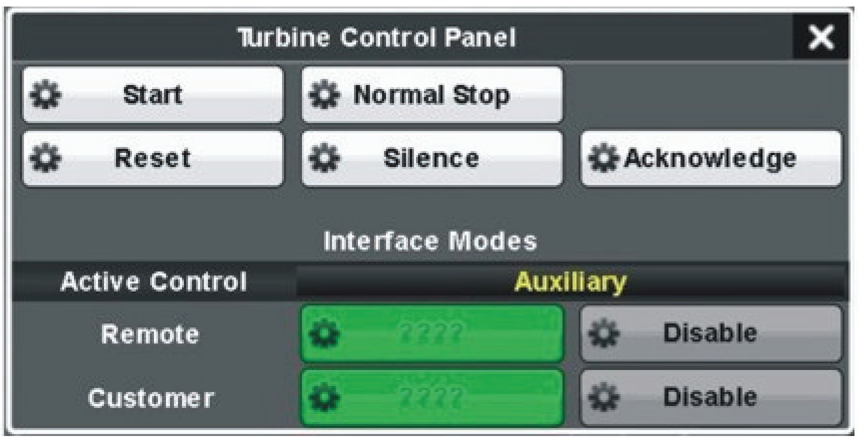


Figure 4.2.1 Turbine Control Panel (TCP) Window

3. On the turbine control panel window, select the remote *Disable* button to disable remote control. Make sure [Remote] or [Customer] no longer highlights as the active control mode.

NOTE

Once [Local] is highlighted as the active control, all operations that use customer-control or remote-control devices cease.

Normal stop and emergency stop pushbutton switches remain active regardless of control selection.

4.2.2 Preparation For Start

WARNING

Before starting the gas-turbine engine and driven equipment, contact maintenance personnel or use written records to verify that all maintenance items have been completed. Physically inspect the gas-turbine engine and driven equipment to verify that there are no maintenance tags attached to any equipment that indicate equipment should not be energized or started. Injury to personnel or damage to equipment may result if warning is not observed.

This subsection describes the procedures used to prepare the gas-turbine engine and driven equipment for a start at the unit control panel.

1. Contact maintenance personnel and verify that all maintenance items have been completed and that there are no maintenance tags attached to any equipment that indicate equipment should not be energized or started.

2. Perform unit control panel activation procedures listed Subsection 4.2.1.

3. At the unit control panel, open the turbine control panel window and make sure [Local] is highlighted as the active control.

4. On the Maintenance screen, select the *Lamp Test* button under Operation.

NOTE

A pop-up window opens. Select the *Lamp Test* button from the pop-up window and then select *OK* to confirm your selection.

5. Make sure all indicator lights illuminate.

6. Select the Gas Fuel Details screen and check fuel pressure.

NOTE

An alarm or shutdown will be indicated on the Alarm Summary window if fuel pressure is out of operating limits.

7. To acknowledge and clear any alarm or shutdown indications, press ACKNOWLEDGE Switch (S117) and then press RESET Switch (S114).

8. Select the Alarm Summary window and check for alarm and shutdown indications. Correct any alarm and shutdown indications that remain.

NOTE

For a list of alarms and shutdowns, refer to the Software Cause and Effect Drawing that is provided in the RSLogix/9000_999/Reports folder of the Project CD-ROM.

9. Select the Engine Details screen and click the Operation Sequence button. The Operation Sequence window opens.

10. Make sure [Ready to Load] is highlighted on the Operation Sequence window.

NOTE

If shutdown indications have not been cleared on the Alarm Summary window, [Ready to Load] will not highlight on the Operation Sequence window. All shutdown(s) must be corrected and reset before [Ready to Load] will highlight.

4.2.3 Start Procedures

This subsection describes the procedures used to start the gas-turbine engine and driven equipment at the unit control panel.

NOTE

A restart may be initiated one minute after the gas-turbine engine speed drops to 15 percent. In case of a malfunction shutdown, do not attempt another restart until the cause of the malfunction has been determined and the condition has been corrected. After three attempted starts have been unsuccessful, additional troubleshooting may be required.

In the following procedure display screen indications shown in brackets [ ] are highlighted in reverse video.

1. Perform prestart procedures listed in Subsection 4.2.2.

2. At the unit control panel, select the Engine Details screen and click the Operation Sequence button. The Operation Sequence window opens.

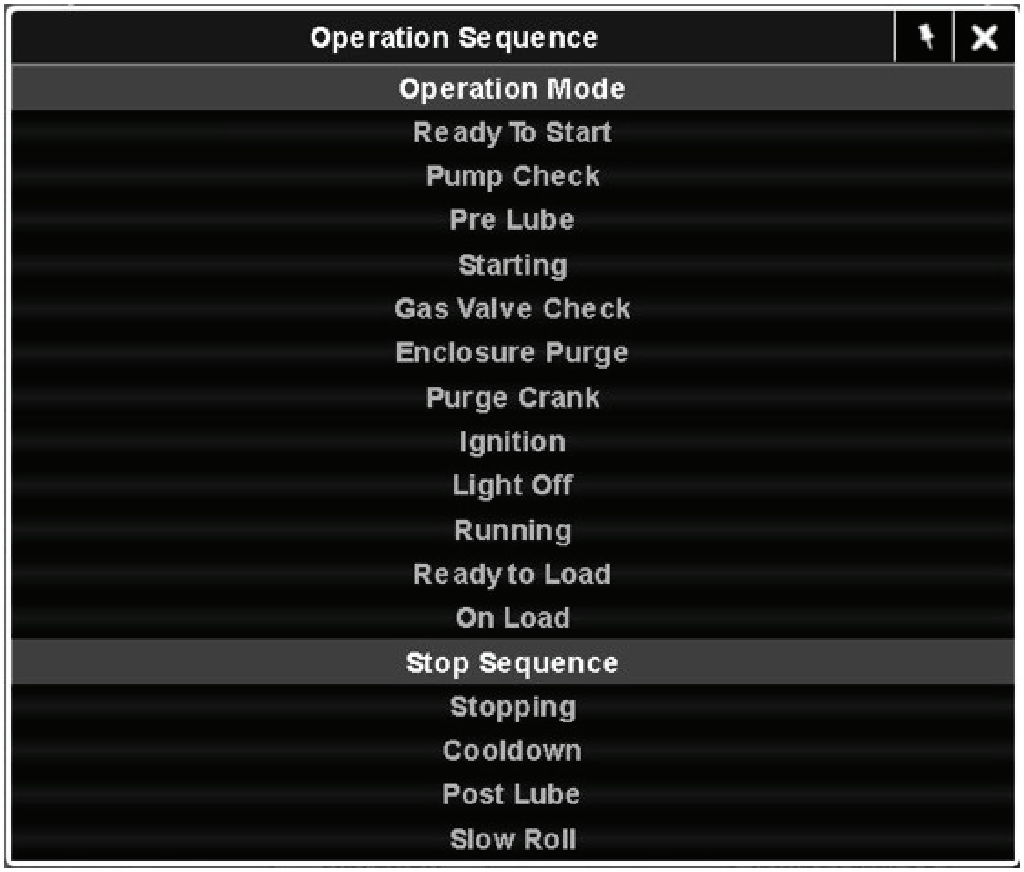


Figure 4.2.2 Operation Sequence Window

3. Monitor the gas-turbine engine during the start sequence from the Operation Sequence window, Figure 4.2.2.

4. To start the gas-turbine engine and driven equipment, press START/STARTING Switch/Light (S/DS110). The following events occur:

   a. START/STARTING Switch/Light (S/DS110) begins flashing and [Starting] highlights on Operation Sequence window, Figure 4.2.2. The backup lube oil pump is tested for operation. The pre/post pump starts and the prelubrication cycle begins. The control system begins a fuel system check. Start system is energized.

   b. After prelube cycle is complete, engine cranking begins.

   c. After starter has cranked engine to 15 percent speed, purge timer provides a preselected period of exhaust system purging via engine air flow. [Purge Crank] highlights on the Operation Sequence window, Figure 4.2.2.

   d. After purge cycle is completed, fuel is admitted into combustor chamber where it is mixed with compressed air and ignited. [Ignition] highlights on Operation Sequence window, Figure 4.2.2. Lightoff occurs within next few seconds and combustion begins.

e. The engine continues to accelerate and engine temperature increases to 400°F (204°C). [Light Off] highlights on Operation Sequence window, Figure 4.2.2, fuel ramp is activated, and ignition is de-energized. ENGINE HOURS/START COUNTER Meter (M210) registers a successful start.

f. Engine speed increases to starter dropout speed. Engine-driven lube oil pump pressure increases and pre/post lube oil pump stops. Start system is de-energized and starter clutch overruns. Combined generator control module is energized. Vibration monitor is switched from offset to normal settings. ENGINE HOURS/START COUNTER Meter (M210) begins to log engine operating hours. START/STARTING Switch/Light is extinguished and [Running] highlights on Operation Sequence window, Figure 4.2.2.

g. Engine speed increases to 90 percent. Speed-sensing circuit assumes fuel control by sending commands directly to fuel actuator. [Ready to Load] highlights on Operation Sequence window, Figure 4.2.2.

5. Perform operational checkout procedures listed in Subsection 4.2.4.

4.2.4 Operational Checkout

To ensure safe operation, perform the following operational checkout procedures each time the gas-turbine engine and driven equipment is started. If gas-turbine engine is continuously running, perform an operational checkout daily to verify normal operation.

1. Record gas-turbine engine and driven equipment speeds, pressures, temperatures, and vibration readings for comparison with normal or designed operating values. If deviations exist, shut down gas-turbine engine and driven equipment and determine cause.

2. Check for leaks from air, oil, and fuel plumbing.

3. Ensure safe operation at all times.

4.2.5 Shutdown Procedures

This section describes the shutdown procedures for the generator set. There are three types of shutdown procedures; normal stop, emergency stop, and control system stop.

NORMAL STOP

A normal stop shutdown sequence includes a cooldown period, which allows the gas-turbine engine and driven equipment to run with no load for a preset period before the gas-turbine engine is stopped.

NOTE

In the following procedure display screen indications shown in brackets [ ].

Do the following procedures to initiate a normal stop at the unit control panel.

1. At the unit control panel, press STOP/STOPPING Switch/Light (S/DS111). The following events occur:

   a. Generator circuit breaker opens and [Cooldown] highlights on the Operation Sequence window, Figure 4.2.2.

   NOTE

   If utility circuit breaker is closed, generator load is decreased 40kW/sec. When 5% of full load is reached, generator circuit breaker opens.

   b. Gas-turbine engine runs with generator unloaded for a preset cooldown cycle.

   NOTE

   Gas-turbine engine may be restarted during cooldown cycle by pressing ACKNOWLEDGE Switch, RESET Switch, and then START/STARTING Switch.

   c. After preset cooldown cycle, fuel system valves close, combustion ceases, and gas-turbine engine begins to decelerate. [Cooldown] indication reverts to normal video, STOP/STOPPING Switch/Light (S/DS111) illuminates, and [Stopping] highlights Operation Sequence window, Figure 4.2.2.

   d. [Running] indication reverts to normal video. ENGINE HOURS/START COUNTER Meter (M210) stops logging operating time.

   e. After engine coasts to a stop and rundown timer expires, a preset postlubrication cycle begins.

EMERGENCY STOP

An emergency stop does not include a cooldown period, which allows the gas-turbine engine and driven equipment to run with no load for a preset period before the gas-turbine engine is stopped. The emergency stop shutdown should only be used when plant conditions require an immediate shutdown.

NOTE

An emergency stop prevents gas-turbine engine operation until the emergency stop shutdown is acknowledged and reset by pressing the local ACKNOWLEDGE and RESET Switches and the backup relay system is reset.

In the following procedure display screen indications shown in brackets [ ] are highlighted in reverse video.

NOTE

Perform the following procedures to initiate emergency stop from unit control panel.

1. At the unit control panel, press EMERGENCY STOP Switch (S112). The following events occur:

    a. Generator unloads immediately.

    b. Engine shuts down immediately with no cooldown cycle. STOP/STOPPING Switch/Light (S/DS111) illuminates and [Stopping] highlights on the Operation Sequence window, Figure 4.2.2

    c. ENGINE HOURS/START COUNTER Meter (M210) stops logging operating time.

    d. After engine coasts to a stop and rundown timer expires, a preset postlubrication cycle begins.

CONTROL SYSTEM STOP

There are two types of control system stops; cooldown stop and fast stop. If an unsafe operating condition is detected by the control system, the control system initiates a shutdown. Depending upon the severity of the shutdown, the control system initiates either a cooldown stop or a fast stop. If the control system stop was initiated due to a condition that is self-correcting, the gas-turbine engine can be restarted after the condition returns to normal. If the control system stop was initiated due to a condition that is not self-correcting, contact maintenance personnel to perform corrective actions.

NOTE

For a list of alarms and shutdowns, refer to the Software Cause and Effect Drawing that is provided in the RSLogix/9000_999/Reports folder of the Project CD-ROM.

Cooldown Stop

If a cooldown stop has been initiated, the gas-turbine engine and driven equipment is unloaded and shut down in the same manner as a normal stop. There are two types of cooldown stops; cooldown lockout and cooldown nonlockout.

- **Cooldown Nonlockout (CN)** - Cooldown nonlockout shutdowns reduce gas-turbine engine speed to idle for a preset cooldown period before initiating a shutdown. Cooldown nonlockout shutdowns include operator-initiated normal stops, operating conditions that reached a shutdown limit because maintenance was not performed, a momentary disruption that causes an out-of-limits condition, and operating conditions that exceed alarm levels but are not serious enough to cause any immediate damage. Cooldown nonlockout shutdowns can be reset after corrective action has been taken or operating conditions revert to normal using either the local or remote ACKNOWLEDGE and RESET Switches.

- **Cooldown Lockout (CL)** - Cooldown lockout shutdowns reduce gas-turbine engine speed to idle for a preset cooldown period before initiating a shutdown. Cooldown lockout shutdowns typically result from a component failure and not because operating conditions have exceeded alarm or shutdown levels. Cooldown lockout shutdowns may not present immediate danger, but corrective action must be taken to avoid damage resulting from a component failure. Cooldown lockout shutdowns prevent gas-turbine engine operation until the shutdown is acknowledged and reset using the local ACKNOWLEDGE and RESET Switches.

NOTE

Remote ACKNOWLEDGE and RESET Switches cannot acknowledge or reset cooldown lockout shutdowns.

Fast Stop

If a fast stop has been initiated, the gas-turbine engine and driven equipment is unloaded and shut down in the same manner as an emergency stop. There are two types of fast stops; fast stop lockout and fast stop nonlockout.

⚠ WARNING

When a fast stop shutdown has been initiated due to fire detection, the postlube oil pump will remain energized for a preset rundown period. After the preset rundown period expires, the postlube oil pump(s) will be deenergized for 20 minutes. After the 20 minute time period expires, the postlube pump will cycle on and off for a preset postlube period.

On units that use pneumatically powered lube oil pump motor(s), if an unsafe condition still exists, the operator must manually abort the post lube cycle by closing the pneumatic supply valve(s) for the lube oil pump motor(s).

On units that use electrically powered lube oil pump motor(s), if an unsafe condition still exists, the operator must manually abort the post lube cycle by opening the facility contactor(s) for the lube oil pump motor(s).

NOTE

For a list of alarms and shutdowns, refer to the Software Cause and Effect Drawing that is provided in the RSLogix/9000_999/Reports folder of the Project CD-ROM.

- **Fast Stop Nonlockout (FN)** - Fast stop nonlockout shutdowns initiate an immediate shutdown of the gas-turbine engine. Fast stop nonlockout shutdowns typically result from a disruption in operation due to abnormal operating conditions and may not require corrective action. Fast stop nonlockout shutdowns can be reset when operating conditions revert to normal using either the local or remote ACKNOWLEDGE and RESET Switches.
- **Fast Stop Lockout (FL)** - Fast stop lockout shutdowns initiate an immediate shutdown of the gas-turbine engine. Fast stop lockout shutdowns prevent gas-turbine engine operation until the shutdown is acknowledged and reset using the local ACKNOWLEDGE and RESET Switches. In addition to using the local ACKNOWLEDGE and RESET Switches, fast stop lockout shutdowns initiated due to a microprocessor failure, fire detection, backup overspeed, or pressing of EMERGENCY STOP Switch will require the backup relay system to be reset. Fast stop lockout shutdowns are the most severe shutdown types and require corrective action before the gas-turbine engine can be restarted.

NOTE

Remote ACKNOWLEDGE and RESET Switches cannot acknowledge or reset fast stop lockout shutdowns.

4.3 ENGINE OPERATION USING AUXILIARY MULTI-UNIT CONTROL PANEL

WARNING

Operate the gas-turbine engine and driven equipment only when it is safe. Unsafe conditions include: fuel leaks, process gas leaks, oil leaks in hot areas, frayed or skinned electrical wiring, or loose or cracked anchor bolt nuts or structural members.

Explosive accumulations of natural gas, fuel fumes, oil tank vent leakage, or solvent fumes must be avoided at all times. This is done by proper ventilation, elimination of leaks, and confining the use of solvents within appropriate maintenance facilities.

Only qualified personnel may operate the gas-turbine engine and driven equipment. The operator must understand gas-turbine engine and driven equipment operation, function, and systems and controls, indicators, and operating limits.

Hearing and eye protection must be used by personnel in the vicinity of operating turbomachinery.

Gas-turbine engine and driven equipment operation is inherently safe and reliable. The control system protects against damaging malfunctions. Refer to the Safety Requirements in the front of this manual and observe the following to ensure proper operation.

- Operate, service, and maintain gas-turbine engine and driven equipment as described in this manual set.
- Understand gas-turbine engine and driven equipment operations, functions, and systems.
- Understand controls, indicators, indications, and operating limits.
- Rely on the instruments provided. Record and compare readings to detect developing problems.
- Learn the significance of possible malfunctions before operating the gas-turbine engine and driven equipment. Be prepared to take appropriate actions in the event of any malfunction.
- Contact Solar Turbines Customer Services for assistance in resolving unique or persistent problems.

4.3.1 Auxiliary Multi-Unit Control Panel Activation

Perform the following procedures to activate the auxiliary multi-unit control panel.

NOTE

In the following procedure display screen indications shown in brackets [ ].

1. At the unit control panel, rotate OFF/LOCAL/AUXILIARY Keyswitch (S101) to AUXILIARY position.

NOTE

Perform the following step, if [Remote] or [Customer] is highlighted on the *Turbine Control Panel (TCP)* window for ACTIVE CONTROL.

2. Select the *TCP* button located on the screen header. This will open the Turbine Control Panel window

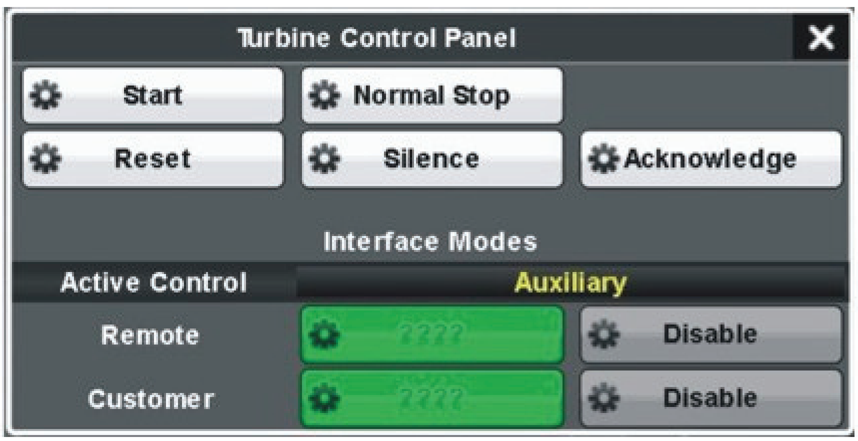


Figure 4.3.1 Turbine Control Panel (TCP) Window

3. On the turbine control panel window, select the remote *Disable* button to disable remote control. Make sure [Remote] or [Customer] no longer highlights as the active control mode.

NOTE

Once [Auxiliary] is highlighted as the active control, all operations that use customer-control or remote-control devices cease.

Normal stop and emergency stop pushbutton switches remain active regardless of control selection.

4.3.2 Preparation For Start

WARNING

Before starting the gas-turbine engine and driven equipment, contact maintenance personnel or use written records to verify that all maintenance items have been completed. Physically inspect the gas-turbine engine and driven equipment to verify that there are no maintenance tags attached to any equipment that indicate equipment should not be energized or started. Injury to personnel or damage to equipment may result if warning is not observed.

This subsection describes the procedures used to prepare the gas-turbine engine and driven equipment for a start at the auxiliary multi-unit control panel.

1. Contact maintenance personnel and verify that all maintenance items have been completed and that there are no maintenance tags attached to any equipment that indicate equipment should not be energized or started.

2. Perform auxiliary multi-unit control panel activation procedures listed Subsection 4.3.1.

3. At the auxiliary multi-unit control panel, verify AUX is illuminated on LOCAL/AUX Light (DS1001), or verify [Auxiliary] is highlighted on the Operation display screen for SYSTEM CONTROL.

4. Press LAMP TEST Switch (S1013). Verify all indicator lights illuminate.

5. Select the Gas Fuel Details screen and check fuel pressure.

NOTE

An alarm or shutdown will be indicated on the Alarm Summary window if fuel pressure is out of operating limits.

6. To acknowledge and clear any alarm or shutdown indications, press ACKNOWLEDGE Switch (S1017) and then press RESET Switch (S1014).

7. Select the Alarm Summary window and check for alarm and shutdown indications. Correct any alarm and shutdown indications that remain.

NOTE

For a list of alarms and shutdowns, refer to the Software Cause and Effect Drawing that is provided in the RSLogix/9000_999/Reports folder of the Project CD-ROM.

8. Select the Engine Details screen and click the Operation Sequence button. The Operation Sequence window opens.

9. Make sure [Ready to Load] is highlighted on the Operation Sequence window.

NOTE

If shutdown indications have not been cleared on the Alarm Summary window, [Ready to Load] will not highlight on the Operation Sequence window. All shutdown(s) must be corrected and reset before [Ready to Load] will highlight.

4.3.3 Start Procedures

This subsection describes the procedures used to start the gas-turbine engine and driven equipment at the auxiliary multi-unit control panel.

NOTE

A restart may be initiated one minute after the gas-turbine engine speed drops to 15 percent. In case of a malfunction shutdown, do not attempt another restart until the cause of the malfunction has been determined and the condition has been corrected. After three attempted starts have been unsuccessful, additional troubleshooting may be required.

In the following procedure display screen indications shown in brackets [ ] are highlighted in reverse video.

1. Perform prestart procedures listed in Subsection 4.3.2.
2. At the auxiliary multi-unit control panel, select the Engine Details screen and click the Operation Sequence button. The Operation Sequence window opens.

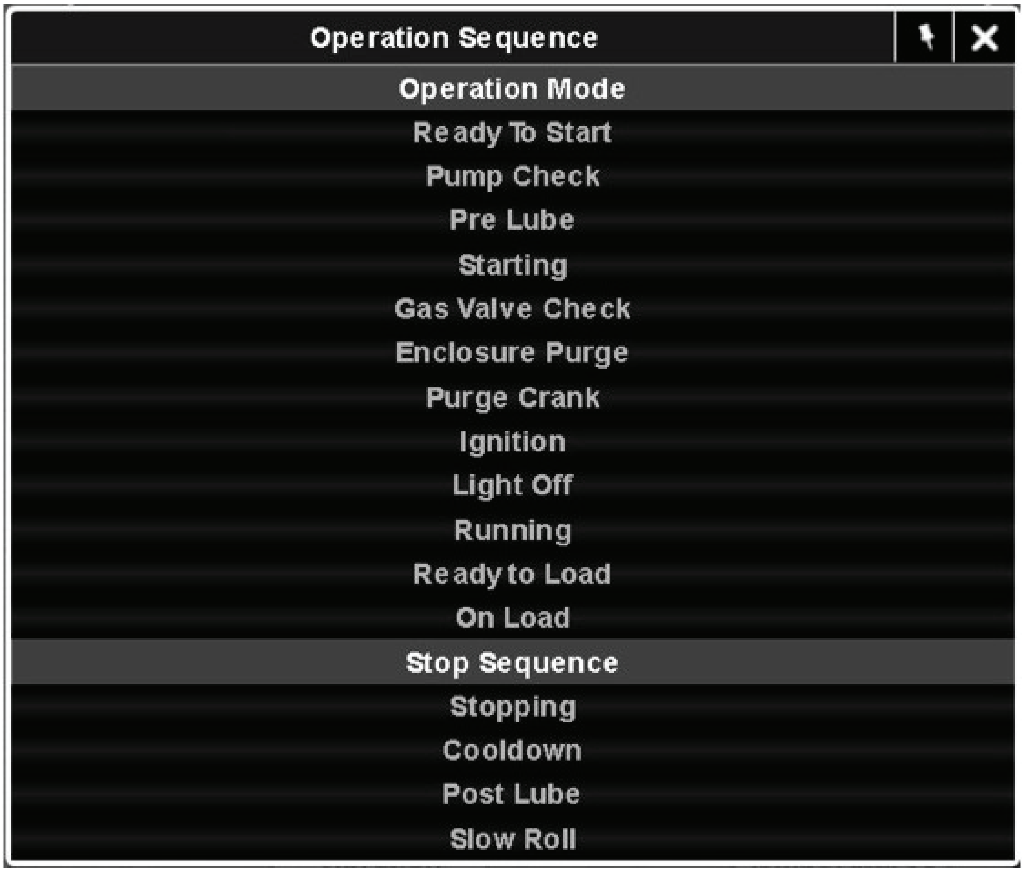


Figure 4.3.2 Operation Sequence Window

3. Monitor the gas-turbine engine during the start sequence from the Operation Sequence window, Figure 4.3.2.

4. To start the gas-turbine engine and driven equipment, press START/STARTING Switch/Light (S/DS110). The following events occur:

   a. START/STARTING Switch/Light (S/DS110) begins flashing and [Starting] highlights on Operation Sequence window, Figure 4.3.2. The backup lube oil pump is tested for operation. The pre/post pump starts and the prelubrication cycle begins. The control system begins a fuel system check. Start system is energized.

   b. After prelube cycle is complete, engine cranking begins.

   c. After starter has cranked engine to 15 percent speed, purge timer provides a preselected period of exhaust system purging via engine air flow. [Purge Crank] highlights on the Operation Sequence window, Figure 4.3.2.

   d. After purge cycle is completed, fuel is admitted into combustor chamber where it is mixed with compressed air and ignited. [Ignition] highlights on Operation Sequence window, Figure 4.3.2. Lightoff occurs within next few seconds and combustion begins.

e. The engine continues to accelerate and engine temperature increases to 400°F (204°C). [Light Off] highlights on Operation Sequence window, Figure 4.3.2, fuel ramp is activated, and ignition is de-energized. ENGINE HOURS/START COUNTER Meter (M210) registers a successful start.

f. Engine speed increases to starter dropout speed. Engine-driven lube oil pump pressure increases and pre/post lube oil pump stops. Start system is de-energized and starter clutch overruns. Combined generator control module is energized. Vibration monitor is switched from offset to normal settings. ENGINE HOURS/START COUNTER Meter (M210) begins to log engine operating hours. START/STARTING Switch/Light is extinguished and [Running] highlights on Operation Sequence window, Figure 4.3.2.

g. Engine speed increases to 90 percent. Speed-sensing circuit assumes fuel control by sending commands directly to fuel actuator. [Ready to Load] highlights on Operation Sequence window, Figure 4.3.2.

4.3.4 Operational Checkout

To ensure safe operation, perform the following operational checkout procedures each time the gas-turbine engine and driven equipment is started. If gas-turbine engine is continuously running, perform an operational checkout daily to verify normal operation.

1. Record gas-turbine engine and driven equipment speeds, pressures, temperatures, and vibration readings for comparison with normal or designed operating values. If deviations exist, shut down gas-turbine engine and driven equipment and determine cause.

2. Check for leaks from air, oil, and fuel plumbing.

3. Ensure safe operation at all times.

4.3.5 Shutdown Procedures

This section describes the shutdown procedures for the generator set. There are three types of shutdown procedures; normal stop, emergency stop, and control system stop.

NORMAL STOP

A normal stop shutdown sequence includes a cooldown period, which allows the gas-turbine engine and driven equipment to run with no load for a preset period before the gas-turbine engine is stopped.

NOTE

In the following procedure display screen indications shown in brackets [ ] are highlighted in reverse video.

Perform the following procedures to initiate normal stop at the auxiliary multi-unit control panel.

1. At the auxiliary multi-unit control panel, press NORMAL STOP Switch (S1011) or select Operation display screen onscreen *STOP* button. The following events occur:

   a. Generator circuit breaker opens and [Cooldown] highlights on the Operation Sequence window, Figure 4.2.2.

   NOTE

   If utility circuit breaker is closed, generator load is decreased 40kW/sec. When 5% of full load is reached, generator circuit breaker opens.

   b. Gas-turbine engine runs with generator unloaded for a preset cooldown cycle.

   NOTE

   Gas-turbine engine may be restarted during cooldown cycle by pressing ACKNOWLEDGE Switch, RESET Switch, and then START Switch.

   c. After preset cooldown cycle, fuel system valves close, combustion ceases, and gas-turbine engine begins to decelerate. COOLDOWN Light (DS1013) extinguishes, [Cooldown] indication reverts to normal video, STOPPING Light (DS1011) illuminates, and [Stopping] highlights Operation Sequence window, Figure 4.3.2.

   d. [Running] indication reverts to normal video. ENGINE HOURS/START COUNTER Meter (M210) stops logging operating time.

   e. After gas-turbine engine coasts to a stop and rundown timer expires, a preset postlubrication cycle begins.

EMERGENCY STOP

An emergency stop does not include a cooldown period, which allows the gas-turbine engine and driven equipment to run with no load for a preset period before the gas-turbine engine is stopped. The emergency stop shutdown should only be used when plant conditions require an immediate shutdown.

NOTE

An emergency stop prevents gas-turbine engine operation until the emergency stop shutdown is acknowledged and reset by pressing the local ACKNOWLEDGE and RESET Switches and the backup relay system is reset.

NOTE

In the following procedure display screen indications shown in brackets [ ] are highlighted in reverse video.

Perform the following procedures to initiate emergency stop from auxiliary multi-unit control panel.

1. At the auxiliary multi-unit control panel, press EMERGENCY STOP Switch (S1012). The following events occur:

   a. Generator unloads immediately.

   b. Gas-turbine engine shuts down immediately with no cooldown cycle. STOPPING Light (DS1011) illuminates and [Stopping] highlights on the Operation Sequence window, Figure 4.2.2.

   c. ENGINE HOURS/START COUNTER Meter (M210) stops logging operating time.

   d. After gas-turbine engine coasts to a stop and rundown timer expires, a preset postlubrication cycle begins.

CONTROL SYSTEM STOP

There are two types of control system stops; cooldown stop and fast stop. If an unsafe operating condition is detected by the control system, the control system initiates a shutdown. Depending upon the severity of the shutdown, the control system initiates either a cooldown stop or a fast stop. If the control system stop was initiated due to a condition that is self-correcting, the gas-turbine engine can be restarted after the condition returns to normal. If the control system stop was initiated due to a condition that is not self-correcting, contact maintenance personnel to perform corrective actions.

NOTE

For a list of alarms and shutdowns, refer to the Software Cause and Effect Drawing that is provided in the RSLogix/9000_999/Reports folder of the Project CD-ROM.

Cooldown Stop

If a cooldown stop has been initiated, the gas-turbine engine and driven equipment is unloaded and shut down in the same manner as a normal stop. There are two types of cooldown stops; cooldown lockout and cooldown nonlockout.

- **Cooldown Nonlockout (CN)** - Cooldown nonlockout shutdowns reduce gas-turbine engine speed to idle for a preset cooldown period before initiating a shutdown. Cooldown nonlockout shutdowns include operator-initiated normal stops, operating conditions that reached a shutdown limit because maintenance was not performed, a momentary disruption that causes an out-of-limits condition, and operating conditions that exceed alarm levels but are not serious enough to cause any immediate damage. Cooldown nonlockout shutdowns can be reset after corrective action has been taken or operating conditions revert to normal using either the local or remote ACKNOWLEDGE and RESET Switches.
- **Cooldown Lockout (CL)** - Cooldown lockout shutdowns reduce gas-turbine engine speed to idle for a preset cooldown period before initiating a shutdown. Cooldown lockout shutdowns typically result from a component failure and not because operating conditions have exceeded alarm or shutdown levels. Cooldown lockout shutdowns may not present immediate danger, but corrective action must be taken to avoid damage resulting from a component failure. Cooldown lockout shutdowns prevent gas-turbine engine operation until the shutdown is acknowledged and reset using the local ACKNOWLEDGE and RESET Switches.

NOTE

Remote ACKNOWLEDGE and RESET Switches cannot acknowledge or reset cooldown lockout shutdowns.

Fast Stop

If a fast stop has been initiated, the gas-turbine engine and driven equipment is unloaded and shut down in the same manner as an emergency stop. There are two types of fast stops; fast stop lockout and fast stop nonlockout.

WARNING

When a fast stop shutdown has been initiated due to fire detection, the postlube oil pump will remain energized for a preset rundown period. After the preset rundown period expires, the postlube oil pump(s) will be deenergized for 20 minutes. After the 20 minute time period expires, the postlube pump will cycle on and off for a preset postlube period.

On units that use pneumatically powered lube oil pump motor(s), if an unsafe condition still exists, the operator must manually abort the post lube cycle by closing the pneumatic supply valve(s) for the lube oil pump motor(s).

On units that use electrically powered lube oil pump motor(s), if an unsafe condition still exists, the operator must manually abort the post lube cycle by opening the facility contactor(s) for the lube oil pump motor(s).

NOTE

For a list of alarms and shutdowns, refer to the Software Cause and Effect Drawing that is provided in the RSLogix/9000_999/Reports folder of the Project CD-ROM.

- **Fast Stop Nonlockout (FN)** - Fast stop nonlockout shutdowns initiate an immediate shutdown of the gas-turbine engine. Fast stop nonlockout shutdowns typically result from a disruption in operation due to abnormal operating conditions and may not require corrective action. Fast stop nonlockout shutdowns can be reset when operating conditions revert to normal using either the local or remote ACKNOWLEDGE and RESET Switches.

- **Fast Stop Lockout (FL)** - Fast stop lockout shutdowns initiate an immediate shutdown of the gas-turbine engine. Fast stop lockout shutdowns prevent gas-turbine engine operation until the shutdown is acknowledged and reset using the local ACKNOWLEDGE and RESET Switches. In addition to using the local ACKNOWLEDGE and RESET Switches, fast stop lockout shutdowns initiated due to a microprocessor failure, fire detection, backup overspeed, or pressing of EMERGENCY STOP Switch will require the backup relay system to be reset. Fast stop lockout shutdowns are the most severe shutdown types and require corrective action before the gas-turbine engine can be restarted.

NOTE

Remote ACKNOWLEDGE and RESET Switches cannot acknowledge or reset fast stop lockout shutdowns.

4.4 ENGINE OPERATION USING REMOTE UNIT CONTROL PANEL

WARNING

Operate the gas-turbine engine and driven equipment only when it is safe. Unsafe conditions include: fuel leaks, process gas leaks, oil leaks in hot areas, frayed or skinned electrical wiring, or loose or cracked anchor bolt nuts or structural members.

Explosive accumulations of natural gas, fuel fumes, oil tank vent leakage, or solvent fumes must be avoided at all times. This is done by proper ventilation, elimination of leaks, and confining the use of solvents within appropriate maintenance facilities.

Only qualified personnel may operate the gas-turbine engine and driven equipment. The operator must understand gas-turbine engine and driven equipment operation, function, and systems and controls, indicators, and operating limits.

Hearing and eye protection must be used by personnel in the vicinity of operating turbomachinery.

Gas-turbine engine and driven equipment operation is inherently safe and reliable. The control system protects against damaging malfunctions. Refer to the Safety Requirements in the front of this manual and observe the following to ensure proper operation.

- Operate, service, and maintain gas-turbine engine and driven equipment as described in this manual set.
- Understand gas-turbine engine and driven equipment operations, functions, and systems.
- Understand controls, indicators, indications, and operating limits.
- Rely on the instruments provided. Record and compare readings to detect developing problems.
- Learn the significance of possible malfunctions before operating the gas-turbine engine and driven equipment. Be prepared to take appropriate actions in the event of any malfunction.
- Contact Solar Turbines Customer Services for assistance in resolving unique or persistent problems.

4.4.1 Remote Control Activation

Perform the following procedures to activate the remote unit control panel from either the unit control panel or auxiliary unit control panel.

NOTE

When remote unit control panel is activated, the control system will respond to all customer-furnished gas-turbine engine and driven equipment inputs in the same way as Solar-furnished gas-turbine engine and driven equipment inputs described in this Chapter.

In the following procedure display screen indications shown in brackets [ ] are highlighted in reverse video.

AT THE UNIT CONTROL PANEL

1. At the unit control panel, select Maintenance display screen, and verify [Local] is highlighted for SYSTEM CONTROL.
2. Select the *TCP* button located on the screen header. This will open the Turbine Control Panel window, 4.2.1.
3. On the turbine control panel window, select the remote *Enable* button to enable remote control. Make sure [Remote Control Enabled] highlights as the active control mode.

NOTE

Once [Remote] is highlighted all operations that use unit control panel or auxiliary unit control panel cease.

Normal stop and emergency stop pushbutton switches remain active regardless of local, auxiliary, or remote control selection.

4.5 FUNCTIONAL DESCRIPTION OF GENERATOR CONTROL MODES

NOTE

This section gives functional description for Solar's standard generator control modes. It is possible that your package has fewer generator control modes.

To competently operate the generator, you must understand the available modes of operation. This section describes the functionality of the following generator control modes that you can configure:

- Speed/load control
- Voltage control
- Run at Rated Volts and Frequency

The two primary control variables for control of the generator are fuel demand and generator excitation. Refer to Figure 4.5.1 to see the relationship between these two variables. Fuel demand and generator excitation affect the following two primary generator controls:

1. Load/Speed Control
   - Speed Control (Frequency)
   - kW Control
2. Excitation Control
   - Voltage Control
   - Reactive Power Control

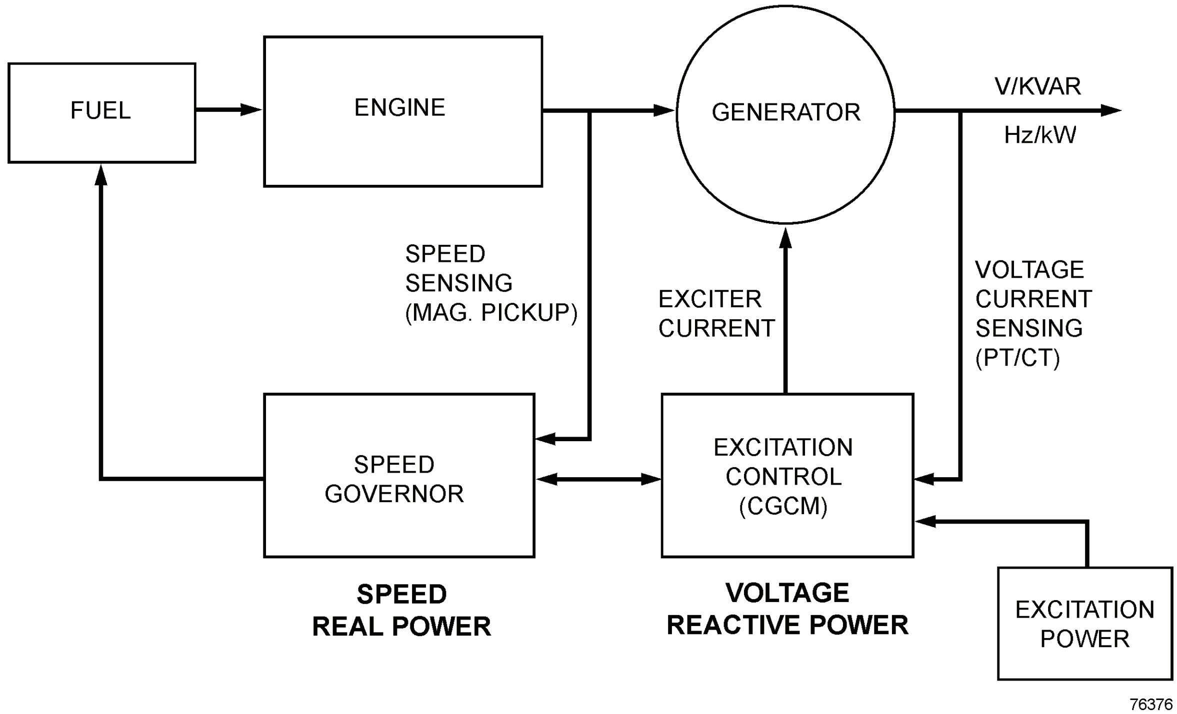


Figure 4.5.1 Primary Control Variables

The control system modulates fuel demand to control generator frequency and/or real power. In this document, variation of fuel flow to control generator frequency and/or real power is mostly referred to as

- speed/load control,

but it is also referred to by other terms such as:

- load/speed control
- speed/kW control
- speed/real power control
- frequency/load control.

The control system modulates excitation to control generator voltage and/or reactive power. In this document, varying excitation to control generator voltage and/or reactive power is mostly referred to as

- voltage control,

but it is also referred to by other terms such as:

- voltage/reactive power control
- Volt/kVar control.

You can configure the load/speed control and the voltage control to attain various goals as explained in the following subsections. These choices that you have are mostly referred to as control modes, but are also referred to as modes of operation.

Subsection 4.5.1 describes the speed/load control modes .

Subsection 4.5.2 describes the voltage control modes.

The speed/load control and the voltage control use the speed setpoint and the voltage setpoint as their inner loop setpoints. It is often desirable to force these setpoints to design rated values in certain modes of operation. The Run at Rated Voltage and Frequency control mode, or for short, the Run at Rated control mode, allows you to determine if you want these setpoints forced to rated values for the given modes of operation. Subsection 4.5.3 describes the Run at Rated control mode.

For speed/load, voltage, and Run at Rated control modes, you can select the *Default* button on the Control Mode Setup pop-up window to apply a group of generator control modes that have been predefined at the factory. Your other choice is to select the *User Defined* button to apply individual generator control modes. Subsection 4.6.1 describes the Default and User Defined control modes and how you apply them. Subsections 4.6.2 and 4.6.3 give procedures to make individual, User Defined, generator control mode selections.

The load/speed control modes and when they are active are summarized in Table 4.5.1.

Table 4.5.1 Load/Speed Control Modes Summary

Sequence State	Default/ User Defined Selection	User Defined Island Operation Selection	User Defined Grid Operation Selection	Generator Breaker Status	Utility Breaker Status	Speed/ Load Control Mode
starting	X[1]	X[1]	X[1]	open	X[1]	inactive
idle	X[1]	X[1]	X[1]	open	X[1]	constant speed
synchronizing	X[1]	X[1]	X[1]	X[1]	X[1]	speed synchronization
cooldown	X[1]	X[1]	X[1]	closed	closed[2]	kW soft unload
stopping	X[1]	X[1]	X[1]	open	X[1]	inactive
on line	Default	X[1]	X[1]	closed	open	Iso- chronous kW Share
on line	Default	X[1]	X[1]	closed	closed	kW/Import
on line	User Defined	Iso- chronous kW Share	X[1]	closed	open	Iso- chronous kW Share
on line	User Defined	Droop	X[1]	closed	open	Droop
on line	User Defined	X[1]	kW/Import	closed	closed	kW/Import
on line	User Defined	X[1]	Droop	closed	closed	Droop

NOTES:

(1) X means that the state of this variable has no effect on the Speed/Load control mode.

(2) Utility breaker is closed or island soft unload is enabled.

The voltage control modes and when they are active are summarized in Table 4.5.2.

Table 4.5.2 Voltage Control Modes Summary

Sequence State	Default/ User Defined Selection	User Defined Island Operation Selection	User Defined Grid Operation Selection	Generator Breaker Status	Utility Breaker Status	Voltage Control Mode
starting	X(1)	X(1)	X(1)	open	X(1)	inactive
idle	X(1)	X(1)	X(1)	open	X(1)	constant voltage
synchronizing	X(1)	X(1)	X(1)	X(1)	X(1)	voltage synchronization
stopping	X(1)	X(1)	X(1)	open	X(1)	inactive
on line	Default	X(1)	X(1)	closed	open	constant voltage kVAR Share
on line	Default	X(1)	X(1)	closed	closed	Power Factor
on line	User Defined	constant voltage	X(1)	closed	open	constant voltage
on line	User Defined	constant voltage kVAR Share	X(1)	closed	open	constant voltage kVAR Share
on line	User Defined	Droop	X(1)	closed	open	Droop
on line	User Defined	X(1)	Power Factor	closed	closed	Power Factor
on line	User Defined	X(1)	Reactive Power	closed	closed	Reactive Power
on line	User Defined	X(1)	Droop	closed	closed	Droop

(1) X means that the state of this variable has no effect on the voltage control mode.

4.5.1 Load/Speed Control Modes

The speed/load control modes all have the following feature in common.

- The control system modulates fuel demand to attain goals related to generator frequency and/or real power.

The goals of the speed/load control vary based on the generator's connection to loads, the generator's connection to other power sources, and the generator's operation sequence status. The connection status is determined by monitoring the following:

- Generator circuit breaker status
- Utility breaker status

The operation sequence statuses that effect speed/load control are:

- Idle,
- Synchronization,
- On Line,
- Cooldown, and
- Stopping.

In certain sequence states, the speed/load control will automatically operate in the following factory defined control modes, and the control modes you select will have no effect:

1. Constant speed control,
   - before synchronization initiation when the generator is at idle speed with the generator breaker open
2. Synchronization speed control,
   - when synchronization is active
3. Soft Unload kW control,
   - when the generator and utility breakers are closed and there is a cooldown shutdown

You can choose one control mode to be active when the generator is in island operation and another control mode to be active when the generator is in grid operation. You can select the following standard speed/load control modes:

1. Island operation
   - Isochronous kW share control mode

- Droop speed/load control mode

2. Grid operation
   - kW control mode
   - kW/Import control mode
   - Droop speed/load control mode

The generator is in island operation when the generator breaker is closed and the utility breaker is open. The generator is in grid operation when the generator breaker is closed and the utility breaker is closed.

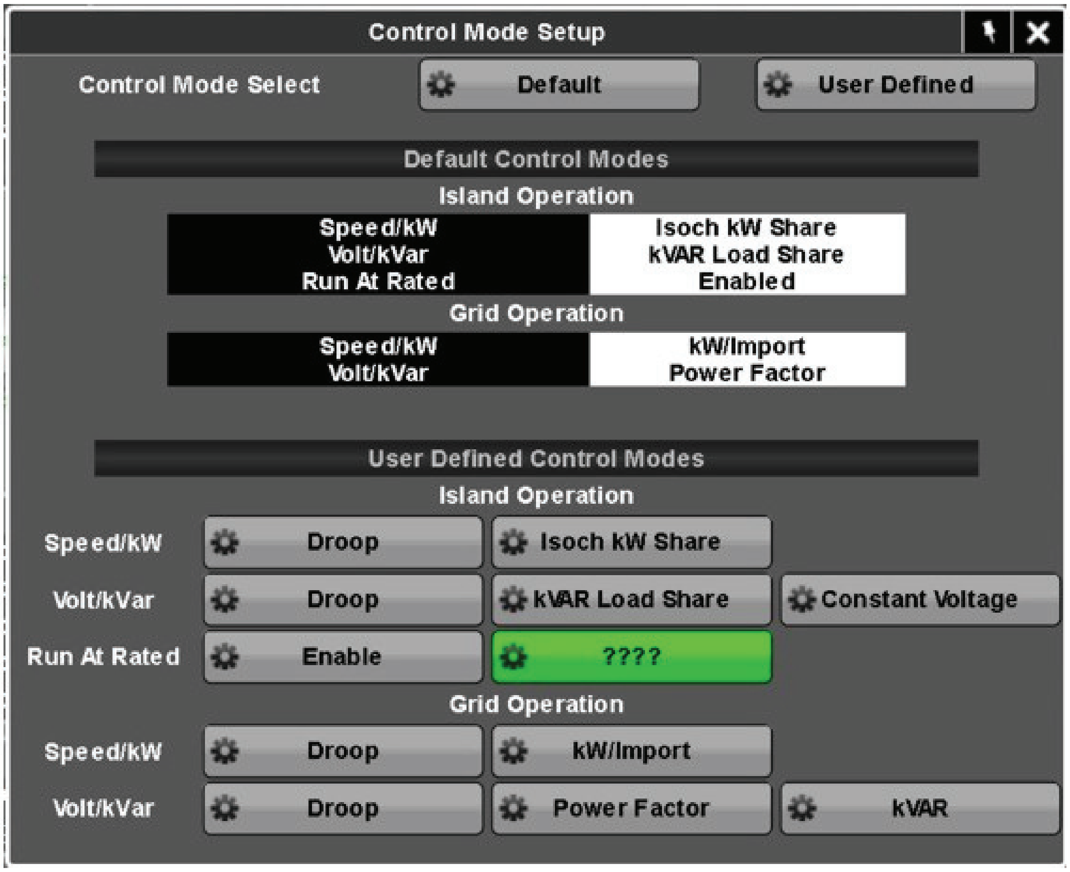


Figure 4.5.2 Control Mode Setup Window

ISOCHRONOUS KW SHARE CONTROL MODE FOR ISLAND OPERATION

Isochronous kW share control mode for island operation can only be active when the generator breaker is closed and the utility breaker is open.

When isochronous kW share control mode is the active mode for multiple generators, the goal of isochronous kW share control mode is to hold generator frequency constant and share the real power load between all connected generators. When isochronous kW share control mode is the active mode for multiple connected generators, and they all have the same speed setpoint, load will be shared equally. If no other generators are connected in isochronous kW share control mode, the control will simply be a constant frequency control.

CAUTION

For proper function, when an isochronous (constant speed) control is the active control mode for multiple connected generators, they must have an active real load sharing system which is compatible between them.

When you select isochronous kW share control mode for island operation, the speed/load control mode will automatically and bumplessly go to isochronous kW share control mode whenever the generator breaker is closed and the utility breaker is open, and the generator is not in a synchronization sequence.

Isochronous kW share control mode for island operation is the Default speed/load control mode for island operation. If you click the *Default* button on the Control Mode Setup window, Figure 4.5.2, isochronous kW share control mode will be the speed/load control mode in island operation. See Subsection 4.6.1 for how to select the Default group of control modes instead of User Defined control modes.

When you click the *User Defined* button on the Control Mode Setup window, Figure 4.5.2, isochronous kW share control mode for island operation will be the control mode in island operation only if it is the current, speed/load control mode selection for User Defined, island operation. See Subsection 4.6.2 for how to select island operation, speed/load control modes.

DROOP SPEED/LOAD CONTROL MODE FOR ISLAND OPERATION

The droop speed/load control mode for island operation can only be active when the generator breaker is closed and the utility breaker is open.

The goal of the droop speed/load control mode for island operation is to control generator frequency and real load to a point on the speed/load droop line for one of the following two purposes:

- to maintain a constant real load when other units connected in parallel have a constant frequency control mode as their active control mode
- to establish load share and frequency when all other units connected in parallel have droop speed/load control mode as their active control mode

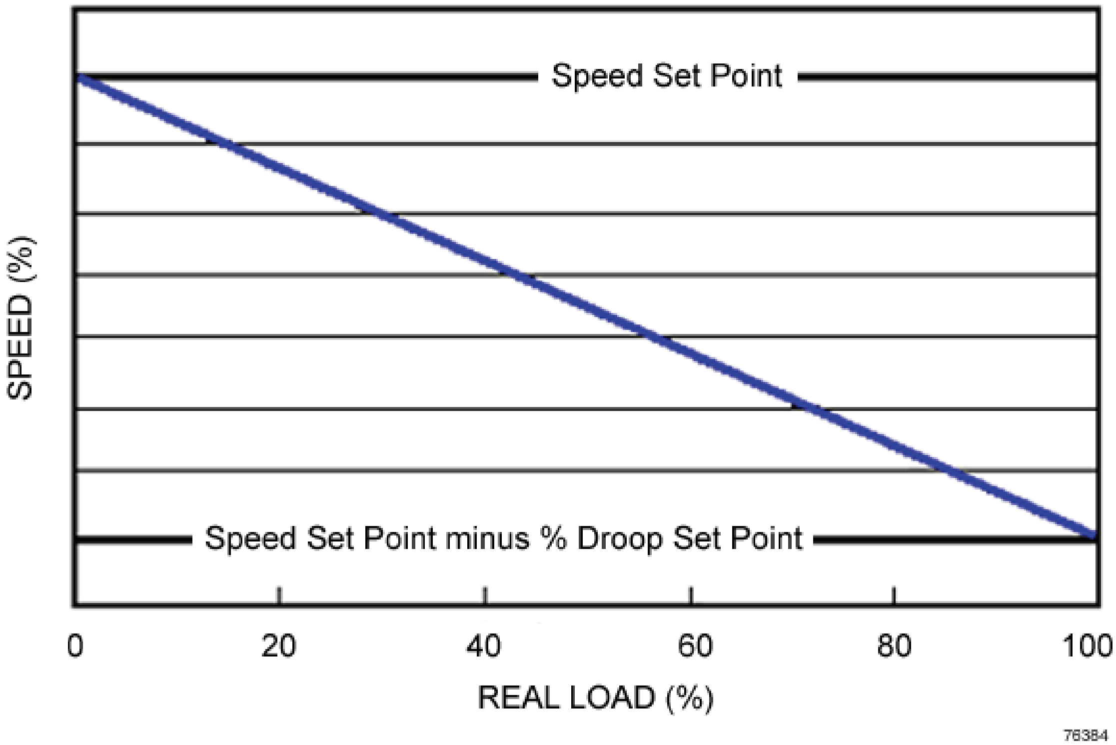


Figure 4.5.3 Droop Load/Speed Relationship

For example, if

- there are no other units controlling speed,
- the speed setpoint is 100%,
- and the droop setpoint is 3.5%,

then the generator will be controlled to

- 100% speed when there is no load,
- 98.25% speed when there is 50% load, and
- 96.5% speed when there is 100% load.

When other units connected in parallel have a constant frequency control mode as their active control mode, then the control systems for the units in speed/load droop will control to a constant real load. The speed set point, the droop set point, and frequency will determine this constant real load.

If there are other units connected in parallel, but none have an active constant frequency control mode, then the units in speed/load droop will share the real power load between all connected generators that have the droop speed/load control mode as their active control mode. In this scenario, the speed setpoints, the droop setpoints, and the total real load determine the load share and frequency.

If there are no other generators connected in parallel, the control system will control generator frequency to a point on the speed/droop line. The real load, the speed setpoint, and the droop setpoint determine this point on the speed/droop line.

When you select droop speed/load control mode for island operation, the speed/load control mode will automatically and bumplessly go to the droop speed/load control mode whenever the generator breaker is closed, the utility breaker is open, and the generator is not in a synchronization mode.

When you click the *User Defined* button on the Control Mode Setup window, Figure 4.5.2, droop speed/load control mode for island operation will be the control mode in island operation only if it is the current, speed/load control mode selection for User Defined, island operation. See Subsection 4.6.2 for how to select User Defined, speed/load control modes.

KW CONTROL MODE FOR GRID OPERATION

The kW control mode for grid operation can only be active when the generator breaker is closed and the utility breaker is closed.

The goal of kW control mode for grid operation is to generate maximum real power without exceeding the generator real power setpoint.

When you select kW control mode for grid operation, the speed/load control mode will automatically and bumplessly go to kW control mode for grid operation whenever the generator breaker is closed and the utility breaker is closed.

KW control mode for grid operation is the Default, speed/load control mode for grid operation. When you click the *Default* button on the Control Mode Setup window, Figure 4.5.2, kW control mode will be the speed/load control mode in grid operation. See Subsection 4.6.1 for how to select the Default group of control modes instead of User Defined control modes.

When you click the *User Defined* button on the Control Mode Setup window, Figure 4.5.2, kW control mode for grid operation will be the control mode in grid operation only if it is the current, speed/load control mode selection for User Defined, grid operation. See Subsection 4.6.2 for how to select User Defined, speed/load control modes for grid operation.

KW/IMPORT CONTROL MODE FOR GRID OPERATION

The kW/import control mode for grid operation can only be active when the generator breaker is closed and the utility breaker is closed.

The goal of kW/import control mode for grid operation is to generate maximum real power without exceeding the generator real power setpoint and without falling below the import real power setpoint.

When you select kW/import control mode for grid operation, the speed/load control mode will automatically and bumplessly go to kW/import control mode for grid operation whenever the generator breaker is closed and the utility breaker is closed.

KW/import control mode for grid operation is the Default, speed/load control mode for grid operation. When you click the *Default* button on the Control Mode Setup window, Figure 4.5.2, kW/import control mode will be the speed/load control mode in grid operation. See Subsection 4.6.1 for how to select the Default group of control modes instead of User Defined control modes.

When you click the *User Defined* button on the Control Mode Setup window, Figure 4.5.2, kW/import control mode for grid operation will be the control mode in grid operation only if it is the current, speed/load control mode selection for User Defined, grid operation. See Subsection 4.6.2 for how to select User Defined, speed/load control modes for grid operation.

DROOP SPEED/LOAD CONTROL MODE FOR GRID OPERATION

The droop speed/load control mode for grid operation can only be active when the generator breaker is closed and the utility breaker is closed.

The goal of droop speed/load control mode for grid operation is to control generator real power to a point on the speed/load droop line that is determined by the grid frequency, the speed setpoint, and the droop setpoint.

When you select the droop speed/load control mode for grid operation, the speed/load control mode will automatically and bumplessly go to droop speed/load control mode whenever the generator breaker is closed and the utility breaker is closed.

When you click the *User Defined* button on the Control Mode Setup window, Figure 4.5.2, droop speed/load control mode for grid operation will be the control mode in grid operation only if it is the current, speed/load control mode selection for User Defined, grid operation. See Subsection 4.6.2 for how to select speed/load control modes for grid operation . See Subsection 4.6.1 for how to select User Defined control modes instead of the Default group of control modes.

4.5.2 Voltage Control Modes

The voltage control modes all have the following feature in common.

- The control system modulates generator excitation current to attain goals that relate to generator voltage and/or reactive power.

The goals of the voltage control vary based on the generator's connection to loads, the generator's connection to other power sources, and the generator's operation sequence status. The control system monitors the following to determine connection status:

- Generator circuit breaker status
- Utility breaker status

The operation sequence statuses that effect voltage control are:

- Idle,
- Synchronization,
- On Line,
- Cooldown, and
- Stopping.

In certain sequence states, the voltage control will automatically operate in the following factory defined control modes, and the control modes you select will have no effect.

1. Constant voltage control,
    - when the generator is at idle speed with the generator breaker open prior to synchronization initiation
2. Synchronization voltage control,
    - when synchronization is active

You can chose one control mode to be active when the generator is in island operation and another control mode to be active when the generator is in grid operation. You can select the following standard voltage control modes:

1. Island operation
    - Constant voltage control mode
    - Constant voltage with reactive load sharing
    - Droop voltage
2. Grid operation
    - Droop voltage
    - Power Factor
    - Reactive Power

The generator is in island operation is when the generator breaker is closed and the utility breaker is open. The generator is in grid operation when the generator breaker is closed and the utility breaker is closed.

DROOP VOLTAGE CONTROL MODE FOR ISLAND OPERATION

The island operation droop voltage control mode can only be active when the generator breaker is closed and the utility breaker is open.

The goal of droop voltage control mode for island operation is to control generator frequency and reactive load to a point on the voltage droop line for one of the following two purposes:

- to maintain a constant reactive load when other units connected in parallel have a constant voltage control mode as their active control mode
- to establish load share and voltage when all other units connected in parallel have droop voltage control mode as their active control mode

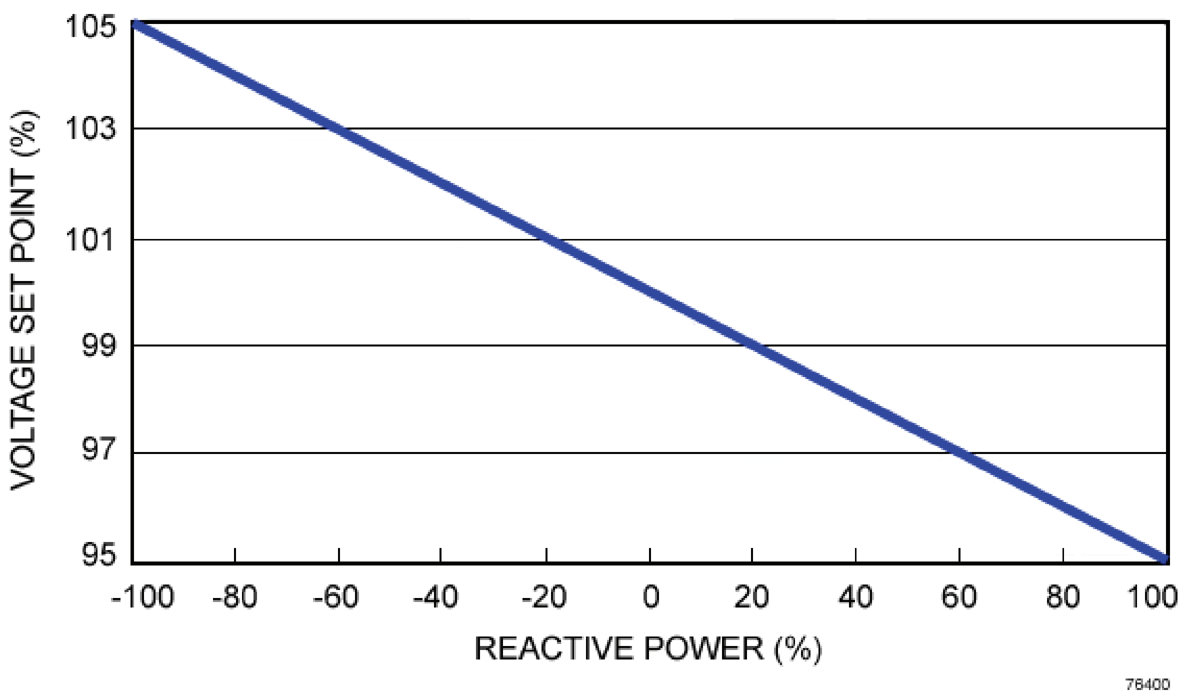


Figure 4.5.4 Droop Relationship With 5% Droop And Voltage Setpoint 100%

For example, if

- there are no other units controlling voltage,
- the speed setpoint is 100%,

- and the droop setpoint is 5%,

then the generator will be controlled to

- 100% voltage when there is no reactive load,
- 97.5% voltage when there is 50% reactive load (50% lagging reactive load),
- 95% voltage when there is 100% reactive load (100% lagging reactive load), and
- 102.5% voltage when there is -50% reactive load (50% leading reactive load).

When other units connected in parallel have a constant voltage control mode as their active control mode, then the control systems for the units in voltage droop will control to a constant reactive load. The voltage setpoint and droop setpoint determine this constant reactive load.

If there are other units connected in parallel, but none have an active constant voltage control mode, then the units in voltage droop will share the reactive power load between all connected generators that have the droop voltage control mode as their active control mode. The voltage setpoints, the droop setpoints, and total reactive load determine the load share and voltage.

When you select droop control mode for island operation, the voltage control mode will automatically and bumplessly go to droop voltage control mode whenever the generator breaker is closed, the utility breaker is open, and the generator is not in a synchronization mode.

When you click the *User Defined* button on the Control Mode Setup window, Figure 4.5.2, droop voltage control mode for island operation will be the control mode in island operation only if it is the current voltage control mode selection for User Defined, island operation. See Subsection 4.6.3 for how to select the droop voltage control mode selection for island operation. See Subsection 4.6.1 for how to select User Defined control modes instead of the Default group of control modes.

CONSTANT VOLTAGE WITH REACTIVE LOAD SHARING CONTROL MODE FOR ISLAND OPERATION

The constant voltage with reactive load sharing control mode for island operation can only be active when the generator breaker is closed and the utility breaker is open.

The goal of constant voltage with reactive load sharing control mode for island operation is to hold generator voltage constant and share the reactive load between all connected generators that have this same control mode as their active control mode. If connected generators operating in constant voltage with reactive load sharing control mode have the same voltage setpoint, load will be shared equally. If no other generators have constant voltage with reactive load sharing control mode as their active control mode, the control will simply be a constant voltage control.

CAUTION

For proper function, when a constant voltage control mode is the active the control mode for multiple connected generators, they must have an active reactive load sharing system which is compatible between them.

When you select constant voltage with reactive load sharing control mode for island operation, the voltage control mode will automatically and bumplessly go to constant voltage with reactive load sharing control mode whenever the generator breaker is closed, the utility breaker is open, and the generator is not in a synchronization mode.

Constant voltage with reactive load sharing control mode for island operation is the Default voltage control mode for island operation. When you click the *Default* button on the Control Mode Setup pop-up window, constant voltage with reactive load sharing control mode for island operation will be the voltage control mode while the generator is in island operation. See Subsection 4.6.1 for how to select the Default group of control modes instead of User Defined control modes.

When you click the *User Defined* button on the Control Mode Setup window, Figure 4.5.2, constant voltage with reactive load sharing control mode for island operation will be the control mode in island operation only if it is the current, voltage control mode selection for User Defined, island operation. See Subsection 4.6.1 for how to select User Defined control modes instead of the Default group of control modes. See Subsection 4.6.3 for how to select User Defined, voltage control modes.

CONSTANT VOLTAGE CONTROL MODE FOR ISLAND OPERATION

The constant voltage control mode for island operation can only be active when the generator breaker is closed and the utility breaker is open.

The goal of constant voltage control mode for island operation is to hold generator voltage constant.

CAUTION

For proper function, only one of a group of connected generators can operate in constant voltage control mode. Other connected generators must operate in droop.

When you select constant voltage control mode for island operation, the voltage control mode will automatically and bumplessly go to constant voltage control mode for island operation whenever the generator breaker is closed, the utility breaker is open, and the generator is not in a synchronization mode.

When you click the *User Defined* button on the Control Mode Setup window, Figure 4.5.2, constant voltage control mode for island operation will be the control mode in island operation only if it is the current, voltage control mode selection for User Defined, island operation. See Subsection 4.6.3 for how to select User Defined, voltage control modes. See Subsection 4.6.1 for how to select User Defined control modes instead of the Default group of control modes.

DROOP VOLTAGE CONTROL MODE FOR GRID OPERATION

The droop voltage control mode for grid operation can only be active when the generator breaker is closed and the utility breaker is closed.

The goal of droop voltage control mode for grid operation is to control generator reactive power to a point on the voltage droop line that is determined by the grid voltage, the voltage setpoint, and the droop set point.

When you select droop voltage control mode for grid operation, the voltage control mode will automatically and bumplessly go to droop voltage control mode for grid operation whenever the generator breaker is closed and the utility breaker is closed.

When you click the *User Defined* button on the Control Mode Setup window, Figure 4.5.2, droop voltage control mode for grid operation will be the control mode in grid operation only if it is the current, voltage control mode selection for User Defined, grid operation. See Subsection 4.6.3 for how to select User Defined, voltage control modes. See Subsection 4.6.1 for how to select User Defined control modes instead of the Default group of control modes.

POWER FACTOR CONTROL MODE FOR GRID OPERATION

The power factor control mode for grid operation can only be active when the generator breaker is closed and the utility breaker is closed.

The goal of the power factor control mode for grid operation is to hold generator power factor constant.

When you select the power factor control mode for grid operation, the voltage control mode will automatically and bumplessly go to the power factor control mode for grid operation whenever the generator breaker is closed and the utility breaker is closed.

The power factor control mode for grid operation is the Default voltage control mode for grid operation. If you click the *Default* button on the Control Mode Setup pop-up window, power factor control mode for grid operation will be the voltage control mode in grid operation. See Subsection 4.6.1 for a description of how to make the selection for the Default group of control modes instead of User Defined control modes.

When you click the *User Defined* button on the Control Mode Setup window, Figure 4.5.2, power factor control mode for grid operation will be the control mode in grid operation only if it is the current, voltage control mode selection for User Defined, grid operation. See Subsection 4.6.3 for how to select User Defined, voltage control modes. See Subsection 4.6.1 for how to select User Defined control modes instead of the Default group of control modes.

REACTIVE POWER CONTROL MODE FOR GRID OPERATION

The reactive power control mode for grid operation can only be active when the generator breaker is closed and the utility breaker is closed.

The goal of the reactive power control mode for grid operation is to hold generator reactive power constant.

When you select reactive power control mode for grid operation, the voltage control mode will automatically and bumplessly go to the reactive power control mode for grid operation whenever the generator breaker is closed and the utility breaker is closed.

When you click the *User Defined* button on the Control Mode Setup window, Figure 4.5.2, reactive power control mode for grid operation will be the control mode in grid operation only if it is the current, voltage control mode selection for User Defined, grid operation. See Subsection 4.6.3 for how to select User Defined, voltage control modes. See Subsection 4.6.1 for how to select User Defined control modes instead of the Default group of control modes.

4.5.3 Run at Rated Voltage and Frequency Control Mode

The Run At Rated Voltage and Frequency control mode

1. locks the unit speed setpoint to the rated speed of the generator when isochronous speed/load control with real load sharing is active.
2. locks the voltage setpoint to the Run at Rated Volts setpoint when reactive load sharing or constant voltage control is active.

When you enable the Run at Rated Volts and Frequency control mode, also referred to as the Run at Rated control mode, it helps other load sharing modes make sure that real and reactive load will be shared equally when the generator operates in load sharing modes.

This feature can be enabled or disabled at any time, but the control system only activates it when the generator set is in island operation, and

- isochronous load/speed control with real load sharing is active (for frequency control).
- constant voltage control with reactive load sharing is active (for voltage control).

The Run At Rated Voltage and Frequency control mode eliminates

- the potential of real power imbalances between parallel units due to operator adjustment of speed and voltage,
- the potential of running the generator at non-nominal frequency and voltage, and
- the need for you to make speed/load adjustments during island operation.

NOTE

When you enable the Run At Rated Voltage and Frequency feature and the control system activates this feature, the control system will not let you make speed setpoint adjustments.

NOTE

When a generator is in offline generator operation, we recommend that you enable the Run At Rated Voltage and Frequency feature before the generator is placed in island operation. This way, when the generator circuit breaker closes and island operation begins, the generator will operate at its rated frequency.

NOTE

While the generator is still in utility (grid) operation, we recommend that you enable the Run At Rated Voltage and Frequency feature. This way, when the utility circuit breaker opens and island operation begins, the generator will operate at its rated frequency.

The Run at Rated Voltage setpoint is *KT_Run_Rated_V_SP*. This is the voltage set point that is effective:

- when the Run at Rated Voltage and Frequency control mode is enabled and
- when the constant voltage with reactive load sharing control mode (island operation) is the generator's voltage control mode.

4.6 GENERATOR CONTROL MODE SELECTION

This section gives you instructions to select generator control modes from the active unit control panel (local).

Refer to Subsection 4.2.1 for procedure to activate the local unit control panel.

You can select these primary control modes:

- Speed/Load Control Mode
- Voltage Control Mode

In addition, you can enable or disable the Run at Rated control mode.

See the functional description for all of these generator control modes in Section 4.5.

4.6.1 Default Control Modes Selection or User Defined Control Modes Selection

This overall selection determines how the following generator control modes operate:

- Speed/Load Control Mode,
- Voltage Control Mode, or
- Run at Rated Control Mode

There are two ways to set the speed/load, voltage, and Run at Rated control modes from Control Mode Select row of buttons on the Control Mode Setup window, Figure 4.5.2 :

1. When you click the *Default* button, generator control modes are set as a factory, predefined group. Speed/load, voltage, and Run at Rated control modes will follow the group of control modes shown on the Control Mode Setup window, Figure 4.5.2, under the heading **Default Control Modes**.
2. When you click the *User Defined* button, speed/load, voltage, and Run at Rated control modes will follow the individual selections shown on the Control Mode Setup window, Figure 4.5.2, under the heading **User Defined Control Modes.**

SELECTION OF DEFAULT GENERATOR CONTROL MODES

This procedure shows you how to select the Default group of generator control modes from the active unit control panel (local).

Refer to Subsection 4.2.1 for procedure to activate the local unit control panel or Subsection 4.3.1 for procedure to activate the auxiliary mult-unit control panel.

1. At the control panel, select the Control System screen, and then click the *Control Mode Setup* button.

NOTE

When you click the *Control Mode Setup* button, the Control Mode Setup window, Figure 4.5.2, appears.

CAUTION

Do not click the *Default* button until you make sure that the Default group of control modes for both island and grid operation are the control modes you want.

2. Look at the top of the Control Mode Setup window. Figure 4.5.2. If the *Default* button is highlighted green and the background of the **Default Control Modes** heading is highlighted and its letters are black, the *Default* button is already selected, and you do not have to do anything. If the *Default* button is dimmed and its letters are gray, click the *Default* button.

NOTE

The *Default* button will highlight green on the Control Mode Select row of buttons.

3. Make sure the background of the **Default Control Modes** heading highlights and its letters are black.

NOTE

You have now selected the Default group of generator control modes for island and grid operation.

4. Go to the Control System screen, and make sure the Default group of control modes for island and grid operation are highlighted yellow in the Voltage Control Mode and Speed/kW Control Mode boxes.

SELECTION OF USER DEFINED CONTROL MODES

This procedure shows you how to select User Defined generator control modes from the active unit control panel (local).

Refer to Subsection 4.2.1 for procedure to activate the local unit control panel or Subsection 4.3.1 for procedure to activate the auxiliary mult-unit control panel.

1. At the control panel, go to the Control System screen, and then click the *Control Mode Setup* button.

NOTE

When you click the *Control Mode Setup* button, the Control Mode Setup window, Figure 4.5.2, appears.

CAUTION

Do not click the *User Defined* button until you make sure that the current, User Defined, control mode selections for island and grid operation are the control mode selections you want.

NOTE

The control mode buttons that are green under the heading **User Defined Control Modes** are the current, individual, User Defined selections.

2. Make sure the individual, User Defined, control mode selections you want are highlighted green.

3. Look at the top of the Control Mode Setup window, Figure 4.5.2. If the *User Defined* button is highlighted green and the background of the **User Defined Control Modes** heading is highlighted and its letters are black, the *User Defined* button is already selected, and you do not have to do anything. If the *User Defined* button is dimmed and its letters are gray, click the *User Defined* button.

NOTE

The *User Defined* button will highlight green on the Control Mode Select row of buttons.

4. Make sure the background of the **User Defined Control Modes** heading highlights and its letters are black

NOTE

You have now made the overall selection of User Defined control modes for island and grid operation.

NOTE

See Subsections 4.6.2 and 4.6.3 for instructions on how to select individual, User Defined, generator control modes.

5. Select the Control System screen, and make sure the individual, User Defined, control mode selections you want for island and grid operation highlight yellow in the Voltage Control Mode and Speed/kW Control Mode boxes.

4.6.2 User Defined Control Mode Selections for Speed/Load Control

The following subsections describe how to select individual, user-defined, speed/load control modes for island and grid operation from the active unit control panel (local).

Refer to Subsection 4.2.1 for procedure to activate the local unit control panel or Subsection 4.3.1 for procedure to activate the auxiliary mult-unit control panel.

See the functional description of these control modes in Subsection 4.5.1.

LOAD/SPEED DROOP CONTROL MODE SELECTION FOR ISLAND OPERATION

1. At the control panel, go to the Control System screen, and then click the *Control Mode Setup* button.

NOTE

When you click the *Control Mode Setup* button, the Control Mode Setup window, Figure 4.5.2, appears.

2. Look at the island operation, Speed/kW row of buttons under the **User Defined Control Modes** heading to see the current selection status. The control mode button that is green is the current, individual, user-defined selection.

3. If the *Droop* button is highlighted green, the *Droop* button is already selected, and you do not have to do anything. If the *Isoch kW Share* button is highlighted green, click the *Droop* button.

4. Make sure the *Droop* button highlights green.

NOTE

If the *User Defined* button is already green and the unit is in island operation when the *Droop* button highlights green, the speed/load control mode will operate in load/speed droop control mode.

5. Go to the Control System screen, and make sure the Droop indicator highlights yellow on the island operation row of the Speed/kW Control Mode box.

LOAD/SPEED ISOCHRONOUS KW SHARE CONTROL MODE SELECTION FOR ISLAND OPERATION

1. At the control panel, go to the Generator screen, and then click the *Control Mode Setup* button.

NOTE

When you click the *Control Mode Setup* button, the Control Mode Setup window, Figure 4.5.2, appears.

2. Look at the island operation, Speed/kW row of buttons under the **User Defined Control Modes** heading to see the current selection status. The control mode button that is green is the current, User Defined selection.

3. If the *Isoch kW Share* button is highlighted green, the *Isoch kW Share* button is already selected, and you do not have to do anything. If the *Droop* button is highlighted green, click the *Isoch kW Share* button.

4. Make sure the *Isoch kW Share* button highlights green.

NOTE

If the *User Defined* button is already green and the unit is in island operation when the *Isoch kW Share* button highlights green, the speed/load control mode will operate in the isochronous kW share control mode.

5. Go to the Control System screen, and make sure the Isoch kW Share indicator highlights yellow on the island operation row of the Speed/kW Control Mode box.

LOAD/SPEED KW/IMPORT CONTROL MODE SELECTION FOR GRID OPERATION

1. At the control panel, go to the Control System screen, and then click the *Control Mode Setup* button.

NOTE

When you click the *Control Mode Setup* button, the Control Mode Setup window, Figure 4.5.2, appears.

2. Look at the grid operation, Speed/kW row of buttons under the **User Defined Control Modes** heading to see the current selection status. The control mode button that is green is the current, User Defined selection.

3. If the *kW/Import* button is highlighted green, the *kW/Import* button is already selected, and you do not have to do anything. If the *Droop* button is highlighted green, click the *kW/Import* button.

4. Make sure the *kW/Import* button highlights green.

NOTE

If the *User Defined* button is already green and the unit is in grid operation when the *kW/Import* button highlights green, the speed/load control mode will operate in the kW/Import control mode.

5. Go to the Control System screen, and make sure the kW/Import indicator highlights yellow on the grid operation row of the Speed/kW Control Mode box.

4.6.3 User Defined Control Mode Selections for Voltage Control

The following subsections give procedures for how to select the User Defined voltage control modes for island and grid operation from the active unit control panel (local).

See the functional description of these control modes in Subsection 4.5.2.

Refer to Subsection 4.2.1 for procedure to activate the local unit control panel or Subsection 4.3.1 for procedure to activate the auxiliary mult-unit control panel.

VOLTAGE DROOP CONTROL MODE SELECTION FOR ISLAND OPERATION

1. At the control panel, go to the Control System screen, and then click the *Control Mode Setup* button.

NOTE

When you click the *Control Mode Setup* button, the Control Mode Setup window, Figure 4.5.2, appears.

2. Look at the island operation, Volt/kVar row of buttons under the **User Defined Control Modes** heading to see the current selection status. The control mode button that is green is the current, User Defined selection.

3. If the *Droop* button is highlighted green, the *Droop* button is already selected, and you do not have to do anything. If the *kVAR Load Share* button or the *Constant Voltage* button is highlighted green, click the *Droop* button.

4. Make sure the *Droop* button highlights green.

NOTE

If the *User Defined* button is already green and the unit is in island operation when the *Droop* button highlights green, the voltage control mode will operate in the voltage droop control mode.

5. Go to the Control System screen, and make sure the Droop indicator highlights yellow on the island operation row of the Voltage Control Mode box.

KVAR LOAD SHARE CONTROL MODE SELECTION FOR ISLAND OPERATION

1. At the control panel, go to the Control System screen, and then click the *Control Mode Setup* button.

NOTE

When you click the *Control Mode Setup* button, the Control Mode Setup window, Figure 4.5.2, appears.

2. Look at the island operation, Volt/kVar row of buttons under the **User Defined Control Modes** heading to see the current selection status. The control mode button that is green is the current, User Defined selection.

3. If the *kVAR Load Share* button is highlighted green, the *kVAR Load Share* button is already selected, and you do not have to do anything. If the *Droop* button or the *Constant Voltage* button is highlighted green, click the *kVAR Load Share* button.

4. Make sure the *kVAR Load Share* button highlights green.

NOTE

If the *User Defined* button is already green and the unit is in island operation when the *kVAR Load Share* button highlights green, the voltage control mode will operate in the constant voltage with reactive load sharing control mode.

5. Go to the Control System screen, and make sure kVAR Load Share indicator highlights yellow on the island operation row of the Voltage Control Mode box.

CONSTANT VOLTAGE CONTROL MODE SELECTION FOR ISLAND OPERATION

1. At the control panel, go to the Control System screen, and then click the *Control Mode Setup* button.

NOTE

When you click the *Control Mode Setup* button, the Control Mode Setup window, Figure 4.5.2, appears.

2. Look at the island operation, Volt/kVar row of buttons under the **User Defined Control Modes** heading to see the current selection status. The control mode button that is green is the current, User Defined selection.
3. If the *Constant Voltage* button is highlighted green, the *Constant Voltage* button is already selected, and you do not have to do anything. If the *Droop* button or the *kVAR Load Share* button is highlighted green, click the *Constant Voltage* button.
4. Make sure the *Constant Voltage* button highlights green.

NOTE

If the *User Defined* button is already green and the unit is in island operation when the *Constant Voltage* button highlights green, the voltage control mode will operate in the constant voltage control mode.

5. Go to the Control System screen, and make sure the Constant Voltage indicator highlights yellow on the island operation row of the Voltage Control Mode box.

VOLTAGE DROOP CONTROL MODE SELECTION FOR GRID OPERATION

1. At the control panel, go to the Control System screen, and then click the *Control Mode Setup* button.

NOTE

When you click the *Control Mode Setup* button, the Control Mode Setup window, Figure 4.5.2, appears.

2. Look at the grid operation, Volt/kVar row of buttons under the **User Defined Control Modes** heading to see the current selection status. The control mode button that is green is the current, User Defined selection.

3. If the *Droop* button is highlighted green, the *Droop* button is already selected, and you do not have to do anything. If the *Power Factor* button or the *kVAR* button is highlighted green, click the *Droop* button.

4. Make sure the *Droop* button highlights green.

NOTE

If the *User Defined* button is already green and the unit is in grid operation when the *Droop* button highlights green, the voltage control mode will operate in the voltage droop control mode.

5. Go to the Control System screen, and make sure the Droop indicator highlights yellow on the grid operation row of the Voltage Control Mode box.

POWER FACTOR CONTROL MODE SELECTION FOR GRID OPERATION

1. At the control panel, go to the Control System screen, and then click the *Control Mode Setup* button.

NOTE

When you click the *Control Mode Setup* button, the Control Mode Setup window, Figure 4.5.2, appears.

2. Look at the grid operation, Volt/kVar row of buttons under the **User Defined Control Modes** heading to see the current selection status. The control mode button that is green is the current, User Defined selection.

3. If the *Power Factor* button is highlighted green, the *Power Factor* button is already selected, and you do not have to do anything. If the *Droop* button or the *kVAR* button is highlighted green, click the *Power Factor* button.

4. Make sure the *Power Factor* button highlights green.

NOTE

If the *User Defined* button is already green and the unit is in grid operation when the *Power Factor* button highlights green, the voltage control mode will operate in Power Factor control mode.

5. Go to the Control System screen, and make sure the Power Factor indicator highlights yellow on the grid operation row of the Voltage Control Mode box.

KVAR CONTROL MODE SELECTION FOR GRID OPERATION

1. At the control panel, go to the Control System screen, and then click the *Control Mode Setup* button.

NOTE

When you click the *Control Mode Setup* button, the Control Mode Setup window, Figure 4.5.2, appears.

2. Look at the grid operation, Volt/kVar row of buttons under the **User Defined Control Modes** heading to see the current selection status. The control mode button that is green is the current, User Defined selection.

3. If the *kVAR* button is highlighted green, the *kVAR* button is already selected, and you do not have to do anything. If the *Droop* button or the *Power Factor* button is highlighted green, click the *kVAR* button.

4. Make sure the *kVAR* button highlights green.

NOTE

If the *User Defined* button is already green and the unit is in grid operation when the *kVAR* button highlights green, the voltage control mode will operate in Reactive Power control mode.

5. Go to the Control System screen, and make sure the kVAR indicator highlights yellow on the grid operation row of the Voltage Control Mode box.

4.6.4 Run At Rated Control Mode Selection

The following subsection describes how to enable or disable the Run At Rated control mode for voltage and frequency.

See the functional description for this control mode in Subsection 4.5.3.

1. At the control panel, go to the Control System screen, and then click the *Control Mode Setup* button.

NOTE

When you click the *Control Mode Setup* button, the Control Mode Setup window, Figure 4.5.2, appears.

2. From the Control Mode Setup window, click the Run at Rated *Enable* button to enable the this control mode, or click the Run at Rated *Disable* button to disable this control mode.

3. Make sure the Run at Rated button that you want, *Enable* or *Disable*, highlights green.

4. Go to the Control System screen, and make sure the value you want, Enabled or Disabled, highlights yellow on the Run Rated V row of the Run at Rated Volts/Frequency box.

4.7 GENERATOR CONTROL SETPOINT ADJUSTMENT

This section gives you instructions to adjust generator control setpoints from the active control panel (local or auxiliary multi-unit).

Refer to Subsection 4.2.1 for procedure to activate the local unit control panel or Subsection 4.3.1 for procedure to activate the auxiliary mult-unit control panel.

This section covers the following three categories of generator control setpoints:

1. Speed/Voltage Setpoints
    - Speed setpoint (external)
    - Speed setpoint (operator)
    - Voltage setpoint (external)
    - Voltage setpoint (operator)
2. Kilowatt Setpoints
    - kW setpoint (external)
    - kW setpoint (operator)
3. Reactive Power Setpoints
    - Power Factor Setpoint
    - kVAR Setpoint

NOTE

An operator setpoint comes from a local, auxiliary, remote, or customer unit control panel.

An external setpoint comes from a hardwired device that sends a 4-20 mA command signal to the unit control panel.

4.7.1 Speed/Voltage Setpoints

SPEED SETPOINT (EXTERNAL)

This subsection gives procedures to enable or disable the external speed setpoint from the active control panel (local or auxiliary multi-unit).

Procedure To Enable The External Speed Setpoint

1. At the control panel, go to Control System screen, and look at the bottom of the Voltage Control Mode box to decide if the current, Run at Rated control mode status is what you want.

NOTE

It is possible to enable the external speed setpoint at any time, but if the Run at Rated control mode is enabled and the unit's active control mode is isochronous kW share control mode, the Run at Rated Voltage and Frequency control mode will override the external speed/load setpoint. To enable or disable this feature, refer to the Run At Rated Control Mode Selection procedure in Subsection 4.6.4.

See the functional description for the Run At Rated Control Mode in Subsection 4.5.3.

2. Go to the Control System screen, and then click the *Set Points* button.

NOTE

When you click the *Set Points* button, the Set Points window appears.

Figure 4.7.1 Setpoints Window

3. From the Set Points window, click the External Setpoints, Speed *Enable* button. Click *OK* to confirm your selection.

NOTE

The External Setpoints, Speed *Enable* button will highlight green.

4. Make sure **Enabled** text is highlighted on the Set Points window.

Procedure To Disable The External Speed Setpoint

1. At the control panel, go to Control System screen, and look at the bottom of the Voltage Control Mode box to decide if the current, Run at Rated control mode status is what you want.

NOTE

It is possible to disable the external speed setpoint at any time, but if the Run at Rated control mode is enabled and the unit's active control mode is isochronous kW share control mode, the Run at Rated Voltage and Frequency control mode will override the external speed/load setpoint. To enable or disable this feature, refer to the Run At Rated Control Mode Selection procedure in Subsection 4.6.4.

See the functional description for the Run At Rated Control Mode in Subsection 4.5.3.

2. Go to the Control System screen, and then click the *Set Points* button.

NOTE

When you click the *Set Points* button, the Set Points window, Figure 4.7.1, appears.

3. From the Set Points window, Figure 4.7.1, click the External Setpoints, Speed *Disable* button. Click *OK* to confirm your selection.

NOTE

The External Setpoints, Speed *Disable* button will highlight green.

4. Make sure **Disabled** text is highlighted on the Set Points window, Figure 4.7.1.

SPEED SETPOINT (OPERATOR)

This subsection gives steps to change the speed setpoint from the active control panel (local or auxiliary multi-unit).

Procedure to adjust the Speed Setpoint From The Local Unit Control Panel

1. Go to the Control System screen, and then click the *Set Points* button.

NOTE

When you click the *Set Points* button, the Set Points window, Figure 4.7.1, appears.

2. Look at the bottom of the Set Points window, Figure 4.7.1, to decide if the current status of the external speed setpoint is what you want.

NOTE

You cannot change the operator speed setpoint (local, auxiliary, or remote) if the external speed setpoint is enabled. To disable the external speed setpoint, refer to the external speed setpoint procedure.

3. If isochronous kW share control mode is active, go to the Control System screen, and look at the bottom of the Speed/kW Control Mode box to make sure that the Run at Rated control mode is not enabled.

NOTE

The Run at Rated Voltage and Frequency Control Mode will override the operator speed/load setpoint if isochronous kW share control mode is active.

See the functional description for the Run At Rated Control Mode in Subsection 4.5.3.

NOTE

If isochronous kW share control mode is active, you must disable the Run at Rated Control Mode before you can adjust the speed/load setpoint. To disable the Run At Rated Control Mode refer to the procedure in Subsection 4.6.4.

4. Obey the following WARNING:

⚠ WARNING

In the following step, when you make an entry for the speed/load control setpoint, do not exceed system frequency limits.

5. Choose one of the following methods to adjust the speed setpoint:

   a. To change the speed setpoint from the Set Points window, Figure 4.7.1:

      (1) Click the shown value for Speed.

NOTE

The LSP_Speed input window appears.

NOTE

To adjust the speed setpoint from the remote unit control panel, you must first enter a user name and password.

(2) Make a new entry in the value field so that the generator achieves the required speed/load output.

(3) Click the *OK* button to confirm your input.

(4) Make sure the new value appears on the Set Points window, Figure 4.7.1.

b. To adjust the speed setpoint from the Unit Control Panel, turn and hold the SPEED INCREASE/DECREASE Switch (S154) to the right to increase the speed setpoint, or turn and hold the SPEED INCREASE/DECREASE Switch to the left to decrease the speed setpoint

c. To adjust the speed setpoint from the Auxiliary Multi-Unit Control Panel, press the DECREASE (Down Arrow) Switch (S1055) or press the INCREASE (Up Arrow) Switch (S1054) so that the generator achieves the required speed/load output.

VOLTAGE SETPOINT (EXTERNAL)

This subsection gives procedures to enable or disable the external voltage setpoint from the active control panel (local or auxiliary multi-unit).

Procedure To Enable The External Voltage Setpoint

1. At the control panel, select the Control System screen, and look at the bottom of the Voltage Control Mode box to decide if the current Run at Rated control mode status is what you want.

NOTE

It is possible to enable the external voltage setpoint at any time, but if the Run at Rated control mode is enabled and the unit is operating in constant voltage with reactive load sharing control mode (kVAR LS), the Run at Rated control mode will override the external voltage setpoint. To enable or disable this feature, refer to the Run At Rated Control Mode Selection procedure in Subsection 4.6.4.

See the functional description for the Run At Rated Control Mode in Subsection 4.5.3.

2. Go to the Control System screen, and then click the *Set Points* button.

NOTE

When you click the *Set Points* button, the Set Points window, Figure 4.7.1, appears.

3. From the Set Points window, Figure 4.7.1, click the External Setpoint, Voltage *Enable* button. Click *OK* to confirm your selection.

NOTE

The External Setpoint, Voltage *Enable* button will highlight green.

4. Make sure **Enabled** text highlights on the Set Points window, Figure 4.7.1.

Procedure To Disable The External Voltage Setpoint

1. At the unit control panel, select the Control System screen, and look at the bottom of the Voltage Control Mode box to decide if the current Run at Rated control mode status is what you want.

NOTE

It is possible to disable the external voltage setpoint at any time, but if the Run at Rated control mode is enabled and the unit is operating in constant voltage with reactive load sharing control mode (kVAR LS), the Run at Rated control mode will override the operator voltage setpoint. To enable or disable this feature, refer to the Run At Rated Control Mode Selection procedure in Subsection 4.6.4.

See the functional description for the Run At Rated Control Mode in Subsection 4.5.3.

2. Go to the Control System screen, and then click the *Set Points* button.

NOTE

When you click the *Set Points* button, the Set Points window, Figure 4.7.1, appears.

3. From the Set Points window, Figure 4.7.1, click the External Setpoint, Voltage *Disable* button. Click *OK* to confirm your selection.

NOTE

The External Setpoint, Voltage *Disable* button will highlight green.

4. Make sure **Disabled** text highlights on the Set Points window, Figure 4.7.1.

VOLTAGE SETPOINT (OPERATOR)

This subsection gives steps to change the voltage setpoint from the active unit control panel (local or auxiliary multi-unit).

Procedure to adjust the Voltage Setpoint From The Unit Control Panel

1. Go to the Generator screen, and then click the *Set Points* button.

NOTE

When you click the *Set Points* button, the Set Points window, Figure 4.7.1, appears.

2. Look at the bottom of the Set Points window, Figure 4.7.1, to decide if the current status of the external voltage setpoint is what you want.

NOTE

You cannot change the operator voltage setpoint (local, auxiliary, or remote) if the external voltage setpoint is enabled. To disable the external voltage setpoint, refer to the external voltage setpoint procedure.

3. Go to the Control System screen, and look at the bottom of the Speed/kW Control Mode box to make sure that the Run at Rated control mode is disabled.

NOTE

You must disable the Run at Rated control mode before you can adjust the voltage setpoint. To disable the Run At Rated Control Mode refer to the procedure in Subsection 4.6.4.

4. Obey the following WARNING:

⚠ WARNING

In the following steps, when you make an entry for the voltage setpoint, do not exceed system limits.

5. Choose one of the following methods to adjust the voltage setpoint from the control panel.

    a. To change the voltage setpoint from the Set Points pop-up window:

        (1) Click the shown value for Voltage.

NOTE

The Setpoint. LSP_Voltage input window appears.

(2) Make a new entry in the value field so that the generator achieves the required voltage output.

(3) Click the *OK* button to confirm your input.

(4) Make sure the new value appears on the Set Points window, Figure 4.7.1.

b. To adjust the speed setpoint from the Unit Control Panel, turn and hold the VOLTAGE INCREASE/DECREASE Switch (S152) to the right to increase the speed setpoint, or turn and hold the VOLTAGE INCREASE/DECREASE Switch to the left to decrease the speed setpoint so that the generator achieves the desired output voltage

c. To adjust the speed setpoint from the Auxiliary Multi-Unit Control Panel, press the VOLTAGE DECREASE Switch (S/DSP1053) or press the VOLTAGE INCREASE Switch (S/DSP1052) so that the generator achieves the desired output voltage.

4.7.2 Kilowatt Setpoints

KW SETPOINT (EXTERNAL)

This subsection gives procedures to enable or disable the external kW setpoint from the active unit control panel (local or auxiliary multi-unit).

Procedure To Enable The External Kilowatt Setpoint

1. Go to the Control System screen, and then click the *Set Points* button.

NOTE

When you click the *Set Points* button, the Set Points window, Figure 4.7.1, appears.

2. From the Set Points window, Figure 4.7.1, click the External Setpoint, Real Power *Enable* button. Click *OK* to confirm your selection.

NOTE

The External Setpoint, Real Power *Enable* button will highlight green.

3. Make sure **Enabled** text highlights on the Set Points window, Figure 4.7.1.

Procedure To Disable The External Kilowatt Setpoint

1. Go to the Control System screen, and then click the *Set Points* button.

NOTE

When you click the *Set Points* button, the Set Points window, Figure 4.7.1, appears.

2. From the Set Points window, click the External Setpoint, Real Power *Disable* button. Click *OK* to confirm your selection.

NOTE

The External Setpoint, Real Power *Disable* button will highlight green.

3. Make sure **Disabled** text highlights on the Set Points window, Figure 4.7.1.

KW SETPOINT (OPERATOR)

This subsection gives steps to adjust the kilowatt (kW) setpoint from the active control panel (local or auxiliary multi-unit).

1. Go to the Control System screen, and then click the *Set Points* button.

NOTE

When you click the *Set Points* button, the Set Points window, Figure 4.7.1,appears.

2. Look at the bottom of the Set Points window, Figure 4.7.1, to decide if the current status of the external kW setpoint is what you want.

NOTE

You cannot change the operator kW setpoint (local, auxiliary, or remote) if the external kW setpoint is enabled. To disable the external kW setpoint, refer to the external kW setpoint procedure.

3. To change the kW setpoint from the Set Points window, Figure 4.7.1, click the shown value for Generator Real Power.

NOTE

The Setpoint. LSP_kW pop-up window appears.

4. Obey the following WARNING:

⚠ WARNING

In the following step, when you make an entry for the kW setpoint, do not exceed system limits.

5. Make a new entry in the value field so that the generator achieves the required real power output.

6. Click the *OK* button.

7. Make sure the new value appears on the Set Points window, Figure 4.7.1.

4.7.3 Reactive Power Setpoints

POWER FACTOR SETPOINT

This subsection gives steps to adjust the Power Factor setpoint from the active control panel (local or auxiliary multi-unit).

1. Go to the Generator screen, and then click the *Set Points* button.

NOTE

When you click the *Set Points* button, the Set Points pop-up window appears.

2. To change the PF setpoint from the Set Points window, Figure 4.7.1, click the shown value for Generator Power Factor.

NOTE

The Setpoint. LSP_PF input window appears.

3. Obey the following WARNING:

WARNING

In the following step, when you adjust the PF setpoint, do not exceed system reactive power limits.

NOTE

In the following step, a positive setpoint value signifies a power factor that lags, and a negative setpoint value signifies a power factor that leads.

4. Make a new entry in the value field for the lead or lag of Power Factor that you want.

5. Click the *OK* button.

6. Make sure the new value appears on the Set Points window, Figure 4.7.1.

KVAR SETPOINT

This subsection gives steps to adjust the kVAR setpoint from the active control panel (local or auxiliary multi-unit).

1. Go to the Control System screen, and then click the *Set Points* button.

NOTE

When you click the *Set Points* button, the Set Points window, Figure 4.7.1, appears.

2. To change the kVAR setpoint from the Set Points window, Figure 4.7.1, click the shown value for Generator Reactive Power.

NOTE

The Setpoint. LSP_kVAR input window appears.

3. Obey the following WARNING:

WARNING

In the following step, when you adjust the kVAR setpoint, do not exceed system VAR limits.

4. Make a new entry in the value field for the absorption or the production of reactive power that you want.

NOTE

Use a positive setpoint when you want the generator to produce reactive power (reactive power that lags). Use a negative setpoint when you want the generator to absorb reactive power (reactive power that leads).

5. Click the *OK* button.

6. Make sure the new value appears on the Set Points window, Figure 4.7.1.

4.8 GENERATOR SYNCHRONIZATION

Do the following steps to automatically synchronize the generator to the bus from the active control panel.

Refer to Subsection 4.2.1 for procedure to activate the local unit control panel or Subsection 4.3.1 for procedure to activate the auxiliary mult-unit control panel.

NOTE

Before you do the generator synchronization procedure, the Ready to Load status indication must appear on the screen's banner.

NOTE

Make sure the current status for Dead Bus Synchronization is what you want. Refer to Subsection 4.8.1 for more information about Dead Bus Synchronization.

1. Make sure you configure the appropriate speed/load and voltage control modes. Refer to Subsections 4.6.1, 4.6.2, and 4.6.3.

2. At the control panel, make sure the Ready to Load status indication appears on the screen's banner.

3. Go to the Generator screen, and make sure the generator circuit breaker is open.

NOTE

Make sure the cumulative load of the switchgear feeder circuit breakers will not overload the generator. Open the individual switchgear feeder circuit breakers if necessary.

Figure 4.8.1 Generator Screen

4. Click the *Auto Sync* button to initiate Auto Sync and close the generator circuit breaker.

5. Click the *Auto Sync* text directly under the *Auto Sync* button. An Auto Sync window opens. Make sure Auto Sync In Progress status indication highlights on the Auto Sync window.

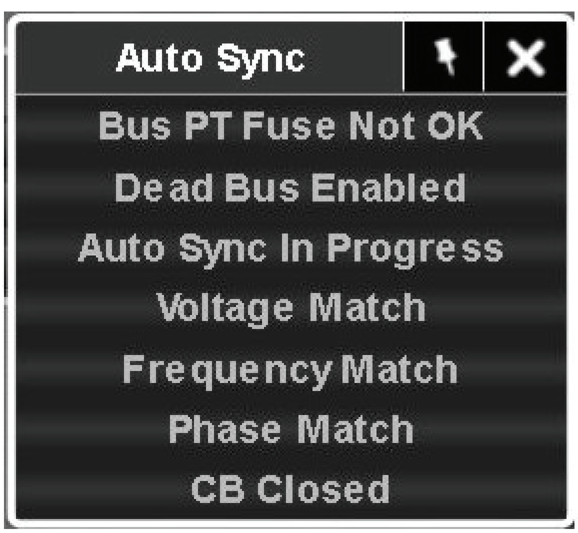


Figure 4.8.2 Auto Sync Window

NOTE

While it is in the synchronization cycle, the control system will bring the generator frequency within ± 0.10 Hz of the bus frequency, the voltage within ± 1.0 percent of the bus voltage, and the phase rotation within ± 5 degrees of the bus phase before it closes the generator circuit breaker.

If the generator circuit breaker fails to close within 30 seconds, the Auto Sync In Progress status indication on the Auto Sync pop-up window will extinguish, and an Auto Sync Fail alarm will appear on the Alarm Bar of the screen. If the Auto Sync Fail alarm appears on the Alarm Bar, go to the screen's banner, and click the *TCP* button; the Turbine Control Panel window will appear. From the Turbine Control Panel window, Figure 4.5.2, press the *Ack.* button, and then press the *Reset* button before you repeat Steps 4 and 5 until the generator synchronizes to the bus.

6. Make sure the On Load status indication appears on the screen's banner.

4.8.1 Dead Bus Synchronization

The goal of Dead Bus Synchronization is to prevent accidental closure of the generator breaker to a dead bus.

When you click the *Auto Sync* button on the Generator screen, Figure 4.8.1, there are three possibilities:

1. If the control system detects a live bus, the automatic synchronization sequence starts.
2. If the control system detects a dead bus and you have dead bus synchronization disabled, the control system does not let the generator breaker close to the dead bus.

CAUTION

You must always keep Dead Bus Synchronization disabled if your plant's standard operating procedures let the generator breaker close only to a live bus.

3. If the control system detects a dead bus and you have dead bus synchronization enabled, the control system will let the generator close to the dead bus.

CAUTION

You must only enable Dead Bus Synchronization if your plant's standard operating procedures include the possibility of letting the generator breaker close to a dead bus.

Procedure to Disable Dead Bus Synchronization

1. Go to the Maintenance screen and click the *Dead Bus Synch* button under System Configuration.

NOTE

When you click the *Dead Bus Synch* button, the Dead Bus Synchronization window appears.

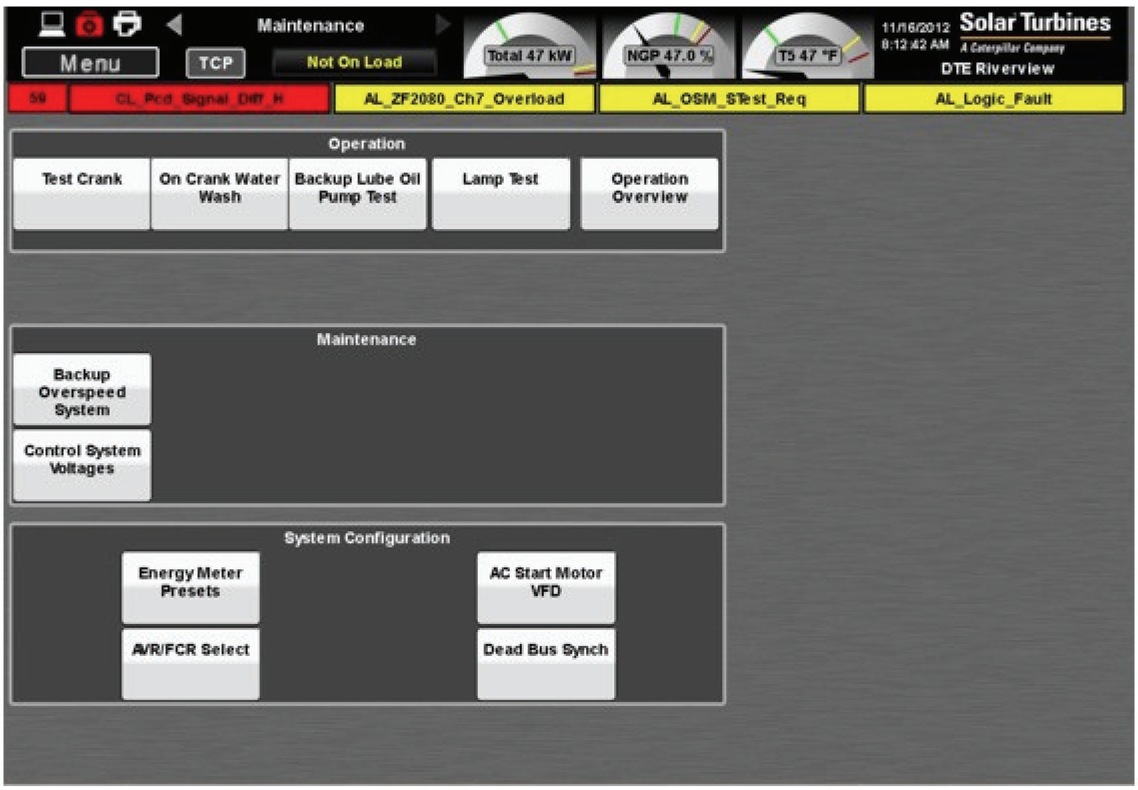


Figure 4.8.3 Maintenance Screen

2. From the Dead Bus Synchronization window, click the *Disable* button to disable dead bus synchronization.

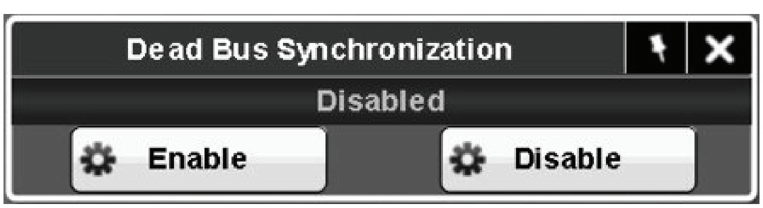


Figure 4.8.4 Dead Bus Synchronization Window

3. Make sure the *Disable* button turns green and the status indication Disabled highlights on the Dead Bus Synchronization window.

NOTE

When the Dead Bus Autosync *Disable* button is green and the Disabled indicator highlights on the Dead Bus Synchronization window, the control system will not let the generator breaker close to the dead bus.

Procedure to Enable Dead Bus Synchronization

1. Go to the Maintenance screen, Figure 4.8.3, and click the *Dead Bus Synch* button.

NOTE

When you click the *Dead Bus Synch* button, the Dead Bus Synchronization window, Figure 4.8.4, appears.

CAUTION

Before you enable Dead Bus Synchronization, contact your plant Maintenance group. Your maintenance group must visually examine bus fuses, and make sure the bus is safe to energize.

2. On the Dead Bus Synchronization window, Figure 4.8.4, click the *Enable* button to enable dead bus synchronization.

3. Make sure the *Enable* button turns green and the status indication Enabled highlights on the Dead Bus Synchronization window.

NOTE

When the Dead Bus Autosync *Enable* button is green and the status indication Enabled highlights on the Dead Bus Synchronization window, Figure 4.8.4, the control system will close the generator breaker to the dead bus when the you initiate the automatic synchronization process.

4.9 MANUAL TRIP OF GENERATOR CIRCUIT BREAKER

Do the following procedure to manually open (trip) the generator circuit breaker from the control panel.

1. At the unit control panel, go to the Generator screen, Figure 4.8.1, and click the *Open* button.

NOTE

The Generator Circuit Breaker Trip window will appear.

2. From Generator Circuit Breaker Trip window, click the *Ok* button to confirm your selection and open the generator circuit breaker.
3. Look at the Generator screen, Figure 4.8.1, and make sure you see the graphic for the generator circuit breaker move to the open position.

