Solar Turbines
A Caterpillar Company

**MARS 100 TURBINE GENERATOR SET**

The *Mars* 100 turbine generator set is a completely integrated, fully operational package consisting of a power module, a generator module, and all accessories and auxiliary systems necessary for normal operation when connected to suitable facilities.

Designed specifically for industrial service, the generator set is a relatively compact, lightweight unit requiring minimum floor space for installation. Proven packaging features greatly reduce installation costs, time, materials, and labor.

The generator set includes:

- *Mars* 100 two-shaft industrial turbine engine
- Engine air inlet and exhaust collectors
- Epicyclic main reduction-drive gearbox
- Generator
- Turbine / generator control system
- Start system
- Fuel system
- Lubricating oil system
- 316L stainless steel piping and manifolds
- Radiographic inspection (5%) of applicable system piping and manifolds
- Base skid(s)
- Onskid electrical wiring
- Onskid digital display

The engine, gearbox and generator constitute the major elements of the package. These elements are installed on separate heavy-steel base frames in an in-line arrangement with the engine and gearbox on the driver module and the generator and oil tank on the generator module. The base frames are structural steel assemblies with beam sections and cross members welded together to form a rigid foundation. Full drip pans are seal welded beneath both frames for collection of any potential liquid spillage and to provide a tight seal for containment of fire suppression agent for packages supplied with an acoustical enclosure. The drip pans are constructed from a minimum of ¼-in. thick carbon steel plate and are formed with slopes to facilitate drainage to dedicated two-inch NPT drain connections at the skid edge. Mechanical interface connection points for fuel, air, and water are conveniently located on the outer skid edge. Electrical connection points are made in onskid junction boxes and terminal strips.

The generator is driven by the gas turbine via a speed-reducing gearbox. The engine is coupled to the gearbox by means of a high-speed shaft splined at both ends. The shaft is a matched part of the gearbox. The gearbox and generator are connected by means of a limited end float, flexible, disk-type dry coupling enclosed in a coupling guard. Jacking points are provided to facilitate alignment of the engine and generator to the gearbox.

Package piping and manifolds are 316L stainless steel material. This applies to all package piping systems, including the start, fuel, lube oil and wet and dry seal systems, and the supply, drain and vent lines. In addition, the associated flange assembly hardware is 316 stainless steel or equivalent. All tubing connections use dual ferrule compression fittings (Swagelok brand). All tubing is 316L stainless steel with 316 stainless steel fittings.

The following items are not stainless steel unless specifically included elsewhere in this proposal:

- Valve bodies and system functional components
- Pipe support brackets
- Oil tank cover assemblies with connection piping and fittings welded in place
- Sliding lube oil drain couplings
- Pipe flexible couplings
- Filter housings
- Lube oil tank
- Weld studs, engine hardware, some structural (load bearing) hardware and some component hardware

Radiographic inspection of the gas fuel (as applicable) and lube oil system piping and manifolds is performed in accordance with ASME Section V. 5% of each welder's work (circumferential butt weld only) is inspected by radiographic examination in accordance with ANSI / ASME B31.3. The specific manifolds on a given unit may or may not be part of the 5% of each welder's work that is examined.

Throughout this proposal, all references to package orientation (left, right, clockwise, counterclockwise, etc.) are based on standing at the "aft" end of the package looking forward. The aft end of the package is always the same end as the turbine engine exhaust.

**Hand Off Automatic Switch**

All continuous duty AC motors to have Hand-Off-Auto (HOA) switches located near the motor.

All continuous duty AC motors to have Hand-Off-Auto (HOA) switches located near the motor. Switches to be spring return to Off from the Hand position.
Solar will also supply a lockable (with Pin and chain) Stop Button on the HOA control box.

Note, these switches are for motor maintenance convenient access. They break the Solar command to start a motor, it is not a replacement for proper electrical isolation prior to maintenance.
This CF does not include the back up lube pump or the DAC start motor.

**High ambient Motors**

This package motors will be modified to operate in an onshore environment where the ambient temperature will be 55 deg C.

Project specific continuous duty motors will be required to be suitable for use with a 55 degree ambient.

**IEC Cable to NEC motor connections**

Junction arrangements for IEC cables on NEC package motor connections. Provide 3-way conduit box for each motor for IEC cable connect to NEC motor.

**MCT Cable Entries for NEC Package**

MCT cable entrys are supplied for customer electrical skid connections in lieu of conduit fittings at the skid edge.

Direct customer cable connections are provided to the package motors and customer connection points through skid edge MCT's and cable trays. 3 way J boxes are provided at package motors. Gland plates are provided on package junction boxes.

**Stainless Steel Instrument Tags**

316SS stainless steel tags are provided for on-skid instruments and hydromechanical components.

The tags are cross referenced with Solar device identification numbers as listed on the hydromechanical schematic and/or electrical schematic drawings, this includes the enclosure devices.

The tags are permanently affixed to the body of the instrument or attached by stainless steel wire.

**NEC Class I, Group D, Division 2**

Onskid electrical equipment is in accordance with NFPA 70 (NEC) requirements for electrical equipment installed in Class I, Group D, Division 2 hazardous locations. All on-skid package wiring is made with cable in covered stainless steel cable trays for physical protection. When supplied, the turbine control console, variable frequency drives, and battery charger are nonexplosionproof and must be installed in a nonhazardous location.

**415 Volt, 50 Hz, 3-Phase AC Power Rating**

The package 3-phase motors and other 3-phase electrical components are rated for 415-Vac, 50-Hz electric power. The required 3-phase contactors are not provided. Refer to the package electrical utilities list for power requirements.

**240 Volt, 50/60 Hz, Single-Phase AC Battery Charger Power Rating**

The package battery charger is rated for 240-Vac, 50/60-Hz electric power. Refer to the package electrical utilities list for power requirements.

**Unsealed NiCd batteries**

Solar will provide un-sealed Ni-Cad batteries similar to our legacy product to fulfill customer requirement.

**240 Volt, 50 Hz, Single-Phase AC Lighting and Space Heater Power Rating**

The package single-phase lighting and heater loads are rated for 240 VAC, 50 Hz electric power. Refer to the package electrical utilities list for power requirements.

# GAS TURBINE ENGINE

## MARS 100 GAS TURBINE

The *Mars* 100 gas turbine engine is a self-contained, completely integrated prime mover of two-shaft, axial-flow design. The gas producer and power turbines have separate shafts and are mechanically independent.

The engine assembly consists of:

- Air inlet collector with flexible flange connection
- Axially split case in the vertical plane, 15-stage axial-flow compressor with variable geometry on the inlet guide vanes and first five rows of stators
- Annular combustor with 21 fuel injectors
- 2-stage gas producer turbine assembly
- 2-stage power turbine assembly
- Turbine exhaust collector

The continuous power cycle and rotating motion of the gas turbine provides several advantages over other types of engines, including lightweight, relatively low maintenance, fewer moving parts and wear points, and a higher quality of ac power in generator applications.

The turbine produces compressed air from the compressor, combustion within the combustion chamber, and power delivery from the four-stage turbine assembly. The axial-flow aerothermal design contributes to the unit's high efficiency. Additionally, cycle parameters have been selected and the aerodynamic design of each section has been executed to attain the highest possible performance consistent with reliable service and long life in industrial applications.

The exceptionally compact *Mars* 100 gas turbine engine has four basic sections: compressor, combustor, gas producer turbine, and power turbine.

Air is drawn into the air inlet of the gas turbine and is compressed by the 15-stage axial-flow compressor. The compressed air is directed into the combustion chamber in a steady flow. Fuel is injected into the pressurized air within the annular combustion chamber. During the turbine start cycle, this fuel / air mixture is ignited and continuous burning is maintained as long as there is adequate flow of pressurized air and fuel. The hot pressurized gas from the combustion chamber expands through the two stages of the gas producer turbine to provide power to the 15-stage compressor.

Gases leaving the gas producer turbine then flow through the two-stage power turbine where the remaining energy of the gas stream is absorbed by the power turbine and is transferred to the output shaft. In generator drive applications, the power turbine runs at a constant speed determined by the control system speed (generator output frequency) set point. This constant power turbine speed control varies the fuel flow to the combustor, resulting in a variable gas producer speed dependent on power level. Protective controls guard against power turbine overspeed in the event of a sudden load reduction.

For stoichiometric combustion, the gas turbine requires approximately one fourth of the total air it compresses. 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 turbine stage. The cooling air keeps metal temperatures in the combustion chamber and turbine section at design levels consistent with component service life objectives.

**Up Inlet Orientation**

The gas turbine air inlet flange terminates in the up position.

**Up Exhaust Orientation**

The gas turbine exhaust flange terminates in the up position.

**Turbine Rating Match at 50°C (122°F)**

For a two-shaft gas turbine engine, by definition, the engine gas producer design speed and design turbine rotor inlet temperature occur simultaneously at the "match point" ambient temperature. The gas turbine engine third-stage turbine nozzle geometry (vane angles and flow area) is configured to provide the match point when operating with a 50°C (122°F) engine air inlet temperature. The engine is controlled to operate at maximum continuous speed and reduced temperature when ambient temperature is below the match point and at reduced gas producer speed and maximum continuous design temperature when ambient temperature is above the match point.

## GEARBOX

**1500 rpm Main Reduction Drive for 50-Hz Generator**

The main reduction-drive gearbox is an epicyclic star-gear industrial design selected specifically for the generator set application. The gearbox is coupled to the turbine through a balanced high-speed shaft, splined at both ends. The epicyclic design facilitates a straight-through shafting arrangement, avoiding offset problems and permitting engine, gear, and generator alignment from a common base. Gear lubrication is provided by the package common lube oil system.

The gearbox reduces the output speed of the turbine to the required operating speed of the generator and is designed for continuous-duty operation at an output speed of 1500 rpm for 50-Hz service.

The output shaft is coupled to the generator through a flexible disk-type dry coupling enclosed in a coupling guard.

Included features of the gearbox are:

- API 613 compliant, where applicable
- AGMA rating in excess of 1.10 for generator applications and up to six times full-load under short-circuit conditions
- Designed for 100,000-hour gear life with 30,000 hours between major inspections
- The gears can be serviced without moving the main case.

## GENERATOR

Synchronous Brushless Revolving Field Generator with a direct connected Rotating Brushless Exciter, in accordance with the following specifications:

Code: 4P63-5000
Type: 4 Pole, 1500RPM
Power Supply: 3 Phase / 50HZ / 11,000Volts
Kilowatt: 8800KW in a 40 0C ambient
KVA: 11,000KVA in a 40 0C ambient
Power Factor: 0.8
ConnectionsTemp. Rise: 6 Wire, Wye800C Rise by Resistance / 400C (B-Rise)
Insulation: Class F with VPI
Duty: Continuous
Bearings: Dual Split Sleeve, Oil Lubrication
Enclosure: WP-II / IP24

The generator will be of independent two bearing design with a shaft extension suitable for direct drive by a turbine engine, and will include the following standard accessories per the Solar Turbines contract with Kato Engineering.

- Permanent magnet alternator·
- Space heaters, 120/240V, 1 phase
- Stator winding RTD's, 2/phase, 100 ohm platinum·
- Oversized terminal box
- Stainless steel nameplates
- WP-II Enclosure IP24/85DBA AT 1 meter no load
- Neutral Ground Resistor 10 second rating shipped loose in a NEMA 3R/IP23, Mill Galvanized Steel enclosure (includes Ground Fault C.T.). Note, Customer to advise the 10 second amperage rating for the NGR and GFCT ratio. NGR is intended to be mounted in a safe / non-hazardous environment.
- (3) Model ITI 780I, Differential Fault C.T.s with a 1000:5 Ratio mounted in the main terminal box and (3) shipped loose
    - Model ITI 780I, Cross Current Compensation C.T. with a 1000:5 Ratio mounted in the main terminal box
    - Model ITI 780I, Metering C.T.s with a 1000:5 Ratio mounted in the main terminal box
- Space Heater (1-Ph/ 50Hz/ 120/240V) in the exciter and main terminal box
- Bently Nevada X Y Proximity Probes 3300 Series (1-set/bearing)
- Key Phaser
- Bearing RTD's 100 Ohm Platinum (1/bearing)
- Single side mounted (LSVFEE) IP56 main terminal box (Carbon Steel painted the Solar color) with provisions for bottom lead entry
- Generator Lateral Analysis
- Routine Testing per NEMA MG-1, IEEE 115, IEC - 34 and Solar specification ES-2033 Rev. G (Non-witnessed/Observed only by Solar).
- Special sound attenuation designed for 85 dBA at 1 meter is required

Testing (Non-witnessed/Observed only by Solar), including Item 16 above, of the following to be performed on the first unit only : Full load heat run (4 hours), Hot winding resistance measurement, Hot spot temperature tests, Calculation of efficiency at 50%, 75% & 100% load, Bearing temperature rise, Winding insulation resistance before and after heat run, Full load wave analysis, Voltage and current phases balance, Over speed test.

## START SYSTEM

The start system provides torque to initiate rotation and assist the engine to self-sustaining speed. At self-sustaining speed, the start system disengages and the engine continues to accelerate under its power to loading speed.

### DIRECT-DRIVE AC MOTOR DRIVEN

The direct-drive ac start system consists of a squirrel-cage, 3-phase ac induction motor with a solid-state variable frequency drive (VFD).

#### Start Motor

The start motor is specifically designed to provide high breakaway starting torque and acceleration from stand-still to starter drop-out speed. The motor is of explosionproof / flameproof construction and standard motor frame size. The motor has integral over-temperature protection thermostats that must be connected to the *Turbotronic*™ 4 control system for hazardous area motor certification and protection. The motor includes a space heater suitable for 115 / 230-volt, single-phase power connection. Separate cable / conduit entries are provided for power connections, thermal protection wiring, and the space heater wiring. The start motor is connected directly to the engine gas producer through an overrunning clutch and shaft assembly.

#### Variable Frequency Drive

The VFD provides a pulse-width modulated variable frequency / variable voltage to the start motor. The VFD requires a supply of 3-phase ac power from 380 to 600 Vac ±5% and 50 to 60 Hz ±2 Hz with a minimum current capacity of 231 amps for 380-to-480 volt supply and 287 amps for 500-to-600 volt supply.

If supply voltage is greater than 600 ±5%, the use of a step-down power transformer is suggested. Operating power factor is a nominal 0.96 with an efficiency of 98%.

The VFD regulates the voltage and frequency to the start motor as required to initiate engine rotation, accelerate to purge speed, and then accelerate to ignition and starter drop-out speed as commanded by the *Turbotronic* 4 control system. The system is capable of performing up to six start attempts per hour, as well as extended purge cycles for heat recovery unit applications and engine water or detergent wash cycles.

The VFD cabinet is loose shipped for installation offskid in a nonhazardous location and provides for direct across-the-line starting control of the motor. Electrical disconnects and overcurrent protection devices are the responsibility of the purchaser. The approximate VFD dimensions for a 380-to-480 volt system are 1457 mm (57.4 in.) high by 465 mm (18.3 in.) wide by 355 mm (14 in.) deep with a weight of 96 kg (211 lb) and for a 500-to-600 volt system are 1499 mm (59 in.) high by 511 mm (20.1 in.) wide by 424 mm (16.7 in.) deep with a weight of 186 kg (410 lb) .

#### Electrical Classification / Certification

The motor and VFD are furnished by a common manufacturer to ensure total system compatibility. In order to maintain hazardous area certification validity and overall system compatibility, it is not possible to change the manufacturer of either the motor or the VFD. With the VFD installed in a suitable safe location, the system is certified to both NEC / UL / CSA and IEC / CENELEC codes for NEC Class I, Group D, Division 1 location and IEC Zone 1 EExde IIA, both to T3 temperature code. In addition, the VFD bears the CE safety mark for European installations.

**Power Wiring**

Requires 3-phase ac power wiring to the VFD and from the VFD to the starter motor. The maximum ac line distribution capacity is 1000 kVA. The maximum symmetrical fault current capacity of the VFD is 30,000 amps. Feeder circuits exceeding this limit require the use of an isolation transformer, line reactor, or other means of adding similar impedance to limit fault current. The power cable run from the VFD to the motor should not exceed 180 m (600 ft). Longer cable runs (thus larger cable) can be accommodated with the addition of an onskid marshaling box at additional cost. Optional motor space heater wires if applicable.

**Control Wiring**

- 380-to-480 volt systems:
  - Motor to VFD, two wires for motor thermal protection thermostats
  - *Turbotronic* 4 control to VFD, one or two BNC cables for control via ContolNet
- 500 to 600 volt systems:
  - Motor to *Turbotronic* 4 control, two wires for motor thermal protection thermostats
  - *Turbotronic* 4 control to VFD, six wires for control

All wiring requirements are documented on Solar's project electrical drawings.

## FUEL SYSTEM

The fuel system, in conjunction with the electrical control system, includes all necessary components to control ignition and fuel flow during all modes of operation.

### NATURAL GAS

A NACE compliant natural gas fuel system with all components necessary to control the fuel according to load requirements.

The natural gas fuel system includes:

- Supply pressure transmitter
- Pilot air operated primary fuel shutoff valve
- Pilot air operated secondary fuel shutoff valve
- Pilot air operated gas vent valve
- Pilot air valves
- Torch with associated shutoff valve and regulators
- Electrically activated fuel control valve
- Main fuel manifold
- Engine fuel injector assemblies
- 316 stainless steel piping, manifolds and tubing
- Inlet gas filter loose shipped for field installation

### System Requirements

- Constant supply of fuel gas conforming to Solar's Specification ES 9-98. Maintaining high gas fuel quality is critical for engine operation. Refer to Solar's Product Information Letter (PIL) 162, "Recommendations for the Sourcing, Handling, Storage and Treatment of Fuels for Solar Gas Turbines", to ensure high fuel quality for optimum performance. Refer to the Utility List for pressures and flows.
- External source of air for operation of fuel system pilot air valves. Refer to the Utility List for pressures and flows.

### Special BTU Content Fuel System

Customer fuel gas composition requires a special turbine fuel system metering hardware and configuration.

### Fuel Control Valve, Gas Fuel, Aluminum Valve Body

The gas fuel control valve is electrically operated and electronically controlled by means of an integral 120-Vdc powered actuator that incorporates a brushless dc servo motor, a linear ball screw drive, a digital controller for precise motor control, and a resolver for position feedback. Control outputs and inputs are 0 to 24 Vdc for discrete signals and 4 to 20 mA for analog signals.

The valve is rated for 3445 kPa (500 psig) operating pressure and can operate in ambient temperatures up to 93°C (200°F). It has a turndown ratio that exceeds 400:1 and provides excellent metering of low light-off and acceleration gas fuel flows, as well as full load and load transient flow conditions. Response time is less than 100 msec from 10-to-90% stroke. Fail-safe operation ensures bubble tight valve closing in case of loss of either the command signal or the control power. The valve body is fabricated from aluminum.

## LUBE OIL SYSTEM

The package lube oil system consists of a complete system suitable for operation with purchaser-supplied lube oil conforming to Solar's Specification ES 9-224. The lubrication system circulates oil under pressure to the various working parts of the drive train rotating elements. The system is supplied from the lube oil tank located in the driver steel base frame. Proper oil temperatures are maintained by thermostatic control valve and optional oil cooler.

The lubrication system incorporates the following components:

- Oil tank
- Engine-driven, rotary screw type, primary pump
- Motor-driven auxiliary pumps including ac pre/post and 120-Vdc backup post-lube pump
- 120 VDC Step starter (ordinary duty)
- Duplex oil filters with replaceable elements
- Offskid oil cooler (optional)
- Oil level, pressure, and temperature indication including engine oil drain temperature
- Pressure and temperature regulators
- Strainers
- Oil tank vent separator
- Oil tank vent flame trap

The filters are supplied with a six-way transfer valve with differential pressure indication and alarm. The system includes all supply and drain piping and manifolds internal to the skid. The interconnect piping between the skid edge connection and the offskid-mounted oil cooler is not supplied as part of this system. The 120 VDC step starter is designed for indoor installation in a nonhazardous area.

**Carbon Steel Lube Filter System**

The lube oil filter canisters and transfer valve are fabricated from carbon steel and external surfaces are painted per Solar's standard paint system.

**Carbon Steel Lube Oil Tank**

The lube oil tank and tank covers are fabricated from carbon steel and all external surfaces are painted per Solar's standard paint system.

**Flanged Skid Edge Connections**

Piping connections at the skid edge except for the fire system will be provided as ANSI flange connections.

NPT to ANSI-Flange Adapters are supplied. Adapters will ship loose and will be shown on Mechanical Interface drawing. Does not include connections for fire suppression (if applicable) unless otherwise noted.

**Lube oil tank drain valves**

Loose ship one 2" 150# ANSI flange ball type drain valve for each lube oil tank drain, customer connection #26.

**AC Motor Driven Lube Oil Cooler, Maximum Temperature 52°C (125°F)**

An air-to-oil lube oil cooler is provided separately for field installation. The cooler fan is V-belt driven by a 3-phase ac motor. The cooler is sized to remove 1.7 x $10^6$ kJ/hr (1.6 x $10^6$ Btu/hr) at 985 L/min (260 gpm) oil flow at ambient temperatures up to 52°C (125°F). The nominal cooler sound pressure level is 85 dBA at 1 m (3 ft). The approximate cooler dimensions are 9.5 x 12 x 8 ft high with a dry weight of 8300 lb.

**Lube Oil Tank Heater**

A 3-phase ac, 18-kW, lube oil tank heater is provided to ensure that lube oil temperature remains above 20°C (68°F) for C32 oil or 29°C (85°F) for C46 oil, for starting with package ambient temperatures as low as -29°C (-20°F). When lube oil temperature falls below a pre-determined value, operation of the heater and the main lube oil pump is initiated, thus providing heated and circulated oil throughout the system.

**Petroleum Base Lube Oil, Viscosity Grade C46 (S215)**

The oil system control components and set points for the equipment in this proposal are for the use of petroleum base oil, viscosity grade C46. This is based on the rotating machinery's oil temperature and viscosity requirements, and the specified ambient temperature range. If a different type of oil or viscosity grade is preferred by the purchaser, this must be communicated to Solar for consideration. The oil used must meet the requirements of Solar's specification ES 9-224, "Specification for Lubricating Oils for Use in Solar Gas Turbine Engines."

## TURBOTRONIC 4 CONTROL SYSTEM

The *Turbotronic* 4 control system provides for automatic starting, acceleration to operating speed, sequencing control, engine and driven equipment monitoring during operation, and normal and malfunction shutdown.

During operation, the control system, by means of automatic warning and shutdown devices, protects the turbine engine and driven equipment from possible damage resulting from hazards such as turbine over speed, high engine temperature or vibration, low lubricating oil pressure and excessive oil temperature.

The main elements of the system are the Allen-Bradley ControlLogix control processor, A-B 1794 Flex I/O input/output modules, Bently Nevada 1701 Vibration Monitoring system, Combination Generator Control Module (CGCM), Windows 2000 based Display and Monitoring system (TT4000), package sensors, backup shutdown system and circuit breaker panels. The system input power is 120 Vdc, with internal power conversion providing the 24 Vdc required by the control circuits.

The control processor (controller) performs proportional control, start-up, operation and shutdown sequencing and protection functions, as well as detection and annunciation of abnormal operating conditions. Control for these functions comes from signals the controller receives from solid-state devices, control switches, speed, pressure and temperature transmitters, relays, solenoids, and vibration sensors. These components provide the controller with the data necessary to control and maintain desired process conditions while maintaining engine speed and temperature at safe levels.

In the event of an abnormal condition or malfunction, the control system indicates the nature of the malfunction. When an alarm or shutdown is displayed, a sequence of appropriate operations begins in response to the detected condition. In the event of a control system failure, the backup system initiates a shutdown while operating the lubricating oil system and other subsystems, as required, to avoid engine and driven equipment damage during shutdown.

The following provides basic information about the hardware and software features.

### RSLogix 5000 Programming Software

The RSLogix 5000 software programming environment provides a Windows-based interface which supports symbolic programming with structures and arrays. This programming environment provides for predefined and qualified sub-system software modules. Each software module is a self-described building block. Each building block supports a corresponding control system feature or option. RSLogix 5000 is compliant with IEC 61131-3 software programming standard.

### ControlNet 1.5

ControlNet 1.5 is the communications backbone of the control system. It provides fast, repeatable, and deterministic communications for the ControlLogix processor, Flex I/O modules, TT4000 Human Machine Interface (HMI), Combination Generator Control Module, Variable Frequency Drive (VFD) motor drives and the Bently Nevada 1701 vibration monitoring system.

### Vibration Monitoring

The standard control system includes a Bently Nevada 1701 Field Monitor and associated vibration sensing devices. The system is physically and functionally integrated with the control system using Flex I/O network adapters. The Field Monitor integrates seamlessly into the ControlNet 1.5 system architecture, providing a distributed vibration monitoring system, and mounting of components locally on-skid. Each Field Monitor can accommodate up to eight vibration channels. Additional 1701 Field Monitor controllers are added as required depending on the number of vibration signals needed. The vibration

data processed by the 1701 is transmitted to the controller through the ControlNet network for alarming and shut down. The vibration data values are displayed on the Video Display Unit on a dedicated Vibration Summary screen.

**Standard Engine Rotor Vibration and Temperature Monitoring**

The turbine engine incorporates the following standard vibration and temperature monitoring

- X and Y proximity probes at each of the 5 engine bearings for a total of 10 channels of engine vibration monitoring
- One main reduction drive gearbox accelerometer
- Turbine gas producer and power turbine rotor shaft axial position monitoring
- Turbine gas producer and power turbine shaft thrust bearing temperature monitoring
- Turbine gas producer and power turbine shaft rotor keyphasor to provide additional vibration diagnostic capability with externally applied diagnostic equipment
- RTDs at all turbine lube oil drain lines

**Combination Generator Control Module (CGCM)**

The CGCM is a highly integrated control module that combines multiple generator control and protection functions in a single device. It is an integral part of the *Turbotronic* 4 control system for power generation applications. Refer to the Generator Control and Monitoring section for more information.

**OFFSKID CONTROL SYSTEM**

The control system is mounted in a two-bay freestanding console for installation in a nonhazardous area. The console contains the key elements of the system, including the Control Processor, the I/O Modules, the Turbine Control Panel (TCP), the Vibration Monitoring System, the Combination Generator Control Module and the TT4000 Display and Monitoring System. In addition, an *onskid* TT4000S display unit provides basic display, control, and communications capability at the package skid.

The Turbine Control Panel provides the essential controls to start and stop the unit, to make process set-point adjustments, and facilitate other optional control functions. Typical operator TCP switches and indicators are:

**Switches**

- Off / Local / Remote control selector with lockable positions
- Start
- Normal Stop (shutdown with normal no-load cool down)
- Emergency Stop (shutdown without cool down)
- Horn Silence, audible alarm
- Alarm Acknowledge (warnings and shutdowns)
- Lamp Test
- Backup Reset (key switch)
- Alarm Reset (warnings and shutdowns)
- Speed Control (increase and decrease)

**Indicators**

- Local / Remote
- Ready
- Starting

- Ready to Load
- On Load
- Backup Active
- Cool down
- Alarm Summary
- Shutdown Summary (lockout)

**Video Display Unit**

The TT4000 Display and Monitoring System provides additional operation and maintenance information typically including the following standard displays and features:

- Operation Summary – Overview of key operation parameters
- Temperature Summary – Display of all monitored temperatures
- Vibration Summary – Display of all vibration readings
- Alarm Summary – Display of all malfunctions with date and time stamping
- Event Log - Display of date and time stamped sequence of events with sorting and filtering functions
- Historical Data - Stores data surrounding specified events. Data can be played back using the Strip Chart feature.
- Strip Chart - Display of real time data for selected analog signals in strip chart format. Configurable with legend, cursor and zoom features
- Program Constants – Password protected display and modification of controls constant values
- Generator Summary – Display of all monitored generator parameters

**Data Storage and Display**

Data can be viewed in a strip chart format in real time, trended, analyzed online, or exported for off-line viewing. All logs are self-describing repositories, containing site information, tag information, and the historical data itself. The data can be viewed online using the Historical Data Display. The Historical Data Display allows selection of up to 10 variables for viewing in a digital strip chart format. The objective of historical data monitoring is to provide information of a type and in a format that allows informed decisions to be made in the areas of operation, maintenance, and optimization of the turbo machinery and associated equipment. The information is collected for on-line viewing and analysis or may be exported for storage and off-line analysis.

**Modbus RS232C/422/485 Supervisory Interface**

A Modbus interface module is installed in the control processor rack and connects to the processor through the rack backplane. The module acts as a Modbus slave device to communicate with the user's Modbus master device. The user may connect to the module with an RS232C, RS422, or RS485 serial link. RS232C is suitable for applications up to 15 m (50 ft); RS422 and RS485 for up to 1219 m (4000 ft). Distances greater than this will require boosters, converters, telemetry or common carrier approaches. Data are transmitted using a subset of the RTU version of the Modbus protocol. Analog and discrete data are stored in one-dimensional arrays in the control processor, which may be read by the user. In addition, the user may send supervisory control signals to the processor. Data available include all input analogs, a number of computed values, status indications, and all active alarms and shutdowns.

Typical data include:

- Driven equipment status
- Gas producer turbine speed
- Power turbine speed

- Turbine T5 temperature
- Lube oil header pressure
- Lube oil temperature
- Ambient temperature
- All alarms and shutdowns
- All panel light status

Supervisory control signals include:

- Start
- Stop
- Acknowledge / Reset
- Remote Speed / Load Set Point

The user is responsible for providing the hardware and software interfaces to the system.

**Control Screen Engineering Units in Metric - bars**

Temperature values are displayed in °C and pressure values are displayed in bars.

**Control Screen Language in English**

Operator interface screen displays are in the English language.

**Engine Performance Map Display**

The engine performance map displays real-time turbine generator performance corrected to standard conditions. This is a calculated performance based on package instrumentation readings. The performance map is essentially for reference and is used to monitor trends in engine performance, not to verify absolute engine performance levels. The system includes instrumentation to measure flow of the fuel to the turbine. For gas fuel flow measurement, a loose shipped flow measuring device (Coriolis Mass Flowmeter) is provided for offskid field installation. For liquid fuel flow measurement, an onskid rotary transducer is provided.

**Field Programming Software, Instruction Manual and Interface**

Programming software, instruction manual and interface card are provided to allow field programming of the control sequences and logic within the control processor. The interface card is to be installed in the purchaser's personal computer that has an available PCI local bus expansion slot. The minimum requirements for the personal computer are Pentium 150 MHz, 64 Mbytes of RAM (128 Mbytes recommended), 50 Mbytes available hard disk capacity, 800 x 600 resolution, any Windows-compatible pointing device, and the Microsoft Windows 2000 Professional Operating System with Service Pack 1.

## GENERATOR CONTROL AND MONITORING

For generator control and monitoring, the *Turbotronic* 4 control system incorporates the Basler Electric / Allen-Bradley Combination Generator Control Module (CGCM). This microprocessor-based device operates as a subsystem of the main control processor and provides extensive control, protection, and monitoring features. Three excitation control modes are available:

- Automatic voltage regulation - a selected generator output voltage is maintained.
- Power factor control - a constant power factor is maintained when operating in parallel with a large power source.
- Reactive power (VAR) control - a constant reactive load is maintained when operating in parallel with a large power source.

The system provides the ability to automatically synchronize the unit to the bus through operator action or by receipt of an appropriate remote signal from a supervisory control system. The control system provides added package protection through preset warning indication and shutdown initiation in the event of unacceptable temperature levels in the generator stator windings. The system uses a 100-ohm platinum RTD at each generator bearing and a 100-ohm platinum RTD imbedded in each phase of the stator windings. Temperature level, warning alarm, and shutdown indications are displayed on the control system video display unit.

The following excitation control features are available:

- Under frequency limiting
- Over and under excitation limiting
- Reactive droop compensation
- Cross-current compensation
- Line-drop compensation

Protection features include:

- Over excitation voltage
- Over and under generator voltage
- Loss of sensing
- Loss of excitation current
- Loss of permanent magnet generator (PMG)
- Reverse VAR
- Over and under frequency
- Reverse power
- Rotating diode monitor
- Phase rotation error
- Generator overcurrent

**NOTE:** These protection features only protect the generator. Protection of the user's power distribution system and any other required generator protective functions are not included and must be handled separately using appropriately certified protective relay components with settings approved by qualified personnel based on a comprehensive analysis of the complete system.

Current, potential and cross current transformers required for input to the CGCM are not included unless provided elsewhere in this proposal.

**Electric Control and Metering Panel**

An electric control and metering panel is provided, mounted on the front of the control console, that permits manual synchronization of the generator and includes analog meters for generator output and exciter field data. These data are also provided as a standard feature on the video display terminal.

The electric metering panel monitors the ac electrical power output of the generator and provides manual control to adjust the generator voltage level and to synchronize and parallel the generator with another electrical source. A synchroscope is included, in addition to the manual synchronizing lights, to enhance the indication of the relative speed and phase angle between the unit and the bus during manual paralleling. The synchroscope is activated by the manual synchronizing interlock switch. In addition, exciter field meters are provided for both current and voltage.

The control and metering panel includes the following analog meters and control devices:

- AC ammeter
- Frequency meter
- KW / KVAR meter
- AC voltmeter
- Power factor meter
- Synchroscope
- Exciter field ammeter
- Exciter field voltmeter
- Generator output breaker control switch
- Manual synchronizing lights
- Manual synchronizing interlock switch

Current and potential transformers required for input to the meters are not included with the panel unless provided for elsewhere in this proposal.

**Kilowatt Control**

The kW control system controls the real load (kW) on a unit operating in parallel with a large source. The control monitors the load carried by the turbine generator set and adjusts turbine fuel flow to maintain a constant load under conditions of varying infinite bus frequency. Protection against excessive kW load while in parallel with a large source is provided by the turbine T5 temperature limiter system. The kW control system provides additional operational flexibility by allowing unit kW load level to be set at any desired level within the capacity of the unit.

**Generator Vibration Monitoring System with 2X and 2Y Proximity Probes, 4 Channels**

The generator vibration monitoring system provides additional package protection through preset warning indication and shutdown initiation in the event of unacceptable vibration levels in the generator. The system uses the Bently Nevada 1701 monitor, as described above, and includes four channels of vibration to monitor an X and Y proximity probe installed at each generator bearing. Vibration level, alarm, and shutdown indications are displayed on the control system video display unit.

**Generator Keyphasor**

A generator keyphasor is included to provide additional vibration diagnostic capability with the use of externally applied diagnostic equipment. The keyphasor signal is available in the Bently Nevada 1701 monitor described above.

# ACCESSORY EQUIPMENT

### Customer-Supplied Air for Self-Cleaning Filter

A supply of clean dry air must be supplied by the purchaser for use by the self-cleaning turbine air inlet filter described in this proposal. Please refer to the filter description for air pressure and flow requirements.

### Nickel Cadmium 120-VDC Control and Accessory Power Supply

The control and accessory battery system supplies 120-Vdc power for the unit control system, electric fuel valve, engine bleed valve, variable guide-vane actuator, and the backup post-lube oil pump. The unit's 24-Vdc control system includes a converter to reduce the 120-Vdc supply to 24 Vdc. The system includes 161 ampere-hour nickel-cadmium batteries on a freestanding, four-step rack and 20-ampere, single-phase charger. The system is designed for indoor installation in a nonhazardous area. The batteries are shipped wet, fully charged and ready for use.

### On-Crank / On-Line Engine Cleaning System

The turbine compressor combination cleaning system consists of both on-crank and on-line cleaning systems. The systems are independent of each other and include separate distribution manifolds with pressure atomizing spray nozzles in the engine air inlet collector and associated onskid piping, filter and solenoid operated shutoff valves to deliver water or approved cleaning fluid to the manifold.

Both systems facilitate periodic cleaning of the turbine compressor and are designed for use in salt-laden or dusty atmospheres or where compressor contamination from hydrocarbon vapors is possible.

With the on-crank system, the engine is operated at the maximum speed attainable with the start system and fuel and ignition systems deactivated. Engine cranking is initiated from the onskid gauge panel or the control console operator interface panel, and water / cleaning solution flow is activated from the operator interface panel.

The on-line cleaning system is operable between 90 and 100% gas producer speed with or without load, with water / cleaning solution flow activated from the operator interface panel. This system is intended to supplement the on-crank system by increasing the time intervals between periodic on-crank water, detergent or fluid cleaning, depending on site-specific contamination.

For both systems, a separate source is required to supply externally pressurized water / cleaning solutions in accordance with Solar's Specification ES 9-62, regulated at 586 to 690 kPag (85 to 100 psig) at the package skid connection.

### ASME Certified Cleaning Tank for Engine Cleaning System

An ASME certified cleaning tank is provided to supply cleaning fluid to the skid edge cleaning system connection. The tank includes a 100-L (26-gal.) 316 stainless steel vessel to mix, hold and pressurize the cleaning solution. Requires filtered shop air supply at 586 to 690 kPag (85 to 100 psig). The portable tank comes with wheels that are removable for stationary installation.

### Package Lift Kit – Split Lifts

A package lift kit is provided to lift the driver package and the driven equipment package separately. The package lift kit is designed in accordance with Solar's Engineering Specification ES 2335. It may be used to lift the driver and driven equipment packages either with or without the packages' export crating. The kit is shipped separately and consists of a spreader bar, slings, and associated lifting hardware.

The package lift kit is not designed to lift the package with ancillary equipment or enclosure ventilation equipment. The generator terminal boxes and cooler must also be excluded from the lift if they are taller or wider than the package enclosure. The lube oil tank must be empty during lifting.

## MISCELLANEOUS

### Long-Term Package Preservation

The package is prepared for shipment with long-term preservation per Solar's Specifications ES 9-248 and ES 9-249, and Product Information Letter (PIL) 097 "Package Preservation and Preparation for Shipment," including export boxing and foil bagging. While the equipment is stored, the Buyer must arrange for periodic inspections to ensure the packing is not compromised. If still in storage after two years from date of shipment, long-term preserved items should be opened, recharged with desiccant and vapor-proof barriers resealed.

### English Language Operation and Maintenance Instruction Manual

The Operation and Maintenance Instruction manual, as described in the Documentation section of this proposal, is provided in the English language.

### English Language Package Labels

Package labels are provided in the English language.

### Torsional Vibration Analysis

The torsional report examines the entire drive train to determine if there are any harmful torsional resonance conditions within ±10% of the operating speed range. If a resonance condition or interference is found, then a fatigue analysis is performed to make sure the resonance will not cause fatigue failure in the shafting. If an interference is determined to be potentially harmful then changes to the coupling(s) may be made to either eliminate the interference or reduce its harmful effects.

### Lateral Vibration Analysis

The lateral analysis involves performing a lateral forced response analysis of the driven equipment to ensure that any lateral critical speeds are far enough away from the operating speed range that they will not cause lateral vibration problems.

### Alignment Tooling

Alignment tooling is provided for aligning the reduction gearbox output shaft hub to the generator input shaft hub. The tooling includes:

- Dial indicator kit
- Engine gearbox to generator alignment tool
- Mounting hardware
- Extension rods
- Wrenches
- Custom storage container

# TEST, QUALITY ASSURANCE AND CERTIFICATION

## STANDARD TESTING PER SOLAR'S SPECIFICATIONS

Factory testing is in accordance with Solar's test specifications and as generally outlined below. The purchaser or purchaser's designated representative is provided access to Solar's Production Test facilities to observe factory production tests scheduled in accordance with production and testing schedules. Unavailability of the purchaser or purchaser's representative shall not be cause for delay in the performance of the production tests.

### Test Facilities

Design of the test cells provides for flexibility so that all types of turbine packages can be tested with a minimum of time required for connection of fluid, electrical and instrumentation services needed for each test run. The computerized real-time data acquisition system collects raw digital and analog data from the turbine package and displays or prints out results in customary engineering forms and units.

The control and display equipment provide the capability to monitor and control the power and test stimuli to operate the unit under test and to measure and evaluate its performance. The system is used to establish specified test conditions by keying in calibration coefficients, constants and operating limits. Test data are displayed by a video terminal as instructed by the test agenda, which includes selecting various parameters for display, checking values and limits, and generating hard copy records as needed. When performance levels have been achieved, the test technician initiates a command to capture all instrumented points, which initiates automatic performance computations and prints the results for review by Engineering personnel and a permanent test record.

### Testing

**Test Phases.** Solar's Production Test facilities are arranged to provide for a three-phase test program. The first phase uses simulation equipment to perform static testing of the control console and package systems to verify electrical and fluid system continuity and calibration. The second phase consists of interconnecting the turbine generator set package and control console in the pre-test area to undergo additional simulated systems tests of the total package and prepare the unit for interconnection with the test cell facilities. In the final phase, the unit is installed in the test cell where it is controlled and monitored by its own control console and the computerized test facility.

**Generator Package Acceptance Testing**. The basic package assembly, including the gas turbine, gearbox, generator (when available), and package-mounted accessories, together with the control console, is tested as a complete system to ensure proper integration and function of the total package in accordance with Solar's package test specifications. Results are recorded and maintained by Solar.

The acceptance test generally includes the following:

- Starting and combustion cycles
- Lubricating oil system, temperature and pressure measurements
- Vibration measurement
- Package power and heat rate measurements at partial and full load for ambient conditions, with electrical load at 1.0 power factor
- Turbine temperature measurement
- Variable guide vane and bleed valve adjustment
- Adjustment and calibration of the voltage regulator, fuel control and speed governing system for generator output, frequency regulation and transient response
- Fuel changeover (on dual fuel units)

- Load / speed transient test
- Testing for malfunction and safety devices and circuitry
- AC metering and control circuitry tests (if ac metering is supplied), calibration of ac metering circuits is performed by bench testing

All packages are tested with contract generator whenever possible. When required due to schedule, availability or test cell limitations, the package may be tested with a slave generator. If so, and the contract generator is available at the completion of testing, the purchased generator will be mounted and aligned prior to shipment. Items excluded from standard package testing are contract inlet and exhaust system ancillary equipment (such as filters, silencers and ducting), battery systems, oil coolers, package enclosure, ancillary skid, switchgear, and any customer-furnished hardware.

**Generator Testing**. The generator is tested in accordance with IEEE standard specifications and Solar's specifications at the manufacturer's plant. These tests satisfy requirements for NEMA and Solar. Supplier testing is under Solar's periodic quality control review to ensure compliance with required specifications.

**Performance Review**

**Acceptance Test Data**. Acceptance test data are reviewed and approved by Product Engineering, Test Engineering, Quality Engineering and the Project Manager prior to submittal to the purchaser. With this review and approval cycle, the test data are furnished approximately four weeks after completion of acceptance testing. The report provides test results and compares the results to Solar's acceptance test specification requirements by means of calculations, graphs, strip charts and descriptions. Data are provided for each turbine generator set. The acceptance test report generally includes the following types of data:

**Turbine Fuel Consumption Rates**. A comparison of measured fuel consumption versus specified fuel consumption, showing correlation of fuel consumption, power output and turbine gas temperature at full load.

**Voltage and Frequency Transients**. Computerized traces are provided, showing voltage and frequency deviations during load application and removal.

**Operating Values**. A chart showing operating values of the following parameters from no load, with step increments, to full load is included:

- Lubricating oil pressure, temperature and flows
- Turbine gas temperature
- Generator power
- Generator voltage, amperage and frequency
- Engine compressor discharge pressure
- Package vibration levels

**Quality Assurance**

All testing operations are conducted under the direct control of Solar's Quality Assurance organization to facilitate compliance with the specified test limits and procedures.

In addition to final in-plant testing of the finished generator set, Quality Control engineers maintain surveillance over the manufacture of all purchased parts and subassemblies, and are responsible for functional testing of incoming components. The same rigid standards applied to parts manufactured by Solar are applied to all parts received by Solar from suppliers.

**DCS Test - One Pkg Only**

The DCS vendor will come to our shop to verify the communication of the DCS with our control panel.

The DCS vendor will hook up the DCS with our UCP's and make sure the buttons and lights work, and communication is confirmed. This test will provide the assurance that the communications are working as expected and are a good baseline test.
Solar is not expected to change our software to accommodate the DCS vendor (unless there is an error on Solar's part).
Duration is expected to be 2-3 days.

Note: Solar will assists with this test only and does not provide any DCS hardware or procure the DCS vendor.

**Post-Test Boroscope Examination Capture**

Photo capture of post test boroscope examination of all units is provided.

This point will be a Solar O1 observation point on the inspection and test plan (ITP).

**Additional 4-Hour Full-Load Test Run, Gas Fuel**

In addition to Solar's standard testing described above, the gas turbine generator set is run continuously on gas fuel for four hours at full load for prevailing ambient conditions.

**Source Inspection for Generator**

Solar will conduct a source inspection at the generator vendor's facility for this project, including rotor balancing and standard generator testing. The purchaser or purchaser's representative is welcome to participate in the source inspection at purchaser's expense.

**Customer Participation to Observe on Noninterference Basis**

The purchaser or purchaser's designated representative is provided access to Solar's Fabrication and Production Test facilities to observe factory production tests and other normal shop inspections and tests such as rotor balancing, casing hydros and final inspections in accordance with production and testing schedules. Observation of UCBOP (Unit Control Balance of Plant) software testing is done only as part of the Static Testing of controls software. Observation of package control software is done only as part of the Package Acceptance Test. Unavailability of the purchaser or purchaser's representative shall not be cause for delay in the performance of the production tests.

## AIR INLET SYSTEM

The air inlet system typically consists of all components upstream of the engine inlet collector that are necessary to supply a clean, smooth flow of air to the turbine. The inlet air system components, silencers, ducting, and air inlet filter are designed to accommodate the required flow as specified on the Mechanical Interface Drawing. At this flow, the inlet pressure loss will be as low as practical consistent with requirements for cost, air filtration and acoustical attenuation. This loss is normally expected to be less than 102 mm (4 in.) of water with a clean air filter.

**Self-Cleaning Barrier Type Filter, Updraft Type**

A self-cleaning barrier type updraft air filtration system with a back outlet is included, suitable for moderate environments. The filter elements are pulsed with air provided either by the customer or from the turbine PCD (Note: If PCD air is used, a separate cleaning kit is required). Standard features include:

- High efficiency Duratek Spider-Web media filter elements
- Differential pressure gauge
- Differential pressure transmitter
- Carbon steel construction
- Electrical connections pre-wired to a common junction box
- Electrical components that comply with the selected area classification

**Turbine Air Inlet Silencer**

A carbon steel inlet silencer is included.

**Inlet System Ducting – Carbon Steel**

The air inlet ducting is steel sheet 10-gauge minimum, approximately 3.4 mm (0.1345 in.). Attaching hardware and a tube of sealant are provided for one flange per duct.

- Unlined Duct, 7.5 ft x 7.5 ft, 5 ft Long

**Turbine Inlet System Support**

An air inlet system support structure is provided for offskid support of the combustion air inlet ducting, silencer and air inlet filter. The air inlet filter may be supplied with separate supports depending on the filter type and layout. The structure is shipped separately for field assembly and installation and includes mounting hardware and assembly / installation drawing.

**Air Inlet Gas Detection**

A single gas detector is provided mounted in the air inlet system.

**Air Inlet System Scope / Process: Standard System**

A complete system is provided consisting of fully pre-engineered standard arrangements, which include all required attaching hardware and gaskets. The arrangements are shown as complete systems on the Mechanical Interface drawing. Only minor changes to the pre-engineered system are permitted without additional commercial impact.

## EXHAUST SYSTEM

The turbine exhaust system typically consists of all components downstream of the engine exhaust flexible section that are necessary to ensure a smooth flow of exhaust from the turbine. The turbine exhaust system is capable of handling the required gas flow as specified on the Mechanical Interface Drawing. Pressure losses should not exceed 152 mm (6 in.) of water. Additional back pressure results in a decrease of available turbine horsepower. The system includes attaching hardware (bolts, nuts, washers, and gaskets) for the inlet flange of each component. The turbomachinery package includes attaching hardware for connection of the turbine engine exhaust flexible section to the first exhaust system component. Exhaust system lagging is not included.

**Exhaust Silencer, 2.3 m x 2.3 m, 1.5 m Long**

Exhaust noise attenuation is achieved by use of an exhaust silencer, which, with associated ducting, must be supported to maintain loads on the engine exhaust connection within the limits shown on the Mechanical Interface drawing. Thermal expansion loads are avoided by proper location of the silencer and ducting and the use of flexible bellows connections. The material is carbon steel.

An exhaust silencer is included. Features include:

- Silencer flange dimensions: 2300 mm x 2300 mm (7 ft 6-9/16 in. x 7 ft 6-9/16 in.)
- Length: 1500 mm (4 ft 11-1/16 in.)
- Materials of construction: carbon steel
- Differential pressure: 40.6 mm (1.6 in.) water gauge
- Duct, Exhaust, 2.3 m x 2.3 m, 3.0 m Long

  Dimensions: 2300 mm x 2300 mm (7 ft 6-9/16 in. x 7 ft 6-9/16 in.)
  Length: 3000 mm (9 ft 10-1/8 in.)
  Basic material: carbon steel plate per ASTM A515, 6.35 mm (¼ in.) thick

- Duct, Transition, 1718 mm x 865 mm to 2.3 m x 2.3 m, Carbon Steel
- Exhaust Bellows, 1718 mm x 865 mm, 535 mm Long, Carbon Steel

**Exhaust System Support (Offskid)**

An exhaust system support structure is provided (loose shipped for field erection) for offskid support of exhaust silencer. Includes mounting hardware and illustrated assembly drawings.

**Exhaust System Scope / Process: Standard System**

A complete system is provided consisting of fully pre-engineered standard arrangements, which include all required attaching hardware and gaskets. The arrangements are shown as complete systems on the Mechanical Interface drawing. Only minor changes to the pre-engineered system are permitted without additional commercial impact.

**Custom Ancillary System**

A Custom Ancillary system is to be provided.

Solar to supply the inlet and exhaust systems in accordance with PD 3A111.

Based on the Complex Project Meeting held on March 10, 2008, the packages will be identical to PD 3A111 except those changes as listed in CF 43504.

# ENCLOSURE

### Basic Construction

The all-steel enclosure housing is a completely self-contained, weatherproof, insulated, and sound-attenuated enclosure assembled on the turbine package skid base.

The enclosure sides and roof include panels and access doors supported on a heavy-duty frame. The side and roof panels are easily removed individually for complete access to the major components for inspection and maintenance and for component removal by forklift and overhead crane. The panels are treated with fiberglass material for noise attenuation and thermal insulation, and weather stripping is installed between all panels for sealing and sound attenuation. The enclosure is constructed to support a roof load of 50 lb/sq ft and to withstand a wind load of 120 mph.

### Included Features

The following standard features are included in the basic enclosure scope of supply:

- Inlet and Exhaust Ventilation Silencers

  The enclosure ventilation openings are equipped with vent silencers with weather louvers.

- Pressurization System

  The driver section of the enclosure is positive pressurized to prevent the ingress of potentially hazardous external atmospheres through the enclosure seams.

- AC Lighting

  110-Vac or 220-Vac lights are provided to illuminate the enclosure interior, with an On / Off switch located at the Customer Interface Panel (CIP).

- Equipment Handling System

  - Two internal movable trolley rails located between the turbine air intake and exhaust collectors for turbine maintenance and removal are included.
  - One built-in jib crane for package component maintenance and removal, such as lube oil pump, starter motor and accessory drive gearbox (when applicable), is included.
  - One internal movable trolley rail for package component maintenance and removal is included.

- Stainless Steel Door Hardware

  All enclosure doors are equipped with a three-point heavy duty 316 stainless steel door locking mechanism including handles, hinges, latching mechanism, internal lock override release, restraining device and attaching hardware.

### Sound Attenuation

The sound-attenuated enclosure is intended for use with suitable turbine air inlet and exhaust silencing systems in environments where low noise levels are a requirement. Ventilation openings are equipped with suitable silencers to achieve maximum sound attenuation.

The estimated A-weighted sound pressure level is 85 dBA at a distance of 1 m (3 ft) from the enclosure wall and a height of 1.5 m (5 ft). This value is based on an average of multiple readings taken around the perimeter of the package. This level applies only to the enclosed equipment and is exclusive of sound generated by piping, unenclosed driven equipment (if applicable), other equipment, reflected sound or contributing site conditions. Sound levels at a specific site will depend on existing walls, barriers, equipment in close proximity, multiple units and other installation considerations.

Solar's publication SPNP/204 "Noise Prediction Guidelines for Industrial Gas Turbines" provides detailed information on sound level calculations.

**Enclosure for Driver Only**

The enclosure houses the driver compartment only. The generator is not enclosed.

**AC Power Outlet On Enclosure**

An interlocking AC power socket outlet will be provided on the gas turbine enclosure, suitable for the hazardous area rating.

Includes a mating plug. Power is to be supplied from the MCC.

**Additional Emergency Shutdown Switches**

Emergency shutdown (ESD) switch is supplied for both side of the enclosure.

**NEC Class I, Group D, Division 2 Electrical System**

Enclosure electrical equipment is in accordance with NFPA 70 (NEC) requirements for electrical equipment installed in Class I, Group D, Division 2 hazardous locations.

**Dual AC Motor-Driven Fan Ventilation System**

Enclosure ventilation is provided by a dual ac motor, direct-driven fan system. The two 100% fans are arranged in series. One fan is designated as the primary or RUN fan and the other is designated as the backup or STANDBY fan. Operator selectable Run / Standby controls provide for operational flexibility and even use. Flow switches in the enclosure inlet ventilation ducting initiate the Standby fan operation. Refer to the Utility List for power requirements.

**Barrier-Type Filter for Dust Protection**

The enclosure ventilation inlet is equipped with a single-stage, disposable, barrier-type filter unit equipped with a delta-P alarm switch. The ventilation exhaust opening is equipped with back-draft dampers to prevent ingress of dust when the unit is not running.

**Standby DC Lights**

Battery-operated fluorescent DC lighting is provided inside the enclosure. The lights turn on automatically in the event of loss of AC power.

**Fire and Gas Detection and Monitoring System**

An automatic, electronically controlled fire and combustible gas detection and monitoring system is installed in the enclosure. The primary fire detection system uses multi-spectrum infrared (MIR) detectors due to their superior performance for enclosed gas turbine applications. The system includes an

automatic optical integrity feature to provide a continuous check of the optical surfaces, detector sensitivity and electronic circuitry of the detector-controller system and automatic fault identification with digital display of system status in numerical code. The secondary fire detection system consists of rate-compensated thermal detectors. The two detection methods act independently in detecting and reporting a fire.

The fire and gas system control panel provides system supervision (for open circuit, ground fault or loss of integrity), initiates alarm and release of fire suppression agent and visual display of system status. The suppression system agent release is activated automatically with release solenoids located on the fire suppression skid. The suppression system can also be activated by electrical push button on the turbine enclosure or manually at the suppression skid. If a fire is detected, the detectors transmit an electrical signal to the fire and gas system control panel to activate the fire alarm and suppression system.

The enclosure is equipped with two gas detectors: one at the turbine enclosure ventilation air inlet and one at the ventilation exhaust to provide continuous monitoring for combustible gases at the enclosure ventilation inlet and outlet. The detectors are diffusion-based, point-type infrared devices that provide continuous monitoring of combustible hydrocarbon gas concentrations. The turbine start signal is interlocked with the fire and gas monitoring system to ensure the atmosphere is safe prior to initiating turbine engine start.

**Additional IR Gas Detectors**

Additional IR point type gas detectors will be provided (in addition to standard quantity).

Additional Detronics IR point type gas detector(s) with stainless steel housing will be provided.
3 gas detectors in ventilation inlet
3 gas detectors in ventilation exhaust

**UV/IR Flame Detectors**

Solar will remove the standard MIR, multispectrum detectors from the project and replace them with UV/IR flame detectors, manufactured by Detronics. (Standard quantity, one each location)

**$CO_2$ Fire Suppression System**

The enclosure is equipped with a $CO_2$ fire suppression system consisting of a primary total flooding distribution system and a secondary metered distribution system to extend the design concentration of 37% $CO_2$ for 20 minutes. The system is designed in accordance with the U.S. National Fire Protection Association Code 12. The CO2 cylinder storage temperature range is 0 °F (-18 °C) minimum to 130 °F (54 °C) maximum.

On detection of fire, the detectors transmit an electrical signal via the fire control panel to activate the fire suppression system release solenoids located on the fire suppression skid. On receipt of this signal, the solenoid actuated control heads activate the discharge valves on the primary and extended extinguishing cylinders, releasing the extinguishing agent into the enclosure. $CO_2$ pressure actuates the pressure trip operated dampers that close all vent openings. $CO_2$ release control heads are also provided with manual release levers.

**$CO_2$ Fire Suppressant Cylinder Cabinet**

The weatherproof fire suppressant cylinder cabinet is sized to house the $CO_2$ extinguishant cylinders and is equipped with doors for servicing. The manual pull levers are routed, by cable, to break glass pull stations on the exterior wall of the cabinet.

**Equipment Handling System**

An equipment handling system is provided, consisting of:

- Two external (10-ft long) trolley beam extensions with support frame for turbine handling
- Four 4-ton movable chain-fall hoists, trolleys and lift attachments (shackles and lift strap) for turbine handling
- One external (10-ft long) trolley beam extension with A-frame support for package component handling
- One 3-ton movable chain-fall hoist, trolleys and attachments for package component handling

The trolley beam extensions allow turbine removal through the side of the enclosure. One end of the beam extension attaches to the inside trolley rails; the other end is a floor-standing frame. The gas turbine is then removed through the enclosure side and placed on a truck bed or cart.