

# PROPOSAL

Presented To:

**PDVSA**

For

2 x Twin Pac FT-4C-1D  
Turbine Equipment

*Prepared By*

**DERWICK**

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PDVSA.**

## Introduction

Derwick Corporation (“DC”) is pleased to provide this proposal to PDVSA (“PDVSA”) for Two (2) Refurbished Pratt & Whitney Twin Pac FT-4C-1D Gas Turbines.



## **FT-4C-1D Power Generation Package**

## THE PWPS FT4C-1D TWIN PAC

### GENERAL DESCRIPTION

The FT4C-1D Twin Pac is an outdoor, completely self-contained, automatic, gas turbine powered electric generating plant, nominally 50 HZ rated at 51 MW at 15\* C. The unit contains all the equipment required for local unattended operation and provisions for interconnection to a remote control panel. It has the capability to start-up in the event of loss of purchaser-provided AC electrical power when the unit is in a stand-by condition. This builtin starting capability, plus the ability of the unit to assume full load in less than four minutes after initiation of the start signal, provides excellent protection in the event of a "black-out".

The FT4C-1D Twin Pac consists of five primary modules; two gas turbines, the electric generator, the control enclosure and a high voltage switchgear enclosure. Each gas turbine unit consists of a Pratt & Whitney aero-derivative FT4C-1D gas generator and a two stage free turbine. The gas turbines provide high energy gas to the free turbines, which in turn, convert this energy into useful work when mechanically coupled to a driven load through flexible couplings. The electric generator is an Electric Machinery air-cooled, two pole, turbine type generator with a brushless excitation system. The control enclosure contains the gas turbine control, generator control, motor control center, low voltage switchgear, batteries and charger, engine fuel controls, an upgraded digital PLC sequencing system, protective relays, auxiliary transformers and a master terminal board. The high voltage switchgear enclosure contains the main circuit breaker and high voltage transformers.

The gas generators and free turbines are provided with low pressure lubrication systems including oil storage tanks and filtration. The electric generator has a separate lubrication system with AC motor driven lube oil pump with a DC pump backup. All systems are air cooled.

The electric generator is an Electric Machinery synchronous generator nameplate rated at 74,500 kVA , 59°F, 0.9 power factor, 60 HZ, 3 phase, 2 pole 3600 RPM, open air cooled, two sleeve bearing bracket type. Generator excitation is provided by a 250 V, 150 kW, direct connected brushless exciter with permanent magnet generator pilot exciter.

The gas turbine inlet stacks are acoustically treated and are fitted with sound attenuating baffles. The exhaust stacks are constructed with "corrosion resistant" steel and sound attenuating baffles. The turbines, generator and controls enclosure are of painted steel construction.

## **SCOPE OF SUPPLY**

Derwick Corporation offers the delivery of Two (2) Refurbished FT-4C-1D Gas Turbine Power Generation Packages, designed in accordance with the specifications outlined in this proposal, comprising of:

### **PRATT & WHITNEY 2 X FT4C-1D TWINPAC 108 MW ELECTRIC GENERATING PLANT**

#### **GENERAL DESCRIPTION**

1. The FT4C-1D TWINPAC Power Island is a completely self-contained, automatic, gas turbine powered electric generating package nominally rated at 54 MW. The unit contains all the equipment required for local unattended operation and provisions for interconnection to a remote control panel. It has the capability to start up in the event of loss of purchaser provided A.C. electrical power when the unit is in a stand-by condition. This built-in starting capability, plus the ability of the unit to assume full load in less than four minutes after initiation of the start signal, provides excellent protection in event of "black-out".

The FT4C-1D TWINPAC consists of a generating module with an Electric Machinery Manufacturing Co. open cycle, air-cooled, 57.3 MVA (Base), 13.8 KV, 0.90 power factor, two-pole, turbine type generator with a brushless exciter driven by two (2) opposed, direct connected Pratt & Whitney Aircraft FT4C-1 Gas Turbines. The Turbines are coupled through diaphragm couplings to each end of the generator shaft which provide for the total thermal growth of the unit while retaining the ability of the generator to operate at half power with one turbine decoupled for inspection or repair.

The gas turbines are provided with their own lubrication system, including storage tanks. The generator has a separate lubrication system with an A.C. motor-driven lube oil pump with D.C. backup. Both systems are air-cooled.

The generator is top connected via 3000 ampere, 15 KV, 95 KV BIL bus duct to its high voltage metal clad switchgear containing the 1000 MVA, 3000 ampere Air Circuit Breaker.

The turbines, generator and controls are housed in painted steel enclosures with painted steel inlet and exhaust stacks. The turbines are separated from the generator by two-diaphragm walls to prevent mixing the turbine secondary cooling air and

generator primary cooling air and to provide more effective fire protection. An automatic fire protection system is provided for each of the gas turbines.

The gas turbine air inlet stacks are acoustically treated and are fitted with sound attenuating baffles. The exhaust stack shells are constructed of stiffened carbon steel plate, externally insulated, and sheathed with ribbed aluminum siding. The interior of the exhaust silencers are lined with stainless steel sheets, and are fitted with sound attenuating baffles constructed of stainless steel face sheets and internal framing.

### **Two FT4C-1D packages will be provided for a total of 104 MW generating capacity Gas Turbine**

The control enclosure contains the gas turbine control, generator control panel, Motor Control Center, high voltage metal clad switchgear and batteries.

This General Description is typical.

## **2. Equipment**

The major equipment included in the TP4-2 TWINPAC consists of:

- a) A steel enclosure with inlet and exhaust stacks fitted with sound attenuating devices.
- b) Gas Turbine Prime Movers, each equipped with the following systems:
  - (1) Operating Controls
  - (2) Lubricating System
  - (3) Fuel Control and Fuel System, including Booster Pump and Filter
  - (4) Starting Turbine
  - (5) Ignition System
  - (6) Automatic Anti-Icing
  - (7) Flexible Coupling
  - (8) Mounts and Base
- c) Open Cycle, Air Cooled Generators with brushless exciters and associated electrical

Equipment including:

- (1) Voltage Regulators
- (2) High and Low Voltage Switchgear
- (3) Turbine and Generator Control Panels
- (4) Sequencers
- (5) Protective Relaying
- (6) Motor Control Centers
- (7) Batteries and Chargers
- (8) Auxiliary Transformers
- (9) Master Terminal Strips

### 3. Operation

The TP4-2 TWINPAC is designed for either local or remote automatic operation on the distribution or transmission system of an electric utility. In the event of a blackout of a main power station, the unit also may be started and operated as an “isolated” generating station from either the local or remote control station.

The TWINPAC has five (5) modes of operation:

(1) Parallel – Manual and Automatic (Remote – Local)

#### **(2) Isolated – Manual and Automatic (Remote – Local) Generator Rotor Withdrawal tool**

- Freight FAS, Port of Export
- MCC / UPS
- Inlet Chiller Coil

(3) Isolated Precise – Manual and Automatic (Local Only)

(4) Idle – (Local Only)

(5) Test – (Local Only)

Mode 1 provides the capability of achieving any desired load level either automatically or manually. When the “normal” loading-unloading rate is selected, the unit can be brought to full load within five (5) minutes from breaker closure, or similarly from full load to breaker opening within five (5) minutes of initiation of stop signal. When the “fast” loading-unloading rate is chosen, these same actions can be accomplished in fifteen (15) to twenty (20) seconds.

When used to compensate for peak-load periods, the TP4-2 TWINPAC is normally operated unattended from a remote control station in the Automatic-Parallel Mode. In this mode, the load selection – Peak, Base Load, or Minimum Load – is made at the control panel by setting the Power Programming Switch to the desired load level. Upon actuation of the Start Switch, the unit will automatically start up, sequence, and synchronize with the line, and go immediately to one of the selected load levels and remain at this level. While in operation, the unit can be automatically shifted from one load level to another by actuation of the power Programming Switch. If the unit is first brought on the line in the Automatic Parallel Mode to any one of the above four programmed load levels, it may be placed in the Manual-Parallel Mode and the load level may be manually adjusted to any desired value between any programmed load level (Maximum, Peak, Base Load or Minimum Load) and zero power by actuation of the speed governor switch.

When the service of the TWINPAC is no longer required, actuation of the remote Stop Switch will automatically unload the unit, sequence it to the “Idle” and “Cool-Down” phases to a complete stop. This same sequence of events can also be accomplished locally at the Control Room.

The unit can also be manually brought on the line from the local control room by selecting the Manual-Parallel Mode of operation. In this mode, actuation of the module Start Switch will automatically start-up and sequence the module to its idle speed condition (3550 rpm free turbine speed) from where it can be manually synchronized and loaded. This feature can also be incorporated into the remote control panel at additional cost.

This TWINPAC can also be used for blacked-out station start-up or “isolated” operating condition by selecting “Isolated Mode”. In this mode, the unit can be started and automatically or manually (depending upon selection) close onto the purchaser’s dead bus. On actuation of its Start Switch, the module will automatically sequence to 2950 rpm generator speed at which point the breaker is closed manually or automatically depending on the method chosen. The unit will load within its capability, governing along a 4% droop slope. Frequency may also be controlled by actuation of the governor switch.

When the unit is the only available source of power, it may be operated in the Isolated Precise Mode from the local control room or remote control panel if this extra equipment is provided. When in this mode, actuation of its Start Switch will automatically sequence the unit to 3600 rpm and maintain the speed. The main breaker can be closed, either automatically or manually, after reaching this speed and governing will be isochronous with load demand. When either the “Isolated” or “Isolated-Precise” modes are selected, “deadbus” relay will prevent closure of the main breaker on a “live-bus”.

To ensure the FT4’s capability to start and provide power when operating in these isolated modes, should purchaser-provided electrical service to the unit become unavailable, a battery pack and station auxiliary transformer are provided. All electrical equipment involved in starting or tripping is designed for direct-current operation. The station auxiliary transformer is energized as soon as the generator is producing power and the main breaker is closed, thus supplying station power, including D.C. through a rectifier, preventing further drain on the battery.

For testing and “trimming” the unit, Idle and Test Modes are provided. In the Idle Mode, the unit will automatically sequence to idle speed (approximately 6000 rpm N2 speed) on actuation of the Start Switch. The Test Mode, with its associated Test Panel, provides direct individual engine speed control and permits manual breaker closure and loading for test and trim purposes.

The TWINPAC has two basic operating controls: a Speed Governor Switch to adjust speed or load, and a "Voltage Adjust Rheostat" (VAR Switch) to adjust terminal voltage or vars. When the unit is in the Isolated Mode, the VAR Switch controls the terminal voltage and the Speed Governor controls the frequency. However, when the unit is in the Parallel Mode, the Speed Governor Switch will change the load on the machine and the VAR switch will change the reactive power from a preset value. Both switches can be used locally or remotely.

The unit can be restarted, if so desired, after the Stop Switch has been actuated, provided the shutdown sequence has not progressed to the fuel cut-off stage, at which point the engine must be allowed to come to windmilling speed before restarting (this requires approximately one {1} minute). Protective relays will prevent restarting during this phase of shutdown sequencing.

In an emergency, the TWINPAC can quickly be brought to the shutdown condition by actuation of either one of the Emergency Stop Buttons located in the Remote or the Local Control Room. Actuation of these buttons, or any of the shutdown relays, will cause the quick acting fuel shut-off valves to close, thus by-passing the normal shutdown sequence and stopping the unit in the shortest time interval.

In the event that an electrical or mechanical fault should occur in one of the units, protective relays will automatically energize an alarm signal if continued operation is permissible, or take the unit off the line if necessary and bring it directly to the shutdown condition. Annunciators are provided in the Control Room to indicate the location or cause of the fault.

## **4. FT4C-1 TWINPAC Control System Description**

### **A. Control System Description**

#### **1. Woodward NetCon 5000**

This system has a central processing unit (CPU) for unit sequencing and fuel governing. It is a 32 bit CPU with high speed and great accuracy, utilizing conventional analog and digital input/output devices. It also includes a final driver for the fuel control valve. A new liquid fuel control valve and integral shutoff valve are provided. The NetCon 5000 is considered to be the best state-of-the-art control available for this type of generating unit. It represents the maximum system integration available at this time. The NetCon 5000 is powered from the 125 VDC batteries.

An industrial 19-inch color CRT is provided and can be used to start/stop, load the unit, and select power levels. Displays are selected by use of a mouse. The CRT



provides the operator with all alarm and trip indications. Additionally, sensors, transducers, or I/O are provided to digitally display and record all parameters including the following for each engine:

- q Speed: N1, N2, N3
- q Pressure: PS4, PT7, P AMB, Fuel Pressures, Lube Pressures
- q Temperature: TAMB, TT2, TT7 Individual, Average and Spread
- q Megawatt Output, Megavar Output, Generator Voltage
- q Performance: Corrected Values of N1, N2, PS4/PT2 (Compressor Pressure Ratio), ~~Wf~~ PT7/PT2 (Engine Pressure Ratio, Wf (Fuel Flow), Ww (Water Flow), TT7 Avg. and Generator Load

## 2. Special Design Features and Options

The following is a list of special design features, which are included in the control equipment:

- a) The DCS has logic to improve reliability and availability by using dual speed sensors and switching from a failed sensor to a good one without tripping, but with an alarm. Also, sensor signal arrangement on I/O boards is such that a degree of fault tolerance is achieved. Operation can continue with some boards out of service while an alarm is displayed.
- b) All set points will have digital accuracy to eliminate the drift of analog controls.
- c) The digital set points and accuracy eliminates many of the tedious calibration procedures performed by the technicians during maintenance, startup, and load trimming of analog controls.
- d) The design philosophy is one that eliminates adjustments and is as self- diagnostic as p e) All alarms are individually printed out and not ganged into one alarm window which helps pin down the cause of a problem to the specific engine parameter involved and therefore contributes to less down time. The "first out" feature identifies the cause of a shutdown.
- f) Start Ramp with Fuel Limit - Eliminates the need for seasonal winter/summer start ramp trim or adjustment.
- g) Black Start - The DCS is DC powered and the vibration monitor is DC powered. A small inverter powers the MMI CRT and computer but black start is still possible with these out of service.

- h) Metal oxide varistor transient suppressors are installed for auxiliary control relays and fuel solenoid valves to protect DCS and vibration monitor electronics from high speed, high amplitude, inductive spikes.
- i) The water wash sequence is integrated into the DCS.
- j) The fuel shut off valve test logic is integrated into the DCS.
- k) Lite-off flow test logic is built into the DCS.
- l) Standard industrial inlet air temperature sensors and transmitters are provided to improve accuracy. Both engines can continue to run if one sensor fails.
- m) Automatic performance calculations are provided to simplify performance trend monitoring.
- n) Improved load sharing between gas generators is provided with digital accuracy and with no adjustments required.
- o) The system documents operator action automatically as an aid to problem diagnosis.
- p) A remote monitoring modem will be provided so that operating history, alarms, operating parameters and performance can be viewed. This requires a dedicated phone line which is to be provided by the Owner. ESI provides the remote monitoring for the warranty period.
- q) Energy control center remote SCADA operation for remote start/stop and load control is an available option.
- r) Local plant office master monitor is also an available option to permit alarm monitoring and group start mode.
- s) All fuel and lube pressures are automatically monitored by new solid-state pressure transducers with plus or minus 0.25 percent accuracy. All transducers are equipped with three way test valves.

## 2. Control CRT

The Control CRT is an industrial color CRT which is used by the operator to start/stop load and select power level, is icon driven, and has a 19" color screen. It provides the operator with alarm and event lists and built in trending capability for approximately 30 days of operational data storage. All analog parameters can be

displayed in groups in a trend format.

4. Operator Control Panel

Operator Control Panel has indicating lights and switches for operator control in addition to control functions on the CRT.

5. Vibration Monitor

Vibration Monitor is a rack-mounted digital device for gas generator vibration monitoring. High temperature accelerometers are used. The signals are processed by the separate vibration monitor and sent to the DCS where the alarm and trip functions are processed, and additionally are made available for trend history. Vibration monitoring of the free turbine is accommodated.

6. NetCon 5000 Main Unit has a single Central Processing Unit (CPU) which is programmed for both the sequencing and the fuel governing function of the control system. It is a 32 bit CPU. The Woodward NetCon 5000 uses a single chassis in order to house all of the circuit boards required for both engines. It contains the maximum system integration that is available at this time.

7. The Main Chassis houses some of the input/output circuit boards (I/O) for the main unit and is located in one of the 19" racks. Other I/O cards are locally mounted in the control panel.

8. Power Supply is a 125 VDC powered unit that provides controlled voltage DC to the rest of the DCS system. It provides system logic during a coast-down following a major power loss.

9. Printer is a unit that is used to print all alarms and events and to provide CRT screen copies in color.

10. I/O connections to the NetCon 5000 are made with plug-in connectors at the I/O cabinets in the control room. The I/O cabinets are standard 19" wide equipment rack mounts. These cabinets have interface terminal boards which are used to terminate all field I/O and connector harnesses to the NetCon control panel terminals.

11. Operator Interface Displays: Numerical data is displayed for alarms. Digital displayed data and analog trend displays are used by the operator to determine equipment status, as well as to control the unit, start/stop, load, etc. Trending is stored for thirty days of operation in the MMI System.

12. The AVR is a new digital device that has independent manual backup voltage control.

### 13. Water Injection System for NOx Control

The water injection skid provides water injection flow to four (4) engines (two (2) TWINPAC units). The skid is located in the turbine auxiliary room which is heated, ventilated and insulated. Maintenance clearances are provided around the skid.

The skid contains all pumps, control valves and shutoff valves for automatic water injection operation. A second pump provides redundancy and both pump motors operate at 480 V supply voltage. The motor starters are located on the skid. Two (2) TEFC 40 HP 480V boost pumps and two (2) TEFC 100 HP 480V main pumps are provided for redundancy. The boost pumps have discharge filters to protect the downstream control valves and engine systems. Either boost pump and either main pump can be valved in to provide full water injection flow to the eight engines. Normally one pump is the main and the other is the backup. Transfer is accomplished manually. The design does not require both pump outputs to run in parallel. The backup pump can also be used for future inlet fogging to provide an evaporative cooling effect to the gas generator air inlets to boost power output on hot days if inlet fogging nozzles, controls and piping are installed.

The boost pumps also serve a dual function as they are used to supply water wash to the engine bellmouth wash nozzles.

The logic for the control of the water injection valves and the protection of the engines is built into the Woodward NetCon digital integrated control system. Common pump services are controlled by a MicroNet NetCon subsystem mounted in a panel in the control room. The NetCon control system uses fuel flow for ratio control purposes within the EPA accuracy limits of five percent. Fuel flow totalization and heat rate calculations are included. Water flowmeters are included for each engine and are located on the skid. Water flow is also totalized in the NetCon.

The system automatically air purges the fuel nozzles of water in the engine at each shutdown. An instrument air supply is provided to the skid to operate the control valves and to the engine base for nozzle air purging purposes.

The engine interface consists of an ESI-patented water and fuel mixing block and necessary piping to accept the interface check valve and mixer. The mixer passes water into the liquid fuel manifold when operating on gas fuel.

Water injection is turned on during the start sequence at minimum power, and it is turned off at minimum power during the stop sequence. Megawatt output can be varied from minimum power to full load while maintaining the appropriate water to fuel ratio. The required water to fuel ratio is different for each fuel and it is automatically controlled by the DCS. Flameout detection monitoring, automatic EGT spread detection, and automatic load limiting are also provided in the DCS. The inlet fogging option is automatically sequenced on if provided

## **BILL OF MATERIAL**

Two (2) FT4C-1 TWINPAC Generating Units

Each remanufactured Model FT4C-1 TWINPAC Generating Unit includes the following equipment:

### **1. COMBUSTION TURBINE PACKAGE**

a) Two (2) weatherproof, prime painted steel enclosures, each including:

- (1) Inlet Air Silencer, Two-Stage Filter
- (2) New Exhaust Stack with Sound Suppression Treatment
- (3) Fire Protection system
- (4) Ventilation System
- (5) Low Voltage Heaters
- (6) AC and Emergency DC lighting system

b) Two (2) P&WA Model FT4C-1 industrial combustion turbines including:

- (1) Operating Controls
- (2) Lubricating System
- (3) Fuel Control and Fuel System, including Booster Pump and Filter
- (4) Starting Turbine
- (5) Ignition System
- (6) Automatic Anti-Icing System
- (7) Flexible Coupling
- (8) Mounts and Base

c) Pratt & Whitney Free (Power) Turbine

### **2. GENERATOR – EXCITER PACKAGE**

a) Weatherproof, acoustically-insulated, prime painted steel enclosure including:

- (1) Sound Treated Air Inlet and Exhaust
- (2) Two (2) Side Mounted Filters

b) One (1) Synchronous Generator, 57,300 KVA; (base rated at 80 F. and 1,000 feet), 0.9 power factor, 60 Hz, 3 phase, 13,800 volts, 2 pole, 3600 RPM, open, air-cooled, two (2) sleeve bearing, bracket type, complete with the following accessories:

- (1) A 300 VDC direct-connected brushless exciter.
- (2) One (1) completely assembled generator lubrication system module; consisting of one (1) AC motor driven oil pump, one (1) DC motor driven oil pump for start up, shutdown and emergency use, three (3) oil pressure switches, one (1) AC motor driven cooling fan, two (2) oil level switches, one (1) 250 gallon oil tank, one (1) vapor extractor fan.
- (3) One (1) neutral grounding transformer 25 KVA.
- (4) One (1) Bus Duct, 15 KV, 95 BIL, 3000 amp. Enclosed bus suitable for throat connection at each end, including terminations and support structures.

### **3. CONTROL AND SWITCHGEAR PACKAGE**

One (1) Pre-fabricated metal control enclosure, NEMA 3 design, prime painted steel, capable of withstanding the following loads: 100 MPH steady, 120 MPH gust wind loads (40 PSF) and 30 PSF snow and/or ice loads.

The enclosure will include electric heating and air conditioning with thermostatic control to maintain an inside ambient temperature of 70 F. The enclosure will also include fluorescent lighting, 125 volt D.C. emergency lighting, and 110 VAC receptacles.

The control enclosure will house the following equipment:

a) One (1) Generator Control Panel – Panel #1, 46"W x 90"H free standing, NEMA construction, hinged for access to interior components with sufficient strip heaters (480 VAC) to preclude condensation and interior lights with switch. The panel will be primed and finish painted.

b) One (1) Breaker Panel – Panel #2, 46"W x 90"H free standing NEMA construction, hinged for access to interior components, with sufficient strip heaters (480 VAC) to preclude condensation. Interior lights will be provided with switch. The panel will be primed and finish painted.

c) One (1) Relay Panel – Panel #3, 46"W x 90"H free standing NEMA construction, hinged for access to interior components, with sufficient strip heaters (480 VAC) to preclude condensation. Interior lights will be provided with switch. Panel is also hinged for back access and provided with suitable structural support for rigidity. The panel is to be primed and finish painted.

d) One (1) Motor Control Center, 600 V, NEMA 1, Class 11, Type C Construction; primed and finish painted.

e) Auxiliary components consisting of the following:

(1) One (1) Station battery, 60 cell 125 VDC, 100 ampere-hour at eight (8) hour rate, C&D Model DCU-9 lead-calcium or equal with free standing battery rack in heated and ventilated compartment.

(2) One (1) set direct-burial, quick-connect cables for interconnections between gas turbine/generators and air start pack enclosure and the local control and switchgear enclosure.

(3) One (1) 150.0 KVA auxiliary Power transformer.

### **3. ACCESSORY EQUIPMENT**

- a) One (1) Air Start Pac with two (2) 15 HP motor driven air compressors and storage capacity for four (4) TWINPAC starts or eight (8) single engine starts housed in a painted steel enclosure for two (2) TWINPACs.
- b) External Winslow liquid fuel filter assembly for two (2) TWINPACs.
- c) One (1) 3" A.O. Scott fuel meter and one (1) 3" fire valve per TWINPAC.
- d) Standard engine water wash and drying systems.
- e) One (1) fiberglass tank (10,000 gallon) for storage of demineralized water for two (2) TWINPACs.
- f) Water injection system for NO<sub>x</sub> control for two (2) TWINPACs.
- g) Bus from control house to transformer for two (2) TWINPACs.
- h) Remote panel
- i) Liquid fuel forwarding skid for two (2) TWINPACs.

### **5. CONSTRUCTION AND TRAINING SERVICES**

- a) Erection, checkout, and startup
- b) Paint units.
- c) Operator and maintenance training.

## **PERFORMANCE**

### **1. RATING**

The FT4C-1D TWINPAC is offered at a Base Load Rating of 108,000 KW output at the generator terminals, with corresponding estimated heat rates of 11,600 BTU/KW-HR (LHV). These ratings assume a clean condition and operation at the Peak or Base Load levels respectively, with water injection at ambient air conditions of 59 F. temperature and 0 feet elevation (14.4 psia) with 3" H2O inlet and 1" H2O exit duct losses and when burning OF FREE WATER Aviation kerosene (Jet A) or other distillate Fuels, conforming to TPM FR-1 and FR-2 Specifications.

### **2. OUTPUT AT OFF-STANDARD CONDITIONS**

Power outputs at other inlet air temperatures are shown on the enclosed Curve.

### **3. HEAT RATE**

The Heat Rate at outputs and temperatures other than those quoted above will generally conform to the enclosed Curve.

### **4. AUTOMATIC START CYCLE**

The TP4-2 TWINPAC will start on initiation of a starting signal from a local or remote control center, automatically sequence, and synchronize to the line in approximately 180 seconds from initiation of the start signal. It will then go to full load in five (5) minutes if the "normal" loading rate is selected or in approximately fifteen (15) to twenty (20) seconds if the "fast" loading rate is selected.

### **5. AUTOMATIC SHUTDOWN CYCLE**

With the initiation of a stop signal, the governor will be energized and run to its minimum stop, unloading the generator and scheduling minimum fuel flow to the engines. The TWINPAC may be unloaded at the fast or normal rate. Upon reaching the no-load condition, the generator main breaker is automatically opened by a no-load sense relay. The engine is run at the minimum fuel setting for a five (5) minute cool-down period. Upon completion of the cool-down, the fuel is cut off, the engine shaft comes to rest within six (6) minutes, and the free turbine-generator shaft coasts to a stop within twenty (20) minutes. During the five-minute cool-down period, the unit may be either locally or remotely signaled to resynchronize and load by actuation of the start switch. Once the fuel cut-off stage has been reached, the engine must be allowed reach windmilling speed before restarting (this requires approximately one (1) minute).



## CHARACTERISTICS AND PERFORMANCE

### 1. GAS TURBINE

#### a) Characteristics (Preliminary)

##### (1) Engineering Data

Controlling Specification: P&WA No. 6382

Type:

A multi-stage reaction turbine driven by hot gases from an axialflow generator, consisting of multi-stage compressors driven by multi-stage reaction turbines.

Model: FT4C-1

Number of Stages:

Gas Generator:

Low-Speed Compressor: 9

High-Speed Compressor 7

Low-Speed Turbine 2

High-Speed Turbine 1

Power Turbine 2

Principal Dimensions:

##### Gas Generator Gas Turbine (over-all)

Length, Inches 158 327.4

Width, Inches 42.5 76.3

Height, Inches 50.5 85.2

Weight,

(Approx. lbs.) 6550 16,300

**Direction of Rotation** - viewed from shaft end CW/CCW

#### (2) Service Requirements

##### Fuel:

##### (a) Liquid Fuel Specification FR-1

\* Delivery Rate – gph (Max. flow rate during acceleration only – Est.) 6930

Delivery Pressure at Gas Turbine, psig 5-50

Delivery Temperature at Gas Turbine

Enclosure, F. Minimum 25

**\*Based on a natural gas fuel containing 950 BTU/SCF (LHV) (HHV/LHV 1.1 and delivered to the engine from Purchaser's supply system in a CLEAN and DRY condition (filtered to 30 Microns absolute).**

**\*\*Cyclic pressure variations can be tolerated so long as total pressure excursion does not exceed  $\pm 5$  psi from average pressure supply.**

**\*Based on a distillate fuel with a density of 6.9 lbs/gal. And a LHV of 18,200 BTU/lb. (HHV/LHV = 1.06), delivered to the engine from Purchaser's supply system in a CLEAN and VOID OF FREE WATER condition (below 5 microns solid particles and 0.01% water by volume).**

**Lube Oil:**

**(a) Gas Turbine**

- q Specification PWA 521
- q Total required for complete system fill, Gals. Per engine 45.6
- q Consumption gph (Avg.) 0.1

**(b) Generator:**

- q Specification – turbine oils similar to Mobile DTE-23 having a viscosity between 130 and 180 S.U.S. at 100 F. and a pour point below the expected Ambient temperature.
- q Total required for complete system fill gals., Per generator 250
- q Consumption gph. Negligible

**Electrical:**

**Purpose: Quantity:**

Lighting, Heating and 50 KW per engine, 440 volt, Intermittent Power 60 Hz or 380 Volt-50 Hz, 3 phase

**b) Performance:**

At ambient air conditions of 59 F. Sea Level (14.4 psia) 3" H2O inlet and 1" H2O exhaust pressure losses with water injection. (Two TWINPACs)  
Utilization: Electric Generator Prime Mover

**Reserve Base**

**Peak Peak Load**

Net Output: KW 108,000  
Estimated heat Rate: BTU/Net KWHR. (LHV). 11,600

## **2. GENERATOR-EXCITER-REGULATOR**

**Manufacturer** - Electric Machinery Mfg. Co.

### **a) Generator Data**

**Type** – Synchronous, two-pole, turbo generator, three-phase 50 Hz, air-cooled.

**Nameplate Rating** – (At ambient conditions of 80 F. and 1000 ft. elevation)

#### **BASE PEAK**

KVA 57,300 61,100

KW 51,600 55,000

Power Factor 0.90 0.90

Voltage 13,800 13,800

Current 2,390 2,570

Speed, RPM 3,000 3,000

Short Circuit Ratio Greater than 0.5

#### **Characteristics**

**Total Temperatures** (Not to exceed) -

#### **BASE PEAK**

Stator - by detectors 110 120

Rotor - by resistance 125 135

Total temperatures are based on continuous operation at nameplate rating.

**Field Characteristics** - (Base Rating)

#### **Amperes Volts**

No-load and at rate generator terminal voltage 210 85

Rated load and at rated generator terminal voltage 510 300

**Reactances** In percent values on generator nameplate (rating) approximate.

Synchronous 198%

Transient 26%

Subtransient 14%

Negative Sequence 14%

Zero Sequence 7.2%

#### **Time Constants**

Open Circuit Time Constant 7.0 secs.

Transient Time Constant 0.6 secs.

Sub transient Time Constant 0.035 secs.

**Dielectric Test Voltages**

Stator

Per ANSI Standards C50-1-14

Rotor

**Physical Data** (Approximate)

Length (including base and exciter) 254"

Width (including base and exciter) 108"

Height (including base and exciter) 131"

Stator Weight 114,000 lbs.

Rotor Weight 33,700 lbs.

Overall Weight (including base and exciter) 154,000 lbs.

Rotor inertia (WK2) Lb-Ft<sup>2</sup> 26,000

Space required to remove rotor 300"

**Insulation System**

Class: Stator B

Rotor B

**Efficiency** - (including windage, bearing and exciter losses)

Full load 98.0%

$\frac{3}{4}$  load 97.3%

$\frac{1}{2}$  load 96.6%

$\frac{1}{4}$  load 94.0%

**Telephone Interference Factor** - (Per ANSI Standard C50-1-16.2)

Balanced 70

Residual 50

**Operating Voltage Variation**

The generator will be capable of operating at rated KVA, power factor and frequency at any voltage  $\pm 5$  percent of the rated voltage although not necessarily with standard temperature rise.

**Voltage Regulation** -

With constant field current and with generator operating at rated voltage, rated speed and rated KVA load.

0.90 power factor 35% 1.00 power factor 25%

.

### **Waveform Deviation**

Open Circuit Terminal Voltage Wave - 10 percent (max).

### **Generator Short Circuit Requirements**

The generator will be capable of withstanding, without injury, a 30 second, 3 phase short circuit at the terminals when operating at the highest capability KVA, rated power factor, and at 5 percent over-voltage. The generator will also be capable of withstanding,

Without injury, and other short circuit at its terminals of 30 seconds duration, or less, provided the machine phase currents under fault conditions are such that the negative phase sequence current ( $I_2$ ), expressed and the duration of the fault in seconds (T), are limited to values which give an integrated product ( $I_2/2T$ ) equal to, or less than, 30. Also, the maximum phase current shall be limited by means of suitable reactance or resistance to a value which does not exceed the maximum phase current obtained from the 3-phase fault.

### **b) Exciter Data**

Type: Brushless

### **Nameplate Rating**

KW 160

Voltage 300

Amps 510

Speed 3000 RPM

### **Insulation System**

Class - Armature B

Field B

### **Total Temperatures**

Field - by Thermometer 140 C.

Armature - by Thermometer 140 C.

### **Performance**

Nominal ceiling voltage: 150 percent

### **(3) Voltage Regulator Data**

**Type:** Static regulator with reactive current compensation circuit and maximum and minimum excitation limit circuits.

### **Performance**

Regulation or sensitivity  $\pm 2\%$

Voltage adjustment range  $\pm 10\%$

**d) Exciter-Regulator Performance**

Speed of response - Better than 0.5 seconds

Short Circuit Sustaining Capability on a sustained three-phase fault – Greater than 150%



## COMMERCIAL TERMS

### Basis of Pricing

### Validity

This proposal is valid until December 15, 2009.

### Taxes

No sales or use taxes have been included in this quotation. These prices quoted exclude any federal, state or local taxes or fees which may be associated with the export, import or purchase of equipment and/or services.

### Price

Two (2) Twin Pac FT4C-1D Gas Turbine Generator Set including as described in the scope of supply. All pricing is based on ex-works factory delivery unless otherwise stated.

### All Equipment Subject to Previous Sale

### GTG UNIT

Generators set price (Unit).....US\$ 20,000,000

Generators set price (Two Units).....>.US\$40,000,000

### *SCHEDULED DATE(S)*

Reference	Equipment Description	Scheduled Date
Unit 1,2,	Pratt & Whitney Remanufactured by OEM	December 15, 2009



***Payment Schedule***

This proposal is based upon receipt of the following progress payments and a Contract Agreement by both Parties by the Validity date Seller may request at any time, Purchaser will demonstrate its financial capability to continue to carry out its obligations under this Contract. This demonstration may require that Purchaser furnish adequate payment security.

	<b>Payment Event</b>	<b>% of Equipment Price</b>
1	At the signature of the Contract	25%
2	At Notice of Readiness to Ship and paid against Seller's invoices before December 30, 2009.	75%

**Instrucciones para transferencias:**

Intermediary Bank:

Citibank, N.A.

ABA: 021000089

Sucursal: New York

Dirección:

111 Wall Street, New York, NY 10043

Beneficiario:

International Union Bank, S.A.

Cuenta: 36246731

Dirección:

Ave. Samuel Lewis, Edif. Omega Piso 5,

Apartado 0391 Wtc Panamá, Republica de Panamá

FFC: Davos International

Bank/000767-224-001

Ref: Derwick Associates/ 13102362

**Warranty**

Derwick Corporation will provide a one ( 1) year warranty on the entire gas turbine generator package and any other balance of plant equipment provided.

**Terms & Conditions**

This proposal shall be valid for thirty ( 30) days; provided, however, the obligation to treat this proposal as confidential, and that it cannot be shared with any third party without the prior written consent of Derwick Corporation shall survive.



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Derwick Corporation and PDVSA will negotiate in good faith to establish general terms and conditions that are usual and customary of the sale of these new equipments.

### **Site Services**

Derwick Corporation would be pleased to also provide a proposal for the installation, startup and commissioning of the facility. This would include providing construction supervision as well as startup engineers for all equipment provided.

Derwick Corporation can also provide an experienced service representative to assist the operating personnel during the first two (2) months after the equipment goes online.

### **Follow Up**

Please contact the following person at Derwick Corporation for information regarding this proposal:

Pedro Trebbau  
Director  
[ptrebbau@derwickssociates.com](mailto:ptrebbau@derwickssociates.com)  
58-412-3007470



DERWICK ASSOCIATES

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## Attachment A

TURBO POWER AND MARINE SYSTEMS, INC.

TP4-2 (C-1D) Gas Turbine Twin Pac

Estimated Heat Rate vs. Megawatt Output

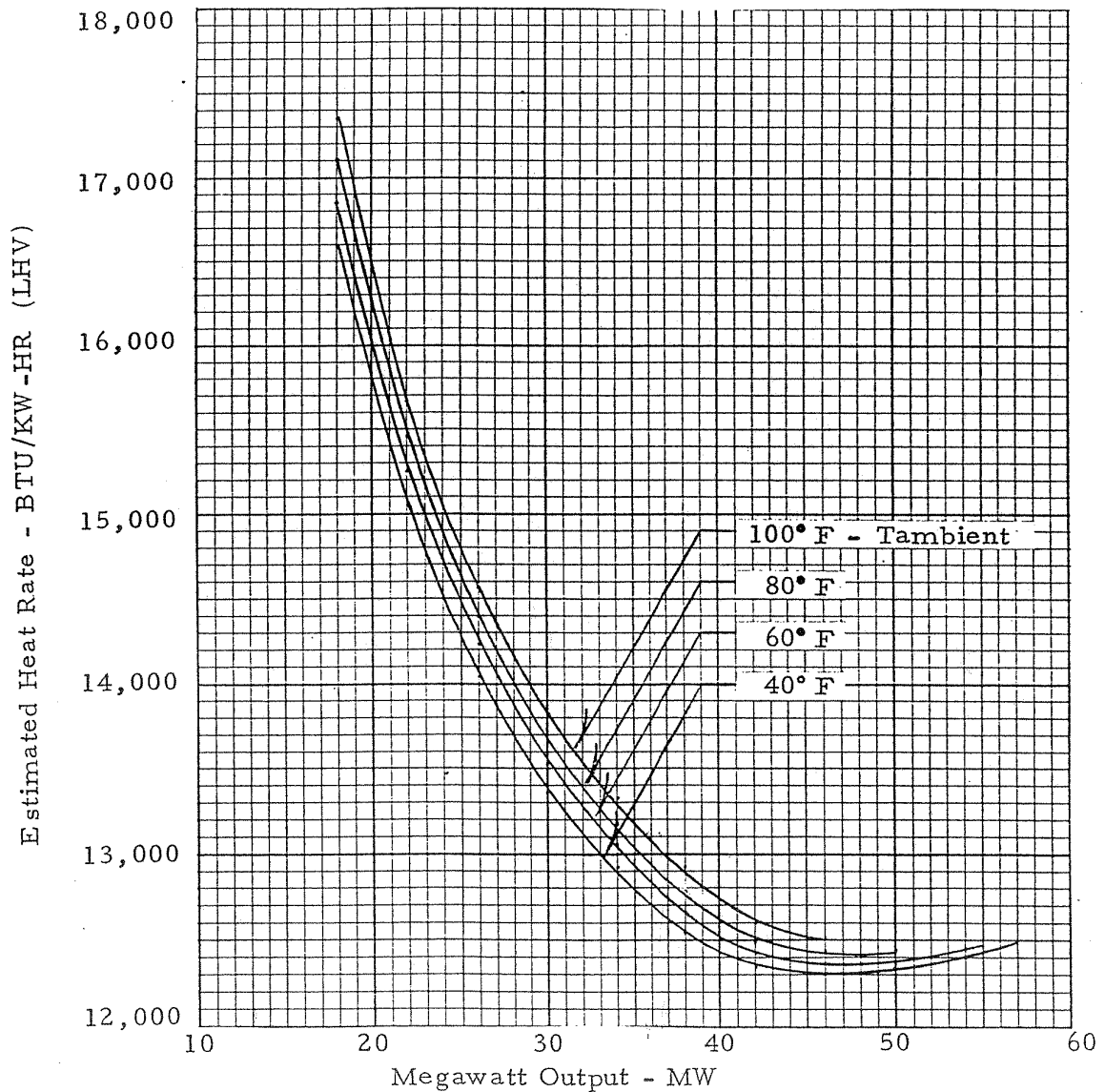
5.5"H<sub>2</sub>O Inlet Duct Pressure Loss

1.0"H<sub>2</sub>O Exhaust Duct Pressure Loss

Sea Level

50 Hz.

Transformer Not Included



TURBO POWER AND MARINE SYSTEMS, INC.

TPA-2 (C-1D) GAS TURBINE TWIN PAC

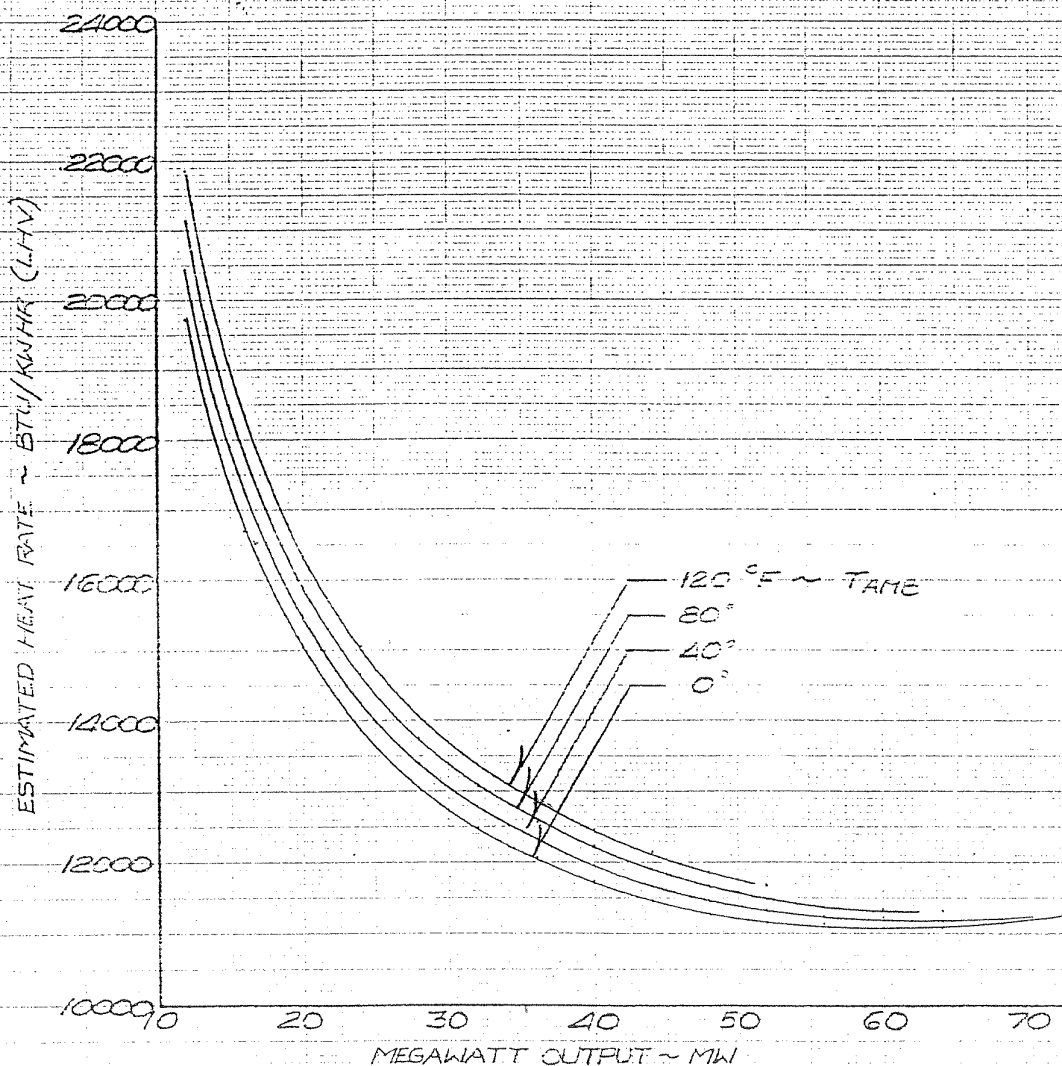
ESTIMATED HEAT RATE VS MEGAWATT OUTPUT

3" H<sub>2</sub>O INLET DUCT PRESSURE LOSS

1" H<sub>2</sub>O EXHAUST DUCT PRESSURE LOSS

SEA LEVEL

N<sub>3</sub> = 3600 RPM



## Scope of Supply and Purchaser's Responsibilities

FT4C-1D TWIN PAC  
EQUIPMENT ONLY  
LIQUID FUEL

Ö^! , æ  
INDUSTRIAL GAS TURBINE SERVICES

Qty: 1 ..... 8 Yfk JW

Item	Description	Quantity	Design	Supply	Installation	Notes
I.	GAS TURBINE POWER ISLAND					
1	GAS TURBINE PACKAGE	2	W	W	C	
	Gas Generator (GG4C-1D Core Engine)		W	W	C	
	Power Turbine		W	W	C	FT4C-1D
	Exhaust elbow		W	W	C	
	Exhaust transition		W	W	C	
	Fabricated gas turbine base and mount assembly		W	W	C	
	Coupling connecting power turbine and generator		W	W	C	
	Air starter		W	W	C	
	Ignition system		W	W	C	
	GG & FT lube oil systems		W	W	C	
	* Oil-to-air coolers		W	W	C	
	* Oil pumps		W	W	C	One gearbox and one DC driven
	* Carbon steel piping		W	W	C	
	* Enclosure		W	W	C	
	Fuel supply systems	2	W	W	C	
	* Liquid fuel filter		W	W	C	
	* Liquid fuel forwarding skid		W	W	C	
	* Last chance liquid fuel fire valve		W	W	C	
	Gas turbine enclosure	2	W	W	C	
	* Secondary cooling air system with louvers		W	W	C	
	* Vents and drains		W	W	C	
	* Interior AC/DC lighting		W	W	C	
	* CO <sub>2</sub> Fire Suppression System		W	W	C	CO <sub>2</sub> Bottles supplied by Customer
	* Sound attenuation estimate		W	W	C	NA
	* Air inlet filter		W	W	C	
	Inlet silencing	2	W	W	C	One inlet section
	Exhaust Stack	2	O	O	C	3 section residential sound treatment
	Air start pac	1	W	W	C	
	Gas turbine heating system	2	W	W	C	
3	GENERATOR PACKAGE	1	W	W	C	60 to 50 HZ conversion optional
	EM Open Ventilated Air Cooled Synchronous Generator		W	W	C	13.8Kv, 3 phase, 60 HZ, 74,500 kVA, 0.9 PF 2 pole
	Brushless Exciter Assembly		W	W	C	With pilot exciter
	Stator Heaters		W	W	C	
	Neutral ground transformer/resistor		W	W	C	
	Current transformers		W	W	C	
	Stator temperature detection		W	W	C	
	Bearing temperature detection		W	W	C	
	Generator and exciter air temperature detection		W	W	C	
	Rotor ground detection		W	W	C	
	Lube oil System		W	W	C	Air cooled
	* Oil filter		W	W	C	
	* Motor driven pumps		W	W	C	AC and DC

W=Ö^! , æ  
C = Customer  
O=Optional

Item	Description	Quantity	Design	Supply	Installation	Notes
	Enclosure		W	W	C	Prime painted
	* Inlet air filter		W	W	C	
	* Inlet and exhaust silencing		W	W	C	
	* Interior AC/DC lighting		W	W	C	
	* Fire detection system		W	W	C	
4	CONTROL PACKAGE	1	W	W	C	
	Prefabricated steel enclosure		W	W	C	
	* HVAC		W	W	C	
	* Fluorescent lighting		W	W	C	
	* DC emergency lighting		W	W	C	
	* AC power outlets		W	W	C	
	* Smoke detector		W	W	C	
	Operator control cabinet		W	W	C	
	* Starting and operating controls		W	W	C	Manual and automatic
	* Speed indication		W	W	C	
	* Voltmeters and frequency meters		W	W	C	Bus and generator
	* Ammeter		W	W	C	
	* Wattmeter		W	W	C	
	* VAR meter		W	W	C	
	* Synchroscope		W	W	C	
	Instrument Cabinet		W	W	C	
	* Automatic voltage regulator		W	W	C	
	* Synchronizer		W	W	C	
	* Vibration monitor		W	W	C	Gas turbine
	* Fire protection system power supplies		W	W	C	
	* Static inverter		W	W	C	
	Unit control cabinet		W	W	C	
	* Woodward Netcon 5000 control system for automatic starting, running, loading, unloading and shutdown of the unit.		W	W	C	
	Generator protective relay panel		W	W	C	
	* Generator protective relays		W	W	C	
	* Lockout relays		W	W	C	
	* Watt hour meter		W	W	C	
	Motor Control Center		W	W	C	
	* AC and DC distribution panels		W	W	C	
	* Motor starters		W	W	C	
	* AC distribution transformer		W	W	C	
	* Breakers as required		W	W	C	
	* Manual transfer switch		W	W	C	
	* Field termination blocks		W	W	C	
	* Power supplies		W	W	C	
	Ventilated cubicle with rack mounted lead acid batteries		W	W	C	125 VDC
	Battery charger		W	W	C	
	Switchgear module 15 kV Class		W	W	C	
	* Metalclad switchgear compartment		W	W	C	
	* Circuit breaker		W	W	C	3000 Amp/ 1000 MVA, 15kV class totally enclosed
	* Non-segregated insulated 3 phase bus duct		W	W	C	
	* Lightning arresters and surge capacitors		W	W	C	
	* Current transformers and potential transformer		W	W	C	
	* 3 phase station auxiliary transformer		W	W	C	

W=Owner, A  
C = Customer

Item	Description	Quantity	Design	Supply	Installation	Notes
	5 INSTALLATION HARDWARE					
	Site interconnecting piping		C	C	C	
	Foundation embedded material		C	C	C	Including all anchor bolts, shims and plates, and grout for Ö^!, & supplied equipment.
	Interconnecting electrical cables		W	W	C	Between Ö^!, & supplied equipment
	6 STARTUP AND COMMISSIONING SPARE PARTS AND CONSUMABLES		W	W		For Ö^!, & Scope of Supply
II.	ADDITIONAL RESPONSIBILITIES DURING CONSTRUCTION AND START-UP					
	Technical Representatives to advise Customer Supervisory Personnel during FT4 equipment erection checkout, and startup			W		
	Instruction Manuals and Plant Documentation provided: Construction Manual, Commissioning Manual & Sign-off Sheets, TPM Drawing Package, Vendor Manuals & Drawings, FT4 Maintenance Manual, FT4 Illustrated Parts Catalog, FT4 Service Bulletins, Operating Instructions, Bill of Material, As Built Drawings, General arrangement drawing, Foundation interface drawing, Loading diagram			WT		
	training			W		Includes customer training on site. Training description can be found in the Ö^!, & Customer Training Document version 21-0802. Travel and lodging for customer's personnel not included.
	Performance Testing			C		The customer is responsible for providing all necessary support to install, calibrate, and remove all temporary and plant instrumentation/equipment necessary for performing the acceptance test. Ö^!, & provides technical support and manages the test plan for this work.
III.	PROJECT DEVELOPMENT AND OWNER'S RESPONSIBILITIES					Owner is responsible for compliance with Ö^!, & operating, installation, and maintenance instructions.
	1 SITE DEVELOPMENT		C	C	C	Owner is responsible for all areas of site development and are not limited to the items listed in this document.
	Adequate Title and Interest, Permanent Facility Permits, Construction Permits and Licensing			C		To permit the installation of such units and their operation for at least the period contemplated by the contract. Provide Ö^!, & representatives unrestricted access at all times as may be reasonably necessary in the performance of their duties.

W=Ö^!, &  
C = Customer

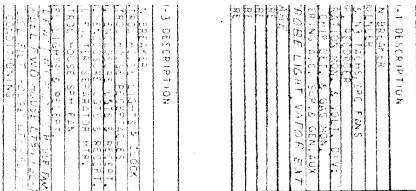



Item	Description	Quantity	Design	Supply	Installation	Notes
	Sub-Soil Investigation & Report		C	C	C	Minimum sub-foundation bearing capacity of 2500 psf (120 kPa) and limits differential settlement of the main foundations equal to or less than 0.0005 times the foundation length.
	Foundations for all Equipment		C	C	C	Ö^!, & will provide Loading Diagrams for Ö^!, & supplied equipment.
	Below Grade Electrical Raceway		C	C	C	Includes Conduit, Duct Bank, Trenches, etc.
	Provision of <b>Secure Field Office</b> . Furnished with electricity, Heating and Air Conditioning, Drinking Water, Desks, Chairs, Parking Area, Lockers and others which are necessary for Field Works, Services & Sanitary Facilities of Office Personnel.		C	C	C	Including 10' x 40' (3 m x 12 m) area for a field office. This field office needs to be able to accommodate 3-4 Ö^!, & individuals.
	Provision of First Aid and Medical Services - OSHA Approved		C	C	C	
	Provisions of Local Communication Facilities		C	C	C	Including radio, telephone (local and long distance) with international direct dialing and fax machine. This should be a minimum of 3 lines in the Ö^!, & field office. A separate dedicated phone line shall be provided to each turbine control system in the control house.
	Temporary Construction Staging & Secure Inventory Area			C		A minimum area of approximately 115' by 136' is recommended per Power Island. A minimum of two shelved conex boxes and one non shelved or enclosed equivalent per PowerPAC prior to delivery of equipment.
	Access Road(s), Interior Roads, and Parking Areas		C	C	C	All-weather and unobstructed
	Transmission System		C	C	C	
2	ENGINEERING AND CONSTRUCTION					
	Plant Engineering			C		
	All Labor for complete off-loading, Inventory, Inventory control, Storage, Erection, Installation, Checkout, Testing, and Start-up of all WGPW and non-Ö^!, & supplied equipment and material.			C		
	Maintaining and Guarding all Facilities, Equipment, and Materials during construction			C		Including security fence
	Site Organization During Construction			C		Including Resident Field Construction Manager; Supervision & Manpower for Erection Works, Checkout, Trouble Shooting, Start-up & Commissioning, Test Operation & Trial Operation, Plant Start-Up Engineering
	Emissions and Acoustic Testing			C		
	Worker's Compensation, Employer's Liability, or any other Local Insurance Required			C		Ö^!, & will cover all Ö^!, & personnel.
	Consumable Material for Erection Works			C		As required


Item	Description	Quantity	Design	Supply	Installation	Notes
	Construction Equipment, Tools and Aids			C		Including but not limited to the following: Cement Mixers, Loaders, Trucks, Cranes of varying capacities, Power Generators, Air Compressors, Welders, Drilling Equipment, Pipe Working Facilities & all hand tools required for expeditiously and competently completing all phases of the work under the contract.
	Required Tests Prior to Startup: Including but not limited to:			C		
	* Resistance ratio and polarity tests			C		Generator and Transformer CTs and PTs
	* All high voltage dielectric tests * Field check and calibration Protective Relay Calibration *			C		All Ö^!_ supplied protective relays and circuits. The Ö^!_ Commissioning and checkout manual further clarifies the Customers responsibilities.
	Phasing and Synchronizing the Generator to Purchaser's system			C		
3	POWER ISLAND INTERFACES					
	BOP Motor Control Centers			C		
	Control System Interface			C		Customer is responsible for all-interconnecting hardware, software and documentation for all BOP I/O communication and control.
	Natural Gas for Start-up, Testing and Operation 445 psig (30 bar), Approximately 4700 scfm (2.2 m3/sec) per gas turbine			C		Interface Point: Flange on Ö^!_ Power Island. Per TPM Natural Gas Fuel Specification FR-2. Fuel to be tested by a certified lab and the results provided to Ö^!_ prior to start-up.
	Potable Water for Gas Turbine Off-line Water Wash 50 psig (3.4 bar) min., Approximately 300 gallons (1150 liters) per gas turbine water wash at 110 gpm (415 liters/m)			C		Interface Point: Flange on Ö^!_ Power Island. Per TPM Potable Water Quality Specification
	Vent and Drain. Maximum flow on Oily Waste drain is 35 GPM for water wash.			C		Interface Point: Connections on Ö^!_ Power Island.
	High Voltage Power			C		Interface Point: Generator Terminals.
	Backfed Electrical Power Supply 75 kVA per Power Island, 13.8kV, 60 Hz, 3 phase for lighting, heating and intermittent auxiliaries			C		Plus as required for BOP and optional equipment loads
	Construction Power-Including distribution to the Ö^!_ supplied equipment			C		480 V, 3 phase, 24 hours per day to electric generator upon arrival of the generator. Reliable temporary 480 V, 100 amp power at the control house for checkout and start-up at least 21 days prior to the first fire date of the first unit to be commissioned.
4	OTHER OWNER RESPONSIBILITIES					The following list of items is provided for your convenience and gives examples of the types of equipment and/or services that are outside the Ö^!_ Scope of work, and if required, are the sole responsibility of the Owner.
	Site Survey/Plot Plan		C	C	C	

W=Ö^!\_ supplied  
C = Customer

Item	Description	Quantity	Design	Supply	Installation	Notes
	Excavation for Foundations, Pipes, Roads, Cabling & Grounding Grid		C	C	C	
	Site Leveling		C	C	C	
	Backfill		C	C	C	
	Finish Grading		C	C	C	
	Foundation embedded material		C	C	C	Including all anchor bolts, shims and plates, and grout for O&A, & supplied equipment.
	Surface Drainage to and including any Collection Pond		C	C	C	
	Oily Water Separator		C	C	C	
	Sanitary Waste Disposal		C	C	C	
	BOP and Plant Fire Protection Systems- Hydrants Panels and Extinguishers			C		Including Fire Protection during construction
	Plant Lighting			C		
	Intra-communication system			C		
	Site Fencing and Gates			C		
	Construction Water			C		
	Builder's All Risk Insurance (BAR)			C		
IV.	OPTIONS					
	1. Spares Parts and Consumables		W	W		
	2. Long Term Maintenance Agreement		W	W		
	3. 60 HZ to 50 HZ conversion		W	W	C	
	4. Off-line compressor internal water wash system		W	W	C	Includes piping system, nozzles, valves, etc internal to the Gas Turbine Enclosure. Excludes Water Wash Skid
	5. Water Injection System		W	W	C	

[illegible][illegible]

 Electric Machines  
MILWAUKEE, WIS.

 <b>Pratt &amp; Whitney</b> A United Technologies Company Pratt & Whitney Power Systems, Inc.	<b>PWPS</b>  <b>SPECIFICATION</b>	FR-1	REV D	SHEET 1 OF 6
		ISSUED BY : P. Lavendier		DATE: 8/18/95
		REVISE BY : D. Tougas		DATE: 7/8/03
	RELEASED	REFERENCE :		REV:

## **GAS TURBINE LIQUID DISTILLATE FUEL REQUIREMENTS**

### **GENERAL**

This document provides the requirements and general guidelines for light and medium hydrocarbon liquid distillate fuels which can be burned satisfactorily in PWPS/P&W aeroderivative industrial gas turbines.

Industrial gas turbines are capable of burning a variety of liquid fuels providing they have appropriate fuel delivery, injection and combustion systems for each class of fuel. Distillate liquid fuels are complex hydrocarbon mixtures processed from a wide variety of basic crude oil stocks, and have a broad range of property values. In some cases, such as gasoline, the hydrocarbon fraction may undergo further processing and acquire additives or, as with naphtha, may be offered for use in the as-distilled form.


This document recognizes three general categories of distillate fuels as defined by ANSI/ASME B 133.7M which may be employed in properly configured PWPS/P&W gas turbines. Category a is No. 0-GT fuels such as light naphtha, gasoline, and JP-4/ Jet B fuels which are highly volatile and require special handling and fuel system design. Categories b and c are No. 1-GT and No. 2-GT such as light to medium kerosene and diesel fuels which can be burned in the standard gas turbine, providing all fuel properties specified in the following Table 1 are met. Fuel treatment or conditioning, including heating, may be necessary to satisfy these requirements. Residual, ash bearing fuels, and blends of distillate and residual fuels are not suitable for aeroderivative gas turbines.

Industrial fuels may be obtained from a large number of producers with a broad range of properties. Contamination in transport and deterioration in storage are common problems. Poor and contaminated fuels greatly affect the performance and durability of gas turbines. Therefore, it is imperative for the gas turbine user to install a proper fuel system design and institute an effective fuel quality management program to insure and maintain clean, high quality fuels.

### **GUIDELINES FOR EFFECTIVE FUEL QUALITY MANAGEMENT**

The fuel management system should be designed and in place prior to the site start-up. The following considerations should be addressed:

- 1) The fuel type is generally chosen on the basis of cost and availability, however, the effects of fuel on gas turbine operation and life cycle economics should be considered. Normally, high viscosity fuels such as heavy diesel are less expensive initially, but usually impact engine life and increase overall life cycle costs. Some fuels can be made usable through treatment and/or conditioning, and the cost of these processes should be factored into the overall economics. Possible treatment processes are water wash, heating, filtration, and centrifuge or cyclone separation.
- 2) The transport path between the fuel producing location and the customer's unloading/ storage area should be analyzed for possible contamination potential. Dedicated transport containers are highly

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		REFERENCE :	REV:	

## **GAS TURBINE LIQUID DISTILLATE FUEL REQUIREMENTS**


recommended.

- 3) The fuel storage equipment should be properly designed and sized and should be free of any contaminating or corrosive materials. Fuel storage time versus tank capacity should be balanced. Sufficient time should be allowed for incoming fuel to settle. The fuel for the gas turbine should not be removed from the bottom of the tanks, so as to avoid picking up heavy bottom ends. Tanks should be regularly drained from the bottom to remove the sediment.
- 4) The on-site conditioning and treatment systems should clean the impurities from the fuel and maintain high quality as it forwards the fuel to the gas turbine. The design should consider the quantity, placement and filtration efficiency of the filters.
- 5) The requirement for fuel preheating, if necessary, should be considered. Preheating is required for viscosity enhancement of heavy fuels and wax removal from high cloud point (waxy) fuels.
- 6) Safety requirements should be considered in the initial design phase, particularly if the fuel is one of the highly volatile Category a type fuels.
- 7) Contaminants brought in with the incoming gas turbine airflow should be considered. Proper air filtration is required. It is the normal practice to subtract the incoming air contaminants from the allowable fuel contaminant limit through a formula given in Note 7 of Table 1.

The operators of PWPS/P&W equipment must comply with all aspects of this specification, and ensure compliance by regularly taking and analyzing liquid fuel samples. Contaminants not normally present in the fuel at the production site may be introduced as a result of contact with sea water, other fuels, or insufficiently cleaned equipment during the transportation, handling and storage phases. If the fuel arriving at the user location falls out of compliance with the specification, and can not be made compliant by treatment, then the fuel supplier should be contacted immediately for a corrective action. Even a short period of operation with fuel of excess contaminants (salts, trace metals, particulates, wax. etc.) could seriously impact the gas turbine life and performance.

To further insure high quality fuel and continuous compliance, a regular maintenance program must be adopted for all on-site fuel handling, storage, conditioning and treatment systems. Regular replacement of filter elements, periodic draining of water, removal of sediments from the tanks, lines and sumps, and replacement of treatment fluids, etc., should be planned for and implemented.

PWPS/P&W requests review of the customer's final overall fuel management system design. PWPS bulletin no. 97M01 entitled "Distillate Fuel System Recommendations" is available for further details on implementing a quality fuel system. Additional guidance can be obtained by contacting your PWPS/P&W Marketing representative.

 <b>Pratt &amp; Whitney</b> A United Technologies Company Pratt & Whitney Power Systems, Inc.	<b>PWPS</b> SPECIFICATION  <b>RELEASED</b>	FR-1	REV D	SHEET 3 OF 6
		ISSUED BY : P. Lavendier	DATE: 8/18/95	
		REVISE BY : D. Tougas	DATE: 7/8/03	
		REFERENCE :	REV:	

## **GAS TURBINE LIQUID DISTILLATE FUEL REQUIREMENTS**


### **RECOMMENDED DISTILLATE FUELS**

The following liquid distillate fuels can be used in the gas turbine, if the fuel property requirements listed in Table 1 are met for the fuel delivered to the inlet of gas turbine.

Category a (No. 0-GT): Naphtha Fuels, Unleaded gasoline types, wide-cut fuels of the JP-4 (MIL-T-5624), and Jet B (ASTM D 1655) types - SEE NOTE 3

Category b (No. 1-GT): Kerosene or other distillates of the JP-5 (MIL-T-5624); Jet A and A-1 (ASTM D1655); No. 1-D diesel fuel (ASTM D975); No. 1 fuel oil (ASTM D 396); and No. 1 GT gas turbine fuel oil (ASTM D2880) types.

Category c (No. 2-GT): Distillates of the No. 2 diesel fuel (ASTM D975) No. 2 fuel oil (ASTM D 396), No. 2 GT gas turbine, and marine diesel (MIL-F-16884) types.


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## GAS TURBINE LIQUID DISTILLATE FUEL REQUIREMENTS

**TABLE 1: GAS TURBINE LIQUID FUEL PROPERTY REQUIREMENTS**

Property	Limit	NOTE(S)	Test Method (Note 1)
Viscosity - cSt: Max. (for category a, b, and c)	6.0 max. for starting, 12.0 max. for operation	2	ASTM D445
Min. at 100 °F (37.8°C) (for category a)	0.5 min.	3	ASTM D445
Min. at 100 °F (37.8°C) (for category b&c)	1.0 min		ASTM D445
Combined Free Water and Sediment, vol. %	0.1 max.	4	ASTM D2709
Particle Contamination, mg/gal.	10.0 max.		ASTM D2276 or ASTM D5452
Particle Size - microns (micrometer)	20 max	13	
Hydrogen - % by weight	12.4 min	5	ASTM D1018
Metal Contaminants - ppm by wt.			ASTM D3605
Vanadium (V)	0.2 max.	6 & 7	
Sodium (Na) + Potassium (K)	0.2 max.	6 & 7	
Calcium (Ca)	2.0 max.	6 & 7	
Lead (Pb)	0.1 max.	6 & 7	
Copper (Cu)	0.02 max.	6 & 7	
Copper corrosion	No.1 max.	8	ASTM D130
Fuel Category a (only)			
Flash Point, °F (°C)	To be reported	9	ASTM D93
Reid Vapor Pressure, psi or	12.5 max.		ASTM D323
Vapor Pressure by Mini- method, psi	12.5 max.		ASTM D5191
Fuel Category b and c (only)			
Flash Point, °F (°C)	100 °F (37.7°C) or local regulatory limit	10	ASTM D93
Cloud Point, °F (°C)	25 °F (14°C) below GT inlet fuel temp.		ASTM D2500
Carbon Residue (on 10% bottoms), %	0.25 max.		ASTM D524
Sulfur, % by mass	1.3	11, 12	ASTM D4294
Ash, % by mass	0.005 max.		ASTM D482
Net Heating Value, Btu/lb (kcal/kg)	To be reported		ASTM D4809
Specific Gravity	To be reported		ASTM D1298



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## **GAS TURBINE LIQUID DISTILLATE FUEL REQUIREMENTS**

### **NOTES TO REQUIREMENTS (TABLE 1)**

#### **NOTE 1**

The most recent revision of the ASTM test method should be used insofar as practicable. An equivalent test method may be used in lieu of ASTM test method, if approved by PWPS/P&W.

#### **NOTE 2**

Maximum fuel viscosity at gas turbine fuel pump inlet shall be 6.0 cSt for starting and 12.0 cSt during operation. Fuel may be heated, to a maximum of 160 deg F (71C), to meet this requirement.

#### **NOTE 3**

In order to operate FT8 with Category a fuels, such as naphtha, specially designed PWPS/P&W fuel system components are required.

#### **NOTE 4**

The fuel delivered to the inlet of the gas turbine is to have a sediment level less than 10 mg./gallon of fuel. However, for practical extended fuel filter life, the fuel should have lower sediment levels

#### **NOTE 5**

Minimum hydrogen percentage by weight is 12.4; however, for optimum combustion, higher hydrogen percentage is recommended.

#### **NOTE 6**

To achieve the level of sensitivity required for the detection of some of these metals, the furnace atomic absorption method may be necessary. Since some trace metals can have harmful effects on gas turbine operation, it is necessary to impose limitations. Higher levels of Table 1 metallic levels, even for short period, will increase the gas turbine maintenance costs.


#### **NOTE 7**

Limits of metal contaminants in Table 1 assume no contaminants in the inlet air or injected water. For operation with contaminants in the inlet air or injected water, the maximum allowable limit of any particular contaminant in the fuel must be reduced according to the following formula:

$$Af = Lf - [C_{air} \times (\text{air/fuel weight ratio})] - [C_{water} \times (\text{water/fuel weight ratio})]$$

where,

Af	= Maximum allowable contaminant in the fuel, ppm by wt.
Lf	= Contaminant Limit as called out in Table 1, for example 0.2 for (Na+K)
C <sub>air</sub>	= Contaminant in inlet air, ppm by wt.
C <sub>water</sub>	= Contaminant in injection and/or evaporative cooling water, ppm by wt.

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## **GAS TURBINE LIQUID DISTILLATE FUEL REQUIREMENTS**

### **NOTE 8**

Copper corrosion test conditions are 2 hours at 212 deg F (100 deg C).

### **NOTE 9**

No flash point limitation is specified; however, local regulatory limits and safety regulations must be met.

### **NOTE 10**

The cloud point shall be at least 25 degrees F below the anticipated gas turbine fuel inlet temperature. To meet this requirement, additional fuel heating, to a maximum of 160 degrees F (71C), may be needed.

### **NOTE 11**

Sulfur content limits Below 1.3% WT. are imposed when:


- a) The local regulatory limits of sulfur oxides exhaust emissions are exceeded; then the fuel sulfur content must be reduced until the local regulatory limits are satisfied. For instance, the USA EPA limits fuel Sulphur content to 0.8% for SO<sub>2</sub> emissions control, but local codes vary widely.
- b) If exhaust heat recovery equipment is employed; then the equipment manufacturer's limit may apply.

### **NOTE 12**

High sulfur fuels will impact hot section repair interval dependent on the amount of alkalai metals present. The combination of high sulfur and high alkalais must be avoided.

### **NOTE 13**

Maximum particle size to be controlled by filtration with a  $\beta_{20}$  ratio of 200.

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		ISSUED BY: P. Lavendier		DATE: 8/28/95	
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## GAS TURBINE LIQUID DISTILLATE FUEL REQUIREMENTS

REV LET	SHEETS AFFECTED	SHEETS ADDED	DESCRIPTION	REV BY & DATE	APPVD & DATE
A	1-4		1) Added 1.7 cs lower limit of viscosity 2) Changed NA + K limit to 0.2 ppm 3) Added sulfur limit to 1.3% max. 4) Changed format to FrameMaker 5) Revised verbiage to put more stringent requirements for fuel management 6) Updated test procedures to current standard	P. Lavendier 8/18/95 EC#8352	
B			Completely re-written and updated to allow the use of Naptha Fuels, lower min viscosities. Max allowable fuel viscosities were changed to be based on actual operating temperatures, rather than a fixed temperature.	EC#9025 T. Fox/D. Dalal 2/11/98	
C	All		Updated Logo to new PWPS Logo. Updated all TPM references to PWPS references.	EC#9925 L. DiSalvo 7/23/01	
D	4		1) Changed Free Water to Combined Free water and sediment. changed limit to 0.1% max by volume. Changed Test Method to ASTM D2709. 2) Changed sediment to Particulate Contamination. Removed metric unit (mg/l) (2.7) from Limit. Changed test method to ASTM D2276 or D5452.	EC#10620 D. Tougas 7/8/03	
	4		3) Added Note 13 to Particle size		
	5 & 6		4) Removed Test Method IP288. 5) Added Test Method ASTM 4809 to Net Heating Valve. 6) Made various typographical changes. Added Note 13 regarding filtering.		