# Appendix 3-2

# Wilbros Data

# COMPRESSOR STATION COST FACTORS

**Alaska Natural Gas Development Authority**

*Prepared for*

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*February 8, 2005*

*"This report is submitted on the basis that Willbros Engineers, Inc. ("Willbros") will only be responsible for liability to the extent directly attributable to errors or omissions of Willbros, but not for any indirect or consequential liability attributable thereto".*

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# COMPRESSOR STATION COST FACTORS

## Alaska Natural Gas Development Authority

## 1.0 Introduction

The objective of this particular study is to identify "Key Leveraging Design Issues", so that there is a basis for comparing different natural gas pipeline/compressor station system flow study configurations and selecting one configuration for going forward with a feasibility study. The estimates for the different configurations are rough, not for financing purposes, but rather to identify relative costs between the different alternatives. This preliminary cost estimate is +/- 30%.

Willbros prepared an initial estimate of a natural gas pipeline/compressor station system in Alaska in early 2000. Much of this data was referred to throughout the preparation of this report.

## 2.0 Compressor Station Cost Factors

### 2.1 Gas Compression Packages

Cost Estimate Assumptions:

2.1.1 Compression equipment pricing is based on updated pricing received from Solar Turbines, Inc. for skid mounted packages in the 7,500; 10,000; 15,000 and 20,000 HP ranges. The Taurus package can be used for the 7,500 and 10,000 HP ranges and the Titan package can be used for the 15,000 and 20,000 HP ranges.

2.1.2 Since the original proposal Solar has developed a C51 compressor that they have selected to meet the HP requirements. It comes in different staging capability so should fit the needs of each site based on a review by Solar of previous conditions.

2.1.3 Pricing for the 15,000 and 20,000 HP ranges is based on two options: the Mars 100 on a Titan skid or the Titan 130 on a Titan skid and includes the Solar C51 compressor. A Mars engine could be replaced with a Titan engine at a later date should the horsepower requirements increase to that level.

2.1.4 The budget prices are based on purchase by April 2008 and shipment by April 2009. Should the dates need to be moved out, an escalation factor of 3.5% per year can be applied.

2.1.5 Vendor data is included for both the Taurus and the Titan packages as Exhibits 2 and 3.

2.1.6 Spares include both commissioning and two year operating and pricing was increased by 20% over original estimate per Solar's recommendation.

2.1.7 The same compressor package spares costs are used for all four packages regardless of HP range. Freight costs from San Diego, CA to the vicinity of Fairbanks, AL for both the Taurus and Titan packages have been estimated by Solar.

2.1.8 Construction man-hour and cost estimates were provided by Willbros construction estimating personnel.

## 2.2 Refrigeration

Cost Estimate Assumptions:

2.2.1 Randall Gas Technologies provided the original estimate so was consulted in the preparation of this estimate.

2.2.2 The refrigeration estimate is based on the 1000 MMscf/d flow case provided by Ward Whitmore. Refrigeration design conditions and parameters are summarized in Exhibit 4.

2.2.3 The estimate assumes two refrigeration trains with each train sized for 500 MMscf/d.

2.2.4 Refrigeration compression includes one each 100% compressor for each train plus a common spare unit.

2.2.5 Refrigeration compression is based upon gas driven engines.

2.2.6 Other Equipment/Building costs include the cost of process equipment and a building. Cost for major electrical or instrumentation equipment is included in the installation cost.

2.2.7 Installation cost is based upon in-house historical data and includes contractor cost associated with engineering, project management and administration, distributive or bulk materials and equipment (electrical, instrumentation, pipe, valves, fittings, insulation, etc.), procurement activities, construction labor, construction overheads and construction equipment, and contractor overhead and profit.

2.2.8 Costs associated with construction camp facilities have not been included.

2.2.9 Power is assumed to be available from either an off-site supplier or on-site generation.

2.2.10 It is assumed that refrigeration equipment (as appropriate) will be installed in a building due to ambient conditions. The cost of a building has been allowed for in the estimate; however no provisions for any type of building heating system have been included.

2.2.11 Refrigeration plant footprint size estimate is 175 ft x 300 ft max.

2.2.12 Equipment pricing based on Randall's in-house historical data.

## 2.3 Compressor Stations

Cost Estimate Assumptions:

2.3.1 No personnel housing/accommodations or maintenance warehouses will be required at the stations.

2.3.2 Material pricing used on the original estimate was revisited and major engineered equipment was requoted where possible. All other material was priced based on either applying an escalation factor appropriate for that type of material or in-house historical data.

2.3.3 The typical station model assumes one launcher, one receiver, two scrubbers, two compressor packages and refrigeration. Pricing for the launcher, receiver, scrubbers, piping, valves, erected buildings, concrete, gravel, etc. is included in the station equipment/materials pricing.

2.3.4 The method of electrical power supply varies greatly among various station locations throughout Alaska. Electrical materials costs were estimated for each site and ranged from 1.5 to 7 million dollars depending on whether or not generators, substations, transformers and transmission lines are required. Therefore, the total cost for ten stations spaced along an assumed pipeline route from the North Slope to Valdez was averaged to provide a cost for one site.

2.3.5 SCADA/Communications costs were included based on an average cost per site.

2.3.6 Construction man-hours for one station have been broken down into the following categories: Civil, Mechanical, Electrical/Instrumentation and Supervisory.

2.3.7 Construction costs have been calculated based on a $/man-hour figure for work in Alaska. An escalation factor was applied to the labor rates used in the original estimate.

2.3.8 Construction equipment costs are estimated at 25% of construction costs.

2.3.9 Annual O&M costs are estimated at 3.5% of initial installation costs. These costs do not include fuel costs.

## 3.0 Summary

The cost and man-hour estimates are summarized in the attached Compressor Station Cost Factors spreadsheet (Exhibit 1). As indicated on the spreadsheet, the refrigeration installation costs are high when compared to the station and compression package installation costs. However, per Randall Gas Technologies, they are estimated to be within +/- 30%.

# EXHIBIT 1

**COMPRESSOR STATION COST FACTORS**
**FOR ALASKA NATURAL GAS DEVELOPMENT AUTHORITY**
**REVISION 1**
**8-Feb-05**

**COMPRESSION:**

| HP RANGE | COMPRESSION PACKAGE (SOLAR) | $ Equipment | $ Freight/Crating | $ Spares/Training | HP | **$/HP** | $ INSTALLATION | TOTAL COST | **$/INSTALLED HP** |
|---|---|---|---|---|---|---|---|---|---|
| 7,500 | TAURUS 60 | $4,230,000 | $80,000 | $57,600 | 7,700 | **$567** | $774,024 | $5,141,624 | **$668** |
| 10,000 | TAURUS 70 | $4,720,000 | $80,000 | $57,600 | 10,300 | **$472** | $774,024 | $5,631,624 | **$547** |
| 15,000 | TITAN COMPRESSOR W/ MARS ENGINE | $7,450,000 | $110,000 | $57,600 | 15,000 | **$508** | $1,127,219 | $8,744,819 | **$583** |
| 20,000 | TITAN COMPRESSOR | $7,950,000 | $110,000 | $57,600 | 20,000 | **$406** | $1,127,219 | $9,244,819 | **$462** |

**REFRIGERATION:**

| REFRIGERATION HP | RANDALL GAS TECHNOLOGIES PACKAGE | $ Equipment/Materials | $ Freight | REFRIG HP | **$/HP** | $ INSTALLATION | TOTAL COST | **$/INSTALLED HP** |
|---|---|---|---|---|---|---|---|---|
| | REFRIGERATION COMPRESSION ONLY | $8,600,000 | | | | | | |
| | OTHER EQUIPMENT/BUILDING | $4,700,000 | | | | | | |
| 17,400 | TOTAL REFRIGERATION | $13,300,000 | $1,200,000 | 17,400 | **$833** | $22,400,000 | $36,900,000 | **$2,121** |

**OVERALL STATION COST LESS COMPRESSION PACKAGE AND REFRIGERATION:**

| $ Equipment/Materials | $ Freight | $ Construction Labor | $ Construction Equipment | TOTAL COST |
|---|---|---|---|---|
| $12,557,802 | $133,425 | $7,890,531 | $1,972,633 | $22,554,391 |

**ESTIMATED MAN-HOURS TO CONSTRUCT TYPICAL COMPRESSOR STATION:**

| DISCIPLINE | STATION ONLY | ADD TWO TITAN COMPRESSORS | ADD REFRIGERATION | TOTAL MAN-HOURS |
|---|---|---|---|---|
| CIVIL | 22,926 | 6,550 | 25,000 | 54,476 |
| MECHANICAL | 2,560 | 731 | 60,000 | 63,291 |
| ELEC/INSTRUMENTATION | 25,014 | 7,147 | 35,000 | 67,161 |
| SUPERVISORY | 12,625 | 3,607 | 40,000 | 56,232 |
| TOTAL | 63,125 | 18,035 | 160,000 | 241,160 |

**COMPRESSOR STATION ANNUAL OPERATION AND MAINTENANCE COST IS ESTIMATED AT 3.5% OF INITIAL INSTALLED COST.**

# TAURUS 70
## Gas Turbine Compressor Set

## General Specifications

***Taurus*™ 70 Gas Turbine**

- Industrial, Two-Shaft
- Axial Compressor
  - 14-Stage
  - Variable Inlet Guide Vanes
  - Compression Ratio: 16:1
  - Inlet Airflow: 26.5 kg/sec (58.5 lb/sec)
  - Vertically Split Case
- Combustion Chamber
  - Annular-Type
  - Conventional or Lean-Premixed, Dry, Low Emission (*SoLoNO$_x$*™)
  - 12 Fuel Injectors
  - Torch Ignitor System
- Gas Producer Turbine
  - 2-Stage, Reaction
  - Speed: 15,200 rpm
- Power Turbine
  - 2-Stage, Reaction
  - Speed: 12,000 rpm
- Bearings
  - Journal: Tilt Pad
  - Thrust: Tilt Pad
- Coatings
  - Compressor Stators and Drums: Inorganic Aluminum
  - Turbine Blades and Nozzles: Precious Metal Diffusion Aluminide
- Vibration Transducer Type
  - Proximity Probes

## Key Package Features

- Base Frame with Drip Pans
- Driven Equipment Base Frame
  - Compressor
  - Compressor Auxiliary Systems
- 316L Stainless Steel Piping ≤4"
- Compression-Type Tube Fittings
- Digital Gauge Panel
- Electrical System Options
  - NEC, Class I, Group D, Div. 1 or 2
  - CENELEC, Zone 1
- *Turbotronic*™ Microprocessor Control System
  - Freestanding Control Console
  - Onskid Control System (Div. 2)
  - Color Video Display
  - Vibration Monitoring
  - Gas Turbine and Package Temperature Monitoring
  - Historical Displays
- Control Options
  - 120-VDC Control Battery/Charger
  - Serial Link Supervisory Interface
  - Turbine Performance Map
  - Printer/Logger
  - Process Controls
  - Compressor Performance Map
  - Compressor Anti-Surge Control
  - Field Programming
- Start Systems
  - Pneumatic
  - Direct Drive AC
- Fuel System
  - Natural Gas
- Integrated Lube Oil System
  - Turbine-Driven Accessories
  - Tank Vent Separator
  - Flame Trap
- Oil System Options
  - Oil Cooler
  - Oil Heater
- Compressor Cleaning System Options
  - On-Crank/On-Line
  - Cleaning Tank
- Gearbox (if applicable)
  - Speed Increaser
- Air Inlet and Exhaust System Options
- Enclosure and Associated Options
- Factory Testing of Turbine with Package and Compressor
- Documentation
  - Drawings
  - Quality Control Data Book
  - Inspection and Test Plan
  - Test Reports
  - Operation and Maintenance Manuals

# TAURUS 70
## Gas Turbine Compressor Set

## Performance

No Inlet/Exhaust Losses,
Relative Humidity 60%,
Natural Gas Fuel with
LHV = 31.5 to 43.3 MJ/nm$^3$
(800 to 1100 Btu/scf)
Optimum Power Turbine Speed
Thermal Efficiency: 34.8%

**Nominal Rating – ISO**
At 15°C (59°F), Sea Level

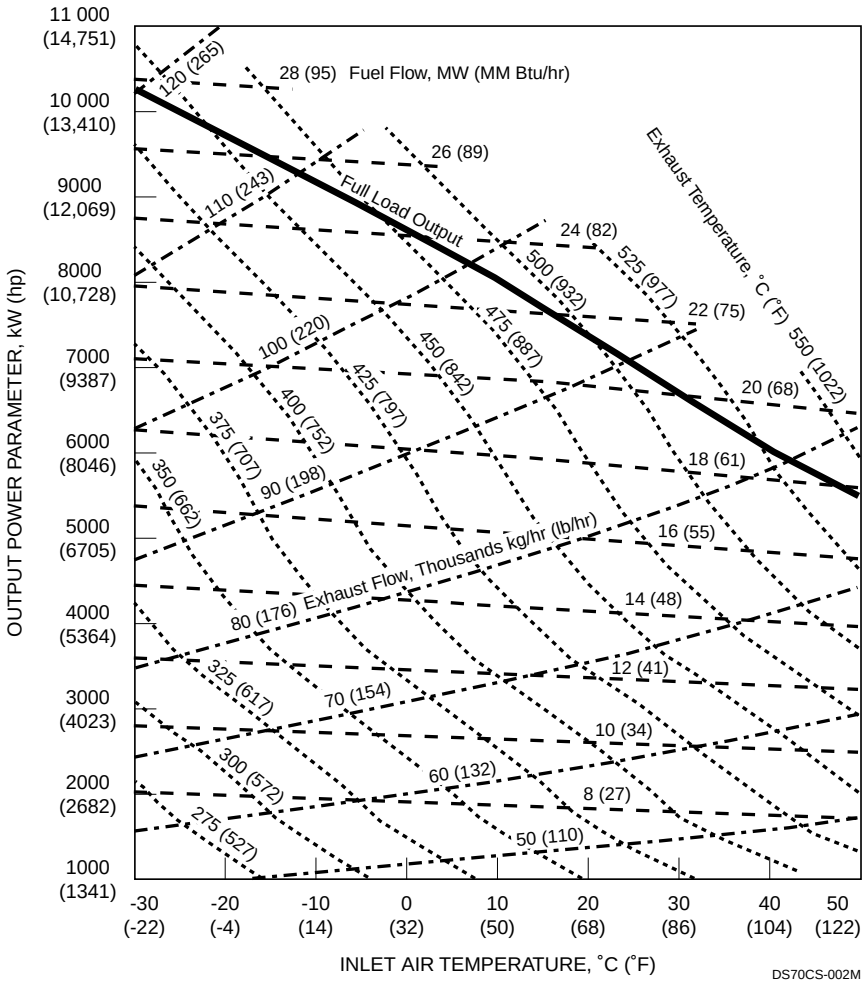
**Output Power**
7690 kW (10,310 hp)

**Heat Rate**
10 340 kJ/kW-hr (7310 Btu/hp-hr)

**Exhaust Flow**
95 630 kg/hr (210,830 lb/hr)

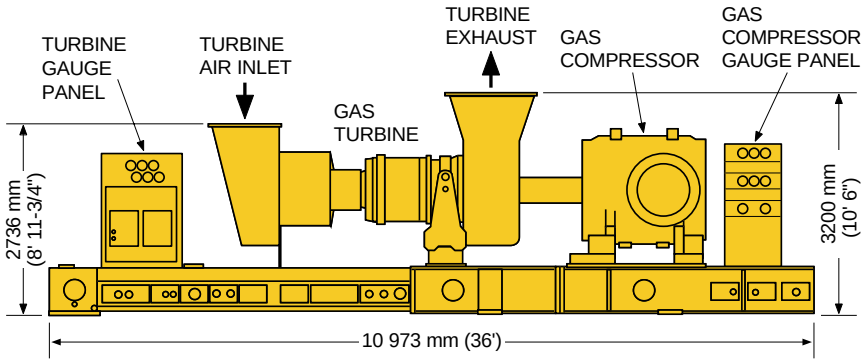
**Exhaust Temperature**
495°C (920°F)

### Available Power




DS70CS-002M

## Package Dimensions




Weight: 29 520 kg (65,080 lb)
Width: 2718 mm (8' 11")

DS70CS-003M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Internet: www.solarturbines.com



DS70CS/702/1M

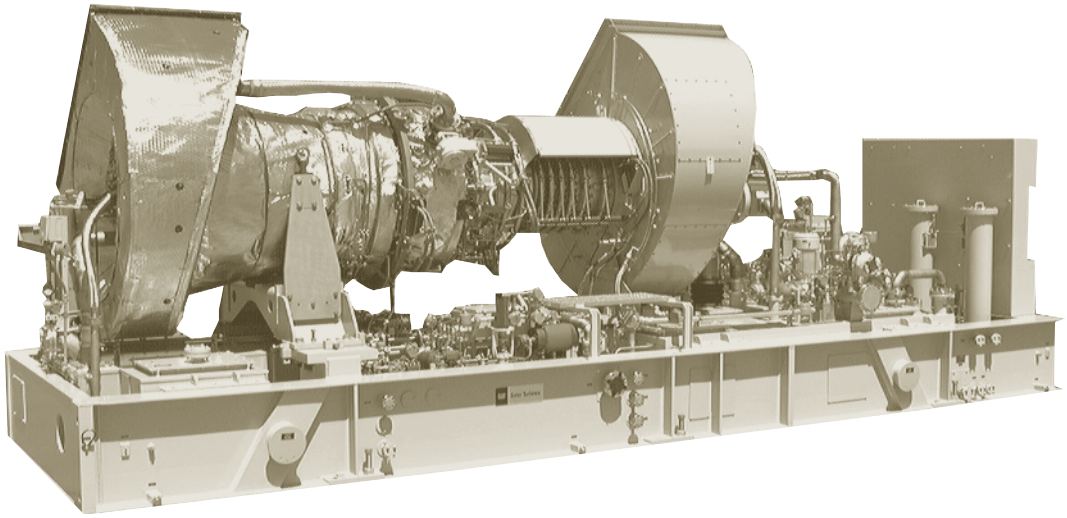
Solar® Turbines

A Caterpillar Company

# TITAN 130

## Gas Turbine Compressor Set

**Oil & Gas**



## General Specifications

### *Titan*™ 130 Gas Turbine

- Industrial, Two-Shaft
- Axial Compressor
  - 14-Stage
  - Variable Inlet Guide Vanes and Stators
  - Compression Ratio: 16:1
  - Inlet Airflow: 47.4 kg/sec (105.2 lb/sec)
  - Max. Speed: 11,215 rpm
  - Vertically Split Case
- Combustion Chamber
  - Annular-Type, Conventional or Lean-Premixed, Dry, Low Emission (*SoLoNO$_x$*™)
  - 21 Fuel Injectors (Conventional)
  - 14 Fuel Injectors (*SoLoNO$_x$*)
  - Torch Ignitor System
- Gas Generator Turbine
  - 2-Stage, Reaction
  - Max. Speed: 11,215 rpm
  - Thrust Bearing, Active: Tilting-Pad
  - Thrust Bearing, Inactive: Fixed Tapered Land
- Power Turbine
  - 2-Stage, Reaction
  - Max. Speed: 8855 rpm
  - Full Tilting-Pad Thrust Bearing
- Journal Bearings
  - Tilting-Pad
- Coatings
  - Compressor: Inorganic Aluminum
  - Turbine and Nozzle Blades: Precious Metal Diffusion Aluminide
- Vibration Transducer Type
  - Proximity Probes

## Key Package Features

- Driver Skid with Drip Pans
- Driven Equipment Skid
  - Compressor
  - Compressor Auxiliary Systems
- 316L Stainless Steel Piping ≤4"
- Compression-Type Tube Fittings
- Gauge Panel Options
  - Analog Gauges
  - Digital Display
- Electrical System Options
  - NEC, Class I, Group D, Div 1
  - NEC, Class I, Group D, Div 2
  - CENELEC, Zone 1
- *Turbotronic*™ Microprocessor Control System
  - Onskid Control System (Div 2)
  - Freestanding Control Console
  - Color Video Display
  - Vibration Monitoring
- Control Options
  - 24-VDC Control Battery/ Charger System
  - 120-VDC Accessory Battery/ Charger System
  - Gas Turbine and Package Temperature Monitoring
  - Serial Link Supervisory Interface
  - Turbine Performance Map
  - Compressor Performance Map
  - Historical Displays
  - Printer/Logger
  - Predictive Emissions Monitoring
  - Process Controls
  - Compressor Anti-Surge Control
  - Field Programming
- Start Systems
  - Pneumatic
  - Direct-Drive AC
- Fuel Systems
  - Natural Gas
  - Liquid
  - Dual (Gas/Liquid)
  - Wide Range
- Integrated Lube Oil System
  - Turbine-Driven Accessories
  - AC Motor-Driven Accessories
- Oil System Options
  - Oil Cooler
  - Oil Heater
  - Tank Vent Separator
  - Flame Trap
- Package Skid Design
  - Accommodates *Mars*® and *Titan* Turbines
  - Drop-In Lube Oil Tank
  - Modularized System Design
- Axial Compressor Cleaning Systems
  - On-Crank
  - On-Crank/On-Line
  - Portable Cleaning Tank
- Gearbox (if applicable)
  - Speed Increaser
  - Speed Decreaser
- Air Inlet and Exhaust System Options
- Enclosure and Associated Options
- Factory Testing of Turbine and Package
- Documentation
  - Drawings
  - Quality Control Data Book
  - Inspection and Test Plan
  - Test Reports
  - Operation and Maintenance Manuals

# Solar® Turbines

A Caterpillar Company

# TITAN 130

## Gas Turbine Compressor Set

Oil & Gas

## Performance

| | |
|---|---|
| Output Power | 14 800 kW (19,830 hp) |
| Heat Rate | 9990 kJ/kW-hr (7065 Btu/hp-hr) |
| Exhaust Flow | 180 100 kg/hr (397,060 lb/hr) |
| Exhaust Temperature | 485°C (905°F) |

*Nominal Rating – ISO*
*At 15°C (59°F), Sea Level*

*No Inlet/Exhaust Losses,*

*Relative Humidity 60%,*

*Natural Gas Fuel with*
*LHV = 31.5 to 43.3 MJ/nm³*
*(800 to 1100 Btu/scf)*

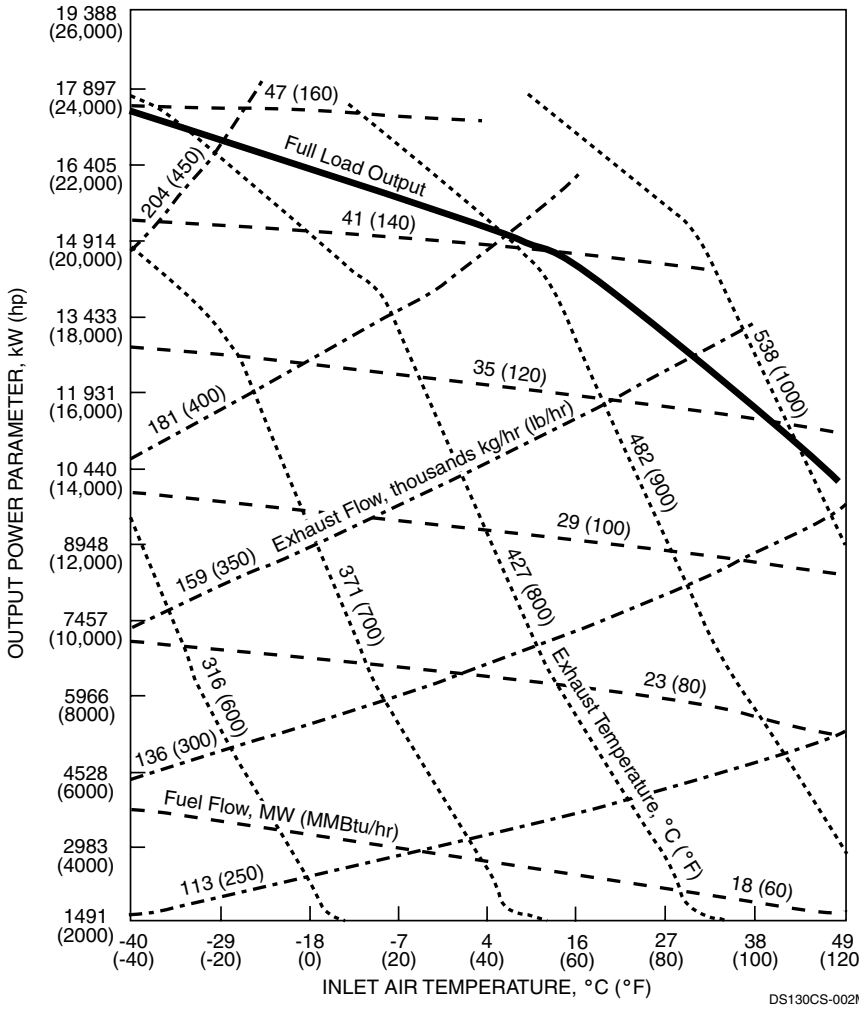
*Optimum Power Turbine Speed*

*AC-Driven Accessories*

*Engine Efficiency: 35.7%*

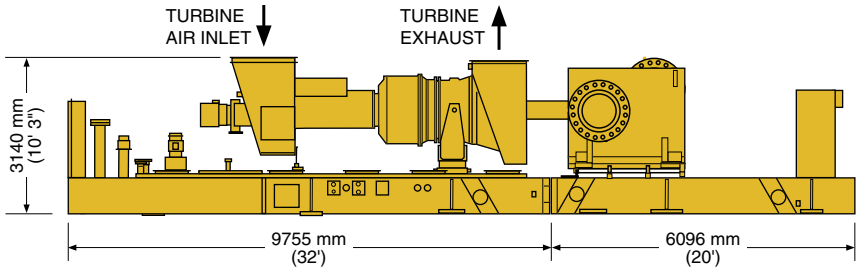
*15°C (59°F) Turbine Rating Match.*
*Other Turbine Rating Match Points*
*Are Available.*

## Available Power




DS130CS-002I

## Package Dimensions




Typical Weight: 72 850 kg (160,600 lb)
Width: 3183 mm (10' 5-5/16")

DS130CS-003M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San Diego, CA 92186-5376 U.S.A.




DS130CS/1299/2M- REV0804/EO


## FOR MORE INFORMATION


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Internet: www.solarturbines.com


ISO-9001
DNV
CERTIFICATED FIRM

# EXHIBIT 4

## DESIGN CONDITIONS AND REFRIGERATION PARAMETERS

### ANGDA Compressor Station Cost Factors

| | |
|---|---|
| **Inlet** | |
| Flowrate - MMscf/d | 1000 |
| Pressure – psig | 2515 |
| Temperature - deg F | 80 |
| **Outlet** | |
| Pressure – psig | 2505 |
| Temperature - deg F | 28 |
| **Refrigeration Parameters** | |
| Condensing Temperature - deg F | 90 |
| Evaporator Temperature - deg F | 23 |
| Chiller Duty - MMbtu/h | 94 |
| Condenser Duty - MMbtu/h | 111 |
| Compressor HP - Without Spare | 8700 |

**CONSTRUCTION MAN-HOURS BREAKDOWN**
**COMPRESSOR STATION COST FACTORS**
**FOR ALASKA NATURAL GAS DEVELOPMENT AUTHORITY**
**18-Feb-05**

| | TOTAL MAN-HOURS | Drivers % | Operators % | Welders % | Helpers/ Laborers % | Supervisory % |
|---|---|---|---|---|---|---|
| **Man-hours:** | | | | | | |
| Civil | 54,476 | **10%** | **25%** | **0%** | **65%** | |
| E & I (See note below) | 38,291 | **0%** | **20%** | **0%** | **80%** | |
| Mechanical | 92,161 | **5%** | **20%** | **25%** | **50%** | |
| Suprv.-25% of Above | 56,232 | | | | | **100%** |
| Total | 241,160 | | | | | |

**Note: Electrical and Instrumentation man-hours and breakdown by % for category of workers are for installation of conduits, ducts and pulling wire only. Terminations are made by electrical/instrument technicians.**