US Army Corps
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Potential Army Application for Micro-Turbine Cogeneration Technology

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Many U.S. Army installations pay relatively high prices for the electricity because they are remotely located. Moreover, Army facilities frequently have heat and electrical needs co-located in a building or cluster of buildings, which makes these locations well suited for energy "cogeneration." Micro-turbines are a miniaturized version of combustion turbines currently used in the aerospace and electric power industries. The micro-turbine's simple construction, when coupled with the cost benefits of mass production, is anticipated to yield electric power at low capitol costs. Also, the unit's exhaust stream is a high quality heat stream that can be used in a cogeneration system to meet steam or hot water needs co-located in the building. This study reviewed ongoing demonstrations to evaluate micro-turbine technology for possible application at Army installations.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

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Foreword

This study was conducted for U.S. Army Corps of Engineers (USACE) under Project 4A162784AT45, "Energy and Energy Conservation;" Work Unit UL-XC7, "Advanced Energy Supply Technology." The technical monitor was John Lanzarone, CEMP-ET.

The work was performed by the Energy Branch (CF-E), of the Facilities Division (CF), U.S. Army Construction Engineering Research Laboratory (CERL). Survey data was gathered by Systems Engineering and Management Corp. under contract DACA-88-D-0002. Cheri Arnsdorff is associated with Systems Engineering and Management. The CERL principal investigator was Michael K. Brewer. Larry M. Windingland is Chief, CECER-CF-E and Dr. L. Michael Golish is Chief, CECER-CF. The CERL technical editor was William J. Wolfe, Information Technology Laboratory.

The Director of CERL is Dr. Michael J. O'Connor.

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1 Introduction

Background

Many U.S. Army installations pay relatively high prices for electricity (more than $0.05 per kilowatt hour [kWh], or more than $12.00/kW demand) under the current regulated environment, primarily because Army installations are commonly remotely located. This situation may be compounded as utilities are deregulated — a circumstance that will make energy prices more volatile. Installations with the greatest energy flexibility will be able to reap cost savings under deregulation.

Army facilities frequently have heat and electrical needs co-located in a building or cluster of buildings. This makes these locations well suited for energy "cogeneration." The term "cogeneration" refers to the simultaneous generation of two types of energy, usually electrical and thermal, from an energy source such as natural gas or diesel fuel. Cogeneration plants offer several advantages over conventional facilities. A cogeneration system's ability to capture energy output in two forms makes it more efficient than conventional energy systems, and results in lower overall operating costs. Many cogeneration plants are designed to use more than one fuel. Such fuel flexibility makes the plant a more reliable source of electricity, reduces its impact on the environment, lessens its vulnerability to fluctuations in fuel prices and availability, and generally lengthens the plant's useful life.

For example, a typical commercial or industrial facility produces steam or hot water in a boiler and purchases electricity from the local utility. The typical power generating plant may be only 35 percent (or less) efficient. A cogeneration unit, by contrast, can be over 80 percent efficient. These higher efficiencies can reduce operating costs to make packaged cogeneration systems economically attractive to Department of Defense (DOD) facilities where there is often a simultaneous demand for thermal and electrical energy in the form of domestic hot water (DHW), process steam, heating, or cooling (via absorption chillers).

Combustion turbines are an emerging electric power generation technology that may be well suited to co-generation. Technological improvements coupled with economic and political factors are rapidly moving electric utilities away from

traditional steam power plants and toward power cycles based on combustion turbines. Micro-turbines are a miniaturized version of combustion turbines currently used in the aerospace and electric power industries. A micro-turbine unit weighing only 75 kg can generate up to 24 kW of electricity. A single rotor supported by air bearings serves as compressor, turbine, and electric dynamo. The micro-turbine's simple construction, when coupled with the cost benefits of mass production, is anticipated to yield electric power at capitol costs as low as $200/kW. Although the combustion cycle efficiency of micro-turbines is low (25 to 28 percent), the exhaust stream is high quality heat that can be used to meet steam or hot water needs co-located in the building.

The U.S. Department of Energy (USDOE) Office of Industrial Technology is currently funding micro-turbine demonstrations. This study reviewed ongoing demonstrations to evaluate the technology for possible application at Army installations.

Objectives

The objectives of this study were to:

- Locate demonstration projects and collect data from those projects to provide general pricing, efficiency, and operational information on the micro-turbine units coming into the market.
- Collect data on the natural gas and fuel oil performance of micro-turbines to identify the parameters for successful implementation of micro-turbine technology at Army installations.

Approach

Systems Engineering and Management Corp. was contracted by the Construction Engineering Research Laboratory (CERL) to research the current status of the micro-turbine technology. Demonstration sites were located and surveyed regarding the performance of the technology in the field. Micro-turbine manufacturers were contacted and surveyed regarding the pricing, efficiency, and operational information of currently available micro-turbine units and those planned for future production.

Scope

The manufacturers who had fielded demonstration units conducted their tests under strict confidentiality agreements and would not release the test data. This report summarizes the information available on demonstration projects and includes data from the various micro-turbine manufacturers.

Mode of Technology Transfer

This report and the survey data collected will be made available through CERL's world-wide web (WWW) URL: http://www.cecer.army.mil.

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 in.	=	2.54 cm
1 ft	=	0.305 m
1 yd	=	0.9144 m
1 sq in.	=	6.452 cm^2
1 sq ft	=	0.093 m^2
1 sq yd	=	0.836 m^2
1 cu in.	=	16.39 cm^3
1 cu ft	=	0.028 m^3
1 cu yd	=	0.764 m^3
1 gal	=	3.78 L
1 lb	=	0.453 kg
1 kip	=	453 kg
1 psi	=	6.89 kPa
°F	=	(°C x 1.8) + 32

2 Demonstration Projects

Of the major micro-turbine manufacturers, only one manufacturer — Elliott Energy Systems — has a commercial unit currently available. Based on discussions with manufacturer representatives, demonstration projects on Alpha and Beta micro-turbine units have all been conducted under confidentiality agreements between the manufacturer and the customer receiving the demonstration unit. Units have been tested at Army facilities, including one unit at the Military Traffic Management Command (MTMC) in Falls Church, VA, and one unit at the Twin Cities Army Ammunition Depot (TCAAP), Arden Hills, MN. Both sites were under signed confidentiality agreements.

The unit tested at MTMC was manufactured by Elliott. The purpose of the test was to determine if the micro-turbine would be suitable for remote power generation for unit deployment where commercial power is not available. Limited tests were conducted, which basically consisted of no-load fuel consumption only. The test was performed on an early Elliott unit that will not be commercially available. Although MTMC personnel were not generally pleased with the overall performance and operation of the demonstration unit, they have agreed to purchase one of the commercially available units from Elliott to package into a remote power-generating station.

The commercial units are designed to use natural gas. Once problems associated with converting the natural gas fuel system to diesel fuel are resolved, MTMC will take delivery of the test unit, which is scheduled for delivery about January 1999. MTMC plans to conduct several tests on the unit, and, if testing is satisfactory, may purchase additional units.

The MTMC point of contact for the purchase of this unit is:

Ben Reischer, HQMTMC
5611 Columbia Pike
Falls Church, VA 22041-6862
(703) 681-7793

The unit tested at TCAAP was actually acquired by the local utility, Northern States Power Company. A Capstone 25 kW unit was installed in September 1996. Detailed testing was performed on this unit and documented in a report

published by the Electric Power Research Institute (EPRI). All parts of the report are covered by a strict and specific copyright, which prohibits translating any part of the report into any derivative work. The report (EPRI TR-108297) is available to EPRI members and was obtained by Systems Corp through the local Tennessee Valley Authority (TVA) office. The report details the testing at TCAAP and a test at the James River Paper Company plant in Ashland, WI. The report has very specific performance related data, including unit output, heat recovery, and fuel consumption.

This is the extent of the demonstration information that Systems Corp was able to obtain while researching micro-turbine applications. Due to the very competitive nature of this product, manufacturers are unwilling to publish data on units not currently commercially available. Chapter 3 of this report details information on the manufacturers of micro-turbines, the products they anticipate producing, and (where available) the dates when their products will be commercially available.

3 Product Manufacturers

NREC

NREC is currently developing the PowerWorks™ line of gas turbines. When packaged as cogeneration units, the sizes will range from 30 to 250 kW of electrical output. NREC currently has no demonstration units. NREC projects that the first units will be available for testing by late 1999 or early 2000. The units are designed to have low emissions (less than 9 ppm NOx) and an electrical efficiency of 30 percent HHV (higher heating value [Btu/lb]). With a cogeneration package, the efficiency is projected to exceed 80 percent. NREC is also planning to utilize the turbines in chiller packages that will yield integrated part Load Value (IPLV) coefficients of performance (COPs) approaching 2.0 HHV under Air-Conditioning and Refrigeration Institute (ARI) conditions.

The point of contact for NREC is:

Jay Johnson
Product Manager - PowerWorks™
39 Olympia Avenue
Woburn, MA 01801
(781) 935-9050 ext 118
www.nrec.com/pwrwrks.htm

Elliott Energy Systems

Elliott Energy Systems is the only manufacturer that currently has a microturbine product on the market. Elliott has had numerous demonstration projects, all of which were conducted under confidentiality agreements. The unit currently on the market is a 45 kW unit with the following specifications:

Price: Basic $28,750
Options: Recuperator $9,750 (increases fuel efficiency to 30%)
Compressor $9,750
Enclosure $3,750
Specifications TA - 45:
Output rating: Power: 45 kW at 59 °F at Sea level

Voltage: 120/208/240 (480 with a transformer) VAC
Frequency: 50Hz/60Hz
Phase: 1 or 3
Operational Temperature Range: -40 °F to 120 °F
Speed (RPM): 116,000
Pressure Ratio: 4:1
Non-Recuperated Outlet Temperature: 1300 °F
Recuperated Outlet Temperature: 600 °F
Efficiency (LHV): 30% Recuperated
MTB Overhaul Hours: 27,000 (estimated)
Noise Level: 70 dBA at 10 ft
Fuel Types: Natural Gas, Diesel, Kerosene, Alcohol, Gasoline, Jet (JP 4/5), Methanol, Ethanol, Propane
Inverter and Controller: Microprocessor Controller, Digital readout, Re-programmable Voltage and Frequency, Auto Shutdown Features, Fault Isolation Detection, System Diagnostics, RS232 Communications Port
Size: Weight - Less that 2000 lb with enclosure
Dimensions (with enclosure): Length 64 in., Width 30 in., Height 34 in.
Emissions (using gaseous fuel): NOx PPM 9 Non-recuperated
NOx lb/hr 0.005 Non-Recuperated
CO PPM 145 Non-recuperated
CO lb/hr 0.082 Non-recuperated

The next unit scheduled to come on the market from Elliott is an 80 kW unit. Their product literature indicates a 60 kW unit, which is not currently scheduled to be produced and a 200 kW unit, which is slated for production sometime after the 80 kW unit. The point of contact at Elliott Energy Systems is:

Rich Sanders, Executive Vice President
Sales & Marketing
2901 SE Monroe Street
Stuart, FL 34997
(561) 219-9449
www.powerpac.com/micro.htm

Capstone Turbine Corporation

Capstone Turbine Corporation appears to be the most aggressive company in terms of field testing their turbine generator product. Based on conversations with a manufacturer's representative, Capstone has field tested over 100 units. All of their field testing has been conducted under confidentiality agreements.

Chapter 2 of this report references an EPRI report that published two of Capstone's demonstration projects. The Capstone Micro-Turbine 28 kW generator package became commercially available during the week of 7 December 1998. The price for a single unit is approximately $40,000. Quantity purchase discounts are available. Preliminary specifications are:

Output: 28 kW
Efficiency (LHV): 26%
Heat Rate (LHV): 13,200 Btu / kWh
Emissions: <9 ppm NOx
Noise Level: 65 dBA @ 10 m
Full Load Fuel Flow (HHV): 410,000 Btu/hr
Exhaust Gas Temperature: 520 °F
Total Exhaust Energy (base @ 59 °F): 277,000 Btu/hr
Dimensions: 74.8 in. H x 28.1 in. W x 52.9 in. D
Weight: 700 lb

The point of contact with Capstone Turbine Corporation is:

Jim Clyde
6025 Yolanda Avenue
Tarzana, CA 91356
(818)774-9600
www.capstoneturbine.com

AlliedSignal

AlliedSignal has developed a 75 kW Turbo-Generator™ micro-turbine. The unit has completed the Alpha phase of testing and is beginning the Beta phase with units being placed in the field. The Beta test period is anticipated to start in the first two quarters of 1999 with commercial units becoming available by the 3rd quarter of 1999. General specifications for the Turbo-Generator™ are:

Efficiency: 28.5% (LHV)
Emissions: 25 ppm NOx
Noise: 65 dBA @ full load at 10 meters
Size: 8 ft x 4 ft x 7 ft
Maintenance: <= $0.01/kWh

Systems Corp contacts have discussed the issue of test units with a Turbo-Generator™ distributor, and they seem receptive to the idea of placing a test unit at an Army installation. The unit must be purchased (contingent upon

satisfactory operation), but pricing is negotiable. The Appendix to this report includes a map showing the nationwide distributors for the Turbo-Generator™.

The point of contact for information on the Turbo-Generator™ is:

AlliedSignal Power Systems, Inc.
2525 W. 190th Street
Torrance, CA 90504
(310) 512-4127

Solar Turbines

Solar Turbines is an established manufacturer of gas turbine engines rated from 1450 to 15,000 hp. Solar Turbines is in the developmental stage of producing a 300 kW turbine generator set. If the unit becomes commercially available, the anticipated market entry date is in 2001. The general specifications include a recuperated efficiency of approximately 30 percent, low NOx and CO emissions, small size, no gear box, and low maintenance. They have built and satisfactorily tested one unit. They have not scheduled a commercial test unit but would anticipate possibly testing one by the second half of the year 2000. They anticipate their market pricing to be in the range of $350-$450/kW, or less (comparable to the price of a gas reciprocating engine).

The point of contact with Solar Turbines is:

Phil Carroll
2200 Pacific Highway
P.O. Box 85376
San Diego, CA 92186
(619) 544-2488

Bowman Power Systems, Ltd.

Bowman Power Systems, Ltd. has been developing micro-turbine technology over the past 4 years. This year they have begun limited production of 45 kW and 80 kW packaged units. They intend to begin volume production of these units in 1999 along with limited production of a 200 kW unit by the end of 1999. Bowman provided a quotation for both of their units along with detailed performance information, which is included in the Appendix to this report. General specifications for both units, including price are:

TG45 Cogeneration System
Output: 45 kW
Efficiency (Non-Recuperated Cogeneration): 86%
Unit Price: £36,000 ($59,760 based upon 1.66 exchange rate)

TG80 Cogeneration System
Output: 80 kW
Efficiency (Non-Recuperated Cogeneration): 87%
Unit Price: £50,000 ($83,000 based upon 1.66 exchange rate)

The point of contact with Bowman Power Systems, Ltd. is:

Tom Gearson
Bowman Power Systems, Ltd.
Ocean Quay
Belvidere Road
Southhampton, Hampshire S014 5QY,
United Kingdom
011-44-1703-236700

Summary

Table 1 provides a brief summary on the unit sizes and pricing available from the various manufacturers.

Table 1. Micro-turbine product chart.

Manufacturer	Unit Size (kW)	Unit Price	Price per kW
NREC	No product on market	—	—
Elliott Energy Systems	45	$52,000	$1,155
Capstone	28	$40,000	$1,428
AlliedSignal	75	Not Available	$350*
Solar	300	Not Available	$350 - $450*
Bowman	45	$59,760	$1,328
Bowman	80	$83,000	$1,037
*Projected Pricing			

4 Conclusions

This study located demonstration projects and collected data from those projects to provide general pricing, efficiency, and operational information on micro-turbine units coming into the market. Data gathering focused on natural gas and fuel oil performance of micro-turbines to identify the parameters for successful implementation of micro-turbine technology at Army Installations. The information gathered included the most prominent manufacturers currently in the micro-turbine product market. The Appendix to this report contains manufacturers' product literature.

The information collected indicates that production of micro-turbines is still in its early stages of development. Production volume of micro-turbines will have to significantly increase for prices to become competitive with the reciprocating engines in this size range currently on the market. While manufacturers project that high future demand for micro-turbines will stimulate production of the units so that micro-turbine pricing will become competitive with alternative technologies, the units currently available are significantly more expensive than the standard reciprocating engine generator packages.

Micro turbines will have thermal conversion efficiencies similar to the larger utility gas turbines. Their fuel-to-electricity efficiency may be slightly less since their regeneration and recuperation systems are simpler. However, the small size of these units will allow them to be located close to the electrical and thermal load they serve. This will increase the overall system efficiency by reducing transmission losses.

The proprietary nature of the data limited the amount of operation information available. However, it seems these units may have some initial operational difficulties related to the fuel delivery and preparation systems. The technical barrier for delivering these units seems to be centered on compression of natural gas to feed the small combustors or designing liquid fuel nozzles that are reliable and low maintenance.

Although manufacturers have done extensive tests, most of that test data is not publicly available. Some vendors (e.g., Capstone and Elliot) have disclosed some specifications and fuel choice options. From this information, it appears that the natural gas-fired units are more market ready than the liquid fuel versions. The

Army should use its leverage as a large potential user of these units to require detailed disclosure of the fuel system limitations of these units before the first procurement.

Appendix: Product Information

NREC Page 1 of 2

NREC is an engineering development company with a reputation for advancing and applying innovative technologies to turbomachinery such as:

- Air compressors, process compressors, axial compressors
- Gas turbines, steam turbines, expanders, hydraulic turbines, hydro-electric turbines
- Turbochargers
- Single and multistage pumps, in-line pumps, axial flow pumps, mixed flow pumps
- Fans, vaneaxial fans, blowers, vacuum systems
- Propulsers, propellers

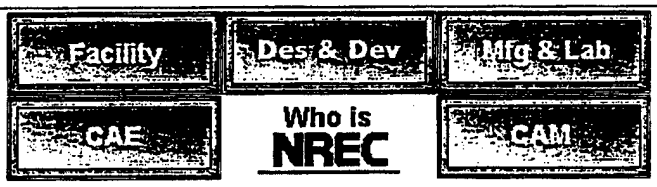
When developing new turbomachinery products for our customers, NREC applies its wide variety of resources, capabilities, and technologies which include:

- Analytical expertise
- Mechanical engineering
- Systems analysis and optimization
- Mechanical design
- Controls engineering
- Manufacturing capability
- Laboratory services

NREC's ability to bring the latest technology to our customers is greatly enhanced by our Advanced Technology Software. These CAE / CFD / CAM software tools combine experience, test data, and theoretical concepts to aid in turbomachinery design, analysis, and manufacture.

In addition, NREC manufactures a variety of turbomachinery products:

- The PowerWorks™ family of small and rugged gas turbine engines (microturbines)
- VAROC® air dynamometers for testing turboshaft gas turbine engines



'New NREC Software

Points of interest:

1. Schedule of upcoming events
2. Customer Success Story!
3. NREC's 40th Anniversary

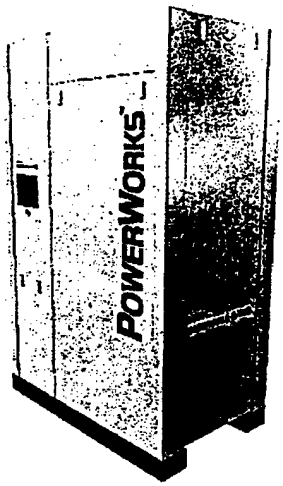
'Request more information

- Facility - Des & Dev - Mfg & Lab - CAE - CAM - Rerating - Energy Systems - Equipment-

NREC
39 Olympia Avenue
Woburn, MA 01801 USA
TEL: (781) 935-9050
FAX: (781) 935-9052

Comments? Please contact WEBMASTER

PowerWorks™
Small Gas-Turbine Products



Each member of NREC's PowerWorks™ family uses a small, long-life, low emissions, gas turbine engine as the prime mover and offers various options for heat recovery. The simple "ruggedized" turbocharger-based engine offers reduced maintenance and lower operating costs when compared to reciprocating engine-driven systems. By employing "off-the-shelf" industrial and vehicle components like turbochargers, we are able to offer cost-effective packages which are better adapted to the rigors of industrial applications than microturbines that have inherited design compromises from their aerospace or vehicle ancestries. The two-shaft turbine PowerWorks™ small gas turbine configuration is also superior to a single shaft design because the latter forces a compromise between the requirements of the gas turbine engine itself and the needs of a particular load. The free power turbine in our two-shaft design provides unparalleled flexibility in matching to mechanical drive load-following while reducing stress and prolonging engine life.

We are currently developing PowerWorks™ systems for a variety of industrial and commercial applications. For example, in our electricity/waste heat cogeneration systems the low-NOx, recuperated gas turbine engine directly drives a low speed induction generator. Sizes range from 30 to 250 kW of delivered AC electrical power while producing dry low emissions (less than 9 ppm NOx) with no postcombustion treatment. Electrical efficiency for the systems are 30% HHV, while overall cogeneration efficiencies can exceed 80%. When packaged as a chiller, systems can be sized to deliver between 100 and 350 RT of chilled water. The gas turbine engine drives the compressor of a vapor cycle chiller system to yield IPLV COPs approaching 2.0 HHV under ARI conditions. In the past decade, natural gas-fueled systems such as these have become less expensive to operate than electric motor-driven chillers due in part to rising electricity costs and comparatively low gas prices in the summer.

Key customer benefits of PowerWorks™ systems include:

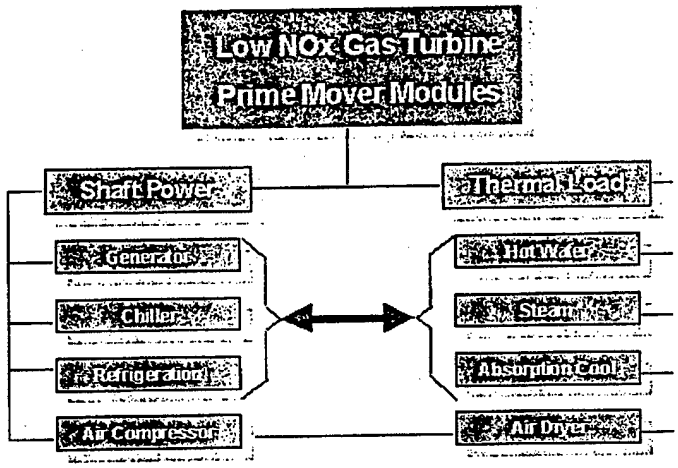
- Significantly improved reliability over existing automotive engine-derived systems
- Significantly lower installation costs
- End-user energy cost savings of 40-50%.
- Dry low emissions capable of meeting California standards
- Low noise levels
- Multiple fuels (gas and liquid) capability
- The elimination of multiple coolant loops and heat exchangers.

It is clear that small gas turbine systems will play an increasingly important role in the future supply of energy worldwide. We are very confident that these products will be pivotal in

filling those energy needs for industrial and commercial users.

Cogeneration

Chillers



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contact information

Comments? Please contact WEBMASTER

THE ELLIOTT COMPANY

A Solutions Company with a Rich History of Innovation

1895 Patented a water motor and "freely swinging arm bead" to clean scale from boiler tubes.

1903 Manufactured an air driven motor for tube cleaning, oil filter and lubrication systems for steam engines.

1918 Developed its first steam jet ejector, Elliott develops a de-aerating heater for removing oxygen from boiler feedwater.

1940 Elliott is the first manufacturer of turbochargers in the United States.

1941 The first turbocharger on a diesel engine in the U.S. is made by Elliott.

1942 Elliott develops the first successful industrial gas turbine.

1962 The Plant Air Package, a centrifugal air compressor is introduced.

1975 Elliott produces the world's highest pressure centrifugal (9200 psi/654 bar) compressor for gas reinjection service.

1980 The world's largest FCC power recovery expander (rated 35,000 HP) designed and built by Elliott.

1997 Introduction of the TA45 Turbo Alternator®. The first commercially affordable, mass produced micro-turbine.

1998 Expansion of the TA series to include the TA-60, TA-80, and TA200.

1999 More great things to come...

Today

The Elliott Company with over 100 years of experience provides high quality, reliable rotating equipment and services, on a world wide basis with facilities in South America, the Pacific Basin, Mexico, Europe, and the Middle East. Here at home, in the United States, we are positioned to serve our customers as a world class competitor.

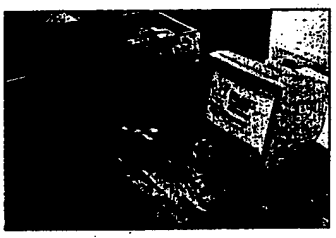
ELLIOTT ENERGY SYSTEMS

The Elliott Energy Systems headquarters and 37,000 sq. ft. Manufacturing facility in Stuart Florida.

Assembly of pre-production units for shipment around the world.

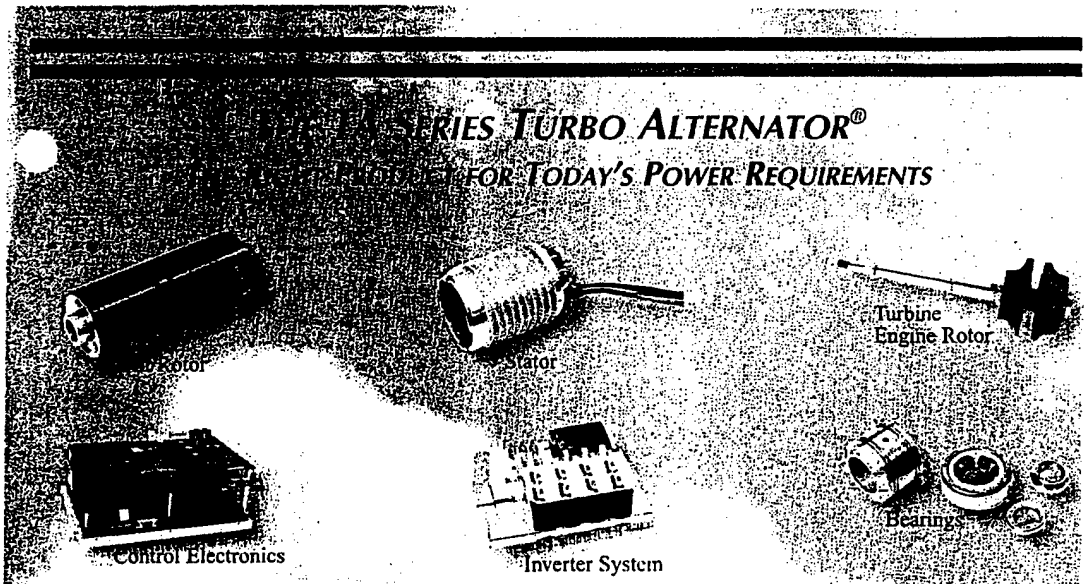
Production of parts for commercial units are manufactured with state-of-the-art CNC and machine tooling equipment.

Computer aided design engineering and quality assurance enabling shorter design cycles and greater reliability



Microprocessor design provides for onsite or remote system operation or diagnostics.

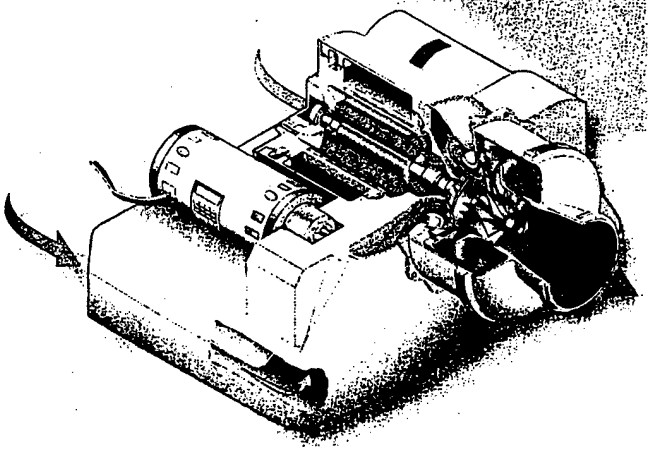
Every unit is inspected and tested fully before shipment by quality assurance engineers.



TA SERIES TURBO ALTERNATOR®

FOR TODAY'S POWER REQUIREMENTS

The Formula: A project driven by a group of engineers with over 250 years of combined knowledge in high speed aero and gas turbine technologies, combined with the resources of a leader in the design and production of turbo machinery.



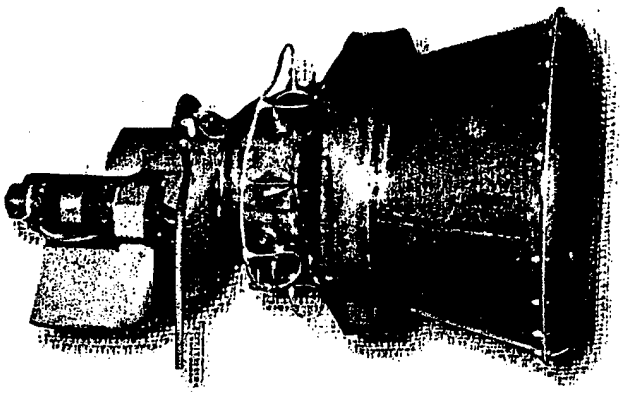
The Product: The first commercially available, cost competitive, feature rich and environmentally friendly micro-turbine alternator set. The **TA-45.**

Commitment: The commitment to design and manufacture Green energy solutions will continue at Elliott Energy Systems with the introduction of the 80 kW and 200 kW frame sizes in 1998, with additional sizes to follow.

Service and Support: We at Elliott Energy Systems understand the needs and requirements of a very diverse customer base.

Whether the need is for standby, peak shaving, primary, portable or other power application demand, Elliott Energy Systems will be there! Through a number of key alliances throughout the world Elliott Energy Systems will be positioned to service and support the products that you need to fill your on site power requirements.

THE ELLIOTT ENERGY SYSTEMS ADVANTAGE



ADVANTAGES

- Lighter
- Smaller
- Provides Green Energy
- Microprocessor Controlled
- Cleaner Output
- Burns Multiple Fuels
- Price Competitive

Typical 45 kW Pollution output using liquid fuel	PPM CO	PPM NOx	G/HR CO	G/HR NOx
Gasoline Engine	1762	1609	380	560
Diesel Engine	2302	2112	502	736
TA-45 Turbo Alternator®	431	26	91	7

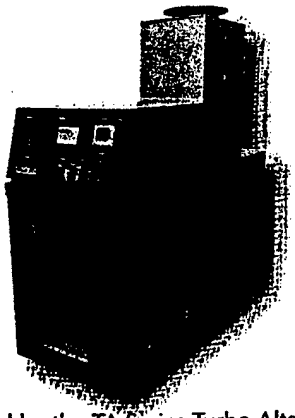
Number of engine parts which could could require maintenance	
Gasoline Engine	112
Diesel Engine	128
TA-45 Turbo Alternator®	12

Typical life cycle of an engine before a major overhaul.	
Gasoline Engine	4000 Hrs
Diesel Engine	10000 Hrs
TA-45 Turbo Alternator®	27000 Hrs

Average weight of a 45 kW Genset	
Gasoline Engine	1500 lbs.
Diesel Engine	2200 lbs.
TA-45 Turbo Alternator®	375 lbs.

Co-Generation Package

Data:	TA-45	TA-60
• Electric power (kWe)	45	60
• Thermal output kW (20° F) flue	361.4°	451.4°
• Fuel flow (gas) (yd.³/hr)	32.773	46.551
• Exhaust gas temp. into heat exchanger (°F)	1036.4°	1023.8°
• Exhaust mass flow (lbs./s)	.919	1.186
• Air mass flow (lbs./s)	.904	1.168
• Rotor speed (r.p.m.)	116,000	105,000
• Generating set efficiency	16.68%	17.4%
• System efficiency	85%	85%



Powered by the TA Series Turbo Alternator®

PRELIMINARY SPECIFICATIONS
TA-80

Output Rating:
- Power: 80 kW at 77° F, 500 Ft., Standard Day
- Voltage: 120/208/240/480 VAC
- Frequency: 50Hz/60Hz
- Phase: 1or 3

Fuel Type:
- Natural Gas
- Diesel
- Kerosene
- Alcohol
- Gasoline
- Jet (JP 4/5)
- Methanol
- Ethanol
- Propane

Emissions: (using gaseous fuel)
NO_X PPM 18 Non-Recuperated
CO PPM 240 Non-Recuperated

Operational:
- Temperature Range: -40° F to 120° F
- Speed (RPM) 68,000
- Pressure Ratio: 4:1
- Non-Recuperated Outlet Temperature: 1200° F
- Recuperated Outlet Temperature: 600° F
- Efficiency % (LHV): 30% Recuperated
- Oil Lubricated Bearings 2
- Integral Alternator
- MTB Overhaul Hours: 27,000 (estimated)

PRELIMINARY SPECIFICATIONS
TA-200

Output Rating:
- Power: 200 kW at 77° F, 500 Ft., Standard Day
- Voltage: 120/208/240/480 VAC
- Frequency: 50Hz/60Hz
- Phase: 1 or 3

Fuel Type:
- Natural Gas
- Diesel
- Kerosene
- Alcohol
- Gasoline
- Jet (JP 4/5)
- Methanol
- Ethanol
- Propane

Emissions: (using gaseous fuel)
NO_X PPM 18 Non-Recuperated
CO PPM 240 Non-Recuperated

Operational:
- Temperature Range: -40°F to 120°F
- Speed RPM: 43,000
- Pressure Ratio: 4:1
- Non-Recuperated Outlet Temperature: 1234°F
- Recuperated Outlet Temperature: 634°F
- Efficiency % (LHV): 30° Recuperated
- Oil Lubricated Bearings 2
- Integral Alternator
- MTB Overhaul Hours: 27,000 (estimated)

SPECIFICATIONS
TA-45

Output Rating:
- Power: 45 kW at 59° F, Sea Level, Standard Day
- Voltage: 120/208/240 VAC
- Frequency: 50Hz/60Hz
- Phase: 1 or 3

Fuel Type:
- Natural Gas
- Diesel
- Kerosene
- Alcohol
- Gasoline
- Jet (JP 4/5)
- Methanol
- Ethanol
- Propane

Operational:
- Temperature Range: -40° F to 120° F
- Speed (RPM) 116,000
- Pressure Ratio: 4:1
- Non-Recuperated Outlet Temperature: 1300° F
- Recuperated Outlet Temperature: 600° F
- Efficiency % (LHV): 30% Recuperated
- Oil Lubricated Bearings
- Integral Alternator
- MTB Overhaul Hours: 27,000 (estimated)

Inverter and Controller:
- Microprocessor Controller
  Digital Readout
- Re-programmable Voltage and Frequency
- Auto Shutdown Features
- Fault Isolation Detection
- System Diagnostics
- RS232 Communications Port

Size:
- Weight: Less than 300lbs., with enclosure
- Dimensions: (with enclosure)
  Length: 64"
  Width: 30"
  Height: 34"
  Volume (feet): 16

Emissions: (using gaseous fuel)
NO_X PPM 9 Non-Recuperated
NO_X lbs../hr. 0.005 Non-Recuperated
CO PPM 145 Non-Recuperated
CO lbs../hr. 0.082 Non-Recuperated

Status:
- Distribution and support commencing February 1998.

ELLIOTT ENERGY SYSTEMS

For More Information Contact
Sales & Marketing
2901 SE Monroe St.
Stuart, FL 34997
Phone: (561) 219-9449
Fax: (561) 219-9448

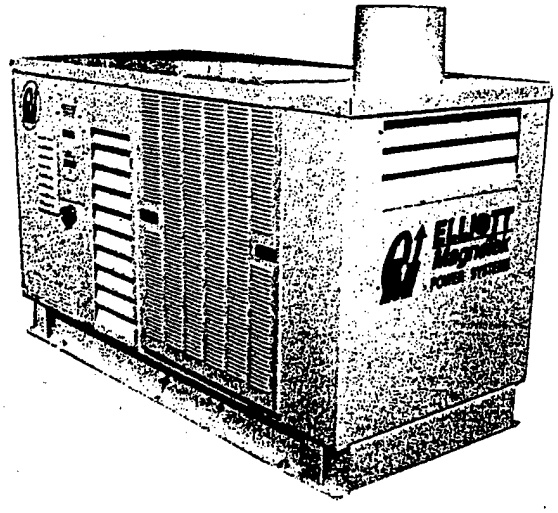
ELLIOTT MagneTek POWER SYSTEMS

Model TA 45
45 kW Turbo Alternator ™
Set

Turbo Alternator™ Set Rating		
Three Phase	60 Hz kW/KVA	50 Hz kW/KVA
Power electronics rated to 75°C		
Continuous		
Standby	45 / 56	45 / 56
Prime Power	45 / 56	45 / 56
Single Phase	60 Hz kW/KVA	50 Hz kW/KVA
Continuous		
Standby	15 / 18	15 / 18
Prime Power	15 / 18	15 / 18

Quality Power Producing Equipment
is our business at Elliott MagneTek Power Systems, Inc.. Our power systems offer solutions to requirements for reliable, quality electrical power.

- 100% full load tested.
- Performance supported by prototype testing.
- 50 or 60 Hz operational.
- Standard Digital Control Panel meeting standards set by NFPA-110.
- IEEE 519 Compliant



EMPS Products
System Reliability and Longevity begin with design experience and integrity. EMPS was formed by two companies Elliott Turbo Machinery and MagneTek, Inc. with over one hundred fifty years experience producing state-of the-art power generation equipment. This experience is designed into our generator sets and Turbo Alternator™ sets.

Single Source Responsibility:
Product service, support and parts are available through EMPS network of distributors, OEM's and Integrators

Accessories and Flexibility
are designed into EMPS' generator sets and Turbo Alternator tm sets at the factory level to meet specific application needs.

Organizational Commitment
to innovative, leading edge technology and environmentally friendly power systems solutions.

Alternator Set Design Features

Model TA 45
45 kW Turbo Alternator ™ Set

Industrial Standards

This unit is designed to meet or exceed standards set forth by:

UL 508
NFPA 70
IEEE 519

Standard Equipment:

- Emergency stop
- RS-232 Data Buss
- Exhaust Muffler
- 45 kW Gas Turbine
- 4 Pole Permanent Magnet Generator
- 45kW Synchronous Output Inverter
- Output Circuit Breaker
- Contactor
- Push Button Start/ Stop
- Automatic Voltage Regulation
- High Performance Output Filtering
- Oil Sight Gauge
- 24 VDC Stand Alone Start System
- 24 VDC Electrical System
- Battery Charger
- Battery Rack And Cables
- Powder Paint Enclosure
- Single Stage Dry Type Air Cleaner
- Corrosion Resistant Hardware
- FADEC Engine Controller
- Digital LCD Display
- Black Start Capable
- 10 Sec Emergency Start
- Status Indicators
  - Ready
  - On Line

Display Options:

- Output AC Voltage/ Amperage
- Oil Pressure Monitor
- Oil Temperature
- Fuel Pressure
- Exhaust Gas Temperature
- Output KVA
- Frequency
- Battery Voltage
- Fault Indications:
  - Low/ High Oil
  - Low/ High Fuel
  - Start Failure
  - Flame out
  - Over Speed
  - Over Temp.

Alternator Specifications

Turbine and Compressor:
The Turbine, Compressor and Main Shaft are inertia welded into a single piece. Compressor and Main Shaft are formed from Stainless Steel, the Turbine is made of a High Temperature Creep resistant alloy.

Main Stator:
The Stator is a conventional copper wound design which is oil cooled and mounted into a common casing with the turbine and compressor assembly.

Main Rotor:
The Alternator Rotor is a permanent magnet four pole design which is pressed onto the rotor assembly. The rotor uses a carbon fiber sleeve to retain the magnets.

Inverter:
The Inverter rectifies the 3866 Hz AC voltage produced by the Alternator into ~550 - 650 VDC unregulated . It then converts the DC voltage into 50Hz or 60 Hz 208/ 120 VAC or 240 VAC 3 phase.

Bearings:
The Micro Turbine Utilizes Two Primary Bearings. The inboard bearing is a conventional hydrodynamic design and the outer-bearing is a rolling element bearing utilizing ceramic balls. Both bearings are lubricated and cooled by synthetic oil.

Exciter:
High intensity
1.6 joules 8 X per sec.

Voltage Regulation: IEEE 519 Compliant.

Radio Interference (RFI): Filtering provides suppression of conducted electromagnetic interference to levels meeting most commercial requirements.

\

Voltage Selections and Full Load Amperage at Standby Rating
(Unbalanced Load)

Three Phase

60/ 50 Hz	Amperage
208	156

Single Phase

60/ 50 Hz	Amperage
124	156

For other voltages please contact EMPS for further information.

Communications:
Proprietary EES Protocal

Advantages of the TA-45 Turbo Alternator Over Traditional Reciprcating Gensets.

- Longer life cycle with first minor overhaul at 27,000 hours and the first major overhaul at 54,000 hours.
- Greater Reliability no water hoses, belts water cooling and only 12 parts that need maintenace vs 128 in reciprocating gensets.
- 25 % of the weight and size of the equivalent reciprocating genset.
- Naturally low poluting providing for output of green power.
- Lower maintenace costs of .005 to .007 cents per kW /hr

Benefits

End users of our Turbo Alternator™ will see savings of a magnitude, which will offset initial capital costs resulting in a payback period of 2-3 years depending upon the application. You will pay lower installation costs, you will pay lower maitenance costs and you will experience more up time by installing our Turbo Alternator™. When used in a peak shaving application our Turbo Alternator™ will provide you with electricity at a lower cost per kW/hr than most grids.

Technical Specifications

Model TA 45
45 kW Turbo Alternator ™ Set

Engine Specifications

Manufacturer	Elliott Energy Systems
Model	TA-45
Type	Single Stage Gas Turbine
Batteries (2)	12V min. Type 65/ 800 (CCA)

Compressor

Pressure Ratio	4.2 to 1
Inlet	77° F

Exhaust Gas

Temperature	1200° F
Flow	750 SCFM

Cooling System

Engine	Oil Cooled
Capacity	3 gal.
Coolant Flow	4 gal. per min.
Inverter and Electronics	Air Cooled

Air System

Engine and Electrical compartments are separate and use single stage filtration.

Radiator Cooling and Engine Compartment Purge.

Air Flow	1000 CFM

Cooling Fan For Electronics Compartment

	300 CFM

Turbo Alternator™

Air Flow	750 SCFM

Exhaust System

Outlet Size	10"
Maximum Allowable Back Pressure	5 In H_20

Fuel System

Fuel Supply

Gaseous	75 PSI min.
Diesel	-2 in. H_20 min.

Fuel Consumption

Diesel Recuperated:

Load	kW	US gal/h	Litre/h
Full	45	4/	15.2

Diesel Non-Recuperated:

Load	kW	US gal/h	Litre/h
Full	45	8/	30.4

CNG Recuperated:

Load	kW	SCFM
Full	45	8.25

CNG Non-Recuperated:

Load	kW	SCFM
Full	45	16.5

Electrical Output Type

Motor Starting Capacity	15 HP/ 3 Phase

Lubrication System

Oil Type	Mobil 824C or Mil-L-23699 Equivalent
Oil Capacity with Filters	2.5 US gal. (9.5 L)
Oil Filter Type	Spin On, 5 Micron

Engine Exhaust Emissions Certification Values

	Diesel	Gas
Exhaust Emissions (g/bhp-hr.)		
CO:	400 PPM	400 PPM
NOx:	35 PPM	20 PPM

Dimensions:

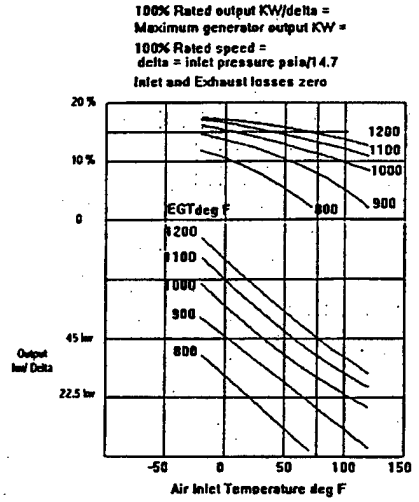
Height	44" /1118 mm
Length	72" / 1828.8 mm
Width	32" / 813 mm

Total Weight with Enclosure:

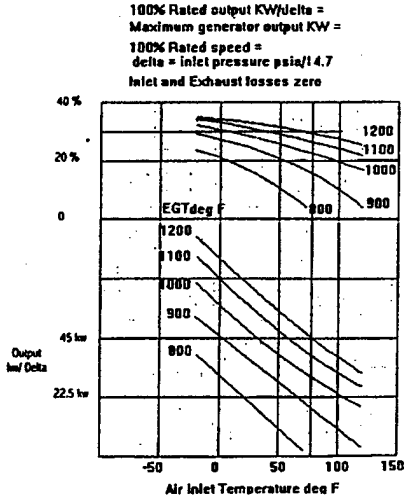
Non- Recuperated	750 Lbs./ 340.9 kg.
Recuperated	1000 Lbs./ 454.6 kg.

Preliminary Data

TA-45 Non-Recuperated Derate Information



TA-45 Recuperated Derate Information



Model TA 45
45 kW Turbo Alternator™ Set

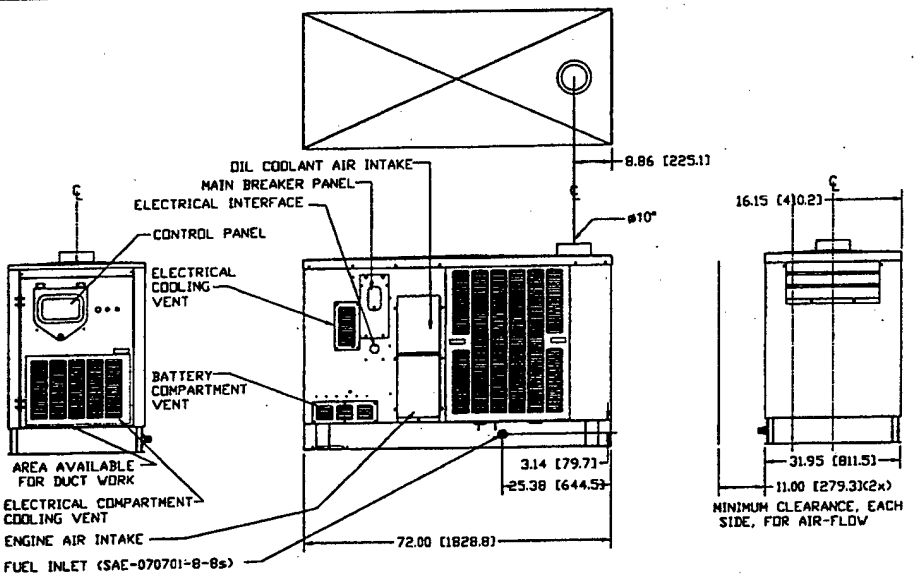
Options:

Control
- ☐ Remote alarm annunciator
- ☐ Fault Indicator
- ☐ Multi-point dry contact board.

Engine
- ☐ Batteries
- ☐ Battery heater
- ☐ Battery maintenance Charger For Stand By Mode
- ☐ Engine pre-heater
- ☐ Exhaust Silencer
- ☐ Fuel/ water separator
- ☐ Oil heater

Turbo Alternator™ Set
- ☐ EMPS automatic transfer switch
- ☐ Industrial silencer
- ☐ Residential silencer
- ☐ Critical silencer
- ☐ Weather Proof Enclosure to NEMA4
- ☐ Sound attenuation
- ☐ Day tank
- ☐ Critical silencer
- ☐ Weather protective

Accessories:
- ☐ NG Compressor
- ☐ Back-Up Remote Lube Pump
- ☐ Remote Communications Package
- ☐ CNG Regulator
- ☐ CNG/ Propane Fuel Inlet Filters



208 Elliott Drive
P.O. Box 403
Lexington, TN 38351
Tel: 901-967-9393
Fax: 901-968-0161

Distributed by:

ELLIOTT MagneTek POWER SYSTEMS

Capstone

Capstone MicroTurbine™

MODEL 330
Grid-Connect
Natural Gas

The Product

Benefits

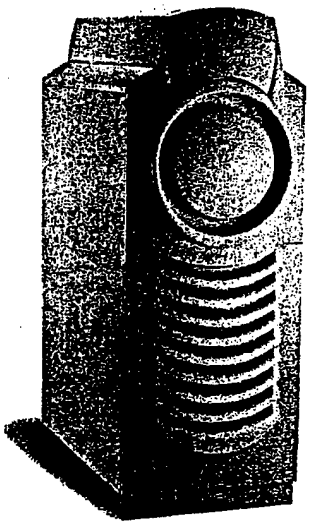
- Ultra-low emissions
- Minimal maintenance
- No liquid lubricants
- No liquid for cooling required
- Small footprint
- Low noise

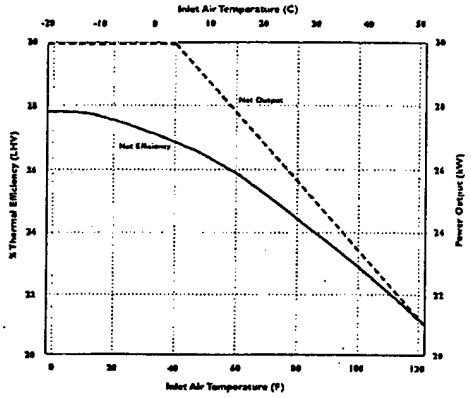
Options

- High pressure natural gas (55psig)
- Low pressure natural gas

Features

- 28kW net*
- 400-480 Vrms VAC, 3 phase, 50/60 Hz
- Grid-connect
- Fuel delivey system
- Air bearings
- Unit-mounted controls
- Year 2000 compliant





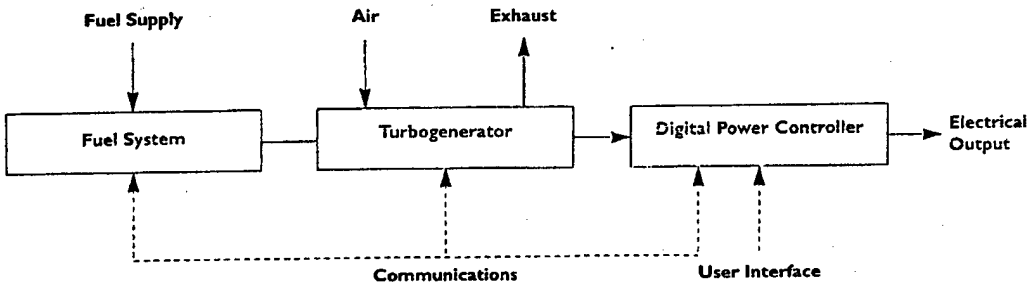
Preliminary Specifications

Output	Power	Efficiency (LHV)	Heat Rate (LHV)
MicroTurbine @ 50 or 60 Hz*	28 kW net	26% (+/- 0.5% points)	13,200 Btu/kWh
Emissions** (natural gas fuel):			
NOx	<9 ppmV / 6.7 g/hr / 0.0147 lb/hr		
Noise Level	65 dBA @ 10 meters		
Full Load Fuel Flow (natural gas-HHV)	410,000 Btu/hr / 428,000 kJ/hr		
Exhaust Gas Temperature	520°F / 271° C		
Total Exhaust Energy (base @ 59F, 15C)	277,000 Btu/hr / 295,000 kJ/hr		
Dimensions	74.8" H x 28.1" W x 52.9"D 1900 mm H x 714 mm W x 1344 mm D		
Weight	700 lb / 317 kg		
Voltage	400-480 VAC 3 phase, 4-wire wye or 3-wire wye, ungrounded delta, 43A max		

*ISO conditions, 59° F (15° C)/sea level; for high pressure natural gas
**At full-load power
Note: The manufacturer reserves the right to change or modify without notice, the design or equipment specifications without incurring any obligation either with respect to equipment previously sold or in the process of construction.

CAPSTONE TURBINE CORPORATION

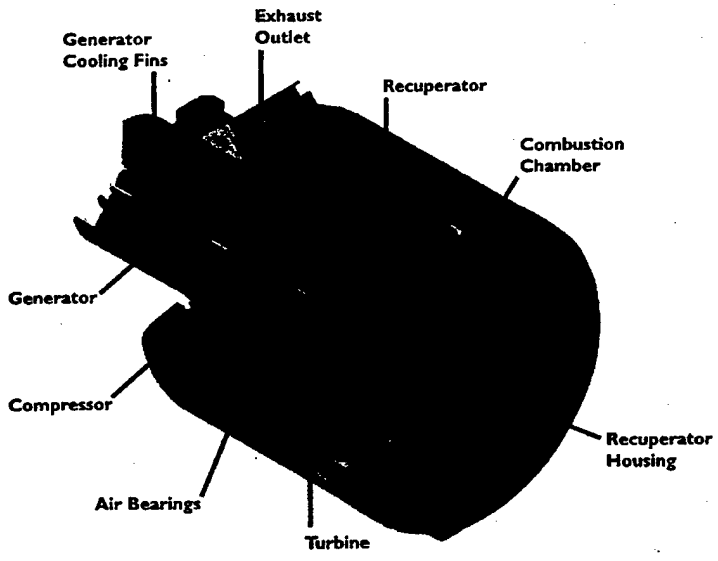
Capstone MicroTurbine™ System



The Capstone MicroTurbine™ is a compact, low emission, power generation system providing electrical power up to 30kW. A turbogenerator is coupled with solid-state power electronics to allow grid-connect operating modes.

The Capstone turbogenerator incorporates a compressor, recuperator, combustor, turbine and permanent magnet generator mounted on a single shaft and supported by patented air bearings. The generator is cooled by air flow into the gas turbine, thus eliminating the need for liquid cooling. The output of the generator is variable frequency (50 or 60 Hz) AC power. The shaft rotates at up to 96,000 RPM (full load).

Capstone Turbogenerator



CAPSTONE TURBINE CORPORATION
16700 Oxnard Street, Tarzana, CA 91356 Tel:(818) 774-9600 • Fax:(818) 774-0228
www.capstoneturbine.com

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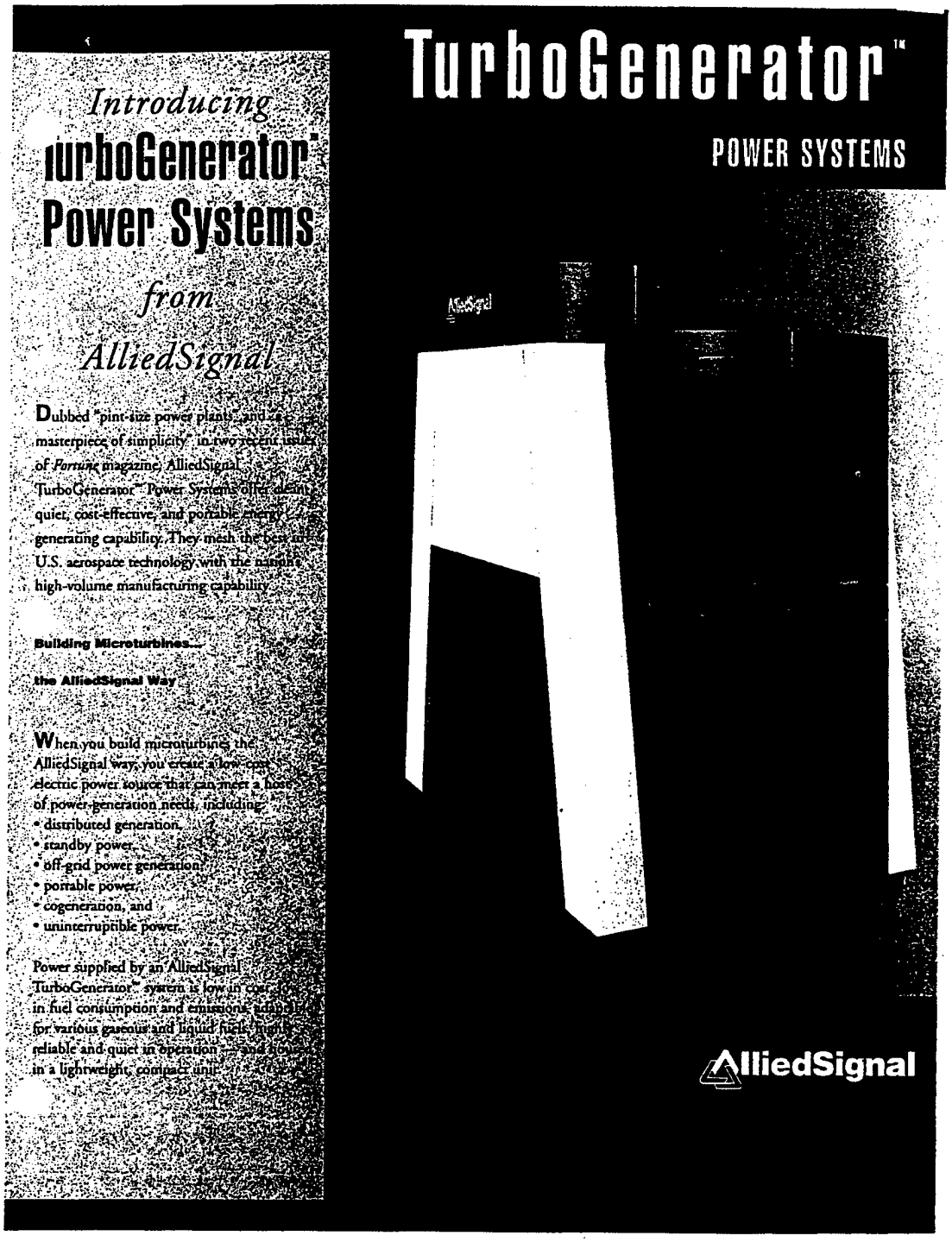

Introducing
TurboGenerator™
Power Systems
from
AlliedSignal
Dubbed "pint-size power plants" and a "masterpiece of simplicity" in two recent issues of Fortune magazine, AlliedSignal TurboGenerator™ Power Systems offer clean, quiet, cost-effective, and portable energy generating capability. They mesh the best in U.S. aerospace technology with the nation's high-volume manufacturing capability.
Building Microturbines...
the AlliedSignal Way
When you build microturbines the AlliedSignal way, you create a low-cost electric power source that can meet a host of power-generation needs, including:
• distributed generation,
• standby power,
• off-grid power generation,
• portable power,
• cogeneration, and
• uninterruptible power.
Power supplied by an AlliedSignal TurboGenerator™ system is low in cost, in fuel consumption and emissions, adaptable for various gaseous and liquid fuels, highly reliable and quiet in operation — and it comes in a lightweight, compact unit.
TurboGenerator™
POWER SYSTEMS
AlliedSignal

'gn is

the Difference

How could AlliedSignal pack so many features into such a small system? Through innovative design.

First, we mount the turbine, compressor and permanent-magnet generator on a single high-speed shaft supported on patented air bearings. That eliminates the need for an oil-based lubrication system and all of its maintenance demands.

Second, the generator is built into the shaft and rotates at the same speed — creating a power generating system with just one moving part. That means increased reliability, quieter operation, lower vibrations and reduced cost when compared with conventional gas turbine or spark ignition engines.

. .rd, the patented, two-pole permanent magnet generator rotor produces 75kW of power at 65,000 rpm, making it compact and highly efficient. And the generator also operates as a starter motor, so no separate starter is needed.

Fourth, our lean, pre-mix, pre-vaporization LPP combustor operates on either unleaded gasoline, diesel fuel, alcohol fuels or natural gas; and our exhaust heat recuperator reduces fuel consumption. The result: a highly fuel-efficient system that operates with flame temperature below NOx-forming levels...the ability to switch fuels when needed...and combustion efficiency of more than 99.5 percent.

The End User Wins

What do all of these features mean to the end user? Plenty.

AlliedSignal TurboGenerator™ Power Systems enable electric power producers to increase capacity without massive capital investments.

They minimize the cost of power outages to electric power producers and consumers alike, by enabling them to switch to turbogeneration whenever necessary.

They offer users a source of low-cost base load power — an on-site alternative to power provided by local utilities.

They also can be used for peak shaving — reducing or eliminating the need to buy power at peak rates.

And they can be used as a heat source for cogeneration.

And the Price is Right

Not only does TurboGenerator™ power make good technological sense, it's also a winner economically.

Ultimately, AlliedSignal TurboGenerator™ systems are expected to be one of the lowest-cost power generation systems on the market.

In North America, using natural gas and the AlliedSignal maintenance program, our TurboGenerator™ systems can be expected to provide in excess of 50,000 hours of reliable operation.

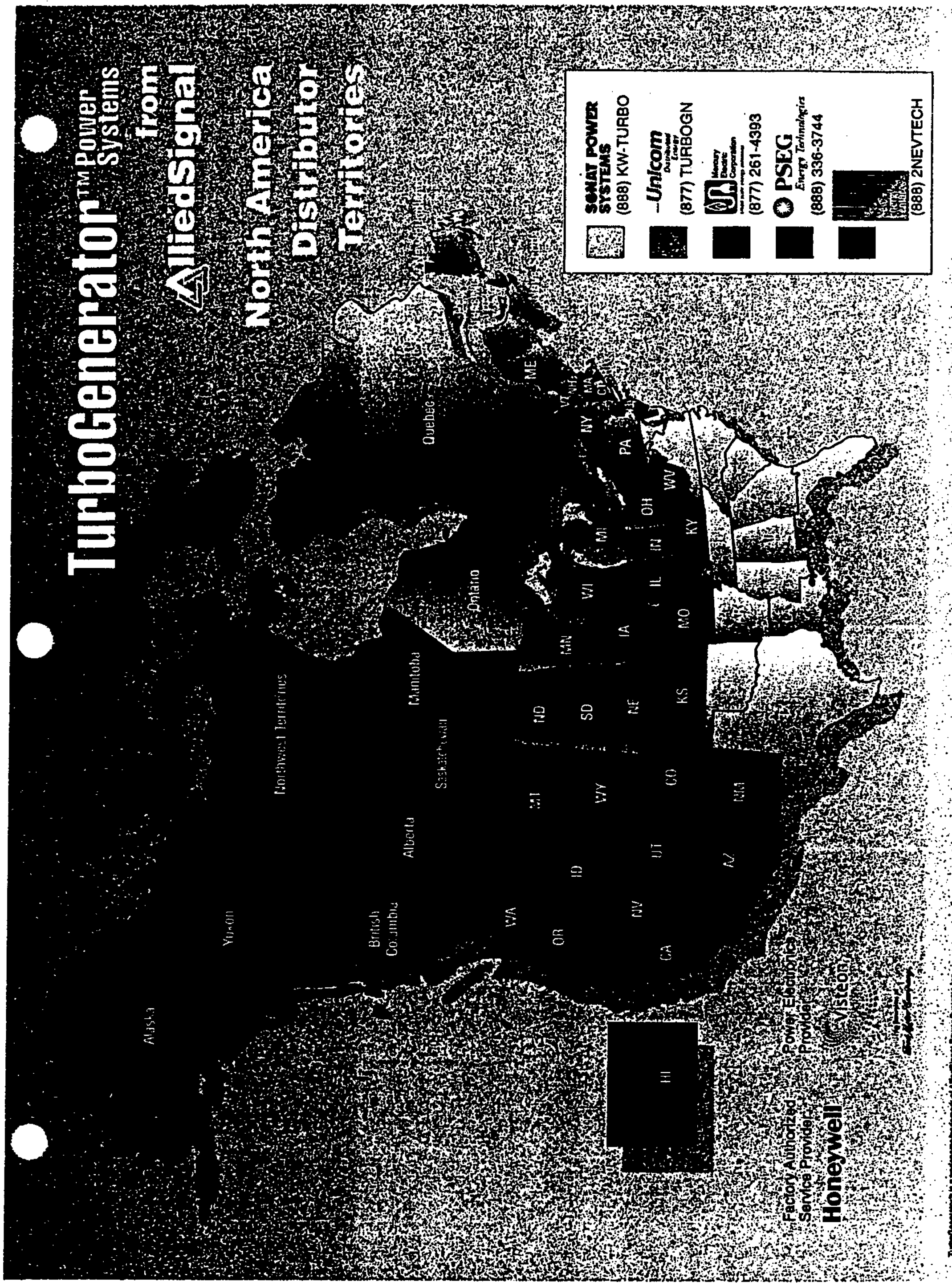
About AlliedSignal

AlliedSignal Power Systems Inc. is a Torrance, California-based developer and producer of clean, portable, high-efficiency, cost-effective power generation systems for use in private businesses and remote locations around the world. The company is a subsidiary of AlliedSignal Inc., an advanced technology and manufacturing company serving customers worldwide with aerospace and automotive products, chemicals, fibers, plastics and advanced materials. With about $14 billion in sales, the company ranks among the top FORTUNE 100 companies, and is a component of the Dow Jones Industrial Average.

For more information, contact:

AlliedSignal Power Systems Inc.
2525 West 190th Street
Torrance, CA 90504
(310) 512-4127
(310) 512-1561 FAX
http://www.alliedsignal.com

AlliedSignal


TurboGenerator™ Power Systems
from
AlliedSignal
North America
Distributor
Territories
SONAT POWER SYSTEMS
(888) KW-TURBO
Unicom
(877) TURBOGN
(877) 261-4393
PSEG
Energy Technologies
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(888) 2NEVTECH
Alaska
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Manitoba
Ontario
Quebec
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OR
CA
NV
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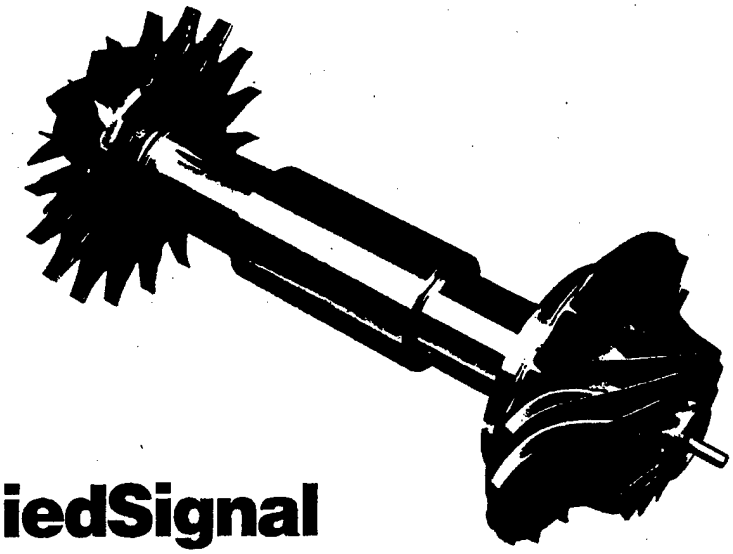
OH
KY
WV
PA
NY
VT
NH
MA
CT
ME
HI
Factory Authorized Service Provider
Power Electronics Provider
Honeywell
Visteon

Designed To Perfection

How can the TurboGenerator offer so much for so little? Without a doubt, it's AlliedSignal's patented design that makes the difference. It focuses on several key elements, including the TurboGenerator's specially designed rotor shaft. Essentially, it's just one moving part.

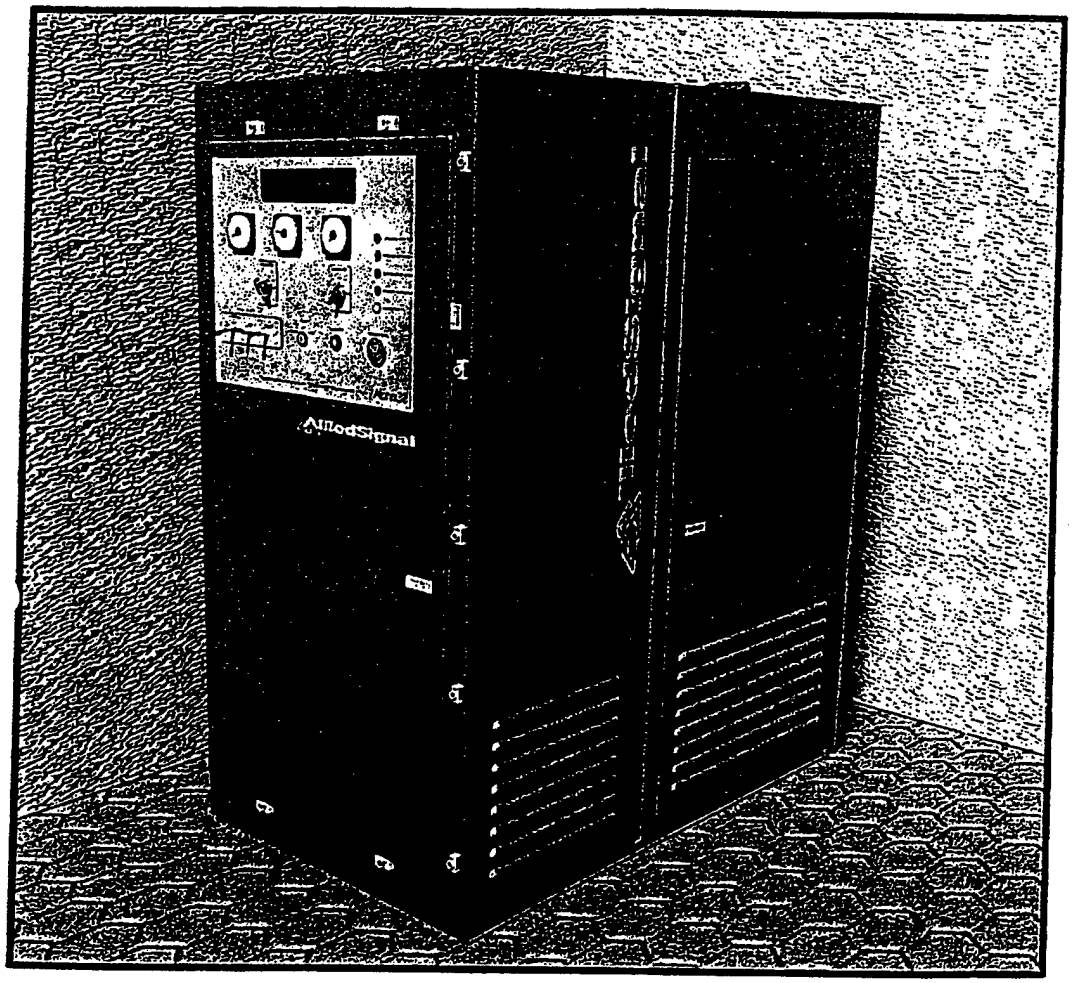
The turbine, compressor and permanent-magnet generator are all mounted on a single high-speed shaft. Then, they're supported on air bearings. With this unique engineering design, there's no need for an oil-based lubrication system. The result is a highly reliable system without the high maintenance demand.

And since the generator is actually built into the shaft and rotates at the same speed, no gearbox is needed. That means a highly efficient power generating system with just one moving part. Of course this also provides increased reliability, quieter operation with lower vibrations and reduced cost when compared with conventional gas turbine or spark ignition engines.



AlliedSignal

SONAT POWER SYSTEMS



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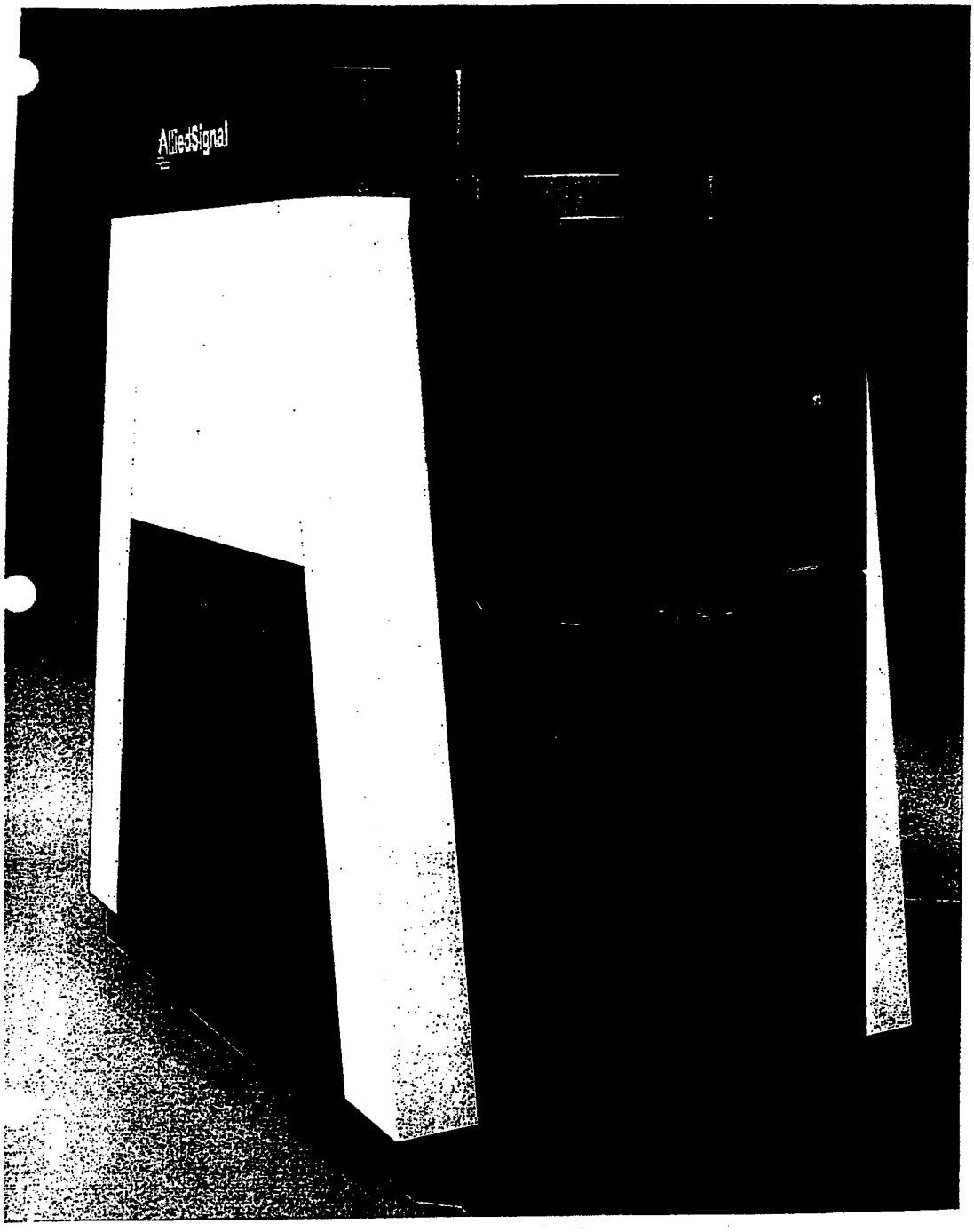
AlliedSignal

CONTRACT CONDITIONS
QUOTATION REF NO : Q05698 dated 14th December 1998

1. BUDGETARY PRICES

Item 1 - Turbogen TG45CG Cogeneration System

One (1) off ~ BPS Turbogen TG45CG Cogeneration System in accordance with the attached Technical Scope of Supply ref. Q05698/A and having an ISO continuous electrical rating of 40kWe, 50kVA, 0.8Pf, 480V, 60Hz, 3ph.

Pounds sterling - £36,000.00 (thirty six thousand) each net ex-works

Item 2 - Turbogen TG80CG Cogeneration System

One (1) off ~ BPS Turbogen TG80CG Cogeneration System in accordance with the attached Technical Scope of Supply ref. Q05698/B and having an ISO continuous electrical rating of 80kWe, 100kVA, 0.8Pf, 480V, 60Hz, 3ph.

Pounds sterling - £50,000.00 (fifty thousand) each net ex-works

Item 3 - Supervision of Installation and Commissioning of the BPS supplied equipment.

This will be charged at a man-day rate of £300.00 (three hundred) plus travel and expenses. A formal fixed price quotation will be submitted when the location of the site has been identified.

Note.

The prices quoted are net ex-works UK. Air freight and forward delivery to your nominated sites in USA excluding any insurance, importation charges or local duties payable in the USA is estimated at £2,000.00 (two thousand) per set, to be confirmed when the actual delivery sites are identified.

2. TERMS OF PAYMENT

All payments to be made to the bank nominated on the invoice.

(a) Items 1&2

25% of the contract price upon submission of the following drawings:-

General Assembly
Electrical Schematic
Mechanical Schematic

75% of the contract price on notification of goods ready for dispatch.

(b) Item 3

100% of the contract price on completion of the Performance Testing or thirty (30) days from arrival of the BPS Commissioning Engineer on site if testing is delayed for reasons outside of BPS control or influence.

3 DELIVERY EX-WORKS

Items 1&2 - Approx. 16 weeks, to be confirmed on receipt of official order.

4 CONTRACT CONDITIONS

Our offer is made subject to BPS Condition of Sale (copy attached).

5 WARRANTY

In accordance with BPS Standard Warranty Terms i.e.12 months from acceptance or 18 months from delivery ex-works, which ever is the sooner.

6 VALIDITY

Our quotation is based on 1998 economics and is valid until the 31st January 1999 after which it is subject to confirmation.

7 EXTENT OF QUOTATION

Our offer includes only such items that are specifically stated therein.

T. Gerson

TOM GERSON ~ Sales Manager

for and on behalf of
BOWMAN POWER SYSTEMS LIMITED.

TECHNICAL SCOPE OF SUPPLY
B.P.S. QUOTATION No. Q 05698/A

Bowman Power Systems Turbogen TG45 Cogeneration system generally in accordance with the following specification:-

1.0 Rating

Continuous electrical output power at ISO conditions (15 ° C, Sea level)	-	40kWe; 50kVA 0.8 Pf 480 V; 3 ph; 60 Hz
Nominal operating speed	-	116,000 rpm
Standard operating temperatures	-	0°C to +35°C.
Gas supply pressure	-	Steady state 5 - 8 bar.g.

1.1 Micro Turbine Generator

- Integrated mono rotor design
- Single Stage radial compressor
- Annular Combustor
- Gas Fuel Nozzles
- Single Radial Turbine
- Pressure Ratio 4.3 : 1
- Permanent magnet alternator rotor
- Oil cooled alternator stator
- Oil lubricated bearings

1.2 Engine Recuperator

- 75 percent effectiveness
- Plate and fin construction from Inconel 625
- Brazed construction to form air cells
- Duct connectors type 321 stainless steel
- Single air side modulating valves
- Stainless steel expansion / isolation valves
- Air pressure switch

1.3 Exhaust Gas Heat Exchanger

- Shell and Finned tube construction
- Mild steel shell and tubes
- Flanged exhaust gas connection
- Flanged water connection
- Water temperature sensors (in / out of heat exchanger)
- Mineral wool thermal insulation

1.4 Gas Fuel System

- Proportional Flow Regulating Valve
- Ignition system
- U V flame sensor

1.5 Lubrication System.

- Lubricating pump (AC motor driven)
- Simplex filter (4 micron)
- Oil Tank incorporating sight level gauge
- Oil cooler (oil / air type) ~ 2 sections
- High Temperature switch..
- Low Pressure switch
- Oil Heater and Thermost
- Check valve

1.6 Inverter Stack Cooling System

- Coolant pump with AC motor drive
- Water cooler (Water / air type)
- Water header tank
- Low level alarm and shutdown switches

2.0 Generator Control and Monitoring Panel comprising ;

a) Generator Control Panel incorporating

- Gas Turbine sequence and protection controller
- Gas Turbine load controller
- Automatic Utility Interface connection

- 4 position system control switch :~ Stop
  Automatic
  Manual
  Engine Test

- Digital Display of following functions :~

Electrical Metering	:~	Volts; Amps; Hz; kW; kWh; Pf
Gas Turbine instrumentation	:~	Exhaust gas temperature
		Engine speed
Events log	:~	Preceding 100 events
Battery Voltage		
Hours run and successful starts		

- Output circuit breaker
- Emergency stop button.
- Status lamps :~ DC System healthy
  AC Aux. supply healthy
  Set ready to load
- Audible Alarm

b) Generator shut down and alarm functions

- Overspeed
- Underspeed
- High exhaust temperature (Gas Turbine)
- Low lube. oil pressure
- High lube. oil temperature
- Low gas pressure
- High gas pressure
- Flame failure
- Start failure
- Ignition failure
- Emergency stop activated
- Grid failure
- Reverse Power
- Overcurrent

c) Remote signal and contacts

- To be agreed for specific project ~ Not included as standard

d) AC Auxiliary system

- Single connection point for single phase AC supply
- Starters and control of package AC motors
- AC isolator switch
- Package AC distribution

e) Cable Entry

- The package will be suitable for top or bottom power and control cable entry

3.0 Battery Control System.

- 2 x 12 V; maintenance free lead acid batteries
- Battery charger
- Battery isolation switch

4.0 Power Conditioning Unit (PCU)

The PCU consists of four elements :

- Rectifier - Converts the high frequency AC to DC
- Boost Converter - Regulates the DC by boosting the unregulated DC to a fixed DC voltage to suit the model output
- Inverter - Converts the DC to AC by producing a digital pulse train which is pulse width modulated under microprocessor control to generate the 60Hz output frequency
- Filter - Converts the pulse train into a good quality sine wave and removes any unwanted high frequencies

5.0 Package

- The gas turbine, alternator, recuperator and hot water heat exchanger complete with their auxiliary systems are mounted on a fabricated base frame
- The enclosure is supported from the package base frame and is suitable for indoor installation
- Noise limitation 75 dBA at 1 metre
- Lift off access doors for routine maintenance
- Air inlet filter mounted in one end of the enclosure
- Control and Monitoring Panel mounted on the enclosure
- Ventilation discharge flange

6.0 System Operation

6.1 Electrical System

- The start controller takes power from the utility supply to drive the alternator as a motor to start the gas turbine, thereby avoiding the use of a dedicated start motor. It controls the start sequence and when the gas turbine is running switches the PCU back to its main function of driving the load using power from the alternator.

- The start sequence includes a purge timer to ensure the boiler system is cleared of gas prior to light off.

- The 24V battery, together with an integral battery charger, provides the running power for system auxiliaries.

- The system is designed for parallel operation with the public utility electricity supply.
  Failure of the utility supply will cause the system to shut down

- Fully automatic control of gas turbine starting/stopping, utility supply connection, power output control including thermal modulation is provided.

6.2 Recuperator by-pass Heat Demand control

- Utilising the unique Turbogen recuperator by-pass facility enables the user to modulate the cogeneration unit heat output to satisfy the installation heat demand

- When the heat demand is low, the unit can be operated in maximum recuperated mode, producing the electrical output at maximum efficiency but minimising the heat available from the exhaust gases.

- As the demand for heat increases, the amount of recuperation can be reduced, consequently reducing the efficiency of the electrical power generation but increasing the amount of heat available from the exhaust gases and maximising system efficiency.

- To operate the recuperator by-pass system, BPS requires a 0-10V DC proportional signal to represent the heat demand.
  i.e. Minimum heat requirement = 0 v
  Maximum heat requirement = 10 v

7.0 Site Installation

- Suitable bonded rubber machinery mountings for the gas turbine Cogeneration system are provided (No foundation bolts are required)
- The Recuperator and Exhaust Gas Heat Exchanger will be fully incorporated into the package at the BPS factory

8.0 Site Services (Optional)

- The BPS engineer will check that all items of BPS supply are correctly installed prior to commencing commissioning
- Commissioning of BPS supplied equipment
- Training of customers personnel to enable them to operate and carry out routine maintenance of the system will be carried out by the BPS commissioning engineer at the time of commissioning.

9.0 Package Termination Points

- Gas turbine air inlet filter flange face (louvre supplied)
- Exhaust gas discharge flange from heat exchanger
- Ventilation air discharge flange
- Fuel inlet connection on generator package
- Water connecting flanges on exhaust heat exchanger.
- Terminals in the control panel (For remote signals and auxiliary supply)
- L V Power at output circuit breaker.
- Underside of generator package

10.0 General

a) Documentation

- Drawings: (2 Copies provided)
  General Arrangement of Generating Set
  Installation Layout including all mounting requirements and loading (Option)
  Loose Items (Option)
  Single Line Electrical Diagram
  Electrical Control Circuit Diagrams
  Fluid Schematic Diagrams
  Gas train pressure test certificate (Option)

- 2 sets of Operation and Maintenance Manuals

b) Miscellaneous

- Delivery ex-works UK
- First fill of lubricants and coolants
- 12 months warranty on all parts including labour
- Finish painting to BPS standard system

11.0 Exclusions

- Civil works
- Builders work/making good
- Site off loading crane (if required)
- Fuel pipework external to unit
- Water pipework to/from heat exchanger
- Exhaust pipework beyond heat exchanger
- Gas compressor (Gas to be supplied at a regulated pressure of 5 bar. g)
- Power cables beyond output circuit breaker
- Station earth bonding and earth system
- Boiler room ventilation system
- Load bank for commissioning.

12.0 Optional Items

12.1 Gas Fuel Safety Train

This comprises a sub-assembly to fit in the gas fuel pipework external to the package, and includes the following :~

- Hand shut-off valve
- Gas Filter
- Pressure monitors - high/low pressure
- Pressure Regulator
- Primary/secondary shut-off valves
- Satronic (or similar) gas sequence controller

12.2 Secondary Water System

- Water pump (AC motor)
- Manual isolating valves
- Water inlet / outlet connections, selectable on either side of package

12.4 Boost Gas Compressor

- Suitable to boost gas pressure from 10mb to 6bar

TG45 Cogeneration System
Performance For Systems Delivered in 1998/1999

Recuperator State	%	75% Recuperated	Non-Recuperated
Recuperator Inlet Temp (EGT)	°C	680	680
Heat Exchanger Inlet Temp	°C	343	680
Flue Temp	°C	95	95
Air Mass Flow	kg/s	0.38	0.38
Exhaust Mass Flow	kg/s	0.39	0.39
Thermal Output Power *	kW(th)	96	223
Water In Temp	°C	70	70
Water Out Temp	°C	90	90
Water Flow	kg/s	1.14	2.67
Engine Speed	RPM	116000	116000
Electrical Power	kW(e)	38	45
Generating Set Efficiency	%	19.00	15.00
Fuel LHV	mJ/m^3	34.88	34.88
Fuel Consumption	m^3/hr	20.64	30.96
Sytem Efficiency	%	67	86

All values at ISO conditions (sea level and 15°C)
* Includes heat recovered from oil

Output Available: 208-480 V, 3 phase, 50/60 Hz

Engine Derating: As per curves ref TN/0028, Issue 2

DA - 27/11/98 - Data Sheets 1999 -TG35 Cogen -Options - Issue 2

TECHNICAL SCOPE OF SUPPLY
B.P.S. QUOTATION No. Q 05698/B

Bowman Power Systems Turbogen TG80 Cogeneration system generally in accordance with the following specification:-

1.0 Rating

Continuous electrical output power at ISO conditions (15 ° C, Sea level)	-	80kWe;100kVA 0.8 Pf 480 V; 3 ph; 60 Hz
Nominal operating speed	-	68,000 rpm
Standard operating temperatures	-	0°C to + 35°C.
Gas supply pressure	-	Steady state 5 - 8 bar.g.

1.1 Micro Turbine Generator

- Integrated mono rotor design
- Single Stage radial compressor
- Annular Combustor
- Gas Fuel Nozzles
- Single Radial Turbine
- Pressure Ratio 4.3 : 1
- Permanent magnet alternator rotor
- Oil cooled alternator stator
- Oil lubricated bearings

1.2 Engine Recuperator

- 85 percent effectiveness
- Plate and fin construction from Inconel 625
- Brazed construction to form air cells
- Duct connectors type 321 stainless steel
- Stainless steel expansion / isolation valves
- Air pressure switch

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- Shell and Finned tube construction
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- Digital Display of following functions :~

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- Manual isolating valves
- Water inlet / outlet connections, selectable on either side of package

12.4 Boost Gas Compressor

- Suitable to boost gas pressure from 10mb to 6bar

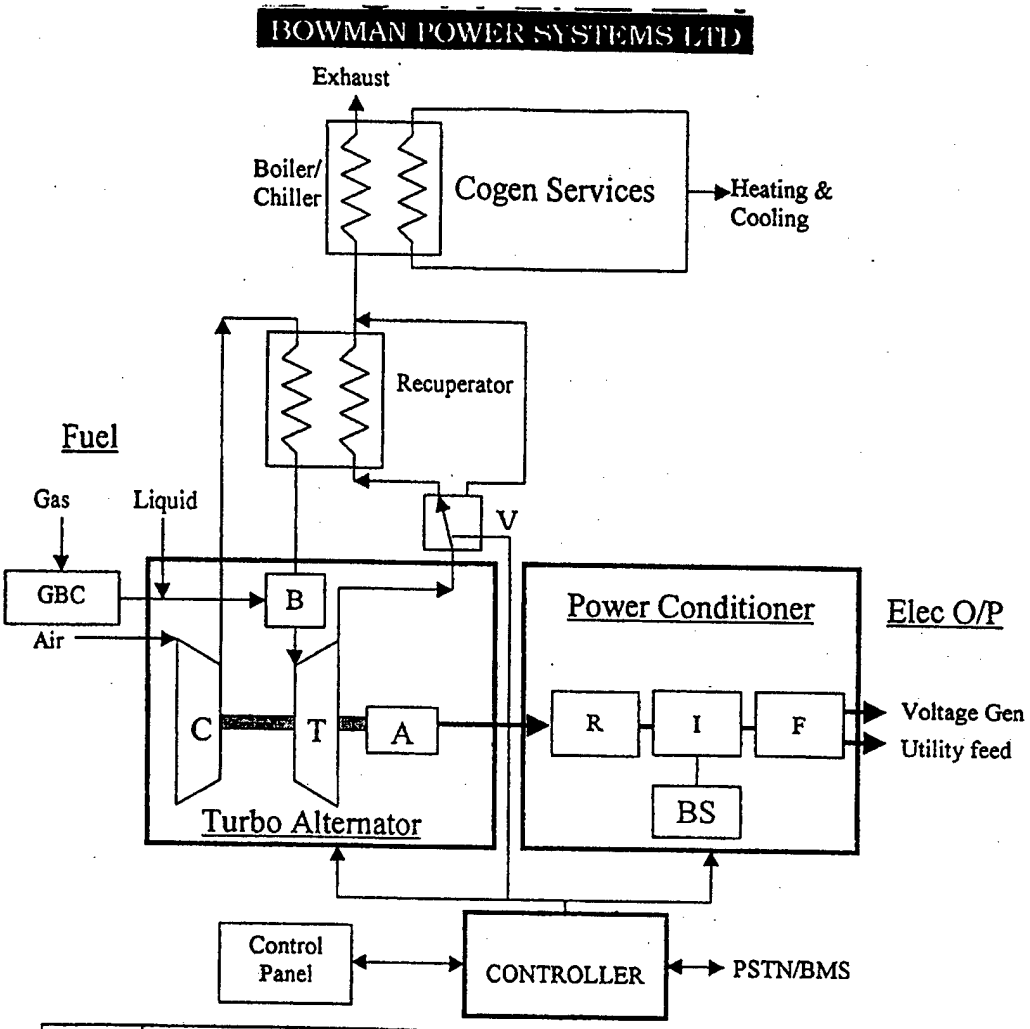
TG80 Cogeneration System Performance

Recuperator Status	%	85% Effective Recuperator	No Recuperator
Recuperator In Gas Temp (EGT)	°C	615	615
Heat Exchanger Inlet Temperature	°C	278	615
Flue Temp	°C	95	95
Air Mass Flow	kg/s	0.81	0.81
Exhaust Mass Flow	kg/s	0.83	0.83
Thermal Output Power	kW(th)	146	429
Water In Temp	°C	70	70
Water Out Temp	°C	90	90
Water Flow	kg/s	1.74	5.12
Engine Speed	RPM	68000	68000
Electrical Output Power	kW(e)	80	90
Generating Set Efficiency	%	25	15
Gas Fuel LHV	mJ/m^3	34.88	34.88
Gas Fuel Consumption	m^3/hr	33.63	61.93
Sytem Efficiency	%	69	87

All values at ISO conditions (sea level and 15°C)
* Includes heat recovered from oil and electronics

Output Available: 208-480 V, 3 phase, 50/60 Hz

Engine Derating: As per curves ref TN/0028, Issue 2



A	ALTERNATOR
B	BURNER/COMBUSTOR
BMS	BUILDING MANG. SYS
BS	BATTERY SYSTEM
C	COMPRESSOR
F	FILTER
GBC	GAS BOOST COMP
I	INVERTOR
PSTN	TELEPHONE LINE
R	RECTIFIER
T	TURBINE
V	BYPASS VALVE

Bowman Power Systems

Turbogen

Microturbine Cogeneration System

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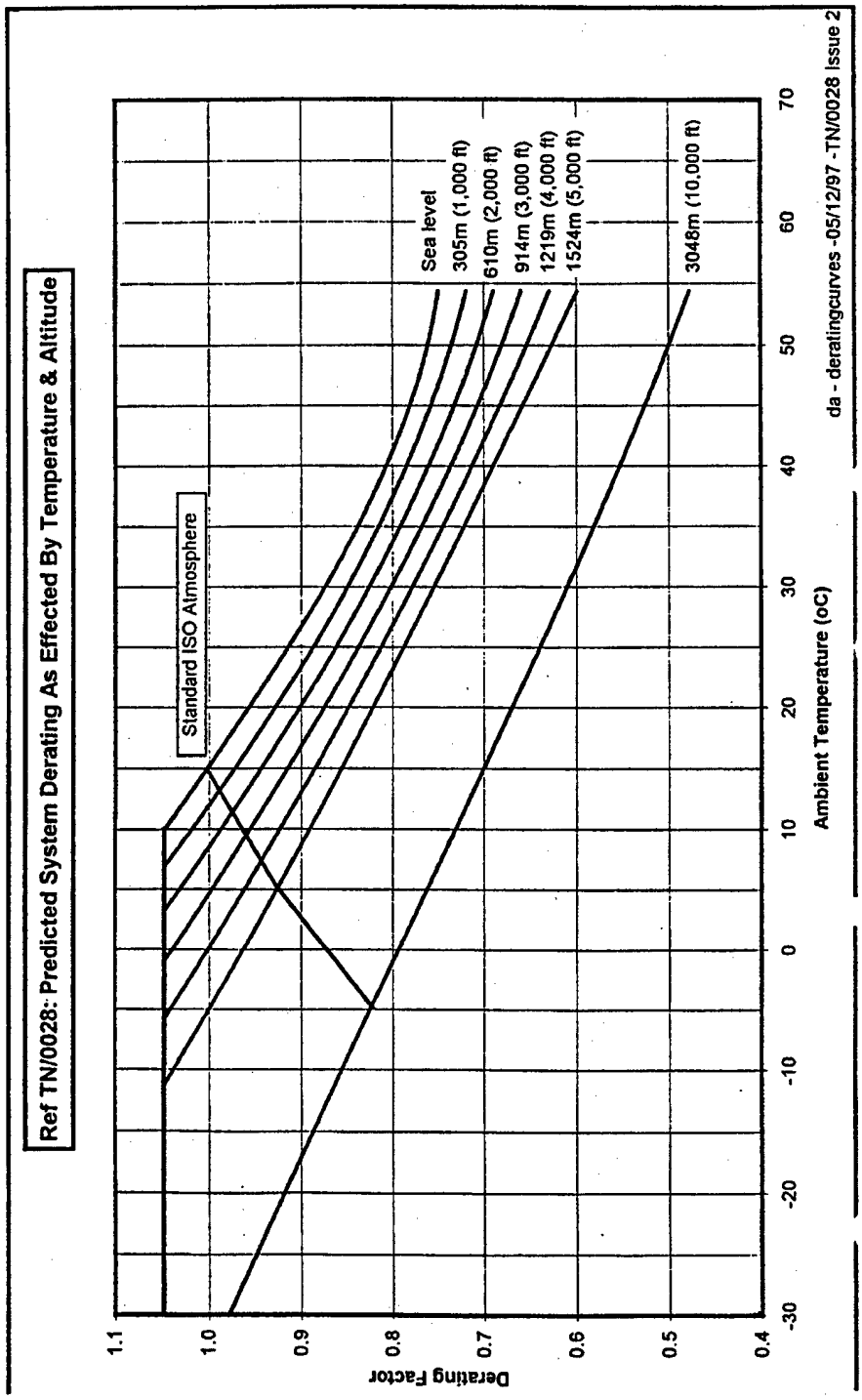

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13. ABSTRACT *(Maximum 200 words)*

Many U.S. Army installations pay relatively high prices for the electricity because they are remotely located. Moreover, Army facilities frequently have heat and electrical needs co-located in a building or cluster of buildings, which makes these locations well suited for energy "cogeneration." Micro-turbines are a miniaturized version of combustion turbines currently used in the aerospace and electric power industries. The micro-turbine's simple construction, when coupled with the cost benefits of mass production, is anticipated to yield electric power at low capitol costs. Also, the unit's exhaust stream is a high quality heat stream that can be used in a cogeneration system to meet steam or hot water needs co-located in the building. This study reviewed ongoing demonstrations to evaluate micro-turbine technology for possible application at Army installations.

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