EXECUTIVE SUMMARY

Collingwood Public Utilities (CPU) commissioned Conestoga-Rovers and Associates Ltd. (CRA) to conduct a Detailed Engineering Study (DES) to research available technologies and evaluate the economic and technical feasibility of constructing and operating one of these technologies using the digester gas produced on site as the primary fuel.

Four major Plant systems would be directly impacted by the addition of a cogeneration plant. These Plant systems include the digester gas system, electrical distribution system, hydronic heating system and natural gas supply system.

In order to determine the economic and technical feasibility of implementing a cogeneration system into the Plant operations, current energy consumption patterns were analyzed to determine base usage, maximum and minimum demand and seasonal or daily trends.

Available technologies were evaluated for potential digester gas destruction and utilization applications. A Capstone Energy, CR65 ICHP microturbine rated at 65 kW and capable of operating on digester gas was selected as the best technology for this application. It is designed to handle high levels of Hydrogen Sulfide in the digester gas but cannot withstand any siloxane contamination. For this reason, multiple gas conditioning systems were considered to be combined with the microturbine solution. A pre-fabricated gas conditioning skid would include a gas compressor, moisture and siloxane removal. A shipped loose coolant chiller would complete the package.

Based on the evaluation of the digester gas utilization technologies available, a cogeneration system design concept has been developed. The proposed system consists of installing new concrete foundations, new pipe supports, a 65 kW microturbine generator equipped with exhaust heat recovery; gas conditioning skid, electrical control building and four overhead utility poles for electrical metering, isolation breaker and a pole mounted transformer.

The economic viability and simple payback period has been evaluated for the proposed design concept noted above. Assuming Collingwood Public Utilities is able to obtain an OPA FIT Contract, the simple payback is expected to be 27 years for a project capital cost of $1,292,566. Social benefits to Collingwood Public Utilities associated with cogeneration facility implementation include continued demonstrated environmental stewardship, leadership and sustainability.
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1.0 INTRODUCTION

1.1 BACKGROUND

The 25.5 MLD Collingwood Waste Water Treatment Plant (CWWTP, the Plant) processes the Town's wastewater to secondary treatment standards before discharging treated effluent to the Collingwood harbor. The CWWTP is a conventional activated sludge secondary treatment facility consisting of a low lift pump station, headwork's containing automatic screening and vortex grit removal processes, primary clarification, fine pore aeration, secondary clarification and Ultraviolet light disinfection. Primary solids and thickened waste activated solids are processed by a mesophilic anaerobic digestion process with liquid stabilized solids application to agricultural land as a nutrient and soil conditioner. The bio-gas produced by the anaerobic digestion process is currently flared by an onsite open gas flare system.

Collingwood Public Utilities (CPU) commissioned Conestoga-Rovers and Associates Ltd. (CRA) to conduct a Detailed Engineering Study (DES) to determine the economic and technical feasibility of constructing and operating a cogeneration (cogen) plant using the digester gas produced on site as the primary fuel. Collingwood Public Utilities is specifically interested in the evaluation of available technologies that can utilize digester gas, reduce the base load electrical demands of the Plant and recover thermal energy for process heating.

1.2 PURPOSE

The objective of this report is to review potential options for digester gas utilization and validate the best technology for the site. The intention of the report is to:

- Evaluate baseline Plant Systems at the site
- Assess the digester gas characteristics and quantity
- Analyze available technology options
- Develop a design concept for the recommended option
- Prepare economic analysis
- Provide an implementation action plan
2.0 BASE CASE

2.1 PLANT SYSTEMS

Four major Plant systems would be directly impacted by the addition of a cogeneration plant. These Plant systems include:

- Digester gas production and distribution systems
- Electrical distribution system
- Hydronic heating system
- Natural gas supply system

For each system, analysis focused on factors affecting the project's technical and economic feasibility. No infrastructure upgrades or operating conditions were evaluated outside of this criterion. A complete site plan outlining the location of existing plant buildings can be found in Appendix A.

2.1.1 DIGESTER GAS SYSTEMS

The CWWTP utilizes an anaerobic digestion process to reduce the total volume of sludge removed from the sewage influent and decrease the pathogen levels therein. A byproduct of the digestion process is the production of digester gas which would serve as the primary fuel for a prospective cogeneration system.

The digester gas capture and utilization process was reviewed to determine potential tie-in locations for a future cogeneration system and to determine any additional gas treatment requirements prior to cogen use.

2.1.2 ELECTRICAL SYSTEM

The plant electrical systems were reviewed for compatibility with a cogeneration system as well as for potential tie-in locations. The CWWTP is currently serviced with a 4160 V overhead pole feeder that terminates at the substation at the south of the plant. Here the electricity is transformed to 600V before being distributed throughout the plant.
2.1.3 HYDRONIC HEATING SYSTEM

The plants process heat comes from a single 40 HP (1,339,000 BTUH) natural gas fired hot water boiler. The plant's hydronic heating system runs underground from the boiler building outwards to the digesters. Domestic heating requirements are met using a separate hot water boiler along with space and roof mounted heaters located throughout the plant.

2.1.4 NATURAL GAS SYSTEM

Natural gas is currently used to provide most of the heating at CWWTP. The process boiler consumes approximately 80 percent of the plants natural gas usage. The balance of natural gas at the site is used by localized unit heaters for space heating purposes.

2.2 CURRENT ENERGY CONSUMPTION

In order to determine the economic and technical feasibility of implementing a cogeneration system into the Plant operations, current energy consumption patterns were analyzed to determine base usage, maximum and minimum demand and seasonal or daily trends.

A detailed analysis was conducted using historical data for electricity and natural gas sourced from utility providers as well as digester gas production documented from plant instrumentation. Data was available in monthly increments providing a strong foundation to fully evaluate the Plant energy consumption trends. Measures for reducing energy consumption were not investigated in this study. Rather, electrical and thermal base loads were quantified in order to appropriately size the cogeneration system. It is anticipated that the cogeneration installation would operate as a base load displacement system.

2.2.1 ELECTRICITY

Electricity is supplied to the CWWTP by CPU. Monthly usage data for the plant was available for the period of 2008 to 2012 and was provided by CPU.

Based on the average monthly consumption, an average hourly load in kW can be calculated. While it is anticipated that usage will vary throughout the day, the hourly
average allows for an initial estimate of the plant's base load. The average monthly electricity consumption (based on monthly data) for the years 2008 to 2012 is shown on Figure 1.

Figure 1: Calculated Average Hourly Electrical Consumption by Month, 2008-2012

Figure 1 shows demand ranging between 250 kW and 460 kW with no discernible yearly or monthly pattern. The trending was reviewed with Plant staff to determine if there were any unusual events such as process upsets, construction upgrades, etc. at the Plant that might explain any of the data outliers. The only logical events that could have explained the data changes related to wet or dry weather influences on the plant process. Based on the above trends, a conservative estimate for the Plant base load would be approximately 300 kW. Monthly averages dipped below this threshold infrequently in the 5 year period. The historical power consumption data summary can be found in Appendix B.

2.2.2 NATURAL GAS

Natural gas is currently used at the CWWTP as a primary fuel to meet the Plants heating demand. A small quantity of natural gas is also used directly for heating of the Plants
buildings and for maintaining the flare's pilot light. Plant usage patterns were derived from historical natural gas consumption data collected by CPU. Reliable daily and hourly data were not available for NG consumption.

Figure 2: Monthly Natural Gas Consumption, 2007-2012

Figure 2 illustrates a monthly consumption of natural gas for the period 2007 through 2012.

Generally, the CWWTP has consumed between 3,000 m$^3$ and 42,000 m$^3$ of natural gas per month in the most recent operating years. Historical natural gas consumption data can be found in Appendix C. As with electricity, gas usage varies significantly from year-to-year and month-to-month depending on environmental factors. Natural gas consumption is generally highest during winter months and lowest in summer. This was expected given that natural gas is mainly used for heating applications.

### 2.2.3 DIGESTER GAS

Digester gas at the CWWTP is currently not being utilized. All the digester gas produced is destroyed at the candlestick flare.
Figure 3 illustrates the monthly digester gas production between 2010 and 2012.

Digester gas has typically been produced at a rate of 800-1300 m$^3$ per day. A more detailed gas analysis can be found in Section 3.

2.2.4 THERMAL DEMAND

The Plant thermal demand is currently met by burning natural gas in a variety of apparatuses. Heat is distributed through the plant via a hydronic heating system. Using the heating value of natural gas and considering the boiler efficiency assumed to be 80 percent; the Plant's thermal demand was evaluated based on natural gas consumption levels.
As depicted on Figure 4, the thermal demand at the CWWTP is highly variable. This can be attributed to the large fluctuation in the seasonal temperatures and variations in the method of operation.
3.0 DIGESTER GAS ASSESSMENT

3.1 DIGESTER GAS PROPERTIES AND AVAILABILITY

In order to assess relevant technologies for digester gas utilization, the volume and composition of digester gas at the CWWTP must be quantified.

3.1.1 DIGESTER GAS QUANTITY

Site Observations

CPU provided data pertaining to wastewater influent flow rates, treatment efficiencies, and gas production for each month from January 2010 to December 2012. The data as supplied has been summarized in Table 1 to illustrate the digester gas production as recorded by the Plant.

Using the data in Table 1 and interpolating while ignoring months of poor performance, it can be assumed that the typical daily digester gas flows are approximately 1,049 m³/day (25.7 scfm).

As can be seen in Table 1, the measured values for digester gas have been highly variable over the past three years. In discussion with plant staff, it is suspected that the data received from the flow meter is problematic due to the configuration of the digester gas piping around the flow meter. As such, a theoretical analysis of the plant digester gas flow is warranted.
**TABLE 1**

**HISTORICAL DIGESTER GAS PRODUCTION - AS RECORDED**
**COLLINGWOOD WWTP**

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m³/day</td>
<td>m³/day</td>
<td>m³/day</td>
</tr>
<tr>
<td>JAN</td>
<td>677.74</td>
<td>1,218.58</td>
<td>956.74</td>
</tr>
<tr>
<td>FEB</td>
<td>911.16</td>
<td>950.19</td>
<td>991.19</td>
</tr>
<tr>
<td>MAR</td>
<td>1,217.42</td>
<td>1,136.16</td>
<td>1,058.81</td>
</tr>
<tr>
<td>APR</td>
<td>1,226.10</td>
<td>1,024.55</td>
<td>754.00</td>
</tr>
<tr>
<td>MAY</td>
<td>1,203.97</td>
<td>1,039.71</td>
<td>635.13</td>
</tr>
<tr>
<td>JUN</td>
<td>1,034.39</td>
<td>985.45</td>
<td>1,062.32</td>
</tr>
<tr>
<td>JUL</td>
<td>1,223.13</td>
<td>935.39</td>
<td>1,021.81</td>
</tr>
<tr>
<td>AUG</td>
<td>1,013.23</td>
<td>742.87</td>
<td>1,189.26</td>
</tr>
<tr>
<td>SEP</td>
<td>974.58</td>
<td>766.65</td>
<td>1,138.32</td>
</tr>
<tr>
<td>OCT</td>
<td>1,029.81</td>
<td>961.87</td>
<td>1,329.19</td>
</tr>
<tr>
<td>NOV</td>
<td>1,042.94</td>
<td>879.10</td>
<td>1,256.84</td>
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<tr>
<td>DEC</td>
<td>1,606.19</td>
<td>756.74</td>
<td>1,115.13</td>
</tr>
<tr>
<td>Total (m³/year)</td>
<td>407,980.00</td>
<td>353,315.00</td>
<td>387,771.00</td>
</tr>
<tr>
<td>Monthly Average (m³/month)</td>
<td>33,998.33</td>
<td>29,442.92</td>
<td>32,314.25</td>
</tr>
<tr>
<td>Daily Average (m³/day)</td>
<td>1,117.75</td>
<td>967.99</td>
<td>1,062.39</td>
</tr>
</tbody>
</table>

**Theoretical Gas Production Based On Volatile Solids Loading**

Often, waste water treatment plants do not have an accurate method of measuring gas being destroyed in a flare or otherwise utilized in boilers. Additionally, digester gas can leak through digester vents. Furthermore, gas production can be adversely affected by lower digester hydraulic retention times although historically this has not been the case at the CWWTP. Therefore, theoretical calculations to determine the production of digester gas based on plant data can be useful in determining the actual gas that could be available for use.

In order to assess digester gas destruction and utilization methods, the total potential for gas generation must be determined.
There are several factors, other than raw plant inflow, that can have a significant impact on the gas produced:

1) sludge production rates
2) percentage of volatile suspended solids (VSS) in the sludge feed
3) VSS destruction rate
4) stable digester operating conditions (i.e., temperature, mixing, hydraulic retention time)

According to the Water Environment Federation (WEF) Manual of Practice (MOP) 8 and typical literature, the theoretical gas production constant ranges from 0.8 to 1.1 m³/kg of Volatile Solids destroyed. In addition, Wastewater Engineering, Treatment and Reuse, Fourth Edition, Metcalf & Eddy Inc., 2003 (pg 1523) states that gas production ranges between 0.75 and 1.12 m³ of digester gas per kilogram of volatile solids (VS) destroyed. The greater the percentage of fats and grease in the incoming feed, the higher the expected specific gas production, provided that adequate retention time and mixing are utilized (fats and grease are slowest to metabolize). Based on experience with other plants, this gas production constant is often at the lower end of the range. In order to remain conservative, a gas production constant of 0.8 was used for the projected gas production at the plant.

For the purposes of this evaluation, the gas predictions were based on the actual measured values where possible. For the plant provided data summarized in Appendix D, all of the required data (Plant Inflow, VS Destruction Rate and VS Loading) for the calculation of gas production was recorded. By assuming a sludge density of 1000 kg/m³, and by assuming a gas production rate of 0.8, it is possible to calculate a reasonable estimate of the potential digester gas production. Appendix E – Calculation #1 shows a sample digester gas production calculation based on volatile solids loading.

Using this data and making the assumptions noted above, average theoretical digester gas production ranged between 900 m³/day (22 scfm) and 1,238.4 m³/day (30 scfm). Refer to Table 2.

**Theoretical Gas Production Based On Plant Inflow**

Another method of estimating the theoretical gas production can be based solely on the plant raw daily inflow and using standard assumptions on wastewater treatment efficiencies.
Assuming that the theoretical solids production rate is approximately 180 g/m³, 80 percent of which are volatile, and that the hydraulic retention time is 15 days and that the gas production rate is 0.8 m³/kg of VSS destroyed, a crude approximation can be made on the amount of gas generated. Appendix E – Sample Digester Gas Production Calculation – Calculation #2 demonstrates how these calculations are made.

Using the above analysis, the average theoretical production ranged between 1408 m³/day (34.5 scfm) and 1,874.4 m³/day (46 scfm). Refer to Table 2.

Measured digester gas flows and theoretical digester gas flow calculations are shown on Table 2 for comparison. The difference between theoretical and measured values is not significantly varied.
## TABLE 2

**DIGESTER GAS PRODUCTION - COMPARISON OF MEASURED AND THEORETICAL VALUES**

**COLLINGWOOD WWTP**

<table>
<thead>
<tr>
<th>Month</th>
<th>Measured Average Gas Production ($m^3$/day)</th>
<th>Theoretical Gas Production Based On VS Loading ($m^3$/day)</th>
<th>Theoretical Gas Production Based On Inflow ($m^3$/day)</th>
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<tr>
<td>10-Jan</td>
<td>677.74</td>
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<td>10-Feb</td>
<td>1,008.79</td>
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<td>10-Mar</td>
<td>1,217.42</td>
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<td>10-Apr</td>
<td>1,266.97</td>
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<td>10-May</td>
<td>1,203.97</td>
<td>803.35</td>
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<tr>
<td>10-Jun</td>
<td>1,068.87</td>
<td>522.46</td>
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<td>10-Jul</td>
<td>1,223.13</td>
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<td>10-Aug</td>
<td>1,013.23</td>
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<td>687.32</td>
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<td>10-Sep</td>
<td>1,007.07</td>
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<td>1,029.81</td>
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<td>10-Nov</td>
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<td>11-Nov</td>
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<td>11-Dec</td>
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<tr>
<td>12-Aug</td>
<td>1,189.26</td>
<td>849.19</td>
<td>809.90</td>
</tr>
<tr>
<td>12-Sep</td>
<td>1,176.27</td>
<td>724.35</td>
<td>857.15</td>
</tr>
<tr>
<td>12-Oct</td>
<td>1,329.19</td>
<td>963.23</td>
<td>1,074.22</td>
</tr>
<tr>
<td>12-Nov</td>
<td>1,298.73</td>
<td>1,028.60</td>
<td>1,194.63</td>
</tr>
<tr>
<td>12-Dec</td>
<td>1,115.13</td>
<td>883.49</td>
<td>985.27</td>
</tr>
</tbody>
</table>
3.2 DIGESTER GAS QUALITY

In order to evaluate possible technologies that can utilize the digester gas and identify any gas conditioning requirements, a detailed gas analysis was performed.

3.2.1 SAMPLE COLLECTION PROTOCOL

Digester gas samples were collected for laboratory analysis of the following list of parameters:

- Matrix gases (CH₄, CO₂, O₂, N₂, CO), units of percent by volume
- Hydrogen sulfide, units of parts per million by volume
- Siloxanes, units of parts per million by volume

Digester gas samples were collected on June 24, 2013 between the times of 11:30 and 1:00 pm. Samples were collected from the main header feeding the flare, on the pressure side of the digester tanks, immediately downstream of the flow meter, and the location associated with condensate drain valve DCR-V-58. This sample location is considered to be representative of the gas generated before it is sent to the flare. Digester gas recirculation pumps were shut down at the time of sampling.

Samples for analysis of matrix gases and hydrogen sulfide were collected using 1.4 litre evacuated canisters ("Silco Coated Cans") that were pre-charged to 30 inches of mercury (407 inches of water column) of vacuum pressure, and equipped with 20-minute orifices for flow control. Samples for analysis of siloxanes were collected using 1.5 litre Tedlar® bags, requiring positive sample pressure to fill each bag.

With regard to collecting samples using evacuated canisters, the sample collection procedure consisted of attaching the specified flow controller on the canister, and making tube connections between the canister and the sample port. The canister valve was then opened. The start-of-sampling vacuum and the end-of-sampling vacuum were monitored to assure even sample collection via the flow controller over the sampling event. At the end of the sampling event, the canister valve was closed fully. Each canister was then labeled with a unique sample designation and shipped to the laboratory in accordance with CRA sample handling protocols.
A similar sample collection procedure was followed for the Tedlar® bags, with the exception that the filling of the bag could be monitored visually, as opposed to use of an inline pressure regulator.

The samples were submitted to Maxxam Analytics in Waterloo, Ontario under chain-of-custody on June 24, 2013. Maxxam promptly shipped the samples to their accredited laboratory, within specified holding times. Tedlar® bag samples submitted for analysis of siloxanes was subcontracted to OSB laboratory in Burlington, Ontario.

### 3.2.2 QUALITY ASSURANCE/QUALITY CONTROL PROTOCOLS

Quality assurance/quality control (QA/QC) was attained for this event by the following provisions:

- Measurements of combustible gases (CH₄, CO₂, and O₂) by portable combustible gas monitor before the sample was collected, to verify parameter levels, but mainly check for air leaks in sample apparatus
- Standard laboratory QA/QC, including duplicate analysis for hydrogen sulphide
- Collection of spare samples using spare canister and bag

### 3.2.3 RESULTS OF THE GAS SAMPLE

The results of the digester gas analysis confirmed that the digester gas at the CWWTP was very close to the industry normal conditions in terms of Methane content (53.9 percent), Carbon Dioxide content (31.3 percent), Nitrogen content (11.8 percent) and Oxygen content of (2.9 percent). The hydrogen sulfide levels in the gas were found to be 85 ppmv along with siloxane levels of 1.6419 ppmv, both of which are considered a relatively low amount. The full gas analysis report can be found in Appendix F. Having this information allowed the various technology vendors to understand the properties of the available digester gas and evaluate its suitability with their technology.
4.0 TECHNOLOGY REVIEW

The following technologies were evaluated for potential digester gas destruction and utilization applications.

4.1 DIGESTER GAS FOR POWER GENERATION - RECIPROCATING ENGINE

Reciprocating gas engines are a common form of generating electrical and thermal energy from biogas applications such as digester gas and landfill gas. Gas engines generally range in size from as small as 100 kW to greater than 3 MW. Gas engines are a robust and well documented technology that have been in existence for many years. Starting in the early 1990’s use of biogas fuels such as digester gas and landfill gas became more prevalent. Early use of gas engines was problematic due to early failure of engine components due to acidification or siloxane buildup.

Reciprocating gas engines generally operate at an electrical efficiency (on a gross fuel basis) of between 35 percent and 40 percent. Product information on a Kraft Energy Systems engine can be found in Appendix G.

Advantages

1. Proven technology
2. Would generate renewable energy in the form of electricity which is eligible for an Ontario Power Authority (OPA) Feed-In Tariff (FIT) Contract at $0.160/kWh for a project smaller than 500 kW and adjusted by performance factors of 1.35 for on-peak times and 0.9 for off-peak times.

Disadvantages

1. Reciprocating engine technology generally requires larger quantities of gas to satisfy the smallest digester gas suitable engine.
2. Proximity to local residences will require a robust sound attenuating system and therefore increase project cost.
Summary

Reciprocating engine power generation and heat recovery is not recommended for the CWWTP.

4.2 DIGESTER GAS FOR POWER GENERATION - FUEL CELL

Fuel cells are electrochemical devices that produce electricity from hydrogen rich sources. Electricity is produced by an electrochemical reaction and not by combustion. The primary residual products from the process are water and heat. The electricity is produced as direct current and needs to be inverted into alternating current in order to be utilized for normal power use. Generally the emission levels of Fuel Cells are significantly lower than competing technologies.

There are very few companies that manufacture fuel cells. Of these companies there is only one company, Bloom Energy that produces a fuel cell that is able to operate at the scale of the CWWTP. More information on Fuel Cell technology providers can be found in Appendix H.

Fuel cell systems can be constructed in such a way that each system has multiple electricity producing fuel cells. Ideally, the fuel cell system will be comprised of individual fuel cells that can be operated a little below full capacity so that if one unit requires maintenance, the other units could "ramp up" to account for the unit that is not producing power.

One of the major benefits of a fuel cell is that it uses less gas to produce more energy than comparative technologies; an example of this is a 100 kW fuel cell only requires 19 m³/hr (11 scfm) of natural gas or in the case of the CWWTP and approximately 38 m³/hr (22 scfm) of digester gas. At this fuel consumption rate there is a possibility of producing approximately 200 kW of power based on a CWWTP gas generation rate of on 68 m³/hr (40 scfm). In comparison, microturbines would only be able to produce 65 kW of power on the same amount of gas. With the ability to generate so much power on such a small amount of gas, the economics of power generation become much more feasible.

Advantages

1. Would generate renewable energy in the form of electricity which is eligible for an Ontario Power Authority (OPA) Feed-In Tariff (FIT) Contract at $0.160/kWh
for a project smaller than 500 kW and adjusted by performance factors of 1.35 for on-peak times and 0.9 for off-peak times.

2. Highest power output available compared to other technologies
3. Very low emissions and noise compared to competing technologies.
4. The modular design makes it easy to install and expand in the future.

Disadvantages

1. Limited track record of successful installations as there are no installations in Canada at this time.
2. Other manufacturer fuel cell technology units which are available in Canada are too large for CWWTP, as Fuel Cell Energy no longer manufactures a 300 kW unit.
3. 200 kW fuel cell units suitably sized for CWWTP are currently not available in Canada
4. Bloom Energy units, that are the correct technical solution, will require Canadian approvals such as ESA, TSSA for installation in Ontario. At this time they are not sold in Canada.

Summary

Although this technology is attractive for a variety of reasons, fuel cells are not available to CWWTP at this time for two reasons; the first being that most manufacturers do not make fuel cells on the scale of the CWWTP. The second reason being, the company that does make a fuel cell that would fit the CWWTP does not sell their products in Canada yet.

The progress of fuel cell product availability should be monitored for future considerations.

4.3 DIGESTER GAS FOR BOILERS

Operation of boilers on digester gas is very common in Canada and is a viable option for utilizing digester gas.

The biogas boiler can be designed to pre-heat the return water of the natural gas boiler thereby reducing natural gas heating costs. Typically digester gas is not conditioned
before it enters the boiler. Requirements for pressurization of the digester gas are very minimal and can be accomplished through the use of a small booster blower. More information on a possible biogas boiler for the CWWTP can be found in Appendix I.

Digester gas heating is used at many wastewater treatment facilities in Canada. They are particularly prevalent at sites that are too small in scale to make power generation feasible.

**Advantages**

1. Non-intrusive implementation
2. Reduces the operational heating costs
3. Can be sized to accommodate the amount of available digester gas
4. Diverts the digester gas away from the flare
5. Low Capital cost compared to the other technologies
6. Proven technology

**Disadvantages**

1. Not a new and innovative technology
2. Digester gas utilization in a boiler previously performed at the site
3. Flaring of digester gas still required during summer months

**Summary**

This option is a cost effective method of utilizing the digester gas at the CWWTP. The current boiler return water could be preheated using a secondary boiler that runs solely on digester gas which would reduce the plant heating costs.

4.4 **DIGESTER GAS FOR POWER GENERATION – MICROTURBINES**

Microturbines are a technology that have been developed from Auxiliary Power Units in airplanes, small jet engines and automotive turbochargers and have been commercially available since the late 1990's.

Microturbines range in size from 30 kW to 250 kW and have a modular design, creating room for future expansion at a facility. Microturbines generally have a fuel to energy
efficiency of about 20 to 30 percent. When a microturbine is outfitted with an exhaust heat recovery system, the fuel to energy efficiency increases as high as 62 percent. In the future as the refinement of the technology occurs, the performance of microturbines will only increase as new materials will be used to allow higher operating temperatures and greater efficiencies.

The models of turbines that are available for this application are all single shaft type microturbines. These types of turbines generally operate between 60,000 and 100,000 rpm. Due to these high speeds, the gases that the turbine combusts for fuel must be completely clean. Any buildup of dirt can cause significant damage to the microturbine. The digester gas would require a significant amount of conditioning before being sent to the microturbine. This conditioning would improve the longevity of the equipment and reduce repair costs and maintenance downtime but adds significant capital and operating costs.

With low emissions compared to the competing technology and its high thermal efficiency, microturbines are a very environmentally friendly method of utilizing digester gas. Refer to Appendix J for Microturbine literature.

Advantages

1. Would generate renewable energy in the form of electricity (eligible for an Ontario Power Authority (OPA) Feed-In Tariff (FIT) Contract at $0.160/kWh\(^1\) for a project greater than 500 kW and less than 10 MW adjusted by performance factors of 1.35 for on-peak times and 0.9 for off peak times.

2. The modular design would allow for relatively easy expansion in the future.

3. Low emissions and a high fuel to energy efficiency create an environmentally friendly option.

4. Generation of both electricity and heat would offset the plant operating costs.

5. The available digester gas at CWWTP can support one 65 kW microturbine.

Disadvantages

1. Requires gas treatment for siloxane removal as the rotational speeds make the microturbine susceptible to contaminants.

2. Requires high gas pressure (usually around 75 – 80 psig)

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\(^1\) Ontario Power Authority Feed-In Tariff Program, Program Overview v.2.1 dated 2012.
3. Requires consistent digester gas production levels. Gas turbine operation at variable or part loads is not recommended.

4. Significant capital investment for micro turbine and gas conditioning system

Summary

Installing this type of technology for this size of plant is a progressive idea and possible solution.

A Capstone Energy, CR65 ICHP microturbine rated at 65 kW and capable of running on digester gas is a proven product with over 4000 units installed since 1998. These turbines are designed to handle high levels of Hydrogen Sulfide in the digester gas but cannot withstand any siloxane contamination. For this reason, conditioning of the digester gas is required to minimize unscheduled maintenance intervals. An efficiency of 62 percent is achieved at full load when the microturbine is outfitted with a heat recovery apparatus.
5.0 **GAS CONDITIONING SOLUTIONS**

Multiple gas conditioning systems were considered for combination with a microturbine solution. These systems include offerings from Unison Solutions, Robinson Group distributed through Pro Aqua Sales, Venture Engineering and Bio-Komp. The gas conditioning solutions, provided by Unison Solutions and Robinson Group are completely turnkey as they provide siloxane and hydrogen sulfide removal as well as gas compression. The third option would require the pairing of a siloxane removal system from Venture Engineering and a compression and condensing system from Bio-Komp. Technical specifications and quotes on all above noted technologies can be found in Appendix K.

After a review of the costs and the technical suitability of each system the gas conditioning system from Unison Solutions is recommended for the CWWTP. This Unison Solutions technology has been utilized in over 150 applications in the biogas marketplace. In addition, Unison Solutions has provided many gas conditioning systems that have been paired with Capstone microturbines in the past. It is this familiarity that has led Unison to become the recommended supplier of gas conditioning systems by the Capstone Turbine Corporation. Unison Solution's statement of qualifications can be found in Appendix K1.

The utilization of a gas conditioning skid provided by Unison Solutions would remove moisture and impurities, monitor gas temperature and pressurize gas for the microturbine. This pre-fabricated gas conditioning skid would include a gas compressor, moisture and siloxane removal. A shipped loose coolant chiller would complete the package.

It may be preferred to enclose the gas conditioning skid in a modular building to ensure shelter from the elements for both the equipment itself and the operators conducting maintenance on the equipment. Such a building could be designed to handle the specific gas conditioning skid. More information on enclosures can be found in Appendix L. The capital cost estimated for this enclosure is $83,200.
6.0  **DESIGN CONCEPT**

Based on the evaluation of the digester gas utilization technologies available, a cogeneration system design concept has been developed based on a Capstone CR65 ICHP microturbine and Unison Solutions gas conditioning system. References were obtained for digester gas utilization installations of similar size and scope of supply to the proposed design concept. Refer to Appendix M for feedback received from Owners of similar installations.

6.1  **DESCRIPTION**

The proposed system design concept consists of the following:

- New concrete pad foundations
- New structural pipe supports
- 65kW Capstone Microturbine generator equipped with exhaust heat recovery
- Unison Solutions Gas Conditioning Skid complete with external chiller unit
- Electrical control building for 480V power distribution panel and equipment control panels
- Four overhead utility poles for utility connection, electrical metering, isolation breaker and 4160V:480V pole mounted transformer
- New buried digester gas piping connected to existing digester gas piping
- New buried hot water piping connected to existing hydronic heating return piping in basement.

The location of the proposed cogeneration system equipment has been identified and is shown on the existing site plan located in Appendix N.

6.1.1  **FLARE CONDITION ASSESSMENT**

Currently, the existing flare is situated at the south end of the site adjacent to the Electrical Substation. As CPU is considering developing both a cogeneration system as well as a future biosolids complex, it may be beneficial to relocate the flare from its current position in order to maximize the available area at the south end of the property. Before any modifications to the existing flare are made, it is recommended that the
CWWTP obtain TSSA to complete a condition assessment and code compliance inspection, in order to avoid any unknown TSSA compliance issues.

6.1.2 SERVICE TIE-INS

The cogeneration system requires integration with the existing plant infrastructure for access to the various utilities in order to take advantage of the microturbines electrical production and heat recovery. Tie-in methods and locations would be chosen to minimize construction costs and manage plant operations.

The electrical connection is proposed to be made at the 4160V level. New electrical infrastructure is required for dedicated hydro metering, isolation breaker and transformer. The addition of four overhead poles is recommended in lieu of ground equipment in the interest of cost savings. A tie-in at the 4160V location allows for a stand-alone electrical system that would be independent of other plant systems.

A new connection is also required to direct digester gas to the gas conditioning skid and microturbine. The connection to the digester gas system is proposed to be made on the 100 mm pipe between the drip trap chamber and the existing flare.

The new microturbine heat recovery system would tie-in to the existing hydronic heating lines on the return side of the hot water system prior to the water returning to the existing boiler. This allows the boiler to "top up" the hot water plant supply temperature as required. Tying into the hydronic heating system would be achieved by boring through the exterior wall of the Digester Control Room basement and connecting to the return side plant loop.

6.1.3 MISCELLANEOUS WORKS AND APPURTENANCES

Various other works would be required to complete the cogeneration system and to fully integrate it into Plant operations. This includes, grading, earthworks, piping and structural supports, concrete foundations for support major equipment and some auxiliary systems.
7.0 **ECONOMIC ANALYSIS**

The economic validity of a project is dependent on costs (capital and operating) and revenue (or avoided costs).

7.1 **CAPITAL COSTS**

The project capital costs can be divided into three categories: soft costs, equipment supply costs and installation or construction costs. Refer to Table 3 – Project Capital Cost Estimate below:

**TABLE 3 – PROJECT CAPITAL COST ESTIMATE**
**DIGESTER GAS UTILIZATION – MICROTURBINE COMPLETE WITH HEAT RECOVERY AND GAS CONDITIONING**

<table>
<thead>
<tr>
<th>Capital Cost Summary</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soft Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Legal/Contractual</td>
<td>$10,000.00</td>
</tr>
<tr>
<td>Permits &amp; Approvals</td>
<td>$25,000.00</td>
</tr>
<tr>
<td>Renewable Energy Approvals</td>
<td>$60,000.00</td>
</tr>
<tr>
<td>Hydro Interconnection Approvals</td>
<td>$10,000.00</td>
</tr>
<tr>
<td>Engineering/Services During Construction</td>
<td>$170,000.00</td>
</tr>
<tr>
<td><strong>Total Soft Costs</strong></td>
<td>$275,000.00</td>
</tr>
<tr>
<td><strong>Equipment Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Microturbine</td>
<td>$115,566.00</td>
</tr>
<tr>
<td>Gas Conditioning Equipment</td>
<td>$342,000.00</td>
</tr>
<tr>
<td>Medium Voltage Electrical - New Hydro Poles</td>
<td>$120,000.00</td>
</tr>
<tr>
<td><strong>Total Equipment Costs</strong></td>
<td>$577,566.00</td>
</tr>
<tr>
<td><strong>Installation Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Flare Condition Assessment and Improvements</td>
<td>$50,000.00</td>
</tr>
<tr>
<td>Construction Costs</td>
<td></td>
</tr>
<tr>
<td>Civil</td>
<td>$117,000.00</td>
</tr>
<tr>
<td>Mechanical</td>
<td>$84,000.00</td>
</tr>
<tr>
<td>Electrical</td>
<td>$189,000.00</td>
</tr>
<tr>
<td><strong>Total Installation Costs</strong></td>
<td>$440,000.00</td>
</tr>
<tr>
<td><strong>Total Project Cost</strong></td>
<td>$1,292,566.00</td>
</tr>
</tbody>
</table>
The Project Capital Cost Estimate is only a statement of probable costs. Refinement of costs will be necessary if the project proceeds and as the design is refined. This cost estimate should be considered to be accurate within 25 percent.

### 7.2 OPERATING COSTS

Operating cost for power generation systems usually consist of fuel, maintenance and consumable cost. In this case there are no fuel costs. With respect to maintenance, equipment does require inspection, servicing and repairs. Based on vendor input, the costs are shown below.

<table>
<thead>
<tr>
<th>TABLE 4 - OPERATING COSTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
</tr>
<tr>
<td>Maintenance</td>
</tr>
<tr>
<td>Microturbine</td>
</tr>
<tr>
<td>Gas Conditioning Skid</td>
</tr>
<tr>
<td>Consumables</td>
</tr>
<tr>
<td>Gas Treatment Media Replacement</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Operation and maintenance (O&M) costs were considered for the life of the cogeneration plant. Operation and maintenance costs were an estimated $0.0753/kWh for the microturbine. This includes both regular scheduled maintenance and unscheduled maintenance that may occur over the lifetime of the microturbine and includes Capstone's Factory Protection Plan. The Factory Protection Plan cost is $65,475 and is valid for 9 years and covers all expected and unexpected maintenance, and a complete overhaul after 40 000 hours of operation. Also included in the $0.0753/kWh O&M fee is an annual maintenance cost of $2500 and the labour and material cost of changing the siloxane removal media which totals approximately $3610 per change in media and must be changed every 60 days.
7.3 REVENUE AND AVOIDED COSTS

The benefit of this project is that electricity can be generated and either returned to the plant (no FIT contract) or be directly exported to the local grid (FIT contract). However a reduction of electricity for sale will occur to run the plant standard service loads (or parasitic loads).

From a thermal perspective the generation of heat will offset natural gas consumed at the facility in the production of hot water.

Only one operating scheme was evaluated for this report. Assuming the microturbine would operate at full load for an average of 7466 hours a year, which is an 85 percent run time. The other 15 percent of the year allows for regular scheduled maintenance. Operating at full load capacity would provide maximum offset of electrical and thermal demand and would only require natural gas heating to "top up" the water in the existing boiler to meet the plants thermal demand.

Current utility prices were considered for electricity and natural gas as an average of the reported price on CWWTP's natural gas and electrical bills over the last year.

The cost of electricity used in the economic analysis includes those rates tied to consumption but excludes local distribution charges, transmission charges, the low voltage charge and the debt retirement charge. The HOEP electricity price for 2013 is 2.06 cents/kWh. In the case where the generation would be consumed within the CWWTP, the global adjustment would also be an avoided cost. Since January 2013, the global adjustment has been 4.90 cents/kWh. If the CWWTP were to sell the power that is generated under a FIT contract, it would receive 16 cents/kWh which would be multiplied by a factor of 1.35 for on peak generation and a factor of 0.9 for off peak generation. Below the economics of both prices along with the appropriate peak adjustments were evaluated.

Natural gas rates at the Plant have remained constant over the past year. This constant price of 16.6 cents/m³ was used for the purposes of this analysis. An example of recent utility bills can be found in Appendix O.
### 7.3.1 ELECTRICITY

**TABLE 5 - ELECTRICITY BENEFIT**  
Detailed Engineering Study - Cogeneration Feasibility

<table>
<thead>
<tr>
<th>Production</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Anticipated Operating Hours (85%)</td>
<td>7,446.00 Hr</td>
</tr>
<tr>
<td>On Peak Hours</td>
<td>1,768.00 Hr</td>
</tr>
<tr>
<td>Off Peak Hours</td>
<td>5,678.00 Hr</td>
</tr>
<tr>
<td>Anticipated Load Level</td>
<td>65.00 kW</td>
</tr>
<tr>
<td>Generalized kWh per year</td>
<td>483,990.00 /kWh</td>
</tr>
<tr>
<td>Anticipated Parasitic Load</td>
<td>10.00 kW</td>
</tr>
<tr>
<td>Parasitic kWh per year</td>
<td>74,460.00 /kWh</td>
</tr>
<tr>
<td>Net Production Per Year</td>
<td>409,530.00 /kWh</td>
</tr>
</tbody>
</table>

**Revenue**

**Option 1 (No FIT)**

<table>
<thead>
<tr>
<th>Description</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Costs HOEP</td>
<td>$0.0206 /kWh</td>
</tr>
<tr>
<td>Global Adjustment</td>
<td>$0.049 /kWh</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$0.0696 /kWh</td>
</tr>
</tbody>
</table>

| Revenue from Option 1                  | $28,503.29 |

**Option 2 (FIT Contract)**

<table>
<thead>
<tr>
<th>Description</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Cost</td>
<td>$0.16 /kWh</td>
</tr>
<tr>
<td>On Peak (Factor of 1.35)</td>
<td>$0.22 /kWh</td>
</tr>
<tr>
<td>Off Peak (Factor of 0.9)</td>
<td>$0.14 /kWh</td>
</tr>
<tr>
<td>On Peak Revenue</td>
<td>$21,392.80</td>
</tr>
<tr>
<td>Off Peak Revenue</td>
<td>$44,969.76</td>
</tr>
<tr>
<td>Revenue from Option 2</td>
<td>$66,362.56</td>
</tr>
</tbody>
</table>
7.3.2 **NATURAL GAS**

**TABLE 6 - NATURAL GAS BENEFIT**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Anticipated Operating Hours (85%)</td>
<td>7,446.00 hr</td>
</tr>
<tr>
<td>Thermal Generation</td>
<td>74.00 kW</td>
</tr>
<tr>
<td>Thermal kW per year</td>
<td>551,004.00 kW</td>
</tr>
<tr>
<td>Boiler Efficiency</td>
<td>80.00%</td>
</tr>
<tr>
<td>Equivalent Boiler Fuel Input</td>
<td>688,755.00 kWh</td>
</tr>
</tbody>
</table>

**Avoided Cost**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Value of 1m³ of Natural Gas</td>
<td>10.50 kWh/m³</td>
</tr>
<tr>
<td>Fuel Consumption Per Year</td>
<td>65,595.00 m³</td>
</tr>
<tr>
<td>Cost of Fuel</td>
<td>$10,888.00</td>
</tr>
</tbody>
</table>

7.4 **OTHER COST IMPACTS**

Although financing costs were not considered as part of the project's payback period, amortization rates and interest payments were calculated for reference. It was assumed that the cogeneration plant would be amortized over a 10 year period with monthly payments. An effective interest rate of 3.3 percent, taken from infrastructure Ontario's website on July 24, 2013, was used for all financing estimates. Results are shown below.

Analysis was conducted with and without adjustment for inflation. Where considered, inflation was estimated at 2 percent according to the Bank of Canada. This is believed to be a conservative estimate given trends in energy pricing and the general volatility of energy markets. Inflation would be applied to electricity and natural gas prices, as well as operation and maintenance (O&M) rates.

7.5 **RESULTS**

Using the methodology described above, the simple payback was calculated for base cost offset and FIT contract scenarios for the cogeneration project. The economics of the operating protocol are shown below.
Table 7 below summarizes the annual savings created under each option.

**TABLE 7 – SAVINGS CREATED BY A MICROTURBINE**

<table>
<thead>
<tr>
<th>Savings</th>
<th>Base Load Offset</th>
<th>FIT Contract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical</td>
<td>$28,503</td>
<td>$66,363</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>$10,880</td>
<td>$10,880</td>
</tr>
<tr>
<td>O&amp;M Costs</td>
<td>-$30,838</td>
<td>-$30,838</td>
</tr>
<tr>
<td>Total Savings Per Year</td>
<td>$8,545</td>
<td>$46,405</td>
</tr>
<tr>
<td>Payback Period</td>
<td>145 Years</td>
<td>27 Years</td>
</tr>
</tbody>
</table>

As seen in Table 7, the payback period for the microturbine is significantly more feasible if the power generated is sold back to the utility under a FIT contract. The simple payback period was calculated by dividing the capital cost by the total savings per year created under each scenario. Flare condition assessment and improvement costs were not burdened in this calculation.
8.0 IMPLEMENTATION

Implementation of a cogeneration system at the CWWTP would undertake the following events:

- Financial reviews and approvals
- OPA contract negotiations
- Permitting
- Design-build contract negotiations
- Design-build project execution
- Commissioning.
9.0 POTENTIAL CONSIDERATIONS

9.1 SUSTAINABILITY

When evaluating the feasibility of the cogeneration facility installation, other factors in addition to simply the economic benefit can be considered. As a municipal entity, CPU has historically demonstrated the importance of being a leader in the community, embracing environmental stewardship and setting high standards in working towards environmentally sustainable operations. The CWWTP has been recognized for operating at a very high environmental standard, as illustrated in the 2013 Great Lakes Sewage Report Card published by Ecojustice.

The 2013 Ecojustice Report has been updated from the previous edition published in 2006 and is an ecosystem based survey and analysis of municipal sewage treatment and discharges into the Great Lakes Basin. Ecojustice has worked to raise awareness in reducing pollutants entering into the Great Lakes and making recommendations to improve sewage treatment. The analysis compares municipalities on a number of criteria related to environmental responsibility. Collingwood received a ranking of 3rd place based on grade point average calculations used to evaluate the 12 cities/regions that participated and volunteered their information. This high ranking in Ontario can be attributed to CPU consistently implementing best practices to protect the environment. The secondary treatment at the CWWTP is performing at tertiary treatment levels due to committed dedication to enhanced facility operations and maintenance. It is likely that the CWWTP ranking in comparison to other municipalities would further improve with the implementation of a renewable energy cogeneration facility.

Once implemented, the proposed cogeneration facility is expected to generate approximately 65 kW of electrical energy and 74 kW of hot water heat recovery, thereby providing facility operating cost savings. More importantly, cogeneration will significantly reduce CWWTP’s carbon emissions through the elimination or reuse of greenhouse gases generated by the plants digestion process. This significant reduction of the facilities carbon footprint falls in line with CPU’s strive toward improved environmental stewardship and doing what is right for the environment.

9.2 DIGESTER GAS FOR BOILERS

Currently the process heat for the plant is provided by one boiler, a Donalee Model No. 542-SP WV-40 N/2. This boiler is fueled by natural gas and annual operation costs
are approximately $22,785. Even though this boiler has been in use for 18 years, it is understood that a recent inspection found it to be in excellent working condition and is expected to remain in operation without any required modifications. This boiler could be supplemented with an adequately sized secondary boiler that runs solely on digester gas. One possibility is the Sterling/Superior AR-X-120 30BHP boiler, for more information on this boiler please refer to Appendix H. The capital cost of this unit is $76,164. Possible upgrade options include the addition of a Continuous Flue Gas Monitoring & Efficiency Trim System as well as a Remote Control & Surveillance System. These options would add an additional $11,881 and $6,585 respectively. It is recommended both options be purchased, bringing the total equipment cost of the boiler to $94,630. It has been assumed that the installation cost would be about $25,000, bringing the total cost for the boiler and installation to $119,630. Annual savings are estimated to be $20,400 through the offsetting of natural gas usage with the digester gas boiler. The simple payback period, which was calculated using the previously noted savings, is approximately 5 to 6 years. A more detailed summary of the economic calculations can be found in Appendix I.
10.0 CONCLUSION

Based on the data analysis, current utility costs, capital cost estimates and likely operational scenarios a Cogeneration Project at the CWWTP is a marginal economic venture. However, other benefits of project implementation to CPU include demonstrated leadership, environmental stewardship and sustainability.

Based on the limitations and conditions of this report:

- Operating at full load and selling the power generated back to the utility under an OPA FIT contract provides the best financial return for CPU.
- Generation should use a Capstone CR65 ICHP microturbine complete with a digester gas conditioning.
- The OPA FIT program is the best benefit to Collingwood Public Utilities for implementation of the project.
APPENDIX A

EXISTING SITE PLAN
APPENDIX B

HISTORICAL POWER CONSUMPTION - AS RECORDED
### Appendix B

**HISTORICAL POWER CONSUMPTION - AS RECORDED**

**COLLINGWOOD WWTP**

<table>
<thead>
<tr>
<th></th>
<th>Power Consumption</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td></td>
<td>2008</td>
<td>2009</td>
<td>2010</td>
<td>2011</td>
<td>2012</td>
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<tr>
<td></td>
<td>kWh</td>
<td>kWh</td>
<td>kWh</td>
<td>kWh</td>
<td>kWh</td>
</tr>
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<td>JAN</td>
<td>255,722.61</td>
<td>229,209.39</td>
<td>240,132.21</td>
<td>306,990.97</td>
<td>242,492.91</td>
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<tr>
<td>FEB</td>
<td>272,797.66</td>
<td>233,446.62</td>
<td>245,827.56</td>
<td>324,332.34</td>
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<td>MAR</td>
<td>248,869.96</td>
<td>245,314.88</td>
<td>224,283.88</td>
<td>281,023.92</td>
<td>231,792.36</td>
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<td>266,993.88</td>
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<td>249,248.00</td>
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<tr>
<td>MAY</td>
<td>255,530.13</td>
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<td>JUN</td>
<td>250,869.57</td>
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<td>218,662.74</td>
<td>254,942.05</td>
<td>270,153.74</td>
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<tr>
<td>JUL</td>
<td>247,532.33</td>
<td>247,744.50</td>
<td>226,513.04</td>
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<td>290,598.30</td>
<td>223,672.46</td>
<td>246,469.33</td>
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<tr>
<td></td>
<td><strong>Total (kWh/year)</strong></td>
<td><strong>3,216,226.36</strong></td>
<td><strong>2,909,946.75</strong></td>
<td><strong>2,974,236.87</strong></td>
<td><strong>3,010,916.66</strong></td>
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<tr>
<td></td>
<td><strong>Monthly Average (kWh/month)</strong></td>
<td><strong>268,018.86</strong></td>
<td><strong>242,495.56</strong></td>
<td><strong>247,853.07</strong></td>
<td><strong>250,909.72</strong></td>
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<tr>
<td></td>
<td><strong>Hourly Average (kWh/hour)</strong></td>
<td><strong>367.15</strong></td>
<td><strong>332.19</strong></td>
<td><strong>339.52</strong></td>
<td><strong>343.71</strong></td>
</tr>
</tbody>
</table>
APPENDIX C

HISTORICAL NATURAL GAS CONSUMPTION - AS RECORDED
## Appendix C

### HISTORICAL NATURAL GAS CONSUMPTION - AS RECORDED

#### COLLINGWOOD WWTP

<table>
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<th></th>
<th>2007</th>
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<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
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<td></td>
<td>m³/day</td>
<td>m³/day</td>
<td>m³/day</td>
<td>m³/day</td>
<td>m³/day</td>
<td>m³/day</td>
</tr>
<tr>
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<td>1,364.13</td>
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<td>1,133.64</td>
<td>414.00</td>
<td>246.96</td>
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<td>754.86</td>
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<td>MAR</td>
<td>690.10</td>
<td>715.42</td>
<td>711.03</td>
<td>756.65</td>
<td>683.71</td>
<td>555.61</td>
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<td>144.57</td>
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<td>1,066.13</td>
<td>347.26</td>
<td>439.90</td>
<td>397.32</td>
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<td>JUN</td>
<td>337.10</td>
<td>464.40</td>
<td>209.73</td>
<td>218.13</td>
<td>218.30</td>
<td>204.73</td>
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<td>204.68</td>
<td>273.84</td>
<td>590.13</td>
<td>90.94</td>
<td>114.32</td>
<td>100.87</td>
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<td>200.23</td>
<td>291.32</td>
<td>185.97</td>
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<td>417.52</td>
<td>448.58</td>
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<td><strong>Daily Average (m³/day)</strong></td>
<td><strong>476.77</strong></td>
<td><strong>603.47</strong></td>
<td><strong>470.53</strong></td>
<td><strong>302.17</strong></td>
<td><strong>460.75</strong></td>
<td><strong>386.44</strong></td>
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</table>
APPENDIX D

RAW PLANT DATA
## APPENDIX D - RAW PLANT DATA

### Collingwood WWTP

<table>
<thead>
<tr>
<th>Month</th>
<th>Plant Inflow (m³/day)</th>
<th>VS Destruction %</th>
<th>VS loading (kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-Jan</td>
<td>16,150</td>
<td>50.07%</td>
<td>1,977.58</td>
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<tr>
<td>10-Feb</td>
<td>14,891</td>
<td>52.37%</td>
<td>2,032.67</td>
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<tr>
<td>10-Mar</td>
<td>23,424</td>
<td>51.34%</td>
<td>2,410.98</td>
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<tr>
<td>10-Apr</td>
<td>17,078</td>
<td>54.87%</td>
<td>2,132.71</td>
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<tr>
<td>10-May</td>
<td>16,568</td>
<td>43.10%</td>
<td>0.00</td>
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<tr>
<td>10-Jun</td>
<td>19,156</td>
<td>40.66%</td>
<td>1,606.34</td>
</tr>
<tr>
<td>10-Jul</td>
<td>17,926</td>
<td>50.77%</td>
<td>1,809.75</td>
</tr>
<tr>
<td>10-Aug</td>
<td>13,491</td>
<td>44.22%</td>
<td>1,541.70</td>
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<tr>
<td>10-Sep</td>
<td>16,199</td>
<td>44.80%</td>
<td>1,765.19</td>
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<tr>
<td>10-Oct</td>
<td>16,378</td>
<td>53.22%</td>
<td>1,923.94</td>
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<tr>
<td>10-Nov</td>
<td>17,776</td>
<td>41.95%</td>
<td>1,786.27</td>
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<tr>
<td>10-Dec</td>
<td>14,873</td>
<td>34.93%</td>
<td>2,225.74</td>
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<tr>
<td>11-Jan</td>
<td>17,154</td>
<td>56.83%</td>
<td>2,473.65</td>
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<tr>
<td>11-Feb</td>
<td>17,105</td>
<td>49.77%</td>
<td>2,190.74</td>
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<td>11-Mar</td>
<td>30,995</td>
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<td>11-Apr</td>
<td>304,451</td>
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<td>11-May</td>
<td>26,678</td>
<td>43.15%</td>
<td>2,348.17</td>
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<td>16,319</td>
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<td>12-Jan</td>
<td>21,822</td>
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<td>18,409</td>
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<td>12-Mar</td>
<td>21,687</td>
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<td>12-Apr</td>
<td>14,239</td>
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<td>14,683</td>
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<tr>
<td>12-Jun</td>
<td>15,516</td>
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<td>1,697.56</td>
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<td>12-Jul</td>
<td>14,167</td>
<td>45.81%</td>
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<td>12-Aug</td>
<td>13,678</td>
<td>51.40%</td>
<td>2,065.20</td>
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<td>12-Sep</td>
<td>16,995</td>
<td>43.78%</td>
<td>2,068.12</td>
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<td>12-Oct</td>
<td>18,039</td>
<td>51.69%</td>
<td>2,329.22</td>
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<tr>
<td>12-Nov</td>
<td>19,308</td>
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<td>12-Dec</td>
<td>16,321</td>
<td>52.40%</td>
<td>2,107.45</td>
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APPENDIX E

DIGESTER GAS PRODUCTION CALCULATIONS
CALCULATION #1 - Gas Production Prediction based on Volatile Solids Loading

\[ G_v = (G_{sgp}) \times V_s \]  
(Equation 22.13 WEF MOP 8)

- \( G_v \) = volume of total gas produced, m\(^3\)
- \( G_{sgp} \) = specific gas production, 0.8 to 1.1 m\(^3\)/kg of VSS destroyed
- \( V_s \) = VS destroyed, kg
- \( V_d \) = Volatile Solids Destruction Rate, %
- \( V_{S\text{tot}} \) = Total Volatile Solids

\[ V_s = V_d \times V_{S\text{tot}} \]

\[ V_{S\text{tot}} = \text{total VS loading, kg} \]

Sample Calculation of Maximum Calculated Gas Production (m\(^3\)/hr) for January 2011

Gas production date in January 2011

Given and Assumed Data for January 2011

- Volatile Solids Destruction Rate = 56.83%
- Total VS loading to digestion (\( V_{S\text{tot}} \)) = 2,473.65 kg/day
- \( G_{sgp} \) = 0.8 m\(^3\)/kg of VSS destroyed, assumed value

\[ G_v = (G_{sgp}) \times V_s \]

\[ V_s = V_d \times V_{S\text{tot}} \]

\[ = 56.83\% \times 2,473.65 \text{ kg/day} \]
\[ = 1,405.7 \text{ kg} \]

\[ = 0.8 \text{ m}^3/\text{kg} \times 1,405.7 \text{ kg} \]
\[ = 1,124.56 \text{ m}^3/\text{day} \]
\[ = 46.85 \text{ m}^3/\text{hr} \]

(1) There exists 2 Primary Digesters (1217 m\(^3\) each).
(2) Operation of Municipal Wastewater Treatment Plants - MOP11, Volume 3, WEF, 1996 Pg.1068
**CALCULATION #2 - Gas Production Prediction based on Plant Inflow**

\[ G_v = (G_{sgp}) \times V_s \]  
(Equation 22.13 WEF MOP 8)

- \( G_v \) = volume of total gas produced, \( m^3 \)
- \( G_{sgp} \) = specific gas production, 0.8 to 1.1 \( m^3/kg \) of VSS destroyed
- \( V_s \) = VS destroyed, kg

**Sample Calculation of Theoretical Gas Production based on Plant Inflow for January 2011**

Average raw sewage influent to the plant for January 2011 = 17,154 \( m^3 \)/day
Assumed that total sludge production is at 180g/m3 of plant inflow.
Assumed that volatile solids concentration is 80% of total solids
Volatile Destruction Rate = 56.83%
The rest of the calculation was determined as follows:

\[ G_v = (G_{sgp}) \times V_s \]

\[ V_s = V_d \times VS_{tot} \]

Total Solids = 17,154 \( m^3 \) \times 0.180 kg/m3
3,087.72 kg

Volatile Solids = 3,087.72 kg \times 80%
2,470.18 kg

Volatile Solids Destroyed = 2,470.18 kg \times 56.84%
1,404.04 kg

\[ \text{Gas Production} = 0.8 \ m^3/kg \times 1,404.04 \ kg \]
\[ = 1,122.98 \ m^3 / \text{day} \]
\[ = 46.8 \ m^3 / \text{hr} \]
APPENDIX F

DIGESTER GAS SAMPLE ANALYSIS
Your P.O. #: 20-016019

Your Project #: 080988-10

Site Location: COLLINGWOOD COGEN STUDY

Your C.O.C. #: 18324

Attention: Jennifer Balkwill
Conestoga-Rovers and Associates Ltd
651 Colby Dr
Waterloo, ON
N2V 1C2

Report Date: 2013/07/02

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B399851
Received: 2013/06/24, 14:39

Sample Matrix: AIR
# Samples Received: 1

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<th>Analyses</th>
<th>Quantity</th>
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<th>Date Analyzed</th>
<th>Laboratory Method</th>
<th>Method Reference</th>
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</thead>
<tbody>
<tr>
<td>Hydrogen Sulfide</td>
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<td>Matrix Gases</td>
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<td>2013/07/02</td>
<td>CAM SOP-00225, CAM SOP-00209</td>
<td>ASTM D1946-90</td>
</tr>
</tbody>
</table>

Remarks:
The lab certifies that the test results meet all requirements of NELAC, where applicable.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Theresa Stephenson, Project Manager
Email: TStephenson@maxxam.ca
Phone# (905) 817-5763

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required “signatories”, as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Analytics Inc. is a NELAC accredited laboratory. Certificate # CANA001. Use of the NELAC logo however does not insure that Maxxam is accredited for all of the methods indicated. This certificate shall not be reproduced except in full, without the written approval of Maxxam Analytics Inc. Maxxam has procedures in place to guard against improper use of the electronic signature and have the required “signatories”, as per section.
### COMPRESSED GAS PARAMETERS (AIR)

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<thead>
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<th>080988-GE01-MATRIXGAS+HS2-01 / 2527 Lab-Dup</th>
<th>RDL</th>
<th>QC Batch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling Date</td>
<td>2013/06/24</td>
<td>2012/06/24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COC Number</td>
<td>18324</td>
<td>18324</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Units</td>
<td>080988-GE01-MATRIXGAS+HS2-01 / 2527</td>
<td>080988-GE01-MATRIXGAS+HS2-01 / 2527 Lab-Dup</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fixed Gases**

<table>
<thead>
<tr>
<th>Gas</th>
<th>% v/v</th>
<th>RDL</th>
<th>QC Batch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>2.9</td>
<td>0.1</td>
<td>3265476</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>11.4</td>
<td>0.1</td>
<td>3265476</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>&lt;0.1</td>
<td>0.1</td>
<td>3265476</td>
</tr>
<tr>
<td>Methane</td>
<td>53.9</td>
<td>0.1</td>
<td>3265476</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>31.3</td>
<td>0.1</td>
<td>3265476</td>
</tr>
</tbody>
</table>

**Gas**

<table>
<thead>
<tr>
<th>Hydrogen sulfide</th>
<th>ppmv</th>
<th>RDL</th>
<th>QC Batch</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>85</td>
<td>83</td>
<td>0.4</td>
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</table>

RDL = Reportable Detection Limit  
QC Batch = Quality Control Batch
<table>
<thead>
<tr>
<th>Test Description</th>
<th>Instrumentation</th>
<th>Batch</th>
<th>Extracted</th>
<th>Analyzed</th>
<th>Analyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Sulfide</td>
<td>GC/FPD</td>
<td>3265343</td>
<td>N/A</td>
<td>2013/07/02</td>
<td>Bhushan Borole</td>
</tr>
<tr>
<td>Matrix Gases</td>
<td>GC/TCD</td>
<td>3265476</td>
<td>N/A</td>
<td>2013/07/02</td>
<td>Bhushan Borole</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Instrumentation</th>
<th>Batch</th>
<th>Extracted</th>
<th>Analyzed</th>
<th>Analyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Sulfide</td>
<td>GC/FPD</td>
<td>3265343</td>
<td>N/A</td>
<td>2013/07/02</td>
<td>Bhushan Borole</td>
</tr>
</tbody>
</table>
GENERAL COMMENTS

Sulfur Analysis: Canister was pressurized with Helium to enable sampling. Results and DLs adjusted accordingly.

Sample SA0565-01: Matrix Gas Analysis: Canister was pressurized with Helium to enable sampling. Results and DLs adjusted accordingly.

Results relate only to the items tested.
### Quality Assurance Report

Maxxam Job Number: GB399851

<table>
<thead>
<tr>
<th>Batch Num</th>
<th>Init</th>
<th>QC Type</th>
<th>Parameter</th>
<th>Date Analyzed</th>
<th>Value</th>
<th>% Recovery</th>
<th>Units</th>
<th>QC Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>3265343 BHB</td>
<td></td>
<td>Method Blank</td>
<td>Hydrogen sulfide</td>
<td>2013/07/02</td>
<td>&lt;0.4</td>
<td>ppmv</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3265476 BHB</td>
<td></td>
<td>Method Blank</td>
<td>Oxygen</td>
<td>2013/07/02</td>
<td>&lt;0.1</td>
<td>% v/v</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nitrogen</td>
<td>2013/07/02</td>
<td>&lt;0.1</td>
<td>% v/v</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carbon Monoxide</td>
<td>2013/07/02</td>
<td>&lt;0.1</td>
<td>% v/v</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Methane</td>
<td>2013/07/02</td>
<td>&lt;0.1</td>
<td>% v/v</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carbon Dioxide</td>
<td>2013/07/02</td>
<td>&lt;0.1</td>
<td>% v/v</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RPD -</td>
<td>Sample/Sample</td>
<td>Nitrogen</td>
<td>2013/07/02</td>
<td>NC</td>
<td>%</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dup</td>
<td></td>
<td>Methane</td>
<td>2013/07/02</td>
<td>0.09</td>
<td>%</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RPD -</td>
<td>Sample/Sample</td>
<td>Carbon Dioxide</td>
<td>2013/07/02</td>
<td>0.07</td>
<td>%</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

### Notes:
- **Method Blank:** A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
- **NC (RPD):** The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.
The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

-----------------------------
Tom Mitchell, B.Sc, Supervisor, Compressed Gases

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.
## Chain of Custody Form - Summa™ Canister

### Maxxam Analysis

**Address:** 8740 Campbell Road, Mississauga, Ontario, L5N 2L8  
**Phone:** (905) 817-5700  
**Fax:** (905) 817-5777

---

### CLIENT INFORMATION

- **Company Name:** Constable Reeves & Associates
- **Project Manager:** Jennifer Balkwill  
  - **e-mail:** balkwill@crwworld.com
- **Address:** 651 Clay Drive, Waterloo, ON N2J 0C2
- **Phone:** 519-884-0530 x 3599  
  - **Fax:** 519-884-0530

---

### SECTION

- **Sampled by:** Shang & K. Kniffels

---

### CANISTERS NOT USED

<table>
<thead>
<tr>
<th>Field Sample ID</th>
<th>Canister</th>
<th>Flow Regulator</th>
<th>Collection Date</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR0938 - GEO1 - Mahogany + H2S - 01</td>
<td>2527</td>
<td>FY 0530</td>
<td>Jan 24/13</td>
<td>HOLD SPARE SAMPLE UNTIL FURTHER NOTICE</td>
</tr>
<tr>
<td>OR0938 - GEO1 - Mahogany + H2S - 02</td>
<td>1891</td>
<td>FY 0530</td>
<td>Jan 24/13</td>
<td>HOLD SPARE SAMPLE UNTIL FURTHER NOTICE</td>
</tr>
</tbody>
</table>

---

### RUSH

- **TAT Requirement:** Project Specific Comments: RUSH

---

### PROJECT INFORMATION

- **Project #:** OR0938 - 40
- **Name:** Delinquent Cogen Study
- **PC #:** 20 016 019
- **Maxxam Quote #:**
- **Maxxam Contact:**

---

### REPORTING REQUIREMENTS

- **Notes:**
  1. please indicate on chain of custody if your samples are soil vapour or ambient air
  2. please list all canisters on the chain of custody even if unused

---

### PROJECT SPECIFIC COMMENTS

- RUSH IN WATERLOO

---

### Client Signature:

**Date/Time:** 06/21/2013

**Received by:**

**Date/Time:** 03/05/2013

---

### CANISTERS NOT USED

- **Date:** 24-Jun-13 14:39
- **Theresa Stephenson**  
  - **Canister:** B399851
  - **MAP:** AIR-001
# REPORT OF ANALYSIS: Maxxam Analytics - B399854 - Selected Siloxanes (TIVA)

**REPORT:** 13028si  (Method - SCAN ATD-GC-MSD Cryogenic Oven Control)

<table>
<thead>
<tr>
<th>CAS #</th>
<th>DESCRIPTION</th>
<th>13062708 SA0570-01R 080988-GE02-Slooxanes-01 V=25mL</th>
<th>13062708 SA0570-01R 080988-GE02-Slooxanes-01 V=25mL</th>
<th>13062708 Silicon Equivalent</th>
<th>13062708 Silicon Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>mg/m³ ppm</td>
<td>mg/m³ ppm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>420-56-4</td>
<td>Trimethylsilyl Fluoride</td>
<td>0.0860 0.0228</td>
<td>0.0262 0.0228</td>
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<tr>
<td>75-76-3</td>
<td>Tetramethyilsilane</td>
<td>&lt;0.0014 &lt;0.0004</td>
<td>&lt;0.0004 &lt;0.0004</td>
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<tr>
<td>1825-61-2</td>
<td>Methoxytrimethylsilane</td>
<td>&lt;0.0351 &lt;0.0082</td>
<td>&lt;0.0095 &lt;0.0082</td>
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<tr>
<td>1825-62-3</td>
<td>Ethoxytrimethylsilane</td>
<td>&lt;0.0338 &lt;0.0070</td>
<td>&lt;0.0080 &lt;0.0070</td>
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<tr>
<td>1066-40-6</td>
<td>Trimethylsilanol</td>
<td>0.6806 0.1850</td>
<td>0.2123 0.1850</td>
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<tr>
<td>1825-64-5</td>
<td>Isoproxytrimethylsilane</td>
<td>&lt;0.0143 &lt;0.0026</td>
<td>&lt;0.0030 &lt;0.0026</td>
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<tr>
<td>1185-55-3</td>
<td>Trimethoxymethyl Silane #</td>
<td>ND ND</td>
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<td>107-46-0</td>
<td>Hexamethyl Disiloxane - L2</td>
<td>0.0051 0.0008</td>
<td>0.0018 0.0015</td>
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<tr>
<td>1825-63-4</td>
<td>Propoxytrimethylsilane</td>
<td>&lt;0.0387 &lt;0.0072</td>
<td>&lt;0.0082 &lt;0.0072</td>
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<tr>
<td>1825-67-8</td>
<td>1-Methylbutoxytrimethylsilane *</td>
<td>ND ND</td>
<td>ND ND</td>
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<tr>
<td>1825-65-6</td>
<td>Butoxytrimethylsilane *</td>
<td>ND ND</td>
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<tr>
<td>2768-02-7</td>
<td>Trimethoxyvinyl Silane #</td>
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<tr>
<td>541-05-9</td>
<td>Hexamethyl Cyclotrisiloxane - D3</td>
<td>0.8409 0.0925</td>
<td>0.3185 0.2775</td>
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<td>107-51-7</td>
<td>Octamethyl Trisiloxane - L3</td>
<td>0.0448 0.0046</td>
<td>0.0160 0.0139</td>
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<tr>
<td>78-08-0</td>
<td>Triethoxyvinyl Silane #</td>
<td>ND ND</td>
<td>ND ND</td>
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<tr>
<td>78-07-9</td>
<td>Triethoxyethyl Silane #</td>
<td>ND ND</td>
<td>ND ND</td>
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<td>556-67-2</td>
<td>Octamethyl Cyclotetrasiloxane - D4</td>
<td>4.4121 0.3640</td>
<td>1.6713 1.4559</td>
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<tr>
<td>141-62-8</td>
<td>Decamethyl Tetrasiloxane - L4</td>
<td>0.0082 0.0006</td>
<td>0.0030 0.0026</td>
<td></td>
<td></td>
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<tr>
<td>78-10-4</td>
<td>Tetraethyilsilicate #</td>
<td>ND ND</td>
<td>ND ND</td>
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<tr>
<td>541-02-6</td>
<td>Decamethyl Cyclopentasiloxane - D</td>
<td>14.0939 0.9301</td>
<td>5.3387 4.6507</td>
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<td></td>
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<tr>
<td>141-63-9</td>
<td>Dodecamethyl Pentasiloxane - L5</td>
<td>&lt;0.0329 &lt;0.0021</td>
<td>&lt;0.0120 &lt;0.0105</td>
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<td></td>
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<tr>
<td>540-97-6</td>
<td>Dodecamethyl Cyclohexasiloxane -</td>
<td>0.2531 0.0139</td>
<td>0.0959 0.0835</td>
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<tr>
<td>Sum</td>
<td></td>
<td>20.5808 1.6419</td>
<td>7.7248 6.7293</td>
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<td></td>
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</tbody>
</table>

< (ND) = Characteristic ions are not present therefore Not Detected  
< (TRACE) = Characteristic ions present but too low to be quantified  
V = Volume of air/gas sampled  
* = Semiquantitative (Response Factor set at 5)  
# = Unstable, poor detectability, commercial standards tested
APPENDIX G

KRAFT ENERGY SYSTEMS TECHNOLOGY LITERATURE
Kraft Energy Systems (KES) provides clean and efficient power for a wide variety of users. We use only the highest quality components to help ensure seamless, around the clock operation for years to come.

Successful CHP projects start with high quality equipment that is designed for continuous operation and long life. KES is the right choice for your long-term success.

KES CHP Modules: Biogas Engines

Kraft Energy Systems (KES) provides clean and efficient power for a wide variety of users. We use only the highest quality components to help ensure seamless, around the clock operation for years to come.

Successful CHP projects start with high quality equipment that is designed for continuous operation and long life. KES is the right choice for your long-term success.

The Kraft Energy Systems Advantage:

- Over 45 Years of Power Generation Experience
- Pre & Post Sale - Engineering Support
- Operation & Maintenance Agreements
- 24 x 7 Parts & Service
- Lower Energy Cost
- Environmentally Responsible

- Most Reliable, Fuel efficient engine
- Fully Automated & User Friendly Control System with Remote Access & Monitoring
- Compact Standardized Design
- Quiet Enclosure Design
- Hot Water or Steam Recovery
- Pre-manufactured Modules Reduce Installation Cost
- Standardized Utility Inter-tie Controls
- Better Load Acceptance Capability
- Biogas Models from 60 kW—350 kW

Kraft Energy Systems
# KES CHP Modules: Biogas Engines

<table>
<thead>
<tr>
<th>KES Module</th>
<th>KMBL-60-4SH</th>
<th>KMBL-100-4SH</th>
<th>KMBL-180-4SH</th>
<th>KMBL-275-4SH</th>
<th>KMBL-350-4SH</th>
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<tbody>
<tr>
<td>MAN Engine Model</td>
<td>E 0834 LE302</td>
<td>E 0836 LE202</td>
<td>E 2876 LE302</td>
<td>E 2848 LE322</td>
<td>E 2842 LE 322</td>
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<tr>
<td>Generator Model</td>
<td>UCI224G</td>
<td>UCI274E</td>
<td>UCDI274J</td>
<td>432RSL4017</td>
<td>HCl534C</td>
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<tr>
<td>BHP</td>
<td>91</td>
<td>148</td>
<td>268</td>
<td>396</td>
<td>510</td>
</tr>
<tr>
<td>Electric Output</td>
<td>kWe</td>
<td>60</td>
<td>100</td>
<td>180</td>
<td>275</td>
</tr>
<tr>
<td># Cylinders/Arrangement</td>
<td></td>
<td>4 IL</td>
<td>6 IL</td>
<td>6 IL</td>
<td>8 V</td>
</tr>
<tr>
<td>Fuel Consumption</td>
<td>Th/Hr</td>
<td>5.95</td>
<td>9.35</td>
<td>16.91</td>
<td>22.76</td>
</tr>
<tr>
<td>Electric Heat Rate (LHV)</td>
<td>BTU/kWe-Hr</td>
<td>9,913</td>
<td>9,348</td>
<td>9,394</td>
<td>9,827</td>
</tr>
</tbody>
</table>

### Hot Water Recovery - Jacket Water & Exhaust Combined

| CoGen Thermal Output | kW | 91.45 | 146.4 | 252.0 | 411 | 495.2 |
| Thermal Output | Th/Hr | 3.00 | 5.00 | 6.60 | 14.02 | 16.90 |
| Recoverable Heat - Jacket | BTU/Hr | 122,621 | 283,906 | 414,565 | 740,400 | 890,827 |
| Recoverable Heat - Exhaust | BTU/Hr | 189,484 | 215,676 | 445,223 | 661,980 | 798,749 |
| Total Heat Recovered | BTU/Hr | 312,064 | 499,582 | 859,788 | 1,402,380 | 1,689,576 |
| Process Water Flow | GPM @ 15°F rise | 41 | 66 | 114 | 200 | 224 |
| Process Water Temp | Deg F | 190 | 190 | 190 | 190 | 190 |

### Efficiencies

| Electrical Efficiency | % | 34.42 | 36.50 | 36.32 | 34.73 | 36.93 |
| Combined Efficiency | % | 52.46 | 53.44 | 50.85 | 51.89 | 52.24 |
| NOx | Gms/BHP-Hr | 1 | 1 | 1 | <1.0 | 1 |
| CO | Gms/BHP-Hr | 2.5 | 1.5 | 1.6 | <2.5 | 2.5 |
| Noise at 3 Feet | dBA | @ 73-75 | @ 73-75 | @ 73-75 | @ 73-75 | @ 73-75 |
| Gas Pressure (Min) | Inches of WC | 10 | 10 | 10 | 10 | 10 |
| Gas Pressure (Max) | Inches of WC | 40 | 40 | 40 | 40 | 40 |
| Enclosure Dimensions | Inches | 150 x 65 x 98 | 150 x 65 x 98 | 150 x 65 x 98 | 178 x 65 x 108 | 178 x 65 x 108 |
| Weight | Lbs | 6000 | 6800 | 7850 | 11,000 | 13500 |

---

i) The Tech Data is based Gas mixture of 60% Methane & 40% Carbon dioxide with a calorific value of 580 Btu/cu ft.

ii) Gas quality must be per engine manufacturer’s specifications & must be cleaned, if necessary.

iii) The Tech Data is based on standard conditions acc to DIN ISO 3046-1. Standard Conditions: Atmospheric pressure: 14.5 psi or 328 ft above sea level, Air Temperature: 77 deg F, Relative Humidity: 30%.

iv) The Tolerances: Electrical Output: +/- 0%, Fuel Consumption: +/- 5%, Thermal Output: +/- 8%

v) The coolant data is based on 40% antifreeze.

---

Technical Data & Dimensional information is subject to change without prior notification.

SSB/07/17/12
Scott,

Attached is Robinson Group's engine recommendation including pricing and engine specifications for the Collingwood project.

Engine Model: KMBL-180-4SH, the engine will use about 47 scfm biogas.
Budget Price for the packaged 180 kWE Biogas CHP system is C$385,000 excluding freight, installation and taxes, but including start-up.

Please let me know what else you need, or if you have any questions.

Thanks,
Scott.

Scott Lenhardt, P.Eng.

Pro Aqua, Inc.
1 Atlantic Avenue
Suite 204
Toronto, ON
M6K 3E7

416-861-0237 x 228
905-330-9244 Cell
scott@proaquasales.com
www.proaquasales.com
APPENDIX H

FUEL CELL TECHNOLOGY LITERATURE
H.1 BLOOM ENERGY TECHNOLOGY LITERATURE
H.2 FUEL CELL ENERGY TECHNOLOGY LITERATURE
APPENDIX H.1

BLOOM ENERGY TECHNOLOGY LITERATURE
CLEAN POWER ON DEMAND
Bloom Energy's ES-5700 delivers clean power to meet your base load electricity needs. Seamlessly producing power in parallel with the utility grid, the ES-5700 will reduce your emissions and save you money.

RELIABLE RISK MITIGATION
The ES-5700 operates at unmatched electrical efficiencies. That means that it consumes less fuel and produces less CO₂ than competing technologies. By providing efficient power on-site, the economic and environmental benefits of your ES-5700 will continue to increase.

INNOVATIVE TECHNOLOGY
Utilizing solid oxide fuel cell (SOFC) technology first developed for NASA's Mars program, the ES-5700 produces clean power. Unlike other fuel cell technologies, Bloom's SOFCs are well-suited to high-volume, low-cost manufacturing which also makes them uniquely affordable. The ES-5700 also employs a modular architecture that enables the total installation size to be tailored to your base load electricity demand.

ALL-ELECTRIC POWER
The ES-5700's superior electrical efficiency eliminates the need for complicated CHP systems, and expands the deployment opportunities available to you. Your ES-5700 can be installed outdoors in hours rather than months or years.

FUEL FLEXIBILITY
The ES-5700 can run on natural gas, as well as, renewable fuels like biogas. You choose what works for you. Onsite fuels can provide added insurance for your critical loads, and the ES-5700 can easily accommodate those needs.

Future generations of Bloom's Energy Servers will offer the unique capacity to operate both as an energy generation and storage device, thus creating a bridge to a 100% renewable energy future.

About Bloom Energy
Bloom Energy is making clean, reliable energy affordable. Our unique on-site power generation systems utilize an innovative fuel cell technology with roots in NASA's Mars program. By leveraging breakthrough advances in materials science, Bloom Energy systems are among the most efficient energy generators; providing for significantly reduced operating costs and dramatically lower greenhouse gas emissions. By generating power where it is consumed, Bloom Energy offers increased electrical reliability and improved energy security, providing a clear path to energy independence.

Headquarters:
Sunnyvale, California

For More Information:
info@bloomenergy.com
ES-5700 Energy Server

YOUR POWER IS SECURE

The ES-5700 has been designed in compliance with Underwriters Laboratories (UL) and a variety of safety standards, and is backed by a comprehensive warranty. The ES-5700 actively communicates with Bloom Energy’s network operations center. Should the system require unscheduled maintenance, we’ll be deploying a solution before you even know there’s a problem.

### Technical Highlights

#### Inputs

<table>
<thead>
<tr>
<th>Fuels</th>
<th>Natural Gas, Directed Biogas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input fuel pressure</td>
<td>15 psig</td>
</tr>
<tr>
<td>Fuel required @ rated power</td>
<td>1.32 MMBtu/hr of natural gas</td>
</tr>
</tbody>
</table>

#### Outputs

<table>
<thead>
<tr>
<th>Nameplate power output (net AC)</th>
<th>210kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base load output (net AC)</td>
<td>200kW</td>
</tr>
<tr>
<td>Electrical efficiency (LHV net AC)</td>
<td>&gt; 50%</td>
</tr>
<tr>
<td>Electrical connection</td>
<td>480V @ 60 Hz, 3 or 4-wire 3 phase</td>
</tr>
</tbody>
</table>

#### Physical

<table>
<thead>
<tr>
<th>Weight</th>
<th>19.4 tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>26' 5&quot; x 8' 7&quot; x 6' 9&quot;</td>
</tr>
</tbody>
</table>

#### Emissions

<table>
<thead>
<tr>
<th>NOx</th>
<th>&lt; 0.01 lbs/MW-hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOx</td>
<td>negligible</td>
</tr>
<tr>
<td>CO</td>
<td>&lt; 0.10 lbs/MW-hr</td>
</tr>
<tr>
<td>VOCs</td>
<td>&lt; 0.02 lbs/MW-hr</td>
</tr>
<tr>
<td>CO₂ @ specified efficiency</td>
<td>773 lbs/MW-hr on natural gas; carbon neutral on Directed Biogas</td>
</tr>
</tbody>
</table>

#### Environment

<table>
<thead>
<tr>
<th>Standard temperature range</th>
<th>-20° to 45° C (extreme weather kit optional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity</td>
<td>0% - 100%</td>
</tr>
<tr>
<td>Seismic Vibration</td>
<td>IBC site class D</td>
</tr>
<tr>
<td>Location</td>
<td>Outdoor</td>
</tr>
<tr>
<td>Noise @ rated power</td>
<td>&lt; 70 DB @ 6 feet</td>
</tr>
</tbody>
</table>

#### Codes and Standards

- Complies with Rule 21 interconnection standards
- Exempt from CA Air District permitting; meets stringent CARB 2007 emissions standards
- Product Listed by Underwriters Laboratories Inc. (UL) to ANSI/CSA America FC 1

#### Additional Notes

- Operates in a grid parallel configuration
- Includes a secure website for you to showcase performance & environmental benefits
- Remotely managed and monitored by Bloom Energy
- Capable of emergency stop based on input from your facility
APPENDIX H.2

FUEL CELL ENERGY TECHNOLOGY LITERATURE
APPLICATION GUIDE
for the use of Biogas Fuel Supplies with
FuelCell Energy Direct FuelCell Powerplants
Application Guide for the use of Biogas Fuel Supplies with FuelCell Energy Direct FuelCell Powerplants

FCE #: 21660
Revision: A
November 2010

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INTRODUCTION

**Objective**
This document provides distributors and end users with information to facilitate the use of FuelCell Energy’s Direct FuelCell powerplants with fuel derived from biomass waste streams. The focus of the guide is on the more common biofuels: methane based gases derived from anaerobic digestion of wastewater sludge or food processing waste materials. Other biofuels, such as syngas from biomass gasification or landfill gas, are also discussed. The guidance and requirements specified in this document need to be followed in order to assure safe and reliable performance of FCE’s powerplant products when using biomass-derived fuel.

Technical data included in this document is based on the latest engineering data available at the time of publication and is subject to change without notice. Detailed engineering documents containing the most current product information are issued during project execution. This includes installation, operations, and maintenance manuals, specifications and drawings.

**Company Profile**
Headquartered in Danbury, CT, with manufacturing facilities in Torrington, CT, FuelCell® Energy, Inc. has more than 35 years of experience and is the world leader in the development, manufacture and application of stationary fuel cell powerplants. Our patented Direct FuelCell (DFC) technology powerplants deliver safe, economical, reliable power to government facilities, hotels, utility companies and commercial industries across the United States and abroad.
Product Features and Advantages

FCE manufactures several products based on the DFC technology: The DFC300, DFC1500MA, DFC1500B, and DFC3000, rated at 300kW, 1200kW, 1400kW, and 2800kW respectively. These powerplants provide high quality baseload electric power using natural gas, LNG, biogas, or other hydrocarbon fuels. Some key features and advantages of the product line include:

- **Ultra Clean Emissions and Low Noise** – The non-combustion energy conversion results in negligible emission levels and the lack of large moving parts result in very quiet operation. These characteristics allow DFC powerplants to be placed in areas where emission restrictions prohibit traditional generation technologies.
- **Scalability** – DFC powerplants can be configured over a wide range of sizes, from single sub-MW units to multi unit installations for multi Megawatt grid support applications.
- **Siting Flexibility** - The powerplants are designed to allow installation at a wide variety of sites including industrial, commercial and municipal facilities.
- **Modular Design** - The modular design allows multiple units to be interconnected allowing for incremental increases of power output capacity.
- **Fuel Flexibility** - Can operate on natural gas or anaerobic digester gas. Fuel switching and blending options are available.
- **Cogeneration** - High grade heat is available in the exhaust from the powerplants, which can be captured for generation of steam or hot water, or for chilling. The power-to-heat ratio of these highly efficient powerplants is well suited for supporting anaerobic digester installations.
- **Efficiency** – All three products provide the best electrical efficiency in their size range. As a result, no other power generation option can produce as much high-value electricity for a given flow of bio derived fuel.

Direct FuelCell Technology

DFC power plants use carbonate fuel cell technology that operates at high enough temperature to allow hydrocarbon fuels (e.g. natural gas or anaerobic digester gas) to be used without an external reforming system. The DFC takes advantage of this by
reforming the hydrocarbon fuel into hydrogen directly in the fuel cell stacks. The hydrogen generated by the internal reforming process is consumed nearly immediately by the fuel cell anodes as part of the electrochemical power generation reaction. The other half of the electrochemical reaction is the consumption of oxygen from air at the fuel cell cathodes. The anode reaction produces electrons which the cathode reaction consumes – this electron circuit is the power output from the fuel cell.

**Schematic of Internal Reforming DFC Fuel Cell Chemistry**

There are several advantages to the internal reforming feature of DFC powerplants. The electricity producing reaction is exothermic, while the reforming reaction is endothermic. The internal reforming approach uses waste heat from the fuel cell reactions to drive the reforming process, eliminating the need to burn fuel in an external reformer. This results in very high electrical efficiency and avoids the cost of the reformer subsystem.

The operating temperature range of the DFC power plant is high enough to allow the use of lower cost nickel-based electrode structures instead of more expensive, precious
metal catalysts. However, operating temperatures are not so high as to exclude the use of standard construction materials such as austenitic stainless steels.

The DFC is also particularly well suited for operation on bio derived fuels, due to its insensitivity to the CO₂ diluent commonly present in these fuels. A unique aspect of the carbonate fuel cell chemistry is that CO₂ is produced in the anodes and consumed in the cathodes. The presence of CO₂ in the fuel will reduce anode performance and improve cathode performance. In practice, the cathode gain is roughly equal to the anode penalty – the DFC power plants perform about the same in the presence of the CO₂ diluent, as long as methane content is above ~ 50%. The following figure compares performance from a test stack operating on pure methane vs operation on methane diluted with CO₂.

Stack Performance on Simulated Dilute Digester Gas Compared to Pure Methane Fuel

These results show that the DFC is uniquely capable of efficiently utilizing digester gas, because it is so insensitive to the CO₂ diluent. This product match has resulted in an increasing involvement in ADG fuel based projects in the installed fleet of FCE powerplants.
POWERPLANT PRODUCTS OVERVIEW

**General Powerplant Description**

The cell reactions described above take place in a repeated cell package unit consisting of thin layer anode, matrix, and cathode components. The anodes and cathodes are provided with corrugated metal gas flow layers, which contact the bipolar plate that electrically connects each cell to the next cell. The cells are stacked to produce the desired system voltage (about 400 cells per stack), and enclosed in a container to form a stack module. In addition to the DC-power generating stack, a complete DFC powerplant needs two other subsystems. A Mechanical Balance of Plant (MBOP) contains the equipment for supplying air and for treating and heating fuel and water for use in the stack module(s). An Electrical Balance of Plant (EBOP) converts the DC produced by the stacks to AC power suitable for supply to the grid. The following figure illustrates the basic functions of the powerplant balance of plant.

![DFC Powerplant System Diagram](image-url)
**FCE Direct FuelCell Product Line**

The FCE power plant product line is comprised of the DFC300MA®, DFC1500®MA®, DFC1500B®, and DFC3000®, rated in capacities at 300 kW, 1.2 MW, 1.4MW and 2.8 MW, respectively. As shown in the following figure, FCE’s products utilize one of two modules: a single-stack module rated at 300kW and a four-stack module rated at 1.4MW. Both modules use the same basic cell package and stack.

---

**FCE Direct FuelCell Power Plant Products**

The DFC300 product has a single stack module and is rated at 300kW. The DFC1500MA powerplant has four of these single-stack modules and is rated at 1.2 MW. The four modules are connected by a header system and fed by a common MW-scale
balance of plant. The DFC 1500B product is rated at 1.4MW, and uses a single four-stack module instead of the four individual single-stack modules used in the DFC1500MA product. The use of the more compact four-stack module makes the 1500B product more compact and lower in cost compared to the 1500MA product. Two of these 4-stack modules are used in the DFC3000 product, which is rated at 2.8MW. All of these ratings are net output of the system to the grid, after providing all necessary powerplant parasitic loads.

Multiple units can be combined as needed, providing distributed applications up to tens of MW in size. Each of the products is capable of providing high quality baseload electricity using natural gas or biogas, or other hydrocarbons as fuel. This document describes in detail the requirements for using biogas with FCE products.
UTILIZATION OF BIOGAS WITH DFC POWERPLANT SYSTEMS

Anaerobic Digester Gas
Anaerobic Digester Gas (ADG) is the most commonly used bio-derived fuel in DFC powerplant applications. ADG is a by-product of anaerobic digestion, a process in which bacteria are used to digest biomass in an oxygen-free environment. Digestion is usually done to reduce the amount of a solid waste stream, and a byproduct of the process is ADG, which is primarily methane diluted with carbon dioxide. Anaerobic digestion is used to break down many different forms of biomass including: wastewater sludge, animal manure, and food processing by-products.

The most common sources for biogas used for combined heat and power (CHP) applications are wastewater treatment facilities due to the volume and quality of gas produced at these facilities. Municipal sewage contains organic biomass solids, and many wastewater treatment plants use anaerobic digestion to reduce the volume of these solids. Sludge digestion typically produces ADG containing about 60% methane and about 40% carbon dioxide, with an energy content of about 550 Btu per standard cubic foot, LHV.

Another common source of ADG is food and beverage waste processing. FCE powerplants have been operated on ADG produced from brewery waste as well as food waste. Brewery waste ADG is typically higher in methane concentration than municipal wastewater treatment ADG, but the amount of gas produced tends to be more variable.

Historically, the ADG byproduct of these operations has been vented, flared, burned to provide heat for the digester reactors, or burned in internal combustion engine generators. Each of these approaches is wasteful and produces emissions of nitrogen and sulfur oxides, particulates, and (in the case of venting) methane.

However, if the ADG is used in a DFC powerplant, the emissions can be avoided and the plant still provides high grade waste heat to support the digester operations. The electricity can be used to power internal operations of the facility, offsetting expensive retail grid power. In a wastewater treatment system, the amount of electricity which can be produced by a DFC powerplant is typically 10 – 20% of the facilities electric power needs.
An overview of the system modifications that are typically done for use with biogas is shown in the following figure.

Typical DFC System Modifications for Biogas

The de-oxidation catalyst is a simple product option involving the use of a catalyst in an existing reactor bed in the BOP – there are no mechanical modifications required. The Fuel Pre-Treatment system shown before the standard fuel treatment removes impurities from the biogas, which are typically present in higher levels than the natural gas that the standard fuel treatment system was designed for. This system is a separate system, in addition to the standard BOP. Its functional requirements are site specific, and the systems are usually specified and provided by the distributor or end user. This application guide will provide additional detail on the types of systems used for fuel pre-treatment, and various options for interfacing with the FCE powerplant products.

The following sections describe specific aspects of ADG which should be considered when evaluating a power generation application with DFC powerplants.

**Sulfur**

ADG typically contains sulfur impurities at levels which will impair fuel cell operation if left untreated. The major constituent is hydrogen sulfide (H₂S), although organic compounds, such as mercaptans and methyl sulfides are also sometimes present. The fuel system of the Direct FuelCell powerplant is designed to deal with sulfur up to the levels typically found in standard pipeline quality natural gas. However, digester gas
can have much higher levels of sulfur. Before use as a fuel for DFC powerplants, excessive sulfur compounds must be removed.

**Siloxanes**

Siloxanes are a family of man-made organic compounds that contain silicon, oxygen and methyl groups. They are widely used in personal care products such as deodorants, tooth-pastes, skin care preparations, hair conditioners, etc. Siloxanes make their way into wastewater treatment facilities and landfills via industrial and domestic discharges, and they are often present as a contaminant in ADG. They are unwanted contaminants for DFC powerplants because they can impair the performance of catalysts used in the systems.

**Other Contaminants**

Although sulfur and siloxanes are a chief concern, other contaminants listed in the FCE Fuel Specification document #5665 must also be considered in the design of an external ADG clean-up system. Levels of contaminants in biogas will dictate the type and amount of clean-up media used for the application. Biogas with overall sulfur or siloxane content higher than conventional digester gas will result in higher maintenance costs due to more frequent media changes or for external ADG cleanup systems. Presence of other contaminants such as chlorides (both organic and inorganic) may require special media to provide sufficient treatment prior to use as a fuel for the DFC powerplant. Benzene and other organic aromatic volatiles, if present in biogas will be trapped in the cleanup media. This may classify the media as a hazardous waste and requires special handling and disposal considerations.

**Oxygen Content**

Oxygen is often present in ADG at levels on the order of 1%. Note that some digester gas clean-up systems (e.g. some iron sponge products) require a low level of oxygen to function properly, typically 1 percent or less. Manufacturer’s recommendation should be reviewed to determine the extent to which the oxygen level needs to be assured. Oxygen would damage portions of the fuel cell system if it were allowed to go into the system. A de-oxygenation catalyst is included in the DFC power plant for applications with fuel streams that have oxygen. The oxygen is reacted with methane over a catalyst. Because this reaction consumes some of the fuel, it reduces the efficiency
(since the consumed fuel is counted in the fuel Btu content, but not used to make electricity) and it also makes the fuel more dilute. The efficiency effect for a 2 to 3 percent oxygen level would be an efficiency reduction of 1 to 1.5 percentage points. A 47% efficient system becomes 45.5 to 46 percent efficient.

**Moisture**

Fuel from anaerobic digesters is saturated with water from the sludge digestion process. The high moisture content of digester gas can pose a problem for DFC powerplants. Any cooling of the gas can cause liquid water to be condensed from the gas. This is a concern because the presence of condensed water in fuel lines causes issues with some of the fuel treatment systems used with ADG. Condensate can also block fuel flow and disrupt fuel system instrumentation. Digester gas must be dried prior to use in a fuel cell application. In order to ensure that no liquid water is condensed from the digester gas anywhere within the DFC powerplant fuel system, the temperature of the gas must be maintained at least 15°F above the dew point at all times. This is especially critical for sites that can experience temperatures below freezing. For cold climate ADG applications, heat tracing may be required on the ADG cleanup system to prevent moisture condensation in the fuel system. Cold climate applications must be assessed on a case by case basis. The coldest ambient temperatures possible at the site should be considered in evaluating the need for heat tracing or insulation to prevent condensation or freezing in the fuel lines.

**Fuel Composition and Variability**

The DFC powerplant is designed to support fully rated power operation with a variety of dilute fuels. Full power output is supported for methane concentrations of above 60%, with de-rated operation possible for lower concentrations. For concentrations below 55% methane, evaluation of plant and site safety systems need to consider the fact that the gas is likely heavier than air due to the CO₂ diluent, so vent system designs may have to be reviewed. For fuels more dilute than 50% power output evaluation will have to be made on a case by case basis. Fuel gasses with methane concentrations below 50% represent a range where there is very little operating experience. Performance impacts associated with the low reactant concentration will begin to limit output at a non-linear rate. The relationship of power output to methane concentration for the DFC product line is summarized in this table:
### Methane Concentration, %

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>910</td>
<td>300</td>
<td>40</td>
<td>1200</td>
<td>160</td>
<td>1400</td>
<td>186</td>
<td>2800</td>
<td>372</td>
<td></td>
</tr>
<tr>
<td>90%</td>
<td>819</td>
<td>300</td>
<td>44</td>
<td>1200</td>
<td>177</td>
<td>1400</td>
<td>207</td>
<td>2800</td>
<td>414</td>
<td></td>
</tr>
<tr>
<td>80%</td>
<td>728</td>
<td>300</td>
<td>50</td>
<td>1200</td>
<td>199</td>
<td>1400</td>
<td>233</td>
<td>2800</td>
<td>465</td>
<td></td>
</tr>
<tr>
<td>75%</td>
<td>683</td>
<td>300</td>
<td>53</td>
<td>1200</td>
<td>213</td>
<td>1400</td>
<td>248</td>
<td>2800</td>
<td>497</td>
<td></td>
</tr>
<tr>
<td>70%</td>
<td>637</td>
<td>300</td>
<td>57</td>
<td>1200</td>
<td>228</td>
<td>1400</td>
<td>266</td>
<td>2800</td>
<td>532</td>
<td></td>
</tr>
<tr>
<td>65%</td>
<td>592</td>
<td>300</td>
<td>61</td>
<td>1200</td>
<td>246</td>
<td>1400</td>
<td>286</td>
<td>2800</td>
<td>573</td>
<td></td>
</tr>
<tr>
<td>60%</td>
<td>546</td>
<td>300</td>
<td>66</td>
<td>1200</td>
<td>266</td>
<td>1400</td>
<td>310</td>
<td>2800</td>
<td>621</td>
<td></td>
</tr>
<tr>
<td>55%</td>
<td>501</td>
<td>275</td>
<td>66</td>
<td>1100</td>
<td>266</td>
<td>1283</td>
<td>310</td>
<td>2567</td>
<td>621</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>455</td>
<td>250</td>
<td>66</td>
<td>1000</td>
<td>266</td>
<td>1167</td>
<td>310</td>
<td>2333</td>
<td>621</td>
<td></td>
</tr>
<tr>
<td>45%</td>
<td>410</td>
<td>180</td>
<td>66</td>
<td>722</td>
<td>266</td>
<td>842</td>
<td>310</td>
<td>1684</td>
<td>621</td>
<td></td>
</tr>
<tr>
<td>40%</td>
<td>364</td>
<td>86</td>
<td>66</td>
<td>344</td>
<td>266</td>
<td>401</td>
<td>310</td>
<td>803</td>
<td>621</td>
<td></td>
</tr>
</tbody>
</table>

The above values represent the power output of the fuel cell power plant at beginning of life. The power output would degrade 10% over the 5-year life of the fuel cell stack. Actual performance may vary due to application, site conditions, variations of equipment and adherence to the maintenance program. Variability of the heating value of a fuel supply by more than ± 1% will impact the performance of the power plant. Detailed requirements defining the allowable variation and impact to performance is defined in the FCE fuel specification, document #5665.

Fuel supply variability and low methane content can be dealt with somewhat by de-rating the output of the power plant or more effectively by incorporating an optional fuel blending system. This is a standard FCE product option which allows mixing of dilute and/or variable fuel supply with a supply of more stable and higher methane content natural gas to create a mixed fuel that is more stable, reliable, and less dilute.

**Pressure Considerations**

Digester gas is generally at very low pressures, typically measured in inches of water column (IWC). FCE fuel specifications require that DFC powerplants be provided an input gas pressure of at least 15 psig. Digester gas must be pressurized to this range in order to be safely and effectively used as a fuel for DFC powerplants. For fuel blending applications (where the digester gas is already polished and bypasses the on-board fuel treatment system), the inlet pressure requirement is lower, in the range of 12 – 15 psig depending on the gas composition.
Digester Gas Treatment Equipment Options

Addressing the contaminant, moisture, and pressure issues discussed above is done with a skid-mounted fuel pre-treatment system. These systems tend to use common design approaches with site specific modifications tailored to the customer’s gas quality and quantity.

A Typical Digester Gas Treatment Skid

Process Description of Digester Gas Pre-Treatment

Although digester gas composition can vary somewhat, a variety of standard processing approaches is emerging as the application becomes more common. Digester gas pre-treatment contains four major steps: removal of sulfur (usually done in two stages – bulk removal and polishing), raising the pressure of the gas, removal of water from the gas, and the removal of other contaminants (such as siloxanes) from the gas. These can be done in any order, but generally bulk sulfur removal is done first. Removing sulfur prior
to compression eliminates any impact of sour gas on the life of the gas compression equipment.

After compression, drying of the gas is required to remove as much water as possible to reduce the possibility of condensation in the DFC powerplant fuel system. This is often accomplished by chilling the gas to low temperatures and condensing the liquid from the digester gas. Chilling of digester gas should not be performed directly using coils filled with refrigerant. Leakage of refrigerant into the digester gas stream will cause permanent damage to the fuel cell stacks. A water or water/glycol loop with an additional heat exchanger should be used to chill digester gas.

The last major step in the process is the removal of other contaminants such as siloxanes, by passing the gas through a vessel containing media selected to absorb siloxanes. This media often does the final sulfur polishing as well.

**Digester Gas Pre-Treatment System Costs and Vendors**

Digester gas pre-treatment systems vary in cost and complexity depending on the quality of raw digester gas feed, and the scale of the treatment system. Smaller systems tend to be more expensive per unit of gas treated, and systems with higher sulfur content will be more expensive than systems with low sulfur content. The cost per kW for DFC gas pre-treatment is lower than pre-treatment for lower efficiency power generation systems because the DFC system generates more kW per unit of treated gas.

The systems deployed to date with DFC powerplants use a variety of treatment approaches, depending on the levels and types of contaminants, and the technology favored by specific treatment system vendors. Ambient pressure absorption, water wash, and Pressure Swing Absorption (PSA) approaches have all been used successfully.
Pre-Treatment System Vendors
A variety of vendors provide gas treatment systems to for DFC as well as other ADG applications. Some of the vendors of gas conditioning equipment for fuel cell applications are listed below.

- BozCo Engineering
  2561 San Simon Street
  Tustin, CA 92782
  (714) 673-1420
  www.bozcoengineering.com

- ESC Corporation
  11206 167th Court NE
  Redmond, WA 98052
  (425) 497-8111
  www.escenviroenergy.com

- SEECO
  16111 Warmington Lane
  Huntington Beach, CA 92649
  (714)840-0075

The vendors are listed alphabetically without preference, and these are not the only sources of pre-treatment systems. This list is provided for information purposes and does not constitute endorsement of specific vendors. Customers are encouraged to consult other users in their industry or field regarding experience with these or other vendors.

Proper selection of the gas pre-treatment skid is essential to a successful biogas fuel cell project. FCE has seen many successful and some unsuccessful skid selections, and the company supports customers in selecting the pre-treatment skid by reviewing proposals submitted by skid vendors. It has been FCE’s experience that in order to specify and select a pre-treatment skid which will operate properly, some key elements need to be present in the request for proposal (RFP) which is sent to skid vendors, and in the actual proposals submitted by vendors. These requirements are summarized in Appendix A, at the end of this Application Guide.
Pre-Treatment System Interface with DFC Powerplant

*Pre-Treatment System Electrical Connection*

It is recommended that the ADG cleanup system (compressor, controls, etc.) be powered independently from the electrical grid. This will prevent full shutdowns during grid outages. If the ADG fuel supply is maintained during grid outages, the unit will trip to Island Hot Standby, waiting for the electrical grid to return. FCE powerplants provide an optional interface to a grid-independent connection (called the customer critical breaker, or CCB). Equipment connected to this breaker remains powered through grid outages. It is recommended that the ADG power be provided through this CCB connection. The CCB connection has limitations on the amount of power provided and the variability, but gas treatment systems usually meet these requirements.

*ADG System Configurations*

There are two options for supplying treated ADG fuel to the DFC powerplant; single fuel and fuel blending. With each of these configurations, heat tracing for the ADG treatment system components may be required for cold climate applications.

1. **Single Fuel**: In this configuration, treated ADG is used as the sole source of fuel to the powerplant. The pre-treatment system is compressing and drying the gas, and removing impurities down to levels typical of pipeline natural gas. The cleanup system within the powerplant is doing the final impurity polishing. The schematic below shows an ADG application configured with ADG as the sole source of fuel.
2. Fuel Blending: For ADG supplies that are very dilute, non-continuous, and/or not considered reliable, FCE's fuel blending option is recommended. In this configuration, the ADG is externally treated and purified. The treated ADG gas is supplied to a secondary fuel blending connection on the MBOP. The primary fuel connection (and the on-board cleanup system) is used for the blending fuel, which is typically pipeline natural gas. Stored LNG could also be used as the blending fuel.

Because the gas blending is performed downstream of the on-board fuel cleanup system, some additional gas clean-up is required. The ADG treatment skid has to provide gas that has the very low levels of impurities which are normally provided by the on-board cleanup system, since the on-board cleanup system is not available to do the final impurity polishing. This additional ADG cleanup must be accomplished in the ADG treatment skid. This figure shows how an ADG application with fuel blending is configured.

ADG configured with Optional Fuel Blending
(Externally Purified ADG)
The features of the FCE fuel blending powerplant option are as follows:

- **Includes:**
  - Additional fuel control train, including flow meter, control valve, block valves, customer interface connection, integrated into the powerplant mechanical balance of plant skid.
  - Additional software to implement fuel blending and switching features.
  - Additional 4-20 mA analog input for customer fuel availability signal.
  - Additional digital input indicating digester gas supply status.
  - Additional digital output indicating digester gas fuel request.

- Allows full power operation with two fuels, typically digester gas and natural gas.

- Provides automatic blending of the two fuels during normal plant heat-up and power generation.

- Automatically maximizes the use of available digester gas, only using natural gas when necessary to maintain consistent combined fuel flow and plant power output.

- Provides for full switch to natural gas in the event of loss of digester supply, without affecting power output. Complete switch takes place over 5-6 minutes.

The fuel blending option has certain interface requirements which allow the powerplant control system to coordinate blending and fuel switching. These requirements are as follows:

- The pretreatment system needs to clean the digester gas to the level specified in FCE fuel specification document #5665, “Limit of Contaminants for Externally Purified Gas.” This purification level shall be tested prior to operation with fuel cell. The treatment system must also meet the other criteria (pressure, humidity, etc) in that specification.

- A secondary fuel meeting FCE specification document #5665 is needed. This is typically pipeline natural gas, but LNG could also be used.

- One of the two fuel sources needs to be continuously available at full pressure and flow. The more consistent source (typically natural gas) will be used for heat-up and standby operation.

- The vessels in the digester treatment system should have enough volume so that upon loss of digester supply, the amount of gas provided by depressurization of the vessels would provide sufficient volume of gas at the supply pressure (this is needed during the transition to full secondary gas flow). This volume is 125 scf for the DFC300MA, 700 scf for the DFC1500 and 1,400 scf for the DFC3000.
• The digester gas source should have sufficient buffer to ensure fuel stability at the external digester treatment system. The digester gas source should be capable of supplying a minimum flow rate of gas for 10 minutes without the digester gas tank pressure dropping its minimum setting. The minimum flow rate is 5 scfm for the DFC300MA, 15 scfm for the DFC1500 and 30 scfm for the DFC3000.

• Digester gas pressure supply variation should be kept to a minimum. For small digesters with very little gas headspace, additional surge volume should be considered to buffer pressure fluctuations.

• Control interfaces between FCE’s Programmable Logic Controller (PLC) and the control system of the Digester Gas Treatment Skid.
  o An external 4-20 mA analog signal to FCE’s PLC indicating digester gas availability using either Digester Tank Level or Compressor Suction Pressure. Analog Input scaling shall be as follows:
    ▪ Pressure: The signal shall be 4mA @ 0 iwc and 20mA @ 50 iwc.
    ▪ Level: The signal shall be 4mA @ 0% level and 20mA @ 100% level
  o An external digital signal to FCE’s PLC indicating the digester gas supply status. The signal shall be fail-safe (contact should be open upon loss of digester gas PLC power) and shall be configured as follows:
    ▪ Open = Digester Gas not available
    ▪ Close = Digester Gas available
  o A digital signal from FCE’s PLC indicating fuel request status configured as follows:
    ▪ Open = No fuel request
    ▪ Close = Fuel request

**Startup Fuel Requirements**
The startup heater in the 2.8MW DFC3000 powerplant operates only on pipeline natural gas, and this plant is not capable of ADG-only operation. The DFC300 uses an electric start-up heater and the DFC1500 start-up heater can be configured for ADG or NG operation; therefore, these two products are capable of ADG-only operation. However, since the continuous and reliable supply of treated ADG typically cannot be guaranteed, it is strongly recommended to configure all DFC powerplants with the fuel blending option and use natural gas as the startup fuel with the in-board natural gas cleanup system.
OTHER BIOFUELS

As discussed above, ADG is the most commonly used biofuel, and it is a naturally good fit for DFC powerplants. Whether derived from municipal, industrial, agricultural, or animal waste it takes the form of methane (the preferred fuel for DFC powerplants) diluted with CO₂ (a diluent the DFC is uniquely insensitive to). However, ADG is not the only available bio-derived fuel. Other fuels derived from biomass are attractive as opportunity fuels, and the ultra-clean, high efficiency conversion offered by DFC technology can also be applied to these fuels. The following sections discuss some of the aspects unique to each of these fuels as applied to DFC power generation.

Land Fill Gas

Land fill gas (LFG) is the product of natural decay of biomass in landfills. It is similar to ADG in that it is primarily methane diluted with CO₂. The main differences between LFG and ADG are:

• LFG is typically more dilute than ADG, with methane levels usually below 60%
• LFG has a wider range of contaminants compared to ADG, based on the variety of materials disposed of in the landfill
• LFG often has more oxygen, due to intrusion of air into the gas collection system at the landfill
• Fuel composition (bulk methane level as well as impurities and oxygen) tends to be more variable than ADG.

Some landfills have higher quality fuel streams than others, which is a function of the quality of the collection system, the age of the landfill, and the materials disposed of in the landfill. Landfills producing gas with <50% methane and high fuel variability are not good candidates for un-blended DFC power generation due to the high de-rate which would occur. Fuel blending with natural gas provides a way to utilize these gas streams. Even for more concentrated LFG fuels, FCE recommends the blending option to at least provide for a backup fuel in the event of LFG supply interruptions.

LFG can have high concentrations of contaminants that are detrimental to the power plant such as chlorides (both organic and inorganic chlorides), aromatic compounds (e.g. benzene, toluene and xylene), sulfur, metals, dust, and siloxanes. The pre-
treatment system needs to be designed with an understanding of the magnitude and variability range for each of the contaminants.

**Biomass Gasification**

Biomass waste which cannot be easily digested can be disposed of in a gasification process. The material is brought up to high temperatures (through partial combustion) where organic materials are broken down to produce gaseous fuel compounds. This type of fuel is very different from the methane based fuels discussed above. Some gasification processes have been adjusted to provide a level of methane content, but generally hydrogen and carbon monoxide are the main fuel constituents. The energy content is usually about one third that of natural gas, at about 300 Btu/ft³. Because of this low energy content, the fuel lines in the standard DFC powerplants cannot flow enough gas to support full rated output. The most cost-effective way to use these fuels is by blending with natural gas to produce a high enough energy content to allow full load operation. Blending rates will vary depending on the specific fuel compositions, so gasification type fuels are evaluated on a case by basis to determine the most economic application with DFC products.

**Liquid Biomass Fuels**

Ethanol and biodiesel are two prevalent bio-derived liquid fuels. Ethanol is a much more developed fuel product, with standardized fuel grades and established production methods and infrastructure. Ethanol requires a pre-processing system in order to be used in standard DFC powerplant products. In addition to impurity cleanup, ethanol pre-processing involves vaporization, mixing with water, and reforming/methanation processing to produce a gas with a mixture of hydrogen and methane fuel. No commercial ethanol projects have been executed yet, but the required processes are well understood.

Biodiesel has high molecular weight compounds and requires much more pre-processing for use in DFC powerplants. Such pre-processing systems are being developed for specialty applications using standard diesel fuels, but these systems are not yet commercially available.
GENERAL GUIDELINES FOR BIOGAS APPLICATION EXECUTION

Fuel Analysis

The key to successful application of biofuels with DFC powerplants is developing an understanding of the fuel characteristics as soon as possible in the project development process. The end user needs to do testing on the raw fuel in order to provide the required design information to potential pre-treatment skid vendors. Ideally, enough data could be obtained to determine how the fuel characteristics trend over time. Pre-treatment skid vendors will use the site fuel information (concentration, contaminants, pressure, variability, etc) to design a pre-treatment skid which provides fuel that meets FCE specifications.

The FCE Fuel Specification document #5665 lists the fuel impurities and constituents the fuel supply must be in compliance with. An analysis by a qualified lab of all the listed impurities and constituents is required to make a full and accurate assessment of the fuel supply. The following table summarizes fuel-testing requirements by fuel type. The fuel specification provides detailed list testing compound required.

Fuel Testing Requirements by Fuel Type

<table>
<thead>
<tr>
<th>Description of Compound Categories</th>
<th>Natural Gas</th>
<th>Digester Gas</th>
<th>Landfill or Other Gas</th>
<th>Analysis Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Composition Analysis &amp; Heating Value</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
<td>ASTM D-1945</td>
</tr>
<tr>
<td>Sulfur Compounds</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
<td>ASTM D-5504</td>
</tr>
<tr>
<td>VOC's + Naphthalene</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
<td>EPA TO-15</td>
</tr>
<tr>
<td>Water</td>
<td>Required or provide gas specification</td>
<td>Provide water knock out process: Dew point, Pressure, and Reheat Temperature</td>
<td>Provide water knock out process: Dew point, Pressure, and Reheat Temperature</td>
<td>ASTM-5454-04</td>
</tr>
<tr>
<td>Halogens</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
<td>NIOSH 7903, 6005</td>
</tr>
<tr>
<td>Siloxanes</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
<td>Specialty</td>
</tr>
<tr>
<td>Metals, including Mercury</td>
<td></td>
<td>Required</td>
<td>NIOSH 7300, 6009</td>
<td></td>
</tr>
<tr>
<td>Particulates</td>
<td></td>
<td>Required</td>
<td>PM 10</td>
<td></td>
</tr>
</tbody>
</table>
These tests (and the 5665 fuel specification limits) refer to the fuel fed to the fuel cell. The customer is responsible for providing a fuel analysis that assures that the fuel source is treated within limits specified in the FCE fuel specification prior to powerplant operation on the treated fuel.

Ongoing fuel sampling and preventative maintenance to support the powerplant’s onboard fuel treatment equipment is available under FCE Long Term Service Agreements (LTSA). If the external pre-treatment skid maintenance is not in FCE’s scope of supply, FCE and the customer should agree on an appropriate fuel sampling and treatment equipment maintenance plan prior to completion of commissioning to assure fuel quality and reliability will be maintained.

**Water and Air Quality**

While the fuel characteristics will be the primary focus during early project development, water quality and air quality at the site also need to be reviewed. Air quality at digester sites is a concern because of the potential for high ambient sulfur levels, although it has been FCE’s experience that customers tend to limit these levels as part of odor control and general safety. Application guides for the individual powerplant products describe the water and air quality requirements.

**Waste Heat Recovery**

Another aspect that should be addressed early in project development is waste heat recovery. FCE powerplants are almost always deployed in combined heat and power (CHP) applications, where waste heat in the fuel cell exhaust is captured and used to offset fuel use in thermal applications. The exhaust from a DFC powerplant is 700° F +/- 50° F. The gas can be used directly (e.g. in a direct fired chiller) but it is more often used with a heat transfer fluid. Heat exchangers are typically installed on DFC powerplant exhaust to make hot water or steam. The most common heat recovery approach at digester sites is the production of hot water which is used to heat the digesters. The amount of usable heat is a function of the lowest grade heat need (how low the user cools the DFC exhaust from 700° F). Heat available from each powerplant at two different exhaust cooling levels is shown in the following table:
Available Waste Heat from DFC Powerplants

<table>
<thead>
<tr>
<th>Exhaust Temperature, F</th>
<th>DFC300 300 kW</th>
<th>DFC1500MA 1200 kW</th>
<th>DFC1500B 1400 kW</th>
<th>DFC3000 2800 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>480,000</td>
<td>1,920,000</td>
<td>2,217,000</td>
<td>4,433,000</td>
</tr>
<tr>
<td>120</td>
<td>808,000</td>
<td>3,232,000</td>
<td>3,730,000</td>
<td>7,460,000</td>
</tr>
</tbody>
</table>

Users should review the heat requirements of their bio-fuel production process to determine the best configuration for a waste heat recovery system in a DFC powerplant application.

**Application Conformance Review**

Once a project is initiated, FCE works with the customer to document the specific site characteristics in a form called the Application Conformance Review (ACR). An ACR form should be completed for every project within 45 days of contract closure. The 45-day time frame is important to keeping delivery schedule if options or plant modifications are needed. The purpose of the ACR is to:

- Document fuel and water quality and site information.
- Enable selection of powerplant desulfurization media for in-plant cleanup system.
- Enable adjustment of water treatment system.
- Determine if any power or efficiency corrections factors apply.
- Determine water pretreatment requirements, if needed.
- Identify any product options that may be needed for application.

Completion of the ACR form is the responsibility of the customer or distributor. FCE Application Engineering works with each customer to complete the form.

**Additional Information**

Beyond these general guidelines, a more detailed description of the requirements for each product is given in that product’s Application Guide. The individual product application guides, combined with the fuel and water specifications provide a good summary of specific product features and project requirements.
Appendix A - Requirements for Proposals for Gas Treatment Systems

A key aspect of ensuring the success of projects using biogas is the correct selection of the gas pre-treatment skid. This is generally sourced by distributors or end users to meet the requirements of FCE's fuel specification based on their individual gas characteristics. FCE has seen many successful and some unsuccessful skid selections, and the company supports customers in selecting the pre-treatment skid by reviewing proposals submitted by skid vendors. It has been FCE’s experience that in order to specify and select a pre-treatment skid which will operate properly, some key elements need to be present in the request for proposal (RFP) which is sent to skid vendors, and in the actual proposals submitted by vendors. These requirements are summarized below:

**Key Elements of Request for Proposal Documents Sent to Gas Pre-Treatment Vendors**

At a minimum, the Request for Proposal (RFP) to the gas treatment skid vendor should contain the following elements:


2. Raw gas conditions: Temperature, pressure, constituents and contaminants. Ideally, the raw gas concentration of contaminants listed in FCE’s fuel specification should be listed, since the clean up vendor will be required to remove these contaminates down to the specification level. If the gas composition is not yet known (for example if the digester is not yet operational) an estimate of the compositions should be made to give the vendor the required design information. The digester system vendor may be able to forecast approximate contaminant levels based on characteristics of the digester feedstock and previous experience. It is very important that the vendor understand which contaminants will be present.

3. Gas flow rate (minimum, maximum and average). The minimum flow rate is important due to concerns with operation of the absorbent vessels at low gas throughput. The minimum digester gas flow rate (assuming a methane content of 60%) for FCE’s products is given below:
DFC300  5 scfm
DFC1500  15 scfm
DFC3000  30 scfm

4. Gas discharge conditions (constituents, temperature, pressure, flow, moisture and contaminants) to be in accordance with specification 5665, with allowances for pressure drop depending on the location of the gas pre-treatment system with respect to the fuel cell.

5. Control Interface Requirements. The RFP should specify that the following control interfaces be provided between FuelCell Energy’s Programmable Logic Controller (PLC) and the control system of the Digester Gas Treatment Skid:
   - An external 4-20 mA analog signal to FCE’s PLC indicating digester gas availability using either Digester Tank Level or Compressor Suction Pressure. Analog Input scaling shall be as follows:
     - Pressure: The signal shall be 4mA @ 0 iwc and 20mA @ 50 iwc.
     - Level: The signal shall be 4mA @ 0% level and 20mA @ 100% level
   - An external digital signal to FCE’s PLC indicating the digester gas supply status. The signal shall be fail-safe (contact should be open upon loss of digester gas PLC power) and shall be configured as follows:
     - Open = Digester Gas not available
     - Close = Digester Gas available
   - A digital signal from FCE’s PLC indicating fuel request status configured as follows:
     - Open = No fuel request
     - Close = Fuel request

**Key Elements that Pre-Treatment Vendors Need to Include in Proposals:**
In addition to key commercial items (company information, site reference list, etc), the RFP should require that vendors submit technical information required for the FCE technical review. The RFP should state that at a minimum, the proposal from the gas treatment skid vendor should contain the following elements:

1. Process description: A Process Flow Diagram and a brief explanation of the process flow (including temperature and pressure at key intermediate points) and how the proposed process cleans specific impurities in the gas.
2. Size and quantity of proposed absorbent vessels.

3. Type of proposed absorbent media. Specific brand name of the media may be proprietary and is not required for proposal evaluation. However, a generic description of media type (such as “activated carbon”) is required.

4. Parasitic power requirement of compressor/blower, chiller, and any other loads.

5. The Operations and Maintenance (O&M) Schedule including but not limited to:
   a. Frequency of absorbent media replacement and whether replacement can be done without shutting down the system
   b. Frequency of gas sampling for contaminant levels
   c. Any other procedures required, such as lubrication of rotating equipment, belt tensioning, etc.
   d. Replacement of other consumables such as filters.
   e. Anticipated replacement of mechanical equipment
APPENDIX I

DIGESTER GAS BOILER TECHNOLOGY LITERATURE
SCOPE OF SUPPLY & PRICING

Quantity: One (1)  
Design: Firebox - Hot Water Boiler  
Rated Output: 30 BHP (294KW)  
Design Pressure: 30 psig (206 kPa)  
Operating Pressure: 25 psig (172 kPa) - To be confirmed  
Maximum Outlet Temperature: 194 deg F (90 deg C)  
Minimum Inlet Water Temperature: 169 deg F (76 deg C)  
Fuel 1: Digester Gas  
Fuel 2: N/A  
Minimum Gas Pressure at Fuel Train: 1 psig (7 kPa)  
Power: 575 / 3 / 60
<table>
<thead>
<tr>
<th>Qty</th>
<th>Part Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Engineering</td>
<td>Project engineering, drawing and data submittals as specified and c/w</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Detailed project schedule</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Liability insurance certificate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WCB certificate and liability insurance (customer confirmation and site specific)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Boiler general arrangement drawing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Boiler P&amp;I diagram</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Boiler control panel wiring diagrams and panel fascia layout</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Boiler trim, controls and component bill of materials</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operation and maintenance manuals</td>
</tr>
<tr>
<td>1</td>
<td>AR-X-120</td>
<td>Sterling / Superior Packaged Firebox Hot Water Boiler</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rated output - 30 BHP (1004 MBH)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ASME Section 4 @ 30 psig design pressure, CRN (Ontario)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4) square feet (0.37) square meters) per BHP heating surface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 pass wet back design</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Generous firebox volume for complete combustion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cladding &amp; 2&quot; thick shell insulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bolted front &amp; rear doors for complete tube access</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Large steam disengaging area storage volume</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Structural steel base with under boiler ventilation</td>
</tr>
<tr>
<td>1</td>
<td>Boiler Trims</td>
<td>Boiler Vessel Trims c/w</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Set of safety relief valve(s) (ASME Section 4) - bronze body</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Boiler pressure gauge c/w shut off cock (90 mm - 0 to 1,378 kPa)</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Boiler water thermometer (115 mm - 10 to 150 deg C)</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Low water cut-off switch - probe type</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Low water flow cut-off switch - mechanical paddle type</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Manual reset high limit temperature switch (mechanical)</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Sets of drain valve(s) for each boiler pass</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Stack thermometer - 65 to 400 deg C</td>
</tr>
<tr>
<td>1</td>
<td>MM10006/100</td>
<td>Temperature Sensor 4&quot; well (0 to 750 deg f)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hot water boilers</td>
</tr>
<tr>
<td>Qty</td>
<td>Part Number</td>
<td>Description</td>
</tr>
<tr>
<td>-----</td>
<td>-------------</td>
<td>-------------</td>
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<tr>
<td>1</td>
<td>CGG-60-S</td>
<td>Pendell &quot;Fuel Master&quot; Fully Modulating Digester Gas burner c/w&lt;br&gt;Digester gas combustion head assembly&lt;br&gt;Flame viewing port&lt;br&gt;Factory mounting of Autoflame servo motor for air flow control&lt;br&gt;Combustion air inlet damper&lt;br&gt;Stainless steel blast tube cone&lt;br&gt;High energy transformer and spark ignition electrodes&lt;br&gt;Factory mounting of Autoflame servo motor and fuel valve</td>
</tr>
<tr>
<td>1</td>
<td>MM60004/HSU</td>
<td>Standard UV Scanner, High Sensitivity&lt;br&gt;A boiler recycle must be initiated each 24 hours to comply with local safety codes</td>
</tr>
<tr>
<td>1</td>
<td>FD Fan</td>
<td>Integral Combustion Air Fan, Motor &amp; Air Inlet Flange&lt;br&gt;3 Phase, 1.5 HP @ 3,600 RPM Motor</td>
</tr>
<tr>
<td>1</td>
<td>MM60013</td>
<td>Combustion Air Proving Switch&lt;br&gt;Low air pressure limit and safety shutdown function</td>
</tr>
<tr>
<td>1</td>
<td>MM10005/D</td>
<td>Small Servo Motor (3 ft lb torque)&lt;br&gt;Combustion air damper control and characterization</td>
</tr>
<tr>
<td>1</td>
<td>Pilot</td>
<td>Pilot Gas Train&lt;br&gt;Natural Gas&lt;br&gt;Carbon steel construction&lt;br&gt;Manual gas shut off valves&lt;br&gt;Pilot gas pressure regulator&lt;br&gt;Low gas pressure switch&lt;br&gt;Solenoid operated safety shut off valves&lt;br&gt;Designed in accordance with current gas code requirements</td>
</tr>
<tr>
<td>1</td>
<td>Digester Gas</td>
<td>Digester Gas Train (1.5&quot;)&lt;br&gt;Stainless steel construction&lt;br&gt;Low gas pressure switches&lt;br&gt;Gas pressure gauges c/w isolation valves&lt;br&gt;Main gas pressure regulator&lt;br&gt;Dual safety shut off valve body c/w connecting flanges</td>
</tr>
<tr>
<td>Qty</td>
<td>Part Number</td>
<td>Description</td>
</tr>
<tr>
<td>-----</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dual safety shut off valve actuators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High gas pressure switch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manual test firing valve and shut off</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flame arrestor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check valve</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Designed in accordance with current gas code requirements</td>
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<tr>
<td>1</td>
<td>MM10005/D</td>
<td><strong>Autoflame Small Servo Motor (3 ft lb torque)</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gas flow valve control</td>
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<tr>
<td>1</td>
<td>GV44022U</td>
<td><strong>Gas Flow Control Valve - 1.5” NPT Threaded</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aluminium body, stainless steel butterfly, shaft and mounting bracket</td>
</tr>
<tr>
<td>1</td>
<td>Control Panel</td>
<td><strong>Boiler Skid Mounted Nema 4 Control Cabinet c/w</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indication lights</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Load demand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fuel on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flame failure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rotary switches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low fire / Auto / Manual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On / Off / Remote</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Push buttons</td>
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<tr>
<td></td>
<td></td>
<td>Autoflame control reset</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alarm silence</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Emergency stop (lock)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control voltage transformer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Servo motor voltage transformer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alarm horn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DIN rail mounted terminal blocks and components</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fuses and fuse holders</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Designed in accordance with current fuel code and electrical requirements</td>
</tr>
<tr>
<td>1</td>
<td>MMM70002/E/110</td>
<td><strong>Mini Mk 7 Evolution - 4 Channel control</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Micro modulation fuel / air ratio control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Integral flame safeguard control and burner management functions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Suitable for UV or external ionization flame monitoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 servo motor positioning channels</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 dedicated VSD speed control channel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 separate and independent fuel characterization curves</td>
</tr>
<tr>
<td>Qty</td>
<td>Part Number</td>
<td>Description</td>
</tr>
<tr>
<td>-----</td>
<td>-------------</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Self adaptive UV amplification</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manual firing rate increase / decrease capability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Auto / Low Fire Hold / Manual switching capability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Integral lead lag and sequencing routines (IBS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fuel flow metering capability, current and totalized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lockout record and display</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Burner history display, hours run and number of start ups for each fuel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operator adjustable pressure or temperature set point</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fuel Curve</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel 1</td>
<td>Digester Gas</td>
</tr>
<tr>
<td>Channel 2</td>
<td>Gas Flow Control Valve</td>
</tr>
<tr>
<td>Channel 3</td>
<td>Burner Combustion Air Damper</td>
</tr>
<tr>
<td>Channel 4</td>
<td>Spare</td>
</tr>
<tr>
<td>Channel 4</td>
<td>Spare</td>
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</table>

<table>
<thead>
<tr>
<th>Qty</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shop Packaging</td>
</tr>
<tr>
<td></td>
<td>Burner mounting and control panel mounting.</td>
</tr>
<tr>
<td></td>
<td>Boiler trims assembly and piping</td>
</tr>
<tr>
<td></td>
<td>Burner and equipment assembly to boiler</td>
</tr>
<tr>
<td></td>
<td>Fuel train piping and assembly</td>
</tr>
<tr>
<td></td>
<td>Conduit and wiring</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Qty</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shop Testing</td>
</tr>
<tr>
<td></td>
<td>Electrical function test</td>
</tr>
<tr>
<td></td>
<td>Safety limit function test</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Qty</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Shipping Preparation</td>
</tr>
<tr>
<td></td>
<td>Touch up and final painting</td>
</tr>
<tr>
<td></td>
<td>Bracing, blanking and weather protection</td>
</tr>
<tr>
<td></td>
<td>Industrial Shrink Wrap</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Qty</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transport</td>
</tr>
<tr>
<td></td>
<td>Truck Cost, Packaged Boiler to Site (Southern Ontario)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Qty</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Commissioning</td>
</tr>
<tr>
<td></td>
<td>Full Load - Site Start Up Services</td>
</tr>
<tr>
<td></td>
<td>Electrical function testing</td>
</tr>
<tr>
<td></td>
<td>Commission burner management (purge timing, safety timing and UV signal)</td>
</tr>
<tr>
<td></td>
<td>Commission Autoflame control options and parameters</td>
</tr>
<tr>
<td></td>
<td>Commission fuel / air ratio curves</td>
</tr>
<tr>
<td></td>
<td>Commission fuel metering - Gas (using dedicated portable gas meter)</td>
</tr>
<tr>
<td></td>
<td>Test for correct operation, stack analysis and report</td>
</tr>
<tr>
<td></td>
<td>Safety limit check</td>
</tr>
<tr>
<td>Qty</td>
<td>Part Number</td>
</tr>
<tr>
<td>-----</td>
<td>-------------</td>
</tr>
</tbody>
</table>
| 1   | Approvals   | Local inspector approvals  
Vessel inspection and stamping (Ontario)  
Witnessed run test and safety inspection  
TSSA Field approval label |
| 1   | Training    | Operator training and manuals |

<table>
<thead>
<tr>
<th>Base</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Packaged Digester Gas Hot Water Boiler - 30 BHP (Qty 1)</td>
<td>$76,164.00</td>
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**Option 1**  
Continuous Flue Gas Monitoring & Efficiency Trim System

<table>
<thead>
<tr>
<th>Qty</th>
<th>Part Number</th>
<th>Description</th>
</tr>
</thead>
</table>
| 1   | MM72004     | EGA Mk 7 - Exhaust Gas Analysis and Trim System c/w  
Touch Screen Display  
Three parameter (O2, CO, CO2) Trim  
Local and MM display of O2, CO, CO2, NO, Exhaust gas temp & efficiency  
6 channel 4 - 20 mA output facility |
| 1   | MM10033     | EGA sampling probe c/w temperature sensor (0 to 750 deg f) |

**Option 1**  
Continuous Flue Gas Monitoring & Efficiency Trim System (Qty 1)  
$11,881.00
<table>
<thead>
<tr>
<th>Qty</th>
<th>Part Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Panel</td>
<td>Remote Mounted Nema 4 Control Cabinet c/w On / Off switch DIN rail mounted terminal blocks and components Fuses and fuse holders</td>
</tr>
<tr>
<td>1</td>
<td>DTI70100/110</td>
<td>Mk 7 Data Transfer Interface System Package c/w 10.4&quot; Colour touch Screen Display DTI control and universal protocol prom Autoflame Windows firmware Version 7 with CEMS DTI to PC Communications lead Documentation, quick set up guide / troubleshooting Modbus reference address listing</td>
</tr>
<tr>
<td>1</td>
<td>DTI70070</td>
<td>Serial Connection to Ethernet MOXA 485/422/232</td>
</tr>
</tbody>
</table>

Option 2  Remote Control & Surveillance System (Common)  $6,585.00
## Pricing Basis

<table>
<thead>
<tr>
<th>Schedule</th>
<th>Allow 10 to 12 weeks from release to manufacture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payment</td>
<td>10% on award and acceptance of a firm contract.</td>
</tr>
<tr>
<td></td>
<td>10% on submittal of engineering and data for review.</td>
</tr>
<tr>
<td></td>
<td>10% on release to commence manufacturing.</td>
</tr>
<tr>
<td></td>
<td>20% on receipt of major materials (defined as boiler vessel tubes and shell plates).</td>
</tr>
<tr>
<td></td>
<td>20% on completion of successful shop hydrostatic testing.</td>
</tr>
<tr>
<td></td>
<td>20% on shipment or offer to ship.</td>
</tr>
<tr>
<td></td>
<td>10% on completion of start up and commissioning (not to exceed 120 days from shipment or offer to ship).</td>
</tr>
<tr>
<td>Funds</td>
<td>Prices quoted are in Canadian Funds.</td>
</tr>
<tr>
<td>FOB</td>
<td>Prices quoted are FOB site (Assuming Southern Ontario)</td>
</tr>
<tr>
<td>Transport</td>
<td>Included (Assuming Southern Ontario) offloading by others.</td>
</tr>
<tr>
<td>Taxes</td>
<td>All taxes are extra.</td>
</tr>
<tr>
<td>Terms</td>
<td>In accordance with Sterling Combustion Inc., terms and conditions of sale.</td>
</tr>
<tr>
<td>Validity</td>
<td>Prices are valid for 60 days from the proposal date and firm through the delivery stated.</td>
</tr>
</tbody>
</table>
Packaged Hot Water Boilers
Digester Gas Fired
Suggested Specification

1.0 General Packaged Boiler Requirements

1.1 Provide a hot water boiler shop assembled of the packaged 3-pass wet back fire box design. The boiler will be designed for pressurized firing, complete with a heavy structural steel base, trim, burner and burner controls. The boiler will be shop hydrostatic tested, inspected and stamped by a recognized government inspector in accordance with ASME Code. As a complete assembled package, the boiler will be ready for the attachment of water, fuel, drain, electrical, stack and venting connections.

1.2 The hot water boiler specified herein will comply with the following minimum performance requirements.

1.2.1 Rated Output Capacity: 1,000 MBH
1.2.2 Rated Fuel Input: 1,250 MBH
1.2.3 Hot Water Return Temperature: 76 Deg C
1.2.4 Hot Water Supply Temperature: 90 Deg C
1.2.5 Efficiency (HHV): 80% (Non condensing)

1.3 All pressure containing parts, accessories, fixtures and fittings will be designed and constructed for 206 kPa design pressure, in accordance with the latest edition of the applicable ASME Code Section 4.

1.4 The boiler will be furnished as a complete factory assembled unit, consisting of the pressure vessel assembly, burner, fuel trains, combustion and flame safeguard controls.

2.0 Acceptable Equipment

2.1 Sterling / Superior 3-Pass Wet Back Fire-box.
3.0 **Boiler Design**

3.1 The boiler shall be a 3-Pass wetback boiler and will have a maximum output of 1,000 MBH (30 BHP) with a design pressure of 30 psig. The boiler shall not have less than 4 square feet of A.S.M.E. heating surface, measured on the fireside, per rated boiler horsepower.

3.2 Boiler shall fit through a standard 36" x 80" doorway opening with trim and controls removed.

3.3 The boiler is to be mounted on a structural steel base with a forced draft burner and burner controls. The boiler is to be designed, constructed and tested in accordance with the latest edition and addenda of the A.S.M.E. Boiler and Pressure Vessel Code and shall be registered with an Ontario CRN number.

3.4 Boiler is constructed to meet the requirement of CSD-1.

4.0 **Structural Specification**

4.1 The furnace is to be located in the bottom third of the boiler to provide for maximum heat transfer while being in contact with the coolest boiler water.

4.2 Shell plate to be constructed of not less than 3/8" thick.

4.3 All tubes are to have a minimum wall thickness of .095" and have an OD of 2". The tubes are to be attached by flare rolling.

4.4 Tube-sheets to be constructed of not less than 1/2" thick plate with minimum tube holes ligament of 1/2".

4.5 The boiler shall be mounted on a heavy structural steel base.

4.6 The rear legs are to be slotted to provide for expansion when the boiler goes from a cold situation to a hot situation.

4.7 The boiler is to be equipped with two lifting eyes.

4.8 All heating surfaces must be fully accessible for inspection and cleaning without disturbing the burner equipment. An access opening complete with a gasketed plug and a Pyrex observation port shall be provided to allow for access into the turnaround and furnace.

4.9 All necessary handholes and manholes shall be provided in accordance with the ASME Code, to improve the ease of waterside inspection and cleaning.

4.10 Tubesheets must be fully accessible for inspections or cleaning when the front or rear doors are open. Opening of the doors is not to be impeded by any fuel lines, door plates, baffles, linkage or electrical connections. The doors are to be insulated with a 1" thick ceramic fiber blanket and to be coated with a hardener to prevent erosion from the flue gases. All doors are to be held in place by replaceable brass nuts. The doors are to be sealed gas
tight with non-proprietary ceramic fiber rope with a minimum density of 20 lbs. per square foot and a continuous use limit of 1800°F.

4.11 The boiler shell is to be insulated with two inch thick, eight pound per cubic foot density mineral wool with a K factor of .27. The insulation is to be held in place by bands and is to be covered with a 22 gauge phosphate coated galvanized steel jacket. All openings in the jacket are to have trim rings.

4.12 The entire boiler is to be painted with a high temperature, 500°F minimum, acrylic silicone based paint. The front and rear doors are to be sand blasted before painting and the jacket is to be primed with a vinyl wash primer before painting.

5.0 **Boiler Trim and Connections**

5.1 A hot water heating system supply connection will be located on the top centerline at the rear of the boiler vessel.

5.2 A hot water heating system return connection will be located on the top centerline at the front of the boiler vessel.

5.3 Provide a boiler water drain connection.

5.4 An air vent connection will be provided on the top centerline of the boiler.

5.5 Safety relief valve(s) in compliance with ASME code will be furnished.

5.6 Provide a boiler water temperature gauge.

5.7 A manual drain valve will be provided.

5.8 Hot water temperature controls will be provided for operation (Autoflame PID), high limit (auto reset) and high / high limit (manual reset).

5.9 A probe type low water cut off control will be furnished as an integral part of the boiler shell.

6.0 **Fuel Burning System**

6.1 The fuel burning system provided will be selected specifically for firing the existing boiler design. Flame geometry and burner fuel input ratings will comply with the required boiler output and be suitable for continuous firing without any flame impingement on the boiler furnace tube or rear wall. Combustion control will be accomplished using independent direct-coupled servomotors on the inlet air damper assembly and fuel valve so that no mechanical linkages are required.

6.2 The burner will be an industrial forced draft burner design, suitable for firing Digester Gas with a characterized fuel / air ratio curve for the rated capacity.
6.3 The burner blast tube, combustion cone and diffuser will be constructed of high-grade high temperature stainless steel for corrosion resistance.

6.4 An integral forced draft fan mounted on the burner front will be electric motor driven of sufficient capacity at maximum firing rate to provide stoichiometric air for combustion plus 20% margin for safe combustion and control requirements. Static and total pressure capability will be coordinated with the requirements of the combustion air and boiler static pressure from fan inlet to stack outlet. The motor will not be overloaded under any condition of operation. The fan will be of rugged construction and balanced to prevent vibration. The fan wheel will be direct connected to a 3,600 rpm motor.

6.5 The pilot and main flame signal strength will be continuously monitored using an Autoflame self-adaptive ultra violet self-checking scanner.

6.6 The burner will operate quietly without pulsation; have turndown range on Digester gas of at least 4 to 1.

6.7 A separate fully adjustable gas pilot assembly will be designed for high energy spark ignition and for main flame light off at the lowest possible firing level.

6.8 Gas flow control to the burner will be controlled using butterfly valves specifically selected for the duty and operated by a direct coupled positioning Autoflame servo motors accurate and repeatable to 0.1 degrees angular.

6.9 Combustion air proving will be provided using air pressure switch for safety shutdown function on a low air condition.

7.0 **Acceptable Burner Equipment**

7.1 Pendell Fuel Master.

8.0 **Digester Gas Train**

8.1 Digester Gas will be provided at pressure of 27” WC (1 psig) at the entrance to the fuel gas train gas regulator.

8.2 A gas pressure regulator will be provided that is adequately sized for the available gas pressure and will be capable of maintaining a constant gas pressure to the burner throughout the firing range.

8.3 High and low gas pressure manual reset gas pressure interlocks will be provided.

8.4 Two motorized gas shutdown valves with proof of closure switches will be provided to positively prevent gas from entering the burner in the event of the opening of any boiler or combustion system limit switch. Safety shut off valves will be interlocked with the flame safeguard control.
8.5 Manual shut off valves and leak test connections are to be provided in accordance with applicable code requirements.

8.6 Provide gas pressure gauges upstream of regulator, downstream of regulator and burner manifold.

8.7 Provide a flame arrester specifically designed for Digester Gas service.

8.8 Provide a back flow prevention check valve designed for Digester Gas service.

8.9 Provide automatic reset high and low pressure switches to enable and verify adequate available Digester Gas pressure for firing.

8.10 All valves will be suitable for corrosive duty specifically selected for Digester Gas service, all piping will be stainless steel.

8.11 The gas train will be designed to comply with current TSSA Digester Gas code requirements as a minimum standard of acceptance.

9.0 **Pilot Gas Train**

9.1 Natural Gas will be provided at pressure of 2 psig at the entrance to the pilot gas train.

9.2 A gas pressure regulator will be provided that is adequately sized for the available gas pressure and will be capable of controlling gas pressure to the burner for pilot gas.

9.3 Two solenoid operated gas shutdown valves will be provided to positively prevent gas from entering the burner in the event of the opening of any boiler or combustion system limit switch. Safety shut off valves will be interlocked with the flame safeguard control.

9.4 Manual shut off valves, leak test connections and pressure gauges are to be provided in accordance with applicable code requirements.

9.5 The pilot gas train will be designed to comply with all local Natural Gas code requirements as a minimum standard of acceptance.

10.0 **Burner Control Panel**

10.1 A NEMA 4 factory pre-wired control cabinet will be supplied with the boiler. The cabinet will be designed for boiler or floor mounting adjacent to the burner and will have separate sections designated for high voltage and control voltage components. The control cabinet will house the specified Autoflame fuel air ratio and flame safeguard control, programming purge
timer, furnace draft controller motor starters, fuses, relays, transformers, control switches and indicating lights as required for the application.

10.2 The control panel will be complete with individual lights with “Lamacoid” nameplates to indicate the following.

10.2.1 Power on
10.2.2 Digester gas firing
10.2.3 Low gas pressure
10.2.4 Remote control
10.2.5 Load demand
10.2.6 Pilot on
10.2.7 Flame failure

10.3 The following control switches will be provided as a minimum.

10.3.1 Emergency stop
10.3.2 Hand / Auto / Low fire
10.3.3 Alarm silence
10.3.4 On / Off

10.4 All control panel wiring is to be tagged and labeled from each component and at the DIN rail terminal in accordance with the wiring diagram.

11.0 Combustion Control and Burner Management

11.1 Provide a fully integrated Autoflame Mini Mk 7 Evolution "Micro Modulation Controller" that will be fully capable of fuel / air ratio control throughout the entire firing range of the burner, such that no mechanical linkages are required to operate the combustion air inlet damper, fuel flow control valves or auxiliary dampers. The control for the specified burner and selected fuel will include all necessary interface wiring, software and hardware for a complete fuel / air metering and flame safeguard system. The system will be easily programmable with the flexibility of optimizing combustion quality and fuel efficiency throughout the burner firing range while maintaining the boiler outlet temperature to within 1 degree C of set point.

11.2 The Autoflame Mini Mk 7 controller will be preprogrammed to allow firing on up to two independent fuel curves. Each fuel / air ratio curve will be commissioned to enable firing of different fuels, rated capacity or reduced capacity firing as required for the application. Required temperature set point will be adjustable from the control increase or decrease buttons.

11.3 The system will include the panel mounted control module containing a microcomputer and power supply and will include the display of data and status indication. The system will be complete to control the fuel /air ratio
near stoichiometric conditions and have 100% repeatability throughout the firing range.

11.4 The front of the panel-mounted control will consist of an LCD screen providing easy to read numeric information. Separate displays will be individually selectable for the specific application to provide continuously updated information as follows:

11.5 Status Display - Fuel fired, percent firing rate, required temperature, actual temperature, hours run and installed software issue.

11.6 Micro – Modulation - Degrees angular position of servo motors for channels 1, 2 and 3 with analogue input signals for channel 4 and the designated O2, CO trim channel.

11.7 Sequencing Status - Boiler designation, lead boiler designation, reduced set point, lag boiler hot standby firing sequence and current status.

11.8 Fuel Metering - On line fuel consumption for fuels being fired and totalized fuel consumption for each fuel curve commissioned.

11.9 Flame Safeguard - Graphical display of current flame safeguard sequence logic with indication of current status showing:
   11.9.1 Flame intensity signal strength for flame.
   11.9.2 Post purge time and actual position in cycle.
   11.9.3 Pre Purge time and actual position in cycle.
   11.9.4 Combustion air damper
   11.9.5 Current firing rate status.
   11.9.6 Main fuel valve status (open or closed).
   11.9.7 Pilot fuel valve status (open or closed).
   11.9.8 Spark ignition status.
   11.9.9 Combustion air fan (running or standby).
   11.9.10 Lockout or run status message.
   11.9.11 Lockout reset capability.

11.10 Self-Adaptive UV Flame Scanner – Display and continuous monitoring of the minimum required flame signal strength as set in the system options. The sampling frequency of the UV circuitry will be adjusted automatically to monitor the mean signal marginally in excess of minimum to extend the safe operating life expectancy of the UV bulb.

11.11 Lockout History - Display of the last 16 limit circuit lockouts with description of lockout, time and date occurred and reset time and date.

11.12 In lieu of mechanical linkages and cams, the system will incorporate direct drive servomotors for the control of combustion air, fuel and auxiliary dampers. The position of each motor will be monitored by a voltage dividing system enabling digitized position information to be encoded into
the controls memory. The relative positions of the air and fuel servomotors will be constantly and automatically checked by the system at a rate of 50 times per second.

11.13 A full three term infinitely adjustable P.I.D. load control package will be included to provide control set point accuracy within 1 degree C via a signal from an Autoflame temperature sensor.

11.14 A non-linkage type fuel flow control valve will be furnished for the precise control and metering of fuel input to the burner. Fuel valves will be designed for dual fuel assembly and common servo motor drive when applicable.

11.15 The controller will be capable of setting commissioned options and parameters to suit the specific application including but not limited to the following:

11.15.1 Designation of boiler operating range.
11.15.2 Adjustable burner modulating ramp up speed.
11.15.3 Intelligent boiler sequencing (lead lag).
11.15.4 External modulation control.
11.15.5 Automatic cold start routine to prevent thermal shock or excessive condensation.
11.15.6 Flue gas recirculation (FGR) management.
11.15.7 Alarm output signal.
11.15.8 Digital limit circuit inputs.
11.15.9 Adjustable purge time.
11.15.10 Adjustable pilot and main flame proving time.
11.15.11 Adjustable flame signal strength threshold.
11.15.12 Selection for operation with a standard or self checking UV scanner.
11.15.13 Password settings to prevent unauthorized access to commissioning routines.
11.15.14 Independent adjustable Proportional Band, Integral Time and Derivative (PID).

12.0 Remote Control and Surveillance (DTI) – Pricing Option

12.1 Provide a fully integrated Autoflame Data Transfer Interface (DTI)™. The DTI will be data linked to the Autoflame Micro - Modulation Controller(s) specified herein to retrieve and display the information stored in memory locally at the burner control panel as follows:
Permanent data storage and display.
12.1.1 Electrical drawings.
12.1.2 Mechanical drawings.
12.1.3 Technical specifications and data
12.1.4 Boiler images.

2 years of data storage and display.
12.1.5 Firing rates.
12.1.6 Actual operating hot water temperature.
12.1.7 Required (set point) hot water temperature.
12.1.8 Servo motor positions.
12.1.9 Lockout history.
12.1.10 Error history.

24 hours of data storage and display.
12.1.11 Lead lag sequencing data.

12.2 The DTI unit will be complete with a 10.4” touch screen display to mirror the display of a selected burner control.
12.2.1 MM controller type.
12.2.2 Actual operating hot water temperature.
12.2.3 Required (set point) hot water temperature.
12.2.4 Fuel selected and fuel metering values.
12.2.5 Operating servo motors and position history.
12.2.6 Burner firing status (off, firing, purge, ignition).
12.2.7 Sequencing status, shuffle sequencing and lead boiler status.
12.2.8 Enable/disable status.
12.2.9 Lockouts, error and first out annunciation status.

12.3 As an operator interface the DTI unit will be capable of remote changes to a selected burner MM control using the touch screen display as follows.
12.3.1 Required hot water set point.
12.3.2 Lead boiler selection.
12.3.3 Enable/disable.
12.3.4 Shuffle sequencing.
12.3.5 Input/output labeling and control.
12.3.6 Remote load index control.
12.4 Information stored at the DTI unit will available for display and remote control at the facility control (BMS) system via the following connection possibilities.

12.4.1 Modbus interface over RS422 connection.
12.4.2 Modbus TCP/IP interface over Ethernet connection.

END OF SECTION
## APPENDIX I - ECONOMIC ANALYSIS

### Digester Gas Boiler

<table>
<thead>
<tr>
<th><strong>Financial Parameters</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Money</td>
<td>3.30%</td>
</tr>
<tr>
<td>Inflation</td>
<td>2.00%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Utility Charges</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas Usage</td>
<td>$0.17 $/m³</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Capital Costs</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Digester Gas Boiler</td>
<td>$76,164.00</td>
</tr>
<tr>
<td>Option 1 - Monitoring and Efficiency System</td>
<td>$11,881.00</td>
</tr>
<tr>
<td>Option 2 - Remote Control &amp; Surveillance System</td>
<td>$6,585.00</td>
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<tr>
<td>Installation Costs</td>
<td>$25,000.00</td>
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<tr>
<td>Total</td>
<td>$119,630.00</td>
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</table>

<table>
<thead>
<tr>
<th><strong>Operation and Maintenance</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td>$5,800.00 $/year</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Digester Gas</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Value (LHV)</td>
<td>531.00 Btu/ft³</td>
</tr>
<tr>
<td></td>
<td>=</td>
</tr>
<tr>
<td>Availability</td>
<td>1,000.00 m³/day</td>
</tr>
<tr>
<td></td>
<td>=</td>
</tr>
<tr>
<td></td>
<td>=</td>
</tr>
<tr>
<td></td>
<td>=</td>
</tr>
<tr>
<td>Heating available from the DG</td>
<td>783,832.90 BTU/hour</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Natural Gas</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Value</td>
<td>905.00 Btu/ft³</td>
</tr>
<tr>
<td></td>
<td>=</td>
</tr>
</tbody>
</table>

| Operating Hours                          | 7,446.00 Hours |
| Engine Runtime (% annual)                | 85.00% |
### Boiler Savings

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler output</td>
<td>627,066.32 BTU/Hour</td>
</tr>
<tr>
<td></td>
<td>17.66 m³/hour</td>
</tr>
<tr>
<td>Boiler Savings</td>
<td>$26,199.77</td>
</tr>
</tbody>
</table>

### Net Annual Savings

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$20,399.77 /Year</td>
</tr>
<tr>
<td>Simple Payback Period</td>
<td>5.86</td>
</tr>
</tbody>
</table>

### Debt

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>$119,630.00</td>
</tr>
<tr>
<td>Amount Financed</td>
<td>$119,630.00</td>
</tr>
<tr>
<td>Interest Rate</td>
<td>3.30%</td>
</tr>
<tr>
<td>Payments/Year</td>
<td>12</td>
</tr>
<tr>
<td>Amortization Period</td>
<td>10 Years</td>
</tr>
<tr>
<td>Payments</td>
<td>$1,171.80</td>
</tr>
<tr>
<td>Interest</td>
<td>$20,985.56</td>
</tr>
<tr>
<td>Yearly Interest</td>
<td>$2,098.56</td>
</tr>
<tr>
<td>Cash Savings</td>
<td>$18,301.21</td>
</tr>
</tbody>
</table>
APPENDIX J

MICROTURBINE TECHNOLOGY LITERATURE
CR65 & CR65 ICHP MicroTurbine
Renewable

Robust power system achieves ultra-low emissions and reliable electrical/thermal generation from waste gas.

- Years of renewable experience
- Ultra-low emissions
- Operates on landfill or digester gas
- One moving part – minimal maintenance and downtime
- Patented air bearing – no lubricating oil or coolant
- 5 and 9 year Factory Protection Plans available
- Remote monitoring and diagnostic capabilities
- Integrated utility synchronization and protection
- Small, modular design allows for easy, low-cost installation
- Reliable – tens of millions of run hours and counting

### Electrical Performance**(1)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Power Output</td>
<td>65kW</td>
</tr>
<tr>
<td>Voltage</td>
<td>400 – 480 VAC</td>
</tr>
<tr>
<td>Electrical Service</td>
<td>3-Phase, 4 wire</td>
</tr>
<tr>
<td>Frequency</td>
<td>50/60 Hz</td>
</tr>
<tr>
<td>Maximum Output Current</td>
<td>100A, grid connect operation</td>
</tr>
<tr>
<td>Electrical Efficiency LHV</td>
<td>29%</td>
</tr>
</tbody>
</table>

### Fuel/Engine Characteristics**(1)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill Gas HHV</td>
<td>13.0 – 22.3 MJ/m³ (350 – 600 BTU/scf)</td>
</tr>
<tr>
<td>Digester Gas HHV</td>
<td>20.5 – 32.6 MJ/m³ (550 – 875 BTU/scf)</td>
</tr>
<tr>
<td>H₂S Content</td>
<td>&lt; 5,000 ppmv</td>
</tr>
<tr>
<td>Inlet Pressure</td>
<td>517 – 552 kPa gauge (75 – 80 psig)</td>
</tr>
<tr>
<td>Fuel Flow HHV</td>
<td>888 MJ/hr (842,000 BTU/hr)</td>
</tr>
<tr>
<td>Net Heat Rate LHV</td>
<td>12.4 MJ/KWh (11,800 BTU/kWh)</td>
</tr>
</tbody>
</table>

### Exhaust Characteristics**(1)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx Emissions @ 15% O₂**(2)**</td>
<td>&lt; 9 ppmvd (18 mg/m³)</td>
</tr>
<tr>
<td>NOx / Electrical Output**(2)**</td>
<td>0.16 g/bhp-hr (0.46 lb/MWhe)</td>
</tr>
<tr>
<td>Exhaust Gas Flow</td>
<td>0.49 kg/s (1.08 lbm/s)</td>
</tr>
<tr>
<td>Exhaust Gas Temperature</td>
<td>309°C (588°F)</td>
</tr>
</tbody>
</table>

---

*Reliable power when and where you need it. Clean and simple.*
C65 ICHP Heat Recovery

Integrated Heat Recovery Module Type: Stainless Steel Core
Hot Water Heat Recovery: 74kW (251,000 BTU/hr)
Total System Efficiency LHV: 62%

Dimensions & Weight

<table>
<thead>
<tr>
<th>CR65</th>
<th>CR65 ICHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width x Depth</td>
<td>0.76 x 1.9 x 1.9 m</td>
</tr>
<tr>
<td></td>
<td>(30 x 77 x 76 in)</td>
</tr>
<tr>
<td>Weight</td>
<td>758 kg (1,671 lb)</td>
</tr>
</tbody>
</table>

Minimum Clearance Requirements

<table>
<thead>
<tr>
<th>CR65</th>
<th>CR65 ICHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical</td>
<td>0.61 m (24 in)</td>
</tr>
<tr>
<td>Horizontal</td>
<td></td>
</tr>
<tr>
<td>Left &amp; Right</td>
<td>0.76 m (30 in)</td>
</tr>
<tr>
<td>Front</td>
<td>0.76 m (30 in)</td>
</tr>
<tr>
<td>Rear</td>
<td>0.91 m (36 in)</td>
</tr>
</tbody>
</table>

Sound Levels

<table>
<thead>
<tr>
<th>CR65</th>
<th>CR65 ICHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustic Emissions at Full Load Power</td>
<td>70 dBA</td>
</tr>
<tr>
<td>Nominal at 10 m (33 ft)</td>
<td></td>
</tr>
</tbody>
</table>

Certifications

- Classified UL 2200 and UL 1741 for raw natural gas and biogas operation (UL file AU5040)
- Complies with IEEE 1547 and meets statewide utility interconnection requirements for California Rule 21 and the New York State Public Service Commission
- Models available with optional equipment for CE Marking
- Models available with optimal 2008 CARB certification for waste gas
## Quotation

### Sold-To-Party
Conestoga-Rover Associates (CRA)  
Attn: Scott Dunbar  
651 Colby Drive  
Waterloo, ON N2V 1C2, Canada

### Information
- **Document Number**: 70009176  
- **Document Date**: 07/24/2013  
- **Customer No.**: 789  
- **Validity Start Date**: 07/24/2013  
- **Validity End Date**: 08/24/2013

### Purchase Order Ref.
- **Gross Weight**: 1,263.000 KG  
- **Incoterms**: EXW Capstone  
- **Payment Term**: NT00 Payable on receipt  

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<thead>
<tr>
<th>Purchase Order Date</th>
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<tbody>
<tr>
<td><strong>Net Weight</strong></td>
<td>1,263.000 KG</td>
</tr>
<tr>
<td><strong>Currency</strong></td>
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### Item Details

<table>
<thead>
<tr>
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<th>Unit Price</th>
<th>Amount</th>
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<tbody>
<tr>
<td>10</td>
<td>65C-BG4-SC00 CR65,DIGSTR GAS,GC,INDPKG,SS HRM,CE</td>
<td>1.00 EA</td>
<td>112,200.00</td>
<td>112,200.00</td>
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</tbody>
</table>

**Sub Total**  
112,200.00

**Total Amount**  
$112,200.00
Technical Reference
Capstone Model C65 Electrical
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1. Introduction

This document defines the electrical performance ratings of the Capstone MicroTurbine® Model C65 in both single and MultiPac configurations. This information is intended for use in the evaluations of applications for the Capstone C65 Microturbine. Refer to Model C65 Product Specification (460044) for microturbine certification compliance.

The Capstone C65 Microturbine provides electrical power generation and can be configured for either Grid Connect or Stand Alone operation. The Grid Connect configuration causes the microturbine to source current into an energized electrical grid, and the Stand Alone configuration allows the microturbine to function as a grid-isolated voltage source.

Capstone C65 Microturbines may be used in applications requiring greater than 65 kW of load. They may be connected together, in groups (identified as a MultiPac), to provide the required amount of power. A MultiPac grouping of microturbines will function as if it were a single unit.

2. Referenced Documents

The following table contains a list of documents referenced in this Technical Reference.

<table>
<thead>
<tr>
<th>Document Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>410002</td>
<td>Fuel Requirements Technical Reference</td>
</tr>
<tr>
<td>410009</td>
<td>Electrical Installation Technical Reference</td>
</tr>
<tr>
<td>410014</td>
<td>CRMS Technical Reference Maintenance Edition</td>
</tr>
<tr>
<td>410028</td>
<td>Stand Alone Technical Reference</td>
</tr>
<tr>
<td>410032</td>
<td>MultiPac Operation Technical Reference</td>
</tr>
<tr>
<td>410033</td>
<td>Protective Relay Technical Reference</td>
</tr>
<tr>
<td>410044</td>
<td>Battery Performance Technical Reference</td>
</tr>
<tr>
<td>410048</td>
<td>C65 Performance Technical Reference</td>
</tr>
<tr>
<td>410071</td>
<td>Dual Mode System Controller Technical Reference</td>
</tr>
<tr>
<td>460044</td>
<td>Model C65 Product Specification</td>
</tr>
<tr>
<td>IEEE 519</td>
<td>Institute of Electrical and Electronic Engineers: Recommended Practices/Requirements for Harmonic Control – Electrical Power Systems</td>
</tr>
<tr>
<td>UL 1741</td>
<td>Underwriters Laboratories: Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources</td>
</tr>
<tr>
<td>VDE-AR-N 4105</td>
<td>Verband der Elektrotechnik: Technical Requirements for Connection to and Parallel Operation with Low-Voltage Distribution Networks</td>
</tr>
</tbody>
</table>
3. Electrical Ratings

Electrical ratings for Grid Connect configuration (Table 2) and Stand Alone configuration (Table 3) are provided in the following paragraphs. Single unit and MultiPac electrical ratings are included. Whenever MultiPac ratings are listed, N equals the number of individual microturbines within a MultiPac (where $1 \leq N \leq 30$). The maximum number of microturbines that may be connected together in a MultiPac is 20, but a MultiPac can be increased to 30 with the use of the Advanced Power Server (APS). Refer to the APS-145 Technical Reference (410079) for details.

C65 microturbines can also be configured for dual mode operation, which combines Grid Connect and Stand Alone modes. A dual-mode microturbine can operate in parallel with the utility grid when available and in Stand Alone during a utility outage. The capability to switch automatically between Grid Connect and Stand Alone modes is provided by the Dual Mode System Controller (DMSC). Refer to the Dual Mode System Controller Technical Reference (410071) for details.

Ratings are at ISO conditions, defined as 15 °C (59 °F), 60% relative humidity, and 101.325 kPa (14.696 psia, standard sea level pressure), with no inlet pressure losses, exhaust back pressure, or parasitic loads.

Protective relay settings are discussed in separate documents. Refer to the Protective Relay Technical Reference (410033) for applicable protective relay settings for Grid Connect Mode. Refer to the Stand Alone Technical Reference (410028) for the applicable protective relay settings for Stand Alone Mode.
## 3.1. Grid Connect

Table 2 presents the Electrical Ratings for the Grid Connect configuration.

### Table 2. Nominal Electrical Ratings: Grid Connect

<table>
<thead>
<tr>
<th>Description</th>
<th>Single Unit</th>
<th>MultiPac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Power</td>
<td>0 to 65 kW (3)</td>
<td>0 to 65 kW * N (3)</td>
</tr>
<tr>
<td>Output kVA</td>
<td>65 kVA</td>
<td>N*65 kVA</td>
</tr>
<tr>
<td>VDE / PF (5)</td>
<td>81 kVA</td>
<td>N*81 kVA</td>
</tr>
<tr>
<td>Voltage Range</td>
<td>400 / 480 VAC</td>
<td></td>
</tr>
<tr>
<td>Voltage Operating Range</td>
<td>360 to 528 VAC, (3-phase only)</td>
<td></td>
</tr>
<tr>
<td>Frequency Range</td>
<td>50 / 60 Hz</td>
<td></td>
</tr>
<tr>
<td>Frequency Operating Range</td>
<td>45–65 Hz. auto synchronization</td>
<td></td>
</tr>
<tr>
<td>Power Factor</td>
<td>± 0.985 displacement PF, for loads &gt; 25% of rated load</td>
<td>0.9 Leading / 0.9 lagging</td>
</tr>
<tr>
<td>VDE / PF (400 VAC) (6)</td>
<td></td>
<td>0.8 Leading / 0.8 lagging</td>
</tr>
<tr>
<td>VDE / PF (480 VAC) (6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Current, Maximum Steady State</td>
<td>100 A_{RMS}</td>
<td>N*100 A_{RMS}</td>
</tr>
<tr>
<td>Standard VDE / PF (5)</td>
<td>120 A_{RMS}</td>
<td>N*120 A_{RMS}</td>
</tr>
<tr>
<td>Grid Fault Current Contribution by Microturbine</td>
<td>145 A_{RMS}, maximum symmetrical and asymmetrical</td>
<td>N*145 A_{RMS}, maximum symmetrical and asymmetrical</td>
</tr>
<tr>
<td>Short Circuit Rating</td>
<td>145 A_{RMS}</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Connection</td>
<td>3-Phase, 4 wire, L1, L2, L3, and Neutral</td>
<td></td>
</tr>
<tr>
<td>Grid Voltage Phase Sequence</td>
<td>Auto synchronization. For Dual Mode applications, the grid voltage phase sequence must be L1, L2, L3</td>
<td></td>
</tr>
<tr>
<td>Grounding (8)</td>
<td>Grid must be neutral grounded</td>
<td></td>
</tr>
<tr>
<td>Maximum Grid Impedance</td>
<td>≤ 10% inductive (814 µH) and ≤ 5% resistive (0.153 ohms), Z_{base} = 3.07 ohms line-to-neutral</td>
<td>≤ 10% inductive (814/N µH) and ≤ 5% resistive (0.153/N ohms), Z_{base} = 3.07/N ohms line-to-neutral</td>
</tr>
<tr>
<td>Grid Voltage Harmonic Distortion (9)</td>
<td>The grid must comply with IEEE 519</td>
<td></td>
</tr>
<tr>
<td>Grid Voltage Balance</td>
<td>Within ± 2% at full load</td>
<td></td>
</tr>
<tr>
<td>Grid Voltage Phase Displacement</td>
<td>120 (± 1) degrees</td>
<td></td>
</tr>
<tr>
<td>Surge Voltage</td>
<td>ANSI C62.45 ± 6 kV</td>
<td></td>
</tr>
<tr>
<td>Output Current Harmonic Content</td>
<td>Complies with IEEE 519 &lt; 5% THD</td>
<td></td>
</tr>
<tr>
<td>Output Current DC Content</td>
<td>&lt; 0.6 Amps DC (per UL 1741)</td>
<td>&lt; N*0.6 Amps DC (UL 1741)</td>
</tr>
<tr>
<td>Power Required @ Start Command</td>
<td>6.8 kW peak, 0.014 kW-Hr, 42 Seconds</td>
<td>N*(6.8 kW peak, 0.014 kW-Hr, 42 seconds)</td>
</tr>
</tbody>
</table>
Table 2. Nominal Electrical Ratings: Grid Connect\(^{(1)}\) (Continued)

<table>
<thead>
<tr>
<th>Description</th>
<th>Single Unit</th>
<th>MultiPac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cool Down Power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gaseous Fuels</td>
<td>Cool Down Power</td>
<td>Cool Down Power</td>
</tr>
<tr>
<td>Liquid Fuel</td>
<td>2.0 kW peak, 0.3 kWh for 90 seconds</td>
<td>N*(2.2 kW peak, 0.3 kWh for 90 seconds)</td>
</tr>
<tr>
<td></td>
<td>5.0 kW peak, 11 kWh for 12 minutes</td>
<td>N*(2.2 kW peak, 11 kWh for 12 minutes)</td>
</tr>
<tr>
<td>Standby Power</td>
<td>0.8 kW</td>
<td>N*0.8 kW</td>
</tr>
<tr>
<td>Grid Inrush Current</td>
<td>24 Amps RMS</td>
<td>N*24 Amps RMS</td>
</tr>
<tr>
<td>@ Disconnect Switch Closure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Power Slew Rate(^{(2),(10)})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type A and Type B</td>
<td>0.35 kW/sec (250 rpm/sec)</td>
<td>N*0.35 kW/sec (250 rpm/sec)</td>
</tr>
<tr>
<td>Liquid Fuel</td>
<td>2.35 kW/sec (1700 rpm/sec)</td>
<td>N*2.35 kW/sec (1700 rpm/sec)</td>
</tr>
<tr>
<td>All Other</td>
<td>1.15 kW/sec (900 rpm/sec)</td>
<td>N*1.15 kW/sec (900 rpm/sec)</td>
</tr>
</tbody>
</table>

Table 2 Notes:

1. Ratings are at full load power and ISO conditions with zero back pressure. Values do not include parasitic losses from any accessories. The nominal values contained in this table do not reflect tolerance ranges. Deviation from the nominal value can occur due to differences between microturbines, measurement inaccuracies, and other factors.
2. Minimum power output is 35 kW for Type A and Type B fuels. Refer to Fuel Requirements Technical Reference (410002) for further definition on fuels.
3. The minimum typical power to the grid is 1.8 kW (@ T\(_{amb}\) = 122 °F) or 3.4 kW (@ T\(_{amb}\) = 59 °F) when the Power Demand is 0 kW. For MultiPac, the typical minimum power to the grid is N* 1.8 kW (@ T\(_{amb}\) = 122°F) or N*3.4 kW @ T\(_{amb}\) = 59°F).
4. Refer C65 Performance Technical Reference (410048) for real power capability as a function of ambient temperature, elevation, and other site conditions.
5. Software versions 5.40 and higher (gaseous fuels) and 2.20 and higher (liquid fuel) include Verband der Elektrotechnik (VDE) and Power Factor (PF) functionality. These software versions meet VDE-AR-N 4105 requirements for low voltage grid interconnection and allow for power factor control. Upgrades in the field to these software versions require key code to enable functionality.
6. The microturbine senses the grid waveform and synchronizes to its phases and frequency before an output connection is made.
7. Power factor adjustable range is from 0.8 leading to 0.8 lagging. Power fold back will occur once current limit of inverter is reached.
8. Refer to the Electrical Installation Technical Reference (410009) for grounding details.
9. Total harmonic voltage must be less than 5% (13.85 Volts RMS line-to-neutral). Also, the high frequency ripple voltage must be less than 5.5 Volts RMS line-to-neutral at frequencies greater than 3 kHz.
10. Slew rate includes both turbine acceleration and deceleration.
## 3.2. Stand Alone

Table 3 presents the Electrical Ratings for the Stand Alone configuration.

**Table 3. Nominal Electrical Ratings: Stand Alone**

<table>
<thead>
<tr>
<th>Description</th>
<th>Single Unit</th>
<th>MultiPac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Power</td>
<td>0 to 65 kW</td>
<td>0 to 0.95* 65 kW*N</td>
</tr>
<tr>
<td>Output kVA Standard (400 VAC)</td>
<td>69 kVA</td>
<td>kVA<em>N</em>0.95</td>
</tr>
<tr>
<td>Standard (480 VAC)</td>
<td>83 kVA</td>
<td></td>
</tr>
<tr>
<td>VDE / PF (400 VAC) (2)</td>
<td>83 kVA</td>
<td></td>
</tr>
<tr>
<td>VDE / PF (480 VAC) (2)</td>
<td>99 kVA</td>
<td></td>
</tr>
<tr>
<td>Voltage Range</td>
<td>400 / 480 VAC</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Adjustment Range</td>
<td>150 to 480 VAC line-to-line (1 VAC adjustment resolution)</td>
<td></td>
</tr>
<tr>
<td>Frequency Range</td>
<td>50 / 60 Hz</td>
<td></td>
</tr>
<tr>
<td>Output Frequency Adjustment Range</td>
<td>10 to 60 Hz (0.1Hz adjustment resolution) ± 0.05% accuracy</td>
<td></td>
</tr>
<tr>
<td>Load Power Factor (3)</td>
<td>0.8 lagging to 0.8 leading</td>
<td></td>
</tr>
<tr>
<td>Output Current Maximum Steady State Standard</td>
<td>100 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
<td>A&lt;sub&gt;RMS&lt;/sub&gt; = 0.9<em>100</em>N</td>
</tr>
<tr>
<td>VDE / PF (2)</td>
<td>120 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
<td>A&lt;sub&gt;RMS&lt;/sub&gt; = 0.9<em>120</em>N</td>
</tr>
<tr>
<td>Output Fault Current</td>
<td>145 A&lt;sub&gt;RMS&lt;/sub&gt;, maximum symmetrical and asymmetrical</td>
<td>N*145 A&lt;sub&gt;RMS&lt;/sub&gt;, maximum symmetrical and asymmetrical</td>
</tr>
<tr>
<td>Output Load Crest Factor Standard</td>
<td>1.8 maximum @ 100 A&lt;sub&gt;RMS&lt;/sub&gt; with CF=180/I&lt;sub&gt;RMS&lt;/sub&gt; for loads &lt; 100 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
<td>1.8 maximum @ A&lt;sub&gt;RMS&lt;/sub&gt; = 0.9<em>100</em>N</td>
</tr>
<tr>
<td>VDE / PF (2)</td>
<td>1.8 maximum @ 120 A&lt;sub&gt;RMS&lt;/sub&gt; with CF=180/I&lt;sub&gt;RMS&lt;/sub&gt; for loads &lt; 120 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
<td>CF=0.9<em>N</em>180/I&lt;sub&gt;RMS&lt;/sub&gt; for loads &lt; 0.9<em>120</em>N A&lt;sub&gt;RMS&lt;/sub&gt;</td>
</tr>
<tr>
<td>Output Instantaneous Load Current</td>
<td>180 A&lt;sub&gt;PEAK&lt;/sub&gt; maximum</td>
<td>0.9<em>N</em>180 A&lt;sub&gt;PEAK&lt;/sub&gt; maximum</td>
</tr>
<tr>
<td>Single Phase Loading (per individual microturbine within the MultiPac)</td>
<td>25 kW line-to-neutral maximum steady state</td>
<td></td>
</tr>
<tr>
<td>Load Unbalance among the 3 phases (per individual unit within the MultiPac)</td>
<td>25 kW maximum</td>
<td></td>
</tr>
<tr>
<td>Output Load Cycle Period</td>
<td>See Battery Performance Technical Reference (410044)</td>
<td></td>
</tr>
<tr>
<td>Motor Start, Across-the-Line</td>
<td>Motor inrush current &lt; 127 A&lt;sub&gt;RMS&lt;/sub&gt; (4)</td>
<td>Motor inrush current &lt; 0.9<em>N</em>127 A&lt;sub&gt;RMS&lt;/sub&gt; (4)</td>
</tr>
</tbody>
</table>
### Table 3. Nominal Electrical Ratings: Stand Alone\(^{(1)}\) (Continued)

<table>
<thead>
<tr>
<th>Description</th>
<th>Single Unit</th>
<th>MultiPac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Start, Ramp Voltage and Frequency(^{(4)})</td>
<td>127 Amps RMS maximum starting current at any frequency and voltage</td>
<td>0.9<em>N</em>127 Amps RMS maximum starting current at any frequency and voltage</td>
</tr>
<tr>
<td>Output Voltage Connection</td>
<td>3-Phase, 4 wire, L1, L2, L3, and Neutral</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Phase Sequence</td>
<td>L1, L2, L3</td>
<td></td>
</tr>
<tr>
<td>Grounding(^{(6)})</td>
<td>Neutral must be solidly connected to earth ground in a single location</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Harmonic Distortion with Linear Load</td>
<td>(\leq 5% \text{THD, which complies with IEEE 519})</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Harmonic Distortion with CF load, Crest Factor (CF) = (I_{\text{PEAK}} / I_{\text{RMS}})</td>
<td>(&lt; 8% \text{THD, } I_{\text{PEAK}} \leq 180 \text{ Amps}) (1.4 \leq \text{CF} \leq 3.0)</td>
<td>(&lt; 8% \text{THD, } I_{\text{PEAK}} \leq 0.9<em>N</em>180 \text{ Amps}) (1.4 \leq \text{CF} \leq 3.0)</td>
</tr>
<tr>
<td>Output DC Voltage Content</td>
<td>(\pm 2.5 \text{ Volts DC line-to-neutral})</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Step Load Regulation, load application or removal</td>
<td>(&lt; \pm 20% \text{ of nominal voltage for any resistive step load} \leq 100% \text{ rated output power capacity})</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Step Load Recovery Time</td>
<td>(&lt; 100 \text{ milliseconds to within } \pm 5% \text{ of nominal voltage for } \leq 100% \text{ rated output power step})</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Phase Displacement</td>
<td>(120 (\pm 1) \text{ degree @ balanced loads})</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Phase Displacement Jitter</td>
<td>(\pm 1 \text{ degree @ balanced loads})</td>
<td></td>
</tr>
<tr>
<td>Surge Voltage</td>
<td>ANSI C62.45 (\pm 6 \text{ kV})</td>
<td></td>
</tr>
<tr>
<td>Output Frequency Regulation</td>
<td>0.05% change for any steady state load or transient load (\leq 100%)</td>
<td></td>
</tr>
<tr>
<td>Output Frequency Stability, Temperature</td>
<td>(\pm 0.05%, -20 \text{ to } +60 \degree \text{C (internal temperature)})</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3 Notes:**

1. Ratings are at full load power and ISO conditions with zero back pressure. Values do not include parasitic losses from any accessories. The nominal values contained in this table do not reflect tolerance ranges. Deviation from the nominal value can occur due to differences between microturbines, measurement inaccuracies, and other factors.

2. Software versions 5.40 and higher (gaseous fuels) and 2.20 and higher (liquid fuel) include Verband der Elektrotechnik (VDE) and Power Factor (PF) functionality. These software versions meet VDE-AR-N 4105 requirements for low voltage grid interconnection and allow for power factor control. Upgrades in the field require key code to enable functionality.

3. Values shown are limited by maximum current capability of the power electronics. For system design, total power factor for all connected loads should not be less than 0.8 (inductive or capacitive).

4. Current limit must not be exceeded at any time during acceleration to full speed.

5. Refer to the Electrical Installation Technical Reference (410009) for grounding details.
4. Instrumentation Accuracy

The displays of the output voltages, currents, frequencies, and power have typical accuracies and coefficients as presented in Table 4.

<table>
<thead>
<tr>
<th>Instrumentation Item</th>
<th>Accuracy and Coefficients (Typical/Maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>±1.5% of Full Scale (typical) / ±3.0% (maximum)</td>
</tr>
<tr>
<td>Current Temperature Coefficient</td>
<td>± 0.2% of Full Scale over –20 to +60 °C range</td>
</tr>
<tr>
<td>Voltage</td>
<td>± 1.0% of Full Scale (typical) /±2.0% (maximum)</td>
</tr>
<tr>
<td>Voltage Temperature Coefficient</td>
<td>± 0.2% of Full Scale over –20 to +60 °C range</td>
</tr>
<tr>
<td>Output Power</td>
<td>± 2.5% of Full Scale (typical) /± 5.0%(maximum)</td>
</tr>
<tr>
<td>Output Power Temperature Coefficient</td>
<td>± 0.4% of Full Scale over –20 to +60 °C range</td>
</tr>
<tr>
<td>Output Frequency</td>
<td>± 0.05% of Reading (or Indication)</td>
</tr>
<tr>
<td>Output Frequency Temperature Coefficient</td>
<td>± 0.005% of Reading over –20 to +60 °C range</td>
</tr>
<tr>
<td>Real Time Clock</td>
<td>±1 minute per month</td>
</tr>
</tbody>
</table>

5. Communications Bay

The Communications Bay provides a user interconnection means for serial communications, digital inputs, digital outputs, analog inputs, and 12/24 volt DC power for a modem and auxiliary load operation. The following topics will be covered in the sections to follow.

- MultiPac Communication
- Serial Communication
- Wake-Up and E-Stop Inputs
- Digital Inputs
- Analog Inputs
- Digital Outputs
- Modem and User Power

Figure 1 presents a typical Model C65 board layout in the Communications Bay.
5.1. MultiPac

The MultiPac feature allows for inter-communication between an array of microturbines in order for all microturbines to be dispatched and controlled as a single power source. The following communication signals are passed among the microturbines in a MultiPac:

- **Ethernet** – passes control commands to all microturbines in the MultiPac from the Master controller.
- **RS485** – synchronizes voltage and frequency in Stand Alone mode for all microturbines in the MultiPac.
- **Passes Global E-Stop and Wake-Up signal** to all microturbines in the MultiPac.

Figure 2 shows two microturbines in a MultiPac configuration with a MultiPac cable and end terminators. Figure 3 shows how multiple microturbines are connected in a daisy chain pattern for a MultiPac configuration. Terminators must be installed on the first and last microturbines in the chain.
5.1.1. Signal Terminations

Signal terminators MUST be present on the initial and final connection for both Ethernet and RS-485 MultiPac cable connections (Figure 3). If termination is not present, electrical ringing may occur and the signal may be severely degraded or interrupted.

5.1.2. Ethernet I/O Connections (J1 and J2)

The connectors used for MultiPac communications are identified as J1 and J2 on the C65 UCB (see Figure 1). These connectors are 10BASE-2 connectors as specified in IEEE 802.3 Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications. Refer to MultiPac Operation Technical Reference (410032) and to APS-145 Technical Reference (410079) for MultiPac operation description.
NOTE: Connectors J1 and J2 are reserved for the interconnection of microturbines only. Connections made to these ports MUST be isolated from ground.

5.1.3. Ethernet Cabling Requirements

The cable type required for Ethernet connection is RG-58A/U (coaxial, 50-Ohm impedance). The recommended cable type is Belden, Part Number 9907 or equivalent. Basic requirements for cabling include the following:

- The maximum segment length of a thin wire 10B2 cable is 185 meters (607 feet). For longer segments, a fiber optic repeater can be used.
- Up to 30 connections (Medium Attachment Units or MAUs) are allowed per Ethernet segment. For larger LAN's, repeater hubs are required. Each repeater connection requires a MAU that must be counted toward the total of 30 MAU connections per segment.
- Each microturbine has 1.93 meters of internal cable length that must be included in the total length considerations. Repeaters may be added whenever the maximum cable length or the maximum numbers of nodes are exceeded.
- Whenever J1 or J2 are at the extremities of the Ethernet network, 50-ohm BNC terminators must be installed at these ports.

5.1.4. RS-485 Harness Interconnections (J6 and J8)

The RS-485 harness is used to transfer the following hardware signals between microturbines:

- Inverter synchronization (Stand Alone only); one microturbine serves as an inverter master, passing voltage and frequency signals to all other microturbines in the MultiPac for synchronization.
- Global E-Stop - Wired to one turbine (typically the master), which shuts down all other microturbines in the MultiPac when opened.
- Battery Wake-Up – Wired to one turbine (typically the master), which wakes up all other microturbines in the MultiPac for Stand Alone operation.

NOTE: The RS-485 harness is not required if operating in Grid Connect mode and the Global E-stop is not configured.

Table 5 and Table 6 define all connection for connectors J6 and J8.
### Table 5. Connector J6 – Inter-Controller (A) RS-485 Port

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J6 (A)</td>
<td>Serial Communication</td>
<td>RS-485, Bus A Protocol (^{1)})</td>
</tr>
<tr>
<td>J6 (B)</td>
<td>(Not Applicable)</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>J6 (C)</td>
<td>Inter-Controller Start</td>
<td>+24 Volts DC @ 15 milliamps per microturbine (^{2)})</td>
</tr>
<tr>
<td>J6 (D)</td>
<td>(Not Applicable)</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>J6 (E)</td>
<td>Global E-Stop</td>
<td>Normal Operation: N*42 milliamps. E-Stop: (+) 24 Volts DC (^{2)})</td>
</tr>
<tr>
<td>J6 (F)</td>
<td>(Not Applicable)</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>J6 (G)</td>
<td>(Not Applicable)</td>
<td>Spare</td>
</tr>
<tr>
<td>J6 (H)</td>
<td>E-Stop Return</td>
<td>Normal Operation: N*42 milliamps. E-Stop: 0 Volts DC</td>
</tr>
<tr>
<td>J6 (J)</td>
<td>(Not Applicable)</td>
<td>Reserved</td>
</tr>
<tr>
<td>J6 (K)</td>
<td>Inter-Controller Start Return</td>
<td>30 milliamps per microturbine @ 0 Volts DC</td>
</tr>
<tr>
<td>J6 (L)</td>
<td>(Not Applicable)</td>
<td>Reserved</td>
</tr>
<tr>
<td>J6 (M)</td>
<td>Serial Communication</td>
<td>RS-485, Bus B Protocol</td>
</tr>
</tbody>
</table>

**Table 5 Notes:**

1. Whenever J6 is at the extremities of the RS-485 multi-drop network; Capstone-provided terminators must be installed. The maximum number of nodes is 32, and the maximum RS-485 cable length is 1000 meters. Each microturbine has 1.93 meters of internal cable length, which must be included in the total length considerations. Repeaters may be added whenever the maximum cable lengths or the maximum number of nodes are exceeded.

2. The Global E-Stop connection sinks 42 mA per microturbine in a MultiPac E-Stop circuit. The voltage drop to the most remote microturbine in the interconnecting cables must be kept to 6 volts DC maximum N≤30 on any global E-Stop.
Table 6. Connector J8 – Inter-Controller (B) RS-485 Port

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J8 (A)</td>
<td>Serial Communication</td>
<td>RS-485, Bus A Protocol</td>
</tr>
<tr>
<td>J8 (B)</td>
<td>(Not Applicable)</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>J8 (C)</td>
<td>Inter-Controller Start</td>
<td>+24 Volts DC @ 15 milliamps per microturbine</td>
</tr>
<tr>
<td>J8 (D)</td>
<td>(Not Applicable)</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>J8 (E)</td>
<td>Global E-Stop</td>
<td>Normal operation: N*42 milliamps. E-Stop: (+) 24 VDC</td>
</tr>
<tr>
<td>J8 (F)</td>
<td>(Not Applicable)</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>J8 (G)</td>
<td>(Not Applicable)</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>J8 (H)</td>
<td>Global E-Stop Return</td>
<td>Normal operation: N*42 milliamps. E-Stop: 0 VDC</td>
</tr>
<tr>
<td>J8 (J)</td>
<td>(Not Applicable)</td>
<td>Reserved</td>
</tr>
<tr>
<td>J8 (K)</td>
<td>Inter-Controller Start Return</td>
<td>30 milliamps per microturbine @ 0 VDC</td>
</tr>
<tr>
<td>J8 (L)</td>
<td>(Not Applicable)</td>
<td>Reserved</td>
</tr>
<tr>
<td>J8 (M)</td>
<td>Serial Communication</td>
<td>RS-485, Bus B Protocol</td>
</tr>
</tbody>
</table>

Table 6 Notes:
(1) Whenever J8 is at the extremities of the RS-485 multi-drop network; Capstone-provided terminators must be installed. The maximum number of nodes is 32, and the maximum RS-485 cable length is 1000 meters. Each microturbine has 1.93 meters of internal cable length, which must be included in the total length considerations. Repeaters may be added whenever the maximum cable lengths or the maximum numbers of nodes are exceeded.

(2) The Global E-Stop connection sinks 42 milliamps per microturbine in a MultiPac E-Stop circuit. The voltage drop to the most remote microturbine in the interconnecting cables must be kept to 6 volts DC maximum N≤30 on any global E-Stop.

5.2. Serial Communication Ports (J3 and J5)

A PC or PLC device may be connected to the UCB for monitoring, controlling, or troubleshooting a microturbine system. The microturbine communicates via RS-232 protocols using a null modem cable with hardware handshaking. A DB9 connector (User Port) and a DB25 connector (Maintenance Port) are available. If devices are connected to both ports, the port accessed at a higher password level has priority for command of the system. If both are at the same password level, the Maintenance Port has priority.

5.2.1. DB25 Connector J3 (Maintenance Port)

Table 7 and Figure 4 define the connections for connector J3.

Table 7. DB25 Connector J3 (Maintenance Port)

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J3</td>
<td>Maintenance Interface Port</td>
<td>DB25 (male polarity) and RS-232 protocol. Maximum null modem cable length is 50 feet</td>
</tr>
</tbody>
</table>

Table 7 Notes:
(1) Connections made to these ports MUST be isolated from ground and/or communication ports of other microturbines.

A 25-pin RS-232 connector is used for Maintenance Port and is identified as J3 on the C65 UCB (see Figure 4). Pin designations are as follows:
### 5.2.2. DB9 Connector J5 (User Port)

Table 8 and Figure 5 define the connections for connector J5.

#### Table 8. DB9 Connector J5 (User Port)

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Signal</th>
<th>Description</th>
<th>RS-232 Connector (DB9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DCD</td>
<td>Data Carrier Detect</td>
<td>Pin 1, Pin 5</td>
</tr>
<tr>
<td>2</td>
<td>RXD</td>
<td>Receive Data</td>
<td>Pin 6, Pin 9</td>
</tr>
<tr>
<td>3</td>
<td>TXD</td>
<td>Transmit Data</td>
<td>Pin 1, Pin 5</td>
</tr>
<tr>
<td>4</td>
<td>DTR</td>
<td>Data Terminal Ready</td>
<td>Pin 1, Pin 5</td>
</tr>
<tr>
<td>5</td>
<td>SG</td>
<td>Signal Ground</td>
<td>Pin 1, Pin 5</td>
</tr>
<tr>
<td>6</td>
<td>DSR</td>
<td>Data Set Ready</td>
<td>Pin 1, Pin 5</td>
</tr>
<tr>
<td>7</td>
<td>RTS</td>
<td>Request to Send</td>
<td>Pin 1, Pin 5</td>
</tr>
<tr>
<td>8</td>
<td>CTS</td>
<td>Clear To Send</td>
<td>Pin 1, Pin 5</td>
</tr>
<tr>
<td>9</td>
<td>RI</td>
<td>Ring Indicator</td>
<td>Pin 1, Pin 5</td>
</tr>
</tbody>
</table>

**Figure 5. RS-232 Connector (DB9)**

A 9-pin RS-232 connector is used for the User Port and is identified as J5 on the C65 UCB (see Figure 5). Pin designations are as follows:
5.2.3. Computer to Microturbine Communication

A communication cable is required for connection from a computer to the microturbine’s User or Maintenance port. A null modem cable is required for this connection.

A null modem (or modem eliminator) cable is commonly used for connecting two computers together without a modem. It is a RS-232 cable that interchanges conductors 2 and 3. Wiring connections for null modem cables with DB9 connector (see Figure 6) and DB25 connector (see Figure 7) are as follows:

![Figure 6. DB9 Null Modem Cable](image)

![Figure 7. DB25 Null Modem Cable](image)
5.2.4. Connections to Third-Party Modems

The following paragraphs present connection details between the microturbine and the third-party modems.

5.2.4.1 Communications Cable

The modem can be connected to the User Port or Maintenance Port of the microturbine. Typically, it is connected to the Maintenance Port. A straight-through serial cable is required in most cases for data connection between the modem and the microturbine.

5.2.4.2 Modem and Microturbine Settings

The microturbine port speed setting must be set to the same speed as the modem.

The default hardware configuration for the User and Maintenance Ports is 57,600 bits per second (maximum speed), 8-bit word length, no parity, one stop bit, and hardware handshake for flow control. It is recommended to use the highest speed available on the modem, not exceeding the maximum speed of the microturbine port.

Upon initialization, the microturbine sends an AT&F command to restore the factory settings of the modem. If this affects the desired settings on the modem, the modem can be powered on by a delay timer of at least two minutes after the microturbine wakes up. In this case, the modem should be configured independently though a HyperTerminal session or using the modem’s PC software.

Some telemetry modems have different modes for data packet transmission. For the microturbine to communicate properly, the transmitted data packets should never be split.
5.3. Wake-Up and E-Stop Inputs (J10)

Table 9 defines all connection for connector J10.

**Table 9. Connector J10 – Wake-Up and E-Stop Connector**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J10 (11)</td>
<td>Local E-Stop (Input)</td>
<td>Dry circuit contact closure. Closed for normal operation, open for E-Stop. (+) 24 Volts DC @ 42 milliamps (1)</td>
</tr>
<tr>
<td>J10 (10)</td>
<td>Local E-Stop (Input)</td>
<td>Return for J10 (11) (1)</td>
</tr>
<tr>
<td>J10 (9)</td>
<td>Global E-Stop (Input)</td>
<td>MultiPac dry circuit contact closure. Closed for normal operation, open for E-Stop. (+) 24 Volts DC @ N*42 milliamps (1)</td>
</tr>
<tr>
<td>J10 (8)</td>
<td>Global E-Stop (Input)</td>
<td>Return for J10 (9) (1)</td>
</tr>
<tr>
<td>J10 (7)</td>
<td>JUCB Battery Power (Output)</td>
<td>+12 Volts JUCB Battery Power, 0.6 Amps re-settable fused (2)</td>
</tr>
<tr>
<td>J10 (6)</td>
<td>Internal Battery Wake Signal (Input)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J10 (5)</td>
<td>Inter Start (Input/Output)</td>
<td>(Output) = MultiPac start signal, +24 Volts DC, 30 milliamps/0.7 Amps maximum, momentary (0.1 to 2 seconds), 27 C65 units maximum connections. (Input) = 755 ohms load (1)</td>
</tr>
<tr>
<td>J10 (4)</td>
<td>Inter Start (Input/Output) Return</td>
<td>Return for signal of J10 (5) (1)</td>
</tr>
<tr>
<td>J10 (3)</td>
<td>Wake up signal if asleep (Input)</td>
<td>Momentary (0.1 to 2 seconds) input +4 to +15 Volts with respect to J10 (2). Opto-isolated (±150 Volts DC maximum to earth)</td>
</tr>
<tr>
<td>J10 (2)</td>
<td>Wake up signal if asleep (Input) Return</td>
<td>Isolated return for signal of J10 (2)</td>
</tr>
<tr>
<td>J10 (1)</td>
<td>Chassis Ground</td>
<td>To be used for cable shield connections</td>
</tr>
</tbody>
</table>

**Table 9 Notes:**
1. Connections made to these terminals MUST be Dry Circuit rated and isolated from ground/chassis. They may not be connected in parallel with other microturbine input terminals.
2. Connections made to this terminal MUST be isolated from ground/chassis. It may not be connected in parallel with other microturbine input and/or power supply terminals.
5.3.1.  E-Stops

| CAUTION: Emergency stops increase stress on the system components. Repeated use of the Emergency Stop feature will result in damage to the microturbine. Use only in emergency situations. |

Two Emergency Stop (E-Stop) inputs are available in the UCB Communications Bay (see Figure 8). The E-Stop inputs are identified as Local and Global E-Stops. These inputs are simple contact closures intended for dry contact circuits.

| NOTE: If no external E-Stop device is installed, the E-Stop terminals in the UCB must be jumpered. |

5.3.1.1  Single MT E-Stop (Local)

Local E-Stop is used on a single microturbine system. When activated, it will only stop the microturbine that the E-Stop is wired to. See to Figure 8 for wiring details.

![Figure 8. Single MT E-Stop (Local)](image-url)
5.3.1.2 MultiPac E-Stop (Global E-Stop)

Global E-Stop is used on MultiPac Configurations (see Figure 9). The external E-Stop only needs to be connected to one microturbine in the MultiPac. When activated, it will stop all microturbine systems in the MultiPac.

The Global E-Stop jumper requirements are as follows:

- The local E-Stop (LCL ESTOP) pins on J10 of each microturbine in the MultiPac must be jumpered.
- The jumper must be removed from the global E-Stop (GLBL ESTOP) pins on J10 of each microturbine in the MultiPac.

![Diagram of MultiPac E-Stop (Global E-Stop)](image)

Figure 9. MultiPac E-Stop (Global E-Stop)

5.3.2. Battery Wake-Up Connections

A Stand Alone capable (battery-equipped) microturbine enters Sleep Mode to conserve battery power during prolonged periods of inactivity. A potential-free external contact that provides a momentary pulse can be used to wake up the microturbine from Sleep Mode, as well as any other microturbine connected through its MultiPac cable.
5.3.2.1 **Single MT/MultiPac Wake-Up (Internal Battery)**

An external UCB connection that uses internal 12 VDC power to wake up the microturbine is shown in Figure 10.

![Figure 10. Single MT/MultiPac Wake-Up (Internal Battery)](image)

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5.3.2.2 **Single MT/MultiPac Wake-Up – Opto-Isolated (Externally Powered)**

An external UCB connection that uses external power (4-15 VDC) to wake up the microturbine is shown in Figure 11.

![Diagram showing UCB External connection with labels and connection points for LCL ESTOP, LCL ESTOP, GLBL ESTOP, GLBL ESTOP, JUCB BAT PWR, BAT START, INTER-STRT, INTER-RTN, ISO BSTART+, ISO BSTART-, CHASSIS, and 4 TO 15 Vdc. A momentary pulse (0.1S - 2S) is indicated.]

**Figure 11. Single MT/MultiPac Wake-Up – Opto Isolated (Externally Powered)**
5.3.2.3 **Single MT/MultiPac Wake-Up (Externally Powered)**

An external UCB connection that uses external power (24 VDC) to wake up the microturbine is shown in Figure 12.

![Diagram of Single MT/MultiPac Wake-Up (Externally Powered)](image)

**Figure 12. Single MT/MultiPac Wake-Up (Externally Powered)**

### 5.4. Opto-Isolated Inputs - Reserved (J11)

The opto-isolated inputs shown in Table 10 are reserved and not available for use.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J11 (9)</td>
<td>OPTO 3 (+)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (8)</td>
<td>OPTO 3 (-)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (7)</td>
<td>OPTO 2 (+)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (6)</td>
<td>OPTO 2 (-)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (5)</td>
<td>OPTO 3 (+)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (4)</td>
<td>OPTO 3 (-)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (3)</td>
<td>AGND</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (2)</td>
<td>DIGINSPIR</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (1)</td>
<td>Chassis Ground</td>
<td>To be used for shield connections</td>
</tr>
</tbody>
</table>
### 5.5. Digital Inputs (J12)

Table 11 defines all connection for connector J12.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J12 (13)</td>
<td>AGND</td>
<td>Return circuit for connector J12 contact closures (1)</td>
</tr>
<tr>
<td>J12 (12)</td>
<td>PWR (+) (Wattmeter)</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms (1)</td>
</tr>
<tr>
<td>J12 (11)</td>
<td>PWR (-) (Wattmeter)</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms (1)</td>
</tr>
<tr>
<td>J12 (10)</td>
<td>KVAR (+) (Wattmeter)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J12 (9)</td>
<td>KVAR (-) (Wattmeter)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J12 (8)</td>
<td>AGND</td>
<td>Return circuit for connector J12 contact closures (1)</td>
</tr>
<tr>
<td>J12 (7)</td>
<td>FLT2 (User Fault Input)</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms (1)</td>
</tr>
<tr>
<td>J12 (6)</td>
<td>FLT1 (User Fault Input)</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms (1)</td>
</tr>
<tr>
<td>J12 (5)</td>
<td>AGND</td>
<td>Return circuit for connector J12 contact closures (1)</td>
</tr>
<tr>
<td>J12 (4)</td>
<td>Start/Stop</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms (1)</td>
</tr>
<tr>
<td>J12 (3)</td>
<td>GC (Grid Connect mode)</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms (1)</td>
</tr>
<tr>
<td>J12 (2)</td>
<td>SA (Stand Alone mode)</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms (1)</td>
</tr>
<tr>
<td>J12 (1)</td>
<td>Chassis Ground</td>
<td>To be used for shield connections</td>
</tr>
</tbody>
</table>

**Table 11 Notes:**

1. Connections made to these terminals MUST be Dry Circuit rated and isolated from ground/chassis. They may not be connected in parallel with other microturbine input terminals.
5.5.1. Load Following Pulse Inputs

Two digital inputs are used for load following and reverse power protection. A power meter is required to provide potential free contacts that provide pulses for forward energy flow, and pulses for reverse energy flow.

Power flow in the forward direction (toward the loads) is measured as +PWR.

Power flow in the reverse direction is measured as –PWR. This input is only used if reverse power protection is required and enabled.

A 5 V wetting voltage is provided by the microturbine. See Figure 13 for wiring details and maximum wire length.

![Figure 13. Load Following Pulse Inputs](image-url)
5.5.2. Load Following Pulse Inputs (Interposing Relays)

Interposing relays are used to extend the distance > 100 feet. See Figure 14 for wiring details.

![Figure 14. Load Following Pulse Inputs (Interposing Relays)](image_url)
5.5.3. Fault Inputs

Fault inputs are simple contact closures intended for dry contact circuits.

The following settings (set in CRMS) are available for fault inputs:

- Enable/Disable (On/Off) – If On, control detects a fault input into the system from an external fault source.
- Fault Level - defines the system severity level of this fault source.
  - Level 2 – Warning issued. Microturbine will continue to operate.
  - Level 3 – Standard microturbine shutdown sequence (cooldown).
  - Level 4 – Fast microturbine shutdown sequence (warmdown).
- Time (sec) - adjusts the debounce time for fault input detection from an external device, i.e., how much time the fault is detected for before the fault is latched in the system.
- Active (Open / Close)
  - Active Open – If the fault input contact changes state and moves from a closed position to an open position the fault will occur.
  - Active Close – If the fault input contact changes state and moves from an open position to a closed position the fault will occur.

Figure 15 shows a wiring example for fault input 1 and 2. This example is set up as follows:

- Fault input 1 is used to shut down the microturbine in the event that the external push button (normally closed) is activated. This change of state is configured as Active Open in CRMS.
- Fault input 2 is used to shut down the microturbine in the event that the contact (normally open) is activated. This is change of state is configured as Active Close in CRMS.
5.5.4. Fault Inputs Using Interposing Relays

Interposing relays are used for cable length greater than a 100ft and to fault multiple microturbines from a single fault device.

**CAUTION:** Interposing relays are required if multiple microturbines are required to be faulted by an external fault input. Microturbine fault inputs cannot be wired together and need to be electrically isolated.

Figure 16 shows a wiring example using interposing relays. This example is set up as follows:

- Fault input 1 is used to shut down the microturbines in the event that the external fault device (normally closed) is activated. This is change of state at relay R1 contacts is configured as Active Close in CRMS.
Figure 16. Fault Inputs Using Interposing Relays
5.5.5. Start/Stop Command in GC Mode

Figure 17 shows how a microturbine is wired for start and stop commands in Grid Connect mode. A contact closure provides a start command and a contact release provides a stop command. The GC interlock must be linked (jumpered) for Grid Connect operation.

![Diagram showing start/stop command in GC mode](image-url)
5.5.6. Start/Stop Command in SA Mode

Figure 18 shows how a microturbine is wired for start and stop commands in Stand Alone mode. A contact closure provides a start command and a contact release provides a stop command. The SA interlock must be linked (jumpered) for Stand Alone operation.

![Figure 18. Start/Stop Command in SA Mode](image-url)
5.5.7. Start/Stop, GC and SA Command with DMSC

Figure 19 shows an example of how a microturbine is wired for start and stop commands in Dual Mode. A contact closure provides a start command and, a contact release provides a stop command. The Stand Alone and Grid Connect interlocks positions are defined by the Dual Mode System Controller (DMSC). Refer to the DMSC Technical Reference (410071) for details.

Figure 19. Start/Stop, GC and SA Command with DMSC
5.6. Analog Inputs (J14)

Table 12 defines all connections for connector J14 and Figure 20 shows a wiring example using the 0-5 VDC analog inputs. Figure 21 shows the difference in wiring between analog inputs configured for voltage signal and current signal. Refer to the following paragraphs for details.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J14 (6)</td>
<td>AGND</td>
<td>Return for analog signals. Impedance = 10 ohms</td>
</tr>
<tr>
<td>J14 (5)</td>
<td>ANIN1</td>
<td>0 to (+) 5 Volts DC, high impedance</td>
</tr>
<tr>
<td>J14 (4)</td>
<td>ANIN2</td>
<td>0 to (+) 5 Volts DC, high impedance</td>
</tr>
<tr>
<td>J14 (3)</td>
<td>ANIN3</td>
<td>0 to (+) 5 Volts DC, high impedance</td>
</tr>
<tr>
<td>J14 (2)</td>
<td>AGND</td>
<td>Return for analog signals. Impedance = 10 ohms</td>
</tr>
<tr>
<td>J14 (1)</td>
<td>Chassis Ground</td>
<td>To be used for shield connections</td>
</tr>
</tbody>
</table>

Table 12 Notes:
(1) Connections made to these terminals MUST be isolated from ground/chassis. They may not be connected in parallel with other microturbine input terminals.
5.6.1. Analog Inputs

Refer to the CRMS Technical Reference Maintenance Edition (410014) and enter the settings for the analog inputs as follows:

1. At the User Connection Bay Settings Panel, select the Input Signal Type:
   - **4-20 mA**: In order for the 4-20 mA input to work, a customer-supplied 250 ohm resistor must be installed. Internal software is scaled to work from 0.9 V to 4.5 V for full range operation (see Figure 21).
   - **0-5 V**: Function range is scaled between 0 V and 5 V.
2. Refer to Table 13 and select a function for the analog input.
3. Refer to Table 14 and enter the Low and High Limits for the function. Table 14 gives the minimum and maximum allowable values. For the Electrical Power Demand function, the High Limit displays 65000 W as the default. For a single microturbine application this value does not need to be changed. For a MultiPac, enter the maximum combined power demand of the microturbines in the MultiPac. For example, if the MultiPac consists of three C65 microturbines, the high limit will be 195000 W (3 X 65000).
Table 13. Connector J14 – Analog Input Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not assigned</td>
<td>No software function assigned (Default).</td>
</tr>
<tr>
<td>Electrical Power Demand</td>
<td>Provides output power demand feedback</td>
</tr>
<tr>
<td>CHP Water Flow Rate</td>
<td>Provides water flow feedback if iCHP option is installed.</td>
</tr>
<tr>
<td>CHP Temperature Feedback</td>
<td>Provides temperature feedback if iCHP option is installed. Input can be used for thermal load following.</td>
</tr>
<tr>
<td>Propane Temperature Feedback</td>
<td>Reserved (Do not use)</td>
</tr>
</tbody>
</table>

Table 14. Analog Input Limits

<table>
<thead>
<tr>
<th>Function</th>
<th>Low Limit</th>
<th>High Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Signal Type</td>
</tr>
<tr>
<td></td>
<td>0-5 V</td>
<td>4-20 mA</td>
</tr>
<tr>
<td>Electrical Power Demand</td>
<td>0W</td>
<td>0 V</td>
</tr>
<tr>
<td></td>
<td>0 V</td>
<td>0.9 V (3.6 mA)</td>
</tr>
<tr>
<td>CHP Water Flow Rate</td>
<td>0 gpm</td>
<td>0 V</td>
</tr>
<tr>
<td></td>
<td>0 V</td>
<td>5 V</td>
</tr>
<tr>
<td>CHP Temperature Feedback</td>
<td>32 °F</td>
<td>0 V</td>
</tr>
<tr>
<td></td>
<td>0 V</td>
<td>5 V</td>
</tr>
</tbody>
</table>

5.6.2. Analog Input Scaling

The high and low limits entered in CRMS for an analog input function are used by the microturbine software as the starting and ending points of a linear scale. As shown in Table 14, the scale is different depending on whether the signal type is 0-5 V or 4-20 mA. How this scale is generated for each signal type is described below:

- Signal Type 0-5 V: The range of values is scaled between 0 and 5 Volts. Using CHP Water Flow Rate as an example, a voltage signal of 0 V represents 0 gpm and a voltage signal of 5 V represents 80 gpm. Therefore, a midrange voltage signal of 2.5 V would represent 40 gpm.

- Signal Type 4-20 mA: The software establishes a range between 0.9 V to 4.5 V for this signal type as shown in Figure 22. Fluctuations above and below this range can be misread by the system. The signal is treated as a fault if it is greater than 18.8 mA or less than 2.8 mA. Using CHP Water Flow Rate as an example, a current signal (using a 250 Ohm resistor) of 3.6 mA (0.9 V) represents 0 gpm and a current signal of 18 mA (4.5 V) represents 80 gpm. Therefore, a midrange signal of 10.8 mA (2.7 V) would represent 40 gpm.
5.7. Digital Outputs (J15)

Table 15 defines all connections for connector J15.

<table>
<thead>
<tr>
<th>Relay</th>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>#6</td>
<td>J15 (12)</td>
<td>AC6-B</td>
<td>AC6 load, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td></td>
<td>J15 (11)</td>
<td>AC6-A</td>
<td>AC6 line, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td>#5</td>
<td>J15 (10)</td>
<td>AC5-B</td>
<td>AC5 load, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td></td>
<td>J15 (9)</td>
<td>AC5-A</td>
<td>AC5 line, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td>#4</td>
<td>J15 (8)</td>
<td>AC4-B</td>
<td>AC4 load, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td></td>
<td>J15 (7)</td>
<td>AC4-A</td>
<td>AC4 line, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td>#3</td>
<td>J15 (6)</td>
<td>AC3-B</td>
<td>AC3 load, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td></td>
<td>J15 (5)</td>
<td>AC3-A</td>
<td>AC3 line, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td>#2</td>
<td>J15 (4)</td>
<td>AC2-B</td>
<td>AC2 load, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td></td>
<td>J15 (3)</td>
<td>AC2-A</td>
<td>AC2 line, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td>#1</td>
<td>J15 (2)</td>
<td>AC1-B</td>
<td>AC1 load, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td></td>
<td>J15 (1)</td>
<td>AC1-A</td>
<td>AC1 line, 25 VAC max, 100 mA max</td>
</tr>
</tbody>
</table>

Table 15 Notes:
(1) These contacts must only be connected in Class 2 circuit for limited voltage and limited current power source at maximum voltage of 25 VAC. If switching at higher voltages and currents is required, please contact Capstone Applications for recommendations.
**CAUTION:** Digital outputs must be configured BEFORE making any electrical connections. Failure to do this may cause damage to the microturbine and void the warranty.

For some applications, the current draw required on the external equipment may exceed the rated current on the UCB relays. In these cases, an interposing relay must be installed.

**CAUTION:** The coil rating of the interposing relay must not exceed the rated current and voltage on the UCB relays. Otherwise permanent damage to the UCB board may occur.

Electromechanical interposing relays are highly recommended over solid-state relays for electrical isolation.

The digital outputs (output relays) are simple contact closures intended for dry contact circuits. Wetting voltage must be provided by external power source.

The following functions (set in CRMS) are available for Digital Outputs:

- Control State Functions - digital outputs can be selected to switch at any control state as defined in Table 16.
- Active (Open / Close)
  - Active Open – If a control state is TRUE the digital output will change from a closed to open position.
  - Active Close – If a control state is TRUE the digital output will change from an open to closed position.

**NOTE:** When the microturbine is powered off the digital outputs revert back to their de-energized state of normally open.

Table 16 lists the control state functions that can be used with the output relays described in Table 15. Refer to the CRMS Technical Reference Maintenance Edition (410014) for details.

<table>
<thead>
<tr>
<th>Function</th>
<th>Control State (Function is True)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standby</td>
<td>System is in the Standby state.</td>
</tr>
<tr>
<td>Run</td>
<td>Engine is running or power electronics are enabled.</td>
</tr>
<tr>
<td>Contactor Closed</td>
<td>Output Contactor is closed.</td>
</tr>
<tr>
<td>Fault</td>
<td>Fault occurs that is severity level 3 or greater</td>
</tr>
<tr>
<td>Stand Alone</td>
<td>System is in the Stand Alone mode</td>
</tr>
<tr>
<td>Stand Alone Load</td>
<td>System is in the Stand Alone mode and in the Load State.</td>
</tr>
<tr>
<td>Disable</td>
<td>System is in the Disable state.</td>
</tr>
<tr>
<td>Fuel On</td>
<td>Electrical fuel shut-off is enabled.</td>
</tr>
<tr>
<td>Fuel Purge</td>
<td>10 seconds after the electrical fuel shutoff is closed (for units equipped for liquid fuel only)</td>
</tr>
<tr>
<td>Load State</td>
<td>System is in the Load State (GC or SA).</td>
</tr>
</tbody>
</table>
Table 16. Control State Functions (Continued)

<table>
<thead>
<tr>
<th>Function</th>
<th>Control State (Function is True)</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Load</td>
<td>System is in Prepare to Start state and DC bus has been raised. This is generally used to start gas compressors that are powered from the DC bus.</td>
</tr>
<tr>
<td>Protective Relay</td>
<td>System has “PRT RLY Fault” (Protective Relay Fault).</td>
</tr>
<tr>
<td>Anti-islanding</td>
<td>System has “ANTI-ISL Fault” (Anti-Islanding Fault).</td>
</tr>
<tr>
<td>Not Assigned</td>
<td>No software function assigned (Default).</td>
</tr>
<tr>
<td>CHP Active (If installed)</td>
<td>This function is true when the system detects microturbine exhaust gas flow. Active in the following states: Light, Acceleration, Run, Load, Recharge (SA only), CoolDown, WarmDown, and Restart.</td>
</tr>
<tr>
<td>Dual Mode Control</td>
<td>This function is true for Dual Mode configured systems only. When selected it will act as an interlock to ensure the main breaker (M1) cannot be opened when performing Stand Alone operation.</td>
</tr>
<tr>
<td>HTC Start Relay</td>
<td>Reserved (Do not use)</td>
</tr>
<tr>
<td>EUCB</td>
<td>Reserved (Do not use)</td>
</tr>
</tbody>
</table>

5.7.1. Solid State Relays

Figure 23 shows how a microturbine is wired to the digital output to provide a start signal for an external gas compressor. The control state for relay #1 (AC1) would be set for External Load and the Active Close. The wiring diagram also shows how the interlock signal would be wired to the Dual Mode System Controller (DMSC). The control state for relay #2 (AC2) would be set for DUAL MODE CNTRL and Active Closed.
5.8. User Power (J16)

Table 17 defines all connections for connector J16. See Figure 24 for example connections using connector J16.

Table 17. Connector J16 – Modem and User Power Outputs

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J16 (4)</td>
<td>PWRGND</td>
<td>User Power Return</td>
</tr>
<tr>
<td>J16 (3)</td>
<td>User Power</td>
<td>24 Volts DC, 1 Amp maximum (fuse protection must be provided when used)</td>
</tr>
<tr>
<td>J16 (2)</td>
<td>PWRGND</td>
<td>Modem Power Return</td>
</tr>
<tr>
<td>J16 (1)</td>
<td>Modem Power</td>
<td>12 Volts DC, 0.5 Amps maximum (fuse protection must be provided when used)</td>
</tr>
</tbody>
</table>

Table 17 Notes:
(1) Connections made to these terminals MUST be isolated from ground/chassis. They may not be connected in parallel with other microturbine input and/or power supply terminals.
Figure 24. User Power (J16)
Scott,

FPP

<table>
<thead>
<tr>
<th>Plans</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan B: 5 yr - 39,999 hrs, Parts &amp; Labor No Overhaul</td>
<td>$24,550.00</td>
</tr>
<tr>
<td>Plan D: 9 yr - 79,999 hrs, Parts &amp; Labor with Overhaul</td>
<td>$65,475.00</td>
</tr>
</tbody>
</table>

Give me a call to discuss anything I have sent.

Thank You,

Sumner Bachman II  
Regional Sales Manager  
Capstone Turbine Corporation  
sbachman@capstoneturbine.com  
direct: 818-734-5420
Technical Reference
Capstone MicroTurbine Electrical Installation

Introduction
This document presents electrical installation information for the Capstone Turbine Corporation® Model C30 and Model C60/C65 MicroTurbine™ systems.

Alternating current electrical power may be paralleled with a utility grid or with another generation source, or the MicroTurbine can act as a Stand Alone generator for standby, backup, or remote off-grid power. Multiple systems can be combined and controlled as a single larger generating source, commonly known as a MultiPac.

State-of-the-art digital power conditioning provides two output choices:

- Built-in utility-synchronized alternating current output with built-in protective relay functions.
- Stand Alone alternating current output (optional).

This document describes proper electrical interconnection for the Alternating Current (AC) output versions only. Refer to our Hybrid Electric Vehicle documentation for Direct Current (DC) model installation instructions.

Additional MicroTurbine electrical performance parameters are contained within the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001).
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System Operating Modes
The Capstone MicroTurbine can function in two operational modes:

- Grid Connect Mode (GC)
- Stand Alone Mode (SA)

A Dual Mode connection option (which requires an optional Dual Mode Controller), is available that allows automatic transition between GC and SA modes.

Operation as a MultiPac is available for both operational modes.

| CAUTION | All of the allowable utility service connections for the various MicroTurbine operating modes are presented in this document. Consult Capstone if your utility service connections do not agree with those presented in this document. |

Grid Connect Output
The Capstone MicroTurbine electrical output in Grid Connect mode is 3-phase, 400 to 480 Volts AC and 45 to 65 Hz (both voltage and frequency are determined by the grid). Refer to Figure 1 as required.

Stand Alone Output
When equipped with the Stand Alone option, the electrical output is user adjustable from 150 to 480 Volts AC, 10 to 60 Hz.

The current in each phase may be continuous and need not be balanced, as long as the electrical current limits are respected. Refer to the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001) for details on electrical ratings.

Stand Alone loads may be connected phase-phase or phase-neutral, so long as the current limits are respected. Overloads up to 10 seconds can be accommodated. The Ramp Start feature can assist in starting loads with large in-rush currents.

Dual Mode Connections
A MicroTurbine equipped with the Stand Alone option is capable of either Grid Connect operation or Stand Alone operation. Conversion from one mode to the other requires a shutdown of the MicroTurbine. Conversion may be accomplished manually or automatically.

Automatic transfer may be accomplished with the optional Capstone Dual Mode Controller. Refer to the Dual Mode Controller Technical Reference (410039) for details.

MultiPac Power Connections
Refer to the MultiPac Technical Reference (410032) for details on MultiPac operation. Connections for the MultiPac are supported in the Stand Alone, Grid Connect, and Dual Mode configurations.

Power Quality
Power Connections between Systems

Power connections between systems are provided for the following connection methods:

- Grid Connect
- Stand Alone
- Dual Mode
- MultiPac

Utility Power Connections

Utility power connections are provided for the following methods of connection:

- Direct Connection
- Transformer Connection

Both solid-grounded and resistance-grounded Wye utility connections are permitted.

Stand Alone Connections

Stand Alone connections are provided as follows:

- Three-Phase Loads
- Single-Phase Loads
- Transformer

Dual-Mode Connections

Dual-Mode connections are provided as follows:

- Direct Connection
- Transformer Connection
Electrical Connections – Grid Connect

Figure 1 presents the various allowable connections for the Grid Connect mode. The upper section of the figure shows the allowable grid connections that are UL1741 compliant, and the lower section shows the allowable connections that are permissible (safe) for the Capstone MicroTurbine but are NOT UL1741 compliant. For details on each configuration, refer to the figure number shown for that configuration.

### LEGEND:
- **3P** = 3-Phase
- **3W** = 3-Wire
- **4W** = 4-Wire
- **MT** = MicroTurbine
- w/o = without
- **GC** = Grid Connect
- **SA** = Stand Alone

#### Allowable Grid Connections

**UL1741 Compliant**

1. **Y-Service, with Neutral**
2. **Non-480V**
   - **Direct Connection (3P-4W)**
   - **Y-Autotransformer (3P-4W)**
   - **Y-Y Transformer (3P-4W)**

See Fig 4 See Fig 5 See Fig 6

**Y-Δ Transformer (Y to MT)**

See Fig 7

#### Allowable Grid Connections

**NOT UL1741 Compliant**

1. **Non-Isolated**
2. **480V (400-480)**
3. **Isolated**

- **Direct Connection w/o Neutral (3P-3W)**
- **Y-Autotransformer w/o Service Neutral (3P-3W to Service)**
- **Y-Δ Transformer (Y to MT)**
- **Δ-Y Transformer (Δ to MT)**
- **Δ - Δ Transformer (Δ to MT)**

See Fig 8 See Fig 9 See Fig 10 See Fig 11 See Fig 12

#### Notes:

1(a). The MicroTurbine chassis ground must always be solidly connected to the same earth ground as that at the Utility Service.

1(b). An electrical disconnect device, with over-current protection (fuses or circuit breaker), must be installed within sight of the MicroTurbine.

1(c). Phase-to-ground voltage at the MicroTurbine must never exceed 480 Vrms, or 277 Vrms for the Model C30 Stand Alone Units (+10% high-line allowed).

2. The Utility Service must be ground referenced, either through solid or resistance grounding.

3. The Utility Service Neutral must be solidly connected to the MicroTurbine Neutral or to the service side of any Transformer Neutrals.

4. The MicroTurbine side Transformer Neutral must be solidly connected to ground and to the MicroTurbine Neutral.

5. Model C30 GC (Not SA) and Model C60/C65 Units may be operated corner grounded (not recommended).

Figure 1. Allowable Grid Connections
Grounding
The Capstone MicroTurbine during Grid Connect operation is designed for ground-referenced, balanced voltage operation.

The recommended connection for Grid Connect operation is to a 4-wire Wye system, where the neutral is solidly grounded. The neutral-to-ground connection should be at the utility service panel of the facility.

A SOLID EARTH GROUND of the MicroTurbine is MANDATORY for successful operation. The MicroTurbine uses digital electronics to sense line voltages and currents that require a solid ground connection to perform accurately. Refer to the following electrical diagrams for proper grounding location.

Neglecting to properly ground the MicroTurbine system (that is, no neutral-to-ground connection, or more than one neutral-to-ground connection) can cause damage to the MicroTurbine system.

In all cases, the neutral-to-ground post (if equipped) MUST be removed from the high voltage bay of the MicroTurbine User Connection Bay. Grid Connect operation with the neutral-to-ground post installed may create multiple neutral-to-ground connections. This condition can lead to circulating currents, resulting in nuisance faults with the MicroTurbine or which may cause safety hazards within the facility. Refer to Figures 2 and 3 for neutral-to-ground post details within the User Connection Bay.

Notice that all electrical wiring, including protection and grounding, must conform to all local and national electrical codes and regulations.

The neutral-to-ground post (and screw) if installed. The actual post is located behind the bus bar as shown.

Figure 2. Model C30 Terminal Block
(Located in Power Bay at Rear of Enclosure)
Electrical Installation Interface

It is the responsibility of the owner/user to supply the electrical cable and switchgear, through which the MicroTurbine delivers its output power.

Proper sizing of transformers in the installation is required to limit high impedance. Calculate the impedance of the line run and transformers to the utility source. Refer to the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001) for impedance limits required for installation. Refer to Appendix A for examples of input impedance calculations.

It is essential that the owner/user consult all of the applicable codes and industry standards before connecting the interface wiring for the MicroTurbine. Notice that a qualified electrician may be required to perform this work.

Circuit Breakers and/or Fused Disconnects

A circuit breaker or fused disconnect must be installed between the MicroTurbine and the electrical service panel, within sight of the MicroTurbine.

The types of fused disconnect and the fault-current ratings of the device must meet all local codes and specifications. Time delay fuses are not required. Fast acting, current limiting fuses are recommended. Circuit breakers or fused disconnects should always have lockout provisions to facilitate safe maintenance operations.

Notice that the circuit breaker or fused disconnect equipment must meet the maximum current and voltage ratings as described in the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001). Additionally, ALL equipment must be properly grounded.

Always refer to the latest national and local codes relative to your location to determine the proper connection requirements.
Additionally, and in accordance with Underwriters Laboratories UL 2200, the various torque specifications required on the terminal block MUST BE as noted in Table 1.

Table 1. Terminal Block Torque Specification

<table>
<thead>
<tr>
<th>Wire Size</th>
<th>Torque Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(AWG)</td>
<td>(mm²)</td>
</tr>
<tr>
<td>2/0 to #6</td>
<td>62 to 13</td>
</tr>
</tbody>
</table>

**Phase Rotation**

During Grid Connect operation, the MicroTurbine phase terminals may be connected to the grid in any order, based upon auto-synchronization to the electric utility grid.

The output from the MicroTurbine is L1-L2-L3 counterclockwise, and must be connected to the grid in this order for Stand Alone or Dual Mode operation.

**Transformer Applications**

A voltage transformer for the MicroTurbine will be required for any of the following conditions:

- Circuit-connect voltages other than 400 to 480 Volts AC.
- Connection to a system where the impedance is high enough to cause overvoltage at the rated output current of the system. In this case, a tapped or autotransformer is required to lower the nominal voltage, if this cannot be done with the installed transformer.

Refer to Figures 4 through 12 for allowable grid connections.

Each of the following items must be observed for proper installation:

- Proper branch circuit disconnect MUST BE installed between the MicroTurbine and the electrical service panel. The branch circuit disconnect may be installed on either side of the transformer within sight of MicroTurbine.

  **NOTE**  
  If a fused disconnect is used at the MicroTurbine, it is recommended to install the fuses on the MicroTurbine side. This applies to all configurations.

- The neutral and ground MUST BE connected in ONLY ONE location at the utility or local branch circuit protection.
- The neutral-to-ground post in the MicroTurbine User Connection Bay MUST BE removed (if equipped).
Allowable Grid Connections – UL1741 Compliant

Figure 4. Connection to 480V Wye Service - Direct Connection (UL1741 Compliant)

Figure 5. Connection to Non-480V Wye Service – Autotransformer (UL1741 Compliant)
Single Unit or MultiPac Connections

Branch Circuit Disconnect

Isolation Transformer (Wye-Wye)

Utility Service

Ground

Figure 6. Connection to Wye-Wye Service: Isolation Transformer (UL1741 Compliant)

Single Unit or MultiPac Connections

Branch Circuit Disconnect

Isolation Transformer (Wye-Delta)

Delta Utility Service

Ground

Figure 7. Connection to Wye-Delta Service: Isolation Transformer (UL1741 Compliant)
Allowable Grid Connections – Not UL1741 Compliant

Figures 8 through 12 present permitted utility (or transformer) connections that do not conform to UL1741 standard for grid interconnection.

**NOTE**
Any external power metering equipment may only be installed on the Wye side of the isolation transformer, and NOT on the Delta side.

---

**Figure 8.** Connection to 480 V Wye Service - Direct Connection
(Not UL1741 Compliant)

---

**Figure 9.** Connection to Non-480V Wye Service – Autotransformer
(Not UL1741 Compliant)
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Figure 12. Connection to Delta-Delta Service: Isolation Transformer (Not UL1741 Compliant)
Electrical Connections – Stand Alone

If the Capstone MicroTurbine is equipped with the Stand Alone option, the operator must supply the electrical cable and switchgear through which the Capstone MicroTurbine delivers its output power. The cabling and switchgear must be capable of safely handling the maximum potential loads, and must meet all applicable local and national regulations.

It is essential that the owner/user consult all of the applicable codes and standards before electrically wiring the MicroTurbine. A qualified electrician may be required to do the work. The electrical connection terminal block for the MicroTurbine can be found in the Power Bay located at the rear of the enclosure.

Stand Alone Loads

Stand Alone loads may be connected in any combination of line-line or line-neutral, while respecting the maximum current and voltage ratings as described in the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001). Notice that in Stand Alone systems, the MicroTurbine(s) neutral must be solidly connected to ground at a single point.

Voltage

The output voltage from the MicroTurbine may be programmed from 150 to 480 volts AC, phase-to-phase, and 10 to 60 Hz. Output power capabilities are reduced at the lower voltage levels, based on the operational current limits.

Phase Rotation

The output voltage/current phase rotation is counterclockwise, as in L1 to L2 to L3. Notice that improper phase rotation connections can damage the connected loads. Capstone cannot be held responsible for equipment damage caused by improper connections. It is the operator’s responsibility to verify the proper phase connections between the MicroTurbine and the load(s).

Stand Alone Transformer Applications

For Stand Alone applications, power transformer(s) will be needed for loads that require voltages different from the programmed MicroTurbine Stand Alone voltage set point. Refer to the Stand Alone Operation Technical Reference (410028) for details on the voltage and protective set points used for Stand Alone operation.

Load Circuits

The MicroTurbine output consists of three phases and a neutral circuit. These may be used in any combination, limited only by current limits on each phase, as described in the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001).

The nominal Stand Alone voltage setting is available between any two phases. Single phase and/or unbalanced loads can be accommodated, respecting the current and power limits previously noted.

Notice that the MicroTurbine Neutral must always be grounded.
Load Capacity

The MicroTurbine output is current limited. The MicroTurbine can operate loads with any power factor, so long as current limits are not exceeded. The current (I) consumed by the load(s) is a function of real power (Watts), volts (V) and the power factor (PF).

\[ I = \frac{W}{\sqrt{3} \times V \times PF} \]

The allowable power factor (PF) will be a function of the real load and the maximum phase current. Power derating curves for ambient temperature and elevation should be considered when determining real power (Watts). Refer to the Model C30 Performance Technical Reference (410004) and to the Model C60/C65 Performance Technical Reference (410005/410048) for additional details.

For example, with a total 30 kW load operating at 480 Volts AC with a current limit of 46 ARMS per phase, the lowest allowable power factor (PF) is as follows:

\[
\frac{30000}{(480 \times 46 \times \sqrt{3})} = 0.78
\]

Operating at 376 volts AC, the lowest allowable power factor (PF) is as follows:

\[
\frac{30000}{(376 \times 46 \times \sqrt{3})} = 1
\]

Operating voltages lower than 376 volts AC will consequently reduce the total available output power of the MicroTurbine according to the following:

\[ W = 46 \times \sqrt{3} \times V \times PF \]

**NOTE** Incorrect determination of load capacity can cause the MicroTurbine to fault.

Grounding

The MicroTurbine system (ground terminal) must **ALWAYS** be connected to **Earth Ground** during system operation.

The neutral terminal of the MicroTurbine output terminal block **MUST BE** connected to ground at the branch circuit disconnect.

The MicroTurbine neutral-to-ground post (if equipped) should be removed. Refer to Figures 2 and 3 as required.
Figure 13 presents the Stand Alone electrical connections for three-phase loads. Notice that for Single and MultiPac Stand Alone systems, the neutral **MUST BE** connected to ground in one location **ONLY**.

![Diagram of Stand Alone Connections: Three-Phase Loads](image)

**Figure 13. Stand Alone Connections: Three-Phase Loads**
Figure 14 presents the Stand Alone electrical connections for single-phase loads. Notice that a single neutral-to-ground connection is essential and required. The loads **MUST NOT** exceed the ratings described in the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001).

![Figure 14. Stand Alone Connections: Single-Phase Loads](image-url)
Electrical Connections – Dual Mode

Dual Mode electrical interconnections are presented in the following paragraphs.

Electrical Cables and Switchgear

If the Capstone MicroTurbine is equipped with the Stand Alone option, it is capable of either Grid Connect operation or Stand Alone operation, and may be converted from one to the other simply and easily.

An installation designed to switch between Grid Connect and Stand Alone operation is identified as a Dual Mode installation. Loads on the same circuit with the MicroTurbine and which may be powered either by the grid or by the MicroTurbine in Stand Alone mode are defined as Protected Loads.

Conversion from one mode to the other requires the following:

1. A shutdown of the MicroTurbine, followed by a
2. Transfer of the electrical connections, and then
3. A reconfiguration of the interlocks and software, and finally,
4. A restart of the MicroTurbine.

These steps may be accomplished manually, or automatically. Automatic transfer and reconfiguration may be accomplished with the Capstone Automatic Dual Mode Controller. Refer to the Dual Mode Controller Technical Reference (410039) for additional details.

Whether manual or automatic, the electrical conversion from one mode to the other must be planned with care, particularly the neutral and ground connections. Safety requirements, code requirements, and functional requirements must all be met.

Sizing Protected Loads

Notice that Protected Loads in a Dual Mode application must be sized as though the MicroTurbine will operate on the loads in the Stand Alone mode, where the cumulative load to each phase is current-limited.

Phase Rotation

Dual mode applications must match the phase rotation of the MicroTurbine in the Stand Alone mode with the phase rotation of the grid, to prevent load phase reversal when switching modes. Therefore, the output from the MicroTurbine MUST BE connected L1-L2-L3 counterclockwise.
Grounding and Neutral Connections

The neutral-to-ground connection requirements in the Dual Mode operation are identical to those in the Grid Connect mode of operation.

The neutral-to-ground bar (if equipped) **MUST BE** removed from all MicroTurbiners in the system.

---

**CAUTION**

It is not possible to connect the DMC to a delta utility service or local transformer. The protected loads must be supplied from a ground-referenced source in both Grid Connect and Stand Alone modes.

For a Wye service or transformer, the ground reference exists via the Neutral when the system is running GC with the DMC switch closed or when the system is running SA with the DMC switch open.

For a delta service or transformer, the ground reference exists via the phases when the system is running GC with the DMC switch closed, but the ground reference is lost when the system is running SA with the DMC switch open. (The open DMC switch isolates protected loads from the phase to ground connection in the utility service or local transformer.) Therefore, it is not permitted to supply the DMC from a delta utility or local transformer.

---

Figure 15 presents direct connection using the Dual Mode Controller. The DMC is installed between the MicroTurbine and the protected loads, and the utility or local transformer. The neutral-to-ground bar **MUST BE** removed from the MicroTurbine User Connection Bay. A single neutral-to-ground connection **MUST BE** made at the local utility.

---

![Diagram of Dual Mode Connections: Direct Connection](image.png)

**Figure 15. Dual Mode Connections: Direct Connection**
Figure 16 presents the indirect connection using the Dual Mode Controller. The DMC is installed between the autotransformer and the protected loads, and the utility or local transformer. The neutral-to-ground connection must be connected at a single point at the utility. The neutral-to-ground bar (if equipped) **MUST BE** removed from the MicroTurbine User Connection Bay.

![Diagram](image)

**Figure 16. Dual Mode Connections: Using an Autotransformer**

Figure 17 presents indirect connection using the Dual Mode Controller. The DMC is installed between the isolation transformer and the protected loads, and the utility or local transformer.

![Diagram](image)

**Figure 17. Dual Mode Connections: Using an Isolation Transformer**
Electrical Connections – MultiPac

MultiPac electrical interconnections are presented in the following paragraphs.

Power connections between the MultiPac systems will be necessary, and these connections must consider the proper phase wiring, neutral wiring, and grounding connections between the various systems. Refer to Figure 18 for electrical connection diagram for permitted MultiPac connections.

There **MUST BE** one neutral-to-ground connection in the system at the point of connection, or at the utility or local transformer. The neutral-to-ground post (if equipped) **MUST BE** removed from all MicroTurbines in the MultiPac system.

- Each MicroTurbine is installed with an individual branch circuit disconnect for service.
- The output of each MicroTurbine is connected via standard conduit or an electrical cable tray. This point of connection is installed to the utility, local transformer, or loads as in the previous diagrams.
- For Stand Alone and Dual Mode installations, NO transformers are permitted between MicroTurbines in the MultiPac. Individual transformers may be used for Grid Connect only installations, but are not recommended.

**NOTE**
The neutral-to-ground bar must be removed from ALL MicroTurbines in the MultiPac. All wiring shown should be connected regardless of utility connection types.

**Figure 18. Power Connections: MultiPac System**
Appendix A

Input Impedance Calculations - Examples

Refer to the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001) for input impedance requirements.

Three examples of the total electrical input impedance calculations which detail the values considering the MicroTurbine output looking towards the utility are provided as follows:

Example 1: Model C30 - Considering 1 MicroTurbine

Total Impedance for all conductors: $Z_L = 0.5\%$, $Z_R = 1.0\%$

$Z_L$ (Total) = 5.6%(30/45) + 6.4%(30/45) + 5%(30/60) + 0.5% = 11%
(Value exceeds acceptable limits)

$Z_R$ (Total) = 1.7%(30/45) + 1.9%(30/45) + 1.6%(30/60) + 1% = 4.22%
(Value is within acceptable limits)

Example 2: Model C60/C65 - Considering 1 MicroTurbine

Total Impedance for all conductors: $Z_L = 0.5\%$, $Z_R = 1.0\%$

$Z_L$ (Total) = 5.6%(60/75) + 6.4%(60/75) + 5%(60/100) + 0.5% = 13.1%
(Value exceeds acceptable limits)

$Z_R$ (Total) = 1.7%(60/75) + 1.9%(60/75) + 1.6%(60/100) + 1% = 4.85%
(Value is within acceptable limits)
Example 3: Considering 3 MicroTurbines

Total Impedance for all conductors: $Z_L = 0.5\%, Z_R = 1.0\%$

MicroTurbine #1 (30 kVA):

$Z_L (MT1) = 5.6\%(30/45) + 7.2\%(120/500) + 5\%(120/2000) + 0.5\% = 6.3\%$

(Value is within acceptable limits)

Note: In these calculations, the number 120 represents the sum of the MicroTurbine outputs (30+30+60)

$Z_R (MT1) = 1.7\%(30/45) + 1.8\%(120/500) + 1.3\%(120/2000) + 1\% = 2.7\%$

(Value is within acceptable limits)

MicroTurbine #2 (30 kVA):

$Z_L (MT2) = 5.6\%(30/45) + 7.2\%(120/500) + 5\%(120/2000) + 0.5\% = 6.3\%$

(Value is within acceptable limits)

$Z_R (MT2) = 1.7\%(30/45) + 1.8\%(120/500) + 1.3\%(120/2000) + 1\% = 2.7\%$

(Value is within acceptable limits)

MicroTurbine #3 (60 kVA):

$Z_L (MT3) = 4.3\%(60/112.5) + 7.2\%(120/500) + 5\%(120/2000) + 0.5\% = 4.9\%$

(Value is within acceptable limits)

$Z_R (MT3) = 1.4\%(60/112.5) + 1.8\%(120/500) + 1.3\%(120/2000) + 1\% = 2.3\%$

(Value is within acceptable limits)
Capstone Technical Support

If questions or problems arise regarding electrical interconnections for your Capstone MicroTurbine, please contact Capstone Technical Support for assistance and information.

Capstone Technical Support
Toll Free Telephone: (877) 282-8966
Service Telephone: (818) 407-3600
Facsimile: (818) 734-1080
E-mail: service@capstoneturbine.com

Capstone Technical Support (Japan)
Service Telephone: (818) 407-3700
Facsimile: (818) 734-1080
E-mail: servicejapan@capstoneturbine.com
CR65 & CR65 ICHP MicroTurbine
Renewable

Robust power system achieves ultra-low emissions and reliable electrical/thermal generation from waste gas.

- Years of renewable experience
- Ultra-low emissions
- Operates on landfill or digester gas
- One moving part – minimal maintenance and downtime
- Patented air bearing – no lubricating oil or coolant
- 5 and 9 year Factory Protection Plans available
- Remote monitoring and diagnostic capabilities
- Integrated utility synchronization and protection
- Small, modular design allows for easy, low-cost installation
- Reliable – tens of millions of run hours and counting

**Electrical Performance**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Power Output</td>
<td>65kW</td>
</tr>
<tr>
<td>Voltage</td>
<td>400–480 VAC</td>
</tr>
<tr>
<td>Electrical Service</td>
<td>3-Phase, 4 wire</td>
</tr>
<tr>
<td>Frequency</td>
<td>50/60 Hz</td>
</tr>
<tr>
<td>Maximum Output Current</td>
<td>100A, grid connect operation</td>
</tr>
<tr>
<td>Electrical Efficiency LHV</td>
<td>29%</td>
</tr>
</tbody>
</table>

**Fuel/Engine Characteristics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill Gas HHV</td>
<td>13.0–22.3 MJ/m³ (350–600 BTU/scf)</td>
</tr>
<tr>
<td>Digester Gas HHV</td>
<td>20.5–32.6 MJ/m³ (550–875 BTU/scf)</td>
</tr>
<tr>
<td>H₂S Content</td>
<td>&lt;5,000 ppmv</td>
</tr>
<tr>
<td>Inlet Pressure</td>
<td>517–552 kPa gauge (75–80 psig)</td>
</tr>
<tr>
<td>Fuel Flow HHV</td>
<td>888 MJ/hr (842,000 BTU/hr)</td>
</tr>
<tr>
<td>Net Heat Rate LHV</td>
<td>12.4 MJ/KWh (11,800 BTU/kWh)</td>
</tr>
</tbody>
</table>

**Exhaust Characteristics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx Emissions @ 15% O₂</td>
<td>&lt;9 ppmvd (18 mg/m³)</td>
</tr>
<tr>
<td>NOx / Electrical Output</td>
<td>0.16 g/bhp-hr (0.46 lb/MWhe)</td>
</tr>
<tr>
<td>Exhaust Gas Flow</td>
<td>0.49 kg/s (1.08 lbm/s)</td>
</tr>
<tr>
<td>Exhaust Gas Temperature</td>
<td>309°C (588°F)</td>
</tr>
</tbody>
</table>

*Reliable power when and where you need it. Clean and simple.*
C65 ICHP Heat Recovery

Integrated Heat Recovery Module Type: Stainless Steel Core
Hot Water Heat Recovery: 74kW (251,000 BTU/hr)
Total System Efficiency LHV: 62%

Dimensions & Weight

<table>
<thead>
<tr>
<th>CR65</th>
<th>CR65 ICHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width x Depth x Height</td>
<td>0.76 x 1.9 x 1.9 m (30 x 77 x 76 in)</td>
</tr>
<tr>
<td>Weight</td>
<td>758 kg (1,671 lb)</td>
</tr>
</tbody>
</table>

Minimum Clearance Requirements

<table>
<thead>
<tr>
<th>CR65</th>
<th>CR65 ICHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Clearance</td>
<td>0.61 m (24 in)</td>
</tr>
<tr>
<td>Left &amp; Right</td>
<td>0.76 m (30 in)</td>
</tr>
<tr>
<td>Front</td>
<td>0.76 m (30 in)</td>
</tr>
<tr>
<td>Rear</td>
<td>0.91 m (36 in)</td>
</tr>
</tbody>
</table>

Sound Levels

<table>
<thead>
<tr>
<th>CR65</th>
<th>CR65 ICHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustic Emissions at Full Load Power</td>
<td>70 dBA</td>
</tr>
<tr>
<td>Nominal at 10 m (33 ft)</td>
<td>70 dBA</td>
</tr>
</tbody>
</table>

Certifications

- Classified UL 2200 and UL 1741 for raw natural gas and biogas operation (UL file AU5040)
- Complies with IEEE 1547 and meets statewide utility interconnection requirements for California Rule 21 and the New York State Public Service Commission
- Models available with optional equipment for CE Marking
- Models available with optimal 2008 CARB certification for waste gas

(1) Nominal full power performance at ISO conditions: 59°F, 14.696 psia, 60% RH
(2) For surrogate landfill and digester gases. Please contact Capstone for additional details
(3) Heat recovery for water inlet temperature of 38°C (100°F) and flow rate of 2.5 l/s (40 GPM)
(4) Approximate dimensions and weights
(5) Depth includes 10 inch extension for the heat recovery module rain hood on ICHP versions
(6) Height dimensions are to the roof line. Exhaust outlet extends at least 7 inches above the roof line
(7) Clearance requirements may increase due to local code considerations
(8) The optional acoustic inlet hood kit can reduce acoustic emissions at the front of the MicroTurbine by up to 5 dBA

21211 Nordhoff Street • Chatsworth • CA • 91311 • 866.422.7786 • 818.734.5300 • www.capstoneturbine.com
©2010 Capstone Turbine Corporation. P0911 CR65 & CR65 ICHP Renewable Data Sheet CAP143 | Capstone P/N 331039D
Technical Reference
Capstone Model C65 Electrical
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1. Introduction

This document defines the electrical performance ratings of the Capstone MicroTurbine® Model C65 in both single and MultiPac configurations. This information is intended for use in the evaluations of applications for the Capstone C65 Microturbine. Refer to Model C65 Product Specification (460044) for microturbine certification compliance.

The Capstone C65 Microturbine provides electrical power generation and can be configured for either Grid Connect or Stand Alone operation. The Grid Connect configuration causes the microturbine to source current into an energized electrical grid, and the Stand Alone configuration allows the microturbine to function as a grid-isolated voltage source.

Capstone C65 Microturbines may be used in applications requiring greater than 65 kW of load. They may be connected together, in groups (identified as a MultiPac), to provide the required amount of power. A MultiPac grouping of microturbines will function as if it were a single unit.

2. Referenced Documents

The following table contains a list of documents referenced in this Technical Reference.

<table>
<thead>
<tr>
<th>Document Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>410002</td>
<td>Fuel Requirements Technical Reference</td>
</tr>
<tr>
<td>410009</td>
<td>Electrical Installation Technical Reference</td>
</tr>
<tr>
<td>410014</td>
<td>CRMS Technical Reference Maintenance Edition</td>
</tr>
<tr>
<td>410028</td>
<td>Stand Alone Technical Reference</td>
</tr>
<tr>
<td>410032</td>
<td>MultiPac Operation Technical Reference</td>
</tr>
<tr>
<td>410033</td>
<td>Protective Relay Technical Reference</td>
</tr>
<tr>
<td>410044</td>
<td>Battery Performance Technical Reference</td>
</tr>
<tr>
<td>410048</td>
<td>C65 Performance Technical Reference</td>
</tr>
<tr>
<td>410071</td>
<td>Dual Mode System Controller Technical Reference</td>
</tr>
<tr>
<td>460044</td>
<td>Model C65 Product Specification</td>
</tr>
<tr>
<td>IEEE 519</td>
<td>Institute of Electrical and Electronic Engineers: Recommended Practices/Requirements for Harmonic Control – Electrical Power Systems</td>
</tr>
<tr>
<td>UL 1741</td>
<td>Underwriters Laboratories: Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources</td>
</tr>
<tr>
<td>VDE-AR-N 4105</td>
<td>Verband der Elektrotechnik: Technical Requirements for Connection to and Parallel Operation with Low-Voltage Distribution Networks</td>
</tr>
</tbody>
</table>
3. Electrical Ratings

Electrical ratings for Grid Connect configuration (Table 2) and Stand Alone configuration (Table 3) are provided in the following paragraphs. Single unit and MultiPac electrical ratings are included. Whenever MultiPac ratings are listed, N equals the number of individual microturbines within a MultiPac (where $1 \leq N \leq 30$). The maximum number of microturbines that may be connected together in a MultiPac is 20, but a MultiPac can be increased to 30 with the use of the Advanced Power Server (APS). Refer to the APS-145 Technical Reference (410079) for details.

C65 microturbines can also be configured for dual mode operation, which combines Grid Connect and Stand Alone modes. A dual-mode microturbine can operate in parallel with the utility grid when available and in Stand Alone during a utility outage. The capability to switch automatically between Grid Connect and Stand Alone modes is provided by the Dual Mode System Controller (DMSC). Refer to the Dual Mode System Controller Technical Reference (410071) for details.

Ratings are at ISO conditions, defined as 15 °C (59 °F), 60% relative humidity, and 101.325 kPa (14.696 psia, standard sea level pressure), with no inlet pressure losses, exhaust back pressure, or parasitic loads.

Protective relay settings are discussed in separate documents. Refer to the Protective Relay Technical Reference (410033) for applicable protective relay settings for Grid Connect Mode. Refer to the Stand Alone Technical Reference (410028) for the applicable protective relay settings for Stand Alone Mode.
### 3.1. Grid Connect

Table 2 presents the Electrical Ratings for the Grid Connect configuration.

**Table 2. Nominal Electrical Ratings: Grid Connect**

<table>
<thead>
<tr>
<th>Description</th>
<th>Single Unit</th>
<th>MultiPac</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output Power</strong></td>
<td>0 to 65 kW</td>
<td>0 to 65 kW * N</td>
</tr>
<tr>
<td><strong>Output kVA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>65 kVA</td>
<td>N*65 kVA</td>
</tr>
<tr>
<td>VDE / PF (400 VAC)</td>
<td>81 kVA</td>
<td>N*81 kVA</td>
</tr>
<tr>
<td><strong>Voltage Range</strong></td>
<td>400 / 480 VAC</td>
<td></td>
</tr>
<tr>
<td><strong>Voltage Operating Range</strong></td>
<td>360 to 528 VAC, (3-phase only)</td>
<td></td>
</tr>
<tr>
<td><strong>Frequency Range</strong></td>
<td>50 / 60 Hz</td>
<td></td>
</tr>
<tr>
<td><strong>Frequency Operating Range</strong></td>
<td>45–65 Hz, auto synchronization</td>
<td></td>
</tr>
<tr>
<td><strong>Power Factor</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>± 0.985 displacement PF, for loads &gt; 25% of rated load</td>
<td>0.9 Leading / 0.9 lagging</td>
</tr>
<tr>
<td>VDE / PF (400 VAC)</td>
<td>0.8 Leading / 0.8 lagging</td>
<td></td>
</tr>
<tr>
<td>VDE / PF (480 VAC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Output Current, Maximum Steady State</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>100 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
<td>N*100 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
</tr>
<tr>
<td>VDE / PF (400 VAC)</td>
<td>120 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
<td>N*120 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
</tr>
<tr>
<td>Grid Fault Current Contribution by Microturbine</td>
<td>145 A&lt;sub&gt;RMS&lt;/sub&gt;, maximum symmetrical and asymmetrical</td>
<td>N*145 A&lt;sub&gt;RMS&lt;/sub&gt;, maximum symmetrical and asymmetrical</td>
</tr>
<tr>
<td><strong>Short Circuit Rating</strong></td>
<td>145 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
<td>N*145 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
</tr>
<tr>
<td><strong>Output Voltage Connection</strong></td>
<td>3-Phase, 4 wire, L1, L2, L3, and Neutral</td>
<td></td>
</tr>
<tr>
<td><strong>Grid Voltage Phase Sequence</strong></td>
<td>Auto synchronization. For Dual Mode applications, the grid voltage phase sequence must be L1, L2, L3</td>
<td></td>
</tr>
<tr>
<td><strong>Grounding</strong></td>
<td>Grid must be neutral grounded</td>
<td></td>
</tr>
<tr>
<td><strong>Maximum Grid Impedance</strong></td>
<td>≤ 10% inductive (814 µH) and ≤ 5% resistive (0.153 ohms), Z&lt;sub&gt;base&lt;/sub&gt; = 3.07 ohms line-to-neutral</td>
<td>≤ 10% inductive (814/N µH) and ≤ 5% resistive (0.153/N ohms), Z&lt;sub&gt;base&lt;/sub&gt; = 3.07/N ohms line-to-neutral</td>
</tr>
<tr>
<td><strong>Grid Voltage Harmonic Distortion</strong></td>
<td>The grid must comply with IEEE 519</td>
<td></td>
</tr>
<tr>
<td><strong>Grid Voltage Balance</strong></td>
<td>Within ± 2% at full load</td>
<td></td>
</tr>
<tr>
<td><strong>Grid Voltage Phase Displacement</strong></td>
<td>120 (± 1) degrees</td>
<td></td>
</tr>
<tr>
<td><strong>Surge Voltage</strong></td>
<td>ANSI C62.45 ± 6 kV</td>
<td></td>
</tr>
<tr>
<td><strong>Output Current Harmonic Content</strong></td>
<td>Complies with IEEE 519 &lt; 5% THD</td>
<td></td>
</tr>
<tr>
<td><strong>Output Current DC Content</strong></td>
<td>&lt; 0.6 Amps DC (per UL 1741)</td>
<td>&lt; N*0.6 Amps DC (UL 1741)</td>
</tr>
<tr>
<td><strong>Power Required @ Start Command</strong></td>
<td>6.8 kW peak, 0.014 kW-Hr, 42 Seconds</td>
<td>N*(6.8 kW peak, 0.014 kW-Hr, 42 seconds)</td>
</tr>
</tbody>
</table>
### Table 2. Nominal Electrical Ratings: Grid Connect\(^{(1)}\) (Continued)

<table>
<thead>
<tr>
<th>Description</th>
<th>Single Unit</th>
<th>MultiPac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cool Down Power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gaseous Fuels</td>
<td>2.0 kW peak, 0.3 kWh for 90 seconds</td>
<td>N*(2.2 kW peak, 0.3 kWh for 90 seconds)</td>
</tr>
<tr>
<td>Liquid Fuel</td>
<td>5.0 kW peak, 11 kWh for 12 minutes</td>
<td>N*(2.2 kW peak, 11 kWh for 12 minutes)</td>
</tr>
<tr>
<td>Standby Power</td>
<td>0.8 kW</td>
<td>N*0.8 kW</td>
</tr>
<tr>
<td>Grid Inrush Current @ Disconnect Switch Closure</td>
<td>24 Amps RMS</td>
<td>N*24 Amps RMS</td>
</tr>
<tr>
<td>Output Power Slew Rate(^{(2),(10)})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type A and Type B</td>
<td>0.35 kW/sec (250 rpm/sec)</td>
<td>N*0.35 kW/sec (250 rpm/sec)</td>
</tr>
<tr>
<td>Liquid Fuel</td>
<td>2.35 kW/sec (1700 rpm/sec)</td>
<td>N*2.35 kW/sec (1700 rpm/sec)</td>
</tr>
<tr>
<td>All Other</td>
<td>1.15 kW/sec (900 rpm/sec)</td>
<td>N*1.15 kW/sec (900 rpm/sec)</td>
</tr>
</tbody>
</table>

### Table 2 Notes:

1. Ratings are at full load power and ISO conditions with zero back pressure. Values do not include parasitic losses from any accessories. The nominal values contained in this table do not reflect tolerance ranges. Deviation from the nominal value can occur due to differences between microturbines, measurement inaccuracies, and other factors.
2. Minimum power output is 35 kW for Type A and Type B fuels. Refer to Fuel Requirements Technical Reference (410002) for further definition on fuels.
3. The minimum typical power to the grid is 1.8 kW (@T\(_{amb}\) = 122 °F) or 3.4 kW (@T\(_{amb}\) = 59 °F) when the Power Demand is 0 kW. For MultiPac, the typical minimum power to the grid is N* 1.8 kW (@T\(_{amb}\) = 122 °F) or N*3.4 kW @T\(_{amb}\) = 59 °F).
4. Refer C65 Performance Technical Reference (410048) for real power capability as a function of ambient temperature, elevation, and other site conditions.
5. Software versions 5.40 and higher (gaseous fuels) and 2.20 and higher (liquid fuel) include Verband der Elektrotechnik (VDE) and Power Factor (PF) functionality. These software versions meet VDE-AR-N 4105 requirements for low voltage grid interconnection and allow for power factor control. Upgrades in the field to these software versions require key code to enable functionality.
6. The microturbine senses the grid waveform and synchronizes to its phases and frequency before an output connection is made.
7. Power factor adjustable range is from 0.8 leading to 0.8 lagging. Power fold back will occur once current limit of inverter is reached.
8. Refer to the Electrical Installation Technical Reference (410009) for grounding details.
9. Total harmonic voltage must be less than 5% (13.85 Volts RMS line-to-neutral). Also, the high frequency ripple voltage must be less than 5.5 Volts RMS line-to-neutral at frequencies greater than 3 kHz.
10. Slew rate includes both turbine acceleration and deceleration.
### 3.2. Stand Alone

Table 3 presents the Electrical Ratings for the Stand Alone configuration.

**Table 3. Nominal Electrical Ratings: Stand Alone**

<table>
<thead>
<tr>
<th>Description</th>
<th>Single Unit</th>
<th>MultiPac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Power</td>
<td>0 to 65 kW</td>
<td>0 to 0.95* 65 kW*N</td>
</tr>
<tr>
<td>Output kVA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard (400 VAC)</td>
<td>69 kVA</td>
<td></td>
</tr>
<tr>
<td>Standard (480 VAC)</td>
<td>83 kVA</td>
<td>kVA<em>N</em>0.95</td>
</tr>
<tr>
<td>VDE / PF (400 VAC)</td>
<td>83 kVA</td>
<td></td>
</tr>
<tr>
<td>VDE / PF (480 VAC)</td>
<td>99 kVA</td>
<td></td>
</tr>
<tr>
<td>Voltage Range</td>
<td>400 / 480 VAC</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Adjustment Range</td>
<td>150 to 480 VAC line-to-line</td>
<td>(1 VAC adjustment resolution)</td>
</tr>
<tr>
<td>Frequency Range</td>
<td>50 / 60 Hz</td>
<td></td>
</tr>
<tr>
<td>Output Frequency Adjustment Range</td>
<td>10 to 60 Hz (0.1Hz adjustment resolution) ± 0.05% accuracy</td>
<td></td>
</tr>
<tr>
<td>Load Power Factor (3)</td>
<td>0.8 lagging to 0.8 leading</td>
<td></td>
</tr>
<tr>
<td>Output Current Maximum Steady State</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>100 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
<td>A&lt;sub&gt;RMS&lt;/sub&gt; = 0.9<em>100</em>N</td>
</tr>
<tr>
<td>VDE / PF (2)</td>
<td>120 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
<td>A&lt;sub&gt;RMS&lt;/sub&gt; = 0.9<em>120</em>N</td>
</tr>
<tr>
<td>Output Fault Current</td>
<td>145 A&lt;sub&gt;RMS&lt;/sub&gt;, maximum symmetrical and asymmetrical</td>
<td>N*145 A&lt;sub&gt;RMS&lt;/sub&gt;, maximum symmetrical and asymmetrical</td>
</tr>
<tr>
<td>Output Load Crest Factor</td>
<td>1.8 maximum @ 100 A&lt;sub&gt;RMS&lt;/sub&gt; with CF=180/I&lt;sub&gt;RMS&lt;/sub&gt; for loads &lt; 100 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
<td>1.8 maximum @ A&lt;sub&gt;RMS&lt;/sub&gt; = 0.9<em>100</em>N CF=0.9<em>N</em>180/I&lt;sub&gt;RMS&lt;/sub&gt; for loads &lt; 0.9<em>120</em>N A&lt;sub&gt;RMS&lt;/sub&gt;</td>
</tr>
<tr>
<td>VDE / PF (2)</td>
<td>1.8 maximum @ 120 A&lt;sub&gt;RMS&lt;/sub&gt; with CF=180/I&lt;sub&gt;RMS&lt;/sub&gt; for loads &lt; 120 A&lt;sub&gt;RMS&lt;/sub&gt;</td>
<td>1.8 maximum @ A&lt;sub&gt;RMS&lt;/sub&gt; = 0.9<em>120</em>N CF=0.9<em>N</em>180/I&lt;sub&gt;RMS&lt;/sub&gt; for loads &lt; 0.9<em>120</em>N A&lt;sub&gt;RMS&lt;/sub&gt;</td>
</tr>
<tr>
<td>Output Instantaneous Load Current</td>
<td>180 A&lt;sub&gt;PEAK&lt;/sub&gt; maximum</td>
<td>0.9<em>N</em>180 A&lt;sub&gt;PEAK&lt;/sub&gt; maximum</td>
</tr>
<tr>
<td>Single Phase Loading (per individual microturbine within the MultiPac)</td>
<td>25 kW line-to-neutral maximum steady state</td>
<td></td>
</tr>
<tr>
<td>Load Unbalance among the 3 phases (per individual unit within the MultiPac)</td>
<td>25 kW maximum</td>
<td></td>
</tr>
<tr>
<td>Output Load Cycle Period</td>
<td>See Battery Performance Technical Reference (410044)</td>
<td></td>
</tr>
<tr>
<td>Motor Start, Across-the-Line</td>
<td>Motor inrush current &lt; 127 A&lt;sub&gt;RMS&lt;/sub&gt; (4)</td>
<td>Motor inrush current &lt; 0.9<em>N</em>127 A&lt;sub&gt;RMS&lt;/sub&gt; (4)</td>
</tr>
</tbody>
</table>
### Table 3. Nominal Electrical Ratings: Stand Alone\(^{(1)}\) (Continued)

<table>
<thead>
<tr>
<th>Description</th>
<th>Single Unit</th>
<th>MultiPac</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motor Start, Ramp Voltage and Frequency(^{(4)})</strong></td>
<td>127 Amps RMS maximum starting current at any frequency and voltage</td>
<td>0.9<em>N</em>127 Amps RMS maximum starting current at any frequency and voltage</td>
</tr>
<tr>
<td><strong>Output Voltage Connection</strong></td>
<td>3-Phase, 4 wire, L1, L2, L3, and Neutral</td>
<td>L1, L2, L3</td>
</tr>
<tr>
<td><strong>Output Voltage Phase Sequence</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Grounding(^{(5)})</strong></td>
<td>Neutral must be solidly connected to earth ground in a single location</td>
<td></td>
</tr>
<tr>
<td><strong>Output Voltage Harmonic Distortion with Linear Load</strong></td>
<td>(\leq 5%) THD, which complies with IEEE 519</td>
<td></td>
</tr>
<tr>
<td><strong>Output Voltage Harmonic Distortion with CF load.</strong></td>
<td>(&lt; 8%) THD, (I_{PEAK} \leq 180) Amps &lt; 8% THD, (I_{PEAK} \leq 0.9<em>N</em>180) Amps</td>
<td>(1.4 \leq CF \leq 3.0) (1.4 \leq CF \leq 3.0)</td>
</tr>
<tr>
<td><strong>Crest Factor (CF) = (I_{PEAK}/I_{RMS})</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Output DC Voltage Content</strong></td>
<td>(\pm 2.5) Volts DC line-to-neutral</td>
<td></td>
</tr>
<tr>
<td><strong>Output Voltage Step Load Regulation, load application or removal</strong></td>
<td>(&lt; \pm 20%) of nominal voltage for any resistive step load (\leq 100%) rated output power capacity</td>
<td></td>
</tr>
<tr>
<td><strong>Output Voltage Step Load Recovery Time</strong></td>
<td>(&lt; 100) milliseconds to within (\pm 5%) of nominal voltage for (\leq 100%) rated output power step</td>
<td></td>
</tr>
<tr>
<td><strong>Output Voltage Phase Displacement</strong></td>
<td>120 (± 1) degree @ balanced loads</td>
<td></td>
</tr>
<tr>
<td><strong>Output Voltage Phase Displacement Jitter</strong></td>
<td>± 1 degree @ balanced loads</td>
<td></td>
</tr>
<tr>
<td><strong>Surge Voltage</strong></td>
<td>ANSI C62.45 ± 6 kV</td>
<td></td>
</tr>
<tr>
<td><strong>Output Frequency Regulation</strong></td>
<td>0.05% change for any steady state load or transient load (\leq 100%)</td>
<td></td>
</tr>
<tr>
<td><strong>Output Frequency Stability, Temperature</strong></td>
<td>(\pm 0.05%), -20 to +60°C (internal temperature)</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3 Notes:**

1. Ratings are at full load power and ISO conditions with zero back pressure. Values do not include parasitic losses from any accessories. The nominal values contained in this table do not reflect tolerance ranges. Deviation from the nominal value can occur due to differences between microturbines, measurement inaccuracies, and other factors.
2. Software versions 5.40 and higher (gaseous fuels) and 2.20 and higher (liquid fuel) include Verband der Elektrotechnik (VDE) and Power Factor (PF) functionality. These software versions meet VDE-AR-N 4105 requirements for low voltage grid interconnection and allow for power factor control. Upgrades in the field require key code to enable functionality.
3. Values shown are limited by maximum current capability of the power electronics. For system design, total power factor for all connected loads should not be less than 0.8 (inductive or capacitive).
4. Current limit must not be exceeded at any time during acceleration to full speed.
5. Refer to the Electrical Installation Technical Reference (410009) for grounding details.
4. Instrumentation Accuracy

The displays of the output voltages, currents, frequencies, and power have typical accuracies and coefficients as presented in Table 4.

<table>
<thead>
<tr>
<th>Instrumentation Item</th>
<th>Accuracy and Coefficients (Typical/Maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>±1.5% of Full Scale (typical) / ±3.0% (maximum)</td>
</tr>
<tr>
<td>Current Temperature Coefficient</td>
<td>± 0.2% of Full Scale over –20 to +60 °C range</td>
</tr>
<tr>
<td>Voltage</td>
<td>± 1.0% of Full Scale (typical) / ±2.0% (maximum)</td>
</tr>
<tr>
<td>Voltage Temperature Coefficient</td>
<td>± 0.2% of Full Scale over –20 to +60 °C range</td>
</tr>
<tr>
<td>Output Power</td>
<td>± 2.5% of Full Scale (typical) / ±5.0%(maximum)</td>
</tr>
<tr>
<td>Output Power Temperature Coefficient</td>
<td>± 0.4% of Full Scale over –20 to +60 °C range</td>
</tr>
<tr>
<td>Output Frequency</td>
<td>± 0.05% of Reading (or Indication)</td>
</tr>
<tr>
<td>Output Frequency Temperature Coefficient</td>
<td>± 0.005% of Reading over –20 to +60 °C range</td>
</tr>
<tr>
<td>Real Time Clock</td>
<td>±1 minute per month</td>
</tr>
</tbody>
</table>

5. Communications Bay

The Communications Bay provides a user interconnection means for serial communications, digital inputs, digital outputs, analog inputs, and 12/24 volt DC power for a modem and auxiliary load operation. The following topics will be covered in the sections to follow.

- MultiPac Communication
- Serial Communication
- Wake-Up and E-Stop Inputs
- Digital Inputs
- Analog Inputs
- Digital Outputs
- Modem and User Power

Figure 1 presents a typical Model C65 board layout in the Communications Bay.
5.1. MultiPac

The MultiPac feature allows for inter-communication between an array of microturbines in order for all microturbines to be dispatched and controlled as a single power source. The following communication signals are passed among the microturbines in a MultiPac:

- Ethernet – passes control commands to all microturbines in the MultiPac from the Master controller.
- RS485 – synchronizes voltage and frequency in Stand Alone mode for all microturbines in the MultiPac.
- Passes Global E-Stop and Wake-Up signal to all microturbines in the MultiPac.

Figure 2 shows two microturbines in a MultiPac configuration with a MultiPac cable and end terminators. Figure 3 shows how multiple microturbines are connected in a daisy chain pattern for a MultiPac configuration. Terminators must be installed on the first and last microturbines in the chain.
5.1.1. Signal Terminations

Signal terminators MUST be present on the initial and final connection for both Ethernet and RS-485 MultiPac cable connections (Figure 3). If termination is not present, electrical ringing may occur and the signal may be severely degraded or interrupted.

5.1.2. Ethernet I/O Connections (J1 and J2)

The connectors used for MultiPac communications are identified as J1 and J2 on the C65 UCB (see Figure 1). These connectors are 10BASE-2 connectors as specified in IEEE 802.3 Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications. Refer to MultiPac Operation Technical Reference (410032) and to APS-145 Technical Reference (410079) for MultiPac operation description.
NOTE: Connectors J1 and J2 are reserved for the interconnection of microturbines only. Connections made to these ports MUST be isolated from ground.

5.1.3. Ethernet Cabling Requirements

The cable type required for Ethernet connection is RG-58A/U (coaxial, 50-Ohm impedance). The recommended cable type is Belden, Part Number 9907 or equivalent. Basic requirements for cabling include the following:

- The maximum segment length of a thin wire 10B2 cable is 185 meters (607 feet). For longer segments, a fiber optic repeater can be used.
- Up to 30 connections (Medium Attachment Units or MAUs) are allowed per Ethernet segment. For larger LAN's, repeater hubs are required. Each repeater connection requires a MAU that must be counted toward the total of 30 MAU connections per segment.
- Each microturbine has 1.93 meters of internal cable length that must be included in the total length considerations. Repeaters may be added whenever the maximum cable length or the maximum numbers of nodes are exceeded.
- Whenever J1 or J2 are at the extremities of the Ethernet network, 50-ohm BNC terminators must be installed at these ports.

5.1.4. RS-485 Harness Interconnections (J6 and J8)

The RS-485 harness is used transfer the following hardware signals between microturbines:

- Inverter synchronization (Stand Alone only); one microturbine serves as an inverter master, passing voltage and frequency signals to all other microturbines in the MultiPac for synchronization.
- Global E-Stop - Wired to one turbine (typically the master), which shuts down all other microturbines in the MultiPac when opened.
- Battery Wake-Up – Wired to one turbine (typically the master), which wakes up all other microturbines in the MultiPac for Stand Alone operation.

NOTE: The RS-485 harness is not required if operating in Grid Connect mode and the Global E-stop is not configured.

Table 5 and Table 6 define all connection for connectors J6 and J8.
### Table 5. Connector J6 – Inter-Controller (A) RS-485 Port

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J6 (A)</td>
<td>Serial Communication</td>
<td>RS-485, Bus A Protocol&lt;sup&gt;(1)&lt;/sup&gt;</td>
</tr>
<tr>
<td>J6 (B)</td>
<td>(Not Applicable)</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>J6 (C)</td>
<td>Inter-Controller Start</td>
<td>+24 Volts DC @ 15 milliamps per microturbine&lt;sup&gt;(2)&lt;/sup&gt;</td>
</tr>
<tr>
<td>J6 (D)</td>
<td>(Not Applicable)</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>J6 (E)</td>
<td>Global E-Stop</td>
<td>Normal Operation: N*42 milliamps. E-Stop: (+) 24 Volts DC&lt;sup&gt;(2)&lt;/sup&gt;</td>
</tr>
<tr>
<td>J6 (F)</td>
<td>(Not Applicable)</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>J6 (G)</td>
<td>(Not Applicable)</td>
<td>Spare</td>
</tr>
<tr>
<td>J6 (H)</td>
<td>E-Stop Return</td>
<td>Normal Operation: N*42 milliamps. E-Stop: 0 Volts DC</td>
</tr>
<tr>
<td>J6 (J)</td>
<td>(Not Applicable)</td>
<td>Reserved</td>
</tr>
<tr>
<td>J6 (K)</td>
<td>Inter-Controller Start Return</td>
<td>30 milliamps per microturbine @ 0 Volts DC</td>
</tr>
<tr>
<td>J6 (L)</td>
<td>(Not Applicable)</td>
<td>Reserved</td>
</tr>
<tr>
<td>J6 (M)</td>
<td>Serial Communication</td>
<td>RS-485, Bus B Protocol</td>
</tr>
</tbody>
</table>

**Table 5 Notes:**

1. Whenever J6 is at the extremities of the RS-485 multi-drop network; Capstone-provided terminators must be installed. The maximum number of nodes is 32, and the maximum RS-485 cable length is 1000 meters. Each microturbine has 1.93 meters of internal cable length, which must be included in the total length considerations. Repeaters may be added whenever the maximum cable lengths or the maximum number of nodes are exceeded.

2. The Global E-Stop connection sinks 42 mA per microturbine in a MultiPac E-Stop circuit. The voltage drop to the most remote microturbine in the interconnecting cables must be kept to 6 volts DC maximum N≤30 on any global E-Stop.
### Table 6. Connector J8 – Inter-Controller (B) RS-485 Port

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J8 (A)</td>
<td>Serial Communication</td>
<td>RS-485, Bus A Protocol</td>
</tr>
<tr>
<td>J8 (B)</td>
<td>(Not Applicable)</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>J8 (C)</td>
<td>Inter-Controller Start</td>
<td>+24 Volts DC @ 15 milliamps per microturbine</td>
</tr>
<tr>
<td>J8 (D)</td>
<td>(Not Applicable)</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>J8 (E)</td>
<td>Global E-Stop</td>
<td>Normal operation: N*42 milliamps. E-Stop: (+) 24 VDC</td>
</tr>
<tr>
<td>J8 (F)</td>
<td>(Not Applicable)</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>J8 (G)</td>
<td>(Not Applicable)</td>
<td>Spare</td>
</tr>
<tr>
<td>J8 (H)</td>
<td>Global E-Stop Return</td>
<td>Normal operation: N*42 milliamps. E-Stop: 0 VDC</td>
</tr>
<tr>
<td>J8 (J)</td>
<td>(Not Applicable)</td>
<td>Reserved</td>
</tr>
<tr>
<td>J8 (K)</td>
<td>Inter-Controller Start Return</td>
<td>30 milliamps per microturbine @ 0 VDC</td>
</tr>
<tr>
<td>J8 (L)</td>
<td>(Not Applicable)</td>
<td>Reserved</td>
</tr>
<tr>
<td>J8 (M)</td>
<td>Serial Communication</td>
<td>RS-485, Bus B Protocol</td>
</tr>
</tbody>
</table>

**Table 6 Notes:**
1. Whenever J8 is at the extremities of the RS-485 multi-drop network; Capstone-provided terminators must be installed. The maximum number of nodes is 32, and the maximum RS-485 cable length is 1000 meters. Each microturbine has 1.93 meters of internal cable length, which must be included in the total length considerations. Repeaters may be added whenever the maximum cable lengths or the maximum numbers of nodes are exceeded.
2. The Global E-Stop connection sinks 42 milliamps per microturbine in a MultiPac E-Stop circuit. The voltage drop to the most remote microturbine in the interconnecting cables must be kept to 6 volts DC maximum N ≤ 30 on any global E-Stop.

### 5.2. Serial Communication Ports (J3 and J5)

A PC or PLC device may be connected to the UCB for monitoring, controlling, or troubleshooting a microturbine system. The microturbine communicates via RS-232 protocols using a null modem cable with hardware handshaking. A DB9 connector (User Port) and a DB25 connector (Maintenance Port) are available. If devices are connected to both ports, the port accessed at a higher password level has priority for command of the system. If both are at the same password level, the Maintenance Port has priority.

#### 5.2.1. DB25 Connector J3 (Maintenance Port)

Table 7 and Figure 4 define the connections for connector J3.

### Table 7. DB25 Connector J3 (Maintenance Port)

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J3</td>
<td>Maintenance Interface Port</td>
<td>DB25 (male polarity) and RS-232 protocol. Maximum null modem cable length is 50 feet</td>
</tr>
</tbody>
</table>

**Table 7 Notes:**
1. Connections made to these ports MUST be isolated from ground and/or communication ports of other microturbines.

A 25-pin RS-232 connector is used for Maintenance Port and is identified as J3 on the C65 UCB (see Figure 4). Pin designations are as follows:
Pin No. | Signal | Description | RS-232 Connector (DB25) |
---|---|---|---|
2 | TXD | Transmit Data | |
3 | RXD | Receive Data | Pin 1 |
4 | RTS | Request to Send | Pin 13 |
5 | CTS | Clear To Send | Pin 14 |
6 | DSR | Data Set Ready | Pin 25 |
7 | SG | Signal Ground | |
8 | DCD | Data Carrier Detect | |
20 | DTR | Data Terminal Ready | |
22 | RI | Ring Indicator | |

Figure 4. RS-232 Connector (DB25)

5.2.2. DB9 Connector J5 (User Port)

Table 8 and Figure 5 define the connections for connector J5.

Table 8. DB9 Connector J5 (User Port)

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J5</td>
<td>User Interface Port</td>
<td>DB9 (male polarity) and RS-232 protocol. Maximum null modem cable length is 50 feet (1)</td>
</tr>
</tbody>
</table>

Table 8 Notes:

(1) Connections made to these ports MUST be isolated from ground and/or communication ports of other microturbines.

A 9-pin RS-232 connector is used for the User Port and is identified as J5 on the C65 UCB (see Figure 5). Pin designations are as follows:

Pin No. | Signal | Description | RS-232 Connector (DB9) |
---|---|---|---|
1 | DCD | Data Carrier Detect | |
2 | RXD | Receive Data | Pin 1 |
3 | TXD | Transmit Data | Pin 5 |
4 | DTR | Data Terminal Ready | |
5 | SG | Signal Ground | Pin 6 |
6 | DSR | Data Set Ready | Pin 9 |
7 | RTS | Request to Send | |
8 | CTS | Clear To Send | |
9 | RI | Ring Indicator | |
5.2.3.  Computer to Microturbine Communication

A communication cable is required for connection from a computer to the microturbine’s User or Maintenance port. A null modem cable is required for this connection.

A null modem (or modem eliminator) cable is commonly used for connecting two computers together without a modem. It is a RS-232 cable that interchanges conductors 2 and 3. Wiring connections for null modem cables with DB9 connector (see Figure 6) and DB25 connector (see Figure 7) are as follows:

**Figure 6. DB9 Null Modem Cable**

- TXD 3  →  3 TXD
- RXD 2  →  2 RXD
- RTS 7  →  7 RTS
- CTS 8  →  8 CTS
- DSR 6  →  6 DSR
- DCD 1  →  1 DCD
- DTR 4  →  4 DTR
- SG 5   →  5 SG
- RI 9   →  9 RI

**Figure 7. DB25 Null Modem Cable**

- TXD 2  →  2 TXD
- RXD 3  →  3 RXD
- RTS 4  →  4 RTS
- CTS 5  →  5 CTS
- DSR 6  →  6 DSR
- DCD 8  →  8 DCD
- DTR 20 →  20 DTR
- SG 7   →  7 SG
- RI 22  →  22 RI
5.2.4. Connections to Third-Party Modems

The following paragraphs present connection details between the microturbine and the third-party modems.

5.2.4.1 Communications Cable

The modem can be connected to the User Port or Maintenance Port of the microturbine. Typically, it is connected to the Maintenance Port. A straight-through serial cable is required in most cases for data connection between the modem and the microturbine.

5.2.4.2 Modem and Microturbine Settings

The microturbine port speed setting must be set to the same speed as the modem.

The default hardware configuration for the User and Maintenance Ports is 57,600 bits per second (maximum speed), 8-bit word length, no parity, one stop bit, and hardware handshake for flow control. It is recommended to use the highest speed available on the modem, not exceeding the maximum speed of the microturbine port.

Upon initialization, the microturbine sends an AT&F command to restore the factory settings of the modem. If this affects the desired settings on the modem, the modem can be powered on by a delay timer of at least two minutes after the microturbine wakes up. In this case, the modem should be configured independently though a HyperTerminal session or using the modem’s PC software.

Some telemetry modems have different modes for data packet transmission. For the microturbine to communicate properly, the transmitted data packets should never be split.
### 5.3. Wake-Up and E-Stop Inputs (J10)

Table 9 defines all connection for connector J10.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J10 (11)</td>
<td>Local E-Stop (Input)</td>
<td>Dry circuit contact closure. Closed for normal operation, open for E-Stop. (+) 24 Volts DC @ 42 milliamps (1)</td>
</tr>
<tr>
<td>J10 (10)</td>
<td>Local E-Stop (Input)</td>
<td>Return for J10 (11) (1)</td>
</tr>
<tr>
<td>J10 (9)</td>
<td>Global E-Stop (Input)</td>
<td>MultiPac dry circuit contact closure. Closed for normal operation, open for E-Stop. (+) 24 Volts DC @ N*42 milliamps (1)</td>
</tr>
<tr>
<td>J10 (8)</td>
<td>Global E-Stop (Input)</td>
<td>Return for J10 (9) (1)</td>
</tr>
<tr>
<td>J10 (7)</td>
<td>JUCB Battery Power (Output)</td>
<td>+12 Volts JUCB Battery Power, 0.6 Amps re-settable fused (2)</td>
</tr>
<tr>
<td>J10 (6)</td>
<td>Internal Battery Wake Signal (Input)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J10 (5)</td>
<td>Inter Start (Input/Output)</td>
<td>(Output) = MultiPac start signal, +24 Volts DC, 30 milliamps/0.7 Amps maximum, momentary (0.1 to 2 seconds), 27 C65 units maximum connections. (Input) = 755 ohms load (1)</td>
</tr>
<tr>
<td>J10 (4)</td>
<td>Inter Start (Input/Output) Return</td>
<td>Return for signal of J10 (5) (1)</td>
</tr>
<tr>
<td>J10 (3)</td>
<td>Wake up signal if asleep (Input)</td>
<td>Momentary (0.1 to 2 seconds) input +4 to +15 Volts with respect to J10 (2). Opto-isolated (±150 Volts DC maximum to earth)</td>
</tr>
<tr>
<td>J10 (2)</td>
<td>Wake up signal if asleep (Input) Return</td>
<td>Isolated return for signal of J10 (2)</td>
</tr>
<tr>
<td>J10 (1)</td>
<td>Chassis Ground</td>
<td>To be used for cable shield connections</td>
</tr>
</tbody>
</table>

**Table 9 Notes:**

1. Connections made to these terminals MUST be Dry Circuit rated and isolated from ground/chassis. They may not be connected in parallel with other microturbine input terminals.
2. Connections made to this terminal MUST be isolated from ground/chassis. It may not be connected in parallel with other microturbine input and/or power supply terminals.
5.3.1. E-Stops

**CAUTION:** Emergency stops increase stress on the system components. Repeated use of the Emergency Stop feature will result in damage to the microturbine. Use only in emergency situations.

Two Emergency Stop (E-Stop) inputs are available in the UCB Communications Bay (see Figure 8). The E-Stop inputs are identified as Local and Global E-Stops. These inputs are simple contact closures intended for dry contact circuits.

**NOTE:** If no external E-Stop device is installed, the E-Stop terminals in the UCB must be jumpered.

### 5.3.1.1 Single MT E-Stop (Local)

Local E-Stop is used on a single microturbine system. When activated, it will only stop the microturbine that the E-Stop is wired to. See to Figure 8 for wiring details.

![Figure 8. Single MT E-Stop (Local)](image-url)
5.3.1.2 MultiPac E-Stop (Global E-Stop)

Global E-Stop is used on MultiPac Configurations (see Figure 9). The external E-Stop only needs to be connected to one microturbine in the MultiPac. When activated, it will stop all microturbine systems in the MultiPac.

The Global E-Stop jumper requirements are as follows:

- The local E-Stop (LCL ESTOP) pins on J10 of each microturbine in the MultiPac must be jumpered.
- The jumper must be removed from the global E-Stop (GLBL ESTOP) pins on J10 of each microturbine in the MultiPac.

![Figure 9. MultiPac E-Stop (Global E-Stop)](image)

5.3.2. Battery Wake-Up Connections

A Stand Alone capable (battery-equipped) microturbine enters Sleep Mode to conserve battery power during prolonged periods of inactivity. A potential-free external contact that provides a momentary pulse can be used to wake up the microturbine from Sleep Mode, as well as any other microturbine connected through its MultiPac cable.
5.3.2.1 **Single MT/MultiPac Wake-Up (Internal Battery)**

An external UCB connection that uses internal 12 VDC power to wake up the microturbine is shown in Figure 10.

![Diagram of Single MT/MultiPac Wake-Up (Internal Battery)](image)

---

**Figure 10. Single MT/MultiPac Wake-Up (Internal Battery)**
5.3.2.2 *Single MT/MultiPac Wake-Up – Opto-Isolated (Externally Powered)*

An external UCB connection that uses external power (4-15 VDC) to wake up the microturbine is shown in Figure 11.

![Diagram](image)

**Figure 11. Single MT/MultiPac Wake-Up – Opto Isolated (Externally Powered)**
5.3.2.3 Single MT/MultiPac Wake-Up (Externally Powered)

An external UCB connection that uses external power (24 VDC) to wake up the microturbine is shown in Figure 12.

![Figure 12. Single MT/MultiPac Wake-Up (Externally Powered)](image)

5.4. Opto-Isolated Inputs - Reserved (J11)

The opto-isolated inputs shown in Table 10 are reserved and not available for use.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J11 (9)</td>
<td>OPTO 3 (+)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (8)</td>
<td>OPTO 3 (-)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (7)</td>
<td>OPTO 2 (+)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (6)</td>
<td>OPTO 2 (-)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (5)</td>
<td>OPTO 3 (+)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (4)</td>
<td>OPTO 3 (-)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (3)</td>
<td>AGND</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (2)</td>
<td>DIGINSPI</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J11 (1)</td>
<td>Chassis Ground</td>
<td>To be used for shield connections</td>
</tr>
</tbody>
</table>
### 5.5. Digital Inputs (J12)

Table 11 defines all connections for connector J12.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J12 (13)</td>
<td>AGND</td>
<td>Return circuit for connector J12 contact closures <em>(1)</em></td>
</tr>
<tr>
<td>J12 (12)</td>
<td>PWR (+) (Wattmeter)</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms <em>(1)</em></td>
</tr>
<tr>
<td>J12 (11)</td>
<td>PWR (-) (Wattmeter)</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms <em>(1)</em></td>
</tr>
<tr>
<td>J12 (10)</td>
<td>KVAR (+) (Wattmeter)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J12 (9)</td>
<td>KVAR (-) (Wattmeter)</td>
<td>Reserved (DO NOT USE)</td>
</tr>
<tr>
<td>J12 (8)</td>
<td>AGND</td>
<td>Return circuit for connector J12 contact closures <em>(1)</em></td>
</tr>
<tr>
<td>J12 (7)</td>
<td>FLT2 (User Fault Input)</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms <em>(1)</em></td>
</tr>
<tr>
<td>J12 (6)</td>
<td>FLT1 (User Fault Input)</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms <em>(1)</em></td>
</tr>
<tr>
<td>J12 (5)</td>
<td>AGND</td>
<td>Return circuit for connector J12 contact closures <em>(1)</em></td>
</tr>
<tr>
<td>J12 (4)</td>
<td>Start/Stop</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms <em>(1)</em></td>
</tr>
<tr>
<td>J12 (3)</td>
<td>GC (Grid Connect mode)</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms <em>(1)</em></td>
</tr>
<tr>
<td>J12 (2)</td>
<td>SA (Stand Alone mode)</td>
<td>Dry circuit closure to AGND from (+) 5 Volt pull up, 4.7 k ohms <em>(1)</em></td>
</tr>
<tr>
<td>J12 (1)</td>
<td>Chassis Ground</td>
<td>To be used for shield connections</td>
</tr>
</tbody>
</table>

**Table 11 Notes:**

*(1)* Connections made to these terminals MUST be Dry Circuit rated and isolated from ground/chassis. They may not be connected in parallel with other microturbine input terminals.
5.5.1. Load Following Pulse Inputs

Two digital inputs are used for load following and reverse power protection. A power meter is required to provide potential free contacts that provide pulses for forward energy flow, and pulses for reverse energy flow.

Power flow in the forward direction (toward the loads) is measured as +PWR.

Power flow in the reverse direction is measured as –PWR. This input is only used if reverse power protection is required and enabled.

A 5 V wetting voltage is provided by the microturbine. See Figure 13 for wiring details and maximum wire length.

![Figure 13. Load Following Pulse Inputs](image-url)
5.5.2. Load Following Pulse Inputs (Interposing Relays)

Interposing relays are used to extend the distance > 100 feet. See Figure 14 for wiring details.

![Diagram](image_url)

**Figure 14. Load Following Pulse Inputs (Interposing Relays)**
5.5.3. Fault Inputs

Fault inputs are simple contact closures intended for dry contact circuits.

The following settings (set in CRMS) are available for fault inputs:

- **Enable/Disable (On/Off)** – If On, control detects a fault input into the system from an external fault source.

- **Fault Level** - defines the system severity level of this fault source.
  - Level 2 – Warning issued. Microturbine will continue to operate.
  - Level 3 – Standard microturbine shutdown sequence (cooldown).
  - Level 4 – Fast microturbine shutdown sequence (warmdown).

- **Time (sec)** - adjusts the debounce time for fault input detection from an external device, i.e., how much time the fault is detected for before the fault is latched in the system.

- **Active (Open / Close)**
  - Active Open – If the fault input contact changes state and moves from a closed position to an open position the fault will occur.
  - Active Close – If the fault input contact changes state and moves from an open position to a closed position the fault will occur.

Figure 15 shows a wiring example for fault input 1 and 2. This example is set up as follows:

- Fault input 1 is used to shut down the microturbine in the event that the external push button (normally closed) is activated. This change of state is configured as Active Open in CRMS.

- Fault input 2 is used to shut down the microturbine in the event that the contact (normally open) is activated. This is change of state is configured as Active Close in CRMS.
5.5.4. Fault Inputs Using Interposing Relays

Interposing relays are used for cable length greater than a 100ft and to fault multiple microturbines from a single fault device.

![Figure 15. Fault Inputs](image)

**CAUTION:** Interposing relays are required if multiple microturbines are required to be faulted by an external fault input. Microturbine fault inputs cannot be wired together and need to be electrically isolated.

Figure 16 shows a wiring example using interposing relays. This example is set up as follows:

- Fault input 1 is used to shut down the microturbines in the event that the external fault device (normally closed) is activated. This is change of state at relay R1 contacts is configured as Active Close in CRMS.
Figure 16. Fault Inputs Using Interposing Relays
5.5.5. Start/Stop Command in GC Mode

Figure 17 shows how a microturbine is wired for start and stop commands in Grid Connect mode. A contact closure provides a start command and a contact release provides a stop command. The GC interlock must be linked (jumpered) for Grid Connect operation.

![Figure 17. Start/Stop Command in GC Mode](image-url)
5.5.6. Start/Stop Command in SA Mode

Figure 18 shows how a microturbine is wired for start and stop commands in Stand Alone mode. A contact closure provides a start command and a contact release provides a stop command. The SA interlock must be linked (jumpered) for Stand Alone operation.

![Diagram of Start/Stop Command in SA Mode](image)

Figure 18. Start/Stop Command in SA Mode
5.5.7. Start/Stop, GC and SA Command with DMSC

Figure 19 shows an example of how a microturbine is wired for start and stop commands in Dual Mode. A contact closure provides a start command and, a contact release provides a stop command. The Stand Alone and Grid Connect interlocks positions are defined by the Dual Mode System Controller (DMSC). Refer to the DMSC Technical Reference (410071) for details.
5.6. Analog Inputs (J14)

Table 12 defines all connections for connector J14 and Figure 20 shows a wiring example using the 0-5 VDC analog inputs. Figure 21 shows the difference in wiring between analog inputs configured for voltage signal and current signal. Refer to the following paragraphs for details.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J14 (6)</td>
<td>AGND</td>
<td>Return for analog signals. Impedance = 10 ohms</td>
</tr>
<tr>
<td>J14 (5)</td>
<td>ANIN1</td>
<td>0 to (+) 5 Volts DC, high impedance</td>
</tr>
<tr>
<td>J14 (4)</td>
<td>ANIN2</td>
<td>0 to (+) 5 Volts DC, high impedance</td>
</tr>
<tr>
<td>J14 (3)</td>
<td>ANIN3</td>
<td>0 to (+) 5 Volts DC, high impedance</td>
</tr>
<tr>
<td>J14 (2)</td>
<td>AGND</td>
<td>Return for analog signals. Impedance = 10 ohms</td>
</tr>
<tr>
<td>J14 (1)</td>
<td>Chassis Ground</td>
<td>To be used for shield connections</td>
</tr>
</tbody>
</table>

Table 12 Notes:
(1) Connections made to these terminals MUST be isolated from ground/chassis. They may not be connected in parallel with other microturbine input terminals.
5.6.1. Analog Inputs

Refer to the CRMS Technical Reference Maintenance Edition (410014) and enter the settings for the analog inputs as follows:

1. At the User Connection Bay Settings Panel, select the Input Signal Type:
   - **4-20 mA**: In order for the 4-20 mA input to work, a customer-supplied 250 ohm resistor must be installed. Internal software is scaled to work from 0.9 V to 4.5 V for full range operation (see Figure 21)
   - **0-5 V**: Function range is scaled between 0 V and 5 V.

2. Refer to Table 13 and select a function for the analog input.

3. Refer to Table 14 and enter the Low and High Limits for the function. Table 14 gives the minimum and maximum allowable values. For the Electrical Power Demand function, the High Limit displays 65000 W as the default. For a single microturbine application this value does not need to be changed. For a MultiPac, enter the maximum combined power demand of the microturbines in the MultiPac. For example, if the MultiPac consists of three C65 microturbines, the high limit will be 195000 W (3 X 65000).

![Figure 21. Analog Input for Voltage (0-5 V) and Current (4-20 mA)](image)
### Table 13. Connector J14 – Analog Input Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not assigned</td>
<td>No software function assigned (Default).</td>
</tr>
<tr>
<td>Electrical Power Demand</td>
<td>Provides output power demand feedback</td>
</tr>
<tr>
<td>CHP Water Flow Rate</td>
<td>Provides water flow feedback if iCHP option is installed.</td>
</tr>
<tr>
<td>CHP Temperature Feedback</td>
<td>Provides temperature feedback if iCHP option is installed. Input can be used for thermal load following.</td>
</tr>
<tr>
<td>Propane Temperature Feedback</td>
<td><strong>Reserved (Do not use)</strong></td>
</tr>
</tbody>
</table>

### Table 14. Analog Input Limits

<table>
<thead>
<tr>
<th>Function</th>
<th>Low Limit</th>
<th>High Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td></td>
<td>Signal Type 0-5 V</td>
<td>Signal Type 4-20 mA</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>Signal Type 0-5 V</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>Signal Type 4-20 mA</td>
</tr>
<tr>
<td>Electrical Power Demand</td>
<td>0W</td>
<td>2090000W</td>
</tr>
<tr>
<td>CHP Water Flow Rate</td>
<td>0 gpm</td>
<td>80 gpm</td>
</tr>
<tr>
<td>CHP Temperature Feedback</td>
<td>32 °F</td>
<td>212 °F</td>
</tr>
</tbody>
</table>

#### 5.6.2. Analog Input Scaling

The high and low limits entered in CRMS for an analog input function are used by the microturbine software as the starting and ending points of a linear scale. As shown in Table 14, the scale is different depending on whether the signal type is 0-5 V or 4-20 mA. How this scale is generated for each signal type is described below:

- **Signal Type 0-5 V**: The range of values is scaled between 0 and 5 Volts. Using CHP Water Flow Rate as an example, a voltage signal of 0 V represents 0 gpm and a voltage signal of 5 V represents 80 gpm. Therefore, a midrange voltage signal of 2.5 V would represent 40 gpm.

- **Signal Type 4-20 mA**: The software establishes a range between 0.9 V to 4.5 V for this signal type as shown in Figure 22. Fluctuations above and below this range can be misread by the system. The signal is treated as a fault if it is greater than 18.8 mA or less than 2.8 mA. Using CHP Water Flow Rate as an example, a current signal (using a 250 Ohm resistor) of 3.6 mA (0.9 V) represents 0 gpm and a current signal of 18 mA (4.5 V) represents 80 gpm. Therefore, a midrange signal of 10.8 mA (2.7 V) would represent 40 gpm.
5.7. Digital Outputs (J15)

Table 15 defines all connections for connector J15.

**Table 15. Connector J15 – Solid-State Relay Outputs**

<table>
<thead>
<tr>
<th>Relay</th>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>#6</td>
<td>J15 (12)</td>
<td>AC6-B</td>
<td>AC6 load, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td></td>
<td>J15 (11)</td>
<td>AC6-A</td>
<td>AC6 line, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td>#5</td>
<td>J15 (10)</td>
<td>AC5-B</td>
<td>AC5 load, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td></td>
<td>J15 (9)</td>
<td>AC5-A</td>
<td>AC5 line, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td>#4</td>
<td>J15 (8)</td>
<td>AC4-B</td>
<td>AC4 load, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td></td>
<td>J15 (7)</td>
<td>AC4-A</td>
<td>AC4 line, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td>#3</td>
<td>J15 (6)</td>
<td>AC3-B</td>
<td>AC3 load, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td></td>
<td>J15 (5)</td>
<td>AC3-A</td>
<td>AC3 line, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td>#2</td>
<td>J15 (4)</td>
<td>AC2-B</td>
<td>AC2 load, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td></td>
<td>J15 (3)</td>
<td>AC2-A</td>
<td>AC2 line, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td>#1</td>
<td>J15 (2)</td>
<td>AC1-B</td>
<td>AC1 load, 25 VAC max, 100 mA max</td>
</tr>
<tr>
<td></td>
<td>J15 (1)</td>
<td>AC1-A</td>
<td>AC1 line, 25 VAC max, 100 mA max</td>
</tr>
</tbody>
</table>

Table 15 Notes:

(1) These contacts must only be connected in Class 2 circuit for limited voltage and limited current power source at maximum voltage of 25 VAC. If switching at higher voltages and currents is required, please contact Capstone Applications for recommendations.
CAUTION: Digital outputs must be configured BEFORE making any electrical connections. Failure to do this may cause damage to the microturbine and void the warranty.

For some applications, the current draw required on the external equipment may exceed the rated current on the UCB relays. In these cases, an interposing relay must be installed.

CAUTION: The coil rating of the interposing relay must not exceed the rated current and voltage on the UCB relays. Otherwise permanent damage to the UCB board may occur.

Electromechanical interposing relays are highly recommended over solid-state relays for electrical isolation.

The digital outputs (output relays) are simple contact closures intended for dry contact circuits. Wetting voltage must be provided by external power source.

The following functions (set in CRMS) are available for Digital Outputs:

- Control State Functions - digital outputs can be selected to switch at any control state as defined in Table 16.
- Active (Open / Close)
  - Active Open – If a control state is TRUE the digital output will change from a closed to open position.
  - Active Close – If a control state is TRUE the digital output will change from an open to closed position.

NOTE: When the microturbine is powered off the digital outputs revert back to their de-energized state of normally open.

Table 16 lists the control state functions that can be used with the output relays described in Table 15. Refer to the CRMS Technical Reference Maintenance Edition (410014) for details.

**Table 16. Control State Functions**

<table>
<thead>
<tr>
<th>Function</th>
<th>Control State (Function is True)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standby</td>
<td>System is in the Standby state.</td>
</tr>
<tr>
<td>Run</td>
<td>Engine is running or power electronics are enabled.</td>
</tr>
<tr>
<td>Contactor Closed</td>
<td>Output Contactor is closed.</td>
</tr>
<tr>
<td>Fault</td>
<td>Fault occurs that is severity level 3 or greater</td>
</tr>
<tr>
<td>Stand Alone</td>
<td>System is in the Stand Alone mode</td>
</tr>
<tr>
<td>Stand Alone Load</td>
<td>System is in the Stand Alone mode and in the Load State.</td>
</tr>
<tr>
<td>Disable</td>
<td>System is in the Disable state.</td>
</tr>
<tr>
<td>Fuel On</td>
<td>Electrical fuel shut-off is enabled.</td>
</tr>
<tr>
<td>Fuel Purge</td>
<td>10 seconds after the electrical fuel shutoff is closed (for units equipped for liquid fuel only)</td>
</tr>
<tr>
<td>Load State</td>
<td>System is in the Load State (GC or SA).</td>
</tr>
</tbody>
</table>
Table 16. Control State Functions (Continued)

<table>
<thead>
<tr>
<th>Function</th>
<th>Control State (Function is True)</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Load</td>
<td>System is in Prepare to Start state and DC bus has been raised. This is generally used to start gas compressors that are powered from the DC bus.</td>
</tr>
<tr>
<td>Protective Relay</td>
<td>System has “PRT RLY Fault” (Protective Relay Fault).</td>
</tr>
<tr>
<td>Anti-islanding</td>
<td>System has “ANTI-ISL Fault” (Anti-Islanding Fault).</td>
</tr>
<tr>
<td>Not Assigned</td>
<td>No software function assigned (Default).</td>
</tr>
<tr>
<td>CHP Active (If installed)</td>
<td>This function is true when the system detects microturbine exhaust gas flow. Active in the following states: Light, Acceleration, Run, Load, Recharge (SA only), Cooldown, Warmdown, and Restart.</td>
</tr>
<tr>
<td>Dual Mode Control</td>
<td>This function is true for Dual Mode configured systems only. When selected it will act as an interlock to ensure the main breaker (M1) cannot be opened when performing Stand Alone operation.</td>
</tr>
<tr>
<td>HTC Start Relay</td>
<td>Reserved (Do not use)</td>
</tr>
<tr>
<td>EUCB</td>
<td>Reserved (Do not use)</td>
</tr>
</tbody>
</table>

5.7.1. Solid State Relays

Figure 23 shows how a microturbine is wired to the digital output to provide a start signal for an external gas compressor. The control state for relay #1 (AC1) would be set for External Load and the Active Close. The wiring diagram also shows how the interlock signal would be wired to the Dual Mode System Controller (DMSC). The control state for relay #2 (AC2) would be set for DUAL MODE CNTRL and Active Closed.
5.8. User Power (J16)

Table 17 defines all connections for connector J16. See Figure 24 for example connections using connector J16.

Table 17. Connector J16 – Modem and User Power Outputs

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>J16 (4)</td>
<td>PWRGND</td>
<td>User Power Return</td>
</tr>
<tr>
<td>J16 (3)</td>
<td>User Power</td>
<td>24 Volts DC, 1 Amp maximum (fuse protection must be provided when used)</td>
</tr>
<tr>
<td>J16 (2)</td>
<td>PWRGND</td>
<td>Modem Power Return</td>
</tr>
<tr>
<td>J16 (1)</td>
<td>Modem Power</td>
<td>12 Volts DC, 0.5 Amps maximum (fuse protection must be provided when used)</td>
</tr>
</tbody>
</table>

Table 17 Notes:
(1) Connections made to these terminals MUST be isolated from ground/chassis. They may not be connected in parallel with other microturbine input and/or power supply terminals.
Figure 24. User Power (J16)
Technical Reference

Capstone MicroTurbine Electrical Installation

Introduction

This document presents electrical installation information for the Capstone Turbine Corporation® Model C30 and Model C60/C65 MicroTurbine™ systems.

Alternating current electrical power may be paralleled with a utility grid or with another generation source, or the MicroTurbine can act as a Stand Alone generator for standby, backup, or remote off-grid power. Multiple systems can be combined and controlled as a single larger generating source, commonly known as a MultiPac.

State-of-the-art digital power conditioning provides two output choices:

- Built-in utility-synchronized alternating current output with built-in protective relay functions.
- Stand Alone alternating current output (optional).

This document describes proper electrical interconnection for the Alternating Current (AC) output versions only. Refer to our Hybrid Electric Vehicle documentation for Direct Current (DC) model installation instructions.

Additional MicroTurbine electrical performance parameters are contained within the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001).
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System Operating Modes
The Capstone MicroTurbine can function in two operational modes:

- Grid Connect Mode (GC)
- Stand Alone Mode (SA)

A Dual Mode connection option (which requires an optional Dual Mode Controller), is available that allows automatic transition between GC and SA modes.

Operation as a MultiPac is available for both operational modes.

| CAUTION | All of the allowable utility service connections for the various MicroTurbine operating modes are presented in this document. Consult Capstone if your utility service connections do not agree with those presented in this document. |

Grid Connect Output
The Capstone MicroTurbine electrical output in Grid Connect mode is 3-phase, 400 to 480 Volts AC and 45 to 65 Hz (both voltage and frequency are determined by the grid). Refer to Figure 1 as required.

Stand Alone Output
When equipped with the Stand Alone option, the electrical output is user adjustable from 150 to 480 Volts AC, 10 to 60 Hz.

The current in each phase may be continuous and need not be balanced, as long as the electrical current limits are respected. Refer to the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001) for details on electrical ratings.

Stand Alone loads may be connected phase-phase or phase-neutral, so long as the current limits are respected. Overloads up to 10 seconds can be accommodated. The Ramp Start feature can assist in starting loads with large in-rush currents.

Dual Mode Connections
A MicroTurbine equipped with the Stand Alone option is capable of either Grid Connect operation or Stand Alone operation. Conversion from one mode to the other requires a shutdown of the MicroTurbine. Conversion may be accomplished manually or automatically. Automatic transfer may be accomplished with the optional Capstone Dual Mode Controller. Refer to the Dual Mode Controller Technical Reference (410039) for details.

MultiPac Power Connections
Refer to the MultiPac Technical Reference (410032) for details on MultiPac operation. Connections for the MultiPac are supported in the Stand Alone, Grid Connect, and Dual Mode configurations.

Power Quality
Power Connections between Systems
Power connections between systems are provided for the following connection methods:

- Grid Connect
- Stand Alone
- Dual Mode
- MultiPac

Utility Power Connections
Utility power connections are provided for the following methods of connection:

- Direct Connection
- Transformer Connection

Both solid-grounded and resistance-grounded Wye utility connections are permitted.

Stand Alone Connections
Stand Alone connections are provided as follows:

- Three-Phase Loads
- Single-Phase Loads
- Transformer

Dual-Mode Connections
Dual-Mode connections are provided as follows:

- Direct Connection
- Transformer Connection
Electrical Connections – Grid Connect

Figure 1 presents the various allowable connections for the Grid Connect mode. The upper section of the figure shows the allowable grid connections that are UL1741 compliant, and the lower section shows the allowable connections that are permissible (safe) for the Capstone MicroTurbine but are NOT UL1741 compliant. For details on each configuration, refer to the figure number shown for that configuration.

LEGEND:
- 3P = 3-Phase
- 3W = 3-Wire
- 4W = 4-Wire
- MT = MicroTurbine
- w/o = without
- GC = Grid Connect
- SA = Stand Alone

![Diagram of Electrical Connections](attachment:diagram.png)

Notes:
1(a). The MicroTurbine chassis ground must always be solidly connected to the same earth ground as that at the Utility Service.
1(b). An electrical disconnect device, with over-current protection (fuses or circuit breaker), must be installed within sight of the MicroTurbine.
1(c). Phase-to-ground voltage at the MicroTurbine must never exceed 480 Vrms, or 277 Vrms for the Model C30 Stand Alone Units (+10% high-line allowed).
2. The Utility Service must be ground referenced, either through solid or resistance grounding.
3. The Utility Service Neutral must be solidly connected to the MicroTurbine Neutral or to the service side of any Transformer Neutrals.
4. The MicroTurbine side Transformer Neutral must be solidly connected to ground and to the MicroTurbine Neutral.
5. Model C30 GC (Not SA) and Model C60/C65 Units may be operated corner grounded (not recommended).

Figure 1. Allowable Grid Connections
Grounding

The Capstone MicroTurbine during Grid Connect operation is designed for ground-referenced, balanced voltage operation.

The recommended connection for Grid Connect operation is to a 4-wire Wye system, where the neutral is solidly grounded. The neutral-to-ground connection should be at the utility service panel of the facility.

A SOLID EARTH GROUND of the MicroTurbine is MANDATORY for successful operation. The MicroTurbine uses digital electronics to sense line voltages and currents that require a solid ground connection to perform accurately. Refer to the following electrical diagrams for proper grounding location.

Neglecting to properly ground the MicroTurbine system (that is, no neutral-to-ground connection, or more than one neutral-to-ground connection) can cause damage to the MicroTurbine system.

In all cases, the neutral-to-ground post (if equipped) MUST be removed from the high voltage bay of the MicroTurbine User Connection Bay. Grid Connect operation with the neutral-to-ground post installed may create multiple neutral-to-ground connections. This condition can lead to circulating currents, resulting in nuisance faults with the MicroTurbine or which may cause safety hazards within the facility. Refer to Figures 2 and 3 for neutral-to-ground post details within the User Connection Bay.

Notice that all electrical wiring, including protection and grounding, must conform to all local and national electrical codes and regulations.

Figure 2. Model C30 Terminal Block
(Located in Power Bay at Rear of Enclosure)
Electrical Installation Interface

It is the responsibility of the owner/user to supply the electrical cable and switchgear, through which the MicroTurbine delivers its output power.

Proper sizing of transformers in the installation is required to limit high impedance. Calculate the impedance of the line run and transformers to the utility source. Refer to the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001) for impedance limits required for installation. Refer to Appendix A for examples of input impedance calculations.

It is essential that the owner/user consult all of the applicable codes and industry standards before connecting the interface wiring for the MicroTurbine. Notice that a qualified electrician may be required to perform this work.

Circuit Breakers and/or Fused Disconnects

A circuit breaker or fused disconnect must be installed between the MicroTurbine and the electrical service panel, within sight of the MicroTurbine.

The types of fused disconnect and the fault-current ratings of the device must meet all local codes and specifications. Time delay fuses are not required. Fast acting, current limiting fuses are recommended. Circuit breakers or fused disconnects should always have lockout provisions to facilitate safe maintenance operations.

Notice that the circuit breaker or fused disconnect equipment must meet the maximum current and voltage ratings as described in the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001). Additionally, ALL equipment must be properly grounded.

Always refer to the latest national and local codes relative to your location to determine the proper connection requirements.
Additionally, and in accordance with Underwriters Laboratories UL 2200, the various torque specifications required on the terminal block **MUST BE** as noted in Table 1.

### Table 1. Terminal Block Torque Specification

<table>
<thead>
<tr>
<th>Wire Size (AWG)</th>
<th>Torque Value (Lb-in)</th>
<th>(Kg-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/0 to #6</td>
<td>62 to 13</td>
<td>120</td>
</tr>
</tbody>
</table>

**Phase Rotation**

During Grid Connect operation, the MicroTurbine phase terminals may be connected to the grid in any order, based upon auto-synchronization to the electric utility grid.

The output from the MicroTurbine is L1-L2-L3 counterclockwise, and must be connected to the grid in this order for Stand Alone or Dual Mode operation.

**Transformer Applications**

A voltage transformer for the MicroTurbine will be required for any of the following conditions:

- Circuit-connect voltages other than 400 to 480 Volts AC.
- Connection to a system where the impedance is high enough to cause overvoltage at the rated output current of the system. In this case, a tapped or autotransformer is required to lower the nominal voltage, if this cannot be done with the installed transformer.

Refer to Figures 4 through 12 for allowable grid connections.

Each of the following items must be observed for proper installation:

- Proper branch circuit disconnect **MUST BE** installed between the MicroTurbine and the electrical service panel. The branch circuit disconnect may be installed on either side of the transformer within sight of MicroTurbine.

**NOTE**
If a fused disconnect is used at the MicroTurbine, it is recommended to install the fuses on the MicroTurbine side. This applies to all configurations.

- The neutral and ground **MUST BE** connected in **ONLY ONE** location at the utility or local branch circuit protection.
- The neutral-to-ground post in the MicroTurbine User Connection Bay **MUST BE** removed (if equipped).
Allowable Grid Connections – UL1741 Compliant

Figure 4. Connection to 480V Wye Service - Direct Connection (UL1741 Compliant)

Figure 5. Connection to Non-480V Wye Service – Autotransformer (UL1741 Compliant)
Figure 6. Connection to Wye-Wye Service: Isolation Transformer (UL1741 Compliant)

Figure 7. Connection to Wye-Delta Service: Isolation Transformer (UL1741 Compliant)
Allowable Grid Connections – Not UL1741 Compliant

Figures 8 through 12 present permitted utility (or transformer) connections that do not conform to UL1741 standard for grid interconnection.

**NOTE**
Any external power metering equipment may only be installed on the Wye side of the isolation transformer, and NOT on the Delta side.

**Figure 8. Connection to 480 V Wye Service - Direct Connection**
(Not UL1741 Compliant)

**Figure 9. Connection to Non-480V Wye Service – Autotransformer**
(Not UL1741 Compliant)
Single Unit or MultiPac Connections

Branch Circuit Disconnect

Isolation Transformer (Wye-Delta)

L3
L2
L1
N
G

Wye Utility Service

Figure 10. Connection to Wye-Delta Service: Isolation Transformer (Not UL1741 Compliant)

Single Unit or MultiPac Connections

Branch Circuit Disconnect

Isolation Transformer (Delta-Wye)

L3
L2
L1
N
G

Wye Utility Service

Figure 11. Connection to Delta-Wye Service: Isolation Transformer (Not UL1741 Compliant)
Figure 12. Connection to Delta-Delta Service: Isolation Transformer (Not UL1741 Compliant)
Electrical Connections – Stand Alone

If the Capstone MicroTurbine is equipped with the Stand Alone option, the operator must supply the electrical cable and switchgear through which the Capstone MicroTurbine delivers its output power. The cabling and switchgear must be capable of safely handling the maximum potential loads, and must meet all applicable local and national regulations.

It is essential that the owner/user consult all of the applicable codes and standards before electrically wiring the MicroTurbine. A qualified electrician may be required to do the work. The electrical connection terminal block for the MicroTurbine can be found in the Power Bay located at the rear of the enclosure.

Stand Alone Loads

Stand Alone loads may be connected in any combination of line-line or line-neutral, while respecting the maximum current and voltage ratings as described in the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001). Notice that in Stand Alone systems, the MicroTurbine(s) neutral must be solidly connected to ground at a single point.

Voltage

The output voltage from the MicroTurbine may be programmed from 150 to 480 volts AC, phase-to-phase, and 10 to 60 Hz. Output power capabilities are reduced at the lower voltage levels, based on the operational current limits.

Phase Rotation

The output voltage/current phase rotation is counterclockwise, as in L1 to L2 to L3. Notice that improper phase rotation connections can damage the connected loads. Capstone cannot be held responsible for equipment damage caused by improper connections. It is the operator’s responsibility to verify the proper phase connections between the MicroTurbine and the load(s).

Stand Alone Transformer Applications

For Stand Alone applications, power transformer(s) will be needed for loads that require voltages different from the programmed MicroTurbine Stand Alone voltage set point. Refer to the Stand Alone Operation Technical Reference (410028) for details on the voltage and protective set points used for Stand Alone operation.

Load Circuits

The MicroTurbine output consists of three phases and a neutral circuit. These may be used in any combination, limited only by current limits on each phase, as described in the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001).

The nominal Stand Alone voltage setting is available between any two phases. Single phase and/or unbalanced loads can be accommodated, respecting the current and power limits previously noted.

Notice that the MicroTurbine Neutral must always be grounded.
Load Capacity

The MicroTurbine output is current limited. The MicroTurbine can operate loads with any power factor, so long as current limits are not exceeded. The current (I) consumed by the load(s) is a function of real power (Watts), volts (V) and the power factor (PF).

\[ I = \frac{W}{\sqrt{3} \times V \times PF} \]

The allowable power factor (PF) will be a function of the real load and the maximum phase current. Power derating curves for ambient temperature and elevation should be considered when determining real power (Watts). Refer to the Model C30 Performance Technical Reference (410004) and to the Model C60/C65 Performance Technical Reference (410005/410048) for additional details.

For example, with a total 30 kW load operating at 480 Volts AC with a current limit of 46 ARMS per phase, the lowest allowable power factor (PF) is as follows:

\[ \frac{30000}{(480 \times 46 \times \sqrt{3})} = 0.78 \]

Operating at 376 volts AC, the lowest allowable power factor (PF) is as follows:

\[ \frac{30000}{(376 \times 46 \times \sqrt{3})} = 1 \]

Operating voltages lower than 376 volts AC will consequently reduce the total available output power of the MicroTurbine according to the following:

\[ W = 46 \times \sqrt{3} \times V \times PF \]

**NOTE** Incorrect determination of load capacity can cause the MicroTurbine to fault.

Grounding

The MicroTurbine system (ground terminal) must **ALWAYS** be connected to Earth Ground during system operation.

The neutral terminal of the MicroTurbine output terminal block **MUST BE** connected to ground at the branch circuit disconnect.

The MicroTurbine neutral-to-ground post (if equipped) should be removed. Refer to Figures 2 and 3 as required.
Figure 13 presents the Stand Alone electrical connections for three-phase loads. Notice that for Single and MultiPac Stand Alone systems, the neutral **MUST BE** connected to ground in one location **ONLY**.

### Single Unit or MultiPac Connections

- **L3**
- **L2**
- **L1**
- **N**
- **G**

### Branch Circuit Disconnect

- **Ground**
  (Ground rod or other low impedance grounding system)

### Delta Loads

- ![Delta Loads Diagram](image)

### Wye Loads

- ![Wye Loads Diagram](image)

### Other 3-Phase Loads:

Connect the neutral if directed to do so in load installation instructions

---

**Figure 13. Stand Alone Connections: Three-Phase Loads**
Figure 14 presents the Stand Alone electrical connections for single-phase loads. Notice that a single neutral-to-ground connection is essential and required. The loads **MUST NOT** exceed the ratings described in the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001).

![Diagram of Stand Alone Connections: Single-Phase Loads](image)

Figure 14. Stand Alone Connections: Single-Phase Loads
Electrical Connections – Dual Mode

Dual Mode electrical interconnections are presented in the following paragraphs.

Electrical Cables and Switchgear

If the Capstone MicroTurbine is equipped with the Stand Alone option, it is capable of either Grid Connect operation or Stand Alone operation, and may be converted from one to the other simply and easily.

An installation designed to switch between Grid Connect and Stand Alone operation is identified as a Dual Mode installation. Loads on the same circuit with the MicroTurbine and which may be powered either by the grid or by the MicroTurbine in Stand Alone mode are defined as Protected Loads.

Conversion from one mode to the other requires the following:

1. A shutdown of the MicroTurbine, followed by a
2. Transfer of the electrical connections, and then
3. A reconfiguration of the interlocks and software, and finally,
4. A restart of the MicroTurbine.

These steps may be accomplished manually, or automatically. Automatic transfer and reconfiguration may be accomplished with the Capstone Automatic Dual Mode Controller. Refer to the Dual Mode Controller Technical Reference (410039) for additional details.

Whether manual or automatic, the electrical conversion from one mode to the other must be planned with care, particularly the neutral and ground connections. Safety requirements, code requirements, and functional requirements must all be met.

Sizing Protected Loads

Notice that Protected Loads in a Dual Mode application must be sized as though the MicroTurbine will operate on the loads in the Stand Alone mode, where the cumulative load to each phase is current-limited.

Phase Rotation

Dual mode applications must match the phase rotation of the MicroTurbine in the Stand Alone mode with the phase rotation of the grid, to prevent load phase reversal when switching modes. Therefore, the output from the MicroTurbine MUST BE connected L1-L2-L3 counterclockwise.
Grounding and Neutral Connections

The neutral-to-ground connection requirements in the Dual Mode operation are identical to those in the Grid Connect mode of operation.

The neutral-to-ground bar (if equipped) **MUST BE** removed from all MicroTurbines in the system.

| CAUTION | It is not possible to connect the DMC to a delta utility service or local transformer. The protected loads must be supplied from a ground-referenced source in both Grid Connect and Stand Alone modes.

For a Wye service or transformer, the ground reference exists via the Neutral when the system is running GC with the DMC switch closed or when the system is running SA with the DMC switch open.

For a delta service or transformer, the ground reference exists via the phases when the system is running GC with the DMC switch closed, but the ground reference is lost when the system is running SA with the DMC switch open. (The open DMC switch isolates protected loads from the phase to ground connection in the utility service or local transformer.) Therefore, it is not permitted to supply the DMC from a delta utility or local transformer.

Figure 15 presents direct connection using the Dual Mode Controller. The DMC is installed between the MicroTurbine and the protected loads, and the utility or local transformer. The neutral-to-ground bar **MUST BE** removed from the MicroTurbine User Connection Bay. A single neutral-to-ground connection **MUST BE** made at the local utility.

![Diagram of Dual Mode Connections: Direct Connection](image-url)

**Figure 15. Dual Mode Connections: Direct Connection**
Figure 16 presents the indirect connection using the Dual Mode Controller. The DMC is installed between the autotransformer and the protected loads, and the utility or local transformer. The neutral-to-ground connection must be connected at a single point at the utility. The neutral-to-ground bar (if equipped) **MUST BE** removed from the MicroTurbine User Connection Bay.

![Diagram of Dual Mode Connections: Using an Autotransformer](image)

**Figure 16. Dual Mode Connections: Using an Autotransformer**

Figure 17 presents indirect connection using the Dual Mode Controller. The DMC is installed between the isolation transformer and the protected loads, and the utility or local transformer.

![Diagram of Dual Mode Connections: Using an Isolation Transformer](image)

**Figure 17. Dual Mode Connections: Using an Isolation Transformer**
**Electrical Connections – MultiPac**

MultiPac electrical interconnections are presented in the following paragraphs.

Power connections between the MultiPac systems will be necessary, and these connections must consider the proper phase wiring, neutral wiring, and grounding connections between the various systems. Refer to Figure 18 for electrical connection diagram for permitted MultiPac connections.

There **MUST BE** one neutral-to-ground connection in the system at the point of connection, or at the utility or local transformer. The neutral-to-ground post (if equipped) **MUST BE** removed from all MicroTurbines in the MultiPac system.

- Each MicroTurbine is installed with an individual branch circuit disconnect for service.
- The output of each MicroTurbine is connected via standard conduit or an electrical cable tray. This point of connection is installed to the utility, local transformer, or loads as in the previous diagrams.
- For Stand Alone and Dual Mode installations, NO transformers are permitted between MicroTurbines in the MultiPac. Individual transformers may be used for Grid Connect only installations, but are not recommended.

**NOTE**
The neutral-to-ground bar must be removed from ALL MicroTurbines in the MultiPac. All wiring shown should be connected regardless of utility connection types.

**Figure 18. Power Connections: MultiPac System**
Appendix A

Input Impedance Calculations - Examples

Refer to the Model C30 Electrical Technical Reference (410000) and the Model C60/C65 Electrical Technical Reference (410001) for input impedance requirements.

Three examples of the total electrical input impedance calculations which detail the values considering the MicroTurbine output looking towards the utility are provided as follows:

**Example 1: Model C30 - Considering 1 MicroTurbine**

Total Impedance for all conductors: $Z_L = 0.5\%, \ Z_R = 1.0\%$

\[
\begin{align*}
\text{30 KVA} & \quad 480 \text{ V} & \quad 208 \text{ V} & \quad 240 \text{ V} & \quad \text{Utility} 5 \text{ kV} \\
\text{240 V} & \quad 240 \text{ V} & \quad 208 \text{ V} & \quad 45 \text{ kVA} & \quad 45 \text{ kVA} & \quad 60 \text{ kVA} \\
L & = 5.6\% \quad & L & = 6.4\% \quad & L & = 5\% \\
R & = 1.7\% \quad & R & = 1.9\% \quad & R & = 1.6\% \\
\end{align*}
\]

$Z_L (\text{Total}) = 5.6\%(30/45) + 6.4\%(30/45) + 5\%(30/60) + 0.5\% = 11\%$

(Value exceeds acceptable limits)

$Z_R (\text{Total}) = 1.7\%(30/45) + 1.9\%(30/45) + 1.6\%(30/60) + 1\% = 4.22\%$

(Value is within acceptable limits)

**Example 2: Model C60/C65 - Considering 1 MicroTurbine**

Total Impedance for all conductors: $Z_L = 0.5\%, \ Z_R = 1.0\%$

\[
\begin{align*}
\text{60 KVA} & \quad 480 \text{ V} & \quad 208 \text{ V} & \quad 240 \text{ V} & \quad \text{Utility} 5 \text{ kV} \\
\text{240 V} & \quad 240 \text{ V} & \quad 208 \text{ V} & \quad 75 \text{ kVA} & \quad 75 \text{ kVA} & \quad 100 \text{ kVA} \\
L & = 5.6\% \quad & L & = 6.4\% \quad & L & = 5\% \\
R & = 1.7\% \quad & R & = 1.9\% \quad & R & = 1.6\% \\
\end{align*}
\]

$Z_L (\text{Total}) = 5.6\%(60/75) + 6.4\%(60/75) + 5\%(60/100) + 0.5\% = 13.1\%$

(Value exceeds acceptable limits)

$Z_R (\text{Total}) = 1.7\%(60/75) + 1.9\%(60/75) + 1.6\%(60/100) + 1\% = 4.85\%$

(Value is within acceptable limits)
Example 3: Considering 3 MicroTurbines

Total Impedance for all conductors: \( Z_L = 0.5\%, \ Z_R = 1.0\% \)

- **MicroTurbine #1 (30 kVA):**
  
  \[
  Z_{L\ (MT1)} = 5.6\% \frac{30}{45} + 7.2\% \frac{120}{500} + 5\% \frac{120}{2000} + 0.5\% = 6.3\%
  \]
  
  (Value is within acceptable limits)

  Note: In these calculations, the number 120 represents the sum of the MicroTurbine outputs (30+30+60)

  \[
  Z_{R\ (MT1)} = 1.7\% \frac{30}{45} + 1.8\% \frac{120}{500} + 1.3\% \frac{120}{2000} + 1\% = 2.7\%
  \]
  
  (Value is within acceptable limits)

- **MicroTurbine #2 (30 kVA):**

  \[
  Z_{L\ (MT2)} = 5.6\% \frac{30}{45} + 7.2\% \frac{120}{500} + 5\% \frac{120}{2000} + 0.5\% = 6.3\%
  \]
  
  (Value is within acceptable limits)

  \[
  Z_{R\ (MT2)} = 1.7\% \frac{30}{45} + 1.8\% \frac{120}{500} + 1.3\% \frac{120}{2000} + 1\% = 2.7\%
  \]
  
  (Value is within acceptable limits)

- **MicroTurbine #3 (60 kVA):**

  \[
  Z_{L\ (MT3)} = 4.3\% \frac{60}{112.5} + 7.2\% \frac{120}{500} + 5\% \frac{120}{2000} + 0.5\% = 4.9\%
  \]
  
  (Value is within acceptable limits)

  \[
  Z_{R\ (MT3)} = 1.4\% \frac{60}{112.5} + 1.8\% \frac{120}{500} + 1.3\% \frac{120}{2000} + 1\% = 2.3\%
  \]
  
  (Value is within acceptable limits)
Capstone Technical Support

If questions or problems arise regarding electrical interconnections for your Capstone MicroTurbine, please contact Capstone Technical Support for assistance and information.

Capstone Technical Support
Toll Free Telephone: (877) 282-8966
Service Telephone: (818) 407-3600
Facsimile: (818) 734-1080
E-mail: service@capstoneturbine.com

Capstone Technical Support (Japan)
Service Telephone: (818) 407-3700
Facsimile: (818) 734-1080
E-mail: servicejapan@capstoneturbine.com
# Biogas Models
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APPENDIX K

GAS CONDITIONING TECHNOLOGY LITERATURE
K.1 UNISON SOLUTIONS TECHNOLOGY LITERATURE
K.2 ROBINSON GROUP TECHNOLOGY LITERATURE
K.3 VENTURE ENGINEERING TECHNOLOGY LITERATURE
APPENDIX K.1

UNISON SOLUTIONS TECHNOLOGY LITERATURE
STATEMENT OF QUALIFICATIONS

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Website: www.unisonsolutions.com

APRIL 2013

Leaders in Biogas Technology
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COMPANY OVERVIEW

Unison Solutions, Inc., founded in 2000, is an industry leader in biogas conditioning. Unison systems have been installed around the world at landfills, wastewater treatment facilities, dairies and food processing plants. Unison has manufactured gas treatment and compression packages in sizes that range from 20 scfm up to 8,000 scfm. To date, Unison has provided over 150 gas treatment and compression systems to the biogas marketplace.

Unison has 40 employees including engineers, CAD drafters, programmers, welders, fabricators, electricians, service technicians, sales, accounting and clerical personnel. Unison is uniquely positioned to provide all facets of a renewable energy project including engineering and design, equipment fabrication, installation and ongoing maintenance support.

12,500 sq. ft. Assembly & Testing Facility

32,000 sq. ft. Vessel & Fabrication Facility
ENGINEERING & DESIGN

ENGINEERING
Our engineers are highly experienced in biogas applications. We understand the science of gas behavior and its thermal properties; we have proven success in areas that have challenged others. We also offer the following services:

- System Evaluation
- Design and Fabrication of Custom Technologies
- Technical Field Engineering and Support
- Start up, Commissioning and Training
- Biogas Testing and Analysis
- H₂S and Siloxane Removal Media Sales

DESIGN
Our CAD drafters use the latest 3D software technology to design and layout our systems prior to fabrication. They work closely with the Project Engineers to finalize manufacturing prints that will be provided to our in-house fabrication department.
FABRICATION & TESTING

FABRICATION

All welders carry welding certificates in TIG and MIG processes.

- ASME B31.3 Process Piping
- Pressure testing of all piping and vessels
- Chemical passivation of all piping and scrubbers

TESTING

Each system undergoes a full ambient air test run at our manufacturing facility prior to shipment. All mechanical and electrical system components are rigorously checked for quality and performance.

- Test records are available for customer review
- Customers are welcome to visit our facility for witness testing
MAINTENANCE SERVICES

Unison Solutions offers maintenance services for all the equipment and systems we sell. Our technicians have the most up to date training and tooling to provide dependable and proficient on-site services.

With our siloxane and sulfur removal services, we do more than just vacuum out and refill the media. We also perform the required TCLP testing, file the waste disposal application and complete all waste manifest forms.

All of our systems are designed with Ethernet technology which allows us to assist our customers in troubleshooting without the need for an on-site service call.

- Factory Trained Service Technicians
- Service for All Unison Equipment (24 hrs/day)
- Annual Service Contracts Available
- Technical Phone Support
- On-line System Diagnostic Support
- Full Inventory of Replacement Components
BIOGAS CONDITIONING SYSTEMS
(1 of 5)

COMPRESSOR SKIDS
Using technology from the sour gas industry, we have developed a line of gas compression systems that resist the destruction caused by biogas. Our equipment has been used to fuel turbines, fuel cells and biogas pipeline projects. Due to increasing maintenance issues caused by siloxanes many of our compressor skids are used in conjunction with integrated siloxane removal systems.

Our compression systems use a two stage condensate removal process to protect not only the end use equipment but also the compressor itself. We have developed a process to remove enough moisture prior to compression to prevent condensation within the compressor. The remaining moisture is removed post-compression where the efficiency is greater and a true pressure dew point can be achieved.

Systems can be designed for any gas flow at pressures up to 200 psig. The gas will be delivered particulate free with a relative humidity consistently lower than 25%. As a standard practice, we design all of our biogas systems for a Class I, Division 1 environment. Our in-house UL panel shop allows us to customize the automation of each system to meet the customers individual requirements. We work hard to make our systems easy to operate and maintain.
BIOGAS CONDITIONING SYSTEMS

(2 of 5)

BLOWER SKIDS

Our low pressure blower systems are designed to treat gas for use in boilers and internal combustion engines such as CAT, GE Jenbacher, GE Waukesha, Cummins, Liebherr, MAN, Guascor and MWM. Due to increasing maintenance issues caused by siloxanes many of our blower skids are used in conjunction with integrated siloxane removal systems.

Systems can be designed for any gas flow and for positive or negative inlet pressures. We choose blower technology that provides the best fit for the application. Our systems have used rotary lobe, regenerative, and multi-stage centrifugal blowers. We also design redundant systems if your system requires minimal down-time for maintenance or repair.

Conditioning options are available such as after-cooling or drying. We specialize in integrating our system with existing equipment such as boilers, flares, or landfill gas extraction systems. Our in-house UL panel shop allows us to customize the automation of each system to meet the customers individual requirements.
DRIYING SKIDS

If compression is not required, we can provide the same level of gas conditioning for use with your blower or compressor. Whether you require filtration, condensate removal, or heat transfer, we can build a system for your application. We can also provide passive drying systems for process gases that are not related to biogas. Our experience with the heat transfer characteristics of gas mixtures allows us to design a system to meet your specifications.

CUSTOM SYSTEMS

Unison Solutions can develop your custom concept into an effective product. We have manufactured multiple systems not related to biogas in which we integrated our in-house engineering, design, fabrication, and automation and controls departments to create a unique, custom solution.

Examples Include:
- VOC Extraction from Vent Gas
- NO\textsubscript{x} Reduction from Flue Gas
- Renewable Energy Research Projects
BIOGAS CONDITIONING SYSTEMS
(4 of 5)

SULFUR REMOVAL
Hydrogen Sulfide ($H_2S$) and organic sulfur removal from biogas is often necessary to prevent corrosion, decrease maintenance of downstream equipment and lower SO$_x$ emissions. $H_2S$ can also inhibit the effective removal of siloxanes.

Unison Solutions offers several different sulfur removal technologies depending on the concentration levels and application. Technologies range from "scavenger-type" media based systems to biological systems.

SILOXANE REMOVAL
Nearly all digester and landfill gas contains one or more species of siloxanes. These are chemicals used extensively in industrial products such as lubricants and in personal care products. When biogas containing siloxanes is combusted in gas turbines, boilers, fuel cells, or internal combustion engines, deposits of solid silica (SiO$_2$) collect within the equipment. Damage inflicted by siloxane deposits can be profound, causing more frequent maintenance and lower generation capacity. Due to increasing issues caused by siloxanes many of our systems are used in conjunction with integrated siloxane removal systems.
BIOGAS CONDITIONING SYSTEMS

BIOGAS TO VEHICLE FUEL SYSTEM

BioCNG™

- Converts landfill or digester gas
- Complete conditioning system
- 3 sizes to meet your requirements

<table>
<thead>
<tr>
<th>Model</th>
<th>Biogas Inlet Flow (scfm)</th>
<th>Fuel Production (GGE/day)</th>
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<tr>
<td>BioCNG™ 50</td>
<td>50</td>
<td>200-275</td>
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<tr>
<td>BioCNG™ 100</td>
<td>100</td>
<td>375-550</td>
</tr>
<tr>
<td>BioCNG™ 200</td>
<td>200</td>
<td>775-1,100</td>
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</tbody>
</table>

Unison Solutions, Inc. has developed a patent pending Biogas Conditioning System that economically produces BioCNG™, a biogas-based fuel, to power compressed natural gas (CNG)

How does it work?

- Biogas is piped to the BioCNG™ gas conditioning system from a landfill or anaerobic digester
- Hydrogen Sulfide (H₂S), Moisture (H₂O), Siloxanes, Volatile Organic Compounds (VOC) and Carbon Dioxide (CO₂) are removed
- Fuel is routed to a CNG fueling station and compressed for use in CNG vehicles
AUTOMATION & CONTROLS

Unison Solutions’ controls and automation team works jointly with engineering and fabrication to produce the highest quality, safest, biogas conditioning equipment on the market. Our in-house, UL 508A panel shop gives us the flexibility to design and build custom control panels that meet the specifications of each individual biogas system installation. Innovative thinking makes our control equipment the most reliable and easiest to use.

- Only the highest quality industrial control products are used in the construction of Unison Solutions’ control panels.

- Our experienced staff of programmers has developed an extensive library of PLC code utilizing Allen Bradley, Modicon, GE, ladder logic and PLC processors. Combined with our comprehensive experience in the biogas industry, it is easy to see why our systems are the safest on the market.

- Unison Solutions’ systems seamlessly integrate with existing facility equipment through the use of optional communication interfaces including but not limited to Ethernet TCP/IP, Modbus, and Modbus/TCP.

- Packages are offered to control process variables such as gas supply pressure or vacuum, digester dome level, and cogeneration electrical output based on available biogas.
VESSELS & CUSTOM FABRICATION

Unison Solutions offers custom vessel design and fabrication services. We are a certified ASME manufacturing shop in compliance with the ASME Section VIII, Division 1 Code using The Hartford Steam Boiler Company as our authorized inspector. We specialize in stainless steel fabrication and offer the following services and products:

- B31.3 Process Piping
- Certified Welding
- Vessels up to 12’ Diameter
- Moisture & Oil Separators
- Scrubber Vessels (Moisture & Particulate Removal)
- Plate Rolling
- Straight Seam Welding
CAPSTONE TURBINE DISTRIBUTORSHIP

Unison Solutions, as a Capstone distributor, has installed turbines at landfills, wastewater treatment facilities, dairies, and food processing plants.

Capstone Turbine Corporation is the industry leader in turbine technology, launching their first commercial unit in 1998. Since then Capstone has sold over 4,000 turbines and has accumulated over 20 million hours of operation. Capstone is 100% turbine focused, has developed third and fourth generation products, and secured more than 100 patents, putting them in a class of their own.

Capstone Turbines are available in multiple sizes from 30 kW, 65 kW, 200 kW, and up to 1,000 kW.

The Capstone Turbine uses natural gas, methane, diesel or a variety of other liquid or gaseous fuels. The turbine is based on the same technology as a jet engine but integrates patented air bearings and state-of-the-art electronics. The results: a versatile, reliable, environmentally beneficial solution for power generation that is virtually maintenance-free. The turbine requires no oils or coolants and has only one moving part.
CLIENT LIST

Advance Pump & Equipment
Alliant Energy
A.P. O’Horo Company
August Winter & Sons, Inc.
U.S. Air Force Academy
BHP Energy Solutions, LTD.
Bowen Engineering Corp.
BRB Contractors, Inc.
Capstone Turbine Corporation
CDM Constructors, Inc.
City of Chippewa Falls, WI
City of Milwaukee, WI
City of Sioux Falls, SD
City of Wausau, WI
C.O. Falter Construction Corp.
Cornerstone Environmental Group
Crowder Construction Company
Dane County, WI Public Works
Environmental Water Solutions, Inc.
FABCO Power Systems
Faith Technologies
Fluxo Solucoes Integradas Ltda.
Foley Company
Gills Onion
Great Lakes Technology
Gunderson Lutheran Hospital
H&H Industries, Inc.

HESCO
Inland Power Group
James D. White Electric, Inc.
J.F. Ahern Co.
Johnson Controls, Inc.
Kendrick Forest Products
Madison Gas & Electric Co.
Madison Metropolitan Sewerage District
McKinstry Co.
Methane Power Development
Michigan Alternative Renewable Energy Center
NMC, Inc.
NRWRF - Fox Lake, IL
PCL Construction Services, Inc.
Planergy
RMT, Inc.
Royal Adhesives & Sealants, Inc.
Seneca Foods Corporation
Siemens Water Technologies
Three Phases Renewables
University of Minnesota
Veolia Cranberry Creek Landfill, LLC
Veolia Energy North America
Waste Management
Wellhead Energy
Xcel Energy
Ziegler Inc.
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<th>SITE</th>
<th>SYSTEM</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altamont Landfill</td>
<td>5,000 scfm Condensate Removal System for LNG Vehicle Fueling</td>
<td>California</td>
</tr>
<tr>
<td>MountainView Landfill</td>
<td>80 scfm Biogas Conditioning System to (2) C65 Capston Turbines</td>
<td>California</td>
</tr>
<tr>
<td>Cherry Island Landfill</td>
<td>1,000 scfm Biogas Conditioning System for (2) Cummins IC Engines and a direct use boiler</td>
<td>Delaware</td>
</tr>
<tr>
<td>Zemel Road Landfill</td>
<td>1,400 scfm Biogas Conditioning System for (2) GE Jenbacher IC Engines</td>
<td>Florida</td>
</tr>
<tr>
<td>Hickory Ridge Landfill</td>
<td>2,200 scfm Biogas Conditioning System for 5 mile Pipeline to (3) GE Jenbacher IC Engines</td>
<td>Georgia</td>
</tr>
<tr>
<td>Taylor County Landfill</td>
<td>4,000 scfm Biogas Conditioning System for (2) GE Jenbacher IC Engines</td>
<td>Georgia</td>
</tr>
<tr>
<td>Antioch HOD Landfill</td>
<td>250 scfm Biogas Conditioning System for (12) CR30 Capstone Turbines</td>
<td>Illinois</td>
</tr>
<tr>
<td>Orchard Hills Landfill</td>
<td>10,000 scfm Flare System</td>
<td>Illinois</td>
</tr>
<tr>
<td>Dubuque County Landfill</td>
<td>700 scfm Flare System</td>
<td>Iowa</td>
</tr>
<tr>
<td>St. Landry Parish</td>
<td>BioCNG™ 50 Vehicle Fuel System</td>
<td>Louisiana</td>
</tr>
<tr>
<td>East Central Landfill</td>
<td>1,200 scfm Biogas Conditioning System for (1) Caterpillar IC Engine</td>
<td>Minnesota</td>
</tr>
<tr>
<td>Andover Landfill</td>
<td>160 scfm Biogas Conditioning System for (4) STM Power Units</td>
<td>Minnesota</td>
</tr>
<tr>
<td>Prairie Bluff Landfill</td>
<td>630 scfm Biogas Conditioning System for (1) Caterpillar IC Engine</td>
<td>Mississippi</td>
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<tr>
<td>Mount Carberry Landfill</td>
<td>1,750 scfm Biogas Conditioning for pipeline to direct use boiler</td>
<td>New Hampshire</td>
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# LANDFILL PROJECTS LIST

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<td>Cape May Landfill</td>
<td>150 scfm Biogas Conditioning System for (2) Waukesha IC Engines</td>
<td>New Jersey</td>
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<tr>
<td>Albany Landfill</td>
<td>800 scfm Biogas Conditioning System for (1) Caterpillar IC Engine</td>
<td>New York</td>
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<tr>
<td>City of Durham Landfill</td>
<td>1,000 scfm Biogas Conditioning System for (2) GE Jenbacher IC Engines</td>
<td>North Carolina</td>
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<tr>
<td>Wayne County Landfill</td>
<td>1,600 scfm Biogas Conditioning System for (2) GE Jenbacher IC Engines</td>
<td>North Carolina</td>
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<tr>
<td>CONSOL Energy, Coal bed field</td>
<td>120 scfm Biogas Conditioning System for (1) CR200 Capstone Turbine</td>
<td>Pennsylvania</td>
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<tr>
<td>Laurel Highlands</td>
<td>3,500 scfm Biogas Conditioning System for a solar turbine</td>
<td>Pennsylvania</td>
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<tr>
<td>Greenwood County Landfill</td>
<td>1,100 scfm Biogas Conditioning System for Direct Use Boiler</td>
<td>South Carolina</td>
</tr>
<tr>
<td>Sioux Falls Landfill</td>
<td>2,300 scfm Biogas Conditioning System for Direct Use Boiler from 10 mile pipeline</td>
<td>South Dakota</td>
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<tr>
<td>Klickitat PUD Landfill</td>
<td>8,000 scfm Biogas Conditioning System for (6) Solar Turbines</td>
<td>Washington</td>
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<tr>
<td>Veolia Cranberry Creek Landfill</td>
<td>2,000 scfm Biogas Conditioning System for Direct Use Boiler</td>
<td>Wisconsin</td>
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<td>Sauk County Landfill</td>
<td>250 scfm Biogas Conditioning System for (24) CR30 Capstone Turbines</td>
<td>Wisconsin</td>
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<tr>
<td>Glacier Ridge Landfill</td>
<td>200 scfm Biogas Conditioning System for (10) CR30 Capstone Turbines</td>
<td>Wisconsin</td>
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<tr>
<td>Brown County Landfill</td>
<td>1,250 scfm Biogas Conditioning System for (2) Caterpillar IC Engines</td>
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**LANDFILL PROJECTS LIST**  
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<td>Dane County Landfill</td>
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<tr>
<td>Hickory Meadows Landfill</td>
<td>2,300 scfm Biogas Conditioning System for (3) Caterpillar IC Engines</td>
<td>Wisconsin</td>
</tr>
<tr>
<td>LaCrosse County Landfill</td>
<td>450 scfm Biogas Conditioning System for 1 mile Pipeline to (1) GE Jenbacher IC Engine</td>
<td>Wisconsin</td>
</tr>
<tr>
<td>Emerald Park Landfill</td>
<td>6,000 scfm Biogas Conditioning System for a direct use pipeline</td>
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**DIGESTER PROJECTS LIST**

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<td>Flagstaff WWTP</td>
<td>60 scfm BioGas Conditioning System for (3) CR30 Capstone Turbines</td>
<td>Arizona</td>
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<td>Daly City WWTF</td>
<td>90 scfm Biogas Drying System for (6) CR30 Capstone Turbines</td>
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<td>Fairfield WWTP</td>
<td>470 scfm Biogas Conditioning System for (2) Waukesha IC Engines</td>
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<td>Dublin San Ramon WWTF</td>
<td>180 scfm Biogas Conditioning System for FCE Fuel Cells</td>
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<td>Tulare WWTF</td>
<td>420 scfm Biogas Conditioning System for FCE Fuel Cells</td>
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<td>Gallo Winery</td>
<td>900 scfm Biogas Drying System</td>
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<td>Chico WCWP</td>
<td>100 scfm Biogas Conditioning System</td>
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<td>Gills Onion</td>
<td>105 scfm Biogas Conditioning System for FCE Fuel Cells</td>
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<td>Bakersfield WWTF</td>
<td>500 scfm Biogas Conditioning System for Direct Use Boiler and an IC Engine</td>
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<td>Moreno Valley WWTF</td>
<td>325 scfm Biogas Conditioning System for FCE Fuel Cells</td>
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<td>Southeast WWTF</td>
<td>850 scfm Biogas Conditioning System for (1) Waukesha IC Engine</td>
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<td>Prince George WWTF</td>
<td>60 scfm Biogas Conditioning System for (6) CR30 Capstone Turbines</td>
<td>Canada</td>
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<td>Guelph WWTP</td>
<td>170 scfm Siloxane Removal System</td>
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<td>U.S. Air Force Academy</td>
<td>20 scfm Biogas Conditioning System for (1) CR30 Capstone Turbine</td>
<td>Colorado</td>
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<td>City of Durango WWTF</td>
<td>25 scfm Biogas Conditioning System for (1) CR65 Capstone Turbine</td>
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<tr>
<td>SITE</td>
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<td>LOCATION</td>
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<td>Palm Beach County WUD</td>
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<td>720 scfm Biogas Conditioning System for Waukesha engines</td>
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<td>Siloxane Removal System</td>
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<td>Fox Lake WWTP</td>
<td>50 scfm Biogas Conditioning System for (1) Tech 3 IC Engine</td>
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<td>West Bengal Ag Digester</td>
<td>15 scfm Biogas Conditioning System for (1) CR30 Capstone Turbine</td>
<td>India</td>
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<td>West Lafayette WWTF</td>
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<td>Waterloo Digester</td>
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<td>Grandville WWTP</td>
<td>85 scfm Biogas Conditioning System for (1) I_Power IC Engine and Direct Use Boiler</td>
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<td>Delhi Township</td>
<td>60 scfm Biogas Conditioning System for (2) CR30 Capstone Turbines</td>
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### DIGESTER PROJECTS LIST

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<tr>
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<td>60 scfm Biogas Conditioning System for (4) CR30 Capstone Turbines</td>
<td>Minnesota</td>
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<td>Empire WWTF</td>
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<td>Winona WWTP</td>
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<tr>
<td>Missouri River WWTF</td>
<td>340 scfm Biogas Conditioning System for (1) Waukesha IC Engine and Direct Use Boiler</td>
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<tr>
<td>Johnson County WWTP</td>
<td>570 scfm Biogas Conditioning System for (2) GE Jenbacher IC Engines</td>
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<tr>
<td>Great Falls WWTP</td>
<td>160 scfm Biogas Conditioning System for (1) GE Jenbacher IC Engine</td>
<td>Montana</td>
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<tr>
<td>Bergen County Utilities WWTF</td>
<td>800 scfm, Siloxane Removal System</td>
<td>New Jersey</td>
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<tr>
<td>Elizabeth WWTF</td>
<td>870 scfm Biogas Conditioning System for (4) Caterpillar IC Engines</td>
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<td>DCO Salem</td>
<td>Siloxane Removal System</td>
<td>New Jersey</td>
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<td>South Monmouth WWTP</td>
<td>120 scfm Biogas Conditioning System for (1) Tech 3 IC Engine</td>
<td>New Jersey</td>
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<tr>
<td>Willingboro WWTP</td>
<td>30 scfm Biogas Conditioning System for (1) CR65 Capstone Turbine</td>
<td>New Jersey</td>
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<tr>
<td>Long Branch WWTP</td>
<td>45 scfm Biogas Conditioning System for (2) Capstone CR65</td>
<td>New Jersey</td>
</tr>
<tr>
<td>Landis Sewerage Authority</td>
<td>90 scfm Biogas Conditioning System for (1) Schmitt Enertec Engine</td>
<td>New Jersey</td>
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<tr>
<td>Jamestown WWTP</td>
<td>50 scfm Biogas Conditioning System for (1) CR65 Capstone Turbine and Direct Use Boiler</td>
<td>New York</td>
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<tr>
<td>Schenectady WPCP</td>
<td>125 scfm Biogas Conditioning System for IC Engines</td>
<td>New York</td>
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# DIGESTER PROJECTS LIST

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<table>
<thead>
<tr>
<th>SITE</th>
<th>SYSTEM</th>
<th>LOCATION</th>
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</thead>
<tbody>
<tr>
<td>Lima WWTF</td>
<td>40 scfm Biogas Drying System for (3) CR30 Capstone Turbines</td>
<td>Ohio</td>
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<tr>
<td>Struthers WWTP</td>
<td>80 scfm Biogas Conditioning System for (1) Waukesha IC Engine</td>
<td>Ohio</td>
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<tr>
<td>Columbia Blvd WWTF</td>
<td>600 scfm Biogas Conditioning System for (2) GE Jenbacher IC Engines</td>
<td>Oregon</td>
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<tr>
<td>Derry Township WWTP</td>
<td>300 scfm Biogas Conditioning System for (1) Tech 3 IC Engine</td>
<td>Pennsylvania</td>
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<tr>
<td>Lackwanna River Basin Sewer Authority</td>
<td>50 scfm Biogas Conditioning System for (2) CR65 Capstone Turbines</td>
<td>Pennsylvania</td>
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<tr>
<td>York WWTP</td>
<td>150 scfm Biogas Conditioning System for (1) CR600 Capstone Turbine</td>
<td>Pennsylvania</td>
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<td>Stiles WWTF</td>
<td>450 scfm Biogas Conditioning System for (1) Cummins engine</td>
<td>Tennessee</td>
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<td>Longview WWTP</td>
<td>25 scfm Biogas Conditioning System for (1) CR65 Capstone Turbine</td>
<td>Texas</td>
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<tr>
<td>Hornsby Bend WWTP</td>
<td>450 scfm Biogas Conditioning for (1) Jenbacher IC Engine</td>
<td>Texas</td>
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<td>Spokane WWTP</td>
<td>140 scfm Biogas Conditioning System for (4) CR65 Capstone Turbines</td>
<td>Washington</td>
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<td>West Point Treatment Plant</td>
<td>770 scfm Biogas Conditioning System for (2) Caterpillar IC Engines</td>
<td>Washington</td>
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<tr>
<td>Chippewa Falls WWTF</td>
<td>30 scfm Biogas Conditioning System for (2) CR30 Capstone Turbines</td>
<td>Wisconsin</td>
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<tr>
<td>Sheboygan WWTF</td>
<td>150 scfm Biogas Conditioning System for (10) CR30 and (2) CR200 Capstone Turbines</td>
<td>Wisconsin</td>
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<tr>
<td>South Shore WWTF</td>
<td>535 scfm Biogas Conditioning System for (3) Caterpillar IC Engines and (1) White Superior IC Engine</td>
<td>Wisconsin</td>
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<tr>
<td>Burlington WWTF</td>
<td>60 scfm Biogas Conditioning System for Direct Use Boiler</td>
<td>Wisconsin</td>
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# DIGESTER PROJECTS LIST

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<table>
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<tr>
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<tr>
<td>La Crosse City Brewery</td>
<td>300 scfm Biogas Conditioning System for (1) GE Jenbacher IC Engine</td>
<td>Wisconsin</td>
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<tr>
<td>Wisconsin Rapids WWTP</td>
<td>90 scfm Biogas Conditioning System for (1) GE Jenbacher IC Engine</td>
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<td>Beaver Dam WWTP</td>
<td>450 scfm Biogas Conditioning System for (1) Caterpillar IC Engine</td>
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<td>Janesville WWTP</td>
<td>140 scfm Biogas Conditioning System for (4) CR65 and (1) CR200 Capstone Turbines</td>
<td>Wisconsin</td>
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<td>Sheboygan WWTP Expansion</td>
<td>150 scfm Biogas Conditioning System for (2) CR200 Capstone Turbines</td>
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<tr>
<td>Bush Brothers WWTP</td>
<td>400 scfm Biogas Conditioning System for (1) IC Engine</td>
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<td>Wausau WWTP</td>
<td>50 scfm Biogas Conditioning System for (2) CR65 Capstone Turbines</td>
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<td>Steven’s Point WWTP</td>
<td>58 scfm Biogas Conditioning System for (1) MAN engine</td>
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<td>Fond du Lac WWTP</td>
<td>180 scfm Biogas Conditioning for (1) CAT Engine</td>
<td>Wisconsin</td>
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<tr>
<td>Madison Metropolitan Sewerage District</td>
<td>800 scfm Biogas Conditioning System for (2) Waukesha IC Engines and (6) Boilers</td>
<td>Wisconsin</td>
</tr>
<tr>
<td>SITE</td>
<td>SYSTEM</td>
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<tr>
<td>OpenCel</td>
<td>Fabrication and assembly of cell lysis equipment</td>
<td>England</td>
</tr>
<tr>
<td>Royal Adhesives and Sealants</td>
<td>550 scfm VOC Reduction System</td>
<td>Indiana</td>
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<tr>
<td>University of Minnesota</td>
<td>Renewable Energy Research Trailer for (1) CR30 Capstone Turbine</td>
<td>Minnesota</td>
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<tr>
<td>Edgewater Power Plant</td>
<td>NOx Reduction System</td>
<td>Wisconsin</td>
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### BioCNG™ VEHICLE FUELING PROJECTS LIST

(1 of 1)

<table>
<thead>
<tr>
<th>SITE</th>
<th>SYSTEM</th>
<th>LOCATION</th>
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<tbody>
<tr>
<td>St. Landry Parish Sanitary Landfill</td>
<td>50 scfm BioCNG™</td>
<td>Louisiana</td>
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<td>Rodefeld Landfill, Dane County</td>
<td>50 scfm BioCNG™</td>
<td>Wisconsin</td>
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<tr>
<td>City of Janesville WWTP</td>
<td>50 scfm BioCNG™</td>
<td>Wisconsin</td>
</tr>
</tbody>
</table>
CUSTOMER REFERENCES

(1 of 3)

**Sheboygan WWTF, Wisconsin:** 10 Capstone model CR30 and 2 CR200 turbines providing electrical and thermal energy to the Sheboygan Regional WWTP. The system is the second largest Capstone system in the US running on biogas from a WWTP anaerobic digester.

Customer: Alliant Energy and City of Sheboygan
Contact Name: Dale Doerr at 920-459-3464
Address: 3333 Lakeshore Dr.
Sheboygan WI 53081

**Rockford WWTF, Illinois:** 650scfm gas conditioning and blower skid for the Rockford IL WWTF. The system supplies gas that has had the moisture and Siloxane removed to a 2.25MW Waukesha engine based generation system.

Customer: Rock River Water Reclamation District
Contact Name: Larry McFall, Plant Operations Manager at 815-387-7584
Address: 3333 Kishwaukee St.
Rockford, IL 61126

**Capstone Turbine:** Supplied Capstone Turbine with several gas treatment systems including the first biogas fueled turbine system in India.

Customer: Capstone Turbine Corporation
Contact Name: Marc Rouse at 713-304-0656
Address: 21211 Nordhoff St.
Chatsworth CA 91311

**GEM Energy LLC:** Multiple systems at waste water treatment facilities and landfills.

Contact Name: Dave Blair at 330-463-5378
Address: 95 Executive Pkwy, Ste 700
Hudson, OH 98296

**Tech 3 Solutions, Inc.:** Multiple systems at waste water treatment facilities including Derry Township and South Monmouth Regional Sewerage Authority.

Contact Name: Preston Dickerson at 305-666-1910
Address: 7301 SW 57th Court, Suite 400
South Miami, FL 33143
CUSTOMER REFERENCES

(2 of 3)

**Albert Lea WWTF, Minnesota:** 4 Capstone model CR30 turbines providing thermal and electrical energy to the anaerobic digester at the wastewater treatment facility. System has the unique feature of turbine output based on digester dome height.

- Contact Name: Rick Ashling at 507-373-9159
- Address: 17424 780th Ave
  Albert Lea, MN 56007

**City of Sioux Falls, South Dakota:** Sioux Falls, SD Landfill 2,300 scfm Biogas Conditioning System for Direct Use Boiler from 10 mile pipeline that won the 2009 LMOP Landfill Project of the Year Award.

- Contact Name: Dave McElroy at 605-367-8162
- Address: 26750 464th Ave
  Sioux Falls, SD 57117-7402

**FABCO Power Systems:** Multiple systems at waste water treatment facilities and landfills including Brown County Landfill in Green Bay, WI.

- Contact Name: Clay Hardenburger at 920-533-3483
- Address: 11200 W. Silver Spring Road
  Milwaukee, WI 53225

**J.F. Ahern Co.:** Multiple systems at waste water treatment facilities and landfills including South Shore WWTF in Milwaukee, WI.

- Contact Name: Tim Schneider at 920-921-9020
- Address: 855 Morris St. PO Box 1316
  Fond du Lac, WI 54936

**Faith Technologies, Inc.:** Multiple systems at waste water treatment facilities and landfills.

- Contact Name: Kevin Quinn at 608-834-2227
- Address: 800 Wilburn Road, Suite O
  Sun Prairie, WI 53590
CUSTOMER REFERENCES
(3 of 3)

Methane Power: Multiple systems at landfills including Durham, NC and Greenwood, SC.

Contact Name: Ryan Hennessy at 704-340-8037
Address: 13801 Reese Blvd. West, Suite 110
Huntersville, NC 28078

Crowder Construction Civil and Environmental: Multiple systems including Taylor County and RM Clayton WWTP in Atlanta, GA.

Contact Name: Greg Cochran at 919-367-2000
Address: 1111 Burma Drive
Apex, NC 27539

South Monmouth Regional Sewerage Authority, New Jersey: 120scfm gas conditioning system supplies gas that has had the hydrogen sulfide, moisture and Siloxanes removed prior to entering the Tech 3 Solutions engines.

Contact Name: Mike Rupple at 732-681-0611
Address: 1235 18th Avenue
Belmar, New Jersey 07719
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LANDFILL PROJECT PHOTOS
(1 of 3)

Zemel Road Landfill, Florida
1,400 scfm Biogas Conditioning System for
(2) GE Jenbacher IC Engines

Glacier Ridge Landfill, Wisconsin
200 scfm Biogas Conditioning System for
(10) CR30 Capstone Turbines

Cherry Island Landfill, Delaware
1,000 scfm Biogas Conditioning System for
(2) Cummins IC Engines and a Direct Use Boiler

Brown County Landfill, Wisconsin
1,250 scfm Biogas Conditioning System for (2) Caterpillar IC Engines
LANDFILL PROJECT PHOTOS
(2 of 3)

**Albany Landfill, New York**
800 scfm Biogas Conditioning System for (1) Caterpillar IC Engine

**Sioux Falls Landfill, South Dakota**
2,300 scfm Biogas Conditioning System for Direct Use Boiler from 11 mile pipeline

**Hickory Ridge Landfill, Georgia**
2,200 scfm Biogas Conditioning System For 5 mile pipeline to (3) GE Jenbacher IC Engines

**Dubuque County Landfill, Iowa**
700 scfm Flare System
Landfill Project Photos

(3 of 3)

Altamont Landfill, California
Condensate Removal System for
LNG Vehicle Fueling

Dane County Landfill, Wisconsin
2,000 scfm Biogas Conditioning System for
(4) Caterpillar IC Engines

Hickory Meadows Landfill, Wisconsin
2,300 scfm Biogas Conditioning System for
(3) Caterpillar IC Engines

Wayne County Landfill, North Carolina
1,600 scfm Biogas Conditioning System for
(2) GE Jenbacher IC Engines
DIGESTER PROJECT PHOTOS
(1 of 4)

Sheboygan WWTF, Wisconsin
(2) 150 scfm Biogas Conditioning System for (10) CR30 and (2) CR200 Capstone Turbines

Rock River WRD, Illinois
600 scfm Biogas Conditioning System for (2) Waukesha IC Engines

York WWTP, Pennsylvania
150 scfm Biogas Conditioning System for (1) CR600 Capstone Turbine

Beaver Dam WWTF, Wisconsin
450 scfm Biogas Conditioning System for (2) Caterpillar IC Engines
DIGESTER PROJECT PHOTOS
(2 of 4)

South Monmouth WWTP, New Jersey
120 scfm Biogas Conditioning System for
(1) Tech 3 IC Engine

Dublin San Ramon WWTF, California
180 scfm Biogas Conditioning System for
FCE Fuel Cells

Moreno Valley WWTF, California
325 scfm Biogas Conditioning System for
FCE Fuel Cells

Columbia Blvd WWTF, Oregon
600 scfm Biogas Conditioning System for
(2) GE Jenbacher IC Engines
DIGESTER PROJECT PHOTOS
(3 of 4)

Delhi Township WWTF, Michigan
60 scfm Biogas Conditioning System for (2) CR30 Capstone Turbines

Dubuque WPCP, Iowa
350 scfm Biogas Conditioning System for Direct Use Boiler

R M Clayton WWTP, Georgia
720 scfm Biogas Conditioning System for (1) Waukesha IC Engine

West Lafayette WWTF, Indiana
120 scfm Biogas Conditioning System for (2) CR65 Capstone Turbines
DIGESTER PROJECT PHOTOS
(4 of 4)

Derry Township WWTP, Pennsylvania
300 scfm Biogas Conditioning System
for (1) Tech 3 IC Engine

Burlington WWTF, Wisconsin
60 scfm Biogas Conditioning System for Direct Use Boiler

Gills Onion, California
105 scfm Biogas Conditioning System for FCE Fuel Cells

Seneca Foods, Minnesota
310 scfm Biogas Conditioning System for Direct Use Boiler
CUSTOM PROJECT PHOTOS

(1 of 1)

OpenCel, England
Fabrication and assembly of cell lysis equipment

University of Minnesota, Minnesota
Renewable Energy Research Trailer for
(1) CR30 Capstone Turbine

Royal Adhesives & Sealants, Indiana
550 scfm VOC Reduction System

Edgewater Power Plant, Wisconsin
NOx Reduction System
BioCNG™ VEHICLE FUELING PROJECT PHOTOS

(1 of 1)

Rodefeld Landfill, Dane County, Wisconsin
50 scfm system

City of Janesville WWTP, Janesville, Wisconsin
50 scfm system

St. Landry Parish Sanitary Landfill, Washington, Louisiana
50 scfm system
BUDGET PROPOSAL

PROJECT INFORMATION

Date: July 19, 2013
Expires: August 19, 2013

Scott Dunbar
Conestoga-Rovers & Associates Ltd.

Proposal Number: PT-313-1509.2
Project Name: Collingwood, ON Canada WWTP

Unison Solutions, Inc. is pleased to provide you with this BUDGET proposal for a Biogas Conditioning System for the Collingwood, ON Canada WWTP Project. This BUDGET proposal includes all the engineering, technician labor, fabrication, CAD design services and materials to construct a Complete Gas Conditioning System.

UNISON SOLUTIONS, INC. CERTIFICATIONS

- ASME Certification Number (U-Stamp) - 37,381
- ASME Certification Number (R-Stamp) - R7415
- UL Certification Number - 20110405-E255550

EQUIPMENT/SUB-SYSTEMS

GAS COMPRESSION/MOISTURE/SILOXANE REMOVAL SYSTEM
- Skid Mounted
- Class I, Division 1 Electrical Area
  Components
  - Pre-cooler
  - Gas Compressor Inlet Moisture/Particulate Filter
  - Gas Compressor
  - Oil/Gas Separator
  - Oil Cooler
  - Oil Particulate Filter
  - Gas to Gas Heat Exchanger
  - Gas to Glycol Heat Exchanger
  - Moisture Separator
  - Gas Recirculation
  - Siloxane Removal Vessels
  - Siloxane Removal Final Particulate Filter
- Initial charge of Siloxane Removal Media
- Piping and Valves

**GLYCOL CHILLER**
- Standalone
- Unclassified Electrical Area
  - Components
    - Glycol Chiller
    - Initial Fill of 50/50 PG Glycol Mixture

**CONTROL SYSTEM**
- Standalone
- Unclassified Electrical Area
  - Components
    - Gas Conditioning System Control Panel
    - Transformer

**PROCESS FLOW DIAGRAM**

![Process Flow Diagram]

**DESIGN CONDITIONS**

**SITE INFORMATION**
Minimum Ambient Temperature: -22°F
Maximum Ambient Temperature: 100°F
Site Elevation: 590’AMSL

**SYSTEM REQUIREMENTS**
Minimum Gas Flow: 25 scfm
Maximum Gas Flow: 40 scfm
ASSUMED INLET GAS CONDITIONS
Inlet Gas Pressure 1"WC
Inlet Gas Temperature 100°F
Relative Humidity 100%
Methane 53.9%
Carbon Dioxide 31.3%
Nitrogen 11.4%
Oxygen 2.9%
Hydrogen Sulfide 85 ppmv
Siloxane 1,649 ppbv

DISCHARGE GAS CONDITIONS
Discharge Gas Pressure 95 psig
Discharge Gas Temperature 80°F
Dew Point Temperature 40°F
Maximum Hydrogen Sulfide <10 ppmv
Maximum Siloxane <100 ppbv
Particulate Removal 99% removal of >3 micron

SYSTEM DETAILS
GAS COMPRESSION/MOISTURE/SILOXANE REMOVAL SYSTEM
- Pre-cooler
  - Within the heat exchanger, the gas will be cooled to 70°F
  - Gas to glycol finned tube core
  - Aluminum fins on stainless steel tubes
  - 150# ANSI B16.5 inlet and outlet connections
- Gas Compressor Inlet Moisture/Particulate Filter
  - 99% removal of 3micron and larger particulates and liquid droplets
  - Mounted upstream of the Gas Compressor
  - Materials of construction will be 316L stainless steel
  - 150# ANSI B16.5 side inlet and outlet connections
  - Fasteners will be F593 316 stainless steel
  - Cleanable polypropylene structured mesh element
  - Differential pressure gauge across the filter element
  - Level indicator for liquid level indication
  - Level switch above the condensate drain to warn of failure
  - Bottom drain with strainer, no gas loss drip trap, manual bypass and piping
- Gas Compressor
  - Oil Flooded Twin Screw Compressor
  - Direct drive 25Hp 480V/3Ph/60Hz EXP electric motor
  - Motor speed will be controlled by a VFD
  - All gas and oil components other than the gas end shall be constructed of stainless steel and/or aluminum
  - Gas inlet and discharge flex connectors
  - Gas inlet and discharge check valves
  - Discharge pressure safety valve
- Oil handling system will include an oil holding reservoir, coalescing filter, pressure safety valve, oil cooler, three way thermal bypass valve, and an oil particulate filter.
- Oil for compressor system will be provided
- Gas Compressor has a hydrogen sulfide tolerance of 40,000 ppmv

- Oil/Gas Separator
  - Oil/Gas Separator equipped with an oil holding reservoir, coalescing filter, and pressure relief valve
  - Oil separator vessel shall be ASME Section VIII, Division 1 code stamped
  - Materials of construction will be 316L stainless steel
  - 150# ANSI B16.5 inlet and outlet connections
  - Fasteners will be F593 316 stainless steel

- Oil Cooler
  - 480V/3Ph/60Hz EXP electric motor
  - Materials of construction will be aluminum
  - 150# ANSI B16.5 inlet and outlet connections

- Oil Particulate Filter
  - Oil Particulate Filter will be built in accordance with ASME Section VIII, Division 1 Code.
  - Materials of construction shall be 316L stainless steel
  - 150# ANSI B16.5 inlet and outlet connections
  - Removable bag style elements for 5 micron

- Gas to Gas Heat Exchanger
  - Brazed plate Gas to Gas Heat Exchanger to reheat 40°F gas from the brazed plate Gas to Glycol Heat Exchanger to 80°F
  - Materials of construction shall be 316L stainless steel with nickel/chrome brazing
  - 150# ANSI B16.5 inlet and outlet connections

- Gas to Glycol Heat Exchanger
  - Brazed plate Gas to Glycol Heat Exchanger to lower gas dew point to a maximum of 40°F
  - Materials of construction shall be 316L stainless steel with nickel/chrome brazing
  - 150# ANSI B16.5 inlet and outlet connections

- Moisture Separator
  - UNI-FLOW
  - Moisture separator shall be ASME Section VIII, Division 1 code stamped
  - Materials of construction shall be 316L stainless steel
  - 150# ANSI B16.5 inlet and outlet connections
  - Centrifugal style with no element to be cleaned or changed
  - Integral level switches for drain control
  - Bottom drain with strainer, solenoid valve, check valve, manual bypass and piping

- Gas Recirculation
  - A Backpressure Regulator will be provided to allow excess gas to flow from the discharge of the system back to the inlet of the Gas Compressor

- (3) Siloxane Removal Media Vessels
  - 12” diameter x 8’ straight side
  - Materials of construction will be 316L stainless steel
  - Flanged top with flat bottom
  - Platform and hand rails will be powder-coated carbon steel. Access ladder will be galvanized steel
  - Flanged manway on top of each vessel
- Internal septas for even gas distribution through media
- 150# ANSI B16.5 side inlet and outlet connections
- Fasteners will be F593 316 stainless steel
- Pressure relief valves included
- Bottom manual condensate drain with stainless steel ball valves
- Test/purge ports with valves on the inlet and exit of each vessel

- Siloxane Removal Media
  - Initial charge of Siloxane Removal Media is supplied
  - The media is specifically engineered for removal of siloxanes and similar contaminants from landfill and digester gas sources
  - Siloxane media to be loaded into Siloxane Removal Vessel by INSTALLATION CONTRACTOR

- Siloxane Removal Final Particulate Filter
  - 99% removal of .5 micron and larger particulate
  - Final particulate filter housing and cartridge style element shall be of stainless steel construction
  - 150# ANSI B16.5 side inlet and outlet connections

- Instrumentation
  - Inlet Pressure Transmitter
  - High Level Switches at each Condensate Drain
  - RTD’s at each Temperature Change Point
  - Temperature Gauges at each Temperature Change Point
  - RTD to monitor Glycol Temperature
  - Gas Compressor Discharge Pressure Transmitter
  - Delivery Pressure Transmitter

- Piping
  - All piping shall be minimum Type 316/316L stainless steel in IPS standard sizes
  - All piping 2 inches and smaller may be threaded or 150# ANSI B16.5 flanged, but threaded piping shall be a minimum of Schedule 40
  - All piping 2 inches and larger shall be welded with 150# ANSI B16.5 flanged connections
  - Fabricated in accordance with ASME B31.3 - Process Piping
  - Fasteners will be F593 316 stainless steel

- Valves
  - Inlet Electric Actuated Butterfly Valve
    - Butterfly valve with cast iron body, stainless steel disk and stem, and Viton seats. Butterfly valve will be lug style
    - Type 7 explosion proof actuator
    - Spring return closed upon power loss
    - 120VAC weatherproof
  - All valves 3 inches and larger will be butterfly valves with stainless steel bodies, stainless steel disk and stem, and Viton seats. Butterfly valves shall be lug style
  - All valves 2-1/2 inches and smaller shall be ball valves
    - Ball valves 1 inch and smaller shall have NPT threaded connections. Bodies and balls shall be 316 stainless steel. Packing or seats will be PTFE
    - Ball valves 1-1/2 inches and larger shall have 150# flanged connections. Bodies and balls shall be 316 stainless steel. Packing or seats will be PTFE
- Check valves 2 inch and smaller shall be ball type, stainless steel and have NPT threaded connections. Check valves 2-1/2 inches and larger shall be spring loaded, stainless steel, with a Viton seat. Valves will be inserted in the pipeline between two flanges.

- Skid Base
  - All components except the Glycol Chiller and the Gas Conditioning System Control Panel will be mounted on a single skid.
    - All components mounted, piped and wired on skid
    - Electrical components pre-wired to one of two junction boxes on edge of skid
    - Condensate drains piped to edge of skid
    - Conduit to be rigid aluminum
    - Satin black powder coated

**GLYCOL CHILLER**

- Glycol Chiller
  - Sized for the heat load of the Pre-cooler and Gas to Glycol Heat Exchangers
  - Suitable for outdoor installation
  - Refrigeration System
    - One refrigeration circuit
    - One compressor sized for 100% capacity
    - EC motor driven condenser fans with die cast aluminum blades
    - Aluminum micro-channel air cooled condenser
    - 316L stainless steel evaporator
    - R-410a refrigerant. R-410a is an HFC refrigerant with 0 ODP
    - Refrigeration circuit has sealed core filter drier, liquid line solenoid valve, liquid line shut-off valve, sight glass/moisture indicator and unload solenoid valve
    - Electronic expansion valve per refrigeration circuit
    - Glycol Chiller will be shipped with complete refrigerant charge

- Glycol Circulation
  - One glycol circulation pump sized for 100% capacity
  - Pump is stainless steel end suction centrifugal
  - Pump motor is 3600rpm TEFC
  - Pump isolation valves on inlet and outlet
  - Pump discharge check valve
  - Glycol reservoir is a 304 stainless steel closed tank
  - Glycol piping is copper with anti-corrosion coating
  - Armaflex insulation
  - Glycol Chiller to utilize propylene glycol/water mix
  - Propylene glycol will be supplied
  - 35°F glycol delivery temperature

- Support Structure
  - G90 galvanized steel member frame
  - Aluminum powder coated cover panels
  - All components mounted, piped and wired on skid

- Glycol Chiller Control Panel
  - UL 508A Listed Industrial Control Panel
  - UL Type 4X
  - 304 Stainless Steel
- 480V/3Ph/60Hz feed will be required
- 480V disconnect
- Microprocessor based controller with full text LCD display
- 480VAC to 24VAC transformer

**GAS CONDITIONING SYSTEM CONTROL PANEL**
- Gas Conditioning System Control Panel
  - Enclosure
    - UL Type 4X
    - UL 508A Listed Industrial Control Panel
    - 316 Stainless Steel
    - Shipped loose for remote installation outdoors, out of direct sunlight
  - Thermal Management *(as necessary)*
    - Rated for installation in ambient temperatures from 40°F to 104°F
    - Air Conditioner
    - Heater
  - Power Distribution
    - Fused Disconnect
    - 480V/3Ph/60Hz feed required
    - 35kA Short Circuit Current Rating
    - Over current and branch circuit protection via fuses
    - 480VAC field wiring to terminate at the component or terminal strips inside control panel
  - 3kVA Transformer *(shipped loose)*
    - 480VAC to 120VAC
    - NEMA 4X; 304 Stainless Steel
  - Surge Suppression
    - 480VAC Transient Voltage Surge Suppressor
    - 120VAC Surge Filter
  - Motor Control *(480V/3Ph/60Hz)*
    - (1) 25 HP Rated VFD for Compressor Motor
    - (1) 1 HP Rated Motor Starter Overload for Oil Cooler Fan
  - Control
    - Programmable Logic Controller
      - Allen Bradley
      - Compact Logix PLC and I/O
      - Native Allen Bradley Ethernet IP data network
    - Managed Ethernet switch - (8) 10/100 BaseTX RJ-45 Ports
  - Proface, Human Machine Interface
    - TFT Color LCD Display
    - 12” diagonal
    - 800 x 600 pixels
    - Instrument wiring to terminate at terminal strips inside control panel

**SUBMITTALS**

- Three Copies of 3 Ring Binders and one electronic CD copy
FACTORY TESTING

- Complete system will be tested on ambient air at the Unison Solutions manufacturing facility in Dubuque IA. If customer would like to witness the testing Unison will inform the customer two (2) weeks prior to anticipated testing date so customer can make travel arrangements.

OPERATION & MAINTENANCE MANUALS

- Six Copies of 3 Ring Binders and one electronic CD copy

OPERATION & MAINTENANCE

- Gas Compression/Moisture Removal System
  - Clean Gas Compressor Inlet Moisture/Particulate Filter
  - Clean/Replace Oil Particulate Filter
  - Change Oil Filter
  - Change Compressor Oil
  - Clean Oil Heat Exchanger
  - Clean Glycol Chiller Condenser
  - Test Glycol for Freeze Point
  - Estimated Cost = $2,500.00/year

- Siloxane Removal System
  - Replace Siloxane Media
  - Estimated Cost = $1,980.00 every 60 days

*Labor for change out, disposal and shipping of media not included

DELIVERY SCHEDULE

- Submittals delivered 4 weeks after order acknowledgement
- Equipment delivery 20 to 24 weeks after submittal approval
- Delivery is subject to confirmation at the time of order placement and/or submittal approval

PRICING SUMMARY

- Price includes all labor and expenses associated with the fabrication of the system.
- Prices do not reflect any taxes that may be applicable and are valid for 30 days.
- Price is FCA; Factory, Dubuque, IA 52002, per Incoterms 2010. Shipping costs not included, see estimate below.
- Price does not include Start-up and Commissioning. Costs are shown below.

BUDGET Gas Compression/Moisture/Siloxane Removal System................................................. $330,000.00 USD

Shipping ESTIMATE to Collingwood, ON Canada.............................................................................. TBD

Cost is an estimate and is subject to change without notice. It does not include any special packaging or permitting that may be required and is dependent on the final equipment dimensions and weights.
Start-up and Commissioning Services **ESTIMATE** .......................................................... $12,000.00 USD

Price includes Four (4) consecutive, 8 hour days, for one Unison Technician onsite with travel and expenses included. Additional days may be necessary to complete start-up and commissioning, they will be billed to the Buyer/Owner/End User at the cost of $1,200 per day, per technician, plus travel & expenses.

**OPTIONAL ADDER**

Custom Enclosure ................................................................................................................ $80,000.00
- Temperature Controlled Enclosure
  - All electrical inside the enclosure is rated Class I Division 1
  - Mounted to skid base
  - Steel exterior with multiple color options for site esthetics
  - 3/4” fire rated plywood construction over steel studs
  - Insulated walls and ceiling
  - Interior 5/8” green board (mildew resistant drywall)
  - Lighted interior with two EXP incandescent light fixtures
  - Thermostatically controlled heater to prevent freezing
  - LEL inside enclosure for gas detection and warning
  - Ventilation fan and intake louver to prevent over heating inside enclosure
  - Double steel entry doors

*Note: Customer will be required to power the heater, ventilation fan and lights*

**PAYMENT SCHEDULE**

- 30% upon order acceptance
- 30% at midpoint of construction
- 30% upon equipment delivery
- 10% upon site acceptance not to exceed 180 days from shipment
- Net 30 days on all payments

**PROVIDED BY OTHERS**

- VPN connection for remote access to Unison supplied equipment for troubleshooting and remote assistance.

**PRICE DOES NOT INCLUDE**

- Shipping of equipment to jobsite
- Start-up or commissioning
- Wind or seismic calculations for all equipment
- Any maintenance work after start-up
- Siloxane removal media after initial fill
- Performance guarantee or service/maintenance contract
- Any gas testing or analyses
ASSUMPTIONS

VESSELS & MEDIA

- H2S and VOC’s present in the gas will foul Siloxane media, additional gas testing will be necessary to finalize all vessel and media requirements, budget pricing is dependent on gas data given at the time of the proposal.
- No assumption of media life has been given; additional gas testing will be required at the Buyer/Owner/End Users expense.
- Vessel sizes are estimates only, gas testing will be necessary to finalize all vessel sizing.

MECHANICAL

- Flare is supplied by others
- If an existing flare is being used, it is assumed this flare is in good working order, with all safety and control equipment.
- Foundations and/or maintenance pads are designed by others to properly support the equipment.

ELECTRICAL & CONTROLS

- 480V/3Ph/60Hz is available
- The Gas Compression/Moisture/Siloxane Removal System will be considered a Class I, Division 1 Electrical Area around all gas components.
- The Glycol Chiller and Gas Conditioning System Control Panel will be located in an Unclassified Electrical Area.

INSTALLATION CONTRACTOR RESPONSIBILITIES

- Installation responsibilities are broken out below into three categories to outline the work; these responsibilities by no means fall on any single contractor or individual. It is the responsibility of the Buyer/Owner/End User to ensure all these conditions are adhered to, as necessary. It is responsibility of the Buyer/Owner/End User to install all equipment in compliance with local and national codes applicable to the installation site.

BUYER/OWNER/END USER RESPONSIBILITIES

- All field and installation work
- All rigging and setting of equipment at site
- Provide installation of Equipment per the Unison Solutions Installation Guide
- Proper storage of the equipment and media prior to installation
- Media is to be installed in respective vessels

MECHANICAL CONTRACTOR RESPONSIBILITIES

- Provide all field piping between the system components, including but not limited to the Gas Compression/Moisture/Siloxane Removal System and the Glycol Chiller. (Unless defined above)
- Provide pipe supports as necessary. Piping shall be self-supporting, and not supported off of the Unison supplied equipment.
- Provide all Heat Trace and/or Insulation as necessary to provide proper freeze protection as defined by Unison Solutions.
- Provide and seal all roof and building penetrations as necessary.
- Install all field located or shipped loose devices
- Provide foundations and/or maintenance pads as necessary for equipment

**ELECTRICAL CONTRACTOR RESPONSIBILITIES**

- Provide conduit seals entering and/or leaving the Class I, Division 1 Electrical Area. Conduit seals will need to be filled during Start-up & Commissioning after verification of field wiring by Unison’s Start-up Technician. Conduit seals are to be filled prior to the introduction of gas to the equipment.
- Provide local disconnects as necessary
- Provide all field wiring and conduits between the supplied equipment to the Gas Conditioning Control Panel and associated equipment.
- Provide all Hazardous location conduits & wiring systems per Article 500 of the NEC
- Provide heat trace power from local lighting panel, as necessary.

**WARRANTY**

Unison Solutions, Inc. will warrant all workmanship and materials in conformance with the attached Warranty Statement. Warranty is valid for 18 months from the time the equipment is shipped from Unison’s factory or 12 months from the date of startup, whichever occurs first.

Unison Solutions, Inc. will not release the PLC program for this system. This is considered proprietary and the intellectual property of Unison Solutions, Inc.

Thank you for giving Unison Solutions the opportunity to propose our services. If you have any questions or require additional information, please contact me at your convenience.

Sincerely,

Tony Schilling
Unison Solutions, Inc.
5451 Chavenelle Road
Dubuque, IA 52002
Phone: 563-585-0901
Fax: 563-585-0970
Cell: 563-543-6069
WARRANTY STATEMENT

Unison Solutions, Inc. (Unison) is committed to providing quality products and services to its customers. As a demonstration of this commitment, Unison offers the following warranty on its products.

Grant of Warranty: Unison provides this warranty for its equipment under the terms and conditions which are detailed herein. This warranty is granted to the person, corporation, organization, or legal entity (Owner), which owns the equipment on date of start-up. This warranty applies to the owner during the warranty period, and is not transferable.

Warranty Coverage: Equipment that is determined by Unison to have malfunctioned during the warranty period under normal use solely as a result of defects in manufacturing workmanship or materials shall be repaired or replaced at Unison’s option. Unison’s liability under this warranty to the Owner shall be limited to Unison’s decision to repair or replace, at its factory or in the field, items deemed defective after inspection at the factory or in the field.

Warranty Exclusions: All equipment, parts and work not manufactured or performed by Unison carry their own manufacturer’s warranty and are not covered by this warranty. Unison’s warranty does not override, extend, displace or limit those warranties. Unison’s only obligation regarding equipment, parts and work manufactured or performed by others shall be to assign to the Owner whatever warranty Unison receives from the original manufacturer. Unison does not warrant its products from malfunction or failure due to shipping or storage damage, deterioration due to exposure to the elements, vandalism, accidents, power disturbances, or acts of nature or God. This warranty does not cover damage due to misapplication, abuse, neglect, misuse, improper installation, or lack of proper service and/or maintenance, nor does it cover normal wear and tear. This warranty does not apply to modifications not specifically authorized in writing by Unison or to parts and labor for repairs not made by Unison or an authorized warranty service provider. This warranty does not cover incidental or consequential damages or expenses incurred by the Owner or any other party resulting from the order, and/or use of its equipment, whether arising from breach of warranty, non-conformity to order specifications, delay in delivery, or any loss sustained by the Owner. No agent or employee of Unison has any authority to make verbal representations or warranties of any goods manufactured and sold by Unison without the written authorization signed by an authorized officer of Unison. Unison warrants the equipment designed and fabricated to perform in accordance with the specifications as stated in the proposal for the equipment and while the equipment is properly operated within the site specific design limits for that equipment. Any alterations or repair of Unison’s equipment by personnel other than those directly employed by, or authorized by Unison shall void the warranty unless otherwise stated under specified written guidelines issued by Unison to the Owner. This warranty does not cover corrosion or premature wear or failure of components resulting from the effects caused by siloxanes, hydrogen sulfide or volatile organic compounds in excess of the design limits. All media must be purchased through Unison Solutions or approved in writing by Unison Solutions during warranty period. Media purchased through alternate sources and not approved in writing by Unison shall void the warranty. The design limit is based on site specific gas data provided by the Owner prior to the proposal for the equipment. Owner shall be responsible for all maintenance service, including, but not limited to, lubricating and cleaning the equipment, replacing expendable parts, media, making minor adjustments and performing operating checks, all in accordance with the procedures outlined in Unison’s maintenance literature. Unison does not warrant the future availability of expendable maintenance items.

Warranty Period: This Unison warranty is valid for 18 months from the time the equipment is shipped from Unison’s factory or 12 months from the date of startup, whichever occurs first.

Repairs During Warranty Period: All warranty claim requests must be initiated with a Return Material Authorization (RMA) number for processing and tracking purposes. The RMA number shall be issued to the Owner upon claim approval and/or field inspection. When field service is deemed necessary in order to determine a warranty claim, the costs associated with travel, lodging, etc. shall be the responsibility of the Owner except under prior agreement for a field inspection. This warranty does not include reimbursement of any costs for shipping the equipment or parts to Unison or an authorized service establishment, or for labor and/or materials required for removal or reinstallation of equipment or parts in connection with a warranty repair. This warranty covers only those repairs that have been conducted by Unison or by an Unison authorized warranty service provider, or by someone specifically authorized by Unison to perform a particular repair or service activity. All component parts replaced under the terms of this warranty shall become the property of Unison.

UNISON ASSUMES NO OTHER WARRANTY FOR ITS EQUIPMENT, EITHER EXPRESS OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY, FITNESS FOR ANY PARTICULAR PURPOSE, OR NONINFRINGEMENT, OR LIABILITY FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGE.

APPENDIX K.2

ROBINSON GROUP TECHNOLOGY LITERATURE
BioGas Powered Energy Solutions
Thank you for honoring Robinson Group (RG) with your request for a preliminary quote and Comparative Market Analysis (CMA).

Robinson Group has pioneered technologies in the processing of BioGas from a variety of methane produced from wastes and energy crops. Our technologies offer a complete integrated approach with single supplier responsibility for the process of cleaning the gas to produce electricity, natural gas and heat.

Our analysis is the culmination of our work over the years on hundreds of BioGas processing systems in operation around the World. Whether responding to a particular specification or providing a "turnkey design", our technology options for sulfur removal, compression, drying, volatile organics, siloxanes and carbon dioxide removal are considered the benchmark standard for BioGas.

With this in mind, we have laid out the following pertinent advice learned over our many years in BioGas processing:

√ Design your system for the future taking into account conditions today ... Not the other way around. Gas characteristics change over time and you can avoid a lot of challenges today by looking to the future of the plant.
√ Use the site characteristics not just the gas characteristics when you look at a project. Taking full advantage of site conditions will save significant time, energy and money.
√ Understand the meaning of your "gas fingerprint". If you understand why certain Siloxanes are higher than others you can often reap great benefits for your project.
√ Integrate your systems rather than buy component parts. This makes sure your vendors are working with you to avoid system limitations and maximize performance. It also will mean you have real accountability with your systems.
√ Get as many guarantees as you can. This will solve both tangible and intangible design, operation and maintenance issues before they happen. If you make vendors accountable you will avoid problems before they happen.
√ Embrace technology and be open to how it will evolve with your project. We strongly recommend working with vendors who you believe are staying in front of the technology curve. This has great potential for improving the systems economics and performance over time.
√ Go with an experienced team. Make sure they have lots of systems fielded and that you are not part of the technology experimentation curve. 10 years in the business and at least a dozen systems fielded.
√ Use a supplier that has a long term commitment to the operational success of the BioGas processing system. This would be a supplier who has the demonstrated capability to periodically test and interpret the BioGas to make adjustments to the system operation as the BioGas changes in composition over time.
√ Choose a supplier with a good history in system operation and maintenance. BioGas processing needs suppliers that will produce the system but also service and potentially operate the system as the needs of the customer and site change.

On the following pages, additional information is presented on RG’s processes for obtaining a custom biogas system solution as well as a sample costs analysis of a system similar to that of which you inquired. We are eager to get you started on your Biogas system!
GETTING STARTED:
RG’s Four Step Process

Robinson Group provides the leading biogas conditioning systems—backed by an unprecedented 10-year guarantee—because our four-step process ensures a comprehensive, trouble-free solution. The following processes are recommended to ensure the best Biogas Conditioning System solution:

Step 1: Get the Gas Tested
Robinson Group offers customers a gas testing service that is fast, accurate, and cost effective. Before unconditioned digester gas can be cleaned and converted into energy, its contaminant matrix or “signature” must be determined. Plant technicians facilitate this process by sending harvested gas to RG’s lab for initial analysis via an RG Gas test kit. This data alerts RG to any elements that will interfere with power generation.

Step 2: Request an RG Engineered Proposal
Robinson Group can complete an engineered proposal based on the level of information received by the site and gas testing. Inside are customized system recommendations that target the individual contaminant problems discovered during the analysis. Also available is a cost-benefit analysis that compares equipment and output options.

Step 3: System Creation
Using the engineered proposal and on-site discussions, RG engineers design and build a system that meets the specific needs of the facility. The complete contract-to-creation process usually takes two years. However, once built, the system can be installed in as little as two days. RG engineers facilitate a smooth transition by being on-site for the installation.

Step 4: Ongoing Monitoring and Gas Analysis
RG ensures the quality of its systems through gas testing, designed to address the normal fluctuations in gas constituents that occur over time. Regular gas analysis allows RG engineers to help our customers identify complications and solve problems before costly downtime occurs.
ADVANTAGES
Robinson Group Systems & Support

RG can offer the following guarantees and experience:

1. 10 Year Gas Quality Guarantee with RG Service Agreement
2. 18 month warranty from equipment delivery
3. Pre-assembled and skid mounted packages for easy installation
4. System remote monitoring available
5. Local RG system support available
6. Next day full gas analysis at the RG Seattle Lab
7. System pressure relief provided
8. Ability to design an integrated, turn-key gas conditioning system
9. Our experience includes over 150 projects in North America on digester gas to energy
10. 16 years of work in biogas processing, the longest of any company

EXPERIENCE
Robinson Group: Industry Leader in Biogas Conditioning

Robinson Group is an expert at helping clients identify and eliminate biogas contaminants and capitalize on their waste streams. RG has custom-designed, installed, fine-tuned and operated biogas-to-energy systems for hundreds of manufacturers, consultants, municipalities, and energy companies so they can generate clean energy and achieve a stronger bottom line.

Robinson Group is the biogas conditioning industry’s most experienced firm, with hundreds of installations around the world. RG designs, builds and operates over 150 SAGPack™, SAG vessels and media, and SulfrPack™ biogas systems worldwide. Each system is fully guaranteed and supported by RG.

Our first system, built in 1996, was installed at the Carson Cogen at Sacramento County MSD to clean digester gas for protection of SCR exhaust catalyst. RG first determined the chemistry and impact of siloxanes in digester gas in 1995. Prior to 1995, very little was known about this organic complex and its impact on power generation and heat transfer equipment.

In our drive to find better ways to eliminate machine-clogging contaminants from waste streams, we have built up an industry-leading number of patents (four, with seven in review). As we move forward, we will continue to engineer biogas conditioning solutions that meet our customers’ needs and bottom lines.
### COMPARATIVE MARKET ANALYSIS

<table>
<thead>
<tr>
<th>Data provided to Robinson Group</th>
<th>Proposed system and approximate cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biogas source:</strong> Municipal digester</td>
<td><strong>SulfrPack ST™ Sulfur Removal System</strong> Estimated Cost: $78,700 (^{1})</td>
</tr>
<tr>
<td><strong>Biogas flow rate:</strong> 1,500 m³/day</td>
<td><strong>SAGPack™ Siloxane removal, gas compression, and moisture removal</strong> Estimated Cost: $308,000</td>
</tr>
<tr>
<td><strong>Inlet pressure:</strong> 5-12” wc</td>
<td></td>
</tr>
<tr>
<td><strong>Inlet temperature:</strong> 30-35 °C</td>
<td></td>
</tr>
<tr>
<td><strong>H₂S content:</strong> 85 ppmv (^{1})</td>
<td></td>
</tr>
<tr>
<td><strong>Siloxane content:</strong> 1.65 ppmv</td>
<td></td>
</tr>
</tbody>
</table>

\(^{1}\) The gas time between H₂S sample and analysis is large. Please aware that H₂S has a relatively large decay rate and the value listed may be under-represented.

### Process Flow Chart

1. Biogas enters system
2. SulfrPack ST™ Sulfur Removal System
3. SAGPack™ Gas Compression and Moisture Removal
4. SAG™ Siloxane Removal System
5. Engine(s)

### SulfrPack ST™ Sulfur Removal System

SulfrPack™ ST is a biogas treatment system that removes sulfur from waste streams at a range of 0-2,000 ppm. SulfrPack™ ST is also equipped with a highly-effective odor control system that neutralizes sulfur and light mercaptan-type odors from any air or gas stream. This high-capacity product’s reliability in partially to fully humid air makes it unique to other sulfur removal systems.

SulfrPack™ ST makes use of SulfaTreat media. This proven technology provides for superior odor control, and can be applied to low-pressure vent gas. The system is completely passive.

### SAGPack™ Gas Conditioning and Siloxane Removal System

The SAGPack system is designed to condition, compress, and remove moisture and siloxanes from biogas. It includes patented technology for stratifying the media and calibration of the siloxane removal capabilities of the system based on the different species identified during gas testing. System size is based on gas velocity, temperature, pressure, and SIL-2 gas analysis. Treated gas operating conditions are 20-40 percent RH at a maximum of 80° F.
SAG™ removes hundreds of different organic and siloxane species, as well as non-methane VOCs and halides. The system includes one or more vessels that use special media and patented polymorphous porous graphite.

RG has developed over 270 SAG media combinations that can be used to target the different species of VOC and siloxane. This system has defined siloxane removal in our industry, and it is the most cost-effective solution for small to mid-sized installations, for any flow rate.

**NEXT STEP – RG Gas Testing**

**Robinson Group** offers comprehensive gas testing services to analyze contaminant levels in biogas waste streams. Our laboratory has extensive experience in gas analysis and utilizes equipment with the highest sensitivity and detection levels to ensure the most accurate results for our customers.

**Advantages of RG Gas Testing**
- RG’s gas analysis is the industry standard for identifying contaminants.
- Gas testing indicates the overall status of the gas conditioning system and its gas quality.
- RG will analyze and generate gas quality reports for single or multiple specified sample points.
- Regular gas testing protects your investment by ensuring your gas conditioning system continually produces clean gas.

**How Do I Get RG Gas Testing Services?**
- Request a customized quote for RG gas testing.
- Order a **RG Gas Sampling Kit**.
- Collect gas samples and send them to the RG lab for analysis. *Samples degrade quickly and must be tested within 24 hours of collection.*
- Gas analysis results are generally available in 7-8 working days.
- RG will then interpret those results based on the customer’s specific needs.

**Contact Information**

Thank you for your interest in Robinson Group. Should you have any additional questions, please contact:

RG’s Regional Sales Manager, Joe Yelpo (908) 930-5322
Why Should I Remove Siloxane?

Even at levels of less than 0.5ppm, siloxane can cause significant damage and fouling of engines, turbines, boilers, fuel cells, and the catalysts they employ to produce energy from biogas. Siloxane damage leads to higher costs and decreased lifespan of energy generation equipment. Siloxanes can also seriously impact the upgrade of gaseous fuels. Siloxane contaminants tend to increase in concentration over time—they are persistent. Removing them is essential to producing clean biogas and protecting your investment in energy generation equipment.

How Do I Get a RG System for Siloxane Removal?

Gas Testing: Having biogas tested for accurate levels of siloxane, sulfur, volatile organic compounds and other engine-fouling contaminants will allow RG to provide customers with the most accurate estimates for their siloxane removal system. Gas testing data will also help RG select the correct siloxane removal process for the customer’s unique biogas waste stream.

Request a Quote: All RG biogas conditioning systems are custom designed, as each site has its own unique amounts and types of contaminants. Our team of skilled representatives will direct customers through this process, making your system design experience informative and hassle-free.
How is Sulfur Removed?
Robinson Group offers several different methods for removing sulfur from biogas waste streams:

- **Fixed Media**
  RG provides two types of media-based systems for reducing sulfur: **CIS media**, which is comprised of wood chips impregnated with iron, for use in **SulfrPack CIS** systems, and **ST media**, which is comprised of clay pellets impregnated with iron, and is used in **SulfrPack ST** systems. Sulfur is removed from the biogas as it filters through the media, reacting with the iron in the media to form water and solid iron sulfide.

- **Biological Processes**
  Biological sulfur removal processes (**BioStrip**) use specialized anaerobic bacteria to reduce sulfur in biogas. Bacteria live on packed media inside the treatment vessel, and require only a supply of water, nutrients, and sulfur.

**SULFUR REMOVAL**

Why Should I Remove Sulfur?
Sulfur is a corrosive substance that damages engines, turbines, boilers, fuel cells, and the catalysts they employ to produce energy from biogas. If sulfur is not removed from biogas waste streams, it will corrode and damage engine parts, resulting in higher costs and decreased lifespan of energy generation equipment. Sulfur can also be an air pollutant.

How Do I Get a RG System for Sulfur Removal?

**Gas Testing:** Having biogas tested for accurate levels of sulfur, siloxanes, volatile organic compounds, and other engine-fouling contaminants will allow RG to provide customers with the most accurate estimates for their sulfur removal system. Gas analysis data will also help RG select the correct sulfur removal process for the customer’s unique biogas waste stream.

**Request a Quote:** All RG biogas conditioning systems are custom designed, as each site has its own unique amounts and types of contaminants. Our team of skilled representatives will direct customers through this process, making your system design experience informative and hassle-free.
Statement of Qualifications

Landfill / Digester Gas

Introduction
Services & Capabilities
Summary of Projects
Quality Management Program
INTRODUCTION

Venture Engineering & Construction (Venture) is a closely held, multi-disciplined engineering and construction management company. Pittsburgh based, Venture provides services to clients throughout North America and abroad ranging from front-end engineering to detailed design and construction management.

Our core staff of engineering professionals is experienced in a variety of process industries including energy, refining, chemicals, petrochemicals, alloys, consumer products, and general manufacturing industries.

We have registered professional engineers heading each discipline, and a design staff reflecting a balance of disciplines and a range of experience. Staffing is currently at 27 employees, all disciplines, of which six are Chemical Engineers.

Our core markets focuses are process industries, and energy. We are leaders in alternative energy solutions such as landfill gas plants, biodiesel plants, cogeneration facilities, and waste-to-energy plants.

Venture works routinely with advanced design tools such as:

- Autodesk products
  - Inventor
  - AutoCAD PID
  - AutoCAD Electrical
  - "Vanilla" AutoCAD
- ChemCAD
- STAAD
- Others

LANDFILL GAS

Specific to the solid waste industry, we have worked for owner/operators, equipment suppliers, municipalities, and developers. Our clients include GSF Energy, DTE Biomass, QuestAir Technologies, Waste Management, DCO Energy, Wheelabrator Technologies Inc., Rumpke Landfill, Monmouth Landfill, etc.

Our solid waste projects have included general consulting to landfill owners/operators, landfill gas conversion to medium BTU and high BTU pipeline quality gas (both balance of plant and equipment design), landfill gas to electricity plant design, biodigester gas to electricity and high BTU gas plants, LFG and digester gas direct use projects via Combined Heat and Power Plant. Natural gas to LFG boiler conversion projects, landfill gas curve analysis, landfill gas collection system design. Further, we have related experience from work in waste-to-energy.
Venture Engineering offers a wide array of engineering and environmental services in support of landfill gas and biodigester gas to energy projects, as well as municipal solid waste (MSW) to energy projects, and conventional cogen / combined heat and power projects.

**DESIGN AND CONSTRUCTION**
- Landfill Gas (LFG) to High BTU Gas Plants
- LFG Direct Use Projects (medium BTU)
- LFG to Electricity (turbines, IC engines)
- Biodigester gas to electricity
- Coal Bed Methane
- Siloxane removal system design
- H₂S Removal System Design
- Thermal Oxidizers
- Enclosed Ground Flares
- Leachate Collection Systems
- Landfill Gas Collection and Control Systems (GCCS)
- Transfer Station and Material Recovery Facilities
- MSW to Energy Plant
- NG to LFG Boiler Conversions
- Construction Management
- Full EPCM service provider!

**FACILITY SITING AND PERMITTING**
- Comprehensive Planning and Permitting Services
- Site Investigations
- Market Evaluation
- Waste Characterization
- Scope & Estimate Studies
- Due Diligence Support Services

**COMPLIANCE AND FIELD SERVICES**
- Groundwater Monitoring
- Biogas Monitoring
- Leachate Collection Systems
- Air Permitting
- NSPS/NESHAP Compliance Services and Reporting
STATEMENT OF QUALIFICATIONS

SUMMARY OF PROJECTS

Montauk Energy—Landfill Gas High BTU Processing Plant

PROJECT SCOPE

Venture Engineering provided full EPC services for a compressor upgrade project at the Montauk Energy, Rumpke Landfill location. The project will increase the production capacity by 1.5 million SCFD of high BTU (pipeline quality) gas.

Services Provided

Venture provided the following services:

- Front end engineering design, including capital cost estimate
- Installation engineering and design, including skid fabrication drawings
- Skid Fabrication (via subcontract)
- Full equipment supply, including new blower skid, heat exchanger, MCC
- Hired all trade contractors and over site of construction activities
- PLC programming
- Commissioning and start-up
SUMMARY OF PROJECTS

Montauk Energy—Landfill Gas High BTU Processing Plant Expansion

PROJECT SCOPE

Venture Engineering staff provided full EPCM services for a high BTU plant expansion at the Montauk Energy, Rumpke Landfill location. The project increased the production capacity by 6.0 million SCFD of high BTU (pipeline quality) gas. The total production capacity at the Rumpke facility is 15.0 million SCFD (inlet), with capabilities to deliver as much as 8.0 million SCFD of high BTU gas into the Duke Energy pipeline.

The project scope included new knock-out pot, inlet compressors, gas conditioning skids to remove siloxanes, NMOCs, moisture and H₂S, pressure swing adsorption using QuestAir Technologies proprietary PSA process, tail gas compressors, new thermal oxidizer, new utility ground flare, condensate collection and mitigation, control room, MCC and switchgear, and mercaptan addition system.

Services Provided

Venture provided the following services:

- Front end engineering design, including capital cost estimate
- Installation engineering and design, including skid fabrication drawings
- Procurement services for all equipment and trade contracts
- Construction Management of all construction activities
- PLC programming
- Commissioning and start-up
SUMMARY OF PROJECTS

Montauk Energy—Landfill Gas to Energy

PROJECT SCOPE

Venture Engineering provided front end engineering services for a 6MM SCFD landfill gas to energy plant. Various options were considered including landfill gas to high BTU gas plant, landfill gas to electricity plant using either turbine gensets or IC engines. The project is located at the Monmouth County regional landfill in Monmouth, NJ. Montauk currently operates a 5 MW landfill gas to electricity plant at this location. The new plant will utilize the gas from new landfill cells and produce high BTU gas which will be sold to the gas utility over a long-term gas supply contract.

Services Provided

Venture provided the following services:

- Technical evaluation and recommendation
- Front end engineering and design, including process design and development
- Specifications including standards and codes governing work, quality control, materials and execution workmanship, tolerances, criteria for temporary works, and required submittals
- Capital Cost Estimate
PROJECT SCOPE

Venture Engineering continues to support Montauk Energy Capital and its various subsidiaries including GSF Energy as part of a multi-year engineering services ‘evergreen’ agreement.

Services Provided

Venture provides the following services:

- Landfill gas curve analysis
- Landfill gas collection system design
- Routine O&M engineering at Rumpke, Monmouth, Valley, Monroeville, and McCarty Road plants
- Closure studies
- Scope & Estimate studies for planned future expansions
- Various Project Development activities, including pro forma analysis
SUMMARY OF PROJECTS

Vancouver Municipal Water Authority—Digester Gas High BTU Processing Plant

PROJECT SCOPE

Venture Engineering is providing engineering and design services for a new 350 SCFM bio-digester gas to high BTU gas plant for the Vancouver Municipal Water Authority, in conjunction with QuestAir Technologies. This plant includes a 100% skid fabricated design concept. Engineering is anticipated to be finalized in early 2009 and construction and commissioning is scheduled to be finalized in Q4 2009.

Services Provided

Venture provided the following services:

- Front end engineering design, including capital cost estimate
- Installation engineering and design, including skid fabrication drawings
- Skid Fabrication (via subcontract)
- Equipment sizing, design and procurement
- PLC programming
- Commissioning and start-up (future services)
SUMMARY OF PROJECTS

QuestAir Technologies, Inc.—Digester Gas High BTU Processing Plant

PROJECT SCOPE

Venture Engineering provided engineering and design services for a 2000 SCFM bio-digester gas to high BTU gas plant for QuestAir Technologies. This plant includes a 100% skid fabricated design concept, and will process municipal wastewater treatment plant anaerobic digester gas and convert to High BTU gas for injection into NG pipeline.

Services Provided

Venture provided the following services:

- Front end engineering design, including capital cost estimate
- Installation engineering and design, including skid fabrication drawings
- Skid Fabrication (via subcontract)
- Equipment sizing, design and procurement
- PLC programming
- Commissioning and start-up (future services)
STATEMENT OF QUALIFICATIONS

SUMMARY OF PROJECTS

DCO Energy Bergen—County CHP

PROJECT SCOPE

Venture Engineering provided commissioning services for this new Combined Heat and Power (CHP) plant for DCO Energy at the Bergen County Utility Authority’s Little Ferry sewage treatment plant in East Rutherford New Jersey. The facility consisted of:

- Duplexed gas compressor skid with glycol cooling for moisture removal
- Siloxane removal columns
- Twin 1.4MW Jenbacher Engine/Generator sets fueled by digester gas or natural gas and generating 4160 V power
- Heat recovery boilers, to provide supplemental heat to the facility’s hot water heating system
- Load paralleling equipment to optimize power generation while preventing export of power
- Atmospheric and digester gas monitoring

Venture staff worked collaboratively with DCO personnel, the contractor, and various suppliers, to coordinate on-site testing, commissioning, and training activities, culminating in a 48 hour Functional Performance Test and report. Other tasks included preparation of a detailed operations description, and punch listing.
SUMMARY OF PROJECTS

Wheelabrator Technologies, Inc.—Scope & Estimate Study: 250 TPD Waste-to-Energy Plant

PROJECT SCOPE

Venture provided various scope and estimate services for the planned 250 TPD MSW to electricity plant for the WTI, Hilo, Hawaii proposed plant.

The proposed Hilo plant will convert 250TPD of MSW into 6 MW (gross) power. The plant is a mass burn facility, based on Von Roll technology. Venture’s project manager, Mr. Steve Kranz, led the overall scope and estimate study. Venture’s scope included process design, including PFD and P&ID development (using new AutoCAD ‘Smart’ P&ID), as well as finalization of the balance of plant scoping drawings and capital cost estimate.

Due to the nature of the lack of trades in Hawaii, as well as basic materials of construction, this plant was proposed as a modular designed and built facility. Where the modules would be fabricated in the continental U.S. and shipped to Hawaii for assembly/erection.
SUMMARY OF PROJECTS

Wheelabrator Technologies, Inc.—Emissions Control Project: Waste-to-Energy Plant

PROJECT SCOPE

This facility burns municipal waste in two 750 ton per day refuse boilers and generates 40 MW of electrical power.

To improve air quality, the existing electrostatic precipitators were replaced. The project included the installation of two fabric filters and ash handling conveyors. The ID Fans were also modified to accommodate higher static pressure required for the new equipment and ductwork. New stack opacity equipment was also installed. The new equipment was installed in parallel with the old equipment. Changeover was accomplished during two 8-day outages.

The project was completed on time and under budget with no unscheduled interruption of the plant operation.

SERVICES PROVIDED

Venture staff provided project development services included scoping and estimating, through installation engineering. Scope included equipment specifications and installation engineering (electrical, control systems, mechanical, piping, structural, and civil), construction bids packages and bid analysis.

Changes were required to the plant DCS control system.

Prior to and during the planned outages, we provided on site engineering support and assisted with the start-up of the new equipment.
SUMMARY OF PROJECTS

Wheelabrator Technologies, Inc.—Master Service Agreement: Waste-to-Energy Facilities

PROJECT SCOPE

Venture Engineering has entered into a multi-year Master Professional Service agreement with Wheelabrator Technologies Inc., (WTI) a wholly owned subsidiary of Waste Management. As part of this agreement, Venture will be providing various engineering, procurement and construction management services at various WTI waste-to-energy facilities in the US.

Services include scope and estimate studies, process modeling services, installation engineering services, procurement and construction management services.

WTI is the U.S. market leader in the waste-to-energy sector.
SUMMARY OF PROJECTS

Wheelabrator Technologies, Inc.—Power Plant Modeling

PROJECT SCOPE

Venture provided steam cycle analysis using the Thermoflex modeling software for a new 1500 TPD MSW to energy plant to be located in Maryland.

The scope included modeling an existing facility (for baseline verification) and then applying the model to the planned 1500 TPD plant. Modeling included optimizing steam production at two pressure levels with and without reheat, towards optimizing overall efficiency.
QUALITY MANAGEMENT PROGRAM

Venture Engineering is committed to a quality system that meets the highest standards.

The quality policy for Venture Engineering states, "The goal of Venture Engineering is to satisfy our clients' needs in all respects and constantly strive to improve our standard of service."

The business of Venture Engineering is to provide quality, cost effective, on schedule, project development and management, engineering, procurement and construction management to the process, industrial, energy and related sectors in the US and internationally.

At Venture Engineering, quality management has three components:

**Assurance** - Planned and systematic actions necessary to provide adequate confidence that services will be supplied in accordance with specified requirements

**Control** - Measuring, evaluating and checking to verify conformance to requirements with the objective of ensuring only those services that conform to requirements are delivered

**Continuous improvement** - Management process involving everyone in the organization to better the performance and delivery of service to our clients

The engineering quality management program provides confidence that the project engineering activities will result in a safe, reliable and economic operating facility in conformance with the client's requirements.

While a number of management activities are employed to attain this confidence, the appointment of a core group of key experienced personnel to the project design team is primary. These personnel are selected on the basis of documented credentials and demonstrated capability to develop and direct a highly technical, proficient staff in performing to established design and drafting standards.
STATEMENT OF QUALIFICATIONS

QUALITY MANAGEMENT PROGRAM

In the execution plan for engineering, the responsibilities related to the quality program include the following:

- Selecting the engineering standards and procedures to be applied to the project
- Establishing the design criteria to be used in the development of the engineering design
- Preparing plans for design reviews for critical and/or unusual designs for equipment and facilities
- Appointing specific personnel including specialists to review, check and approve engineering documents including drawings, specifications, calculations and studies
- Performing pre-planned internal audits of the procedures related to the development of engineering design activities
- Reviewing the designs and engineering of subcontractors
- Reviewing engineering operations and procedures to reduce waste in materials, time and money
QUALITY MANAGEMENT PROGRAM

The supporting engineering activities to be used to assist and offer objective evidence of quality in this program include:

- Maintaining an organization, which is documented in an organization chart) showing specific personnel and their interrelationship
- Maintaining job descriptions, defining specific responsibilities and authorities of engineering personnel
- Establishing responsibilities for technical information exchanges, both internal and external
- Establishing control of design documents, including the activities for their review, approval, release, distribution and revision
- Providing for the safe and easy location, retention and retrieval of design documents
- Periodic review of the status and adequacy of the quality system
- Training, and upgrading of engineering personnel to perform to meet project requirements
- Identifying appropriate design needs or inputs
- Preparing necessary design documents
- Specifying quality levels, acceptable criteria and standards, and quality records requirements
- Conducting audits of design activities, their reporting and follow-up
- Taking appropriate corrective action necessary throughout the engineering design
- Controlling design changes
- Adjudicating and conducting feasibility studies of proposed alternative designs
QUALITY MANAGEMENT PROGRAM

Project control activities, including cost, schedule, man-hour, material and document control, are also part of quality management. Where applicable to specific contract requirements and Venture Engineering’s management requirements, this system is controlled through the application of documented standards, procedures and manuals. This provides for a consistent and efficient control function sized to contract needs.

To verify that these agreed standards, procedures and instructions are being adhered to; the project control function is audited, both internally by function staff and externally by corporate staff, on a regular basis.

Copies of the following documents demonstrating Venture Engineering’s commitment to quality management are available, for use on the project:

- **Corporate quality assurance manual** - Establishes the policy and objectives, responsibilities and authorities related to quality of work performed by Venture Engineering and the concept of doing the job right the first time, every time.

- **Departmental quality procedures** - Identifies Venture Engineering’s policy, objectives, organization, responsibilities and procedures with respect to the implementation and maintenance throughout a project of an effective and efficient quality management system.

These model documents are made specific to each project to reflect contract scope requirements following contract award. They are made available to all project personnel and form the basis for internal audit of project activities.
APPENDIX L

SKID ENCLOSURE LITERATURE
Custom Enclosures for our Gas Conditioning Systems

**FABRICATED PANEL ENCLOSURE SPECIFICATIONS**

- Class I Division 1 electrical rating
- 14GA formed and powder coated sheet steel construction
- Insulated and sound attenuation with mineral wool held by perforated steel
- Service and maintenance access through double doors
- Roof hatch to service siloxane vessels
- Logos and custom paint available

**STEEL REINFORCED ENCLOSURE SPECIFICATIONS**

- Class I Division 1 electrical rating
- Steel exterior with multiple color options for site aesthetics
- 3/4” fire rated plywood construction over steel studs
- Interior 5/8” green board (mildew resistant drywall)
- Fiberglass insulation

**Additional Enclosures—Call for details**

- Fabricated Panel Enclosure
- Steel Reinforced Enclosure
- Aluminum Enclosure
- Modified Shipping Container Enclosure

*Leaders in Biogas Technology*
5451 Chavenelle Road  ■  Dubuque, IA  52002  ■  Phone: 563.585.0967  ■  unisonsolutions.com
Custom Enclosures

All enclosures are custom built
Please contact Unison sales for pricing

Standard Features

- Mounted to skid base
- Insulated walls and ceiling
- Double entry doors
- System tie points on exterior

Options Available

- Thermostatically controlled heater
- Ventilation fan and intake louvers to prevent overheating or for continuous ventilation per NFPA requirements
- Combustible gas detector (LEL) inside enclosure for gas detection and warning
- Explosion proof light fixtures
- Multiple points of entry

Don’t see an option to meet your requirements?
Please contact our sales staff for a consultation
sales@unisonsolutions.com
APPENDIX M

REFERENCE CHECKS
Reference Check Question Sheet

Date and Time: Monday August 19, 2013

Name: John Sandhaus

Title: WWTP Superintendent

Contact Information: Phone – 970-375-4895 Email – sandhausj@ci.durango.co.us

Project Name: Durango WWTP

Installation Date: 2006

SCFM: 25

Number and Size of Microturbines: 1 x Capstone CR65

Factory Protection Plan - None

Microturbine Information:

Uptime: Most of the year except for minor shut downs to maintain it and replace the carbon

Maintenance Costs Per Year:

Satisfied/Not Satisfied – Why/Why Not: Very Reliable – There were a few programming glitches at the beginning but as the technology developed they were worked out

Any Operational Issues: The turbine had to be replaced after 4 to 5 years. This was a regular warranty issue. Another issue was an internal leak in the heat exchanger – This is a very rare case and not a warranty issue.

Effects of Varying Quantities of Gas: No real effect. The microturbine can ramp up and down throughout the day with no issues. The higher the altitude, the lower the power output.

Gas Conditioning Skid Information

Media Replacement Cost: $300 to $350 dollars for the media.

Frequency of Replacement: 9 to 10 months

Procedure – How is it Replaced? Removed using a shop-vac

- How is it Disposed of – Cost? Disposed in a landfill – Had to get a T-Clip for the materials which is costly but good for 5 years or so
Recommendations and Other Comments

- Would recommend a similar installation
  - Initially there were a few leaks but once that was fixed everything was fine
- Have had a good experience with Unison
  - To this day they respond to his calls within a day or two
Reference Check Question Sheet

Date and Time: Thursday August 22, 2013

Name: Paul Drazkowski

Title: WWTP Superintendent

Contact Information: Phone – 507-457-8207 Email – pdrazkowski@ci.winona.mn.us

Project Name: Winona WWTP

Installation Date: 2010

SCFM: 25

Number and Size of Microturbines: 1 x Capstone CR65

Factory Protection Plan - None

Microturbine Information:

Uptime: Most of the year except for minor shut downs to maintain it and replace the carbon

Maintenance Costs Per Year:

Satisfied/Not Satisfied – Why/Why Not: Satisfied

- No real maintenance to it
- Heat recovery reduces natural gas usage by 25%

Any Operational Issues: No major issues. The intake filter has to be changed on occasion

Effects of Varying Quantities of Gas: No effect. The microturbine has the ability to run like a VFD.

Gas Conditioning Skid Information

Media Replacement Cost: $800/change

Frequency of Replacement: Every 6 weeks right now. Now with a new media they are hoping to get the change to be every 12 weeks.

Procedure – How is it Replaced? Removed using a shop-vac

- How is it Disposed of – Cost? Disposed in a landfill. Required an analysis of the carbon before it was allowed to enter the landfill.
Recommendations and Other Comments

- Have had a good experience with Unison.
- Their service is excellent
- It is recommended that several gas samples are taken. This will allow a greater understanding of what’s actually in the gas.
APPENDIX N

PROPOSED COGENERATION LAYOUT
Appendix N

PROPOSED COGEN PLANT LAYOUT
COLLINGWOOD WASTEWATER TREATMENT PLANT
DETAILED ENGINEERING STUDY

Collingwood Public Utilities
APPENDIX O

EXAMPLE UTILITY BILLS
## SEWAGE DISPOSAL

<table>
<thead>
<tr>
<th>Account Number</th>
<th>Name</th>
<th>Service Address</th>
<th>Power Factor</th>
<th>Adjust Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>00010264-01</td>
<td>TOWN OF COLLINGWOOD</td>
<td>3 BIRCH ST</td>
<td>90.9</td>
<td>90.9</td>
</tr>
</tbody>
</table>

### Messages:

PREVIOUS BALANCE: $257.77
PAYMENT Jul/05/2013
BALANCE FORWARD

YOUR ELECTRICITY CHARGES
- STANDARD SUPPLY SERVICE: $5,403
- GLOBAL ADJUSTMENT: $15,339
- DELIVERY: $1,995
- REGULATORY CHARGES: $1,340
- DEBT RETIREMENT CHARGE: $1,558
- TRANSFORMER DISCOUNT: $971
TOTAL ELECTRICITY CHARGES: $26,521

YOUR WATER AND SEWER CHARGES
- WTR MTR RATE 1.5" COMM: $69
- CPU WATER SUPPLY FIXED CHARG: $35
- SWR MTR RATE 1 1/2 COMM: $100
- GWOOD SEWER SUPPLY FIXED CHARG: $76
TOTAL WATER AND SEWER CHARGES: $282

HST (86616834RT0001): $3291
CURRENT CHARGES: $28,995
TOTAL AMOUNT DUE: $28,995

CONSUMPTION COMPARISON (Usage Per Day)

<table>
<thead>
<tr>
<th>Electric (kWh)</th>
<th>Water (m3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Bill</td>
<td>Last Bill</td>
</tr>
<tr>
<td>7718.32</td>
<td>7910.11</td>
</tr>
<tr>
<td>4.18</td>
<td>4.36</td>
</tr>
</tbody>
</table>

An interest charge is applied on all overdue amounts at 1.5% per month.

**P.A.P. DO NOT PAY**

Account Number: 00010264-01

Bill Date: 2013-07-15
Due Date: 2013-08-09
Amount Due: $28,856.93

Service Address: 3 BIRCH ST

TOWN OF COLLINGWOOD
PO BOX 157
STN MAIN
COLLINGWOOD, ON L9Y 3Z5
2. Message Area:

- For easy reference we provide important information to our customers in this area. Further info available at www.colluspowersstream.ca

3. Conservation Management Zone (Consumption Comparison):

- Electricity and/or Water Average Use Per Day comparison of current period to previous month and to the same period the year before. If available

- Additional conservation tips can be found on our website

4. Statement of Account:

- The record includes a summary of transactions since the last statement invoice produced for this account to calculate the Balance Forward as of the Bill Production Date.

- Any positive Balance Forward amount is currently due; payment should be made to cease any further interest charges from being applied

- Detailed calculations of the period charges are provided for electricity and when applicable water, sewer and/or any related charges (you can request an explanation of electric charges provided below)

- Any applicable Tax is calculated and provided along with our current HST number for customer reference

- Current charges are shown and these are payable by the Due Date that is noted in the Summary area of the invoice form

5. Time-Of-Use Information:

- TOU charges are applicable to most electricity customers

- Detailed information of TOU and On, Mid, and Off-Peak periods and calculation is available on our website or please call the office

6. Summary:

- The final information area on the Customer Receipt Portion of the statement which is there for your records

- Bill Type (either First, Regular or Final Bill) is provided along with a customers designated Account Type for our internal use

- Bill Date of when the invoice was produced at our office is noted along with the Due Date that current charges are due to avoid interest charges

- Payment Type will provide an explanation such as “Do Not Pay Credit Balance” and “Please Pay By Due Date”

7. Remittance Portion:

- For customer use when making payment on account to ensure accurate information is provided upon receipt of each payment

- A reminder is provided to Pre-Authorized Payment (PAP) customers not to pay invoice amount.

---

ACCURACY OF BILLING INFORMATION. The electricity supplied to you during the billing period and is part of the bill that is subject to collection. The electricity consumed is multiplied by the adjustment factor. Collus PowerStream collects the money and pays this amount directly to the service providers.

Adjustment Factor: When electricity is delivered over a power line, it is normal for a small amount of electricity to be consumed or lost as heat. Equipment, such as wires and transformers, consumes this power before it gets to your home or business. The adjustment factor accounts for these losses.

Regulatory Charges: Regulatory charges are the costs of administering the wholesale electric system and maintaining the reliability of the provincial grid.

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ERRORS & OMISSIONS EXCEPTED. Every effort is made to ensure that all billings are accurate. However, billing errors can occur and we reserve the right to provide corrections as per the terms within their Conditions of Service.

PAYMENTS - If payment is made at a location other than our office, please allow 5 days for processing.

COMMENTS - If you have any questions or comments, please note them below. If you would like our staff to respond by phone, please indicate a number where you can be reached during office hours.

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CONDITIONS OF SERVICE

Collus PowerStream supplies electricity and bills for services as per rates in place at the time of billing. Water/Sewer is supplied/retrieved and billed by the Collingwood Public Utilities. For detailed Conditions of Service and rates information please visit our website at www.colluspowersream.ca or call our office.

All bills are due when rendered. Service is subject to be disconnected for non-payment after 30 days. Recent payments may not be reflected in the total amount due, if paid, please accept our thanks and disregard the reminder on the reverse side of this bill shown as Balance Forward (Due Now).

The water/sewer or electricity supply is not guaranteed, nor is it to be resold or supplied to any other person by the customer without authorization by the appropriate corporation.
Your Enbridge Bill

Invoice Date: December 30, 2011
Account Number: 85 36 65 81999 4

Service At: COLLINGWOOD SEWAGE TREATMENT PLANT
3 BIRCH ST
COLLINGWOOD ON L9Y 2T8

Summary of All Charges (taxes included)
Your last month's bill: 4,643.14
Payment received 15 DEC 11 - Thank you: 4,643.14CR
Balance forward & past due - if paid, Thank You: NIL
New Gas Charges: 4,556.69
Total HST: 592.37

Total Amount Due Now: 5,149.06

# Items subject to HST (Harmonized Sales Tax)

Terms & Conditions
Enbridge Gas Distribution charges are regulated by the Ontario Energy Board. Gas Charges are based on either actual meter readings or estimates. Questions about the taxes charged for any particular services should be directed to your service provider.
For additional information, Please visit: www.enbridgegas.com
HST Registration: 105205140

Enbridge Gas Distribution
Emergency, such as the smell of gas: 1-866-763-5427
Billing, Moving, Collections, Inspections or Meter Work: 1-877-ENBRIDGE (1-877-362-7434)

An OEB-approved late payment charge equal to 1.5% per month or 18% per annum (for an effective rate of 19.58% per annum) multiplied by a total of all unpaid Enbridge Gas Distribution charges will be added to your bill if full payment is not received by the late payment effective date below. A late payment charge, calculated and assessed in the same manner, will also be added to your bill if full payment for all other charges on your bill is not received by 19 JAN 12.

Enbridge Gas Distribution

PO Box 660
Scarborough ON M1K 5E3

ACCOUNT # | AMOUNT DUE NOW | LATE PAYMENT EFFECTIVE DATE | AMOUNT PAID
---|---|---|---
85 36 65 81999 4 | 5,149.06 | 19 JAN 12 | 

How to pay your Enbridge bill:
- Direct withdrawal from your chequing account
- Mail
- PC or online banking
- Most chartered banks

Please return this stub with your payment.

8536658199940005149060005149061201198
### Charges For Gas

**Invoice Date**  
December 30, 2011

**Billing Period**  
Nov 25, 2011 - Dec 22, 2011

**Account Number**  
85 36 65 81999 4

**Service At:**  
COLLINGWOOD SEWAGE TREATMENT PLANT  
3 BIRCH ST  
COLLINGWOOD ON L9Y 2T8

#### Details about your new gas charges

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Charge</td>
<td>65.00</td>
</tr>
<tr>
<td>Delivery to you</td>
<td>778.84</td>
</tr>
<tr>
<td>Transportation to Enbridge</td>
<td>953.78</td>
</tr>
<tr>
<td>Cost Adjustment</td>
<td>9.81 CR</td>
</tr>
</tbody>
</table>

For questions about your gas commodity contract, call  
FireFly Energy  
@ 866-618-8828.

**Gas Supply Charge**  
16,080 m3 @ 0.166000  
2,768.86

#### Total New Gas Charges  
# Items subject to HST (Harmonized Sales Tax)  
4,556.69

---

### Customer Charge

A fixed amount charged monthly per meter to recover a portion of the fixed costs that Enbridge incurs to keep our system available.

### Meter Reading Information

<table>
<thead>
<tr>
<th>Rate 6</th>
<th>Meter Number 503912</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current actual meter reading</td>
<td>22 Dec 11 57238</td>
</tr>
<tr>
<td>Loss previous meter reading</td>
<td>25 Nov 11 51975</td>
</tr>
<tr>
<td>Billing Period Days</td>
<td>0028</td>
</tr>
</tbody>
</table>

**Gas used this period (CCF to m3)**

<table>
<thead>
<tr>
<th>PEF Value</th>
<th>Adjusted m3</th>
<th>Total m3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.002300</td>
<td>16680</td>
<td></td>
</tr>
</tbody>
</table>

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### Payments

If you pay at the bank or by mail, to avoid the late payment charge, allow 7 days for your payment to reach our office.

Payments may be mailed to:

PO BOX 844  
Scarborough, ON M1K 5H1

Please make cheques payable to: Enbridge

All payments made to Enbridge are accepted under the express condition that the Company may demand payment of account balances irrespective of any condition attached to the payment by the customer.