Capstone

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Application Guide

Landfill/Digester Gas Use with the Capstone MicroTurbine

This document presents fuel application information for the Capstone MicroTurbine operating on landfill gas or digester gas. This combination may be referred to generically as "biogas".

Introduction

Compliance with the requirements detailed in this document is essential to avoid problems that may affect the performance, life, reliability, warranty, and in some cases, the safe operation of the Capstone MicroTurbine.

For additional information regarding different fuels and fuel usage, please refer to the Capstone MicroTurbine Fuel Requirements Technical Reference (410002).

The major areas of this document are detailed in the Table of Contents as follows:

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Biogas Fuel Requirements

Operational fuel requirements for the Capstone MicroTurbine are provided in Capstone MicroTurbine Fuel Requirements Technical Reference (410002). Capstone bases its warranty on the quality of the gas at the MicroTurbine inlet. This leaves the business partner and/or end-user responsible for the following items:

- Assessing the need for gas cleanup and conditioning.
- Selecting and properly installing, operating, and maintaining the appropriate gas cleanup and conditioning equipment.

This Biogas Application Guide is intended to provide supplementary, application-specific information for use by Capstone business partners and end-users. In the event of any conflict between the information provided herein, and the information and requirements contained within the Capstone MicroTurbine Fuel Requirements Technical Reference (410002), the Fuel Requirements Technical Reference shall take precedence.

Biogas originates from the anaerobic digestion of organic waste materials. Anaerobic refers to a process that occurs in the absence of oxygen. Digestion refers to a biological process performed by microbes or bacteria, which accomplishes the digestion of the organic waste materials. The microbes/bacteria consume the organic waste material, rendering its solid residue essentially inert. The process occurs in the presence of water, ideally with the temperature and pH controlled to optimize the digestion reactions and the health of the microbes/bacteria. The primary byproducts of this process are methane (CH_4) and carbon dioxide (CO_2). Typically, the volumetric gas ratio of methane to carbon dioxide is approximately 60:40 for digester gas.

The Capstone MicroTurbine Fuel Requirements Technical Reference (410002), table titled "Gaseous Fuel Composition and Properties Requirements," presents the required fuel composition and physical properties for gaseous fuels. While all of these requirements are important and must be observed, the most important limitations contained in this table with respect to biogas are noted as follows:

- The fuel temperature must be at a minimum of 10° C (18° F) above its dew point anywhere within the fuel connections and the system between the Capstone MicroTurbine fuel inlet and the fuel manifold block (refer to Note 2).
- Calorific value (average Higher Heating Value, or HHV) must be at least 13.04 MJ/m^3 (350 Btu/ft^3). If necessary, biogas with less than 350 Btu/scf can be blended with natural gas for use in the Capstone MicroTurbine.

Also in the aforementioned document, the table titled "Gaseous Fuel Contaminants Limitations," presents the required fuel contaminant limitations for gaseous fuel. All limitations must be observed for compliance. The limitation regarding the presence of siloxanes, however, is specific to both landfill gas and wastewater treatment plant digester gas. This limitation is identified as follows:

- Siloxanes must be limited to a maximum of 5 parts per billion (ppb) by volume. This is approximately the detection limit for siloxanes.
- Effectively, this limitation means that the fuel must contain no detectable level of siloxanes.

Some of the implications of these requirements are discussed in the following paragraphs. The focus is primarily on moisture and siloxane removal.

Typical Biogas Fuel Delivery System

A flowsheet for a typical biogas fuel preparation and delivery system to the Capstone MicroTurbine is provided in Figure 1. Not all of the steps may be required for all sites, and the steps may appear in different sequences in other cases. An example of a fuel pretreatment system not requiring initial sediment filtration nor pre-compressor dew point suppression is illustrated in Figure 2; however, as is described throughout this document, though often similar, every biogas installation is unique, and proper care should be taken when engineering the pretreatment system for a given application.

Capstone recommends that a sediment trap or filter be placed at the beginning of the line coming from the main gas manifold or pipe to the MicroTurbine plant. This filter will eliminate most of the black powder sludge material (corrosion products) and scale coming from the existing plant systems. Appropriate care should be taken to provide for the adequate drainage and disposal of any condensate and sediments/solids captured by this trap.

The siloxane filter can be placed either before or after the compressor (it is shown after the compressor in Figure 1). Placement of this filter will affect the pressure rating, overall size, and cost of the vessel, as well as the cost of graphite media replacement. Other considerations should be made when determining the overall configuration and layout of the equipment, including the siloxane filter. These additional considerations are discussed at length throughout this application guide.

Decisions such as these are a function of the existing site features, the preferences of the designer and end-user, and the size of the facility (that is, the quantity of Capstone MicroTurbines).

The Capstone business partner or end-user is responsible for the fuel delivery system, and may use any equipment that reliably meets the fuel inlet requirements of the Capstone MicroTurbine.

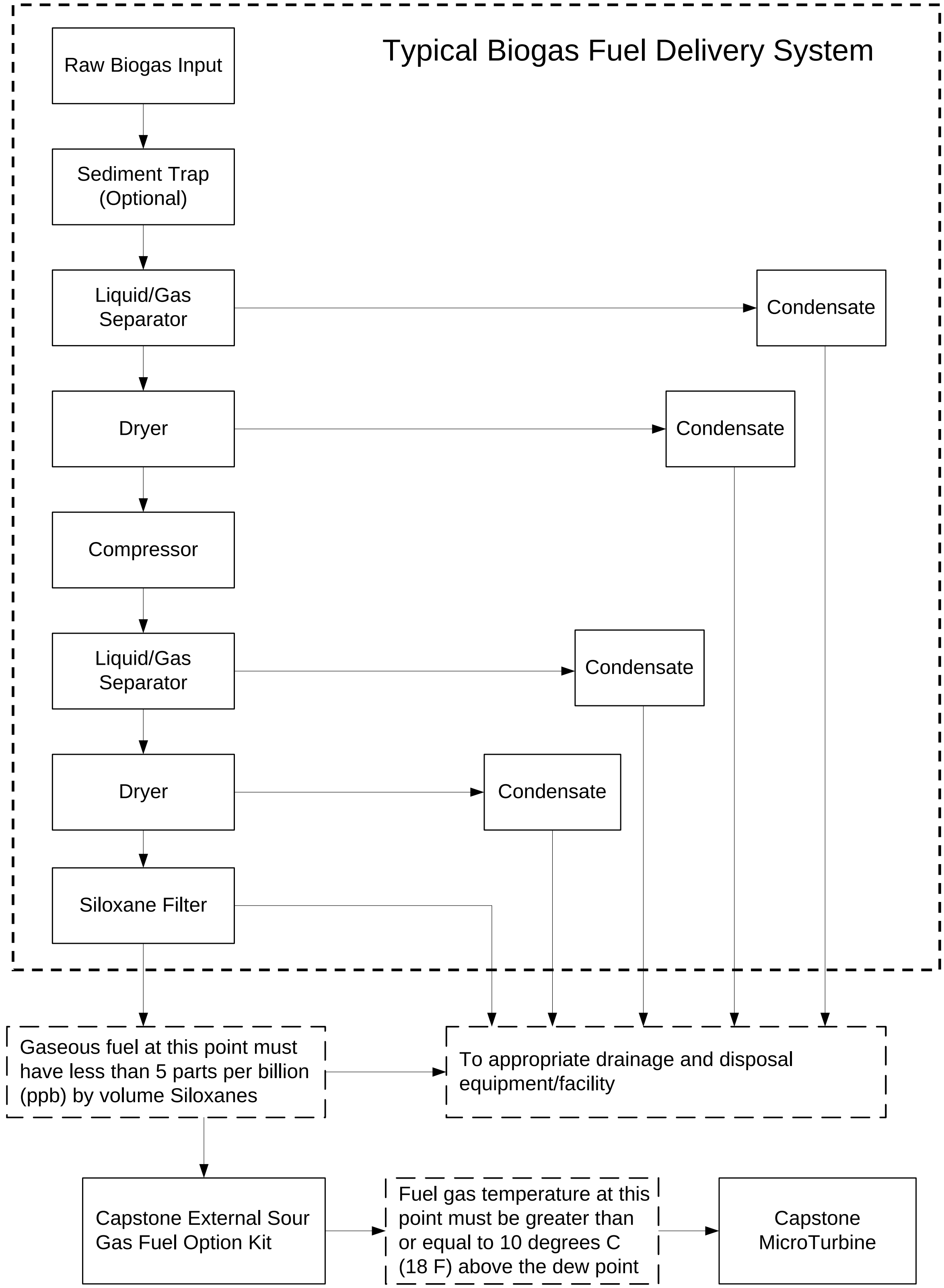

Figure 1. Typical Flowsheet for Biogas Fuel Delivery System

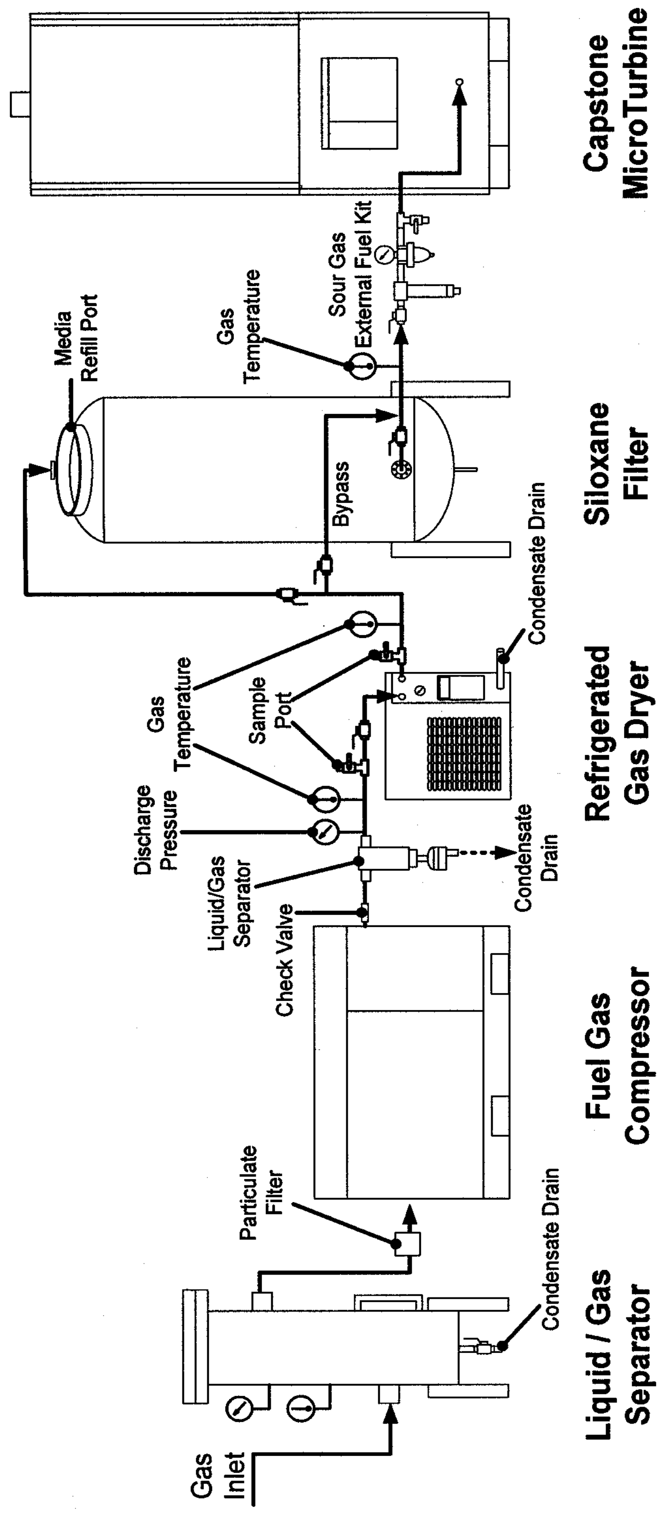

Figure 2. Illustration of a Possible Biogas Pretreatment System

Moisture Concerns

Because of the way it is produced, biogas is saturated with water. Any cooling of the gas in process lines almost always generates liquid phase condensate. This condensate must be knocked out when the gas first enters the Capstone MicroTurbine flowsheet. Compressing the gas, and cooling it afterwards in a compressor after-cooler, produces more condensate. The compressed gas must be chilled, separated, and reheated (if downstream of the gas compressor). On the typical flowsheet (Figure 1), these operations are labeled with the term dryer.

The ultimate objective is to introduce the pressurized gas into the Capstone MicroTurbine in such a condition that it will arrive at the manifold block at least 10° C (18° F) above its dew point temperature. Planning for this introduction must take into account both the hottest and the coldest ambient temperatures that will be encountered at the site. This planning is especially critical for installations operating in regions experiencing very cold climates that might otherwise freeze condensate in the fuel or drain lines.

Additionally, and as stated in Note 2 of the table titled "Gaseous Fuel Contaminants Limitations" in the Capstone MicroTurbine Fuel Requirements Technical Reference (410002): "If the fuel or fuel system must be heated to a temperature above the ambient temperature in order to meet this requirement, or to prevent condensed water from freezing, precautions must be taken to prevent the condensation of water vapor or freezing when the MicroTurbine is shut down, so that freezing of control valves does not occur and no liquid may enter the MicroTurbine control system when started or during operation." Careful attention to this requirement is essential at outdoor installations subject to freezing temperatures.

Early Capstone biogas installations have shown that the use of industry-accepted, proven technology for compression and drying of landfill gas and digester gas is essential; for example:

- Sour gas compatible rotary sliding vane or screw compressors.
- Refrigerated dryers or water/glycol chillers.
- In both cases, stainless steel or equivalent construction is specified for biogas.

Two of the most important points of plumbing design at a biogas site are to use the right material and allow for drainage. Plastic pipe is used in some locations but is not permitted in others. This type of pipe has the advantage of being corrosion-proof, but can be damaged. All piping must have provision for drainage. If the pipe goes underground or has a low point, the condensate will collect there and needs to be drained. Even if the piping diagram plan view appears to be perfect, the plumber may be tempted to route elevated pipe back to the ground level between various components like the compressor and the dryer. That pipe, and all others, must either slope toward a vessel with a drain or take appropriate means for condensate drainage.

Other considerations must also be made for the condensate removal system. For example, a device in front of the gas compressor intended for liquid/gas separation may be operating under a vacuum during normal operation. This is due to the high volume of gas that the compressor must intake in the area near its inlet to achieve the desired levels of flow and pressure. Under these conditions, care should be taken when draining condensate to avoid drawing in air that may result in MicroTurbine flameout or condensate ingestion by the gas compressor. Typical approaches may include the addition of condensate level switches and a small pump to remove the condensate; or perhaps an additional container and valves on the drain line to isolate the liquid from the vacuum so that the condensate may be manually drained while not introducing air to the fuel.

Additional care should be applied to selecting the types of liquid/gas separators used in such a system. Common applications employ coalescing, mesh-pad, cyclonic, or baffled separators made of stainless steel. Such separators may be acceptable for an application for a pressurized system, but these types of separators are not always appropriate for separation at very low pressure (i.e., at the compressor inlet). For the low-pressure separator, great care should be taken in both selecting the separator size and type. The approach will be different from one site to another, depending on ambient temperatures, fuel type, moisture content, existing fuel treatment, etc.

Regardless of the approach or technology applied for condensate control, it is required that all gas-wetted components be constructed of stainless steel or some other appropriate material capable of tolerating the presence of hydrogen sulfide in the system and any relevant weather conditions. In some cases, this may include the upgrade of any heat exchangers in the dryer or chiller to stainless steel. Moreover, it is highly recommended that temperature indicators and/or alarms be added, if possible, at the point of lowest temperature. This should be done so that a failure of the chiller/dryer component can be used to stop operation and provide maximum protection to the MicroTurbine and gas compressor.

Since a significant portion of the overall condensate formed will occur during the after-cooling process of the gas compressor, it is recommended that some form of liquid/gas separation take place after the gas compressor, so that the operation of a refrigerated dryer/chiller is not impaired or rendered less efficient. In many cases, this separation may be achieved with the addition of a coalescing filter so that the filter can both remove liquid phase condensate as well as provide additional filtration prior to the inlet of the refrigerated dryer/chiller heat exchanger. Also, the portion of pipe directly after the compressor needs to have a method of draining into an appropriate vessel. This may require elevating the compressor so that condensate will flow away from the compressor. A check valve should also be installed directly after the compressor to prevent any moisture from flowing back into the compressor upon shutdown.

Aside from the direct impacts that moisture may have in the MicroTurbine itself (which may include stuck fuel valves and plugged fuel injectors), moisture may also present a significant indirect affect to the MicroTurbine. In some biogas applications, it may be necessary to filter out several components of the fuel known collectively as siloxanes (see below for additional detail on siloxanes). Many of the filters that are used for siloxane removal are impaired by the presence of liquid condensate, which in turn, may allow siloxanes to reach and impact the MicroTurbines. For this reason, the temperature of the fuel must be higher then the fuel's dew point when passing through the siloxane removal devices. In Figure 1, for example, this is accomplished by placing the siloxane removal after a gas dryer.

Drain lines from all condensate producing devices should be directed towards an appropriate drainage disposal facility/equipment. Since there are many points of condensate drainage from the system, care should be taken to avoid over-pressurizing the drainage lines themselves. Condensate drain lines from high-pressure sources should not be tied together with drain lines from low-pressure sources. Ideally, all drain lines should be kept separate. However, should any drain line manifolding occur, it would be necessary to add check valves to the drain lines of all devices.

Timer-based drainage systems have proven to be common in many applications, especially with refrigerated dryers. Other types of drains and traps are also used to as part of an effort to create a fully automatic drainage system for a pretreatment system. However, even if a fully automatic drainage system is in place, all condensate traps on the drain line should have a bypass available for manual draining should an issue arise with an existing trap. Furthermore, if an installation will be operated without oversight for any length of time, the drainage system should also include high-level switches as alarms to cease operation of the overall installation in the event that some portion of the drainage system fail. When possible, the entire system, including the drainage system, should be manually inspected for potential or developing issues. It is recommended that such inspections occur daily for a new installation.

Capstone can assist business partners and end-users in the selection of appropriate equipment, and in the design and integration of the fuel processing equipment into the overall installation. However, the Capstone business partner or end-user is responsible for the fuel delivery system, and may use any equipment that reliably meets the fuel inlet requirements of the Capstone MicroTurbine.

Fuel Pressure Concerns

As mentioned previously, rotary sliding vane compressors have shown a tolerance for hydrogen sulfide in low to moderate levels. However, regardless of the compressor technology ultimately employed, the ability of the gas compressor (a.k.a. fuel gas booster) to supply an adequate level of pressure is vital to the success of the installation. The Capstone MicroTurbine Fuel Requirements Technical Reference (410002) provides useful information indicating that a decrease in the energy content of the fuel will require an increase in the available pressure at the fuel valve of the MicroTurbine; however, the gas compressor is still required to provide gas pressures in the range of 90-95 psig at the compressor discharge point for low and medium Btu installations.

This increased pressure discharge from the compressor compensates for several things. First, it provides sufficient pressure to overcome the pressure losses across most devices downstream of the compressor and upstream of the MicroTurbine. Second, it allows for a minimum of 12-15 psig pressure drop across the pressure regulator on the external fuel kit near the inlet of the MicroTurbine. This pressure drop allows the regulator to adequately protect the MicroTurbine from most moderate pressure fluctuations upstream of the regulator as well as the fluctuations caused by the starting/stopping of additional MicroTurbines consuming fuel from the same fuel header. Third, this compressor discharge pressure allows the MicroTurbine to receive the necessary fuel pressure it requires in steady fashion, which may be as high as 70-74 psig in low Btu applications.

The ability of the gas compressor to maintain the required pressure levels, as well as successfully operate in the long term, is affected by the levels of Hydrogen Sulfide (H_2S), Carbon Dioxide (CO_2), gas moisture content and the actual frequency of oil changes. Many compressors that operate on biogas will use specific oils intended to both lubricate the compressor, as well as provide some degree of protection against corrosion. Since the level of both H_2S and CO_2 in a fuel is very site specific, the rate of oil degradation is site specific as well. Thus, it may be necessary to periodically sample and test the oil to determine the frequency of required compressor oil changes to maintain compressor life and performance.

A serious consideration for the gas compressor, regardless of the technology utilized, is the temperature of the inlet gas stream. As discussed previously, the fuel coming to the gas compressor will probably be saturated with moisture. Since the ability of this type of fuel to hold moisture increases dramatically with temperature, it will often be required to pre-cool the fuel to a lower temperature and remove the resulting condensate (see Figure 1). This ensures that the moisture in the fuel does not leave the vapor state as it passes through the gas compressor. Biogas from an anaerobic digester, and at some landfills, may arrive at the pretreatment system at temperatures in excess of 120 degrees Fahrenheit.

Ideally, the dew point temperature of the fuel entering the gas compressor should be lower then 60° F for maximum protection of the compressor, but if 60° F or lower dew point temperatures cannot be achieved, then the lowest possible dew point temperatures should be obtained. In some cases, it may be necessary to modify the compressor to run hotter internally to prevent moisture from condensing within the compressor; although this is not always a viable option.

In some installations, a refrigerated gas dryer will be used instead of a chiller on the discharge side (high pressure side) of the gas compressor. Many refrigerated dryers use timer-based drainage systems for purging of the collected condensate. Since many of these dryers are placed after the gas compressor, but still in close proximity to the compressor discharge, there is the possibility that the dryer draining periods will cause a local drop in pressure that can be detected by the gas compressor. This condition often results in a cycle of the compressor rpm (for systems with a variable speed drive) each time the dryers opens its drain. If such events are severe and occur rapidly, it may result in an accelerated loss of compressor oil into the gas stream. This situation, however, may be addressed in several ways, from the addition of a small buffer tank, to the addition of a small restriction in the dryer drain line that minimizes gas loss and local pressure fluctuation. Note that if the siloxane filter vessel is located relatively close to the compressor and dryer, the vessel may double as a high-pressure buffer tank. This minimizes the pressure fluctuation that would otherwise be seen by the MicroTurbines while assisting the gas compressor to cope with the local loss in pressure from the refrigerated dryer drain.

Filter Element Concerns

Following commissioning of MicroTurbines using digester gas or landfill gas as fuel, the coalescing filters on the Capstone external fuel kit and inside the MicroTurbine enclosure should be inspected once a week during the first month of operation. These inspections will determine whether the filters are wet or dry, and if they are collecting significant amounts of particulate matter (such as carbon particles from the siloxane filters).

If the filters are wet, the gas does not meet the Capstone fuel specification. As a consequence, performance of the MicroTurbine will be impacted, and the warranty may be voided if damage to fuel system components is caused by fuel moisture. If this occurs, take corrective action to the fuel delivery system: replace the filter elements, and continue checking once a week for several weeks, to verify that the filters remain dry. Notice that the inside surface of the cylindrical filter element is the surface that collects the particulate matter.

Once the weekly filter inspections have verified that the fuel is dry, it is recommended that at least one filter be inspected every month for several months. Depending on the results of these inspections, it may be necessary to change the filter elements more often than every 8,000 hours (which is the guideline for pipeline-quality natural gas), as noted in the MicroTurbine Standard Maintenance Work Instruction (440000).

Moreover, the fuel filters should be inspected within 1000 hours of a siloxane filter media change. The change of the siloxane media introduces new particulate impurities to the system that will likely be captured by the fuel filters at the inlet of the MicroTurbine (if the siloxane removal system is placed as shown in Figure 1). Thus, it may be necessary to change the fuel filters soon after a change of the siloxane filtration media to ensure that the fuel filters do not become significantly clogged and allowing additional impurities to pass into the MicroTurbine.

Siloxane Concerns

Siloxanes are composed of carbon (C), hydrogen (H), oxygen (O), and silicon (Si) and are relatively volatile organic/silicon compounds manufactured and used as a basic building block monomer for polymerized silicone formations. Further, siloxanes are used extensively in consumer products as a volatile dispersant agent to help evenly spread organic-based specialty chemicals. Some of these products include deodorant, lipstick, and makeup.

As man-made compounds that typically are washed down the drain or thrown in the trash, siloxanes are ALWAYS found in landfill gas and wastewater treatment plant digester gas. However, siloxanes are NOT likely to be found in certain other types of digester gases. Examples of operations that are likely to produce siloxane-free digester gas include the following:

- Dairy and hog farms (manure digesters).
- Breweries and ethanol plants.
- Food processing plants.

Analysis of biogas from wastewater treatment plant digesters and landfills reveals that cyclic (ring-structure) siloxanes are the most prevalent form. Figure 3 presents the structure of a specific siloxane molecule, commonly called D4, found in wastewater treatment plant digester gases. However, since many other types of siloxanes may be present in biogas, a complete fuel analysis should be performed to identify the types and quantities of other present siloxane molecules, so that the appropriate graphite media may be used for optimal filtration.

Siloxane (D4)

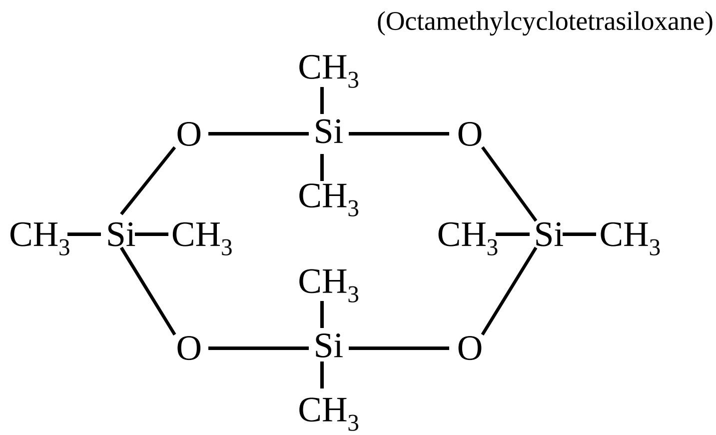

Figure 3. Chemical Structure for a Siloxane (D4) Molecule

Siloxanes have limited water solubility, and they agglomerate in the solids (sludge) fed to digesters at wastewater treatment plants. In the hot environment of digesters, concentrations of volatile siloxanes increase due to the decomposition of silicones and other polymers composed of siloxanes. As a result, the concentration of siloxanes in digester gas is in the measurable ppb (parts per billion) or ppm (parts per million) range.

As biogas that contains siloxanes is combusted, the silicon reacts with oxygen to form silicon dioxide (SiO_2), a solid white powder commonly known as silica. Sand (quartz) is nearly pure silica. Silica particles are abrasive and have a very high melting temperature.

When siloxanes are present in the fuel to a Capstone MicroTurbine, tiny particles of silica form in the combustion section. The silica particles travel with the exhaust gases at very high speeds through the nozzle vanes into the turbine wheel, and then exits through the recuperator and heat exchanger (if installed). Over time, these abrasive particles can cause erosion of some of the metal surfaces they contact, as well as fouling and plugging of heat exchanger surfaces - leading to a gradual increase in fuel consumption and exhaust temperature and a decrease in system efficiency. Additionally, silica may deposit all throughout the combustion section of the MicroTurbine and behind the turbine wheel, which could lead to seizing of the turbine shaft.

In other power generating equipment (internal combustion engines and gas turbines) used for landfill gas and digester gas, troublesome silica deposits and erosion have also been found. These deposits are often found on the cylinder heads and rings of internal combustion engines, and on the heat recovery steam generator tubes of gas turbines. Maintenance and rebuild requirements tend to be very high, as shown by unit availability data. It is not uncommon for internal combustion engines at wastewater treatment plants to have top-end rebuilds twice a year.

As more stringent NO_x emission requirements are imposed, generators other than Capstone MicroTurbines are being forced to incorporate post-combustion catalytic controls. Silica particles in the exhaust gas from these generators operating on biogas have been observed to blind the catalyst and render it ineffective within a few hours of operation.

For these reasons, as technology is driven towards higher performance levels and lower emissions, siloxane removal is expected to become a more common process step in all biogas power generation systems, not just in Capstone MicroTurbine systems.

Siloxane Removal Concerns (Capstone MicroTurbines)

Applied Filter Technology (AFT) of Snohomish, Washington provides siloxane removal systems and services specifically designed for Capstone MicroTurbines. Upon request, Capstone will review and may approve the use of other systems or vendors that can reliably meet the basic requirement of no detectable siloxanes (<5 ppb) in the fuel entering the Capstone MicroTurbine.

The basic technology is absorption of siloxanes in the pores of graphite media. Applied Filter Technology has a number of different media with different pore sizes and structures, and layers them differently for each biogas to optimize overall performance. Applied Filter Technology refers to this system as Segmented Activity Gradient (or SAG).

The services performed by Applied Filter Technology include the following:

- Providing the special gas sampling equipment and method needed to obtain an accurate siloxane analysis.
- Coordination with the analytical laboratory.
- Evaluation of the concentrations of siloxanes and other organic compounds.
- Calculation of removal efficiencies and media replacement rates.
- Design and manufacture of the siloxane removal system.
- Engineering consultation as necessary.

In order to keep the cost to a minimum, the siloxane removal system may be designed without a lead-lag vessel system. Bypassing the vessel for a couple of hours while the media is being changed will not cause any measurable loss in Capstone MicroTurbine performance, if this operation is performed just a few times a year. A biogas with an extremely high concentration of siloxanes would be treated as an exception to this typical guideline.

Hydrogen sulfide (H_2S) is normally present in biogas, and is preferentially absorbed in graphite media. Sites with high H_2S content in the biogas may require more extensive fuel treatment systems (possibly including separate H_2S removal) to ensure complete removal of siloxanes with reasonable run lengths between graphite media changes.

The Capstone installer or end-user is responsible for the fuel delivery system, including the selection, design, and operation of the siloxane removal system.

Materials of Construction Concerns

Biogas is sour gas, containing H_2S in the 100 to 10,000 ppm range. High CO_2 content makes it acidic as well. Biogas condensate is a foul-smelling, noxious material that contains some difficult-to-handle compounds. Stainless steel, plastic, and aluminum are the preferred materials of construction. Parts made of yellow metals, such as brass valves and copper heat exchanger tubes are inappropriate. Carbon steel will also eventually corrode, leaving byproducts that can clog and damage other equipment.

Resources

These resources have hardware that may be appropriate for biogas applications:

Refrigerated Dryers & Chillers:

Company:	Pneumatech
Contact Information:	Titus A. Mathews Phone - (262) 658-4300 Fax - (262) 658-1945 Email - tmathews@pneumatech.com Web Page - http://www.pneumatech.com/
Company:	Q-Air California
Contact Information:	Richard Walsh Phone - (562) 906-8687 Fax - (562) 946-0327

Fuel Compressors (Fuel Gas Boosters):

Company:	CompAir
Contact Information:	Gavin Monn Phone - (937) 498-2565 Fax - (937) 492-3811 Email - gavin.monn@compair.com Web Page - http://www.compair.com/

Company:	A-C Compressor
Contact Information:	Web Page - http://www.gepower.com/geoilandgas

Company:	Davey Compressor
Contact Information:	Web Page - http://www.daveycompressor.com/
Notes:	***Compressors require third party modification for biogas. Contact Capstone for additional details.***

Exhaust Heat Exchangers for Biogas:

Company:	Cain Industries
Contact Information:	Jim Rozanski Sales Engineer Phone 1 - (800) 558-8690 x19 Phone 2 - (262) 251-0051 x19 Fax - (262) 251-0118 Email - jim.rozanski@cainind.com Web Page - http://www.cainind.com/

Stainless Steel Exhaust Ducting:

Company:	Heat & Power Products, Inc.
Contact Information:	Bruce Ames Phone - (920) 858-2004 x4 Fax - (920) 428-1390 Email - bames@hpprep.com Web Page - http://www.heatandpowerproducts.com/

Capstone distributors who have installed and/or operated biogas installations with MicroTurbine equipment are:

Calpwr

Primary Biogas Application(s):	Waste water treatment plants
Primary Contact(s):	Joe Silva San Diego, CA Phone - (858) 277-8585 Fax - (858) 277-8514 Email - joes@calpwr.com

Unison Solutions

Primary Biogas Application(s):	Anaerobic digesters, landfills, waste water treatment plants
Primary Contact(s):	Jan Scott or Dave Broihahn Dubuque, Iowa Phone 1 - (563) 585-0968 Phone 2 - (563) 585-0969 Fax - (563) 585-0970 Email - jan.scott@unisonsolutions.com Email - dave.broihahn@unisonsolutions.com

Stellar Power & Utilities

Primary Biogas Application(s):	Waste water treatment plants
Primary Contact(s):	Eric Fox Jacksonville, FL Phone - (904) 899-9485 Mobile - (904) 631-4799 Fax - (904) 899-9485 Email - efox@thestellargroup.com

Designers, installers, or end-users with little or no practical experience in installing and/or operating a biogas-to-energy project may benefit from using services of companies experienced in this field. Capstone does not recommend that those inexperienced in biogas applications undertake such projects without engaging appropriately skilled personnel as these can be particularly technically challenging applications.

It remains the full responsibility of the designer and installer to properly engineer, integrate, and install any component selected for such a pretreatment system and for the integration of the pretreatment system with the MicroTurbine. Capstone undertakes no obligation to update this resource list provided in this Application Guide.

Safety Considerations

Consideration should be given to minimizing the exposure of workers to both the biogas and the condensate as they perform maintenance on the systems. Purge valves and purge gas systems, bypass lines, media replacement hatches, and media maintenance procedures, in addition to ventilation requirements, are important considerations. In addition, all workers must have H_2S safety training.

Capstone Technical Information

For additional information, or if specific Biogas questions arise, feel free to contact the Biogas Product Director or the Biogas Applications Manager at Capstone Turbine Corporation:

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