Waukesha®

Digester Gas
Premium Gas Engine Fuel

DRESSER® Waukesha

FORM 537

Waukesha Engine
Dresser, Inc.
Waukesha, Wisconsin 53188
Printed in U.S.A. 6/96, 3/99, 10/03
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DIGESTER GAS

While digester gas has been an alternative gas engine fuel for almost half a century, the value of this high energy, high quality gaseous fuel is more enhanced today because of numerous environmental, economic and technical advantages.

From an environmental perspective, digester gas provides several major benefits. First, it utilizes a readily available source of free energy that is produced in large quantities daily in municipal and industrial wastewater treatment plants. Second, the production of electric power from the combustion of digester gas does not compete with the growing electrical needs of the community, and thus postpones the construction of new and expensive fossil powerplants. Lastly, the exhaust emissions produced in the combustion process are easily controlled, either through the use of lean combustion or catalytic converter technology.

From an economic perspective, digester gas is a very attractive alternative to the production of electrical or mechanical power from natural gas, coal or fuel oil. Fossil fuel prices have recently undergone little or no inflation, but, the long-term trend is to higher prices, based on the depletion of lower-cost fuel supplies, and the higher cost of producing in offshore and wilderness areas. Digester gas also facilitates demand side management, in which individual pump or blower drives can be converted from electric motor to gas engine drive. Of growing importance, too, is the advantage of a purely domestic fuel source. North America is importing close to 50% of its liquid fuels, and incurring a serious trade deficit in the process. The same pattern is taking place in other industrial nations.

Today hundreds of wastewater treatment plants are quipped with digester-fueled gas engine systems. In the case of older engine generating systems, it is a simple process to upgrade them from naturally aspirated to turbocharged, and from rich-burn to lean combustion by means of off-the-shelf service parts conversion kits. An evaluation of current opportunities to upgrade equipment at each site can be made by a consulting engineering firm in conjunction with the local Waukesha distributor.

Introduction

Every community produces both liquid and solid wastes. The liquid portion – wastewater – is essentially the water supply of the community after it has been fouled by a variety of uses. Wastewater may be defined as a combination of the liquid or water-carried wastes removed from residences, institutions, and commercial and industrial establishments, together with such groundwater, surface water, and storm water as may be present.

If untreated wastewater is allowed to accumulate, the decomposition of the organic materials it contains can lead to the production of large quantities of odorous gases. In addition, the untreated wastewater usually contains nutrients. These nutrients stimulate the growth of aquatic plants but may also contain toxic compounds. For these reasons, the immediate and nuisance-free removal of wastewater from its sources of generation, followed by treatment and disposal, is not only desirable but necessary in an industrialized society.

Digester History

The history of sludge digestion can be traced from the 1850's with the development of the first tank designed to separate and retain solids. In about 1860, it was observed that if the solids were kept in a closed vault (cesspool) they were converted to a liquid state. The first unit used to treat settled wastewater solids was known as the Mouras automatic scavenger. It was developed by Louis H. Mouras of Vesoul, France.

The first person to recognize that a combustible gas containing methane was produced when wastewater solids were liquefied was Donald Cameron. He built the first septic tank for the city of Exeter, England, in 1895. He collected and used the gas for lighting in the vicinity of the plant. In 1904, the first dual-purpose tank incorporating sedimentation and sludge treatment was installed at Hampton, England. It was known as the Travis hydrolytic tank, and continued in operation until 1936. Experiments on a similar unit, called a Biolytic tank, were carried out in the United States between 1909 and 1912.

In 1904, a patent was issued to Dr. Karl Imhoff in Germany for a tank now commonly known as the Imhoff tank. One of the first installations in the United States using separate digestion tanks was the wastewater treatment plant in Baltimore, Maryland.

In the period from 1920 to 1935, the anaerobic digestion process was studied extensively. Heat was applied to separate digestion tanks, and major improvements were made in the design of the tanks and associated equipment. It is interesting to note that the same practice is being followed today, but great progress has been made in the fundamental understanding and control of the process, sizing of tanks, and the design and application of equipment.

Digester Process

Anaerobic digestion is one of the oldest processes used for the stabilization of sludges. It involves the decomposition of organic and inorganic matter in the absence of molecular oxygen. The major applications have been, and remain today, in the stabilization of concentrated sludges produced from the treatment of wastewater and in the treatment of some industrial wastes. Because the anaerobic digestion process is of such fundamental importance in the stabilization of organic material and biological solids, it is the most widely used form of digestion today for sludge volume reduction and gas production. Sludge volume reduction of 45 - 50% is not uncommon.

Process description: In the anaerobic digestion process, the organic material in mixtures of primary settled and biological sludges under anaerobic conditions (in the absence of oxygen) is biologically converted to methane (CH_4) and carbon dioxide (CO_2). The process is carried out in an airtight reactor. Sludges are introduced continuously or intermittently and retained in the reactor for varying periods of time. The stabilized sludge, which is withdrawn continuously or intermittently from the process, is for all practical purposes biologically inert and odorless.

Two types of digester are now in use, standard-rate and high-rate. In the standard-rate digestion process the contents of the digester are usually unheated and unmixed. Detention times for this process vary from 30 to 60 days. In a high-rate digestion process the contents of the digester are heated and completely mixed. The required detention time is 15 days or less. A combination of these two basic processes is known as the two-stage process. The primary function of the second stage is to separate the digested solids from the liquids; however, additional digestion and gas production may occur.

The biological conversion of organic matter is very complex; however, several conditions must be present to stabilize organic waste.

1. The reactor should be void of dissolved oxygen.
2. The reactor should be free from heavy metals and sulfides.
3. PH of the aqueous environment should range from 6.6 to 7.6.
4. Sufficient amounts of nitrogen and phosphorus should be available to ensure proper growth of the biological community.
5. Temperature is another important environmental parameter - the optimum temperature range for human waste is 85 - 100 °F.

DIGESTER GAS AND HOW IT IS PRODUCED

Digester Gas

The gas produced contains about 65 – 75% methane (CH_4) by volume, 30 – 35% carbon dioxide (CO_2), and small amounts of nitrogen (N_2), hydrogen (H_2), and other gases. Digester gas has a specific gravity of approximately 0.86 referred to air. The production of digester gas is one of the best measures of the progress of digestion. Because the gas can be used as fuel, the designer should be familiar with its production, collection, and utilization.

Gas Collection

Floating covers fit on the surface of the structures containing digester contents. This allows the volume of the digester to change without allowing air to enter the digester. Gas and air must not be allowed to mix, or an explosive mixture may result. Digester gas system piping and pressure–relief valves must include adequate flame traps. The covers may also be installed to act as gas holders that store a small quantity of gas under pressure and act as reservoirs. This type of cover can be used for single–stage digester or in the second stage of two–stage digester.

Fixed covers provide a free space between the roof of the digester and the liquid surface. Gas storage must be provided so that (1) when the liquid volume is changed, gas, and not air, will be drawn into the digester, and (2) gas will not be lost by displacement. Gas can be stored either at low pressure in gas holders that use floating covers or a high pressure if gas compressors are used. Gas meters should be installed to measure gas produced and gas used or wasted.

Gas Production

Total gas production is usually estimated from the volume of the volatile–solids loaded into the digester or from the percentage of volatile–solids reduction in the digestion process. Gas production can fluctuate over a wide range, depending on the volatile–solids content of the sludge feed and the biological activity in the digester. Excessive gas–production rates sometimes occur during startup which may cause foaming and escape of foam and gas from around the edges of floating digester covers. If stable operating conditions have been achieved and gas–production rates are being maintained, the operator can be assured that the result will be a well–digested sludge.

Gas production can also be estimated on a per capita basis. The normal yield is 15 to 22 m^3 per 1000 persons per day (0.6 to 0.8 ft^3/person/day) in primary plants treating normal domestic wastewater. In secondary treatment plants, this is increased to about 28 m^3 per 1000 persons per day (1.0 ft^3/person/day).

One cubic meter of methane at standard temperature and pressure has a net saturated low heating value of approximately 35,800 kJ/m^3 (960 Btu/ft^3). Since digester gas is only 65% methane, the saturated low heating value of digester gas is approximately 22,400 kJ/m^3 (600 Btu/ft^3). By comparison, natural gas, which is a mixture of methane, ethane, and slight traces of propane, has a low heating value of approximately 37,300 kJ/m^3 (1000 Btu/ft^3).

GAS PREPARATION

The fuel obtained from the digester gas process in most instances is not ready for use in an engine. Certain parameters with regard to the fuel temperature, liquid water, fuel contaminants, compressor oil carryover and siloxanes must be considered prior to the utilization of the digester gas fuel.

Fuel Gas Temperature

Under normal operating conditions, the fuel gas temperature at the inlet to the engine mounted gas regulator should be maintained between –20° F(–29° C) and 140° F(60° C). The lower limit is due to the elastomer components inside the engine mounted gas regulator. The high temperature is limited due to the elastomers and potential power losses.

Liquid Water

Liquid water is not allowed in the fuel because it can result in corrosion and fouling. Saturated fuel gas at the carburetor inlet is acceptable. Precautions must be taken to ensure that no liquid water forms in the fuel system. The dew point of the fuel should always be at least 20° F(11° C) below the measured temperature of the gas entering the engine mounted gas regulator.

Water content can be reduced to acceptable levels by several methods:

1. Condensation of excess moisture can be removed by passing the gas through a refrigeration system. This process will also remove heavy hydrocarbons.
2. Selective stripping of the moisture with a chemical process such as Selexel.
3. Heating will also reduce the water content in the fuel:

   a. If the fuel is 30° F (17° C) or more above the ambient temperature it can be cooled by passing it through a heat exchanger and then reheating it.

   b. If the fuel is 20° F (11° C) or more below the ambient temperature it can be heated.

Fuel Contaminants

Solid contaminant particles can cause abrasive wear of cylinder liner, piston rings, bearings, etc., and must be removed. In sufficient quantity these particles will damage critical engine components and reduce normal engine life. A one micron filtration system is recommended.

Sulphur compounds are commonly found in digester gas fuel. These compounds are highly undesirable in fuel gas as the combustion process produces gases which can combine with water to form corrosive acids. The acid formed is hydrogen sulfide. Any internal acid formation within the engine will lead to shortened engine life. Any fuel with a concentration of hydrogen sulfide greater than 0.1% by volume must be treated (scrubbed) to lower the concentration to 0.1% or less.

Compressor Oil Carryover

Fuel gas compressor lubricating oil carryover must be removed from the fuel stream. This oil is hydrogen based and combustible, however, it contains additive packages with barium, calcium and other undesirable elements and compounds. If the carryover is not removed it can lead to regulator problems, excessive spark plug and combustion chamber deposits, cylinder varnish, ring stacking and other problems.

Siloxanes

Siloxanes compounds are used in “down-the-drain” products such as shampoos, deodorants, cosmetics and medicine. The siloxanes enter a wastewater treatment plant as part of the liquid influent which change to a gas during the digester process. Siloxanes do not react with water to create acids within the engine but do involve the formation of deposits within the engine’s combustion chambers. The result is the formation of silicon dioxide. This is a fine, white, powdery substance which forms on cylinder heads, exhaust valves and spark plugs. While the effects of siloxanes are not as severe as those caused by hydrogen sulfide, problems due to silicon deposits within the engine may require fuel treatment such as refrigeration dehydration.

GAS UTILIZATION

Waukesha Engine Division of Dresser Industries, Inc. has more than 50 years of experience in supplying gas engines that use digester gas as a fuel. The use of an internal combustion gas engine to drive blowers, pumps and generators to produce electricity, is an effective way to utilize this fuel.

A. A Waukesha spark ignition gas engine which normally operates on 1000 Btu natural gas needs only a few minor changes to utilize digester gas as a fuel. Digester gas as described has methane as its basic component, but also contains 30 – 35% inert gases. Because of the inerts, it has only 600 Btu per cubic foot which means a larger volume of gas must be supplied to the engine with the correct air fuel ratio.

B. Engine features to efficiently utilize digester gas.

1. Larger carburetors for larger volumes of the lower Btu gas.

2. Electronically variable timing to accommodate secondary fuels.

C. Engine or horsepower sizing is a function of the combination of the fuels used, whether the engine is naturally aspirated or turbocharged and the operating speed. Waukesha recommends contacting a local distributor for sizing and application assistance.

1. For preliminary calculations, it is acceptable to consider that an engine can produce 80 – 85% of its continuous natural gas rating when operated on digester gas for naturally aspirated and 100% for turbcharged engines.

Typical Installations

A. Electrical drive: Electrical Prime Power - In this application, a gas engine-generator or multiple generator units are supplied to meet the electrical needs of the site, or the necessary capacity and number of units are selected to burn the available digester gas.

1. Sizing of the system can be determined as adequate to run continuously and use the available gas production 24 hours a day.

2. Sizing of the system can be determined by the load profile as the customer may decide to store digester gas by using a floating cover and produce a greater output for a shorter period of time, such as to meet peak loading or time of day electrical rates.

3. With each of the above operating methods, it is possible to size the system for a higher KW output than is available from only digester gas production. Natural gas is generally supplied as a secondary fuel and used when digester gas is not available to produce the required electric power.

a. An automatic system can be supplied to switch the fuel supply from digester gas to natural gas without interruption.

4. As a further alternate, the site can be supplied with a third fuel source such as HD-5 propane. This fuel can be used to provide emergency service whenever electrical power is needed and the primary digester gas or natural gas is not available. This is normally considered for standby service only.

a. Serious consideration should be given to this option as it can provide the necessary alternate power source to meet system design criteria per EPA guidelines.

5. Remember that a system can be sized to supply the available heat load and any over-supply of electricity can be exported and sold to the electric utility.

B. Direct Drive: In this application a gas engine is used to drive equipment such as pumps and blowers can be an alternate choice of how to effectively burn digester gas.

1. Alternate fuels such as natural gas or HD-5 propane should also be considered as for electric operation.

C. Heat Recovery: Heat recovery from the engine jacket water and exhaust system should always be considered to maximize the utilization of the fuel burned. For sewage treatment plants, digester and building space heating can be supplied from recovered heat of an engine system. Remember that digesters work most effectively at 85 - 100° F and at this temperature the heat transfer from an engine system can be accomplished at a very low cost. Many installations can use a water heat exchanger.

See attached typical heat recovery drawing.

Summary

A. Digester gas is a valuable energy source and a desirable fuel for engine operation.

B. Selecting the proper sized system for maximum efficiency depends on site conditions, electric load, heat load, digester gas capacity and use of possible alternate fuels.

C. A greater emphasis should be made to use this fuel source.

Two Pump Heat Recovery System