Understanding Design Standards and Codes for Biogas Systems

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Biogas is typically produced during the biological breakdown of organic solids through anaerobic digestion. The gas generated through this process is an energy source that can be captured and utilized, or can be safely burned. It's a highly moist mixture of gases, consisting of approximately 55 to 70 percent methane, 25 to 35 percent carbon dioxide, and trace amounts of nitrogen and hydrogen sulfide.

In the last five years, there has been a rising trend in upgrading municipal wastewater treatment facilities that utilize anaerobic digesters. The main reasons for the upgrade are to fix the inherent issues dealing with a highly corrosive gas and increase a plant's capacity to handle higher solids loading.

The funds for the upgrade usually come from local state revolving funds or through privatization. Priority is usually given when a plant upgrade is necessary in order to comply with state and/or federal environmental regulations. Since biogas is a renewable energy source and has multiple uses, there has been an increase in funding because of the payback potential that biogas reuse offers.

Biogas is highly flammable, and to be useful, it needs to be safely captured. Anaerobic digestion is one of the most safe and effective methods of treating biosolids from municipal and industrial wastewater. That being said, it's important to stay informed on the latest and best practices and design concepts for biogas capture, transmission, and utilization.

The most common design standard used is the Water Environment Federation (WEF) Manual of Practice (MOP) No. 8, *Design of Water Resource Recovery Facilities*. In 2017, WEF published the sixth edition. Chapter 25 on sludge stabilization contains relevant and important information on biogas systems.

The 2017 MOP No. 8 edition references ANSI/CSA B149.6-15 Code for digester gas, landfill gas, and biogas generation and utilization from the American National Standards Institute (ANSI). The ANSI/CSA B149.6 was written by the Technical Committee on Digester Gas, Landfill Gas, and Biogas Generation and Utilization, which became an ANSI-approved standard on March 27, 2015, and published in August 2015 by CSA Group, which collaborated on the publication[1]. The ANSI B149.6 code is more focused and practical in its approach of designing biogas systems.

Figure 1. 95-ft-diameter steel floating covers at the Salt Lake City Water Reclamation Facility.

Depending on the plant site, there are also localized standards that are available. Some local standards have unique requirements that are not covered in MOP No. 8 that must be taken into consideration when designing at a specific locale.

An example of a local or regional standard is the 10 States Standards. The ten member states and provinces that collaborated on the standards are Illinois, New York, Indiana, Ohio, Iowa, Michigan, Pennsylvania, Minnesota, Wisconsin, Missouri, and the Ontario Province in Canada. Chapter 84 covers the safety requirements for biogas systems.

A different regional standard is TR-16, Guides for the Design of Wastewater Treatment Works. The member states of TR-16 are Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont.

Another handy and focused design standard is the National Fire Protection Association (NFPA) 820, Fire Protection Standard for Wastewater Treatment Facilities. This is especially helpful when determining area classification.

Biogas Production

Biogas production is related to the volatile solids reduction (VSR) during anaerobic digestion. The VSR is typically expressed as a volume of gas produced per unit of mass of volatile solids (VS) destroyed. The VSR rate varies for different organic substances. In a typical anaerobic digester, approximately 13 to 18 ft^3 of gas is produced per lb of VSR. For fats, oils, and grease (FOG), the gas produced jumps to 20 to 25 ft^3/lb of VS destroyed. Besides the feed stock composition, biogas production is a function of temperature, pH, solids retention time (SRT) and hydraulic retention time (HRT), mixing efficiency, and organic loading rate and frequency.

Temperature

The VSR increases as temperature increases (Salsali and Parker, 2007) and the temperature range is dependent on the type of bacteria and staged operation. The most common is a mesophilic digestion where the digester is maintained at a range of 95 to 102°F. A higher temperature range of thermophilic digestion runs at 122 to 135°F.

Solids Retention Time and Hydraulic Retention Time

The SRT is calculated by the mass of solids going into the digester(s) and the mass rate of the solids leaving the digester(s). The HRT is calculated by the volume of solids in the digester(s) and the volume rate of the solids leaving the digester(s). Optimized retention time (RT) is dependent on the type of bacteria and the temperature. For typical mesophilic digestion, a 15-day retention time achieves Class B biosolids.

Mixing Efficiency

During digestion, the sludge is mixed, and there are different methods or types of mixing sludge. One example of mixing technology is a linear motion mixer, which uses a single ring-shaped disc inside the tank that is driven by a motor in an up-and-down motion, causing oscillating pressure waves in the sludge.

Sludge viscosity and revolutions per minute (rpm) for direct mixing affect gas buildup within the sludge. Without adequate mixing, gas within the digester will naturally alleviate; however, this generally results in an enormous release in gas over a short period of time. With adequate mixing, solids will be evenly mixed, allowing the biogas to escape at a consistent rate.

Organics Loading Rate and Frequency

The VS loading rate is the mass of VS added to the digester(s) each day divided by the working volume of the digester(s); the solids can range between 6 to 8 percent. A typical sustained peak VS loading rate equals .12 - .16 lb VS/ft^3/day, while a typical maximum VS loading rate equals .2 lb VS/ft^3/day.

With effective mixing, biogas is conveyed from the digester. A typical schematic of the biogas piping is shown in Figure 3, which is derived from Chapter 25 of MOP No. 8.

After total gas production is calculated with safety factors (peak or future) taken into account, the pipe is sized so that the gas velocity does not exceed 12 ft per second (fps), given the flow rate. The lower velocity helps minimize pressure drop and condensate carryover. Once the pipe size has been established, the related piping equipment should be the same size as the piping.

Due to the corrosive nature of biogas, the material of construction used for piping is stainless steel; the material for equipment is usually low copper aluminum and stainless steel. The gas piping should be laid out to slope to a low point, at a minimum of ¼ to ½ in. per ft of pipe. The slope allows any moisture in the gas to be collected and drained. Water in the pipe, especially in cold-weather application, can freeze and block the pipes; over time, the water will corrode, calcify, and eventually block the piping.

The most common culprit in biogas is moisture. Moisture in the pipe is removed through the use of sediment traps on the digester gas take-off line and drip traps at low points in the piping; a drip trap, instead of an isolation valve, allows moisture to collect inside a vessel. The vessel is drained or emptied, but keeps the gas line isolated so that no gas escapes during the draining process.

More-enhanced moisture removal includes the use of coalescing filters to remove particulates and a combination of heat exchangers, glycol chillers, and compressors to effectively heat, cool, and reheat the gas to create a dew-point barrier and decreased relative humidity.

Another component of biogas that is highly corrosive is hydrogen sulfide (H_2S). Most gas utilization equipment, such as an engine generator, requires less than 100 parts per mil (ppm) of H_2S. The H_2S is usually removed in the gas using a media; it's required for siloxane removal and the media used is easily degraded with the presence of H_2S (e.g., activated carbon). Biogas contains one or more species of siloxane, and when it's combusted, the silicate has an abrasive sandy texture that shortens the life span of gas turbines, boilers, or cogens.

The most common media used for H_2S removal is a form of iron oxide, where it reacts with water to form ferric sulfide. The reaction produces heat, so it's important to keep the media bed moist to avoid spontaneous combustion when reacting with air during regeneration or disposal.

Iron oxide media can be regenerated, and after the first regeneration, the bed life is 75 percent of the initial bed life calculated, given the H_2S concentration in the gas. Media effectiveness diminishes over time because it's determined by the volume available for sulfur conversion. A plant should do frequent sampling of outlet concentration to ensure that the levels of H_2S are within the required tolerance

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Figure 2. Linear motion mixer for sludge mixing on a 95-ft-diameter steel floating digester cover at the Salt Lake City Water Reclamation Facility.

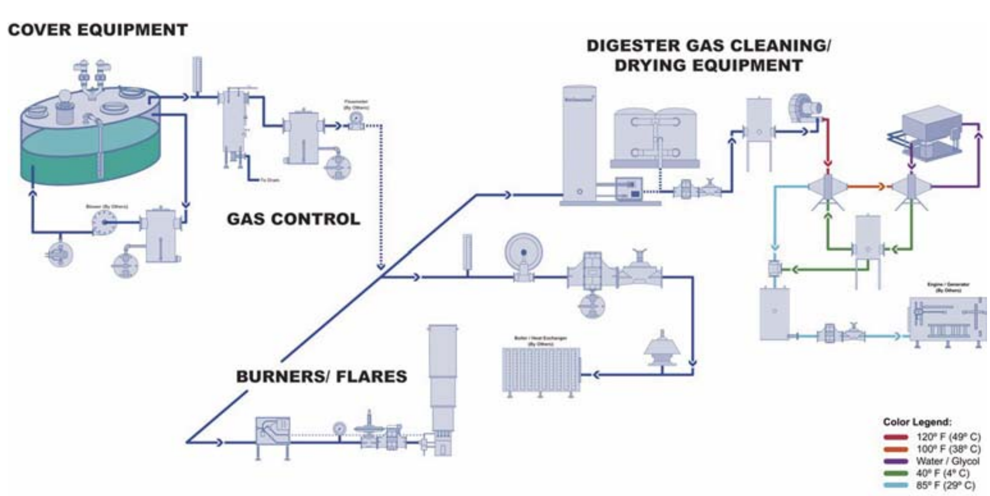

Figure 3. Diagram of gas control system[2].

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of the boiler, gas turbine, or engine. The drawback in using iron oxide is replacement and disposal after the media is spent.

Another method of removing H_2S in the gas is via a biological process, which is not unlike an anaerobic digester. The sulfur oxidation bacteria thrive and multiply on a packed media inside a closed acid-proof tank.

The bacteria require sulfur from the H_2S, carbon from the carbon dioxide (CO_2), oxygen (O_2) from atmospheric air, water and nutrients (nitrogen, phosphorus, and potassium) from the treated effluent, and a temperature between 86 to 130°F. Atmospheric air is injected into the tank and the amount of air required depends on the H_2S level in the raw biogas. The volume of methane (CH_4) will remain unchanged and the air injection will dilute the relative CH_4 content in the clean gas proportionally.

A frequency-regulated air blower is used for adjustable air injection. The main part of the O_2 is used for oxidation of the H_2S to sulfate (SO_4), and the O_2 in the clean gas will be well below the flammable limits of the gas.

The SO_4 is discharged with the effluent from the tank and typically measures to 8 percent. The chemical composition of the effluent will depend on the water or treated digester effluent added to the process.

Proper Selection of Safety Equipment

Anaerobic digesters should be equipped with a pressure/vacuum relief valve and flame arrester. The valve relieves the digester of an overpressure or vacuum condition and the flame arrester ensures that the flame doesn't flash back into the digester when vented gases are ignited. The MOP No. 8 recommends redundancy of equipment, which will allow maintenance on one unit, while the other is keeping the digester protected.

Flame arresters or flame trap assemblies must be installed within 15 ft of a potential flame source. A flame arrester with a thermal shutoff valve allows gas shutoff so the flame can be quenched in the arrester.

Combusting biogas at waste gas burners is the safest method of getting rid of waste biogas when it's not recovered for use, when there are no storage capabilities, and in an emergency. The type of waste gas burner specified will depend on local air regulations (contact the local U.S. Environmental Protection Agency for any specific emissions criteria).

Design Recommendations for Biogas Systems

Since its publication in 2015, ANSI/CSA B149.6-15 provides the most practical and safest design recommendations for biogas systems, and is referenced in WEF MOP No. 8. It takes into account biogas constituents when recommending the type of material of construction; for example, pipe and fittings utilized for biogas piping and tubing systems shall be fabricated from stainless steel, plastic, or copper for specific applications. Cast iron pipe and fittings (including flanges) shall not be used.

Components and accessories made of cast iron or cast aluminum (e.g., valves, traps, or flashback [flame] arresters) may be used in the system, but caution should be taken when using cast iron with highly corrosive gases that have significant sulfur, ammonium, or nitrate concentrations that add to the corrosiveness of the gas. All gaskets shall be made of at least ⅛-in.-thick neoprene, full-faced, with a hardness of not less than 40 measured on a Shore durometer A scale, or of other material capable of positively resisting the action of the biogas.

All gas piping systems (including bleed vent piping), whether outdoors, inside buildings, or buried, shall be installed having a minimum 2 percent slope. The noteworthy items that impact specification of safety equipment in biogas systems are related to the digester protection.

Digester and gas storage tanks, including membrane-type gas holders, should be equipped with redundant safety pressure relief valves. In addition, a secondary pressure relief system for the digester (without flame arrester) is also required to protect the digester gas-holding space. Installing isolation valves on any safety relief devices are a listed prohibited practice.

There must be a minimum of two or more digester access holes for covers that are 50 ft or less, or three of more access holes for digesters covers that are 50 ft or greater. At least one of the access holes should be a minimum of 42 in. in diameter.

The code also covers the most commonly asked questions when choosing a location for the waste gas burner. Its distance from other structures should be a minimum of 50 ft from the digester perimeter. For open-type flares, the tip should be a minimum of 1 to 5 ft above maintenance ground level. Any open-type stack tip should be a minimum of 25 ft from any other stack tip or exhaust vent.

Open-type flares should be installed at a minimum of 25 ft from the property line or road; an enclosed flare can be installed at 10 ft, as long as a safety barrier is installed around it.

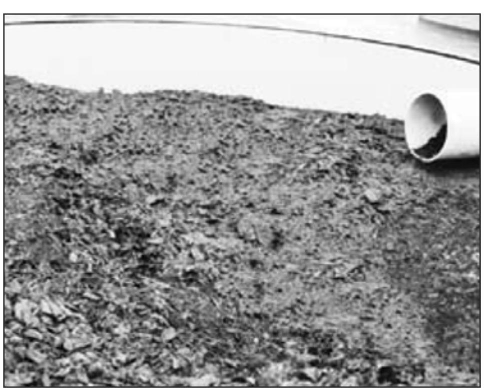

Figure 4. Iron sponge (wood chips impregnated with rust).

Figure 5. Fiberglass-insulated vessel with Iron sponge media at the Sioux City (Iowa) Wastewater Treatment Plant.

Figure 6. BiogasClean biological H_2S removal system at the Truckee Meadows Wastewater Treatment Plant in Reno, Nev.

The typical arrangement of a waste gas burner is:

- Flame trap assembly within 15 ft with no vent valve on main gas header or pilot line (e.g., explosion relief valve)
- Manual shutoff valve upstream of pressure regulator preferably inside a building to protect from cold
- Manometer or pressure measurement without power source
- Pilot lines equipped with flame check or flame arrestor

10-States Standards: Recommended Standards for Wastewater Facilities

The regional standard follows MOP No. 8, but has specific requirements not covered in the manual, and the 2014 edition does not take into account ANSI/CSA B149.6. The 10 States Standards do have some unique requirements that aren't required in MOP No. 8; for example, float-operated drip traps are not allowed for automatic emptying of the trap or vessel using a float. The drain line is controlled by a needle valve that opens when the float is tripped. There is no means to isolate the "fill" line or its connection to the gas line when the trap or vessel drain is opened. This could result in gas leaking into a confined space when the needle valve doesn't seal or close properly.

Regardless of flow rate, the minimum pipe size is 4 in. in diameter and the pipe should be sized to the 12-fps gas velocity rule.

The standard mentions that flares are installed at a minimum of 50 ft from any plant structures, which is a little more difficult to attain, especially in plants with no space to expand.

TR-16 Guide for the Design of Wastewater Treatment Works: Chapter 11 Residuals Treatment and Management

This is the design standard published by New England Interstate Water Pollution Control Commission; the seven member states are Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. This standard was modeled after the 2011 MOP edition and requires an update to factor in ANSI/CSA B149.6. Some of the requirements that should be clarified are the flare locations, which can be installed in a building as long as the building is a minimum of 50 ft from the digester perimeter. It also does not allow float-operated drip traps and follows the 12-fps gas velocity guideline.

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Figure 7. Redundant pressure/vacuum relief valve (vent to atmosphere) with flame arrester and safety selector valve.

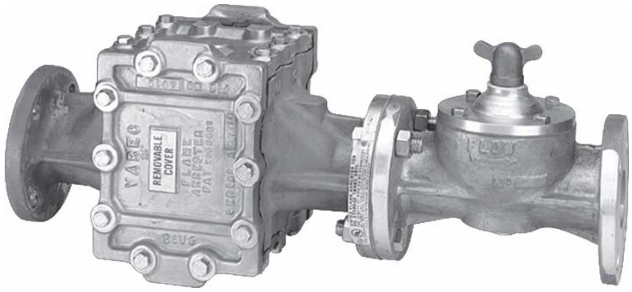

Figure 8. Flame trap assembly with a thermal shutoff valve and flame arrester combination.

Figure 9. Pressure-reducing valve (PRV)/flame arrester with insulating jacket.

Figure 10. Digester cover with 48-in. manhole cover, redundant PRV/flame arrester with three-way safety selector valve, and secondary pressure relief via the emergency pressure relief manhole cover.

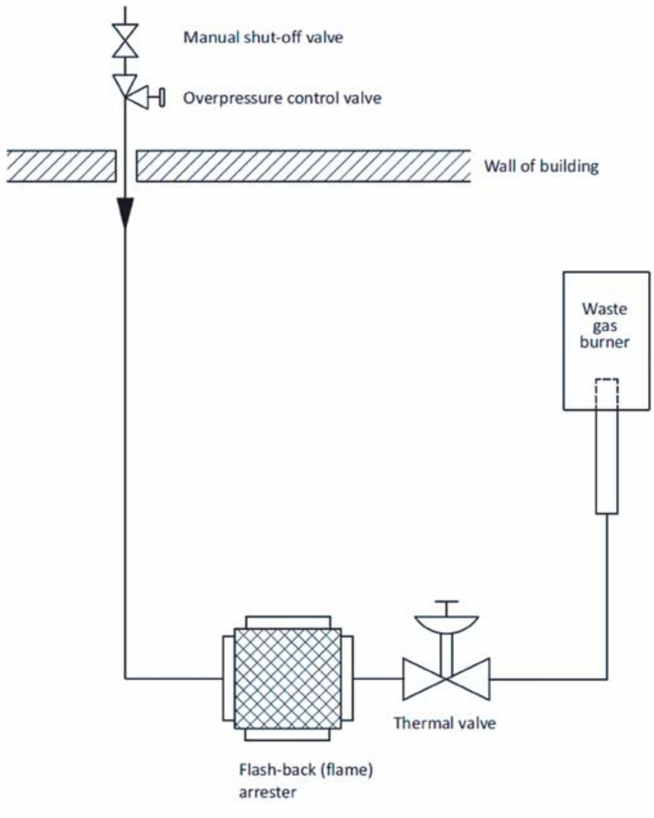

Figure 11. Possible arrangement for waste gas flare stack burners burning digester gas[3].

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NFPA 820: Standard for Fire Protection in Wastewater Treatment and Collection Facilities

For area classification in a wastewater treatment facility, the best guideline to use is NFPA 820, 2016 edition, which provides tables for specific areas. Biogas falls under Table 6.2.2.(a); for example, a 10-ft horizontal distance from a waste gas flare is class 1, division 1, and a 15-ft horizontal distance from the waste gas flare is class 1, divisions 1 and 2. This makes it easy to determine where to locate the flare control panel, and all components installed inside the 15-ft distance should be supplied as explosion-proof.

Conclusions

Converting biogas to energy currently dominates the industry's focus, which makes it important to know how to safely handle biogas production, collection, and transmission. Today there are an influx of plant upgrades that are driven by a plant expansion to allow for increased capacity and loading. There are also projects that use technology that helps to enhance biogas production, where in the past, biogas was a nuisance, smelled bad, and was disposed of by burning it as a flare.

A clear understanding of design principles will allow wastewater treatment facilities and engineers to excel in creating safer, more-efficient designs, thereby shifting biogas from the sidelines to the forefront of technological progress.

Footnotes

[1] ANSI/CSA B149.6 Code for digester gas, landfill gas, and biogas generation and utilization. Technical Committee on Digester Gas, Landfill Gas and Biogas Generation and Utilization; August 2015.

[2] Fig. 23.33, ANSI/CSA B149.6 Code for digester gas, landfill gas, and biogas generation and utilization. Technical Committee on Digester Gas, Landfill Gas and Biogas Generation and Utilization; August 2015.

[3] Annex B, Fig. B.3, ANSI/CSA B149.6 code for digester gas, landfill gas, and biogas generation and utilization. Technical Committee on Digester Gas, Landfill Gas and Biogas Generation and Utilization; August 2015.

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- Recommended Standards for Wastewater Facilities: Policies for the Design, Review, and Approval of Plans and Specifications for Wastewater Collection and Treatment Facilities. Wastewater Committee of the Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, 2014 edition.
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