CH FOUR BIOGAS

Your Organic Energy Potential Realized.

Hazardous Zones
Our Biogas Systems

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For general information on CH Four products and services or to obtain technical support, please contact our customer care department within the US and Canada at 866-730-6500, outside of North America at 613-224-8308, or visit our website at CHFourBiogas.com

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About CH Four Biogas

CH Four Biogas was founded in 2006 by Chief System Designer Benjamin Strehler and based on more than 20 years of anaerobic digester know-how from Switzerland.

By successfully adapting the technology from Europe to fit the Western markets, the company has more than a dozen systems in operation in North and South America. The systems range in size from 100 kW to over 1 MW, and use mixed-substrate designs to turn waste into energy. All of the digesters have consistently outperformed their owners' expectations.

With a solid base in technology and design, as well as customer service as a top-priority, CH Four Biogas continues to grow its staff and resources. CH Four's numerous engineers and associates as well as an established network of partner companies, are able offer its customers any one or all elements of project development, ensuring effective and efficient implementation at all stages.

Services CH Four and its partners provide include:

- Feasibility studies
- Permitting
- Digester Rescue
- Feedstock Modeling
- Design
- Construction
- Operational Support
- System Optimization
- Regulatory Review
- Feedstock Sourcing

CH Four Biogas is headquartered in Ottawa, with satellite offices located in Vancouver, BC, and Rensselaer, NY.

Please find more detailed information at our website: CHFourBiogas.com

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Introduction

Well-designed anaerobic digester facilities – also called “biogas systems” – offer a safe environment for humans – provided certain design parameters are met and signage is obeyed. Since biogas systems are specifically designed to produce gas, all safety precautions that generally pertain to gas-containing facilities apply. Signage is mounted throughout to prohibit open flames, and explosion-proof equipment is installed within certain areas and monitoring devices and instrumentation is installed to ensure system safety.

Hazardous Areas Are Defined by Zones and Divisions

The areas where opportunity for explosion exists are referred to as “zones” or “divisions” according to parameters set forth by applicable engineering and fire safety codes: National Electrical Codes (NEC), Canadian Electrical Code (CEC), and National Fire Protection Association (NFPA).

Whether referred to as “zones” or “divisions”, a lower assigned number presents a greater risk of explosion, whereas for example “Zone 0” pertains to spaces inside vented tanks where the potential of exposure to gas is much greater than in “Zone 2”, which presents minimal if any risk of exposure to gas.

According to NEC - Article 505 zones are classified as follows:

- Zone 0 = greater than 1000 hrs/year and is confined to spaces inside vented tanks.
- Zone 1 = less than 100 hrs/year
- Zone 2 = less than 10 hrs/year
- Division 1 = areas that are hazardous under normal operations in Zones 1 and 2.
- Group D = gases with the lowest volatility[i]

The Codes permit the use of electrical equipment suitable for non-hazardous locations in zones that would normally be classified as Class 1, Division 1 hazardous locations, provided that:

- Detection equipment is CSA approved for the intended use and gas type(s), and installation is acceptable to the Electrical Safety Authority.
- For positive pressure areas, fan(s) are engaged to exchange the air 5 times per hour via continuous ventilation.
- At 20% of the lower explosion limit (LEL) the gas detection equipment energizes a ventilation strategy whereby ventilation increases to a minimum 10 air changes per hour.
- The gas detection equipment will automatically de-energize the equipment being protected when the gas concentration reaches 40% of the LEL or upon failure of the gas detection instrument.

CH Four Designs for Human Safety First

In its designs, CH Four specifies state-of-the-art equipment specifically constructed for hazardous zones and follows or exceeds all applicable Codes specified by electrical standards and fire safety authorities.

Process engineers are responsible for classifying these specific areas as hazardous locations, which are determined by the type of process equipment installed and the proximity of flammable materials, as well as the frequency and duration of material exposure to potential gas release.

Dispersion Modeling for Added Safety

To accurately designate the appropriate classification, CH Four Biogas process engineers undertook a dispersion modeling study that was based on the following summary of clearances related to "hazardous zones" according to various applicable Codes[ii]:

- The digester building shall be designed, constructed and located so as to eliminate all sources of ignition.
- The engine exhaust vent stack termination shall be no less than 3 m from the nearest source of gas. This also applies to waste burner stacks and boiler vent stacks. There is also a minimum separation distance between these and multiple stacks.

The modeling of the lower explosion limit of biogas dispersion in accordance with the Code suggests that 3 m surrounding the area around the digester, other than the area around the pressure relief valve, is considered Class 1, Division 2, Group D Hazardous Location.

Our modeling of the lower explosion limit of biogas dispersion suggests that 3 m surrounding the spherical area of the relief valve is considered to be Class 1, Division 1 Hazardous Area.

Enclosed areas within a Class 1, Division 2 zone shall be designed, constructed and tested to have ventilation with no less than 5 exchanges of air per hour, and the ventilation system shall be interlocked with a 2-stage combustible gas detection and alarm system[iii].

While additional technical details on the dispersion modeling study can be found at the end of this document, Table 1 contains a list of potential sources of flammable materials and the estimated direction and frequency of release of biogas into surrounding areas in an anaerobic digester system designed by CH Four Biogas.

Potential flammable materials in digester design	Design Release Exposure Frequency	Release Exposure Duration estimate	Class
1. Concrete Digester tank liner	Continuous	Continuous	Zone 0
2. Feed pipe (PVC) in freeboard space	Continuous	Continuous	Zone 0
3. Materials within 5 m of Relief valve near top of tank wall	Rare/intermittent	Max. 48 hours/year permitted in Ontario	Zone 1
4. EPDM[iv] membrane exterior (interior is continuously exposed/resistant to gas)	Max. 2 times per year	>9 hours/year	Zone 2
5. Cast-in-place PVC raceway (cast/submerged in concrete)	Rare	> 9 hours/year	Zone 2
6. Expanded polystyrene board under steel sheeting	Rare	> 9 hrs/yr	Zone 2
7. Polyethylene and dynema rope	Rare	> 9 hrs/year	Zone 2
8. Nylon reinforced hose in PVC raceway, enveloped in EPDM	Rare	>9 hours/year	Zone 2
9. Wood strapping under steel sheeting	Rare	> 9 hrs/year	Zone 2
10. Wood framed/steel clad pipe enclosures and shelters	Rare	> 9 hrs/year	Zone 2
11. PVC pipe inside pipe enclosures or encapsulated with steel-wool insulation and metallic jacket	Rare	Rare	None except where in close proximity to relief valve
12. HDPE[v] pipe transporting biogas away from digester	Rare	Rare	Zone 2

Table 1 – Hazardous Zone Classifications in a CH Four Biogas Facility

CH Four Design Standards Meet or Exceed Code Requirements

The following are some built-in measures that address the safety of human life and system:

Safeguards in and around the digester vessels

- Pressure within the digester is continuously monitored by the control system.
- The digester vessel wall features two pressure relief valves mounted near the top which expel gas in the event of excess pressure and/or vacuum.
- Gas combustion equipment (flare) is in operation outside of the classified zone(s) and operates independently of the control system. All areas that are regularly used to observe digester contents and other equipment are outfitted with combustible gas detection instruments.

Safeguards around electrical equipment installed in hazardous zones

- All areas surrounding electrical wiring and controls are monitored by gas detection equipment.
- All electrical wiring including controls are piped within a threaded rigid conduit system.
- Where gas detection instruments are designed to automatically de-energize the equipment being protected when the gas concentration reaches 40% of the lower hazardous limit, the Canadian Electrical Code specifies equipment as per Code Part 1, per Class 1, Division 2 Hazardous locations, which may include the following:
    - electric motorized digester mixer) that is mounted through the wall
    - light fixture(s) in the observation shelter
    - process instrumentation sensors
    - combustible gas detection instruments

Pumps

Where site drainage controls require, submersible sump pump(s) may be installed in the bottom of the monitoring well within 15 meters of the digester tank[vi]. These pumps are not considered to be subject to hazardous gas exposure due to the nature of their submersion in water combined with the fact that biogas potentially expelled from the digester will be lighter than air, and is quickly dispersed. The location of the well bottom is outside of the 3-meter perimeter of Zone 1 and thus outside of the Classified Hazardous area.

Despite this exception, CH Four Biogas stipulates methane gas detection equipment is inside the monitoring well near the entry hatch. The gas detection equipment will automatically de-energize the equipment being protected when the gas concentration reaches 40% of the lower explosive limit (LEL) or upon failure of the gas detection instrument. It will also activate a central visible strobe alarm and local audible alarm, accompanied by a flashing light on the detector panel. The alarm circuit is wired to the PLC in all cases, where the alarm is communicated to the project operator. This is true of all LEL detection equipment design and operation.

Technical Details of Dispersion Modeling Study

Pressure Relief Valve (PRV) Data

Digester biogas production rate		**1365**	**kW/hr**
	Or	4657380	BTU/hr
safety factor		1.1	
biogas methane content		60	% (min)
methane energy content		1000	BTU/cu ft
methane production		4657.38	/hr
biogas production		7762.3	/hr
biogas production X 1.1		8538.53	/hr
biogas production		2.371814	/sec
PRV diameter		6	Inches
PRV area		113.04	sq inches
PRV area		0.785	sq ft
Maximum gas velocity		3.021	ft/sec
Maximum gas velocity		0.921	m/sec

The following details were factored into our model:

Point Source

3 meters off the ground
Receptor is at 3 meters as well (i.e.: calculations are done horizontally)
diameter of 6 inch (0.15 m)
area of diameter = 0.018 m^2
biogas velocity = 0.921 m/s
density of methane at 20 degrees C, 1 atm is 0.668 kg methane/m^3
gas temperature = 313 K
methane emission rate = $\frac{4657.38\, ft}{hr} \times \frac{hr}{3600\, sec} \times \frac{0.028 m^3}{ft^3} \times \frac{0.668\, kg}{m^3} \times \frac{1000 g}{kg} = 24.2\ g\ methane/sec$

Environmental Factors

- Ambient temperature = 293 K
- Typical rural setting
- All meteorological settings
- Simple Terrain
- No downwash for buildings

Formula for Calculating Explosion Zones

The following are calculations for the lower and upper level concentrations. Methane is explosive between 5 and 15% of methane in air at STP

LL = $\frac{0.05 m^3 CH4}{m^3} \times \frac{0.668\ kg}{m^3} \times \frac{1000000000 \mu g}{kg} = 0.334 \times 10^8 \mu g\ methane/m^3$

UL = $\frac{0.15 m^3 CH4}{m^3} \times \frac{0.668\ kg}{m^3} \times \frac{1000000000 \mu g}{kg} = 0.1 \times 10^9 \mu g\ methane/m^3$

Based on these formulas, the hazardous zone at LEL is at 1.5 meters and UEL is at 3 meters.

Digester Membrane

Methane permeability through 60 mil EDPM= 1.27 x 10^{-4} m^3 methane/m^2/d

Diameter of digester = 19.2m

Area of digester = 289m^2

Methane Emission Rate

$$= \frac{1.27 \times 10^{-4} m^3 CH_4}{m^2 day} \times 289 m^2 membrane \times \frac{1\ day}{86400\ sec} \times \frac{0.668\ kg}{m^3} \times \frac{1000 g}{kg} = 2.74 \times 10^{-4}\ g\ methane/sec$$

Result:
Based on these parameters and calculations, there is no risk of explosion within this area.

i Gases are grouped by volatility, with the highest volatility in Group A descending to gases with the lowest volatility in Group D
ii 2012 CSA SPE 149, the 2006 Canadian Electrical Code Part 1 Section 18, and 2010 CSA B149.1-10
iii There are additional Building Code and electrical requirements that apply around this point but are too detailed and varied to summarize.
iv ethylene propylene diene monomer (M-class) rubber, a type of synthetic rubber
v High-density polyethylene (HDPE) or polyethylene high-density (PEHD) is a polyethylene thermoplastic made from petroleum, known for its large strength to density ratio
vi (Nutrient Management Act 2002, pub. 01/2006)