Safety

RNG Upgrading and Anaerobic Digestion

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Webinar Series #2

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With over a decade of experience in Renewable Natural Gas (RNG), we are ready to help you achieve success

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Operations Consulting

- Process design review and optimization
- Digester optimization and gas production estimates
- Plant optimization recommendations
- Financial review of plant costs with recommendations
- Technology review and recommendation
- Metering layout and review in relation to CARB/EPA verification

Acquisition and Greenfield Due Diligence

- Technology review
- Maintenance schedule with OPEX and downtime estimates
- Production estimates, including gas curves, downtime, and parasitic loss
- Financial modeling of Project
- Metering setup review and CI score optimization
- Employee skill set interviews

Farmer Representative for Awarding of Gas Rights

Disclaimer

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Agenda

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Safety Motivation

Hydrogen Sulfide and Methane Safety

Safety in Plant Design

Personal Protective Equipment (PPE)

Building the Safety Culture

Anaerobic digestion and RNG production of a history of fatalities and major incidents that are not being widely discussed

2015: Worker killed from hydrogen sulfide (H2S) poisoning as he was trying to remove the roof of a digester. First responders and other workers also suffered poisoning while trying to rescue him. Worker not equipped with PPE and unaware of hydrogen sulfide dangers.

2017: 2 workers seriously injured (burns) when a pressurized tank containing anaerobic gas exploded as they were working on equipment

2019: A gas company worker suffered serious head injuries after being struck in head by a failed high-pressure hose from a CNG trailer. The coupling came loose from the trailer and did not have an anti-whip cable

2014: Workers started an exhaust fan to inflate a digester after it had been emptied. They heard a loud noise followed by the digester roof bursting into flames

While OSHA does not specifically track fatalities for AD/RNG, the fields supporting RNG have 7x fatalities as the US Average

Field	Fatalities per 100,000 full time workers
Truck Transportation	28.3
Waste Remediation	21.3
Farming	20.1
Oil and Gas	14.7
US Average	3.5

Source: 2018 OSHA fatality rates

Poisonous and explosive gases, high voltage electrical risk, working at heights, and a young, inexperienced industry create and environment ripe for injuries if safety is given a backseat to production

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Hydrogen sulfide poisoning is one of the largest risks in operating anaerobic digesters

Concentration (ppm)	Symptoms/Effects
0.00011-0.00033	Typical background concentrations
0.01-1.5	Odor threshold (when rotten egg smell is first noticeable to some). Odor becomes more offensive at 3-5 ppm. Above 30 ppm, odor described as sweet or sickeningly sweet.
2-5	Prolonged exposure may cause nausea, tearing of the eyes, headaches or loss of sleep. Airway problems (bronchial constriction) in some asthma patients.
20	Possible fatigue, loss of appetite, headache, irritability, poor memory, dizziness.
50-100	Slight conjunctivitis ("gas eye") and respiratory tract irritation after 1 hour. May cause digestive upset and loss of appetite.
100	Coughing, eye irritation, loss of smell after 2-15 minutes (olfactory fatigue). Altered breathing, drowsiness after 15-30 minutes. Throat irritation after 1 hour. Gradual increase in severity of symptoms over several hours. Death may occur after 48 hours.
100-150	Loss of smell (olfactory fatigue or paralysis).
200-300	Marked conjunctivitis and respiratory tract irritation after 1 hour. Pulmonary edema may occur from prolonged exposure.
500-700	Staggering, collapse in 5 minutes. Serious damage to the eyes in 30 minutes. Death after 30-60 minutes.
700-1000	Rapid unconsciousness, "knockdown" or immediate collapse within 1 to 2 breaths, breathing stops, death within minutes.
1000-2000	Nearly instant death

Source: OSHA

Novilla RNG has observed steady state hydrogen sulfide levels in the 2,000 to 6,000 PPM range, with levels spiking as high as 20,000 PPM (2%) in newly filled digesters

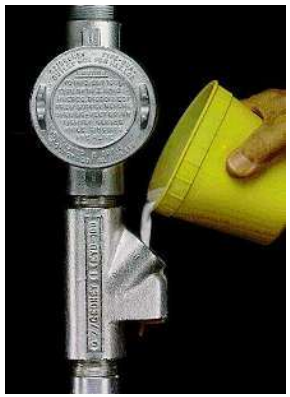
Digesters and RNG plants have multiple locations where hydrogen sulfide has been shown to leak

Pressure Relief Valves

Manure Sumps

Fittings/Line Breaks

Short flares that fail to light



Electrical Conduits

Condensate Lines and sumps

Confined space entry and vessel cleanouts require a well executed plan to mitigate hydrogen sulfide risk

Digester cleanouts require confined space permit entry teams, air sampling, and caution when removing manure as pockets of hydrogen sulfide can still be released

Vessels are considered confined spaces and the plane of the vessel should not have a body part cross it without a confined space entry permit

While oxygen injection into digesters has been used as an inexpensive way of lowering hydrogen sulfide levels, it has its own risks

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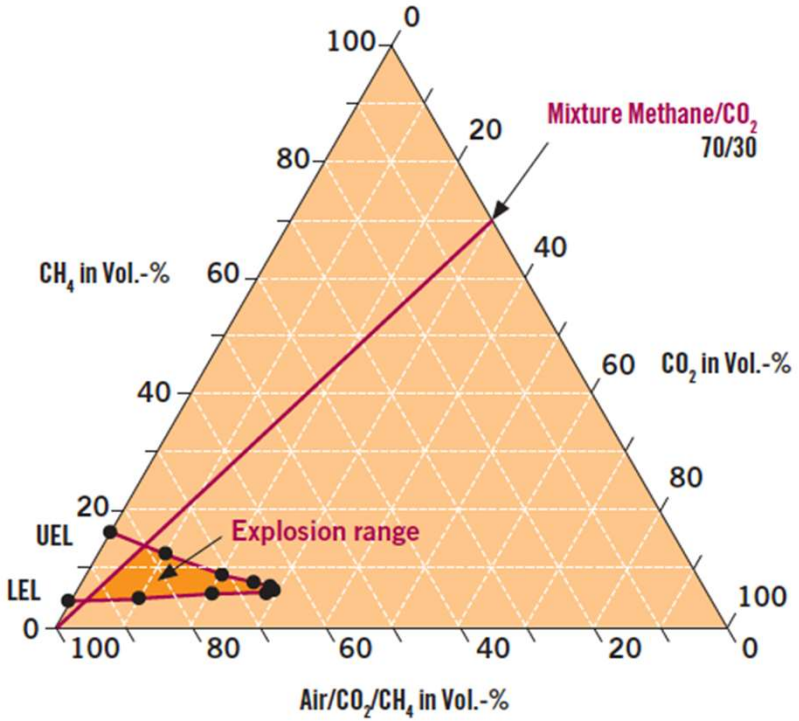
Biogas ”Fire Triangle”



Source: German Biogas Association

- Any oxygen injection needs to be well thought and controlled or there is a risk of explosion
- Only properly rated electrical equipment should be used around digesters and Class I/Div II areas. Areas should be marked and understood
- Vessel cleanouts or methane leaks can result in the right Air/Methane/CO2 risk for explosions

Proper training, PPE, and a safety culture are critical in preventing hydrogen sulfide and methane incidents

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Have multiple employees trained and medically cleared to use an SCBA and confined space entry

Ensure you have the right fit-tested masks and gear onsite with filled canisters

<u>Employees should be clean shaven</u>

Wear a calibrated and bump tested 4-gas monitor. Know what your emergency escape routes are if it goes off.

Train and drill your employees on the dangers of hydrogen sulfide and have a rehearsed rescue plan

Know how to properly sample for hydrogen sulfide

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Per the previous section, hydrogen sulfide and methane safety should be at the forefront of plant design

Flame Detector

Hydrogen Sulfide (low) or Methane Detector (high)

E-stops located at exits of building with lights indicating what shutdown the facility for first responders

Place E-stops in locations the farmer and first responders can access, test shutdown procedures, and rehearse with local fire department

Emergency stops should be located at the fence line or sufficiently far away from plant

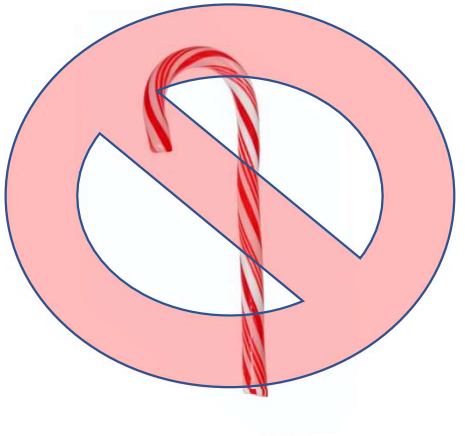
Make sure to mark locations with a sign for first responders

Should shutdown all gas flow to the plant – have fail safe closed valves to prevent gas from entering plant

During commissioning, make sure that the automated responses of the plant do what you expect.

Place pressure relief valves high enough where a downdraft does not endanger people

Previous pressure relief valves on catwalk were replaced with ones extending 14 feet up



Avoid “Candy Cane” pressure relief vents that can direct poisonous gases downward

Place equipment in locations that are easily accessible for your operators

Placing flow meters in hard-to-reach locations will encourage employees to take risks in servicing the meter. Engineers should design the piping with fall protection in mind

On flares, place ignition system and meters near ground level so operators do not have to get on a manlift and expose themselves to gases

Place platforms around media vessels for easy and safe changeouts

Virtual pipeline trailers present a unique risk of high pressures, explosive gas, and cold injury (while unloading)

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Ensure anti-whip cables are in place and operators are trained in connection/disconnection of the hoses
Make sure the anti-whip cables are short enough to prevent whip-back to operator's face. During unloading, gas temperatures can reach extreme cold

E-stops at each unloading lane, fire eyes looking for flame, grounding cable interlock for unloading, bollards, and pull through lanes. Breakaway hoses in case hose is left on trailer

Before commissioning a plant, make sure to perform a Process Hazard Analysis (PHA) as part of the Process Safety Management (PSM)

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If you are running a virtual pipeline you will likely have more than 5,000lbs of methane stored on site and be considered a PSM site. PSM sites are required to have Process Hazard Analysis done.

Regardless of whether you have to do a PHA, it is worth doing for the following reasons

- It brings multiple disciplines together to walk through plant operations and what could go wrong
- For each potential failure point, a “what if” analysis is done to expose potential ramifications. If the ramification ranks high enough, corrective action needs to be taken.
- Requires coordination and rehearsals with first responders. Typically the first responders will be rural volunteer fire fighters who aren’t used to industrial sites or hydrogen sulfide. By having walk-throughs of the site prior to commissioning, the first responders will understand how to shutdown them down and you will build good local relations

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Gas Monitors are essential PPE at an RNG site or farm

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Good

H2S Only, 2-year life, easy to use

Good for visitors to site

Better

4 Gas monitor

Good for non-solitary workers

Best

4 Gas monitor with lone worker call-out

Employees who may be isolated

Beyond the standard safety boots, eye-protection, ear-protection, and gloves, every RNG site should have the following:

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Fall Protection

Arc Flash Protection

SCBA (x2)

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Before every task, a job hazard analysis should be completed

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- Identify what tasks will be performed
- Identify the hazards
- Assess the hazards
- Find ways to mitigate the hazards
- Determine how much risk is left after mitigation
- Who is responsible for the controls and how will they be implemented?

A. Mission or Task:	B. Date/Time Group	C. Date Prepared:
Conduct a deliberate attack	Begin: 010035R May XX End: 010600R May XX	28 April XX

D. Prepared By: (Rank, Last Name, Duty Position) CPT Smith, Cdr

E. Task	F. Identify Hazard	G. Assess Hazard	H. Develop Controls	I. Determine Residual Risk	J. Implement Controls (How To)
Conduct obstacle breaching operations	Obstacles	High (H)	Develop and use obstacle reduction plan	Low (L)	Unit TSOP, OPORD, training handbook
	Inexperienced soldiers	High (H)	Additional training and supervision	Moderate (M)	Rehearsals, additional training
	Operating under limited visibility	Moderate (M)	Use NVDs, use IR markers on vehicles	Low (L)	Unit TSOP, OPORD
	Steep cliffs	High (H)	Rehearse using climbing ropes	Moderate (M)	FM 3-97.6, Mountain Operations; FM 3-97.61, Military Mountaineering
	Insufficient planning time	High (H)	Plan and prepare concurrently	Moderate (M)	OPORD, troop-leading procedures

K. Determine overall mission/task risk level/after controls are implemented (circle one)

LOW (L) (MODERATE (M)) HIGH (H) EXTREMELY HIGH (E)

The US Military has seen an 70%+ reduction in training injuries by using the risk assessment matrix (Job Hazard Analysis in the civilian world). Every frontline leader must fill it out prior to a mission or training exercise and brief their soldiers

Building a safety culture doesn't start at the top, it starts at the bottom

Employee Safety Initiatives (Good Catches)

- Weekly improvement in either plant conditions or employee actions. Meant to continuously improve their plant

Example: Taking the manway cover off media tanks has the potential to "pop" off and hit technician.

Improvement: Add longer bolts to manway cover so that media can pour out without a danger to the technician

Employees should be encouraged and rewarded for reporting injuries and near misses

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Near Miss
(An accident that could have resulted in an injury, but didn't)

An example from landfill gas:

A technician was backing up a UTV on the side slope of a landfill when he hit a rock and rolled the UTV. The technician was not hurt but he reported the incident.

The employees at the site built a "tip table" to determine the roll over angle of the UTV. They experimented with different tires and axle extensions to find the safest configuration.

They then installed an audible inclinometer on the UTV to warn that the tip-angle was being approached.

Employee honesty, and lack of reprisal from management, led to employees finding a way to make their jobs safer after an accident was reported.

Suggested safety training for AD/RNG technicians

General	Lock Out/Tag Out
	Job Hazard Analysis
	Energy Control Plan
Mobile Machinery	Forklift
	Scissor Lift
	Manlift/Bucket Lift
	Overhead Crane
	Standard Driver's License
	CNG Trailer operations
Electrical	Use of Multimeter
	Qualified Electrical Worker
	P&ID and One Line Drawings
	NFPA 70e Arc Flash
	Arc Flash
Gas Safety	SCBA
	Respirator Fit
	H2S Sampling
	Gas Rescue
	DOT Pipeline Operator Training
Medical	First Aid/CPR/AED

Resources

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Portable Pipelines for First Responders

ANSI/CSA-B149.6-15 – Code for Digester Gas, Landfill Gas, and Biogas Generation and Utilization

Risks and Safety Measures For Anaerobic Digestion: How Can You Make Your Plant Safer

Common Safety Practices for On-Farm Anaerobic Digester Sytems

Health and Safety Planning in Anaerobic Digestion

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Questions?