Renewable Natural Gas: considerations for the safe design and operation for an innovative process for achieving a sustainable future.

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September 1, 2021

The U.S. produces almost 70 million tons of waste each year[1], which, over time, generates biogas with the help of bacteria. Biogas is a mixture of methane, carbon dioxide, and other trace gases and is generally released into the atmosphere. However, waste collection plants are now looking at ways to collect the biogas and refine it into pure methane, also known as Renewable Natural Gas (RNG). RNG can be used for injections into existing natural gas pipelines or used as fuel for RNG-dependent transportation vehicles. In recent years, the number of RNG plants has grown significantly within the U.S.

Despite the many benefits and solutions that RNG provides, hazards are still present, and because RNG is a relatively new technology, these hazards aren't as commonly known. Most RNG plants are small and not covered under OSHA PSM 1910.119, which is required if a facility contains 10,000 lbs. or more of flammable gas or liquid. However, when dealing with flammable and toxic materials, it is important to recognize the potential hazards and/or risks associated with the process regardless of formal requirements.

Examples of previous incidents and studies conducted by BakerRisk illustrate the significant hazards that are present in RNG plants:

1. An explosion in the Anaerobic Digester (AD).
2. An overpressure or vacuum within the Animal Waste AD, causing the release of toxic and flammable material into the atmosphere.
3. An explosion in an enclosed Compressor Building.

This article discusses each of the events described above and highlights the potential hazards and provides examples of potential safeguards and/or mitigations that could be employed to reduce injury or fatality.

The RNG Process

The process to produce RNG starts at waste, whether it be animal, landfill, or water waste. The feedstock undergoes anaerobic digestion, where organic material is decomposed into biogas[2]. Depending on the feed, the digestion can take place in different storage containers called the Anaerobic Digester (AD): usually, landfill waste underground, water waste in covered lagoons, and animal waste in non-pressurized tanks. After several weeks the generated biogas can be collected. Water, hydrogen sulfide, carbon

[1] Tanikawa, S., "Fact Sheet | Biogas: Converting Waste to Energy," Environmental and Energy Study Institute, October 13, 2017, https://www.eesi.org/papers/view/fact-sheet-biogasconverting-waste-to-energy.

[2] "An Overview of Renewable Natural Gas from Biogas," EPA, July 2020.

dioxide, and other trace chemicals are removed from the biogas through various separation steps. Finally, the product stream is high quality methane and is compressed and sent to end users.

(1) Anaerobic Digester Explosion

The AD's sole purpose is to produce and collect the flammable biogas and operating an AD for waste comes with several potential hazards: flammable, explosive, and toxic. Combined with the confinement, oxygen from air, and ignition source, the AD can be a potential source for a confined vapor cloud explosion. Air and ignition sources are typically not present in the AD, but with poor maintenance or operation, it can occur—similar to the 2018 in-ground AD tank explosion[3] at the Calumet Water Reclamation Plant in Chicago, Illinois, which caused 10 injuries. Investigation concluded that the manhole sealing the in-ground tanks was leaking flammable gas while contractors were conducting hot work nearby. Measures to eliminate an influx of air and nearby ignition sources if taken could have prevented the explosion in the AD.

Safeguards and Mitigations:

- Prevent the creation of a flammable/explosive environment in the AD:
    - Routine inspection and repair to eliminate potential sources for an influx of air into the AD. This not only eliminates the possibility of a flammable/explosive environment but is also operationally beneficial for the AD
    - Automatic shut-off of downstream blowers to prevent reverse flow of air into the AD, if applicable
    - Create and follow proper purging protocols of the AD with nitrogen rather than air to remove pockets of biogas and eliminate an oxygen source prior to hot work
- Reduce ignition potential by determining hazardous area classification (HAC) surrounding the AD and using appropriately classified equipment.

(2) Anaerobic Digester Rupture

Another concern is any loss of containment of the biogas. The released gases pose flammable and toxic hazards to nearby onsite personnel. If ignited, the flammable gas can lead to a flash or jet fire while the concentration of H_2S gas can be lethal to personnel close to the AD if there is no ignition.

Specifically for animal waste, anaerobic digesters are constructed with floating roofs to account for the growing volume of vapors. However, if not properly monitored, the pressure inside the vessel can increase rapidly to cause the roof to "pop off" or the vessel to rupture. Based on three past events in 2012 and 2013 reported by the UK's Environment Agency[4], pressure-relief valves (PRV) failed to mitigate over-pressures in the AD, causing the rupture of the process vessel and the release of flammable and toxic material into the atmosphere. Overfeeding the AD and poor temperature control can cause increased foaming and liquid level in the vessel. If high enough, this level can block the PRVs and prevent them from

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[3] Wiss, Janney, Elstner Associates, Inc., "CALUMET WATER RECLAMATION PLANT—Investigation of Explosion and Structural Collapse in Gravity Belt Thickener Room," Prepared for Metropolitan Water Reclamation District of Greater Chicago, November 16, 2018.

[4] "A Review of Environmental Incidents at Anaerobic Digestion (AD) Plants and Associated Sites between 2010 and 2018," Environmental Agency 2018, September 2019.

operating on demand. Alternatively, the pressure inside the vessel can drop below design pressure. Under feeding the AD will cause the vessel to vacuum, buckle, and release biogas into the atmosphere.

Safeguards and Mitigations:

- Properly inspect PRVs
- Closely monitor pressure, level, and temperature operations of the AD
- Use Process Hazard Analysis studies to determine the appropriate level of safety interlocks needed to prevent over-pressure and vacuum conditions in the AD
- Perform a Safety Instrumented System and Safety Integrity Level (SIS/SIL) evaluation to ensure safety interlocks meet the desired level of reliability

(3) RNG Compressor Building Explosion

At the end of processing, the RNG is compressed for transport to end users. However, releases from compressors can be a high risk resulting in several fatalities. Compressors are typically housed in buildings to protect against the weather; however, if a leak were to occur, the high-pressure gas can quickly accumulate inside the confined structure, which can result in a confined vapor cloud explosion. Unlike the AD explosion, air and ignition sources are typically present in the building. A small failure of the compressor equipment can quickly provide the flammable concentration required for the explosion.

Safeguards and Mitigations:

- Consider using weatherized compressor so they can be outdoors or under a roof structure but not walls.
- If you choose to have compressors indoors, these additional mitigation options should be reviewed and implemented to meet risk tolerance:
    - Provide general building ventilation to mitigate small releases of RNG
    - Provide adequate gas detector coverage to accompany the automatic shut-off of feed gas and shut-down of compressors
    - Provide automatic shut-off of RNG feed to compressors as well as automatic shut-down of compressors on gas detection to limit inventory available to release into the building
    - Determine hazardous area classification in the building
    - Design deflagration venting panels on the building to mitigate severity of explosion
- Relocate occupied spaces like control rooms, maintenance offices, or other occupancies to separate buildings away from the compressor structure to reduce population vulnerability.

How can BakerRisk help?

Baker Engineering and Risk Consultants, Inc. (BakerRisk®) is an internationally recognized firm specializing in predicting, preventing, and mitigating hazards from explosions, fires, and toxic hazards. Studies helpful in the understanding of hazards and risk from the operation of RNG plants are listed below:

- Facility Siting Study (FSS) and Quantitative Risk Assessment (QRA): Used to model and assess hazards associated with operation of the facility and evaluate the associated risk of those hazards to personnel onsite. A FSS/QRA can assess the risk associated with site operations such as the AD explosion, over pressure rupture, biogas release, and compressor confined vapor cloud explosion poses to personnel.

    - Our hazard and risk analyses are structured in a way to provide review and quantification of potential risk reduction measures, as needed.
- HAC Study: Used to define hazardous areas for electrical classification inside of the compressor building and near the AD tanks.
- PRV Dispersion Study: Useful to accompany a HAC study because intentional releases from a PRV can become ignition sources to the internal explosion of ADs, based on historical incidents.
- Ventilation Design Study: Performed to determine the minimum required air exchange rate to ensure adequate ventilation to mitigate confined vapor cloud explosion hazards posed by small releases.
- F&G Study: Evaluates whether a particular hazardous release can be detected considering the device location in relation to the hazardous release scenario. Adequate detection is pertinent in the automation of safeguards to mitigate hazards as well as to prevent spurious trips.
- SIS/SIL: Used to verify the safeguards in place and sufficient testing intervals to achieve SIL target.
- NFPA 68 Vent Panel Design: Provide expert knowledge in NFPA standards and designs.