Benefits of Digester Gas Scrubbing at the Dayton WWTP

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Overview

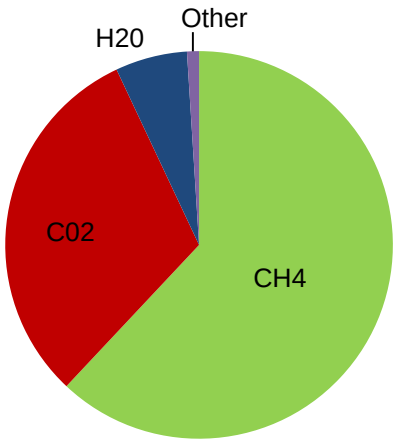
- Characterization of Digester Gas
- Undesirable Constituents
- Gas Scrubbing Technologies
- Gas Scrubber Case Study at Dayton WWTP
  - Process Selection
  - Implementation into Existing System
  - Start-up Issues

Digester Gas

- Gas produced during reduction of organic matter under anaerobic conditions.
- Composed primarily of methane and carbon dioxide.
- Fuel (heat) value of digester gas is typically 550 to 650 BTU/CF.
- Contains lesser quantities of other gases such as hydrogen sulfide, nitrogen, water vapor, and volatile organic compounds (specifically siloxanes).

Composition of Digester Gas

- Methane, CH_4: 60 – 65%
- Carbon dioxide, CO_2: 35 – 40%
- Water Vapor, H_2O: 1 – 6%
- Nitrogen, N_2: <1%
- Hydrogen sulfide, H_2S: 100 to 3,000 ppm
- Siloxanes: 100 to 10,000 ppb

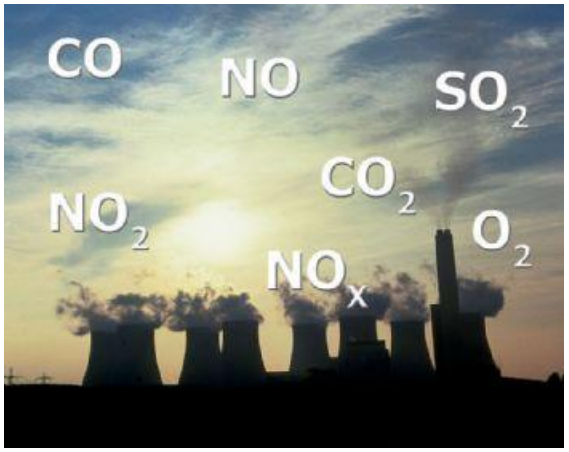


Heat value of methane is approximately 1,000 BTU/CF

Undesirable Digester Gas Components

- Hydrogen Sulfide
- Siloxanes
- Particulates
- Water Vapor
- Carbon Dioxide
- Nitrogen

Hydrogen sulfide, H_2S



- H_2S gas when combined with water vapor produces a weak acid: *hydrosulfuric acid*
- Corrosive to metals
  - Combustion chamber
  - Intake and exhaust piping
- Produces sulfur dioxide during combustion
- Target concentration in feed gas : <100 ppm

Siloxanes

- The word *siloxane* is derived from the words *silicon, oxygen*, and *alkane*.
- They belong to the wider class of organo-silicon volatile organic compounds (VOCs).
- Siloxanes can be found in products such as cosmetics, deodorants, de-foamers, toothpaste, water repelling windshield coatings, lubricants, food additives, and soaps.
- Most common siloxane types found in digester gas are the D3, D4, and D5 compounds.
- Recommended target concentration:
  - Reciprocating engines and boilers <100 ppb
  - Turbines / Micro-turbines < 50 ppb

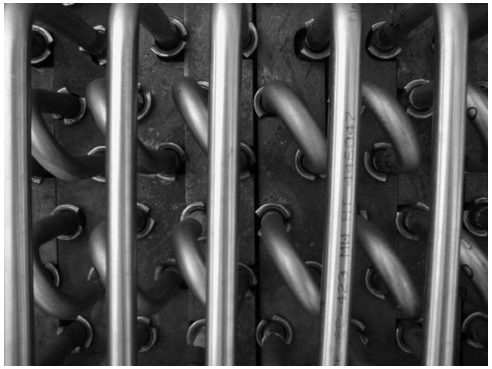
Effect of Siloxanes

- Siloxanes degrade to silicates (SiO_2 & SiO_3) at high temperature and create impermeable glass particles. These particles bond onto hot metal surfaces.
  - Reciprocating piston engines – forms deposits and hot spots in the combustion chamber, valves, valve seats, piston crowns and cylinder walls.

Siloxane damage to upper cylinder area and piston

Effect of Siloxanes

- Boilers – deposits a coating of silicate on boiler tubes that lowers heat transfer efficiency.
- Gas turbines – deposits on turbine blades leading to blade erosion and a significant drop in operating efficiency.



Clean boiler tubes

Siloxane deposits on tubes

Other Digester Gas Components

- Particulates
  - Form deposits on engine surfaces and boiler equipment
- Carbon Dioxide
  - Inert gas, lowers heat value of digester gas
- Nitrogen
  - Inert gas
- Water Vapor
  - “Wet” gas is more corrosive to machinery
  - Lowers heat value

Digester Gas Scrubbing

- Definition – Process of removing one or more undesirable components from a gas stream.
  - Typically targeted at removing hydrogen sulfide (H_2S), siloxanes, and particulates.
  - Optional removal of carbon dioxide, nitrogen, and water vapor for specific applications.

Reasons for Gas Scrubbing

- Decrease engine maintenance intervals
- Improve fuel (heat) value
- Improve engine performance – more power!
- Sell gas to utility (pipeline quality)
- Produce compressed natural gas (CNG) for City fleet use
- Provide higher quality fuel to boiler
- Happier maintenance staff!

Gas Scrubbing Technologies

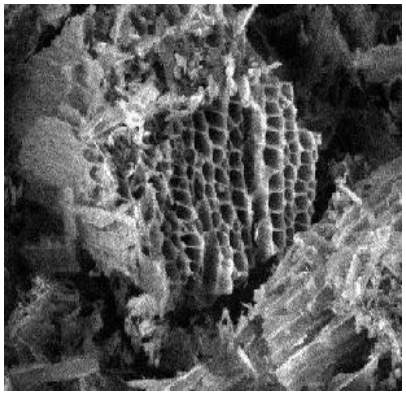
- Unit Processes
  - Adsorption (Dry Scrubbing)
  - Wet Scrubbing
  - Refrigeration (Chilling)
- Pressure Swing Adsorption (PSA)
  - Molecular Sieve Media

Adsorption (Dry Scrubbing)

- Passing gas through adsorption media such as activated carbon, activated alumina, iron sponge, or synthetic resins.
  - Component is adsorbed onto media.
  - Media is either exhausted and replaced or regenerated

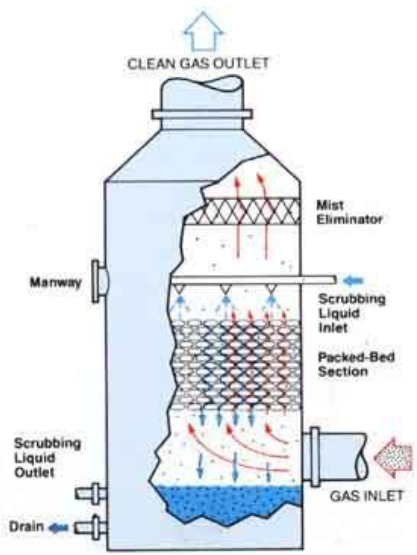
- Gas Scrubbing Usage:
  - Iron sponge (iron oxide on wood chips) for removing H_2S
  - Activated carbon, activated alumina for siloxane removal

Activated alumina



Activated carbon under electron microscope

Wet Scrubbing



- A method of passing the gas through water or another liquid medium for the purpose of removing particulates or other gases.

Gas Scrubbing Usage

- CO_2 removal – carbon dioxide is soluble in water.
- Particulate removal

Refrigeration (Chilling)

- Mechanical refrigeration that removes moisture by lowering the temperature of the gas to condense the water vapor. Other impurities also removed in condensate.

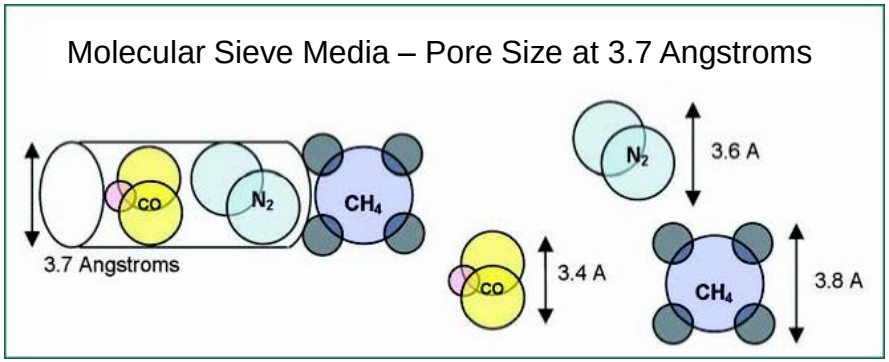
- Removes:
  - Moisture - dewpoint < 40ºF
  - 90 - 100% particulates
  - 70 - 80% siloxanes
  - 20 - 30% H_2S

Pressure Swing Adsorption (PSA)

- A mechanical pressure switching system that rapidly cycles from adsorption to regeneration.
- Uses molecular sieve media and other adsorption media to allow the passage of methane but reject carbon dioxide, H_2S, and siloxanes.

Molecular Sieve Media

- Specialized adsorption media that traps (adsorbs) smaller molecules in media while allowing larger molecules to pass through. Media can be rapidly regenerated.



- Digester Gas Scrubbing - Traps carbon dioxide, nitrogen, and other smaller molecules while allowing methane to pass through media.

Angstrom – length equal to 1 x 10^{-10} meter

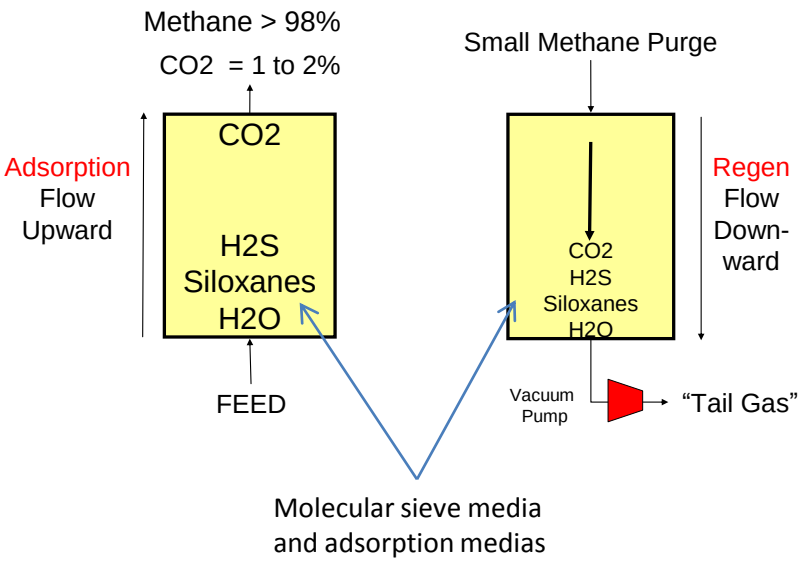
PSA Cycle Diagram

Pressure Phase – Adsorbing

- Feed gas flows upward thru media bed
- Targeted compounds are trapped or adsorbed in the media bed
- CH4 passes thru the bed
- Over time the bed will become saturated

Vacuum Phase – Purging and Regenerating

- Pressure is released thru the bottom of adsorbent bed
- Releases adsorbed compounds as Tail gas



Gas Scrubbing Approaches

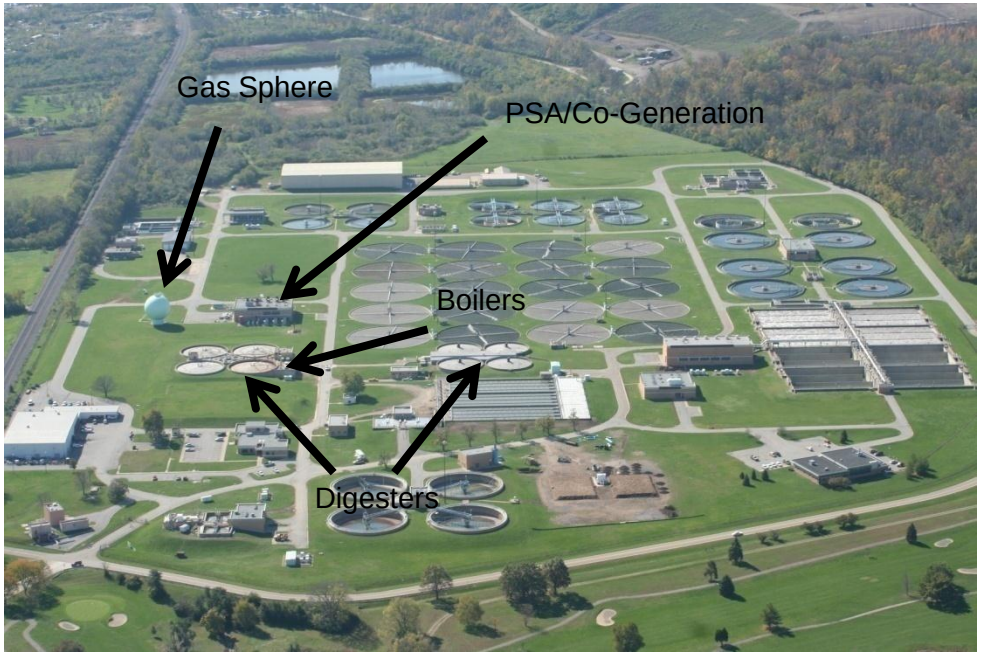
- Unit Processes in Series
  - Series of unit processes to remove each undersirable component.

    Example: Remove H2S, CO2, Particulates and Siloxanes

    Processes: Iron sponge adsorption → Wet scrubber → Chiller → Activated Carbon
- Pressure Swing Adsorption (PSA)
  - Remove multiple gas components in single process.
  - Utilizes molecular sieve media

City of Dayton WWTP – Case Study

- The City of Dayton Wastewater Treatment Plant is located at 2800 Guthrie Road, Dayton, OH 45417. Its design capacity is 72 MGD with a peak capacity of 180 MGD. The plant provides preliminary, primary, secondary, advanced secondary (nitrification), filtration, chlorination/ dechlorination and post-aeration to all wastewater. Additional background and technical information on the facilities and its operation can be found on the internet at http://water.cityofdayton.org/Water/wwtp_main.asp



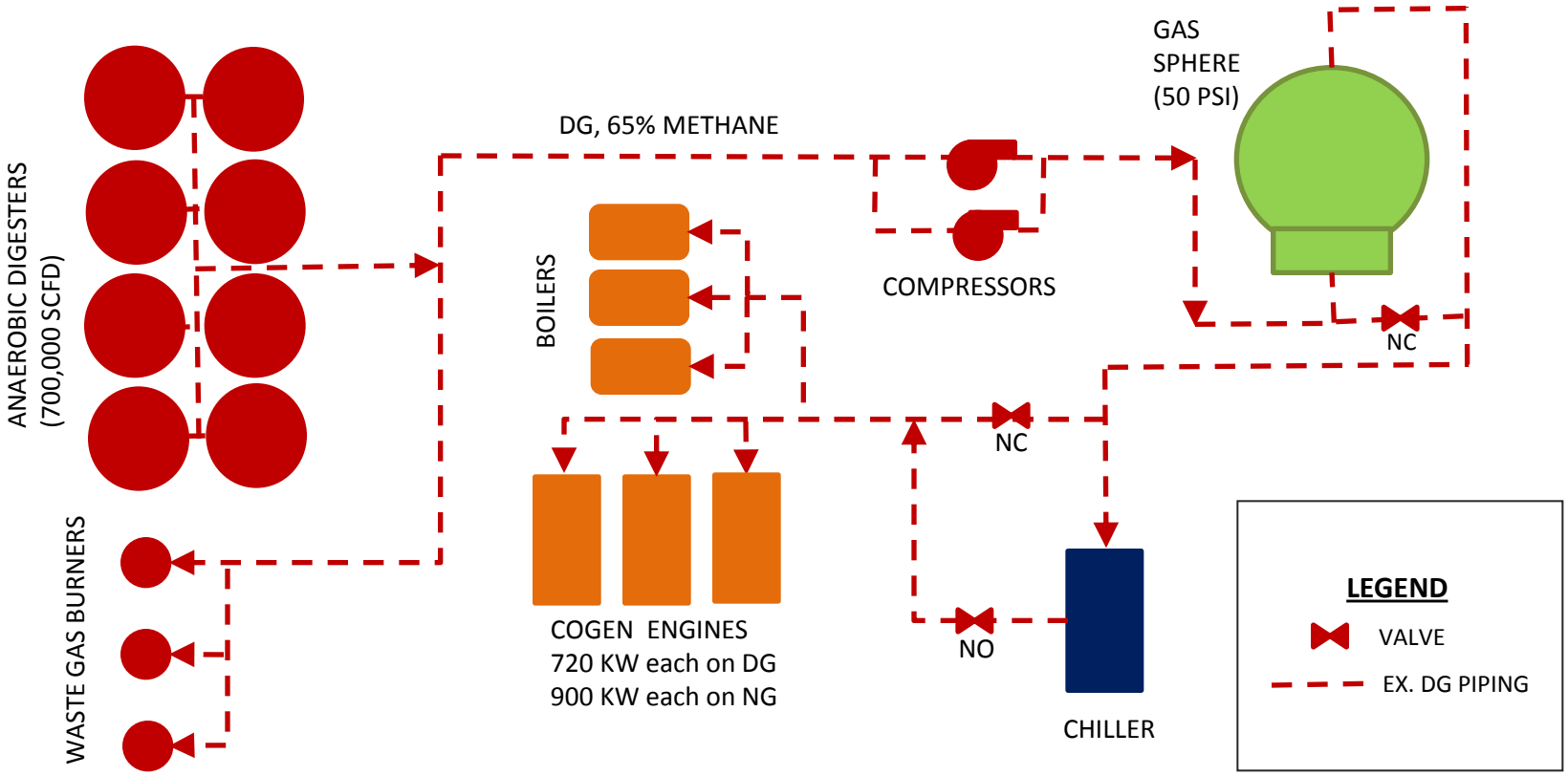
Gas Utilizing Equipment

- Co-generation Engines
  - 3 Waukesha Engines
  - Dual fuel: Digester Gas and Natural Gas.
  - Lean burn engines
  - 900 kw each on clean gas
  - 720 kw each on digester gas
- Present Strategy:
  - Peak Demand Shaving.
  - Running engines only during high flow to reduce periods of high demand.

Gas Utilizing Equipment

- Boilers
  - 3 HURST Hot water boilers
  - 350 Horse Power
  - Design: 3 Pass Wet-Back
  - Capacity: 14.7 Million BTU/Hour
  - Hot water Temperature: 180 °F

Previous Digester Gas Schematic



Process Selection

- Problems with the dirty gas since engines were installed in 1989.
- In 1994 Consultant studied to clean the Digester gas and evaluated different methods.
- Found Gas Chiller was the best and most economical method to clean the Digester gas. Added Chiller in 1995.
- Still Siloxane was not removed completely.
- Visited Guild Associates, Inc., Dublin, OH in 2009 who manufactures a PSA system for Digester gas.
- We were impressed with the new method of gas scrubbing.
- Received American Recovery and Reinvestment Act money in 2009 to finance the project.

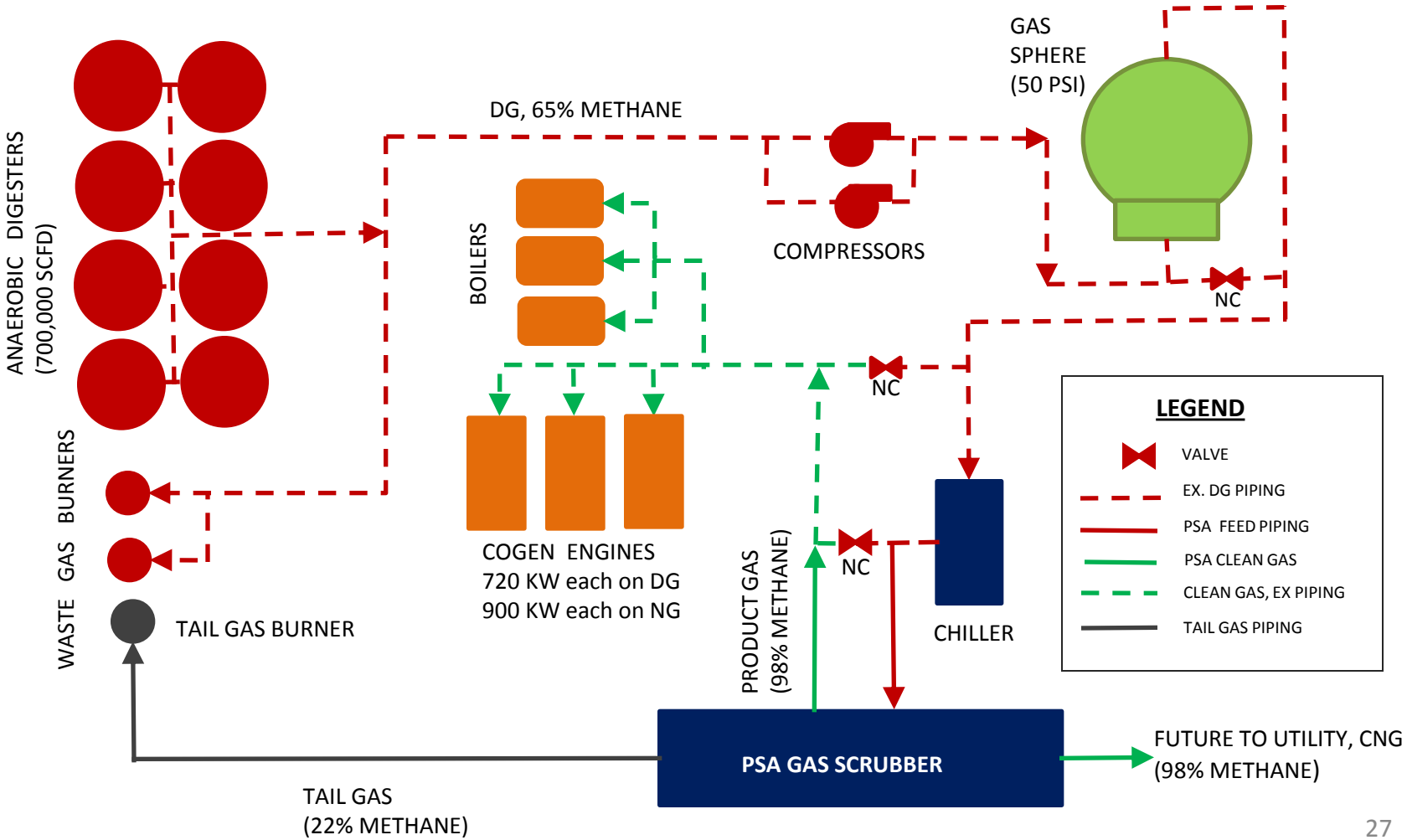
PSA Gas Scrubber Specifications

- Designed Capacity: 1,000,000 SCFD
- Clean gas
  - 524,000 SCFD
  - Methane: > 98%
  - CO_2: < 2%
- Tail Gas
  - 476,000 SCFD
  - Methane: 22%

Biogas Feed Properties	
Flow, SCFD	1,000,000
Pressure, psig	40 - 50
Temperature, F	55-110
Composition, Mol %	
CH4	61.9
CO2	37.8
H2S	0.1
Siloxanes	< 10 ppm
H2O	0.2
HHV BTU/FT3	~600

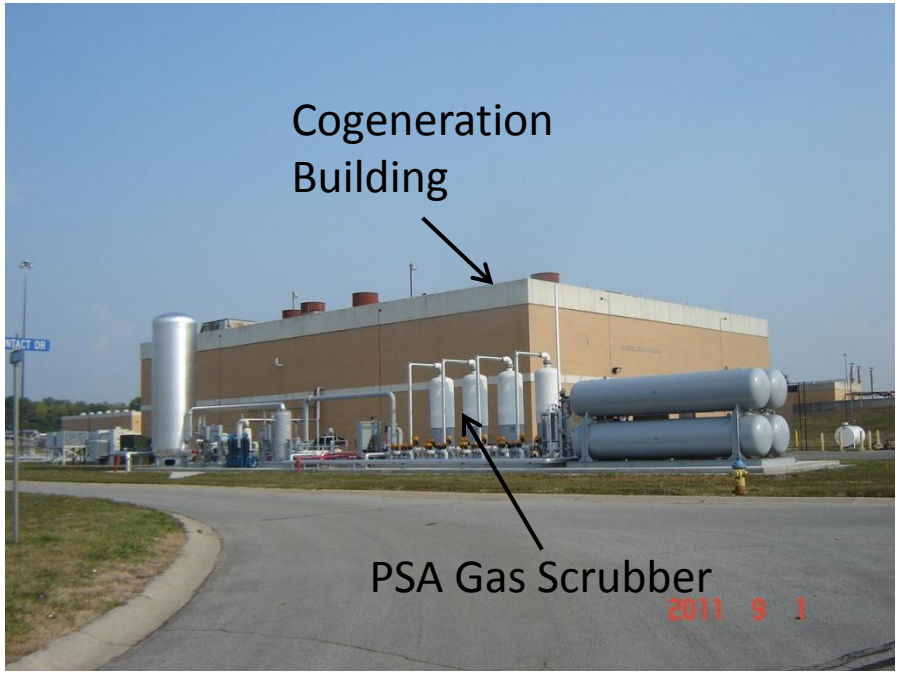
Clean Gas Properties	
Flow, SCFD	524,000
Pressure, psig	90
Temperature, F	< 120
Composition, Mol%	
CH4	98.0
CO2	2.0
H2S	<4 ppm
Siloxanes	< 20 ppb
H2O	< 5 lb/MM SCF
HHV BTU/FT3	>1000

Present Digester Gas Schematic



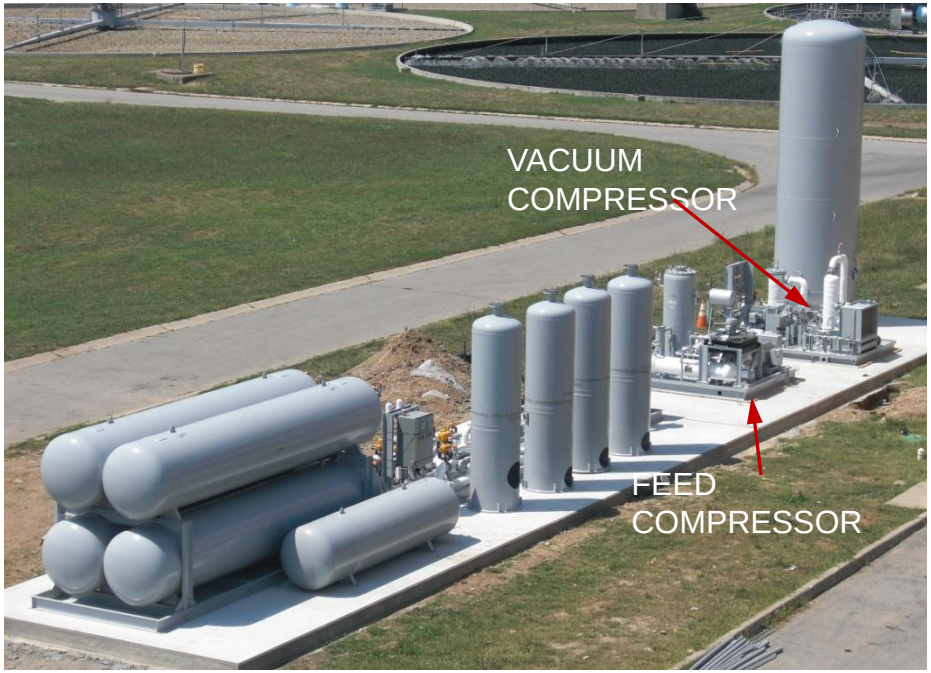
Location of PSA Gas Scrubber

Location of PSA Gas Scrubber next to Co-generation Building



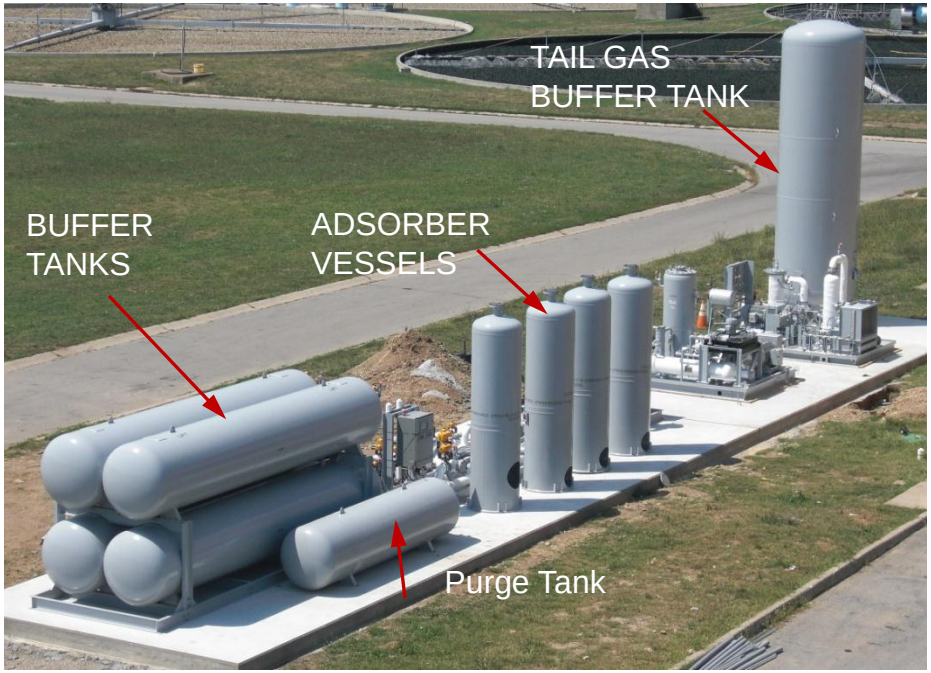
Major Components of PSA Gas Scrubber

- Feed Compressor
  - Type: Reciprocating
  - Capacity: 1 Million SCFD
  - 60 HP Motor
  - Compresses from 40-50 to 105 PSIG
- Vacuum Compressor
  - Type: Liquid Ring
  - Capacity:0.5 Million SCFD
  - 150 HP Motor
  - Reduces from -3 to -18 in of HG



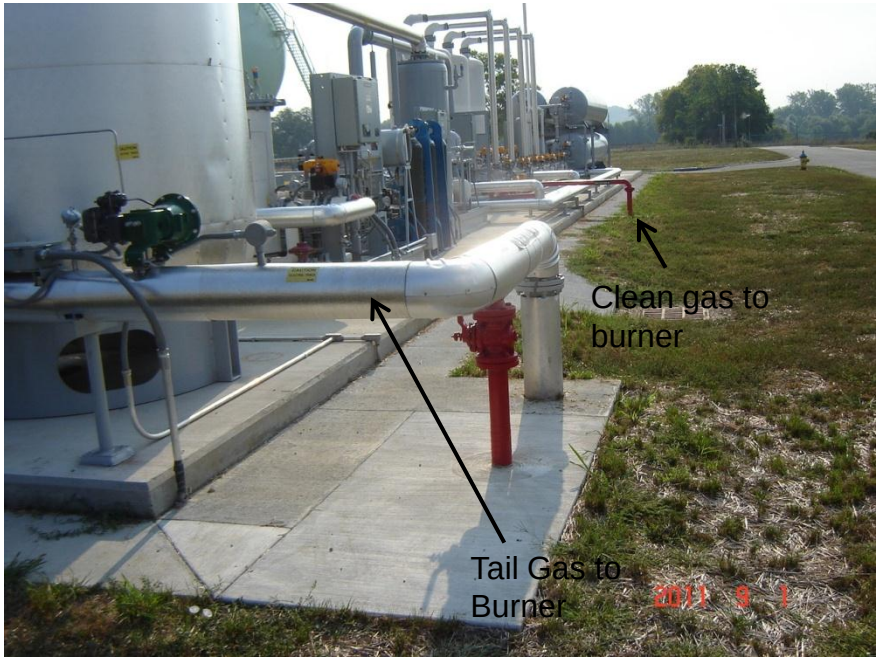
Major Components of PSA Gas Scrubber

- Adsorber Vessels
  - Four Adsorbers: On-line, De-pressurizing, Re-pressurizing, and Purging.
- Buffer Tanks
  - Two Equalization and Two Repressurization Tanks
- Tail Gas BufferTank
- Purge Tank



PSA Gas Scrubber

- This slide shows:
  - Connection to the tail gas burner from tail gas buffer tank.
  - Connection of clean gas to the tail gas burner in case we can not use the clean gas.

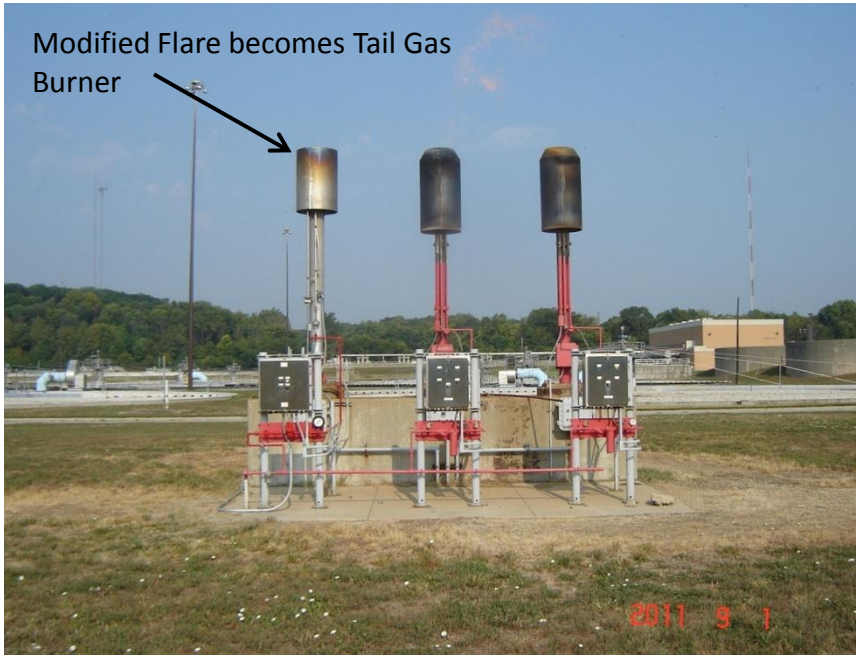


PSA Gas Scrubber

- This slide shows:
  - Digester gas insulated piping to the PSA from Co-generation building Chiller.
  - Clean gas red piping to the Boiler and Co-generation Engines.

Tail Gas Flare

- Tail Gas Burning obstacles
  - Existing flare would not work because of low methane contents in tail gas.
  - Getting a new permit from Regional Air Pollution Control Agency (RAPCA).
  - Long lead time on customized flare
  - Zeeco is the only known lean burning flare supplier



Advantages of PSA Scrubbing

- No consumables. PSA media has 5+ year life
- Single process versus multiple processes
- Less liquid discharge (compared to wet scrubbing for CO2 removal)
- Lower maintenance cost- WE HOPE
- Lower operating cost- We HOPE

Scrubber Start-up

- Generator startup issues
  - Connect to the Natural Gas Line
  - Retune the engines to accept clean gas

- Boiler startup issues
  - Adjusted the burners in two boilers to accept the Clean gas

Cost of the project

- Received American Recovery and Reinvestment Act (ARRA) money for the project.
- Pay back period will be between 5-10 years.
  - By using clean gas reduction in maintenance cost of the engines and boilers.
  - Sell the gas to Gas Company or
  - Build a CNG station

THANK YOU

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