Waste Gas Treatment Systems

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Methane Sources

Human sources of methane
- Fossil fuel production, distribution and use: 33%
- Livestock farming: 27%
- Landfills and waste: 11%
- Biomass burning: 10%
- Rice agriculture: 4%
- Biofuels: 0%

Natural sources of methane
- Wetlands: 78%
- Termites: 12%
- Oceans: 10%
Biogas Sources in the US

- Landfill gas dominates (~4,000 Nm3/h typical)
- WWTP digester gas (~1,500 Nm3/h typical)
  - Easier to process
- Agricultural Digesters (~300 Nm3/h typical)
  - Added cost of digester
  - Rarely upgraded.
Landfill Gas (LFG) Utilization in the US

- Electric generation is most common
  - Incentives for electric (fed gov’t grants, tax credits)

- Upgrading
  - Typically to pipeline quality
  - Zero US federal government incentives
  - Some states (California) offer added “renewable value”

- Almost ½ the US LFG is still not utilized
Technology Trends Direct-Use Projects

- Boiler
- Direct Thermal
- High Btu
- Leachate Evaporation
- Greenhouse
- Compressed Natural Gas
- Liquefied Natural Gas
- Medium Btu
- Hydrogen

Number of Projects

Operational Projects
Under Construction and Planned Projects
Concerns with LFG Emissions

- Landfills were the 3rd largest human-made source of methane (CH$_4$) in the U.S. in 2010
- LFG contains app. 50% CH$_4$
- CH$_4$ is a greenhouse gas (GHG), i.e. absorbs infrared radiation that would otherwise escape to space
- CH$_4$ as a GHG is over 20x more potent by weight than CO$_2$
Producing High BTU Gas: The Technologies

Three main technologies currently used:

• Pressure Swing Adsorption (PSA)
• Selexol Solvent – Oldest Technology
• Membrane – Currently Most Commonly Used
**Pressure Swing Absorption (PSA) Technology**

Uses Solid Porous Media with 3.7 Angstrom Pore Size

<table>
<thead>
<tr>
<th>Gas</th>
<th>Size (Angstroms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>3.8</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>3.6</td>
</tr>
<tr>
<td>Oxygen</td>
<td>3.5</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>3.4</td>
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</tbody>
</table>
Typical One Line of a PSA High BTU Project:

- Higher yield 92%
- Complexity reduction
- Better $O_2$ capacity
- Reliable Rotary Valves
2010 PSA Plant
(5200 scfm design)
Selexol Technology

- Selexol is a blend of dimethyl ethers of polyethylene glycol
- Selexol absorption is a physical reaction vs a chemical reaction
- Acid Gases, i.e. CO$_2$ and H$_2$S are stripped and the lean solution is returned to the absorber unit
Typical One Line of a Selexol BTU Project:
2009 Selexol Plant
(2750 scfm design)
Typical One Line of a Membrane High BTU Project:

- 1% CO₂
- Up to 990 Btu/SCF
- ~1.6 x Feed N₂
- ~0.6 x Feed O₂
- Ultra Dry, Clean <15 ppm H₂S

Diagram:
- Biogas Source
- H₂S Removal
- Pre-Treat
- 2 Stage Membrane
- Flare
- End Use
River Birch Landfill:
Landfill Gas Collection System
Landfill Gas Collection Wells
# River Birch Landfill Gas

<table>
<thead>
<tr>
<th>CONSTITUENT</th>
<th>CONCENTRATION</th>
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</thead>
<tbody>
<tr>
<td>Methane</td>
<td>53-58%</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>40-45%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1-4%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0-1%</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>120-150 ppmv</td>
</tr>
<tr>
<td>Non-Methane Organic Cpds (NMOCs)</td>
<td>1500-2500 ppmv</td>
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</table>
River Birch LGTE Plant
(June 2010)

6000 scfm design with max capacity of 8000 scfm
Single Line Diagram of River Birch Landfill Gas Plant
Landfill Gas Blowers
PD Blowers /Aftercooler
Cameron™ Biological Sulfide Treatment System
Thiopaq® Process Flow Diagram

- Sour Gas
- Sweet Gas
- Nutrients
- Caustic Water
- Air
- Absorber
- Bioreactor
- Sulfur Handling
- Purge
- Sulfur
General Process Chemistry

SCRUBBER
- CO$_2$ Absorption
- H$_2$S Absorption
- Bicarbonate Formation
- Neutralization
- Polysulfide Formation

BIOREACTOR
- Carbonate Formation
- Sulfur Formation
- Sulfur Oxidation
- Polysulfide Oxidation
- Thiosulfate Formation

SULFUR SEPARATION

Landfill Gas In, ~ 150 ppm H$_2$S

Gas Out, < 5 ppm H$_2$S

Air In

Air Out

S$^0$ Out
Anoxic Biological Conversion of Sulfide to Sulfur

Absorption
Caustic treating at gas pressure

\[ \text{H}_2\text{S} + \text{OH}^- \rightarrow \text{HS}^- + \text{H}_2\text{O} \]

Bio-regeneration
Selective oxidation – caustic regeneration

\[ \text{HS}^- + 0.5 \text{O}_2 \rightarrow \text{S}^0 + \text{OH}^- \]

Anoxic Conditions Important!!!!
Redox Potential Around -340 mV
Thiobacillus Bacteria Excreting Sulfur
Ammonia Chiller

Inlet Gas: 100°F
Outlet Gas: 45°F
PSA Units
PSA Beds

BASF SORBEAD H

BASF COS

BASF CDX

BASF F200 and ABS

30%

10%

10%

40% and 10%
Biogas Membranes

Stage 1 Membranes

Stage 2 Membranes
Membrane Hollow Fiber
How the Biogas Membrane Works

Biogas Feed
100 SCFM
100-200 PSIG
55/45% CH₄ /CO₂

Product
~50 SCFM
99 % CH₄
1 % CO₂

CO₂ Vent

CO₂, O₂, H₂O, H₂S

CH₄, N₂
Stage 1 Membranes

• “First Pass” as separating CO$_2$ and CH$_4$

• Permeate Stream $\sim$90% CO$_2$ and 10% CH$_4$
  o Regenerates PSA Beds then goes to the Thermal Oxidizer

• Residue Stream $\sim$80% CH$_4$, 20% CO$_2$
  o Feed for the Stage 2 Membranes
Stage 2 Membranes

- Polishes the Stage 1 Residue Stream

- Permeate Stream ~50% CH\textsubscript{4} 50% CO\textsubscript{2}
  - Recycled to capture the CH\textsubscript{4}

- Residue Stream ~ 95+% CH\textsubscript{4}
  - Transported to Gas Pipeline
Sales Gas Compressor

Pressure to 400 psi to Gas Pipeline
LFGTE Membrane Plant

Landfill Gas Blowers

PD Blowers /Aftercooler

Cameron™ Biological Sulfide Treatment System

PSA Units

Primary Compressors

Ammonia Chiller

Biogas Membranes

Sales Gas Compressor

Sales Gas Skid
Pipeline Quality Gas Production

• Current Production is App. 2500 MMBTU/Day (4000 SCFM of LG)
• 1 MMBTU = 1 Decatherm = 8 GGE
• In Energy Equivalents, the Plant is Producing ~20,000 gallons of gasoline/day
• The Purified Gas is Sold to Atmos Energy
LFGTE Capital and Operating Costs

- Capital Costs for 6000 scfm Plant $14M
- Monthly Operating Costs = $86,900/Mo
- Monthly Electricity Costs Average $100K/Mo
- Revenue per Day at Current NYMEX Price ($3.68) + $1.00/MMBTU REN Credit = $4.68/MMBTU
Historical Energy Costs

Energy Cost Per MMBtu

- Oil
- Natural Gas
- Coal
QUESTIONS??

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