Anaerobic Digester System Failure Analysis, Corrective Actions and BMPs

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October 30, 2012
Quantalux LLC: Developers of innovative renewable energy technologies

Current Focus: - Small-scale Biogas Technology Development
- Thermal/Energy Modeling of AD Systems
- Value-enhancement for Feedstock Selection

Anaerobic Digester Research and Education Center (ADREC)

Based at Michigan State University, ADREC has a fully-equipped teaching & research facility specifically tasked to enhance digester technology.

- Feedstock, Additive and Biogas Characterization
- Pilot Digesters and Test equipment
- Experienced Staff and Students
AD System Failure Analysis

Goal: *Use past history to improve system performance*

- **Approach:**
  - Use documented data to identify Cause and Frequency of Digester Failures
  - Seek trends and ID common problems

- **Sources include published info and personal interviews**
  - Case Study Data from Dairy Farms across the US
  - Sensor Data from AD systems in NY State

*By “Failure”, we mean: Failure to Perform to Spec, Failure to meet Cash Flow, etc.*
Methodology and Resources

• 25 Dairy Farms in the US
  - Published Case Studies
  - Phone interviews

• NYSERDA CHP Operational Data (4 farms)

• Failures divided into 5 categories

• Document solutions and corrections that took place
Agricultural Digesters in the US

- **US EPA AgSTAR**
  - 192 operating anaerobic digesters on farms in the U.S.
- **Dairy farms are leading adopters**
  - 159 systems (82% of farm projects)

Majority of Digesters are Plug-Flow and Complete Mix.

Our Sample Set for the Study

This sample set includes published case studies

<table>
<thead>
<tr>
<th>Study Statistics</th>
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</thead>
<tbody>
<tr>
<td>Sample Size</td>
</tr>
<tr>
<td>Percentage of Operating Agriculture Digesters*</td>
</tr>
<tr>
<td>Farm Size Range (Dairy Cows)</td>
</tr>
<tr>
<td>Total Capacity ~</td>
</tr>
<tr>
<td>Total Dairy Cow Count</td>
</tr>
<tr>
<td>Cogeneration</td>
</tr>
<tr>
<td>Thermal Energy Only</td>
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</tbody>
</table>

*U.S. EPA AgSTAR
In order to keep the focus is on the resulting data (and not on the specific farm operator), we are not identifying farms by name. Instead, we use Farm 1, 2, 3, etc.
Failure Categories (5x)

- **Site Planning & Design** – includes site plan development and integration into existing facilities
- **Engineering** – includes all engineering related activities (civil, structural, electrical and mechanical)
- **Construction & Equipment** – includes construction quality and equipment selection for the digester
- **Biogas Utilization** – includes equipment selection and system integration of the biogas utilization system
- **System Control & Operation** - monitoring and control (including personnel issues)
Failure Breakdown in our Sample Set

Appx. 60% of failures arise in design and construction phase.

Appx. 40% of failures occur after the system is completed.
## Failure examples

### Site Planning & Design
- Includes site plan development and integration into existing facilities.

### Issue

<table>
<thead>
<tr>
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<th>Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Excess heat loss to soil and groundwater below the pad of the digester vessel.</td>
<td>➢ Provide plenty of insulation to avoid heat loss. Require calculations for expected heat transfer.</td>
</tr>
<tr>
<td>▪ High solids content of the manure required additional dilution water to allow the material to be transferred from the barn to the digester.</td>
<td>➢ Analyze manure characteristics to assess flowability (solids content &amp; viscosity) of the manure. Operator must follow engineering recommendations for transferring manure with a wide range of solids characteristics.</td>
</tr>
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### Failure examples

**Engineering** – includes all engineering related activities (civil, structural, electrical and mechanical)

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<td>Gas leakage from the concrete hard top of the digester resulted in raw biogas emissions causing odor problems plus loss of energy.</td>
<td>Post-construction validation and verification (V&amp;V) needed – initial pressure tests plus leak monitoring during system ramp-up.</td>
</tr>
<tr>
<td>Difficulty in heating the manure entering the digester caused poor biogas production. Frozen manure clogged pipes.</td>
<td>Mild preheating (biogas-fired) using a pipe-grid melted frozen chunks of incoming manure and maintained material flow.</td>
</tr>
</tbody>
</table>
Failure examples

**Construction & Equipment** – includes construction quality and equipment selection for the digester

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<tr>
<td>▪ CHP units failed after 3000 hr</td>
<td>➢ Input to CHP requires enhanced scrubbing (H2S removal) and a water separator. Periodic testing of H2S levels into CHP essential.</td>
</tr>
<tr>
<td>▪ Mechanical issues with Genset exceeding benefit from electrical production. Repairs included valves, muffler and biogas lines.</td>
<td>➢ Inadequate biogas scrubbing was corrected and regular maintenance procedures for Genset were instituted.</td>
</tr>
</tbody>
</table>
## Failure examples

**Biogas Utilization** – incl. equipment selection & system integration of the biogas system

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<tr>
<td>▪ <strong>Boiler Corrosion</strong> due to excess H2S levels</td>
<td>➢ Provide for continuous H2S monitoring AND train personnel on scrubber/filter operation and maintenance.</td>
</tr>
<tr>
<td>▪ Biogas pipe connecting the flare was undersized (3”) and inadequate when the flare was the only outlet for the gas.</td>
<td>➢ Biogas piping must be sized for anticipated flow <strong>PLUS</strong> an appropriate safety factor.</td>
</tr>
</tbody>
</table>
## Failure examples

### System Control & Operation - monitoring and control (including personnel issues)

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<td>Variable biogas pressure and methane concentration led to poor performance by microturbines.</td>
<td>➢ Designers must adhere to technical specifications for all equipment.</td>
</tr>
<tr>
<td>Periodic operation of mixers resulted in crust formation (and decrease in biogas)</td>
<td>➢ <strong>Optimize</strong> the duty cycle for mixers for a given feedstock to assure best mixing while using minimum energy.</td>
</tr>
<tr>
<td>Difficulty maintaining digester temperature</td>
<td>➢ Prewarm frozen manure, and also assure that all temperature sensors are calibrated and functioning properly.</td>
</tr>
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</table>
Data from Operational Anaerobic Digesters: 
*Trends and Observations*

- Data from 4 farms in NY State:
  - Sensor Data: Generator Down-Time, Gas Flows, Facility Energy, Useful Heat Recovery (CHP) and Ambient Temperatures
  - On-site performance reports (quarterly updates)

- From the data, we calculated:
  - Average Generator Output (kWh)
  - % Biogas in Flare
  - Contract Capacity
  - Revenue Lost due to Down-Time (assuming $0.10/kWh)
1) Dry manure causing piping problems = low biogas production
2) Unknown event
3) Unknown event
4) Genset down for cleaning. Repairs to digester heating and system recirculation pumps

Documentation of generator downtime is necessary to determine cause of failure!

Lost revenue from Generator Hours Down accumulates over term of the project

Farm 1: Plug Flow – 1800 Cow – 500 kW
Farm 2: Complete Mix – 360 Cows – 250 + 225 kW

After four years of consistent operation, significant problems with the original Genset!

1) Second generator added
2) The oil cooler on the existing genset went bad and contaminated the antifreeze with oil.
3) Overheating issues associated with the inability to reject enough heat in summer months.
4) Existing engine rebuild, expected down time was 30 day, actual = 3 months
5) Existing engine required new radiator
6) Change in feedstock results in lower biogas production
Farm 3: Plug Flow – 1100 Cow – 416/500 kW

1) Initial issues getting the generator up and running.
2) Generator re-tuned to run at 500kW
3) Oil Change and header replacement (5 days of downtime)

Meeting design expectations is important for considering contract capacity.
Farm 4: Plug Flow - 2700 Cows – 500 kW

Operational problems within the first 3 years led to significant loss of revenue for the AD owner.

1) Manure shortage
2) Headers changed
3) UNK Event
GenSet Downtime – All A.D.s in NY State

Note that the data on GenSet downtime is very well correlated with key maintenance events.
Key Take-Aways

Different Problems: Short Term vs Long Term
• Over initial 2-5 years
  ✓ Engineering/Design issues arise, and must be addressed.
  ✓ Avoid problems with good contract/contractor.
• Over 20+ yr design lifetime – Different issues
  ✓ Genset maintenance/repair
    • Typically takes longer than expected
    • Result = Additional lost revenue (-$)
  ✓ Feedstock management critical (no foam, no additives)
Final Thoughts

• Data and case studies can be valuable to identify typical problems
  ✓ Sensor data is highly detailed
    • BUT incomplete without accompanying report.
    • All failure events must be documented to ID “cause”

Recommend:
• The industry develop a shared database of information on digester performance.
  ✓ Broad view of digester systems across the US

More data on performance => better reliability and improved finances.
Best management practices (BMPs)

KEY Long term strategy

Assure Continuous Gen-Set Operation

• Train Personnel
  ✓ Define and Follow to Maintenance Schedules
  ✓ Monitor feedstocks and biogas production
  ✓ Follow pre-defined Standard Operating Procedures

• Pre-stage spare parts for rapid replacement
  ✓ Once identified, repairs must be accomplished and biogas production returned to normal

• Pre-plan major overhauls
  ✓ Predictable events
  ✓ Large potential for lost revenue
Acknowledgements

We gratefully acknowledge support from the US Department of Agriculture, National Institute for Agriculture (NIFA) for this analysis under SBIR Contract # 2011-33610-30777 (Phase II SBIR to Quantalux, LLC “A Biogas Heat Engine for Small to Mid-sized Farms”)

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