CONSERVATION INNOVATION GRANTS
Final Report

Grantee Name: Utah State University and Scott Sunderland	
Project Title: Cost Effective & Reliable Anaerobic Digestion for Animal Feeding Operations	
Project Director (co-director): Carl Hansen	
Contact Information:	**Phone Number:** 435 797 2999 **E-Mail:** cshansen@cc.usu.edu
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Summary: An IBR system (4 digestion tanks) was installed at the Sunderland Dairy, and digestion was started the end of March 2006. It was maintained in operation for 5 months, during which time operation of the IBR was periodically monitored and controlled from a remote location at Utah State University. Biogas production never reached maximal production or efficiency because the dairy was not able to supply sufficient waste material according to the original design. Still, the biogas produced was more than sufficient to fuel two boilers (285,000 BTU each) demonstrating the system's potential for heating, or to run engines that generate electricity. Biogas was never used to generate electricity because changes in policies of the utility company (from when the proposal was submitted) precluded connecting to the grid. Operation of the IBR was terminated by Sunderland Dairy to allow for improvements in safety and technology, and to obtain approval to generate electricity into the grid. Termination of IBR operation precluded the taking of measurements needed for estimation of digester efficiency and economic analysis. We have identified several areas of opportunity for system and technology improvement.

Deliverables (as described in the project proposal):

1. Demonstrate the IBR system on the Scott Sunderland 1200 cow dairy located at Chester, Utah in Sanpete County.

Construction of the IBR digester system (4 tanks) was completed in February 2006, and digestion was started the end of March 2006. The IBR system produced biogas for 5 months, and the biogas was used to two fuel two boilers (285,000 BTE each) demonstrating the systems potential for heating, or to run engines and generate electricity. Biogas production did not approach maximal rate or efficiency because the IBR digester system was designed for 1,200 cows, and the Sunderland dairy had remained at about 650 cows. Operation of the IBR system was terminated by Sunderland Dairy to allow for improvements in safety and technology, and to obtain approval to generate electricity into the grid.

2. Digest at least 50% of the volatile solids in 8 days or less as measured by biogas production or actual lab tests of solids destruction.

After five months of digester operation at below maximal capacity, replicate samples were taken of manure before and after digestion in this system. The average volatile solids destruction was 53.3% in 12 days when the digesters were supplied with waste from 650 cows. Digestion efficiency (especially a decrease in days of digestion) is expected to improve when the digesters are operated at maximal capacity, but this will require additional waste streams from another source such as other dairy farms or food processing operations, or perhaps poultry waste from the Sunderland's own poultry operation.

3. Demonstrate how high rate digestion produces biogas with at least a 10% higher methane content than biogas produced from conventional digesters.

Methane content of the biogas was not determined because we intended to perform the needed analyses after the system had stabilized, which typically requires a startup of 6 months or more. Analyses of biogas produced at the Sunderland dairy can be implemented once the system is connected to the grid and has operated for at least six months. A similar digester installed at the Wade Dairy in Utah is currently producing biogas containing 78% methane compared to the 55-65% methane content of biogas produced by most other anaerobic digesters with longer retention times that are commonly used on farms.

4. Demonstrate remote monitoring techniques for assessing performance.

Remote monitoring from Utah State University was achieved. We remotely monitored the IBR digester parameters including temperature, feed rate, pH, and gas production, and were able to remotely change controllable parameters including feed rate and temperature.

5. Identify areas of opportunity for system and technology improvement.

Improvements are suggested based on observation and analysis of data acquired during the 5 months operation of the IBR. Suggested improvements include:

- Incorporate a larger hole in the septum with a method to vary the open area.
- Add another redundancy relief system for potential over pressure in the IBR tank.
- Develop a better effluent trap.
- Improve the arrangement of welds that hold the rotating arms in the top of the tanks.
- Develop a better system for maintaining tank pressure.
- Identify a more reliable influent pump and non-plugging gas flow meter.
- Investigate the proper solids concentration for optimal operation and size to grind solids to avoid plugging.
- Develop certification standards for safety, piping, and electrical systems in conjunction with appropriate agencies and utilities.

- Modify the system so as to address several safety features, such as stainless steel gas piping, a flare for burn off of excess bio-gas, and a flame trap device.

6. Do an economic analysis to compare high rate digestion with present day technology.

An economic analysis was not completed for the IBR at the Sunderland Dairy because it was not operated long enough at maximal capacity, nor was it connected to the grid. The economic analysis can be completed in the future pending completion of improvements to safety and operation of the digestion system, and generation of electricity into the grid. Additionally, and to ensure the most accurate analysis, it would be beneficial to increase the waste stream so that the system can operate at maximal capacity, and to have sale of solids in place. Current economic predictions are that all anaerobic digesters will barely break even from on sale of electricity, and that economic viability depends on the development of other revenue streams such as the sale of the solids. The IBR digester has the advantage here because of the higher quality of digested solids that it produces, and the ease of capturing and processing the solids.

7. Communicate technology to agriculture, government, academic, and business interests.

Three papers have been written and six conference presentations have been given that convey information about the IBR digester in general and mention the Sunderland digester in particular. The reports in early 2005 only reported that a full sized IBR digester was being built on the Sunderland dairy, but later reports in 2006 compared conditions existing on Sunderland Dairy and different farms, and the respective adaptations that were implemented.

Sunderland Dairy Digester Consulting Report June 28, 2007

Objective:

Dr. Stan Weeks and Mr. Patrick Topper (independent consultants) were asked by Utah State University to travel to Utah and perform a review of an anaerobic digester complex located at the Sunderland Dairy. The intent of the review was for the University to gain the opinion from the consultants to determine if the anaerobic digestion project at the Sunderland Farm should continue construction into the operational phase or if the project should be terminated. Operational and design change input to facilitate continued operation if suggested, was requested from the consultants.

Executive Summary:

In our opinion, the anaerobic digester system located at the Sunderland Dairy will not operate successfully long term without significant changes to the system. This is due to the fact that manure entering the digester tanks is reported at 6% to 8 % total solids, resulting in floatation and accumulation of solids within the tanks. This solids accumulation results in a mat or crust effect, and we are now aware that at least one tank at three different locations provided by the same company, have been lifted off of their base due to this effect. These steel tanks are 13.5 feet in diameter and 32 feet high.

Since 1980, experiences with anaerobic digester systems have shown that raw dairy manure entering an anaerobic digester tank will form mats or crusts of solids if the total solids content is less than 10%. Too much water added to as-produced manure and urine washes the solid particles and thus the solids tend to float and accumulate at the top of unmixed digesters. Elimination of this crust or mat formation requires either significant mixing within the digester or removal of large solids prior to digestion.

Much of the system design and components can be effectively utilized for a revised anaerobic digester system. This revised system will produce a low odor liquid, without large manure solids, capable of being pumped long distances and subsequently spray irrigated. Biogas produced by the system may be used to produce electricity and hot water for the Dairy.

Introduction:

Sunderland Dairy operates a 650-700 milking head dairy farm in Northern Utah. An Induced Blanket Reactor (IBR) anaerobic digester facility was installed in 2005. The four tank, parallel operation arrangement was designed for 1200 head of Holstein dairy cows with a calculated five day hydraulic retention time (HRT). The solids retention time was unknown but generally accepted to be greater than five days. The digesters operated for about 6 months with start-up in early 2006 and shutdown in late 2006. Operational problems were encountered during the start-up phase resulting in the farm owners to stop the attempt to reach steady state operation. The combined heat and power unit (CHP) consisting of an internal combustion engine generator set, nameplate rated for 150 KW, has never been run on biogas and is not connected to the electrical grid, biogas system or the hot water heating system. A 150 KW gas turbine is located in the engine generator room and is not connected to the electrical grid.

The consultants were given a tour of a similar IBR digester facility located at the Wade Dairy before the review was conducted at the Sunderland Farm. Operational and safety issues were observed at this site including gas production rates failing to meet expectations. The site manager was very cooperative in explaining the design features of the IBR system. This site manager was the technology license holder for the IBR system located at the Sunderland Dairy. He was directly involved in the installation of equipment at the Sunderland Dairy. Biogas concentrations were measured at this operating facility and hydrogen sulfide (H_2S) concentration was 2,100 ppm and carbon dioxide (CO_2) concentration was 33%. Raw manure pH was 7.4 and the digester effluent pH was 7.9.

Findings of Facts and Suggested Corrective Actions:

Manure Handling and Solids Separation

The flush – flume manure transfer system to the existing reception pit that is currently in use is operating effectively and should be continued to be used as is.

At the reception pit, provide a means to direct contents to the first lagoon, if the digester complex or separators ever need to be bypassed. Add a tee, valves and line to allow pumping of raw manure directly to the first lagoon with the flush-flume pump.
As observed, if the reception pit overflows, it enters the third lagoon. The third lagoon is the lagoon with the most treated manure liquid and all attempts to keep solids from entering this lagoon should be made. This will ensure the most reduced odor and solids liquid will be used during nutrient irrigation.

Continue to use the Houle piston pump and existing grinder to feed the two FAN separators from the reception pit. Add an overflow line from the separators back to the reception pit. Direct the separated liquid from the separators using the existing PVC piping to the digester feed pit. The separated liquid from the FAN separators will be the feed stock for the digesters. At the FAN separators, add a bypass line and valve to allow bypassing the raw manure to the first lagoon if the separators are not in operation.
In the digester feed pit, only one of the two Houle agitators need to be used to keep the reduced solids liquid in suspension. This pump should cycle on and off as needed, controlled with a timer. Use the existing digester influent feed pump located in the digester feed pit to feed the digesters through the existing digester tube and shell heat exchanger. This feed pump is critical for all four (4) digester tanks to operate and consideration should be made to locate the closest repair/replacement pump and motor or obtain a spare for inventory.

Anaerobic digester tanks and digester building

Continue to operate the digesters at 100°F. Remember, whenever recovering from a loss of temperature control, do not change temperature rapidly. The microbes inside the digester are slow workers but steady and need time to adjust to temperature changes. Foaming is usually the indication that temperature was adjusted too rapidly.

Observe the top of the digester liquid surface through the clear viewing window and outlet piping access and operate the water spray as necessary to control foam. The water spray control should be on a timer with the goal of using only enough water to control the foam. During the observation through the viewing window, determine if operation of the rotary arms with hanging chains need to be operated for crust control.

The digesters should be cleaned of all manure solids before the initial feedings for startup. The 24 inch diameter access plate inside the digester tanks on the four septums should be removed to allow free passage of digested manure to enter to the area above the septum. When entering the digester, for personnel safety, ensure to follow confined tank entry procedures. Also inspect and repair as necessary the foam suppression water spray system and rotating chain arms.

Gas Handling and Conditioning

Remove PVC gas supply line piping and replace with stainless steel piping or tubing. PVC vent lines at the P-Traps can remain in place.

Remove water trap pressure relief and replace with a commercially available biogas pressure relief valve.

Install a gas handling skid, which should include a gas pressurization blower, gas line chiller for water moisture removal, condensate drain, particulate filter, and a biogas rated gas flow meter.

Energy Production and Biogas Utilization

Change the operation of the hot water boilers to one on biogas and one on natural gas. Continue operating the water side of the boilers in series with the first boiler using biogas fuel. Add a hot water storage tank on to the outlet of the second boiler. The goal is for the boilers/CHP unit to heat this tank to approximately 200°F. This will help eliminate fire side fouling in the boiler. The water inlet to the first boiler is from this tank. All heating loads on the system, such as the digester heat exchanger and building space heater, draw from this storage tank.

Consider switching out the existing heat dump radiator skid with a commercial unit that will dump excess heat from the boiler and CHP unit. These units are sized for the CHP unit and can have variable speed fan(s) for fine temperature control.

Information provided to us for the gas turbine on site indicate parts and servicing support is questionable. Recommend using an internal combustion engine designed for biogas with servicing support.

Select a combined heat and power unit (CHP), internal combustion or micro-turbine, sized to use all biogas produced. Biogas production from the digesters is unknown and needs to be determined before a CHP unit can be selected. Internal combustion engine powered generators are our recommendation since they have controls to vary electrical output to follow biogas production. Also remember, maximum power plant efficiency is normally obtained when a unit is near or at full load.
The CHP unit selection needs to be based on analysis of total and volatile solids in the digester feed, which is the liquid stream from the separators that is collected in the digester feed pit. An estimated biogas production rate can be calculated using an estimated volatile solids destruction rate.

Renegotiate the Power Purchase agreement with the utility based on new CHP unit KW rating.

Safety Issues and Recommendations:

The control building is a well insulated enclosed space designed to retain the heat from the uninsulated digester tanks. This building has minimal ventilation. Functioning hydrogen sulfide and combustibles gas detectors with alarms are needed in the control and digester buildings.

Replace biogas PVC piping with stainless steel piping.

Extend sides of the four ladders at the digester tops to extend above the top of the tanks. Install safety chains on the tank tops between the tank handrails and the new ladder extensions.
Replace the plastic pipe water sealed biogas pressure relief trap with a commercial, mechanical, biogas rated overpressure relief valve.

Add a flare to the biogas system with a capacity to burn all biogas produced. The flare should be located away from any buildings and combustible materials.

Check the digester building emergency ventilation fan for proper operation. It should operate automatically and continuously when the gas detectors call for ventilation.

Add a small but continuously operating minimum building ventilation fan. It is suggested this fan be located to draw on the digester building and discharge into the separator building. An inlet air louver sized to match the minimum ventilation fan capacity should be located near the digester building access walk door.

Seal the drilled holes that were installed on the P traps for the "deleted" water jet system.

The digester tanks should not clog with solids and experience an over pressurization event as observed previously. A over pressurization system located on the system below the digester tank internal septum is not warranted.

Advantages of Proposed Operation:

The FAN separators will operate on raw manure, eliminating hydrogen sulfide (H_2S) and other volatile gases from the separator building. Chemical buildup (calcium deposits) will be minimized from forming on the separator auger and screen. All piping is currently installed except for the raw manure return pipe from the separator room to the reception pit and the reception pit overflow pipe directing raw manure to the first lagoon. Those two pipes may be installed in the same trench.

Separated manure liquid from the separators will be low in large solids and will be easy to agitate and pump from the digester feed pit.

Separated manure liquid will not plug the 2 inch ID line inside the shell and tube heat exchanger, so the current heat exchanger will perform well.

Separated manure liquid will not form a mat or crust within the digester tanks, and since approximately 20% of the raw manure volume was removed by the FAN separators, the digester hydraulic retention time will increase. This increased retention time should increase the volatile solids destruction inside the digesters resulting in increased biogas production.

The separated manure liquid will rise inside the digester tanks as digestion proceeds, creating a "vertical plug flow" digester effect. The six inch overflow piping at the P traps will not clog with previously separated manure liquid which is now the digester effluent.

The commercially available gas handling skid will chill the biogas & drain condensate which reduces the corrosion effects caused by the H_2S gas and water on the boiler fire side and inside the engine. The skid mounted variable speed biogas pressurization blower will control the digesters at a low biogas pressure thus helping to minimize biogas leaks into the building; and this same blower will provide the needed biogas pressure for proper control of the boiler and engine.

Operating the biogas boiler water at a high temperature will reduce the fireside condensation previously observed and the resulting chemical residue formation should be minimized.

The CHP unit will include a tracking system to adjust the engine load control throttle based on biogas production.

The CHP unit heat dump radiators, with variable speed fan(s) will closely control the engine loop temperature.

The flare will eliminate odorous, raw biogas flow to the environment. Solar operated flares are simple. A flame arrestor needs to be installed in the biogas line prior to the flare.

Better ladders including railing, improved biogas piping, functional biogas detectors with alarms, less volatile gases at the separators, commercial biogas relief valve; all contribute to improved safety of the entire digester facility.

The digester system will produce a low odor, effluent liquid, without large manure solids, capable of being pumped long distances and subsequently spray irrigated. Fertilizer nutrients, especially nitrogen, will be readily available.

Incorporation of Suggested Changes:

The suggested changes and improvements are recommended to be incorporated in two phases.
Phase one can be incorporated immediately and should include all suggested changes and improvements except the installation of the new CHP unit. More information is needed to estimate daily biogas production; so thus, the CHP unit can not be sized yet. Total and volatile solids of the manure measured before and after the FAN separators are needed to calculate the expected daily biogas production. With the solids information and knowing the daily volume of manure, an estimate of biogas production can be made. The most accurate method to size the CHP unit is after the biogas is actually produced and measured by the gas meter. Then the exact sized machine can be obtained. Usually though, the CHP unit size is **estimated** using the volatile solids content which is directly correlated to the biogas potential. Since a CHP unit my take many months to be built and installed, those units are usually designed and purchased during digester construction.

Phase two would be the installation of the properly sized CHP unit that can send power to the utility electrical grid.

Submitted June 27, 2007

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Dr. Stan Weeks

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Mr. Patrick Topper