Denali Emerging Energy Technology Grant:
"Improving Cold Region Biogas Digester Efficiency"
Year 1 Quarterly Report, Q3 – September 30, 2010

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i. Y1Q3 Summary

The project is on target with regards to progress in Phase 1. Phase 1 commenced January 2010. The entire project team met on site in Cordova in Nov. 2009 to conduct a pilot study, in January 2010 to start Phase 1, and in June 2010 for a mid-phase project meeting.

The most exciting result since the Y1Q2 report is that we have achieved healthy biogas production in our phsychrophile-only tanks in both the warm and cold rooms and in the mesophile tank in the warm room. These results support our original hypothesis that psychrophilic organisms extracted from permafrost thaw lakes are capable of producing biogas at low temperatures (15-25°C), whereas conventional mesophile methane production would be limited to warm temperature conditions (≥25 °C). Methane concentrations in the biogas reactors reached a maximum of 82% CH_4 by volume, which is 22% higher than conventional biogas digesters. During the remainder of Phase 1 we will make improvements to our gas collection system and raise the feeding rate of the digesters to determine their maximum biogas production rate. Our production target is 1,000 liters per day on a 2kg per day feeding regime, comparable to warm climate digesters of the same household scale. This information will be necessary for commencement of Phase 2, demonstrating the use of biogas to power gas-powered technologies.

ii. Schedule and milestone information

The project continues to closely follow the original outlined plan:

- Construct Digesters for Phase 1 by December 15, 2009 – Completed January 21 2010
- Begin Data Collection by February 1, 2010 – Ongoing, commenced January 18, 2010
- June 25-27, 2010, project meeting onsite in Cordova (all team members present); High school student presentations
- Perform mid-term Analysis of Data by July 30, 2010 – Completed informally internally as a project team, and formally in Quarterly reports 2 and 3.
- Year 1 Q4 Report due December 15, 2010
- Phase II Scoping Deadline January 25th 2011
- Phase I Report, including analysis of all Phase I data, due February 28, 2011
- Year 2, Q1 Report due March 15, 2011
- Year 2, Q2 Report due June 15
- Year 2, Q3 Report due September 15
- Final project report due September 30, 2011

ii.a) Personnel:

Cordova Electric Cooperative http://cordovaelectric.com/

Clay Koplin – Grant Administrator. Koplin has managed most of the financial aspects of the project thus far on behalf of the Cordova Electric Cooperative, serving as the project manager. Koplin serves as a technical advisor to the project.

University of Alaska, Fairbanks http://www.alaska.edu/uaf/cem/ine/walter/

Katey Walter Anthony – Research Director. Walter-Anthony acts as the primary investigator, and has spearheaded the scientific goals and directions of the project. She provides continual scientific expertise and project management. She contributed to the data analysis, interpretation and writing of this report.

Casey Pape – Research Technician. Pape joined the project in early September, 2010, to replace Laurel McFadden as the primary project technician. Pape is currently working on-site in Cordova, maintaining the digester experiment, including data collection, analysis, and troubleshooting. Pape led the preparation of the current quarterly report with assistance from other team members. A recent graduate of Western Washington University, Pape has a long history of experience with small scale (<1 MW) alternative energy projects – including biogas digesters – and is excited to be working on this project. Due to prior work commitments, Pape will be away from the project Oct. 15 – Dec. 5, 2010. In his absence, Adam Low and Clay Coplin will maintain feeding and measurements in Cordova. They will work with Pape to collect data in preparation for the Y1Q4 Report. Pape will lead the assembly and writing of the report upon his return to Cordova on Dec. 5. Pape plans to remain with the project until its completion in September 2011.

Dane McFadden – Project Intern. Currently an undergraduate at Stanford University, Dane McFadden helped maintain digester performance over the summer. Job responsibilities included: maintaining daily gas data collection, feeding, chemistry measurements and gas sampling. McFadden will be using his experience here in Cordova as his required internship at Stanford University and will generate an intern project report which will be submitted to the PI, the Denali Commission, and to Stanford University.

Laurel McFadden – Research Technician. McFadden, having begun a graduate program at UAA in mid August 2010, now consults on the project and has provided invaluable training of new project team members (i.e. Dane McFadden and Casey Pape). She provided feedback and assistance with the writing of this report. McFadden was a key contributor to the project development and took the lead on organization and preparation for the initial construction and setup. McFadden completed the first draft of a Biogas Handbook for Alaskans, which will be submitted as a deliverable in final form to the Denali Commission by the end of the project.

Peter Anthony – Research Technician. Anthony consults on the project and continues to provide technical expertise to the maintenance and application of digesters. He participated in the on-site project meeting in June 2010 and provided recommendations for simplification and winterization of the gas collection system in preparation for Phase 2. Anthony conducted the gas chromatography analyses of biogas composition for this report.

Jeffrey Werner – State FFA Director. Werner is looking into using the effluent from anaerobic digesters as a liquid fertilizer for agricultural crops. Located at the horticultural center at UAF, Werner remains enthusiastic about the possibilities of the potential uses of the once thought of waste product.

Cordova High School http://blogs.cordovasd.org/chs/

Adam Low – Science Teacher. Low was integral in bringing in student involvement via classroom curriculum and extracurricular projects. He was on the construction team and continues to assist troubleshooting, construction, and maintenance.

Cordova High School Students – Volunteers. The students have been highly involved with construction, feeding, maintenance, and public presentation. They include the seventeen Chemistry class students and Science Club students (Craig Bailer, Ben Americus, Adam Zamudio, Sophia Myers, James Allen, Eli Beedle, Josh Hamberger, Keegan Crowley, Kris Ranney, and Carl Ranney). Ian Americus, Ben Americus, Erin Hess, James Allen, and Adam Zamudio presented at the Alaska Rural Energy Conference in Fairbanks along with Adam Low.

SOLAR Cities http://solarcities.blogspot.com/

TH Culhane – Biogas Expert. With an extensive history in biogas technologies, Culhane developed the water-pressure tank design and provided extensive technical knowledge to the engineering of the project. He worked with and advised the on-site construction in January 2010 and provides expert advice from his home base in Germany.

Sybille Culhane – Co-founder of SOLAR Cities. S. Culhane assisted in initial construction efforts and managing financial aspects of SOLAR Cities involvement.

Chena Hot Springs http://www.chenahotsprings.com/

Bernie Carl – Owner of Chena Hot Springs. Carl has expressed interest in deploying a digester at Chena Hot Springs, and has offered space for testing a digester in his greenhouse.

Others http://www.cordovaenergycenter.org/

Brandon Shaw – Website Development. Shaw designed and manages the CordovaEnergyCenter.org website, where the project is hosted. He also assisted at the initial construction site, and was integral in the assembly of the flow meter system.

Keywords: Biogas, anaerobic digester, reactor, phsychrophiles, mesophiles, methane, etc.

iii. Narrative summary of the project status and accomplishments to date, and addressing the following questions: is the project on schedule, is the project on budget, and what actions are planned to address any project problems.

iii.a) Project Status and Accomplishments

The project is on target in Phase I of the original research proposal. Phase I involves the testing of several different blends of methanogenic microbial populations (mesophilic and psychrolphilic) in order to examine different characteristics of digesters that operate in cold environments. The primary goal of Phase I experiments are to construct and monitor six different anaerobic digesters and to try to maximize the amount of gas that can be produced in depressed temperature climates (see original research proposal for more details on Phase I goals and objectives).

We have achieved substantial improvements in biogas production during the past few months following resolution of challenges experienced during the previous quarter (see Y1Q2 report). All of the complications encountered are common among new biogas start-up efforts (Gerardi 2003). Our gradual chemical amendments to raise the pH in digesters to 6.8-7.2 have been largely successful. In response to our concern about the possibility of low microbial population sizes, we added additional fresh manure to Tank 6 (mesophiles, 25°C) and additional fresh thaw-lake lake mud to Tank 4 (psychrophiles, 25°C). The microbial additions could not have hurt the biogas production progress in these tanks; however, since we have since observed successful biogas production not only in Tanks 4 and 6, but also in Tanks 1 (psychrophiles, 15°C) and most recently also in Tank 5 (mixed phsychrophile/mesophile), it is possible that the microbial amendments were not necessary.

Preliminary analysis of recent gas samples shows that tanks are producing methane in high concentrations (as high as 50-82% in some cases). This is a very encouraging finding as it illustrates that not only are tanks supporting microbial populations, but that those communities are healthy and supporting active methanogenesis. At this time it is the researchers' intention to begin pilot-level experiments for Phase II (-finding usable applications for biogas produced from the anaerobic digesters), while at the same time maintaining the Phase I study through completion in effort to improve yield and efficiency. Phase II will also incorporate data collection and monitoring of time and effort required to build and maintain biogas digesters to provide economic assessment as part of our assessment of biogas technology in Alaska.

Successful remediation of digester pH

Several setbacks occurred during the initial Phase I study that resulted in the delay of biogas production. The greatest setback was the early issues encountered with over-feeding the digesters causing the tanks to accumulate high concentrations of volatile fatty acids (VFAs) and acidify. The methane fermentation pathway involves several steps and multiple species of bacteria and archea in order to produce biogas (Weiland 2010). Prior to microbial synthesis of methane, acetogenic and other bacteria must first break down complex volatile organic matter to form simpler VFAs. Those VFAs can be further decomposed by methanogens in order to form methane and other trace gases. Often times, however, acetogenic microbial metabolic rate can exceed other microorganism activity and result in a buildup of the concentration of acids within the system (Gerardi 2003). Early in our experiment we suspect this acidification to have occurred in our digesters and resulted in minimal amounts of biogas production and decreased methanogen activity. Chemical remediation was then considered as a means to restore system pH.

Soon after sealing the tanks and beginning our initial feeding schedule in January of this year a marked drop in pH was noted among all six digesters. In subsequent months the declining pH became too great an issue to be ignored and it became clear that remediation steps would have to be taken in order to maintain the integrity of methanogen communities (Table 1). As of March 22, 2010, all feeding was stopped and chemical remediation was set to begin restoring optimal pH conditions for psychro- and mesophilic methanogenic communities (pH 6.8-7.2). This required the sending of a full-time UAF technician (Laurel McFadden) to Cordova in order to preserve accurate measurements and perform the necessary chemical treatments to restore digester pH. McFadden's schedule of chemical treatment involved the careful additions of calcium carbonate, calcium oxide (lime), and sodium hydroxide to all six tanks (information regarding treatment schedule can be found in the Y1Q2 R report). The last treatment of alkaline chemicals was performed on June 6, 2010 and pH values have since stabilized at their desired range (Figure 1) with the exception of tank 3 which continues to remain at a very low pH (4.9 as of 9/21/10). Probing of different areas of the tanks during the acidification period revealed that only the liquid water columns of the digesters were acidified, and that methanogens may have still been viable in the neutral-pH of the sediment and manure sludges at the tank bottoms. After successful remediation of water column pH and demonstrated flammability of produced biogas, we resumed feeding of digesters, but at a lowered rate to allow all stages of microbial metabolism (fermentation and methanogenesis) to increase slowly together.

Table 1. Tank acidity recorded at their lowest pH values in April 2010 and at their current, largely restored, values in September 2010. Active methanogenesis does not occur efficiently at pH values < 6.5. Cessation of feeding and chemical remediation resulted in higher pH, conditions favorable to biogas production.

Tank	Date of lowest recorded pH	pH value	Date of last sample	pH Value
1	3/31/10	4.5	9/21/10	6.86
2	3/29/10	5	9/21/10	7.26
3	4/29/10	3.96	9/21/10	4.9
4	4/19/10	4.49	9/21/10	7.32
5	4/19/10	4.9	9/21/10	7.32
6	3/17/10	4	9/21/10	7.37

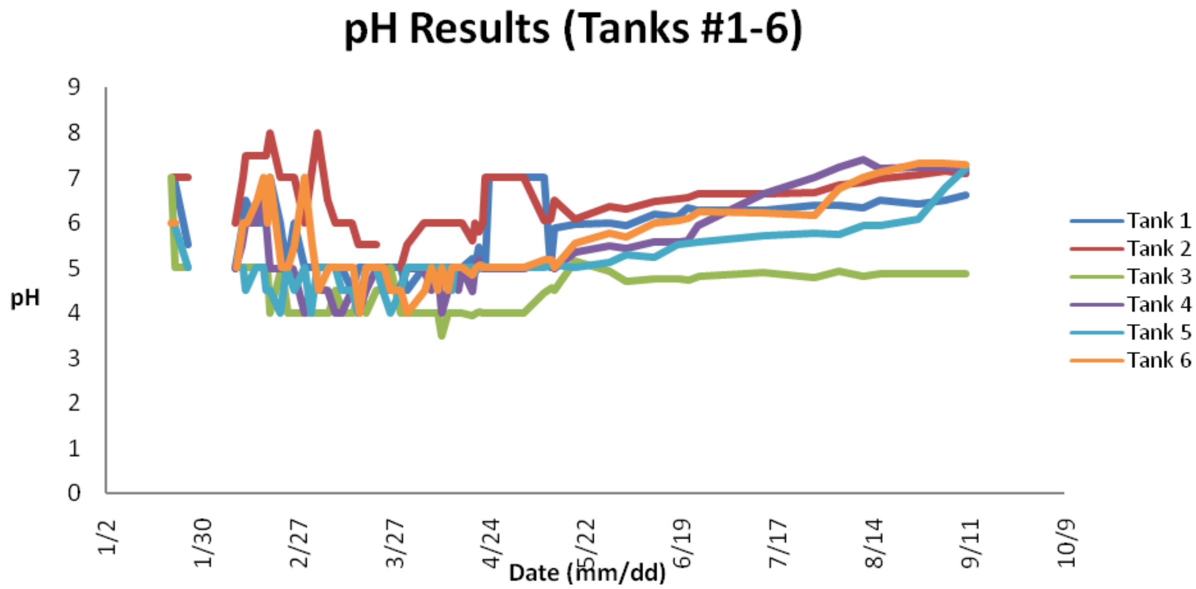

Figure 1. pH results indicate that the acidity of the tanks is declining and optimal pH values (ideally 6.8-7.2) have been restored. Despite of multiple additions of Calcium carbonate, Lime, and Sodium hydroxide Tank 3 has shown little response chemical treatments. Tank 3 remains as low pH of 4.9 and is unlikely to support methane production at this time. pH was measured with Macherey-Nagel litmus paper January 21-April 16, following which it was more precisely measured with an Oakton PC510 pH meter.

In accordance with restoration of biogas digester conditions, we also observed changes in dissolved oxygen and redox within tanks. Both dissolved oxygen and redox levels declined to anaerobic levels favorable to methanogenesis (See data figures in Appendix 1).

Flammable biogas restored

Flammable biogas is once again being observed in many of the original six digesters. We interpret this as an indication that the digesters contain healthy microbial communities of fermenters and methanogens working synergistically. Due to low feeding rates, biogas production rates are also still relatively low; however, recent analysis of gas composition on a Shimadzu 2014 gas chromatograph equipped with a flame ionization detector revealed that CH_4 concentrations in gas flowing from the digester tanks is up to 82% by volume (Figure 2). Typically conventional biogas reported in the literature is 40-60% by volume. It is possible that as we increase feeding rates to increase gas production rates, we will observe a decline in CH_4 content associated with rebalancing of fermentation and methanogenesis and in variation with feedstock quality.

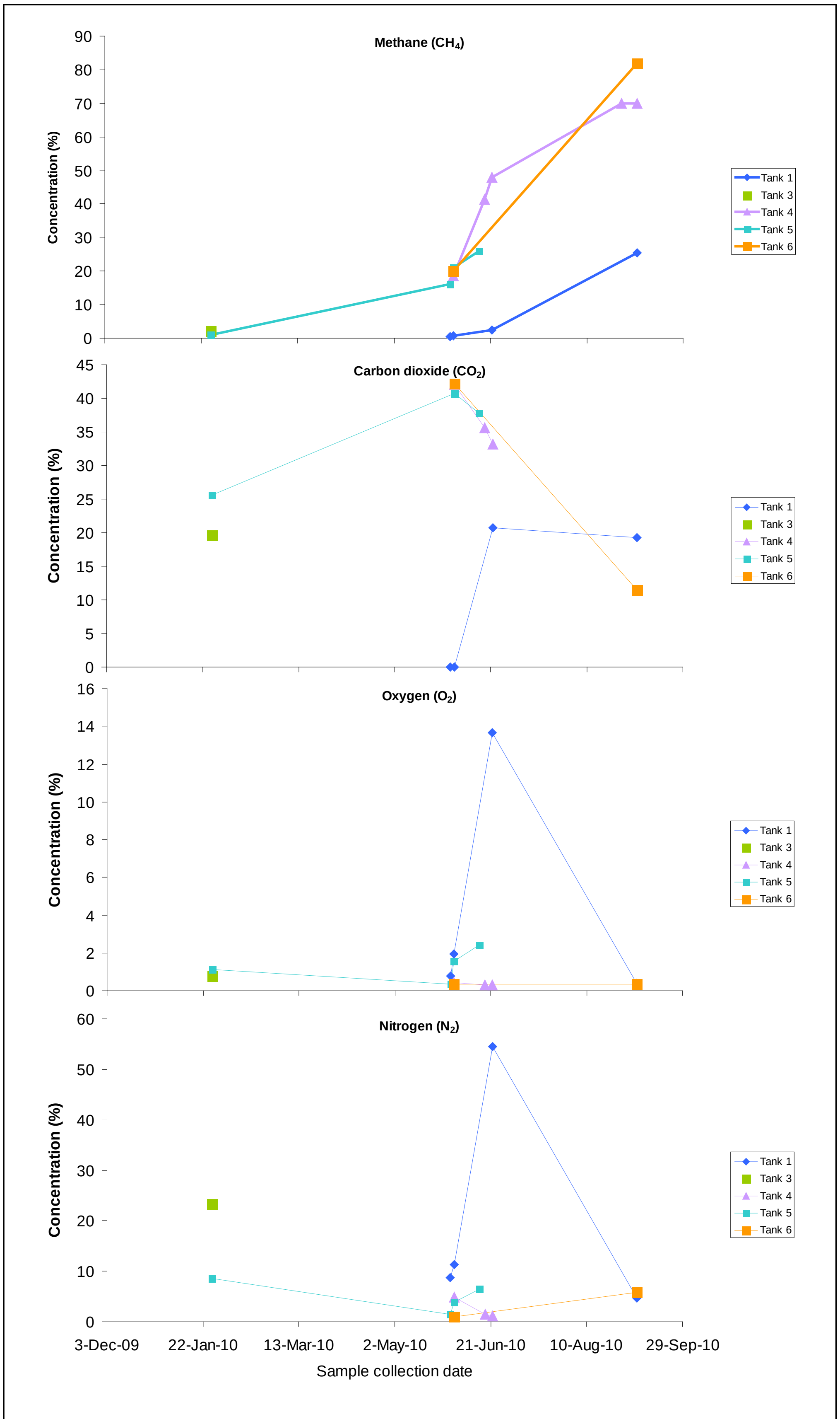
Methane (CH_4)
Carbon dioxide (CO_2)
Oxygen (O_2)
Nitrogen (N_2)
Concentration (%)
Tank 1
Tank 3
Tank 4
Tank 5
Tank 6
3-Dec-09
22-Jan-10
13-Mar-10
2-May-10
21-Jun-10
10-Aug-10
29-Sep-10
Sample collection date

Figure 2. Gas composition results determined by measuring concentrations of methane, CO2, oxygen and nitrogen on a Shimadzu 2014 gas chromatograph equipped with FID and TCD. Concentration of gases are presented as percent by volume. It should be noted that 70% CH4 in Tank 4 shown for Aug. 28 and Sep. 5 was calculated as a correction to lower concentrations measured in samples due to a leak in the sampling system. Both the samples from August/September Tank 4 had the same methane/carbon dioxide ratio - =4.4 Based on a review of the other biogas samples, this should put the methane level of the biogas at ~65-70%, after correcting for presumed dilution from air contamination. The fact that the two samples had the same ratio of these gases, despite a two-fold difference in the methane level, is a good indication that the low reading is due to dilution by atmospheric air in the sample collection stage.

Additional gas analyses will be performed to complete the time series of gas composition for assessment of digester behavior over time; however, these preliminary results look good and give invaluable insight into the current health of our digesters.

Flame tests show that Tanks 1, 4, 5, 6 have been producing flammable gas (Table 2); however, methane-rich gas from Tank 4 is being diluted by air through a discovered leak in the in the secondary holding tank (water-pressure system). Due to too low of gas flow rates, gas from tanks 2 and 3 is not being collected and we have no data on its composition.

Table 2. Results of produced gas flammability tests. Positive results of the flammability test indicated usable biogas. For technical and safety reasons, flame tests were not performed directly from the tanks after flow meters were installed on 2/18/2010. Flame tests are still conducted on Tanks 1, 4, 5, and 6 as they are connected to water-pressure tanks that may be isolated from the flow meters. Tank 4, which is producing 60-70% CH_4, is no longer showing positive flame tests due to a leak identified in the secondary gas holding tank.

Tank	First positive flame	Last confirmed flame
1	1/31/10	9/18/10
2	NA	NA
3	1/22/10	2/1/10
4	2/1/10	2/18/10
5	1/21/10	9/18/10
6	1/26/10	9/18/10

GC analysis provides valuable information about digester integrity and microbial fitness. For a digester to be producing gas that is of such high methane content as we have observed recently is a very good thing, regardless of the amount, as it shows we have active methanogens within several tanks and to some extent indicates the health of the microbial communities inside. Since our digesters are now producing high concentrations of methane within the biogas we can determine that these methanogenic archea are now more prevalent in our tanks than they were once before. The time series GC results show that methane concentrations have increased since chemical remediation (Figure 2). Low oxygen levels and declining CO2 concentrations are also indicators of healthy biogas conditions in the tanks. More work will have to be done with current and future samples, but our preliminary assessment is that several tanks are producing proportionally high amounts of methane and that this is an indication that methanogens are active and in healthy proportions within the tanks. We expect that an increase in feeding will increase absolute number of moles of CH_4 produced by the digesters throughout the remainder of Phase 1.

Resuming feeding of digesters to increase gas production

The digesters have not been feed on a consistent basis since the decision to stop feeding them as part of pH remediation on March 22, 2010. No feeding took place from March 22 to June 22, 2010. The tanks were sealed following chemical treatments, and then feeding was resumed at low levels by Laurel and Dane McFadden. Since the feeding protocols and responsibilities were initially designed by and for the Cordova High School chemistry and science club students, lack of student participation over the summer has hampered the ability to feed digesters. Following protocols for a precise feeding plan (for the purpose of scientific data analysis) requires considerable time inputs, and is the type of activity that the project depends on student volunteers to perform. Engineers and technicians funded by the grant are better used to collect and analyze data, trouble shoot problems, and design and implement technical aspects of biogas production and use. We anticipate that biogas production rates will increase once feeding resumes at a regular rate of acceleration. With the start of the new school year students have begun collecting food once again. Student participation is likely to increase this fall and will be welcomed to the project. New techniques are being implemented in order to streamline the feeding process as well as improve its sanitation and minimize variability between feeds (Appendix 1).

In order to return to the initial feeding schedule as defined by the original project proposal (1kg food + 1kg water), careful attention will have to be paid to prevent tank re-acidification. As of September 27, 2010, we have begun to feed the digesters on a strict and consistent feeding schedule. For one week the digesters will be fed equal parts (1:1) totaling 500g of food combined with 500g water at every other day intervals. The following week the same amount of food and water will be added at every day intervals. Assuming no detectable decrease in pH or other chemistry is noted, the digesters will begin to resume our original feeding proposal of 1kg food and 1kg water on daily intervals the following week (October 11 – 17th). Chemistry and gas measurements will be closely monitored in order to detect any changes that result from increased feeding. Careful measurements of gas flow output should provide insight into whether increased feeding results in measurable increases in gas production.

Gas flow measurements

In order to improve our confidence in measurements of gas production, we will look into an independent means of measuring gas flow for cross-checking of the currently employed in-line gas flow meters. Gas flow is at this time measured on all tanks with Sierra Instruments Top-Trak 820 Series Mass Flow Meters. These meters were installed on February 18, 2010. They measure gas flow based on a pressure differential between two fluid reservoirs (Sierra TopTrak

Manual). The output measurement is rated in Volts and must be converted in order to obtain standard liters per minute (SLPM). One concern is that the measurement is only of an average flow rate and not of the total cumulative amount of biogas moving through the meter. Each instrument has its own distinctive characteristics and error factor which is also a cause for concern, it is suspected at this time that the flow meter on tank 3 is miss calibrated and will need an appropriate correction factor after contacting the manufacturer. During the next quarter, Casey Pape will investigate the principle of data collection through the Sierra Mass Flow Meters and determine the best way of analyzing and presenting the data.

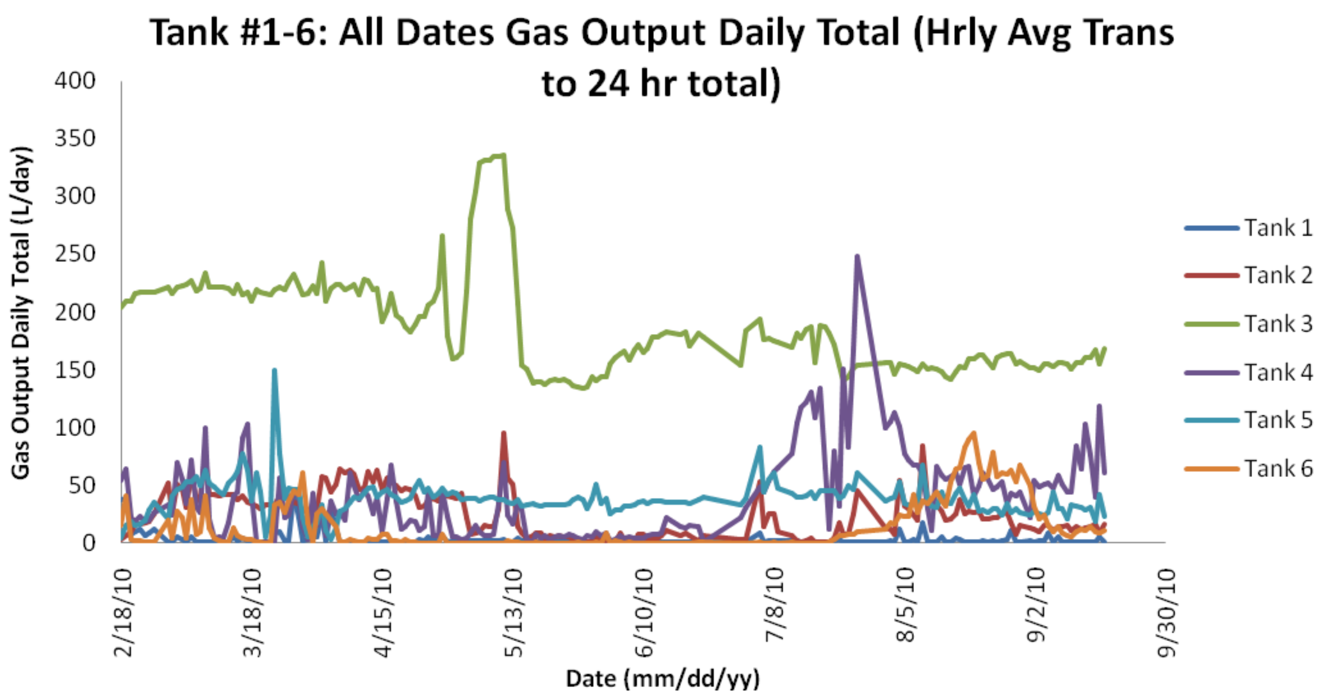

Figure 3. Mean daily gas flow rates from digesters. The flow meters averaged flow over a defined unit of time (hours in this case) rather than totaling the gas moving across the meter. We suspect that the represented data in Figure 3 underestimate total gas production. We aim to resolve this uncertainty during the next quarter. For an optimally operating biogas system, daily flow rates should be approximately 800-1,000 L/day. Regular feeding began on February 15 and was stopped on March 21. Spikes seen in mid-May are a result of chemical mediation. Lower rates of feeding resumed June 22, 2010. Feeding rates are scheduled to increase during the remainder of Phase 1 to increase production rate towards the optimal target of 800-1,000 L/day. Measurements were obtained with Sierra Instruments Top-Trak 820 Series Mass Flow Meters and were calibrated by the manufacturer. It should be noted that the flow-meter on Tank 3 was apparently miscalibrated. Data from Tank 3 need to be corrected. Tank 3 actually produces minimal volumes of gas.

In the immediate future, in order to achieve a secondary form of control of our gas measurements we propose installing tipping cup gas flux traps further down line from the Sierra Top-Trak instruments in order to obtain total gas output for each of the anaerobic digesters. The addition of tipping cups, built to the standard of those used to quantify gas flux in previous ecosystem methane flux studies (Walter Anthony et al. 2010), will be used in order to check and correct for any error seen among the Sierra Top-Trak meters. It is possible that at such low pressures and flow rate the Sierra flow meters will not be accurately detecting the amount of gas that is flowing through them. That is not to say that they are not appropriate at higher rates of flow or that they are not working properly now, but at this time we would like to double check our numbers. The installation of tipping cups will implement the use of liquid-filled five gallon buckets which are to be sealed and have the added barrier of a water-trap bubbler to ensure no air is entering back into our tanks. These measurement devices will be installed in line with the Sierra instruments and will not require stopping any of the loggers, thusly preserving the continuity of our data set.

Temperature control in the Connex

Several important factors in biogas production are microbial community, substrate availaibility for methanogenesis, and temperature. Because the goal of Phase 1 is to test microbial community capacity for biogas production at two different temperatures, it is important to control feeding and temperature according to the experimental design.

The Connex was built by the project team to maintain digesters in two separate rooms at cold (15 °C) and warm (25 °C) temperatures. Dataloggers record temperature in these rooms as well as inside each digester. Several digesters have multiple dataloggers suspendted at different height locations in order to better understand temperature stratification within the tanks. Figure 5 shows the summary data from all tempertature loggers over the course of the experiment. One of the goals of this study was to precisely control the temperature range in which the microbial communities were exposed to. Daily fluctuations occur as a result of opening the Connex to download flow meter data, but overall stays generally consistant (Figure 4). Average temperature of the 'Cold Room' Connex since June 15, 2010 was 16.14 °C. This would seem to indicate that Connex temperature flucuates with the local Cordova weather as winter temperatures averaged 2-4 °C below our intended 15°C controlled environment. Average 'Warm Room' temperature was recorded at 25.56°C for the same period. Cold room variation is expected to be greater than the warm room as the cold room is disturbed daily in order to download our gas flow data. A slight variation can be dectect between winter 'cooler' and summer 'warmer' months, but we are not concerned this is a major issue at this time. Also, in-tank temperatures recorded from January-May 2010 show that the large volume of liquid in the tanks buffers the tanks against the rapid temperature flucutations occuring in the room air. Temperate loggers continue to record temperatures inside all of the tanks; however, we plan to download them at the end of Phase 1 so as not to open the tanks and disturb the anaerobic conditions in there now.

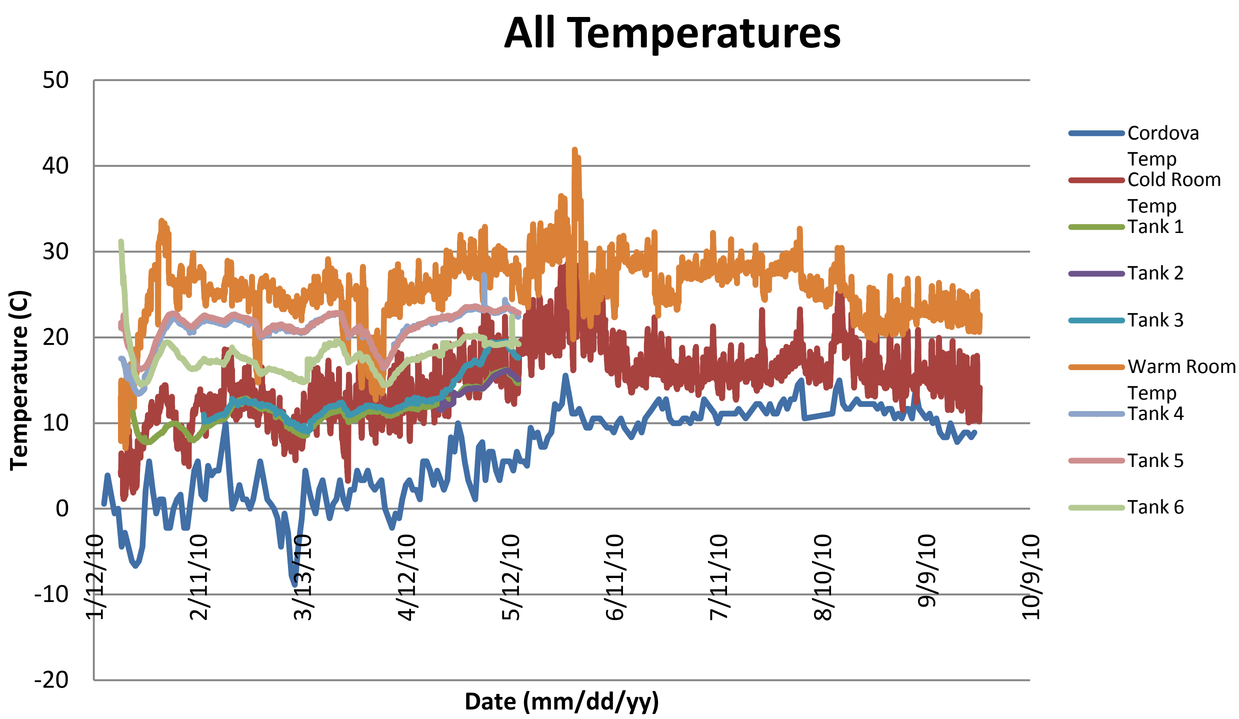

Figure 4. Mean hourly temperature of the data loggers in the Connex cold and warm room, and mean daily temperature recorded in Cordova. Tank temperatures have not been downloaded since May 12 in an effort to maintain the anaerobic environment in the tanks (accessing the temperature loggers requires opening the tanks to the air). According to the patterns we have seen thus far, though, we could predict an increase in tank temperatures following the increase in room and environmental temperatures. Biogas project temperatures are measured with Hoboware U22-001 Water Temp Pro V2 loggers recording hourly.

Removal of the outdoor water pressure system

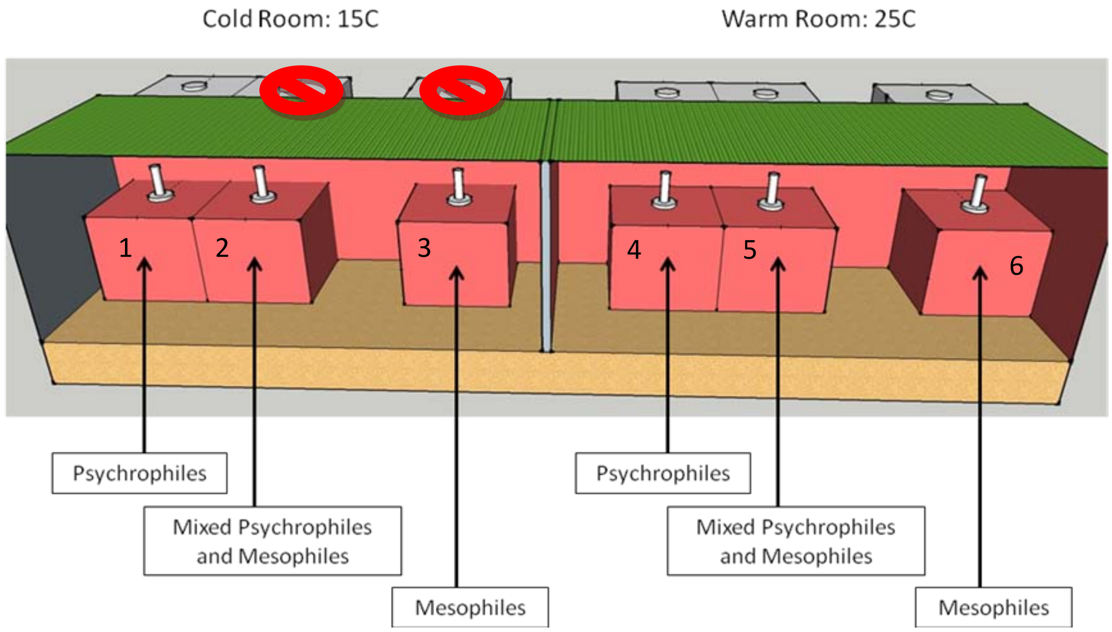

Figure 5. The diagram above illustrates the current layout of Phase 1 testing of biogas production efficiency of different combinations of psychrophilic and mesophilic methanogen communities under cold and warm temperature treatments. Tank 2 and 3 are not currently attached to any water-pressure system and exhaust gases are simply vented to the outside. The remaining tanks closely mimic this initial design though noticeable flexion and deformation is observed due to the large volume of liquids contained within each tank. Adding additional lateral support could help to address this issue as any distension among the containers puts considerable stress on joints and brings to question the integrity of the system.

Figure 5 illustrates the current configuration of all six digesters in the temperature controlled Connex and their outdoor secondary gas collection containers. The ability to store and pressurize biogas is outside the scope of the phase I study. Gas collection is relevant to Phase II. The outdoor water-pressure system was installed in January 2010 by T.H. Culhane to show the Alaska project team members the design he has built in other warm-climate regions. Unfortunately, these water pressure systems, if stored outdoors, are not appropriate for Alaskan environments (i.e. seasonal rain, snow, ice and wind). Their effectiveness for use in biogas technology is questionable altogether. Electric pumps are required to move the water intended to generate the necessary water pressure in order to operate the system (Figure 6). These pumps do not aid our attempts to minimize electrical inputs nor does the system have pipes big enough to sustain a high enough flow in order to maintain a steady pressure on the stored biogas. Finally, the use of water to this extent is not practical for the project's intended users, rural Alaskans who live in freezing winter conditions. As a result these tanks are now to be dismantled and their parts inventoried for future use. Ideally liquid-free gas containment systems would be most useful to the current system design. We hope to design a successful gas containment system intended for widespread use in Alaska. Design ideas will be developed between now and the next quarterly report with prototypes hopefully being constructed and tested at the beginning of next year.

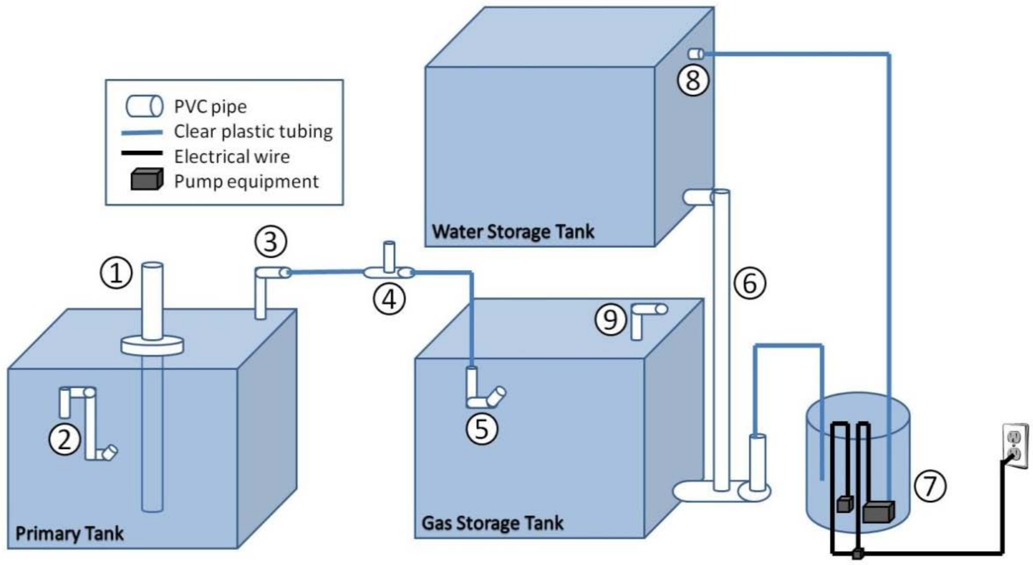

Figure 6. T.H. Culhane's water pressure system for storing and dispensing pressurized biogas. System components include: 1) Feeding tube 2) Effluent pipe 3) Primary gas outlet 4) Flame tester 5) Gas inlet 6) Water transport 7) Pump bucket 8) Water inlet 9) Final gas outlet. This system is deemed to be inadequate for our needs in Alaska and for the purposes of this study.

Cordova High School students brainstorming for Phase II

During the fourth quarter, this project would like to begin aspects of the Phase II study to develop practical applications of these small-scale anaerobic digesters. Currently (due to low feeding rates over summer) biogas production rates are insufficient to make use of conventional combustion applications of the gas feasible. During the remainder of Phase I we aim to increase gas production rates through enhanced feeding, in order to generate sufficient gas to power gas-powered technologies.

In the immediate term, creative alternatives will be considered. Students and community members should be encouraged to design useful applications of biogas. Recent interest has been expressed in using anaerobic digesters for use in improving greenhouse efficiency as biogas could be used as a source of heat and carbon dioxide (CO_2) for plants. Cordova science teacher Adam Low has recently obtained two large collapsible green houses. Science club students will be encouraged to perform experiments with growing agricultural crops that may be enriched with high levels of CO_2 from burned biogas as well as fertilized with effluent material. All these options will be explored as we begin to look into practical applications of the anaerobic digesters we have at the Cordova site.

iii.b) Health and Safety

Conventional small-scale anaerobic digesters are generally considered to be non-hazardous when given proper ventilation and maintenance. Still anaerobic digesters are used for the synthesis of combustible gases and have some safety concerns associated with them.

Flammability/explosions: Biogas is flammable. Methane is explosive at a concentration of 5-15% in atmospheric air. It is important that the biogas digesters do not have any leaks, especially if they are in an enclosed space, as they are in the Connex.

In order to prevent potential sources of flammability, the digesters should be checked for leaks regularly. The use of soapy water can help to positively identify leaks at seems and joints where small leaks may not be audible or visible to the naked eye. These checks should be preformed fairly regularly as the tanks are constantly experiencing stresses from both operation and the varying weather of Cordova. Periodic room air will be sampled and analyzed on the gas chromatograph in the Anthony lab at UAF for quantification of background levels in the Connex. We will investigate options for acquiring gas detection alarm systems for the Connex.

Signs are clearly posted inside of the Connex that explain(s) the presence of flammable gas and expressly prohibits the use of open flames inside. More signs should be visible from the outside, however, both to warn the general public of the danger, but also to encourage curiosity about the study. All students and researchers should wear proper safety glasses when conducting flame tests or working with pressurized digesters.

There are several options available for the detection and alarm of dangerous concentrations of flammable gases. Current detectors can sample gases for flammable elements through either use of catalytic beads or infrared technology. For our purposes it would probably be best to investigate infrared options as they would be less likely to experience failure due to potential catalyst poisoning. Several companies make detectors that measure the lower explosive limit (LEL) of flammable gas mixtures. These detectors measure a range of different gases and are not selective to just methane. We will explore possibilities of acquiring a flammable gas detector for the Connex.

Hydrogen Sulfide (H_2S): Hydrogen sulfides can be produced as a side product of fermentation. The gas is flammable and toxic. At higher concentrations, or prolonged exposure to low concentrations, it is a mucus membrane irritant and is considered a broad-spectrum poison. Exposure can lead to headaches, nausea, and in extreme cases, pulmonary edema, heart irregularities, and unconsciousness.

We have installed hydrogen sulfide detection badges in the rooms to monitor higher levels of H_2S (at low, non-toxic levels, hydrogen sulfide can be detected by its smell of rotten eggs).

Carbon Monoxide (CO): There is no mechanism for the formation of CO gas within the methane fermentation pathway and is not of major concern in this study. Carbon monoxide can be formed through improper combustion and should be taken into consideration whenever combusting biogas in a poorly ventilated area.

Ventilation: The build-up of certain gases in an enclosed space can be toxic. Biogas digesters produce methane, carbon dioxide, hydrogen sulfide, and other gases which can be deadly at high concentrations.

Though the tanks are checked often for leaks, the inside of the Connex container has a very noticeable smell reminiscent of manure. The air is cycled daily to a certain extent when the Connex container is opened for daily download of the gas flow data. Tubes are connected to the tanks to allow lighter than air constituents escape the container. **The Cordova fire department has visited the site and tested it for noxious gases. The results of the fire departments' testing came up negative for any toxic gases.**

iii.c) Schedule of project

The project is still on schedule as defined by the original project outline. Phase I of the study is still of major importance to the project and should be continued, possibly through until the project's completion. We plan efforts to begin Phase II of the study at the start of 2011 to incorporate the practical use of digester biogas and effluent waste products. Attempts to produce large quantities of biogas have not been successful up to date. This has been due to many factors including a significant acidification of the tanks that had to be remedied for several months during the projects' first year of study and subsequent low feeding rates. Preliminary GC analysis provides encouraging evidence as to digester health and productivity. It is suspected at this time that an increased regiment of food inputs will likely result in more biogas output.

iii.d) Project budget

The UAF budget is on track with the project schedule, neither over nor under budget. This is somewhat to be expected as the UAF budget is primarily labor and is fairly predictable and manageable. Originally we planned for the UAF team to operate through part-time technical support to the project including regular site visits to Cordova; however, complications of acidification of tanks and more rigorous remediation necessitated the move of a full time UAF technician (Laurel McFadden) to the site. On-sight full time UAF technician salary until June 2010, followed by part-time support thereafter, required re-budgeting a fraction of the PIs salary to technician salary. Casey Pape replaced Laurel in September, and is working full time on the project. The grant match funds were reported as approximately on budget, the detail will be available in the next report. Lesli Walls will also submit a separate financial report to the Denali Commission.

The CEC and Cordova Schools budget is slightly over, but the match is over approximately 40%. The CEC budget was primarily for materials. The Cordova Schools budget is primarily for travel and dissemination of project results. Since travel and showcase events are discrete events representing most of the cost, the budget consumption has been high for the presentations to the Alaska Power Association in Juneau in February, 2010 and at the Rural Energy Conference in April, 2010. This travel represents more than half of the project related travel, but has consumed less than half the total budget. The level of effort applied to the project by both the High School teacher and the students has been much more enthusiastic than anticipated, as reflected in the matching hours. A portion of the travel funds have been redirected to pay for Adam Low's additional new time on the biogas project and the development of the website.

In summary, the UAF and CEC/Cordova Schools budgets are within expectations for this phase of the project. No budget overrun is expected at this time.

ii.e) Hurdles and solutions

Project problems and solutions were mentioned in iii.a, and are outlined in more detail here.

Low biogas production – In order to be of any practical use to the general public - a major goal of the study - an anaerobic digester would have to consistently produce relatively high amounts of methane (on the order of 1000 L/day). So far, our digesters have been unsuccessful in this effort. We speculate two causes. The most plausible explanations were that initially low pH in the tanks inhibited methanogenesis, and more currently, now that we have neutral pH and otherwise good tank conditions, our feeding rates are too low.

(1) Low pH. Problem: The low pH problem has, for the most part, been solved. Initially, all digesters were scheduled to be feed on a daily basis of about 1kg food + 1kg water. Beginning in January, feeding in this manor was continued until March 21, 2010 when overfeeding was suspected to be the cause of an observed decline in pH. Since that time, efforts to restore initial pH chemistry within the tanks has proven very successful with the exception of Tank 3 (Table 1). Probing conducted among the sludge of the digesters revealed that acidic conditions were not consistent throughout the tank and that microbial viability may have been preserved in the sludge, which measured near neutral pH. Tank 3 has not recovered even with the addition of alkaline chemicals and is suspected to have fully "crashed". **Solution:** We are currently pleased with pH levels in all but Tank 3. Additional probing in Tank 3 may reveal more about the current status of pH stratification within this digester and sludge. This information would indicate the probability of a viable methanogen community remaining in the sludge if it has a neutral pH. However, raising the pH of tanks through chemical remediation is time consuming and requires an adult technician. Given time constraints and other priorities, it may not be possible to remediate Tank 3. Tank 3 is currently suspected to no longer be performing; any gas readings that are observed are thought to be the result of improper flow reader calibration and variations in atmospheric pressure.

(2) Feeding procedure. Problem: Following the observation of acidification within each of the digesters by Laurel McFadden and PI Walter Anthony, a teleconference meeting was held among project participants including also Adam Low, Clay Koplin and Peter Anthony, to concur on steps mediating digester chemistry. It was determined at that time that feeding should be stopped and remediation using alkaline chemicals should take place. As of March 21, 2010, daily feeding in all digesters was halted. This proved to be a major disappointment to the students of Cordova High School as feeding was not only their main responsibility and contribution to the project, but also discouraged them in that collected food scraps were now no longer of any use to the project and simply were discarded after intense effort to convince the school and students of the importance of recycling.

After the alkalinity of the tanks was restored partial feeding was maintained by Laurel McFadden and Dane McFadden over the summer of 2010. Digesters # 1, 4, 5, 6 were feed periodically, but lower rates than originally projected. Low feeding rates with gradual increases are important to maintain concomitant growth of synergistic microbial processes required for methane production.

Current feeding procedures are inadequate and unsanitary as food overflow and clogging are of constant issue (Appendix 1). Food stratification as a result of mixing slurry also presents a problem to researches who would like to maintain constant measurements of the exact amount of food + water that is added to each tank. **Solution:** Since this project is both a scientific study as well as a community outreach program it is important that both interests are met throughout the course of the study. Students gain much from being involved in a primary research study, but also from the educational aspects it provides for sustainability and conservation. Food preparation to date has been somewhat of an ad hoc procedure and leaves potential for falsifying the results of the experiment as well as contaminating the digesters with foreign pathogens and materials. It would be ideal to stabilize this variable in our study. One means for accomplishing this while also involving the students would be to collect large amounts of food and freeze it prior to mixing. This way food could be combined in large batches that are more homogenous and pathogen free.

In addition, other forms of digesters could be built (i.e. aerobic composters) that could compost the remaining food if not needed for the anaerobic digesters. Students could then use the composted products for other experiments. More thought and design needs to be put into correcting the current feeding procedure as it is currently not serving the project in an effective and safe way.

Other potential considerations:

The following factors are important considerations that generally can lead to problems in biogas technology. While we have no reason to think that any of these factors is causing a problem in our systems, for the sake of thoroughness, here we evaluate each as a potential problem in the context of our study.

Lack of ability to quantify total gas output. Problem: Gas output is currently being measured by six Sierra Instruments Top-Trak 820 Series Mass Flow Meters. These meters take instantaneous readings of pressure differences between two tubes that are internal to the meter. Based on the pressure difference, the meter measures the rate of gas flow that must be traveling through the meter. The reading is generated in Volts, but can be easily converted to standard Liters per minute (SLPM). These SLPM readings are then averaged and multiplied in order to obtain daily total liters that traveled through the meter. We are concerned that this is not a true reading; however, because the data averaging may include zero and low-flux values, which would serve to lower the average flow rate. We are interested in the cumulative volume of gas produced per unit time. **Solution:** Casey Pape will gain a better working knowledge of the Mass Flow principle and data analysis to provide accurate gas flow determinations from these instruments. An independent method for measuring total gas flow will also be employed (see main text).

Temperature fluctuation. Problem: Methanogens are sensitive not only to a general temperature range, but also to changes within their acceptable range. Most mesophiles and psychrophiles cease functioning with temperature variations of +/-2°C within an hour (Gerardi 2003). As seen in iii.a) Fig 5, there is some temperature variation within all six tanks. Although daily temperatures are fairly stable, there are some cases in which the temperature changes a couple degrees within a day. This is probably not enough to affect the methanogens, but it is possible with a jump of more than a few degrees the microbial communities could be negatively affected. **Solution:** Although temperature variability within treatments is not ideal, we hope the small changes do not have a significant effect, especially when spread over time. However, temperature fluctuation can affect the metabolic rate of bacteria. We are closely monitoring temperature with dataloggers. We can correlate increases or decreases in gas production to possible temperature variability.

Hydraulic retention/residence time. We do not suspect any problems with residence time in our digesters. Feeding rates are too low relative to the digester tank volume to be a concern for dilution of microbial populations.

Lack of Mixing. Problem: Most large-scale biogas digesters, within the scientific and industrial setting, benefit greatly from being mixed. Even occasional turnover of materials would periodically expose different microbial communities to new sources of food and cycle nutrients and waste. Digester tanks in this study were intended for use by residential and rural Alaskans. The digesters were built to be very cost effective and simple to operate. In order to cut down cost the digester tanks were not built with any means to mix the solution inside. Once sealed, the digesters have no simple way of being mixed and there is observed stratification of particles and chemical concentrations within the tank. For small-scale digesters, it has been deemed not to be cost effective to mix digesters (House 1978). **Solution:** Mechanical mixing could be as simple as installing a gearing system that could be attached to a bicycle gear. This option would be cost effective and have the added benefit of not decreasing digester efficiency as other means of mixing (i.e. electric pump) would.

Chlorine content. Problem: It is unknown at this point whether digester efficiency is retarded by use of Chlorinated tap water. As this is the most easily attainable source of water for most Alaskan communities (as well as for this study) it was chosen to be used in all six tanks. **Solution:** We tested the use of chlorinated tap water vs. non-chlorinated Lake Eyak water in the November pilot study and found that the High School tap water did not prevent biogas production. More research should be done to consult the scientific literature and see whether Chlorinated tap water has any effect on hampering microbial activity.

Scum and foam. Problem: It is not believed that there is a significant issue with scum or foam buildup to merit taking any additional action at this time. As feeding increases again in the future we may observe foaming to become more prevalent and will address it at that time.

Cold temperature(s). Problem: Due to limited resources and a priority for allocating resources to low-temperature digestion, there is no extremely-warm-temperature control currently designed into this experiment. Typical digesters of proven replication and reliability claim to be operated at much warmer temperatures than that observed in this experiment (35-50°C). **Solution**: The students at Cordova High School and members of the science club propose that smaller digester reactors be built in controlled "hot" and "cold" environments in order to determine whether or not the lack of 'hot' temperature is playing a significant role in our digesters. Any and all experiments would be conducted under supervision of Cordova High School science teacher Adam Low.

Little knowledge of microbial population and size. Problem: While outside the original scope of this project, there has been little effort to examine the microbiological populations within the tanks. Efforts to understand microbial communities within anaerobic digesters are an important step because digester efficiency is dependent on both microbial activity (metabolism) and microbial abundance (population size). **Solution:**

Simple efforts to look at effluent samples under dissecting microscope could reveal much about population dynamics within individual tanks. Simple “live or dead” counts of bacteria could give insight into relative reactor activity and be used to compare microbial activity between tanks. This could be a good activity for high school science students. Since there are multiple types of bacteria involve in the methane fermentation process, efforts to examine effluent bacteria could provide insight into possible favoring (e.g. abundance of acetogens compared with other pathway contributors). More advanced “Gram-staining” identification techniques could be used if further information about taxonomy were determined to be desired. For example dominant forms of methane forming microbes for mesophilic systems are *Methanobacterium formicium* and *Mehtanobrevibacter arboriphilus* and positive identification (or lack thereof) could be of importance to our study (Gerardi 2003).

Logistical and management concerns:

Digester/tank and fittings integrity. Problem: Initially, digester tank design was based on commonly available and recycled materials that were in abundance to the people of Cordova. The intention being that once a design was proven effective, that design could easily be replicated throughout other Alaskan communities. Unfortunately, the materials being used for the project were not designed for their current use and have proven inadequate given their condition. Each of the main 1000-L HDPE containers used for the digester reactor as well as water-pressure systems (Figure 6) has experienced significant flexing and distension over the course of the experiment. The tanks have not yet been provided with adequate lateral support and as a result deform whenever internal water volumes or gas pressure is fluctuated (See Pictures at end of the report). Any distension of the tanks results in unwanted joint stress that leads us to question joint integrity. Every additional fitting used on the tanks is a possible point of failure and several leaks have already been uncovered as mentioned in section iii.a). **Solution:** Soapy water may be used to uncover additional leaks in the system. It is recommended that these be conducted biweekly on all tanks to ensure system integrity. Reactor tanks should be installed with proper lateral and vertical support. Properly reinforced containers are available (Appendix 3); however, if cost and feasibility determine that these tanks cannot be obtained, then retrofitting our existing system is still of importance. Lateral support can be provided through use of horizontal tie-down straps. Tie-down straps have the additional benefit of being cheap, easily adjustable and could have vertical supports associated with them.

Water-pressure System. Problem: Pressurization of produced biogas can be advantageous for running certain types of gas-powered appliances or an electrical generator. The current system in place uses elevated tanks with aid of a pump bucket in order to provide a means to pressurize the biogas (Figure 6). This system has several disadvantages; however, and is not thought to be working as initially desired by TH Culhane. The pump bucket also presents a problem as it is ultimately consuming more energy than the digesters are currently producing. Only one water-pressure system is working as is designed (Tank 4) and that is suspected to be because of a known air leak found in the gas holding tank (current flames tests of Tank 4 prove negative) which would allow siphon to be generated between the pump bucket and the gas holding tank. All other systems are poorly or non-functioning. Water-pressure systems are not necessarily feasible for the given climate as water used to pressurize the gas will freeze this upcoming winter. Additions of propylene glycol or natural anti-freezes are not practical for rural use and may react adversely with the electric pump. **Solution:** All water-pressure systems are advised to be taken out at this time. They have not been shown to work, nor are they designed for winter conditions in Cordova. New designs should be entertained at this time that incorporate low cost materials and ideally non-liquid containment systems (i.e. pressurizing inflatable bags or covered piston configurations).

Balance of responsibilities. Problem: The project was originally designed to be constructed by the full team on-site in Cordova in early January, and then to be maintained by Cordova High School students for the duration of the project with occasional (2-3 yearly) site visits by UAF technical staff for troubleshooting and advanced chemical monitoring. Although construction was completed as planned, a number of unanticipated problems have required the presence of a full-time onsite technician (Laurel McFadden and later Casey Pape). Chemical imbalances, discussed above, led to the failure of the systems to produce biogas. Monitoring, standard chemical measurements, mechanical maintenance, and feeding took significantly more time than anticipated. Although this was partially alleviated when Cordova High School students realized the extent of their time commitment and sought to streamline the feeding process, the chemical treatments and troubleshooting were beyond the scope of the Cordova contingent. **Solution:** The project now employs a full-time technician (Casey Pape) as well as dedicates partial salary of Cordova High School teacher Adam Low to work on the project. There is time allowed for continual research in how to improve digester output as well as ample enthusiasm to see its success. Additional student participation will likely increase over the coming months with the onset of the current school year. Student involvement will also provide valuable creativity and energy to move the project forward.

iii.e) Positive accomplishments:

Biogas production- high methane and proven flammability – One of the primary goals of this project was to determine if the psychrophiles that produce methane in thermokarst lakes could be harnessed in an artificial environment to produce biogas. With the initial production of biogas from both psychrophilic and mesophilic microbes we proved flammability possible (refer to Y1Q2 report).

Biogas from conventional anaerobic digests typically contains methane content between 40-60%. Recently it has been discovered that our biogas contains increasingly high concentrations of methane (50-82%). We suspect that the increased methane concentration(s) observed in our tanks are the result of using psychrophilic methanogens whereas typical anaerobic digesters commonly use mesophilic bacteria and archea found in bovine and animal manure. This is an important finding as it implicates the use of psychrophilic methanogens for improving the energy content of biogas as opposed to more common mesophilic anaerobic digester systems.

Successful Chemical Remediation of Digester Tanks – As mentioned before in section iii.a) early in the experiment, observed declining pH was foreseen as a potential threat to the digester(s) microbial health and action was taken to restore pH to previous levels. Ideally, digester psychrophilic and mesophilic-communities perform under optimal conditions at a pH of around 6.8-7.2, observing tank pH(s) much lower than this (pH 3.5 – 6) was an indication that the tanks were acidifying and VFA's were likely being produced in large quantities. From this point chemical remediation was determined necessary to stop the digesters from potentially "crashing" or "souring" from prolonged exposure to low pH.

Remediation was performed in two steps. The first step involved stoppage of the initial feeding schedule as specified in the project proposal. Stopping feeding was a necessary step as it was essential to minimize the amount of variability in the tanks while alkalinity was restored. The second step entailed adding calculated quantities of Calcium Carbonate, Lime, and Sodium Hydroxide in order to bring the pH back to the initial conditions. Care had to be taken to restore the pH in a gradual manner as to not "shock" the microbial communities. Slow remediation was also essential as over treating the tanks could cause them to become too basic, as anaerobic digester bacteria are particularly sensitive to increased ammonium concentration and this is to be avoided as even slightly basic tanks can cause total failure of mesophilic communities (comm. TH Culhane). All digesters are now at relatively stable pH values with the exception of Tank 3.

Proven High Methane Content of Biogas – Recent GC analysis of gas samples collected from tanks 1, 4, 5, and 6 shows high levels of detected methane in most cases. Preliminary analysis shows that methane concentrations have increased since the onset of Phase I research. To some extent this is an indication that we are observing healthy proportions of microbes in several tanks enough to support active methanogenesis. More work will have to be performed on the GC in order to understand long term trends and behavior of our tanks, but at first look the results seem promising.

Student education – This project has the fortunate opportunity of involving High School students in a primary scientific study. Cordova High School students have the unique ability to see some of the technical aspects and complications that go along with scientific research. The science club and chemistry class provide an excellent platform to organize student involvement. Previously, students have had the opportunity to troubleshoot and take the lead on feeding procedures for the project resulting in several very clever and innovative ideas being implemented.

Students were disappointed last year when tank acidification resulted in decreased feeding of the digesters. Despite the necessary remediation of the tanks, students were given little responsibility and direction once they were told to stop feeding. It is important to maintain a high level of enthusiasm in order to build morale among the students. If in the future, we should determine it necessary to halt a certain student experiment it is important that they be provided with other avenues in order to participate in the project. Their creativity and energy is welcomed to the project as student ideas bring new perspective to current issues found in the experiment.

Community outreach – We have had the opportunity to present our project ideas and preliminary results at meetings with the Alaska Power Association and Alaska state legislators in Juneau, and at a variety of conferences, including the Alaska Forum on the Environment and the Alaska Rural Energy Conference. Five Cordova High School students traveled to present at the Alaska Rural Energy Conference in Fairbanks. Titles of our project presentation at the Alaska Forum on the Environment and Alaska Rural Energy Conference were:

Walter Anthony, K., Culhane, TH., Koplin, C., McFadden, L., Low, A. "Improving Cold Region Biogas Digester Efficiency." McFadden, L. Alaska Forum on the Environment. Anchorage, Alaska. February 8-12, 2010.

Walter Anthony, K., Culhane, TH., Koplin, C., McFadden, L., Low, A. "Improving Cold Region Biogas Digester Efficiency." Low, A., Hess, E., Allen, J., Americus, I., Americus, B., Zamudio, A. Alaska Rural Energy Conference. Fairbanks, Alaska. April 27-29, 2010.

Biogas Handbook for Alaskans- McFadden completed the first draft of a Biogas Handbook for Alaskans, an instructional booklet specific to biogas production and applications for Alaskan communities. The Handbook will continue to be revised, and submitted as a deliverable in final form to the Denali Commission by the end of the project.

Website development- Website developer Brandon Shaw designed a site (www.cordovaenergycenter.org) for the Cordova Energy Center, the venue at which the biogas experiment has been conducted. The website provides a venue for students and community members to obtain information about the project and how to get involved. It is important to update the website often as a means to show visitors that the project is still underway, that is still producing results and that people are still encouraged to get involved.

References:

Gerardi, Michael. *The Microbiology of Anaerobic Digesters* (New Jersey: John Wiley & Sons, Inc., 2003), 23 - 45.

House, David. (1978) *The Complete Biogas Handbook*. (Alternative House Information, United States), 52.

Walter Anthony, K. M., D. A. Vas, L. Brosius, F. S. Chapin III, S. A. Zimov, Q. Zhuang (2010) Estimating methane emissions from northern lakes using ice-bubble surveys. *Limnology and Oceanography: Methods*, in press.

Weiland, P. (2010) "Biogas production: current state and perspective." *Applied Microbiology Biotechnology*. 85:849–851.

Appendix 1. Problems and solutions to managing digester feeding

Figure 7. Common overflows following a typical feeding regiment of 1kg food + 1kg water. The PVC inlet tube does not allow for easy use of a funnel and it is hard (especially for students) to observe an overflow prior to it occurring. Issues with sanitation result as many of the digesters exhibit this problem. Clogging continues to slow the feeding process and will need to be improved in the project future.

In the past, students complained that feeding the digesters was an inherently gross process, often messy, smelly and unsanitary. Digester feeding inlet tubes often clog leading to unsightly backups in the system and overflows (Figure 7). This is both undesired from a research perspective to measure the amount of input into the tanks as well as from a public health perspective to provide a safe environment for student education. As a result, preparation of food ‘slurry’ mixtures to be added to the tanks will be performed in the following way:

- Food will be collected from the Cordova High School lunch room and be placed in an industrial freezer in order to sterilize prior to being blended.
- Once a large amount of food has been accumulated, individual collections will be thawed and combined into larger, more uniform batches. These large batches of food will be blended, separated into individual digester portions and labeled.
- Labels will include the date, the sample size (mass), notes describing the food contents within the sample, and initials of quality control from either science teacher Adam Low or Casey Pape. No sample will be fed to any digester should it be missing an approved initial as both Low and Pape will be responsible for making sure all samples were prepared and cataloged properly.
- The individual ‘slurry’ will be placed back into the freezer for storage.
- The day prior to a feeding, the individual samples will be removed and mixed with the appropriate equivalent of water to assist in thawing the frozen ‘slurry’. The mixture can then be pulverized one last time prior to being added to the digesters. Final measurements will be recorded on the day of the feeding

confirming the wet weight of: total solid, total water added, combined solid plus water.

In addition, students will be required to wear gloves, apron and appropriate eye protection while feeding. Methods for preventing overflow and spill will still have to be developed as there is currently no easy solution given digester design. During the summer when students were gone and turnover in technicians was occurring, Pape arrived to the project grounds to find containers, glassware and funnels left out after chemical treatments and feedings with the buildup of mold and potentially noxious bacteria (Figure 8). In the future all materials used in the preparation of feeding will be required to be cleaned and sanitized immediately following feeding. The use of bleach will help to ensure that pathogens are not exposed to students or food material. With careful controls such as these we can begin to feed the digesters on a more consistent basis as well as maintain high levels of student morale. Our intention is to eventually get feeding back up to the original schedule as defined in the initial project proposal.

Figure 8. Dirty glassware and feeding containers found within the Connex. From now on any beakers or containers used to feed or remediate the chemistry of the primary digesters will be cleaned expressly after use. Cordova High School does not have any access to distilled or deionized water at this time. The use of non-chlorinated water, though not of practical necessity to the project, could be purchased and stored in a hand-pump reservoir available on site.

Appendix 2.

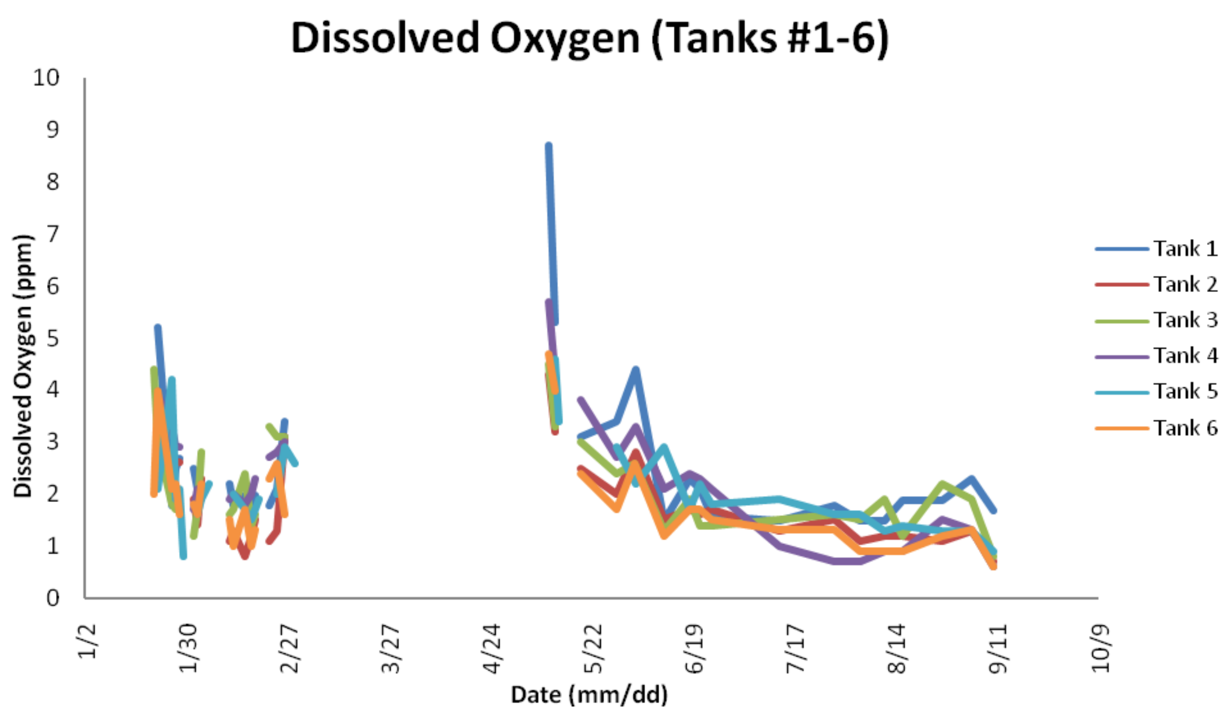

Figure 9. Dissolved oxygen (DO) readings indicate the amount of oxygen in the system. The tanks should have a DO as close to 0ppm as possible (1 ppm = 1 mg/L). Gaps in the chart above indicate periods where DO could not be measured due to improperly functioning equipment. The high readings in early May could have been caused by exposure of the tanks to air in our attempts to mediate low pH concerns. DO measurements were taken with a Xplorer GLX Pasco PS-2002 Multi-Datalogger until March 24, following which they have been taken by a Hanna HI9142 DO meter.

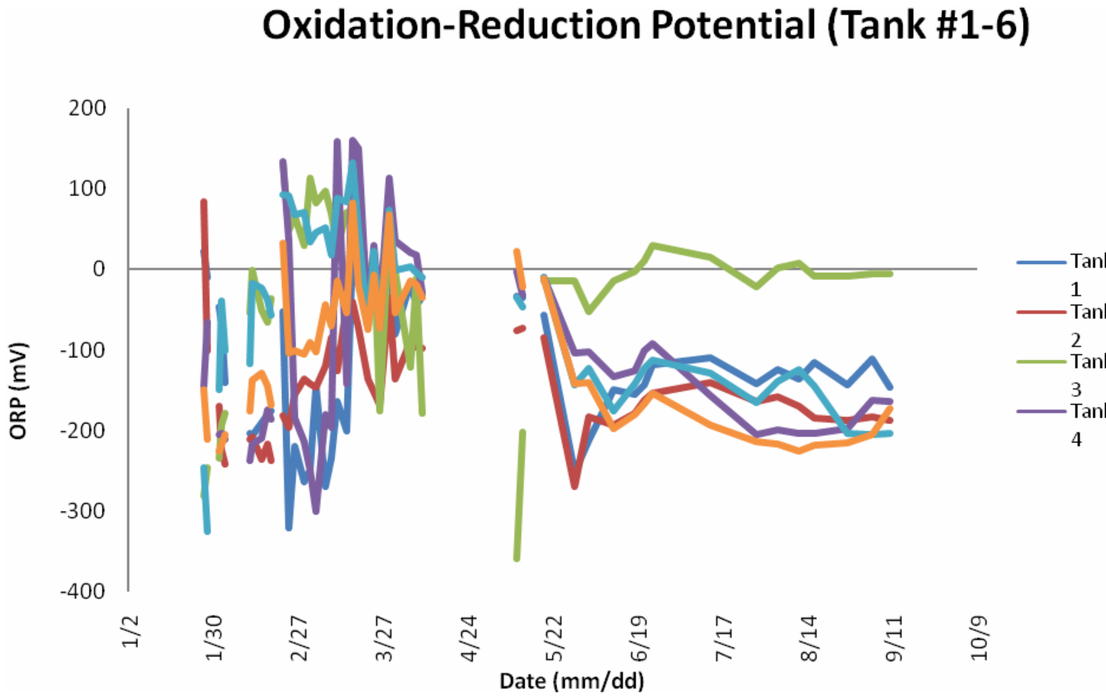

Figure 10. Oxidation-reduction potential (ORP) indicates the availability of oxidative molecules and ions in the system. ORP is a valuable measure as it determines the likelihood that bacteria will follow the methane fermentation pathway. For healthy methane production, samples should have an ORP of -300. From January 21-April 9, ORP was measured with a Xplorer GLX Pasco PS-2002 Multi-Datalogger. From May 10 forward, it was measured with an Oakton PC510 ORP meter.

Appendix 3. Pictures of project since Y1Q2 report (digital format with a short description of the activity and names of those in the photos).

Mr. Low's 2010 Science Club students after one of their weekly meetings. (In this picture: Craig Bailer, Ben Americus, Adam Zamudio, Sophia Myers, James Allen, Eli Beedle, Josh Hamberger, Keegan Crowley, Kris Ranney, and Carl Ranney)

1,000 L HDPE reinforced containers used for storing Phosphoric acid at the local fish oil plant in Cordova. These containers could be used in order to improve digester support.

Casey Pape observed enthusiastically washing glassware after feeding the tanks.

Current configuration of secondary water-pressure tanks with attached pump buckets. Weathering on the tanks has caused considerable lead and distention.

Small leaks caused by joint stress due to flexion of secondary tanks.

Current layout of the Connex container and project site. More signs might spark public interest in the project research and grant stakeholders.

Cordova High School senior Craig Bailer along with science teacher Adam Low preparing food samples prior to feeding.

Senior Craig Bailer, observed taking effluent samples for chemistry measurements.