

**CHARACTERIZATION OF SULFUR FLOWS  
IN FARM DIGESTERS  
at  
SHELAND FARMS**

Prepared for

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## **Section 1 DESCRIPTION**

The Sheland Farm is located on County Rt 79 near Adams, NY. A schematic of the layout of the digester and associated equipment can be found in the Appendix, Figure A-1. At the time of this study there were 473 milking cows, 93 dry cows and 71 bred heifers. Based on the American Society of Agricultural & Biological Engineers (ASABE) equations there were 558 equivalent milking cows during the study. The cows are housed in a freestall barn where the stalls are bedded with separated solids. The alleys are scraped with a “bobcat” tractor at 8:00, 16:30 and 1:00. A *Houle* piston manure pump moves the manure from a single raw manure pit in the barn to a reception tank next to the building that houses the manure handling equipment, liquid – solids separator and the engine/generator set. This building is attached to the vertical digester.

The reception tank is 24 ft 4 in x 15 ft 10 in x 10 ft deep and holds 240 gallons per inch of depth. There is a 10 hp mixer in the reception tank that operates 50% of the time. A 5 hp separator manure pump continuously pumps manure from the reception tank to the separator. The separated solids drop into a rotating drum composter where the solids are composted. The composted solids are transferred to a truck with a flat belt elevator. The separated liquid flows by gravity back to reception tank where it is mixed with the incoming raw manure. The 10 hp digester feed pump moves the mixed liquid manure from the reception tank to the digester. This pump operates 1.2 minutes every 30 minutes (30% of the time). The digester effluent overflows the digester at the top of the digester and flows by gravity to a long term storage lagoon.

The biogas pipe from the digester enters the machine room where a temperature and pressure compensated gas meter measures and records the flow. The biogas then flows through a “U” shape condenser where chilled water is circulated to remove water from the biogas prior to entering the engine. A second meter measures the flow of biogas to the engine. The biogas that cannot be used by the engine is sent to a flare via a pressure regulator. A slightly positive pressure is maintained in the digester.

**Section 2**  
**RESULTS – 24 HOUR TEST, JANUARY 29-30, 2008**

Four times during the 24 hr test the biogas was tested for carbon dioxide and hydrogen sulfide. The tests were conducted using *Gastec* gas tubes and a *Bacharach* unit for carbon dioxide and *Gastec* gas tubes for hydrogen sulfide. The values measured are given in Table 2-1. All values are for dry gas. The average

Table 2-1. Concentration of Carbon Dioxide and Hydrogen Sulfide in Biogas at Sheland Farm.

| Test Number            | CO <sub>2</sub> percent |           | H <sub>2</sub> S <sup>+</sup> | Gas Pressure* | Gas Temp* |
|------------------------|-------------------------|-----------|-------------------------------|---------------|-----------|
|                        | Tubes                   | Bacharach | percent                       | in water      | °F        |
| No. 1<br>Jan 29, 15:00 | 40                      | 40.5      | 0.55                          | 11            | 104       |
|                        | 40                      | 40        | 0.55                          |               |           |
| No. 2<br>Jan 29, 17:00 | 40.5                    | 39.5      | 0.55                          | 11            | 105       |
|                        | 40                      | 39        | 0.50                          |               |           |
| No. 3<br>Jan 30, 7:45  | 40                      | 40        | 0.55                          | 11            | 104       |
|                        | 40                      | 39        | 0.55                          |               |           |
| No. 4<br>Jan 30, 8:45  | 39                      | 39        | 0.55                          | 11.5          | 101       |
|                        | 39                      | 38.5      | 0.55                          |               |           |
| Average                | 39.8                    | 39.7      | 0.54                          | 11            | 104       |
| Standard Dev.          | 0.53                    | 0.61      | 0.02                          | 0.25          | 1.7       |
| Confidence Int ±       | 0.15                    | 0.1       | 0.005                         | 0.06          | 0.4       |

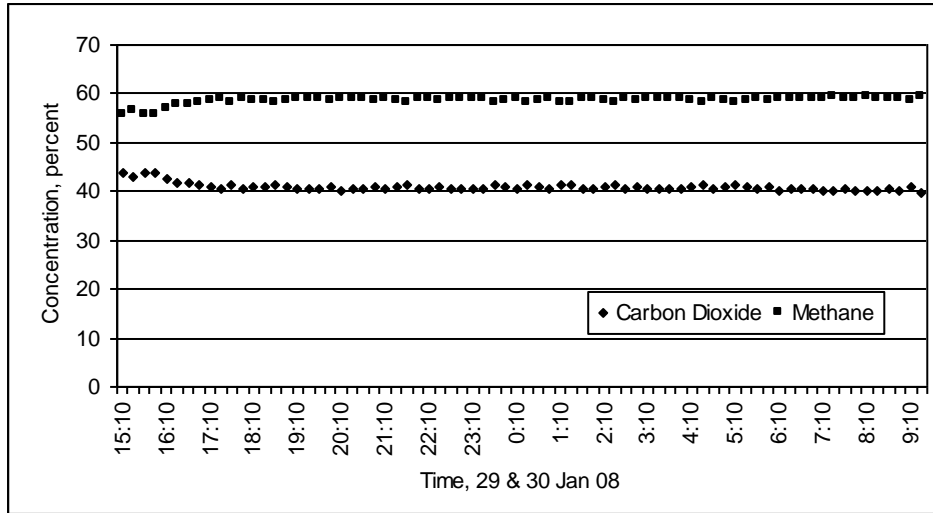
+ after condenser

\* conditions at engine after blower

concentration of carbon dioxide measured with the gas tubes (39.8%) and the Bacharach unit (39.7%) were nearly equal. The values for hydrogen sulfide appear to be nearly the same. However, the graduation on the gas tubes used were every 0.2% (0.4 to 0.6) which meant that all readings were estimated [ $\pm 0.05\%$ ]. The pressure of the biogas near the engine averaged 11 inches of water. The temperature of the biogas increased through the blower that was on the engine side of the condenser.

During the 24 hr test the carbon dioxide and methane were monitored with a *GEM 2000* instrument. The biogas was analyzed every 15 minutes. The values for carbon dioxide are plotted in Figure 2-1. A problem was encountered with measuring CH<sub>4</sub>. There apparently was an interference with the hydrogen sulfide. The manufacturer suggested that because these values are for a dry gas and there are few trace gases such as hydrogen sulfide, the concentration of methane could be by difference. The methane plot in Figure 2-1 takes into account the concentration of hydrogen sulfide to be constant at 0.55%. There is no known reason why there was a change in the CO<sub>2</sub> level during the first two hours. The digester is fed every 30 minutes.

**Figure 2-1. Carbon Dioxide and Methane Concentration in Dry Biogas at Sheland Farms.**



The statistical analysis of the data recorded by the *GEM 2000* is shown in Table 2-2. The standard

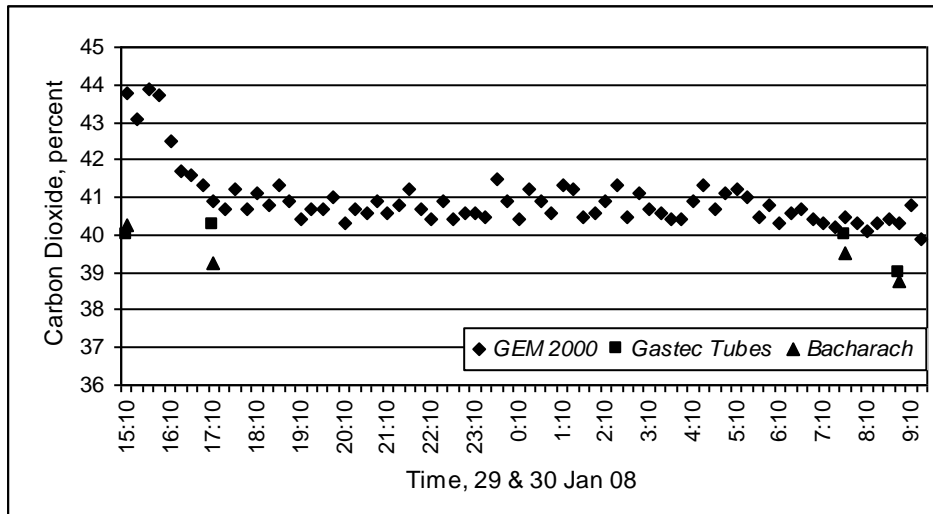
Table 2-2. Statistical Analysis of Data from *GEM 2000* Unit.

| Gas             | Average | Maximum | Minimum | Std Dev | Confidence |
|-----------------|---------|---------|---------|---------|------------|
| CO <sub>2</sub> | 40.9    | 43.9    | 39.9    | 0.77    | 0.18       |
| CH <sub>4</sub> | 58.5    | 59.6    | 55.6    | 0.77    | 0.18       |

deviation and confidence interval are the same for both gases because the concentration of methane was calculated by difference. The average value of carbon dioxide as measured by all three methods was within 1.2% of each other.

The percent carbon dioxide measured with the three different analyzers is shown in Figure 2-2. The change in concentration during the first two hours is seen clearly. However, the concentration measured with the gas tubes and Bacharach unit did not show this decline. Instead they showed a more consistent concentration throughout the 24 hours. Because concentration of methane in biogas will generally be based on the percent carbon dioxide measured with a Bacharach unit, validating this procedure is important.

Figure 2-2. Carbon Dioxide Concentration Measured with Three Analyzers.

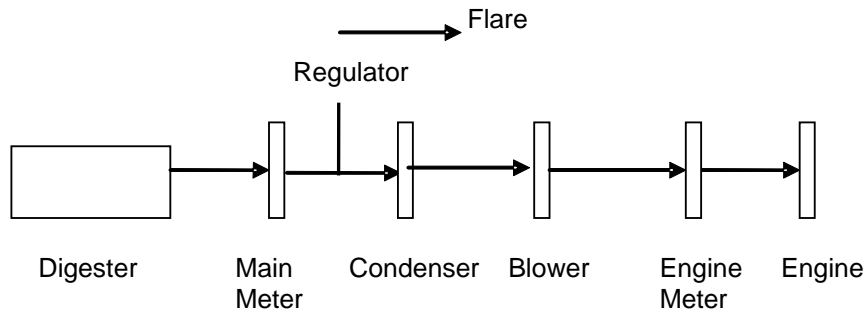




**Section 3**  
**RESULTS: 30 DAY TEST, NOVEMBER 16 – DECEMBER 15, 2007**

During the 30 day test the operator recorded data free time each day. The following data was recorded; biogas temperature and pressure at the meter, reading from the biogas meters, two samples of biogas each for hydrogen sulfide (gas tubes) and carbon dioxide (Bacharach unit). The raw data from the 30 day test can be found in the Appendix. Tables A-1, 2. There are two biogas meters, main and engine, at Sheland Farm as shown in Figure 3-1. Both meters record the gas flow at standard pressure (1 atm or 14.696 psi) and temperature (0° C). There is a water cooled condenser and a blower between the two meters. The pressure regulator and takeoff for the flare are before the condenser.

**Figure 3-1. Diagram of Flow of Biogas at Sheland Farms.**



The properties (average and statistical) of the biogas recorded by the main meter and the engine meter are shown in Table 3-1. The statistical analysis includes average, standard deviation and confidence interval ( $\pm$ ). The temperature of the biogas increased about 25 F and the pressure increased about 13 inch of water between the two meters. This was because of the blower. More heat was added to the biogas than was observed at other farms. This increase in temperature reduces the density of the gas so the engine receives

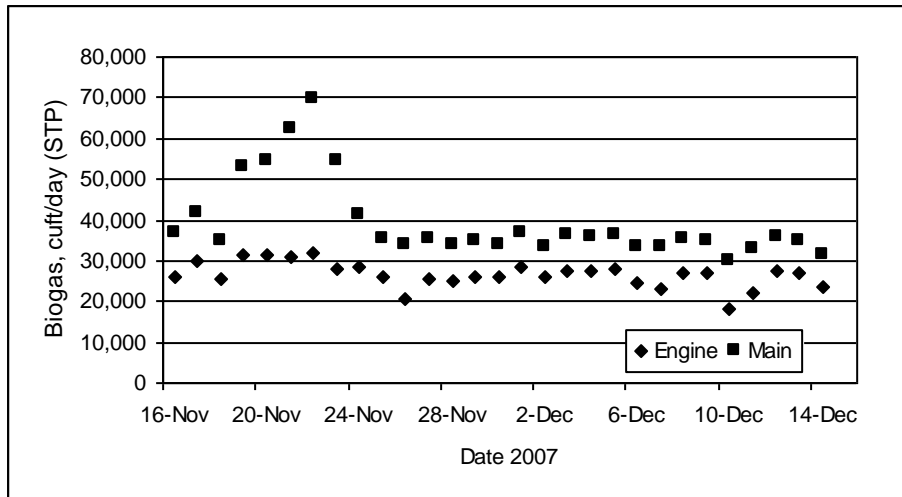
Table 3-1. Summary of Analysis of the Data Recorded During the 30 Day Test at Sheland Farms.

| Parameter  | Main Meter |                |                    |            |          | Engine Meter |                |                    |            |          |
|------------|------------|----------------|--------------------|------------|----------|--------------|----------------|--------------------|------------|----------|
|            | Temp<br>F  | Pres<br>In H2O | Biogas<br>cuft/day | H2S<br>ppm | CO2<br>% | Temp<br>F    | Pres<br>In H2O | Biogas<br>cuft/day | H2S<br>ppm | CO2<br>% |
| Average    | 71.7       | 3              | 39,177             | 2,241      | 35.8     | 97.1         | 16.5           | 26,590             | 2280       | 36.5     |
| Stand Dev  | 6.0        | 3              | 9,780              | 1,310      | 2.7      | 10.6         | 6.0            | 3,170              | 1320       | 2.6      |
| Confid Int | 1.2        | 0.7            | 3,560              | 223        | 0.06     | 2.2          | 1.6            | 1,160              | 226        | 0.4      |
| No. Sample | 90         | 89             | 29                 | 132        | 90       | 90           | 57             | 29                 | 131        | 180      |

fewer pounds of methane per cubic foot of gas drawn into the engine. The concentration of hydrogen sulfide and carbon dioxide were similar. However, because the temperature and pressure of the biogas where these samples were taken were not the same, the sulfur and carbon dioxide would be different. For the sulfur analysis the flow and properties at the main meter will be used.

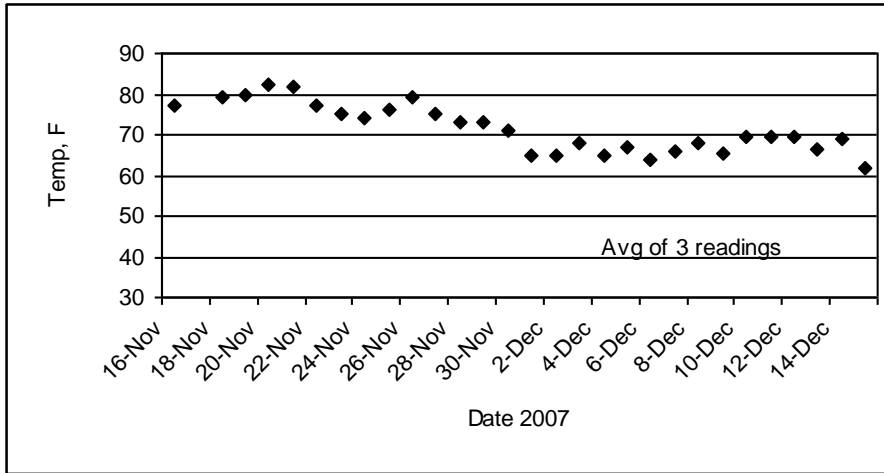
The flow of biogas at the main and engine meters is shown in Figure 3-2. There is no firm explanation for the rapid rise and decline in the production of biogas during the first week of the 30 day test. The engine meter did not show a corresponding increase. The vent to the flare is between the two meters. Perhaps there was a gas leak or the flare was operating. There was a small increase in the temperature of the biogas during this time as seen in Figure 3-3. This increase could indicate an increase in digester temperature.

Figure 3-2. Biogas Flow at the Main and Engine Meters at Sheland Farms.



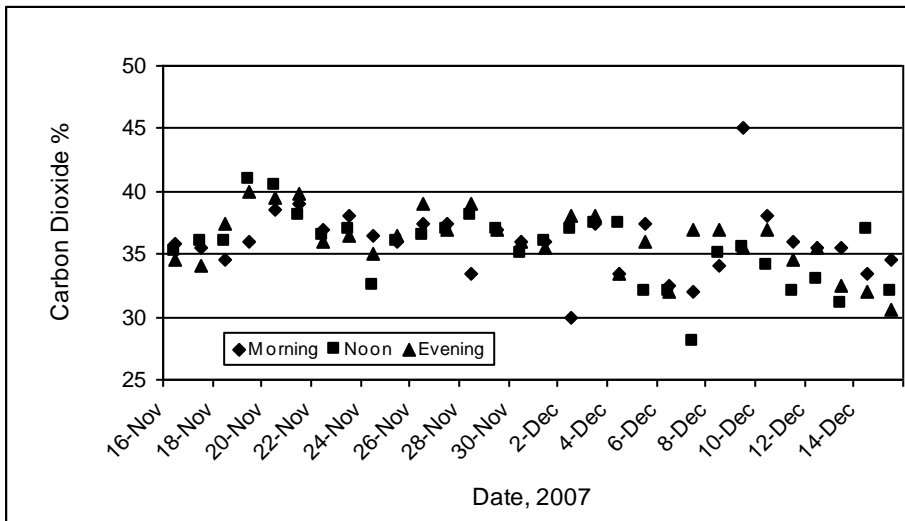
The difference in flow between the two meters is believed to be due to an error in the engine meter. However, there was a smaller increase in gas temperature on November 26 and 27 but there was no corresponding increase in gas production. For the purposes of analyzing for sulfur flow, the average daily flow of biogas between November 24 and December 15 of 34,700 cuft/day will be used.

**Figure 3-3. Average Daily Temperature of Biogas at the Main Meter at Sheland Farms.**



The concentration of carbon dioxide in the morning, noon and evening during the 30 day test is shown in Figure 3-4. The concentrations varied more than at the other farms tested. This digester had not been operating as long as other digesters but there was no indication that the digester had not reached steady state. There was a change in the digester mixing schedule during the 30 day test. On November 14 the digester mixing pump was operating 6 minutes every hour. After December 9 the mixer was set to operate 3 minutes every 15 minutes or 12 min/hr. There seemed to be more variation in percent CO<sub>2</sub> after early

**Figure 3-4. Concentration of Carbon Dioxide at Main Meter, Morning, Noon and Evening.**



The results are shown in Table 3-2. The average concentration of the three times during the day are similar as are the standard deviations and confidence levels.

Table 3-2. Statistical Analysis of Concentration of CO<sub>2</sub> and H<sub>2</sub>S for Morning, Noon and Evening.

| Analysis | Carbon Dioxide, percent |      |         |         | Hydrogen Sulfide, ppm |       |         |         |
|----------|-------------------------|------|---------|---------|-----------------------|-------|---------|---------|
|          | Morning                 | Noon | Evening | Average | Morning               | Noon  | Evening | Average |
| Average  | 36.0                    | 35.4 | 36.1    | 35.8    | 2,108                 | 2,206 | 2,157   | 2,238   |
| Stdev    | 2.7                     | 2.8  | 2.4     | 2.0     | 1,397                 | 1,325 | 1,387   | 1,103   |
| Confid   | 0.97                    | 1.03 | 0.87    | 0.72    | 508                   | 500   | 523     | 401     |

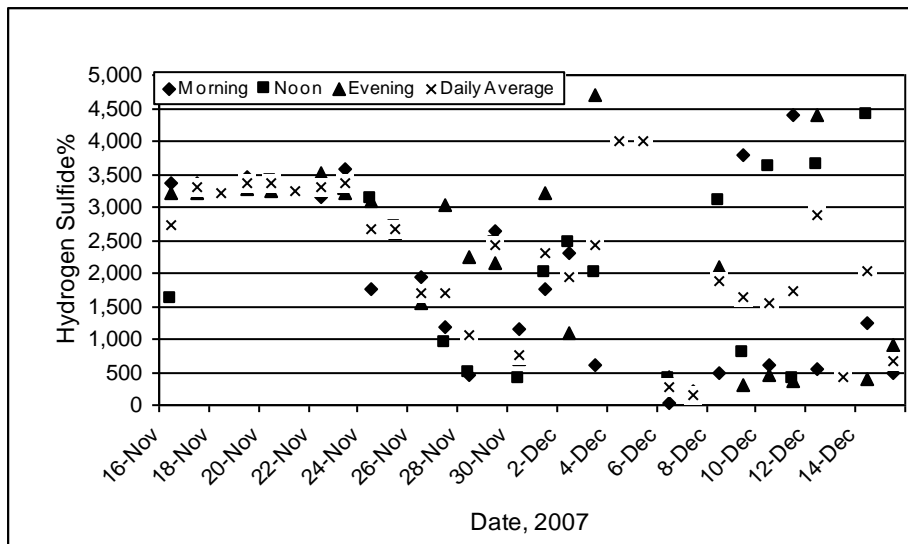
The concentration of carbon dioxide was also analyzed before and after December 1. The results are shown in Table 3-3. The average concentration after December 1 increased about 2% while the standard deviation increased nearly 70% and confidence interval increased 80%.

Table 3-3 Analysis of the Concentration of Carbon Dioxide.

| Dates         | Average | Stdev | Confidence |
|---------------|---------|-------|------------|
| Through Dec 1 | 36.8    | 1.78  | 0.50       |
| After Dec 1   | 34.7    | 3.01  | 0.91       |

The concentration of hydrogen sulfide at the main meter during the 30 day test is shown in Figure 3-5. Again there was considerable variation after November 25 with no reason why this should be the case. To emphasize this variation the average daily values were plotted and are shown as X. The values for morning, noon and evening were also analyzed. The results are shown in Table 3-2. The average, standard deviation and confidence intervals were all similar. There was no greater variability between days whether morning, noon or evening.

Figure 3-5. Concentration of Hydrogen Sulfide at Main Meter, Morning, Noon and Evening.



**Section 4**  
**MASS FLOW OF SULFUR**

Samples of the total mixed ration (TMR), drinking water, digester influent and effluent were taken at three different times during the study. The TMR and digester influent and effluent were analyzed for total solids (TS) and sulfur (S) by Dairy One, Inc. in Ithaca, NY. Drinking water was analyzed by Community Science Institute, also located in Ithaca, NY.

**TOTAL MIXED RATION**

Manure from 637 animals (473 milking, 71 bred heifers and 93 dry cows) entered the separator and digester system. The TMR fed to these animals is listed in Table 4-1. The animals consumed 97% of the TMR fed. The sulfur content (as fed) of the TMR is also given in Table 4-1 along with the pounds of sulfur in the TMR consumed by the animals. The raw data for the TS and sulfur concentration for the samples collected can be found in the Appendix Table A-3. A total of 72.3 lbs of sulfur enter the system daily via the TMR.

Table 4-1. Numbers of Animals, TMR Fed and Sulfur Content.

| Animals      |        | lbs TMR/day |          | Sulfur  |         |
|--------------|--------|-------------|----------|---------|---------|
| Milking      | Number | Delivered   | Consumed | Percent | lbs/day |
| Group 1      | 148    | 19,425      | 18,842   | 0.11    | 20.02   |
| Group 2      | 151    | 22,225      | 21,558   | 0.10    | 20.48   |
| Group 3      | 144    | 23,630      | 22,921   | 0.07    | 15.76   |
| Group 12     | 30     | 2,575       | 2,498    | 0.09    | 2.22    |
| Bred Heifers | 71     | 7,000       | 6,790    | 0.09    | 5.86    |
| Dry Cows     | 93     | 10,400      | 10,088   | 0.08    | 7.94    |
| Total        | 637    |             |          |         | 72.3    |

**DRINKING WATER**

The drinking water at Sheland Farm comes from wells. The results of the analysis of the cow drinking water are given in Table 4-2. The contribution of the drinking water to the sulfur input to the manure averaged 0.71 lb S/day.

Table 4-2. Sulfur in Cow Drinking Water.

| Date       | Sample | mg Sulfate/L | lbs S/1000 gal | lbs S/day |
|------------|--------|--------------|----------------|-----------|
| 11/21/2007 |        | 16           | 0.045          | 0.71      |

conversion factor; mg sulfate/l to lb sulfur/1000gal = 0.0028  
 Water Consumption, 15,925 gal/day @ 25 gal/cow-day

**MANURE**

The properties (total solids and sulfur) for the digester influent and effluent are given in Table 4-3. As stated in the Description the raw manure is pump from the pit in the freestall barn to the reception pit. When sample were taken of the raw manure on November 28 surface runoff was entering the pit. The percent TS in the influent samples taken on November 28 were more than 4 standard deviations below the mean. These values were not used. The concentration of the total solids in the influent is lower than the raw manure because solids are removed by a liquid/solid separator. The percent total solids in the reception pit changes continuously as solids are removed by the separator and solids are added every hour by raw manure pump. The 6.69% TS is probably unreliable. The total solids did show a decrease to 5.16% within the digester.

Table 4-3. Properties of Raw Manure and Digester Influent and Effluent, Sheland Farm.

| Date     | Raw Manure |       |              | Influent |        |              | Effluent |       |              |
|----------|------------|-------|--------------|----------|--------|--------------|----------|-------|--------------|
|          | Sample     | % TS  | % S          | Sample   | % TS   | % S          | Sample   | %TS   | % S          |
| 11/12/07 | SFRM1      | 9.62  | 0.04         | SFDI 1   | 6.52   | 0.03         | SFDE1    | 5.45  | 0.025        |
|          | SFRM2      | 8.98  | 0.03         | SFDI 2   | 6.79   | 0.03         | SFDE2    | 5.62  | 0.030        |
|          |            |       |              |          | SFDI 3 | 6.37         | 0.03     | SFDE3 | 5.82         |
| 11/28/07 | SFRM1      | 3.14* | 0.015        | SFDI 1   | 4.81*  | 0.02         | SFDE1    | 4.9   | 0.025        |
|          | SFRM2      | 1.30* | 0.02         | SFDI 2   | 4.63*  | 0.02         | SFDE2    | 4.98  | 0.025        |
|          | SFRM3      | 5.83* | 0.02         | SFDI 3   | 5.07*  | 0.025        | SFDE3    | 5.24  | 0.025        |
| 12/21/07 | SFRM1      | 5.95  | 0.025        | SFDI 1   | 6.91   | 0.03         | SFDE1    | 4.93  | 0.03         |
|          | SFRM2      | 6.44  | 0.02         | SFDI 2   | 6.70   | 0.025        | SFDE2    | 4.64  | 0.03         |
|          | SFRM3      | 5.31  | 0.025        | SFDI 3   | 6.82   | 0.025        | SFDE3    | 4.86  | 0.025        |
|          | Average    | 7.26  | <b>0.024</b> |          | 6.69   | <b>0.028</b> |          | 5.16  | <b>0.027</b> |
|          | Stand Dev  | 1.92  | 0.008        |          | 0.203  | 0.003        |          | 0.395 | 0.003        |
|          | Conf Int ± | 1.68  | 0.005        |          | 0.163  | 0.002        |          | 0.258 | 0.002        |

\* Values not used - excess water in pit from runoff.

Based on the samples used the percent sulfur decreased during digestion. These values will be used with the mass flow through the digester to determine actual sulfur “loss” in the digester.

**BEDDING**

Separated solids are used for bedding at Sheland Farm. The properties of the bedding are given in Table 4-4. Samples of the separated solids were taken at the discharge from the rotatory composter, as the material entered the elevator. The solids content of this material was 39.1%. The weight of separated solids used per day (4,040 lb) was obtained by weighing the truck. The percent dry matter of the separated solids when weighed was 47.5% (reported by Mr. Shelmidine). The sulfur added to the manure flow from the freestall via the bedding was 3.9 lb S per day.

Table 4-4 Properties of Separated Solids at Sheland Farms (samples taken by Ludington).

| Date                  | lbs/day (wet)     | lbs/day (dry) | Samples delivered to Dairy One |                |                  | lbs S/day  |
|-----------------------|-------------------|---------------|--------------------------------|----------------|------------------|------------|
|                       |                   |               | Sample                         | Total Solids % | S % (dry matter) |            |
| 11/12/2007            | 4,040<br>47.5% dm | 1,920         | SF SS1                         | 38.1           | 0.22             | 4.22       |
|                       |                   |               | SF SS2                         | 38.6           | 0.26             | 4.99       |
|                       |                   |               | SF SS3                         | 38.4           | 0.22             | 4.22       |
| 12/21/2007            | 4,040<br>47.5% dm | 1,920         | SF SS1                         | 39.2           | 0.16             | 3.07       |
|                       |                   |               | SF SS2                         | 39.8           | 0.18             | 3.46       |
|                       |                   |               | SF SS3                         | 40.2           | 0.18             | 3.46       |
| Average               |                   |               |                                | <b>39.1</b>    | <b>0.20</b>      | <b>3.9</b> |
| Standard Dev          |                   |               |                                | 0.83           | 0.04             |            |
| Confidence Integral ± |                   |               |                                | 0.66           | 0.03             |            |

### MILK

The concentration of sulfur in milk is low but with the volume of milk shipped from the farm the sulfur in milk can not be ignored. Table 4-5 shows the calculation for the sulfur in milk to be 9.6 lb S per day.

Table 4-5 Sulfur in Milk at Sheland Farm

| RHA | lbs/cow-yr | lbs/cow day | # of Cow | Sulfur* | S             | Total      |
|-----|------------|-------------|----------|---------|---------------|------------|
|     |            |             |          | %       | lbs S/cow day | lbs S/day  |
|     | 24,800     | 67.9        | 473      | 0.03    | 0.020         | <b>9.6</b> |

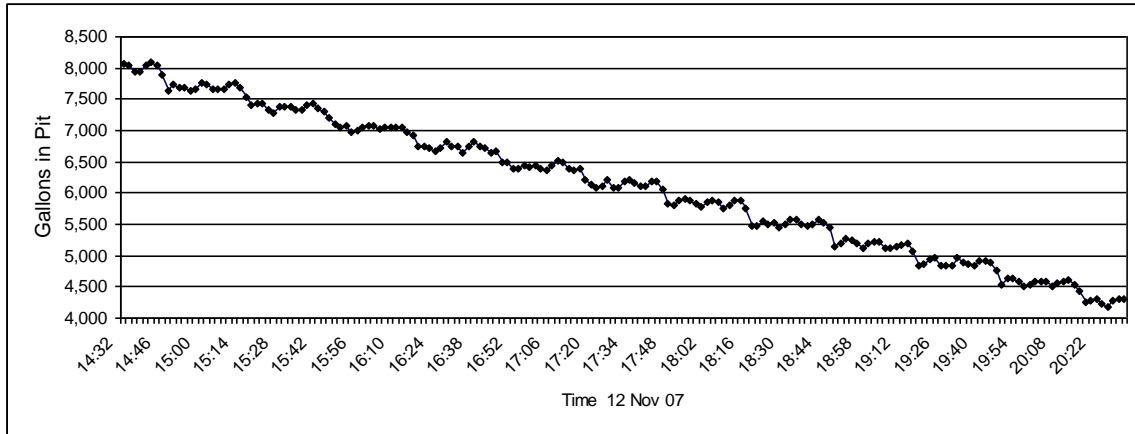
\* based on data from Trace Minerals Research

### MASS FLOW OF MANURE

The liquid level in the influent pit was monitored for 3 days in November 12 – 16, 2007. On November 12 there were 6 hours when the raw manure pump did not appear to operate. The results of the recording are shown in Figure 4-1. During this period the change in volume was 3,640 gal. The digester influent pump operated 12 times giving an average flow per cycle of 300 gal. With 48 pump cycles per day the flow to the digester was 14,400 gal/day. Using an assumed density of 8.5 lb/gal and the total solids content given in Table 4-3 of 6.69%, the flow of total solids to the digester was 8,190 lb per day.

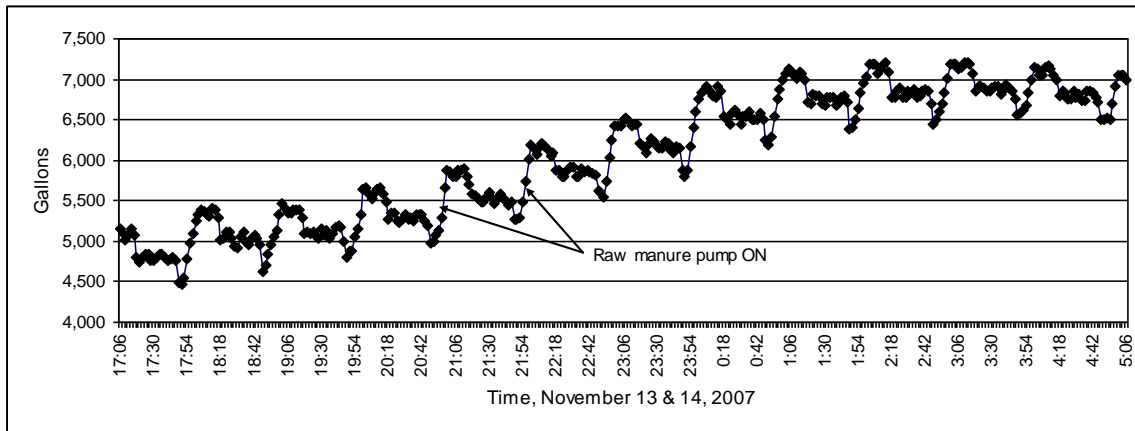
With 8,190 lb TS going to the digester and 1,920 lb TS removed by the separator per day (see Table 4-4) and assuming steady state, the total solids delivered to the reception pit via the raw manure pump would be 10,100 lb/day.

**Figure 4-1. Digester Influent Pump Operation at Sheland Farm.**



The plot in Figure 4-2 shows the change in gallons of manure in the reception pit over a 12 hour period. The increase in gallons which happened 12 times is when the raw manure pump operated. The reduction in gallons in the pit, which happened 24 times (difficult to see), occurred when digester influent pump operated.

**Figure 4-2. Gallons in Reception Pit at Sheland Farm During a 12 Hour Period.**



The raw manure pump averaged 780 gallons per cycle or 18,700 gallons per day (24 cycles per day). Assuming a density of 8.5 lb/gal and with a total solids content of 7.26% (see Table 4-3) the total solids delivered to the reception pit would be 11,500 lb/day.

Formulas from ASABE were used to predict the total solid produced by these 673 animals. The result was a production of total solids at 9,850 lb/day. This worksheet can be found in the Appendix, Table A-4. The total solids production is equivalent to 558 milking cows. The bedding (separated solids) must be added to get the total solids leaving the freestall barn or  $9,850 + 1,920 = 11,770$  lbs.



A fourth method for determining the total solids entering the digester is the “mass balance method”. The results are shown in Table 4-6. The total solids in the digester influent are calculated to be 10,500 lb/day (after solids were removed). This compares favorably with the ASABE estimate of 9,850 (without bedding).

Table 4-6. Mass Balance Method for Determining Influent Total Solids.

|                   |         |                                 |        |                                  |                          |
|-------------------|---------|---------------------------------|--------|----------------------------------|--------------------------|
| Vo =              | 39,560  | ft <sup>3</sup> /day, dry       |        | Volume of biogas                 |                          |
| CH <sub>4</sub> = | 0.641   |                                 |        | Concentration of methane         |                          |
| CO <sub>2</sub> = | 0.36    |                                 |        | Concentration of carbon dioxide  |                          |
| IPTS =            | 6.69    | %                               |        | Percent total solids in influent |                          |
| EPTS =            | 5.16    | %                               |        | Percent total solids in effluent |                          |
| IPS =             | 0.028   | %                               |        | Percent sulfur in influent       |                          |
| EPS =             | 0.027   | %                               |        | Percent sulfur in effluent       |                          |
| B =               | 2,869   | lb biogas/day dry               |        | Weight of biogas                 |                          |
|                   |         |                                 |        |                                  |                          |
| T =               | 72      | F                               |        | Biogas temperature at meter      |                          |
| T =               | 22.2    | C                               |        |                                  |                          |
| bVS =             | 2,583   | 90%*                            |        | Volatile solids consumed         |                          |
| bW =              | 287     | 10%*                            |        | Mass of water consumed           |                          |
| Dw =              | 0.00104 | lb water/ft <sup>3</sup> biogas |        |                                  |                          |
| We =              | 41.3    | lb water/day                    |        | Water in saturated biogas        |                          |
| ITS =             | 0.067   | ITW =                           | 0.933  | Total solids in influent         |                          |
| ETS =             | 0.052   | ETW =                           | 0.948  | Total solids in effluent         |                          |
|                   |         |                                 |        |                                  |                          |
| ITM =             | 159,497 | lb/day                          | 18,764 | gpd                              | Total mass of influent   |
| ETM =             | 156,586 | lb/day                          | 18,422 | gpd                              | Total mass of effluent   |
| Δ TM =            | 2,911   | lb/day                          |        |                                  | Change in mass           |
| ITS =             | 10,662  | lb/day                          |        |                                  | Total solids in influent |
| ETS =             | 8,080   | lb/day                          |        |                                  | Total solids in effluent |
| Δ TS =            | 2,583   | lb/day                          |        |                                  | Total solids "lost"      |
| Sulfur In         | 45.2    | lb/day                          |        |                                  | Sulfur in influent       |
| Sulfur Out        | 42.6    | lb/day                          |        |                                  | Sulfur in effluent       |
| Δ Sulfur          | 2.56    | lb/day                          |        |                                  | Sulfur "lost"            |

\*Richards, B.K., R.J. Cummings, T.E. White, W.J. Jewell. Methods For Kinetic Analysis of Methane Fermentation in High Solids Biomass Digester, Biomass and Bioenergy, Vol. 1, No. 2, pp 65-73, 1991.

These methods are summarized in Table 4-7. For the purposes of determining the mass flow of sulfur through the digester the mass balance method will be used because this method also determine the mass flow of the digester effluent.

Table 4-7. Summary of Methods for Determining Mass Flow of Total Solids at Sheland Farm.

| Method           | Gal/day | Lb/day  | % TS | Manure<br>Lb TS/day | Bedding<br>Lb TS/day | Total<br>Lb TS/day |
|------------------|---------|---------|------|---------------------|----------------------|--------------------|
| To Reception Pit |         |         |      |                     |                      |                    |
| Raw Manure Pump* | 18,700  | 158,950 | 7.26 |                     |                      | 11,500             |
| ASABE            |         |         |      | 9,850               | 1,920**              | 11,770             |
| To Digester      |         |         |      |                     |                      |                    |
| Influent Pump    | 14,400  | 122,400 | 6.69 |                     |                      | 8,190              |
| Mass Balance     |         | 159,500 | 6.69 |                     |                      | 10,660             |

\* Includes manure and bedding

\*\* From separated solids

## BIOGAS

The results of analyzing the biogas for sulfur are shown in Table 4-8. Data from the 30 day test [average biogas production per day, gas temperature and pressure along with the concentration of carbon dioxide] were used. See Appendix A, Tables A-1, 2. The mass flow of sulfur “lost” during digestion and removed via the biogas was 7.2 lb S per day.

The flow of sulfur through the system is summarized in Table 4-9. The sulfur in the raw manure and bedding (TMR + drinking water – milk + bedding) was calculated to be 67.3 lb S/day. The digester influent flow based on the influent pump operation was 14,400 gal/day or 122,400 lb/day. With a sulfur content of 0.028%, the sulfur flow to the digester was 34.3 lb S/day. The mass balance method estimated 45.2 lb S/day. These numbers are considerably less than the 67.3 lb computed based on the inputs in the barn. There is no known explanation for this discrepancy.

The sulfur in the digester effluent was calculated to by 42.6 lb S/day or a change (loss) in sulfur of 2.6 lb S/day. The sulfur in the biogas was calculated to be 7.2 lb S per day. This is shown in Table 4-8.

Table 4-8. Analysis of the Biogas

Based on averages from 30 day test, main meter  
 Biogas meter, Temp & pressure compensated (60F & 14.696 psia)

**Input Data - yellow area**

|                              |                         |
|------------------------------|-------------------------|
| Biogas temp @ meter          | 71.7 F                  |
| Pressure in gas line         | 3.4 in H <sub>2</sub> O |
| Biogas flow (meter)          | 39,177 cuft/day         |
| Elevation of meter           | 610 ft                  |
| H <sub>2</sub> S (dry basis) | 2,238 ppm               |
| CO <sub>2</sub> (dry basis)  | 35.8 %                  |

|                       |             |
|-----------------------|-------------|
| P <sub>elev</sub>     | 14.373 psia |
| P <sub>m</sub>        | 0.123 psig  |
| P <sub>line</sub>     | 14.496 psia |
| Volume of water vapor | 2.60 %      |

|   |                           |
|---|---------------------------|
| Standard Pres.                            | 14.696 psia               |
| Standard Temp.                            | 0 ° C                     |
| Methane, low heating value                | 21,518 Btu/lb             |
| Weight CH <sub>4</sub> at 0° C and 1 atm  | 0.0446 lb/ft <sup>3</sup> |
| Weight CO <sub>2</sub> at 0° C and 1 atm  | 0.1227 lb/ft <sup>3</sup> |
| Weight H <sub>2</sub> S at 0° C and 1 atm | 0.0948 lb/ft <sup>3</sup> |

**Calculations** (assume pressure at 1 atm)

|                             |                 |
|-----------------------------|-----------------|
| Biogas flow (wet) at 71.7 F | 40,618 cuft/day |
| Biogas flow (dry) at 71.7 F | 39,561 cuft/day |

|   |                             |
|---|-----------------------------|
| Concentration of methane, CH <sub>4</sub> | 64.0 %                      |
| Volume of CH <sub>4</sub> @ 71.7 F        | 25,310 ft <sup>3</sup> /day |
| Volume of CH <sub>4</sub> @ STP           | 23,100 ft <sup>3</sup> /day |

**Weight of CH<sub>4</sub>** **1,030 lb/day**

|                            |                         |
|----------------------------|-------------------------|
| <b>HEATING VALUE (low)</b> | 22,169,365 Btu/day      |
|                            | 923,724 Btu/hr          |
| Raw biogas (wet)           | 546 Btu/ft <sup>3</sup> |
| Energy available           | 271 kW                  |

|                                     |                           |
|-------------------------------------|---------------------------|
| Volume of H <sub>2</sub> S @ 71.7 F | 88.5 ft <sup>3</sup> /day |
| Volume of H <sub>2</sub> S @ STP    | 80.8 ft <sup>3</sup> /day |
| Weight of H <sub>2</sub> S          | 7.7 lb/day                |
| <b>Weight of Sulfur (S)</b>         | <b>7.2 lb/day</b>         |

|                              |                            |
|------------------------------|----------------------------|
| Volume of water vapor 71.7 F | 1,057 ft <sup>3</sup> /day |
| Weight of water vapor        | 0.0465 lb/ft <sup>3</sup>  |
| Water                        | 49 lb/day                  |
|                              | 5.9 gal/day                |

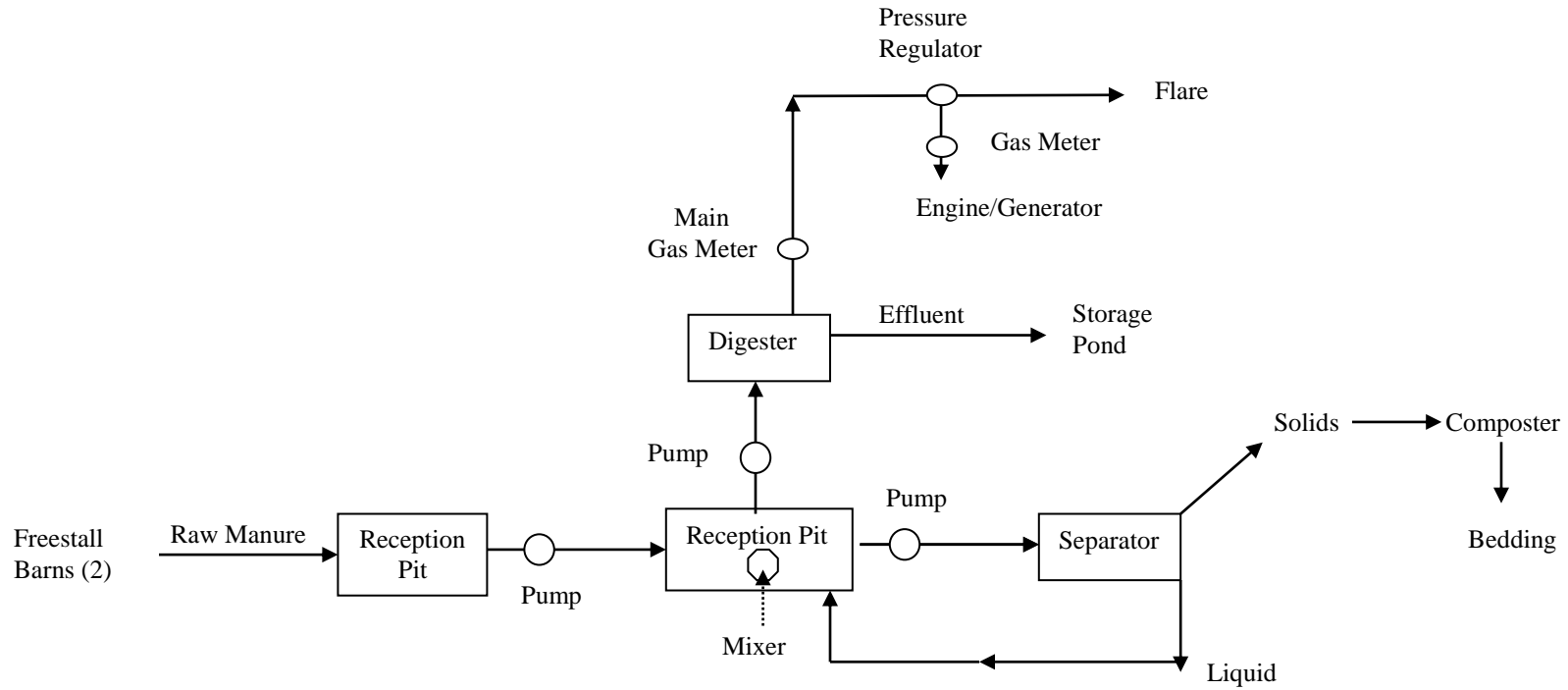
A summary of the sulfur flow at Sheland Farms in shown in Table 4-9.

Table 4-9. Summary of Sulfur Flow, Sheland Farm

| Parameter                  | Value          | Comments                                   |
|----------------------------|----------------|--|
| Number of Cows             | 558            | Given (equivalent milking cows)            |
|                            | Sulfur, lb/day |  |
| TMR                        | 72.3           | Weight given, concentration – lab tests    |
| Drinking Water             | 0.71           | Volume assumed, concentration – lab tests  |
| Milk                       | 9.6            | Volume given, concentration – literature   |
| Raw manure & bedding       | 67.3           | Volume measured, concentration – lab tests |
| Bedding (separated solids) | 3.9            | Volume measured, concentration – lab tests |
| Digester influent          | 45.2           | Mass balance method                        |
| Digester influent          | 34.3           | Volume measured, concentration – lab tests |
| Digester effluent          | 42.6           | Mass balance method                        |
| “Lost” in digester         | 2.6            | Difference (mass balance)                  |
| Biogas                     | 7.2            | Volume measured, concentration measured    |

APPENDIX

Figure A-1. Schematic Drawing of Manure Handling System, Sheland Farm



Not to scale

Figure A-2. Mass Flow Diagram of Sulfur, Sheland Farms.

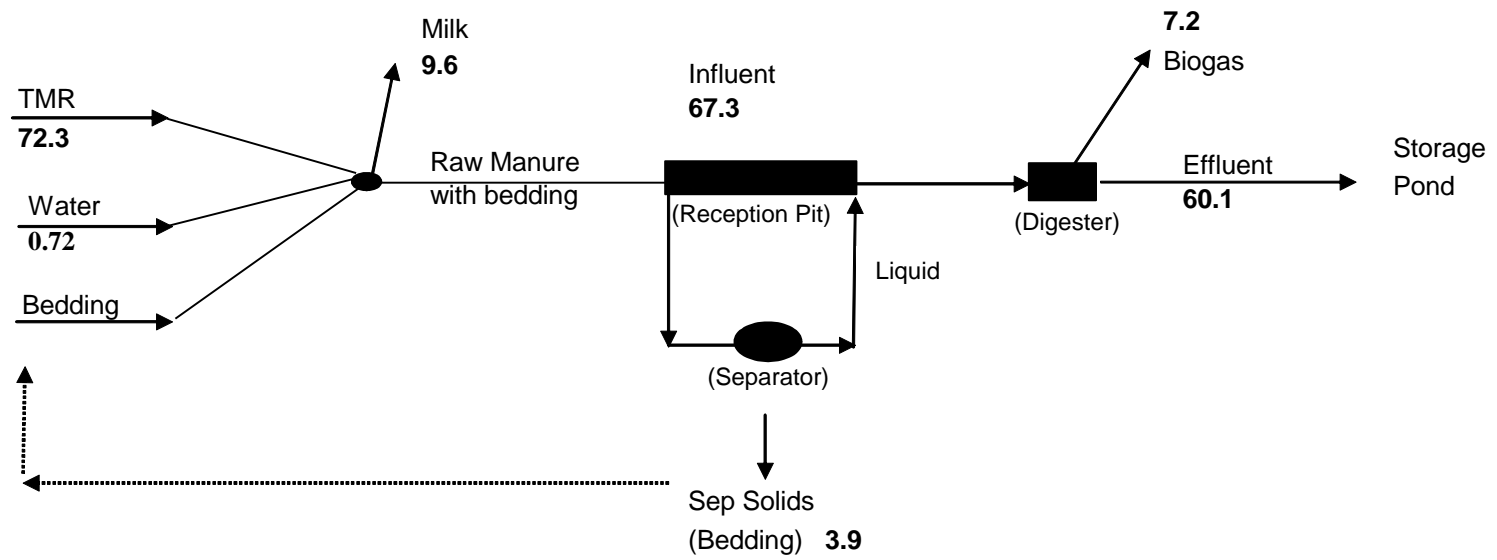


Table A-1. Sheland Farms, 30 Day Test Data, Main Biogas Meter (Ahead of Condenser).

| Day # | Date 2007 | Time    | Biogas Meters |      |          |           |           | H2S            |       |       |        | CO2     |      |      |         | Comments |         |
|-------|-----------|---------|---------------|------|----------|-----------|-----------|----------------|-------|-------|--------|---------|------|------|---------|----------|---------|
|       |           |         | Main          |      |          |           |           | Biogas ft3/day | ppm   |       |        |         | %    |      |         |          |         |
|       |           |         | Temp          | Avg  | Press RO | Press gag | Reading   |                | #1    | #2    | Avg(2) | Avg (9) | #1   | #2   | Avg (2) |          | Avg (9) |
| 1     | 16-Nov    | 6:00am  | 78            |      | 5.1      | 5.0       | 3,609,276 |                | 3,300 | 3,400 | 3,350  |         | 35.5 | 36   | 35.75   |          |         |
|       |           | 10:30am | 77            |      | 7.0      | 7.0       | 3,616,415 |                |       | 3,200 | 1,600  |         | 35.5 | 35   | 35.25   |          |         |
|       |           | 5:00pm  | 77            | 77.3 | 4.2      | 4.0       | 3,626,704 | 36,891         | 3,250 | 3,150 | 3,200  | 3,260   | 34.5 | 34.5 | 34.5    | 35       |         |
| 2     | 17-Nov    | 5:45am  | 76            |      | 6.7      | 6.8       | 3,646,167 |                | 3,350 | 3,400 | 3,375  |         | 35.5 | 35.5 | 35.5    |          |         |
|       |           | 11:20am | 79            |      | 2.3      | 2.5       | 3,654,912 |                | 3,300 | 3,300 | 3,300  |         | 36   | 36   | 36      |          |         |
|       |           | 5:35pm  | 76            |      | 7.4      | 7.0       | 3,664,892 | 41,581         | 3,200 | 3,250 | 3,225  | 3,300   | 34   | 34   | 34      | 35       |         |
| 3     | 18-Nov    | 7:45am  | 74            |      | 0.2      | 0.1       | 3,687,748 |                | 3,200 | 3,250 | 3,225  |         | 34   | 35   | 34.5    |          |         |
|       |           | 1:50pm  | 83            |      | 2.0      | 2.5       | 3,697,428 |                | 3,250 | 3,200 | 3,225  |         | 36   | 36   | 36      |          |         |
|       |           | 5:05pm  | 81            | 79.3 | 3.1      | 4.2       | 3,702,519 | 34,694         | 3,150 | 3,200 | 3,175  | 3,208   | 37   | 38   | 37.5    | 36       |         |
| 4     | 19-Nov    | 5:25am  | 78            |      | 7.8      | 7.9       | 3,722,442 |                | 3,400 | 3,500 | 3,450  |         | 36   | 36   | 36      |          |         |
|       |           | 12:35pm | 81            |      | 4.8      | 5.0       | 3,735,040 |                | 3,500 | 3,250 | 3,375  |         | 41   | 41   | 41      |          |         |
|       |           | 5:00pm  | 81            | 80.0 | 5.5      | 5.5       | 3,744,601 | 53,202         | 3,300 | 3,250 | 3,275  | 3,367   | 40   | 40   | 40      | 39       |         |
| 5     | 20-Nov    | 5:45am  | 79            |      | 7.5      | 7.5       | 3,775,644 |                | 3,450 | 3,350 | 3,400  |         | 38   | 39   | 38.5    |          |         |
|       |           | 12:10pm | 82            |      | 7.5      | 7.3       | 3,787,627 |                | 3,400 | 3,400 | 3,400  |         | 40   | 41   | 40.5    |          |         |
|       |           | 5:30pm  | 86            | 82.3 | 8.2      | 8.2       | 3,797,948 | 54,646         | 3,200 | 3,300 | 3,250  | 3,350   | 40   | 39   | 39.5    | 40       |         |
| 6     | 21-Nov    | 6:50am  | 83            |      | 8.4      | 8.5       | 3,830,290 |                | 3,250 | 3,300 | 3,275  |         | 39   | 39   | 39      |          |         |
|       |           | 12:30pm | 82            |      | 8.0      | 8.0       | 3,847,630 |                | 3,250 | 3,200 | 3,225  |         | 38   | 38   | 38      |          |         |
|       |           | 4:45pm  | 80            | 81.7 | 8.2      | 8.5       | 3,858,651 | 62,368         | 3,200 | 3,200 | 3,200  | 3,233   | 39.5 | 40   | 39.75   | 39       |         |
| 7     | 22-Nov    | 5:55am  | 78            |      | 8.1      | 8.3       | 3,892,658 |                | 3,150 | 3,150 | 3,150  |         | 37   | 37   | 37      |          |         |
|       |           | 11:25am | 77            |      | 8.1      | 8.1       | 3,908,054 |                | 3,250 | 3,250 | 3,250  |         | 36   | 37   | 36.5    |          |         |
|       |           | 4:55pm  | 76            | 77.0 | 9.8      | 9.5       | 3,923,560 | 69,624         | 3,500 | 3,550 | 3,525  | 3,308   | 36   | 36   | 36      | 37       |         |
| 8     | 23-Nov    | 6:05am  | 75            |      | 8.2      | 8.2       | 3,962,282 |                | 3,550 | 3,600 | 3,575  |         | 39   | 37   | 38      |          |         |
|       |           | 11:50am | 76            |      | 7.0      | 7.1       | 3,979,161 |                | 3,250 | 3,250 | 3,250  |         | 38   | 36   | 37      |          |         |
|       |           | 4:55pm  | 75            | 75.3 | 5.0      | 5.0       | 3,991,862 | 54,278         | 3,250 | 3,200 | 3,225  | 3,350   | 36   | 37   | 36.5    | 37.2     |         |
| 9     | 24-Nov    | 6:00am  | 72            |      | 2.0      | 2.0       | 4,016,560 |                | 1,600 | 1,900 | 1,750  |         | 36   | 37   | 36.5    |          |         |
|       |           | 11:45am | 74            |      | 0.1      | 0.1       | 4,026,872 |                | 3,100 | 3,150 | 3,125  |         | 29   | 36   | 32.5    |          |         |
|       |           | 4:45pm  | 76            | 74   | 3.4      | 3.8       | 4,035,415 | 41,351         | 3,000 | 3,200 | 3,100  | 2,658   | 34   | 36   | 35      | 38       |         |
| 10    | 25-Nov    | 7:50am  | 75            |      | 7.2      | 7.3       | 4,057,911 |                | 2,700 | 2,650 | 2,675  |         | 36   | 36   | 36      |          |         |
|       |           | 12:30pm | 76            |      | 1.1      | 1.0       | 4,066,101 |                | 2,650 | 2,750 | 2,700  |         | 36   | 36   | 36      |          |         |
|       |           | 5:00pm  | 78            | 76.3 | 1.9      | 2.0       | 4,073,186 | 35,190         | 2,700 | 2,500 | 2,600  | 2,658   | 37   | 36   | 36.5    | 36       |         |
| 11    | 26-Nov    | 5:40am  | 78            |      | 6.1      | 6.2       | 4,093,101 |                | 1,950 | 1,950 | 1,950  |         | 38   | 37   | 37.5    |          |         |
|       |           | 11:30am | 79            |      | 6.7      | 6.7       | 4,101,413 |                | 1,600 | 1,650 | 1,625  |         | 36   | 37   | 36.5    |          |         |
|       |           | 4:55pm  | 80            | 79   | 7.7      | 8.0       | 4,000,344 | 33,644         | 1,550 | 1,550 | 1,550  | 1,708   | 40   | 38   | 39      | 38       |         |
| 12    | 27-Nov    | 6:10am  | 75            |      | 7.7      | 7.5       | 4,126,745 |                | 1,200 | 1,150 | 1,175  |         | 37   | 38   | 37.5    |          |         |
|       |           | 12:05pm | 75            |      | 8.0      | 8.0       | 4,133,848 |                | 950   | 900   | 925    |         | 37   | 37   | 37      |          |         |
|       |           | 4:50pm  | 76            | 75   | 4.2      | 4.5       | 4,141,113 | 35,560         | 3,000 | 3,050 | 3,025  | 1,708   | 37   | 37   | 37      | 37       |         |
| 13    | 28-Nov    | 6:20am  | 72            |      | 1.1      | 1.1       | 4,162,305 |                | 450   | 450   | 450    |         | 33   | 34   | 33.5    |          |         |
|       |           | 1:15pm  | 74            |      | 4.5      | 4.5       | 4,172,078 |                | 450   | 500   | 475    |         | 38   | 38   | 38      |          |         |
|       |           | 5:00pm  | 73            | 73.0 | 2.9      | 3.0       | 4,177,569 | 33,799         | 2,250 | 2,250 | 2,250  | 1,058   | 38   | 40   | 39      | 37       |         |
| 14    | 29-Nov    | 6:20am  | 73            |      | 1.2      | 1.0       | 4,196,104 |                | 2,650 |       | 2,650  |         | 37   | 37   | 37      |          |         |
|       |           | 12:50pm | 74            |      | 4.3      | 4.5       | 4,204,127 |                | 2,450 |       | 2,450  |         | 37   | 37   | 37      |          |         |
|       |           | 4:45pm  | 73            | 73.3 | 1.2      | 1.2       | 4,211,044 | 34,621         | 2,150 |       | 2,150  | 2,417   | 37   | 37   | 37      | 37       |         |
| 15    | 30-Nov    | 6:10am  | 71            |      | 0.8      | 0.5       | 4,230,725 |                | 1,150 |       | 1,150  |         | 36   | 36   | 36      |          |         |
|       |           | 3:07pm  | 71            |      | 2.0      | 1.7       | 4,243,718 |                | 400   |       | 400    |         | 35   | 35   | 35      |          |         |
|       |           | 4:45pm  | 71            | 71   | 0.8      | 0.0       | 4,245,989 | 34,066         | 700   |       | 700    | 750     | 36   | 36   | 36      | 36       |         |
| 16    | 1-Dec     | 5:50am  | 66            |      | 1.0      | 1.0       | 4,264,791 |                | 1,750 |       | 1,750  |         | 36   | 36   | 36      |          |         |
|       |           | 12:15pm | 65            |      | 1.2      | 1.0       | 4,273,880 |                | 2,000 |       | 2,000  |         | 36   | 36   | 36      |          |         |
|       |           | 4:45pm  | 63            | 64.7 | 0.5      | 0.5       | 4,280,149 | 36,736         | 3,200 |       | 3,200  | 2,317   | 35   | 36   | 35.5    | 36       |         |

Table A-1. Sheland Farms, 30 Day Test Data, Main Biogas Meter (Ahead of Condenser), Cont.

| Day # | Date 2007 | Time    | Biogas Meters |     |          |                |           |         | H2S   |       |        |         | CO2 |    |         |         | Comments  |
|-------|-----------|---------|---------------|-----|----------|----------------|-----------|---------|-------|-------|--------|---------|-----|----|---------|---------|---|
|       |           |         | Main          |     |          | Biogas ft3/day | ppm       |         |       |       | %      |         |     |    |         |         |   |
|       |           |         | Temp          | Avg | Press RO |                | Press gag | Reading | #1    | #2    | Avg(2) | Avg (9) | #1  | #2 | Avg (2) | Avg (9) |   |
| 17    | 2-Dec     | 7:45am  | 61            |     | 9.0      | 9.0            | 4,301,527 |         | 2,300 |       | 2,300  |         | 30  | 30 | 30      |         | 7"+ within 30 seconds<br>7" engine shut down              |
|       |           | 12:10pm | 66            |     | 2.1      | 2.0            | 4,308,035 |         | 2,450 |       | 2,450  |         | 37  | 37 | 37      |         |   |
|       |           | 5:10pm  | 68            | 65  | 3.5      | 2.1            | 4,315,390 | 33,520  | 1,100 |       | 1,100  | 1,950   | 38  | 38 | 38      | 35      |   |
| 18    | 3-Dec     | 6:10am  | 70            |     | 4.3      | 4.5            | 4,335,047 |         | 600   |       | 600    |         | 37  | 38 | 37.5    |         |   |
|       |           | 11:20am | 69            |     | 4.2      | 4.2            | 4,342,881 |         | 2,000 |       | 2,000  |         | 37  | 38 | 37.5    |         |   |
|       |           | 5:15pm  | 65            | 68  | 2.8      | 2.8            | 4,351,678 | 36,231  | 4,700 |       | 4,700  | 2,433   | 38  | 38 | 38      | 38      |   |
| 19    | 4-Dec     | 6:05    | 63            |     | 0.6      | 0.5            | 4,371,278 |         | 4,000 |       | 4,000  |         | 34  | 33 | 33.5    |         | Took gen off line to get                                  |
|       |           | 11:50am | 65            |     | 1.8      | 1.8            | 4,379,847 |         |       |       |        |         | 37  | 38 | 37.5    |         |   |
|       |           | 6:05pm  | 66            | 65  | 2.2      | 2.5            | 4,388,970 | 35,837  |       |       |        | 4,000   | 33  | 34 | 33.5    | 35      |   |
| 20    | 5-Dec     | 6:05am  | 67            |     | 0.1      | 0.1            | 4,407,115 |         | 4,000 |       | 4,000  |         | 37  | 38 | 37.5    |         | Took gen off line   |
|       |           | 2:07pm  | 67            |     | 1.0      | 1.2            | 4,419,320 |         |       |       |        |         | 32  | 32 | 32      |         |   |
|       |           | 5:05pm  | 67            | 67  | 0.1      | 0.1            | 4,423,542 | 36,224  |       |       |        | 4,000   | 36  | 36 | 36      | 35      |   |
| 21    | 6-Dec     | 5:45am  | 62            |     | 0.4      | 0.5            | 4,443,339 |         | 50    | 20    | 35     |         | 32  | 33 | 32.5    |         | Shut gen set down to get gas pressure                     |
|       |           | 12:05pm | 65            |     | 3.0      | 2.5            | 4,451,889 |         | 400   | 400   | 400    |         | 32  | 32 | 32      |         |   |
|       |           | 5:05pm  | 65            | 64  | 7.5      | 7.0            | 4,456,918 | 33,173  | 400   | 450   | 425    | 287     | 32  | 32 | 32      | 32      |   |
| 22    | 7-Dec     | 5:55am  | 65            |     | 0.3      | 0.25           | 4,476,512 |         | 250   | 200   | 225    |         | 32  | 32 | 32      |         | Gen set off to test<br>off to test<br>off to test         |
|       |           | 2:25pm  | 66            |     | 4.5      | 4.5            | 4,486,314 |         | 50    | 60    | 55     |         | 28  | 28 | 28      |         |   |
|       |           | 5:109pm | 67            | 66  |          |                | 4,493,050 | 33,169  | 10    | 350   | 180    | 153     | 40  | 34 | 37      | 32      |   |
| 23    | 8-Dec     | 5:40am  | 67            |     | 6.5      | 6.5            | 4,509,681 |         | 450   | 500   | 475    |         | 33  | 35 | 34      |         | Gen set restart after off 4-5<br>Gen set off line to test |
|       |           | 1:10pm  | 69            |     | 4.5      | 4.5            | 4,521,213 |         | 3,050 | 3,150 | 3,100  |         | 35  | 35 | 35      |         |   |
|       |           | 5:05pm  | 68            | 68  | 1.2      | 1.2            | 4,526,908 | 35,488  | 2,100 |       | 2,100  | 1,892   | 37  | 37 | 37      | 35      |   |
| 24    | 9-Dec     | 5:50am  | 64            |     | 0.5      | 0.5            | 4,545,169 |         | 3,800 |       | 3,800  |         | 45  | 45 | 45      |         | CO2 40 after engine restart                               |
|       |           | 12:00pm | 66            |     | -1.5     | -1.5           | 4,554,059 |         | 800   |       | 800    |         | 36  | 35 | 35.5    |         |   |
|       |           | 4:30pm  | 66            | 65  | 1.3      | 1.5            | 4,560,705 | 35,032  | 300   |       | 300    | 1,633   | 35  | 36 | 35.5    | 39      |   |
| 25    | 10-Dec    | 5:45am  | 68            |     | -2       | -2             | 4,580,201 |         | 600   |       | 600    |         | 36  | 40 | 38      |         |   |
|       |           | 2:00pm  | 70            |     | -2       | -2             | 4,592,169 |         | 3,600 |       | 3,600  |         | 34  | 34 | 34      |         |   |
|       |           | 5:00pm  | 71            | 70  | -1       | -1             | 4,596,007 | 29,965  | 450   |       | 450    | 1,550   | 36  | 38 | 37      | 36      |   |
| 26    | 11-Dec    | 6:00am  | 68            |     | 7.7      | 7.8            | 4,610,166 |         | 4,400 |       | 4,400  |         | 37  | 35 | 36      |         | Took off line   |
|       |           | 12:25pm | 70            |     | -2       | -2             | 4,619,432 |         | 400   |       | 400    |         | 32  | 32 | 32      |         |   |
|       |           | 5:10pm  | 70            | 69  | -2       | -2             | 4,626,937 | 32,904  | 350   |       | 350    | 1,717   | 35  | 34 | 34.5    | 34      |   |
| 27    | 12-Dec    | 6:00am  | 69            |     | 7.5      | 8              | 4,643,070 |         | 550   |       | 550    |         | 35  | 36 | 35.5    |         | Engine set had been off                                   |
|       |           | 1:15pm  | 71            |     | 5.2      | 5              | 4,653,553 |         | 3,650 |       | 3,650  |         | 32  | 34 | 33      |         |   |
|       |           | 5:20pm  | 68            | 69  | 3        | 2.3            | 4,659,426 | 35,831  | 4,400 |       | 4,400  | 2,867   | 36  | 35 | 35.5    | 35      |   |
| 28    | 13-Dec    | 6:15am  | 65            |     | -2.2     | -2.2           | 4,678,901 |         | 400   |       | 400    |         | 35  | 36 | 35.5    |         |   |
|       |           | 11:30am | 67            |     | 2        | -2             | 4,686,979 |         | 400   |       | 400    |         | 30  | 32 | 31      |         |   |
|       |           | 5:40pm  | 67            | 66  | -1       | -1             | 4,696,310 | 34,952  | 450   |       | 450    | 417     | 32  | 33 | 32.5    | 33      |   |
| 29    | 14-Dec    | 6:15am  | 69            |     | 0        | 0              | 4,713,853 |         | 1,250 |       | 1,250  |         | 33  | 34 | 33.5    |         |   |
|       |           | 12:00pm | 69            |     | 5.6      | 6              | 4,720,687 |         | 4,400 |       | 4,400  |         | 37  | 37 | 37      |         |   |
|       |           | 5:00pm  | 69            | 69  | 0.5      | 0.5            | 4,728,692 | 31,558  | 400   |       | 400    | 2,017   | 31  | 33 | 32      | 34      |   |
| 30    | 15-Dec    | 4:20am  | 61            |     | -2       | -2             | 4,745,411 |         | 500   |       | 500    |         | 35  | 34 | 34.5    |         |   |
|       |           | 11:25am | 61            |     | -2       | -2             | 4,755,735 |         | 600   |       | 600    |         | 32  | 32 | 32      |         |   |
|       |           | 5:50pm  | 63            | 62  | -1       | -1             | 4,764,692 |         | 900   |       | 900    | 667     | 30  | 31 | 30.5    | 32      |   |

|                       | Temp, F | Press RO | Press gage | Biogas/day | H2S   | CO2  |
|-----------------------|---------|----------|------------|------------|-------|------|
| Average               | 71.7    | 3.39     | 3.34       | 39,177     | 2,241 | 35.8 |
| Standard Dev.         | 6.03    | 3.35     | 3.43       | 9,785      | 1,310 | 2.72 |
| Confidence Interval ± | 1.25    |          | 0.71       | 3,561      | 223   | 0.56 |
| (# of samples)        | 90      | 89       | 89         | 29         | 132   | 90   |

Table A-2 Sheland Farms, 30 Day Test Data, Engine Biogas Meter.

| Day # | Date 2007 | Time    | Engine Biogas Meters |        |       |            |           | Biogas cuft/day | H2S   |       |         |           | CO2   |      |      |  | Comments |
|-------|-----------|---------|----------------------|--------|-------|------------|-----------|-----------------|-------|-------|---------|-----------|-------|------|------|--|----------|
|       |           |         | Temp                 | Avg, F | Press | Press Eng* | Reading   |                 | ppm/% |       |         |           | ppm/% |      |      |  |          |
|       |           |         |                      |        |       |            |           |                 | #1    | #2    | Avg (2) | Total Avg | #1    | #2   | Avg  | Avg  |          |
| 1     | 16-Nov    | 6:00am  | 107                  |        | >25   |            | 1,960,897 |                 | 3,600 | 3,500 | 3,550   |           | 36    | 35   | 35.5 |  | 37       |
|       |           | 10:20am | 103                  |        | >25   |            | 1,965,788 |                 | 2,350 | ##### | 2,150   |           | 36    | 36   | 36.0 |  |          |
|       |           | 5:05pm  | 99                   | 103    | >25   |            | 1,972,910 | 26,168          | 3,250 | 3,300 | 3,275   | 2,992     | 38.5  | 38.5 | 38.5 |  |          |
| 2     | 17-Nov    | 6:00am  | 101                  |        | >25   |            | 1,987,065 |                 | 3,800 | 3,620 | 3,710   |           | 36    | 37   | 36.5 |  | 37       |
|       |           | 11:15am | 107                  |        | 18.0  |            | 1,993,169 |                 | 3,600 | 3,500 | 3,550   |           | 36    | 36   | 36.0 |  |          |
|       |           | 5:20pm  | 108                  | 105    | 12.0  |            | 2,000,547 | 30,119          | 3,400 | 3,500 | 3,450   | 3,570     | 38    | 37.5 | 37.8 |  |          |
| 3     | 18-Nov    | 7:15am  | 103                  |        | 11.5  |            | 2,017,184 |                 | 3,200 | 3,200 | 3,200   |           | 36    | 36   | 36.0 |  | 37       |
|       |           | 1:45pm  | 109                  |        | 20.5  |            | 2,024,283 |                 | 3,500 | 3,400 | 3,450   |           | 37    | 38   | 37.5 |  |          |
|       |           | 5:15pm  | 106                  | 106    | 22.0  |            | 2,028,248 | 25,651          | 3,250 | 3,400 | 3,325   | 3,325     | 37    | 37   | 37.0 |  |          |
| 4     | 19-Nov    | 5:40am  | 102                  |        | >25   | 5.0        | 2,042,835 |                 | 3,550 | 3,550 | 3,550   |           | 36.5  | 34   | 35.3 |  | 41       |
|       |           | 12:30pm | 88                   |        | 13.5  | 5.0        | 2,051,709 |                 | 3,350 | 3,250 | 3,300   |           | 41    | 40   | 40.5 |  |          |
|       |           | 4:55pm  | 89                   | 93     | 13.0  | 6.0        | 2,057,375 | 31,569          | 3,200 | 2,700 | 2,950   | 3,267     | 48    | 45   | 46.5 |  |          |
| 5     | 20-Nov    | 5:55am  | 80                   |        | 15.0  | 6.0        | 2,074,404 |                 | 3,350 | 3,500 | 3,425   |           | 41    | 41   | 41.0 |  | 41       |
|       |           | 2:00pm  | 90                   |        | 15.0  | 6.0        | 2,082,105 |                 | 3,200 | 3,300 | 3,250   |           | 41    | 42   | 41.5 |  |          |
|       |           | 5:20pm  | 96                   | 88.7   | 14.0  | 6.0        | 2,089,189 | 31,207          | 3,200 | 3,250 | 3,225   | 3,300     | 38    | 40   | 39.0 |  |          |
| 6     | 21-Nov    | 6:05am  | 93                   |        | 14.5  | 6.0        | 2,105,611 |                 | 3,300 | 3,300 | 3,300   |           | 39    | 40   | 39.5 |  | 39       |
|       |           | 12:30pm | 92                   |        | 14.0  | 6.0        | 2,113,986 |                 | 3,250 | 3,300 | 3,275   |           | 38    | 39   | 38.5 |  |          |
|       |           | 4:50pm  | 90                   | 91.7   | 14.5  | 6.0        | 2,119,511 | 31,007          | 3,200 | 3,200 | 3,200   | 3,258     | 40    | 39.5 | 39.8 |  |          |
| 7     | 22-Nov    | 6:00am  | 86                   |        | 14.0  | 6.0        | 2,136,618 |                 | 3,200 | 3,200 | 3,200   |           | 39    | 39   | 39.0 |  | 38       |
|       |           | 11:20am | 85                   |        | 13.5  | 5.5        | 2,143,335 |                 | 3,300 | 3,250 | 3,275   |           | 36    | 38   | 37.0 |  |          |
|       |           | 5:00pm  | 83                   | 84.7   | 14.8  | 6.5        | 2,150,819 | 31,950          | 3,400 | 3,500 | 3,450   | 3,308     | 36    | 37   | 36.5 |  |          |
| 8     | 23-Nov    | 6:10am  | 80                   |        | 15.0  | 6.3        | 2,168,568 |                 | 3,200 | 3,250 | 3,225   |           | 36    | 37   | 36.5 |  | 37       |
|       |           | 11:55am | 82                   |        | 13.00 | 5.8        | 2,175,901 |                 | 3,250 | 3,250 | 3,250   |           | 36    | 36   | 36.0 |  |          |
|       |           | 5:00pm  | 83                   | 81.7   | 11.0  | 4.3        | 2,179,506 | 27,927          | 3,250 | 3,300 | 3,275   | 3,250     | 37    | 37   | 37.0 |  |          |
| 9     | 24-Nov    | 6:00am  | 99                   |        | 7.0   | 0.0        | 2,196,495 |                 | 3,250 | 3,300 | 3,275   |           | 38    | 37   | 37.5 |  | 38       |
|       |           | 11:40am | 99                   |        | >25   | 10.0       | 2,203,789 |                 | 400   | 3,500 | 1,950   |           | 40    | 40   | 40.0 |  |          |
|       |           | 4:30pm  | 102                  | 100    | 5.0   |            | 2,209,775 | 28,660          | 3,250 | 3,300 | 3,275   | 2,833     | 37    | 38   | 37.5 |  |          |
| 10    | 25-Nov    | 7:50am  | 100                  |        | >25   | 8.50       | 2,225,155 |                 | 2,900 | 2,800 | 2,850   |           | 36    | 36   | 36.0 |  | 37       |
|       |           | 12:35pm | 103                  |        | >25   | 10.0       | 2,231,705 |                 | 2,850 | 2,900 | 2,875   |           | 36    | 37   | 36.5 |  |          |
|       |           | 4:55pm  | 107                  | 103    | >25   | 10.0       | 2,266,505 | 26,014          | 2,850 | 2,900 | 2,875   | 2,867     | 37    | 37   | 37.0 |  |          |
| 11    | 26-Nov    | 5:50am  | 108                  |        | >25   | 8.5        | 2,251,169 |                 | 2,050 | 2,050 | 2,050   |           | 37    | 37   | 37.0 |  | 37       |
|       |           | 11:40am | 109                  |        | 23.0  | 8.0        | 2,258,444 |                 | 1,600 | 1,650 | 1,625   |           | 36    | 36   | 36.0 |  |          |
|       |           | 5:00pm  | 107                  | 108    | 21.0  | 8.0        | 2,264,874 | 20,802          | 1,500 | 1,500 | 1,500   | 1,725     | 37    | 39   | 38.0 |  |          |
| 12    | 27-Nov    | 6:15am  | 70                   |        | >25   | 8.5        | 2,271,971 |                 | 1,150 | 1,150 | 1,150   |           | 39    | 39.5 | 39.3 |  | 38       |
|       |           | 12:15pm | 74                   |        | >25   | 8.5        | 2,276,182 |                 | 800   | 1,000 | 900     |           | 37    | 37   | 37.0 |  |          |
|       |           | 4:55pm  | 104                  | 82.7   | 23.5  | 8.5        | 2,281,623 | 25,652          | 3,100 | 3,050 | 3,075   | 1,708     | 37    | 37   | 37.0 |  |          |
| 13    | 28-Nov    | 6:15am  | 101                  |        | >25   | 10.0       | 2,297,623 |                 | 500   | 600   | 550     |           | 37    | 38   | 37.5 |  | 37       |
|       |           | 1:20pm  | 104                  |        | >25   | 9.5        | 2,304,624 |                 | 500   | 500   | 500     |           | 37    | 37   | 37.0 |  |          |
|       |           | 5:10pm  | 105                  | 103    | >25   | 9.5        | 2,308,676 | 25,201          | 2,400 |       | 2,400   | 900       | 37    | 37   | 37.0 | Went to one H2S sample per day to conserve tubes |          |
| 14    | 29-Nov    | 6:15am  | 106                  |        | >25   | 9.5        | 2,322,824 |                 | 2,700 |       | 2,700   |           | 37    | 38   | 37.5 |  | 38       |
|       |           | 12:05pm | 107                  |        | >25   | 9.0        | 2,328,837 |                 | 2,600 |       | 2,600   |           | 37    | 37   | 37.0 |  |          |
|       |           | 4:40pm  | 106                  | 106    | 24.0  | 8.5        | 2,334,065 | 26,212          | 2,200 |       | 2,200   | 2,500     | 39    | 40   | 39.5 |  |          |
| 15    | 30-Nov    | 6:15am  | 105                  |        | 24.5  | 9.0        | 2,349,036 |                 | 1,200 |       | 1,200   |           | 36    | 36   | 36.0 |  | 37       |
|       |           | 3:00pm  | 103                  |        | 23.5  | 9.0        | 2,358,832 |                 | 400   |       | 400     |           | 36    | 36   | 36.0 |  |          |
|       |           | 4:55pm  | 102                  | 103    | 23.0  | 9.0        | 2,360,769 | 26,104          | 750   |       | 750     | 783       | 38    | 37   | 37.5 |  |          |
| 16    | 1-Dec     | 6:00am  | 104                  |        | >25   | 9.0        | 2,375,140 |                 | 1,900 |       | 1,900   |           | 36    | 36   | 36.0 |  | 36       |
|       |           | 12:20pm | 106                  |        | >25   | 9.0        | 2,382,138 |                 | 2,000 |       | 2,000   |           | 36    | 36   | 36.0 |  |          |
|       |           | 4:50pm  | 99                   | 103    | >25   | 9.0        | 2,386,974 | 28,381          | 3,350 |       | 3,350   | 2,417     | 35    | 36   | 35.5 |  |          |



Table A-2. Sheland Farms, 30 Day Test Data, Engine Biogas Meter, Cont.

| Day # | Date 2007 | Time    | Engine Biogas Meters |        |       |            |           | Biogas cuft/day | H2S   |      |       |           | CO2   |    |      |   | Comments |
|-------|-----------|---------|----------------------|--------|-------|------------|-----------|-----------------|-------|------|-------|-----------|-------|----|------|---|----------|
|       |           |         | Temp                 | Avg, F | Press | Press Eng* | Reading   |                 | ppm/% |      |       |           | ppm/% |    |      |   |          |
|       |           |         |                      |        |       |            |           |                 | #1    | #2   | Avg   | Total Avg | #1    | #2 | Avg  |   |          |
| 17    | 2-Dec     | 7:50am  | 87                   | 96     | >25   | 8.0        | 2,403,521 | 25,946          | 2000  |      | 2,000 |           | 34    | 32 | 33.0 |   |          |
|       |           | 12:17pm | 99                   |        | 24.0  | 8.5        | 2,408,602 |                 | 2550  |      | 2,550 |           | 37    | 38 | 37.5 |   |          |
|       |           | 5:02pm  | 101                  |        | >25   | 9.0        | 2,414,118 |                 | 1100  |      | 1,100 | 1,883     | 36    | 37 | 36.5 |   | 36       |
| 18    | 3-Dec     | 6:15am  | 103                  | 103    | 13.0  | 6.5        | 2,429,467 | 27,584          | 600   |      | 600   |           | 39    | 40 | 39.5 |   |          |
|       |           | 11:25AM | 104                  |        | 22.0  | 8.5        | 2,435,440 |                 | 2350  |      | 2,350 |           | 38    | 38 | 38.0 |   |          |
|       |           | 5:20PM  | 101                  |        | 22.5  | 8.5        | 2,442,200 |                 | 4900  |      | 4,900 | 2,617     | 37    | 39 | 38.0 |   | 39       |
| 19    | 4-Dec     | 6:10am  | 98                   | 100    | 20.5  | 8.5        | 2,457,051 | 27,527          | 2750  |      | 2,750 |           | 38    | 40 | 39.0 | Ran out of H2S tubes                      |          |
|       |           | 11:55AM | 102                  |        | 19.5  | 8.5        | 2,463,604 |                 |       |      |       |           | 37    | 39 | 38.0 |   |          |
|       |           | 6:00pm  | 100                  |        | >25   | 11.0       | 2,470,562 |                 |       |      | 2,750 |           | 30    | 31 | 30.5 |   | 36       |
| 20    | 5-Dec     | 6:10am  | 97                   | 99     | 11.5  | 4.0        | 2,484,578 | 27,944          |       |      |       |           | 35    | 36 | 35.5 |   |          |
|       |           | 2:00pm  | 102                  |        | >25   | 12.0       | 2,493,825 |                 |       |      |       |           | 32    | 32 | 32.0 |   |          |
|       |           | 5:10pm  | 99                   |        | 14    | 7.0        | 2,497,132 |                 |       |      |       |           | 35    | 35 | 35.0 |   | 34       |
| 21    | 6-Dec     | 6:15am  | 84                   | 82     | >25   | 9.0        | 2,512,522 | 24,315          | 200   | 250  | 225   |           | 29    | 31 | 30.0 |   |          |
|       |           | 12:15pm | 100                  |        | >25   | 9.0        | 2,519,203 |                 | 400   | 400  | 400   |           | 34    | 35 | 34.5 |   |          |
|       |           | 5:00pm  | 62                   |        | >25   | 9.0        | 2,521,473 |                 | 450   | 450  | 450   | 358       | 34    | 34 | 34.0 |   | 33       |
| 22    | 7-Dec     | 6:10am  | 94                   | 98     | 6.5   | 0.0        | 2,536,837 | 23,013          | 250   | 200  | 225   |           | 32    | 34 | 33.0 | off to test<br>Just shut down - restarted |          |
|       |           | 2:20pm  | 102                  |        | >25   |            | 2,545,524 |                 | 350   | 300  | 325   |           | 28    | 32 | 30.0 |   |          |
|       |           | 5:30pm  | 98                   |        | 16    | 7.5        | 2,549,704 |                 | 400   | 400  | 400   | 317       | 34    | 34 | 34.0 |   | 32       |
| 23    | 8-Dec     | 5:45am  | 68                   | 90     | 7.25  | 9.0        | 2,559,850 | 27,115          | 500   | 600  | 550   |           | 35    | 35 | 35.0 | Off 4-5 hrs, just restarted               |          |
|       |           | 1:15pm  | 105                  |        | 9.5   |            | 2,568,357 |                 | 3230  | 3200 | 3,215 |           | 34    | 35 | 34.5 |   |          |
|       |           | 5:15pm  | 97                   |        | 23.5  | 9.0        | 2,572,819 |                 | 3050  |      | 3,050 | 2,116     | 36    | 36 | 36.0 |   | 35       |
| 24    | 9-Dec     | 6:05am  | 101                  | 102    | >25   | 9.0        | 2,586,965 | 26,764          | 4050  |      | 4,050 |           | 37    | 37 | 37.0 |   |          |
|       |           | 12:05pm | 102                  |        | 24    | 9.0        | 2,593,630 |                 | 1300  |      | 1,300 |           | 37    | 36 | 36.5 |   |          |
|       |           | 4:35pm  | 102                  |        | 22.5  | 8.5        | 2,598,726 |                 | 250   |      | 250   | 1,867     | 35    | 36 | 35.5 |   | 36       |
| 25    | 10-Dec    | 5:50am  | 103                  | 102    | 20    | 8.5        | 2,613,729 | 17,955          | 550   |      | 550   |           | 37    | 38 | 37.5 |   |          |
|       |           | 2:15pm  | 97                   |        | 7.25  | 9.0        | 2,622,936 |                 | 3800  |      | 3,800 |           | 38    | 39 | 38.5 |   |          |
|       |           | 5:05pm  | 106                  |        | 17.5  | 8.0        | 2,625,919 |                 | 450   |      | 450   | 1,600     | 37    | 37 | 37.0 |   | 38       |
| 26    | 11-Dec    | 6:05am  | 72                   | 82     | >25   | 10.0       | 2,631,684 | 22,078          | 4400  |      | 4,400 |           | 37    | 37 | 37.0 | just restarted                            |          |
|       |           | 12:30pm | 72                   |        | 12    | 7.0        | 2,638,708 |                 | 350   |      | 350   |           | 32    | 32 | 32.0 |   |          |
|       |           | 5:10pm  | 103                  |        | 7.5   | 0.0        | 2,644,403 |                 | 350   |      | 350   | 1,700     | 33    | 34 | 33.5 |   | 34       |
| 27    | 12-Dec    | 6:05am  | 72                   | 95     | >25   | 9          | 2,653,762 | 27,612          | 450   |      | 450   |           | 37    | 38 | 37.5 | Genset had been off 5 hrs                 |          |
|       |           | 1:20pm  | 107                  |        | 25    | 8.5        | 2,667,871 |                 | 3650  |      | 3,650 |           | 34    | 35 | 34.5 |   |          |
|       |           | 5:25pm  | 105                  |        | 24    | 8.5        | 2,666,269 |                 | 4400  |      | 4,400 | 2,833     | 36    | 38 | 37.0 |   | 36       |
| 28    | 13-Dec    | 6:20am  | 100                  | 101    | 11    | 4          | 2,681,374 | 27,012          | 400   |      | 400   |           | 35    | 36 | 35.5 |   |          |
|       |           | 11:35am | 101                  |        | 7     | 0          | 2,687,405 |                 | 400   |      | 400   |           | 32    | 33 | 32.5 |   |          |
|       |           | 5:40pm  | 102                  |        | 24    | 9          | 2,694,630 |                 | 450   |      | 450   | 417       | 35    | 34 | 34.5 |   | 34       |
| 29    | 14-Dec    | 6:25am  | 104                  | 103    | >25   | 8          | 2,708,386 | 23,521          | 1250  |      | 1,250 |           | 38    | 38 | 38.0 |   |          |
|       |           | 12:05pm | 103                  |        | >25   | 9          | 2,717,918 |                 | 4700  |      | 4,700 |           | 36    | 37 | 36.5 |   |          |
|       |           | 5:05pm  | 103                  |        | 6     |            | 2,719,038 |                 | 350   |      | 350   | 2,100     | 33    | 34 | 33.5 |   | 36       |
| 30    | 15-Dec    | 4:25am  | 97                   | 96     | 23    | 8.5        | 2,731,907 | 27,466          | 500   |      | 500   |           | 34    | 36 | 35.0 |   |          |
|       |           | 11:30am | 95                   |        | 21    | 8          | 2,735,858 |                 | 700   |      | 700   |           | 34    | 35 | 34.5 |   |          |
|       |           | 6:00pm  | 97                   |        | 23    | 8.5        | 2,746,900 |                 | 1050  |      | 1,050 | 750       | 31    | 32 | 31.5 |   | 34       |

\* Pressure after regulator

|                       | Temp, F | Press | Press, Eng | Biogas | H2S    | CO2  |
|-----------------------|---------|-------|------------|--------|--------|------|
| Average               | 97.1    | 16.45 | 7.63       | 26,587 | 2,280  | 36.5 |
| Standard Dev.         | 10.58   | 6.03  | 2.40       | 3,174  | 1319.6 | 2.6  |
| Confidence Interval ± | 2.19    | 1.57  | 0.54       | 1,155  | 226.0  | 0.4  |
| (# of samples)        | 90      | 57    | 77         | 29     | 131    | 180  |

Table A-3. Sulfur Content in TMR at Sheland Farms.

| Date                  | Group 1 |              |              | Group 2 |              |              | Group 3 |              |              | Group 12 |              |              |
|-----------------------|---------|--------------|--------------|---------|--------------|--------------|---------|--------------|--------------|----------|--------------|--------------|
|                       | Sample  | Dry Matter % | S % (as fed) | Sample  | Dry Matter % | S % (as fed) | Sample  | Dry Matter % | S % (as fed) | Sample   | Dry Matter % | S % (as fed) |
| 11/12/2007            | SFG1 1  | 41.90        | 0.10         | SFG2 1  | 40.00        | 0.10         | SFG3 1  | 33.00        | 0.07         | SFG12 1  | 38.20        | 0.08         |
|                       | SFG1 2  | 42.20        | 0.10         | SFG2 2  | 41.70        | 0.11         | SFG3 2  | 33.30        | 0.07         | SFG12 2  | 38.00        | 0.09         |
|                       | SFG1 3  | 41.80        | 0.10         | SFG2 3  | 39.20        | 0.10         | SFG3 3  | 33.90        | 0.07         | SFG12 3  | 39.00        | 0.09         |
| 11/28/2007            | SFG1 1  | 35.90        | 0.10         | SFG2 1  | 40.90        | 0.10         | SFG3 1  | 30.60        | 0.06         | SFG12 1  | 38.50        | 0.09         |
|                       | SFG1 2  | 36.60        | 0.10         | SFG2 2  | 40.70        | 0.10         | SFG3 2  | 31.90        | 0.07         | SFG12 2  | 38.90        | 0.09         |
| 12/21/2007            | SFG1 1  | 42.7         | 0.12         | SFG2 1  | 37.20        | 0.08         | SFG3 1  | 32.70        | 0.06         | SFG12 1  | 43.30        | 0.09         |
|                       | SFG1 2  | 42.8         | 0.12         | SFG2 2  | 38.50        | 0.09         | SFG3 2  | 32.80        | 0.07         | SFG12 2  | 42.50        | 0.09         |
|                       | SFG1 3  | 41.7         | 0.11         | SFG2 3  | 38.30        | 0.08         | SFG3 3  | 33.10        | 0.08         | SFG12 3  | 41.30        | 0.09         |
| Average               |         | 40.70        | 0.106        |         | 39.6         | 0.095        |         | 32.7         | 0.07         |          | 39.96        | 0.09         |
| Standard Dev          |         | 2.78         | 0.01         |         | 1.52         | 0.01         |         | 1.01         | 0.01         |          | 2.09         | 0.00         |
| Confidence Integral ± |         | 1.93         | 0.01         |         | 1.06         | 0.01         |         | 0.70         | 0.00         |          | 1.45         | 0.00         |

| Date                  | Dry Cows |              |              | Bred Heifers |              |              |
|-----------------------|----------|--------------|--------------|--------------|--------------|--------------|
|                       | Sample   | Dry Matter % | S % (as fed) | Sample       | Dry Matter % | S % (as fed) |
| 11/12/2007            | SFDC 1   | 29.0         | 0.07         | SFBH 1       | 31.7         | 0.08         |
|                       | SFDC 2   | 28.5         | 0.08         | SFBH 2       | 31.8         | 0.08         |
|                       | SFDC 3   | 29.3         | 0.08         | SFBH 3       | 31.2         | 0.10         |
| 11/28/2007            | SFDC 1   | 30.7         | 0.10         | SFBH 1       | 35.8         | 0.09         |
|                       | SFDC 2   | 30.0         | 0.08         | SFBH 2       | 36.9         | 0.10         |
| 12/21/2007            | SFDC 1   | 29.6         | 0.07         | SFBH 1       | 35.0         | 0.09         |
|                       | SFDC 2   | 29.3         | 0.07         | SFBH 2       | 36.6         | 0.08         |
|                       | SFDC 3   | 29.3         | 0.08         | SFBH 3       | 35.2         | 0.07         |
| Average               |          | 29.46        | 0.08         |              | 34.28        | 0.09         |
| Standard Dev          |          | 0.66         | 0.01         |              | 2.34         | 0.01         |
| Confidence Integral ± |          | 0.46         | 0.01         |              | 1.62         | 0.01         |

Table A-4. ASABE, Calculating Manure Production.

|                                | Animal<br>Number | Manure Prod   |        | Total Solids  |        |              | Total Solids<br>collected, lb/yr |                  |
|--------------------------------|------------------|---------------|--------|---------------|--------|--------------|----------------------------------|------------------|
|                                |                  | lb/animal-day | lb/day | lb/animal-day | lb/day | % TS         |                                  |                  |
| Milking Cows, RHA*, lb/cow-day | 65.5             | 473           | 137.1  | 64,841        | 17.4   | 8,242        | 12.7%                            | 3,008,383        |
| Dry Cows, Body Weight          | 1500             | 93            | 80.9   | 7,528         | 10.1   | 937          | 12.5%                            | 205,263          |
| Heifers, average Body Weight   | 1200             | 71            | 60.7   | 4,311         | 7.9    | 560          | 13.0%                            | 122,746          |
| Total                          |                  | <u>637</u>    |        | <u>76,681</u> |        | <u>9,740</u> | 12.7%                            | <u>3,336,391</u> |

117,066 lb/day @ 8.32% TS  
 13,854 gal/day @ 8.45 lb/gal  
 559 cow equivalents