MEASUREMENT AND VERIFICATION (M&V) PLAN

FOR

SWISS VALLEY BIOLOGICAL SCRUBBER SYSTEM

Agreement # - 51035

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Submitted to:

New York State Energy Research and Development Authority
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Albany, NY 12203-6399

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Introduction

Swiss Valley Farms is a dairy farm located Wyoming county. The farm consists of approximately 1,200 milking cows, which produce nearly 39,000 gallons of manure / day. In 2009, Swiss Valley Farms installed a mixed, plug flow, anaerobic digester designed by GHD to treat manure produced on site. The biogas produced by the digester is used to fuel a 300 kW Guascor SFGLD 240 reciprocating engine and generator.

The original digester design incorporated an air injection system intended to reduce biogas hydrogen sulfide (H_2S) levels to below the engine manufacturer's warranty levels. However, this approach was only capable of reducing H_2S levels to 1,000 – 1,600 ppm, well above the engine manufacturers warranty level of 800 ppm, and resulted in significant corrosion of the digester heating system piping. The high H_2S levels have resulted in increased downtime and maintenance of the engine due to high cylinder temperatures, spark plug fouling, and H_2S buildup on the cylinder heads.

This plan describes the approach to monitor the performance of the biological scrubber system that has been installed by Swiss Valley Farms. A monitoring system is installed to measure and collect pre and post scrubber H_2S levels to quantify the H_2S removal by the biological scrubber. The data will serve as the basis for payment of a capacity incentive to help offset the capital expenses associated with the procurement of the new biological scrubber equipment and ten (10) years of performance incentive payments, which Swiss Valley Farms has applied for under a Standard Performance Contract with NYSERDA.

Biological Scrubber System Description

The biological scrubber system at the farm was designed by Energy Cube LLC. The scrubber is designed for a biogas flow rate of 200 standard cubic feet per minute (scfm) containing up to 3,500 parts per million (ppm) of H_2S.

Table 1. Biological Scrubber System Design Specifications

Biological Scrubber	Energy Cube LLC
Scrubber Design Operation	Temperature: 120 °F PH: 2
Designed Biogas Flowrate	200 cfm
Biogas Pressure	Inlet: 5" WC Outlet (min)[1]: 2" WC
Biogas Composition (est.)	CH4 Inlet: 65 % CH4 Outlet: 55% O2 Inlet : < 1% O2 Outlet: < 3% H2S Inlet (max): 3,500 ppm H2S Outlet: 200 ppm

The biological scrubber system consists of the following major components; scrubber vessel, gas testing equipment, and scrubber control panel.

Scrubber Vessel

The scrubber vessel is an eight (8) foot diameter, twenty-five (25) foot tall tank located adjacent to the existing engine / generator building. The lower five (5) feet of the scrubber vessel contains a compartment that houses all of the systems pumps, blowers, heater, and 275 gallon nutrient tank. The upper portion of the scrubber contains the media on which the bacteria grows, which is separated from the 750 gallons of water stored in the bottom of the media section by a perforated floor.

Fresh water is fed into the bottom of the scrubber vessel at regular intervals during the day. This fresh water is heated from recovered hot water produced by the engine. The scrubber vessel has an overflow drain which keeps the water level from exceeding a certain height as fresh water

[1] Scrubber to be cleaned once differential pressure across scrubber reaches 4" WC.

flows into the scrubber. The main water pump in the bottom of the scrubber vessel has two modes of operation; low and high. When running in low the pump circulates and heats the water nutrient mixture in the bottom of the media section. Once an hour the pump runs in high mode, which pumps water to the top of the scrubber vessel and sprays it down over the media to keep the bacteria moist and provide nutrients. Nutrients are fed into fresh water as it is pumped into the scrubber vessel.

Biogas flows into the water storage portion of the upper media section of the scrubber, just above the water line. It then flows up thru the media, and out the opposite side of the scrubber and thru the mist eliminator on the side of the scrubber. This helps remove some of the moisture introduced to the biogas in the scrubber, before it reaches the existing cooling and de-watering heat exchanger.

Gas Testing Equipment

Gas monitoring equipment for the scrubber is located on the back left side wall, close to the back door, of the existing engine building. This equipment includes an INCA 4003 gas analyzer, two solenoids for taking samples, and necessary tubing for sampling the biogas.

Scrubber Control Panel

The scrubber control panel is located on the same wall as the gas testing equipment in the engine building. The panel has a system schematic as the main display screen which shows real time values of the critical control point measurements (biogas flow, O_2 flow, nutrient water flow, H_2S ppm, biogas pressures, etc.). The display is a touch screen for a simple user interface. The control panel also contains a Red Lion data logger, which is responsible for trending the critical scrubber control point measurements.

Figure 1, includes photographs of the biological scrubber system, Figure 2, shows a diagram of the biological scrubber system, and Figure 3 schematically shows the digester system with the addition of the new scrubber and new monitored data points.

Energy Cube biological scrubber tower, located behind existing engine building.

Scrubber control panel, located in existing engine building.

INCA 4003 gas analyzer and sampling solenoids (left H_2S into scrubber, right H_2S out of scrubber).

Media on which bacteria grow, located in upper portion of scrubber.

Figure 1. Photos of System Components

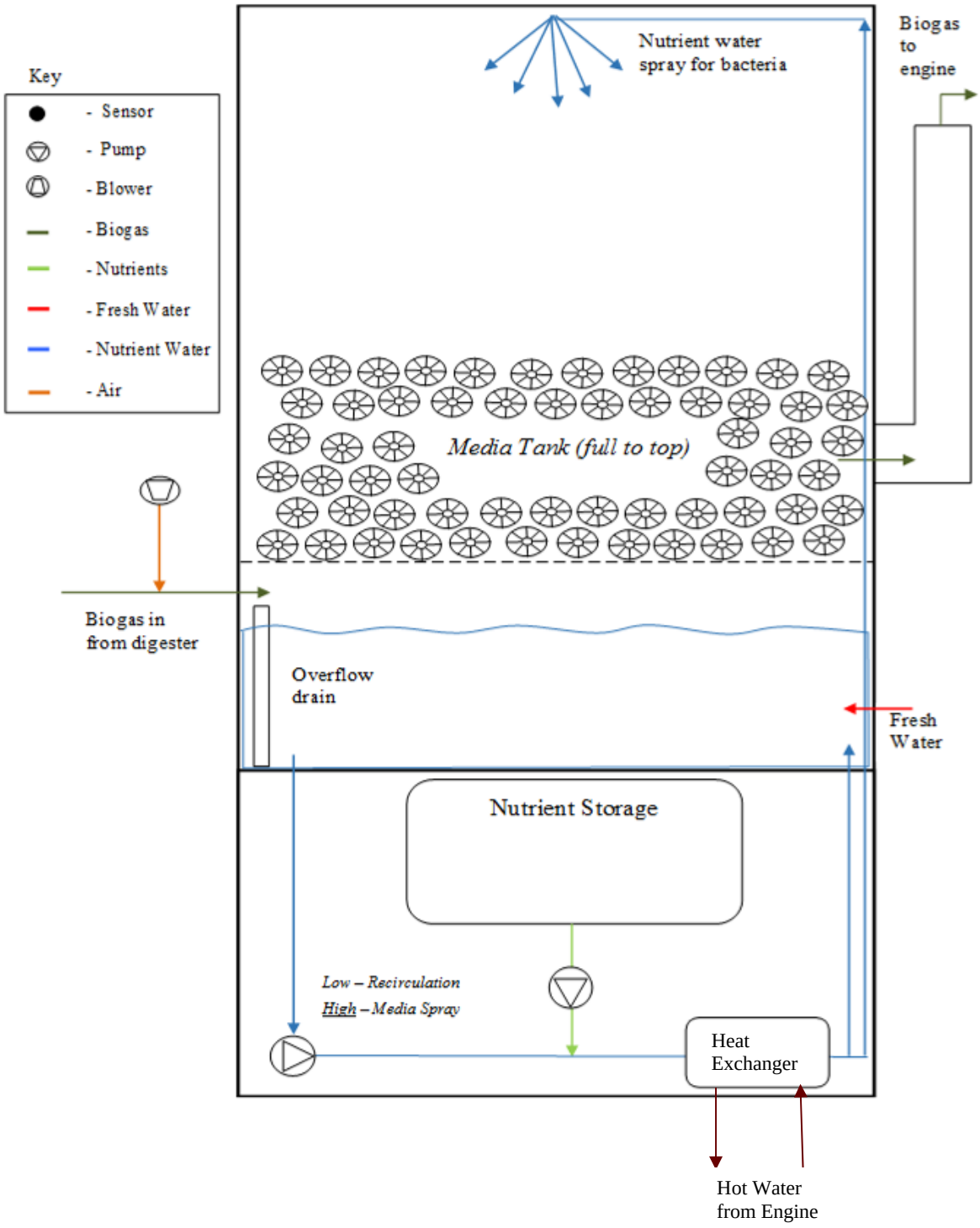

Figure 2. Schematic of Scrubber

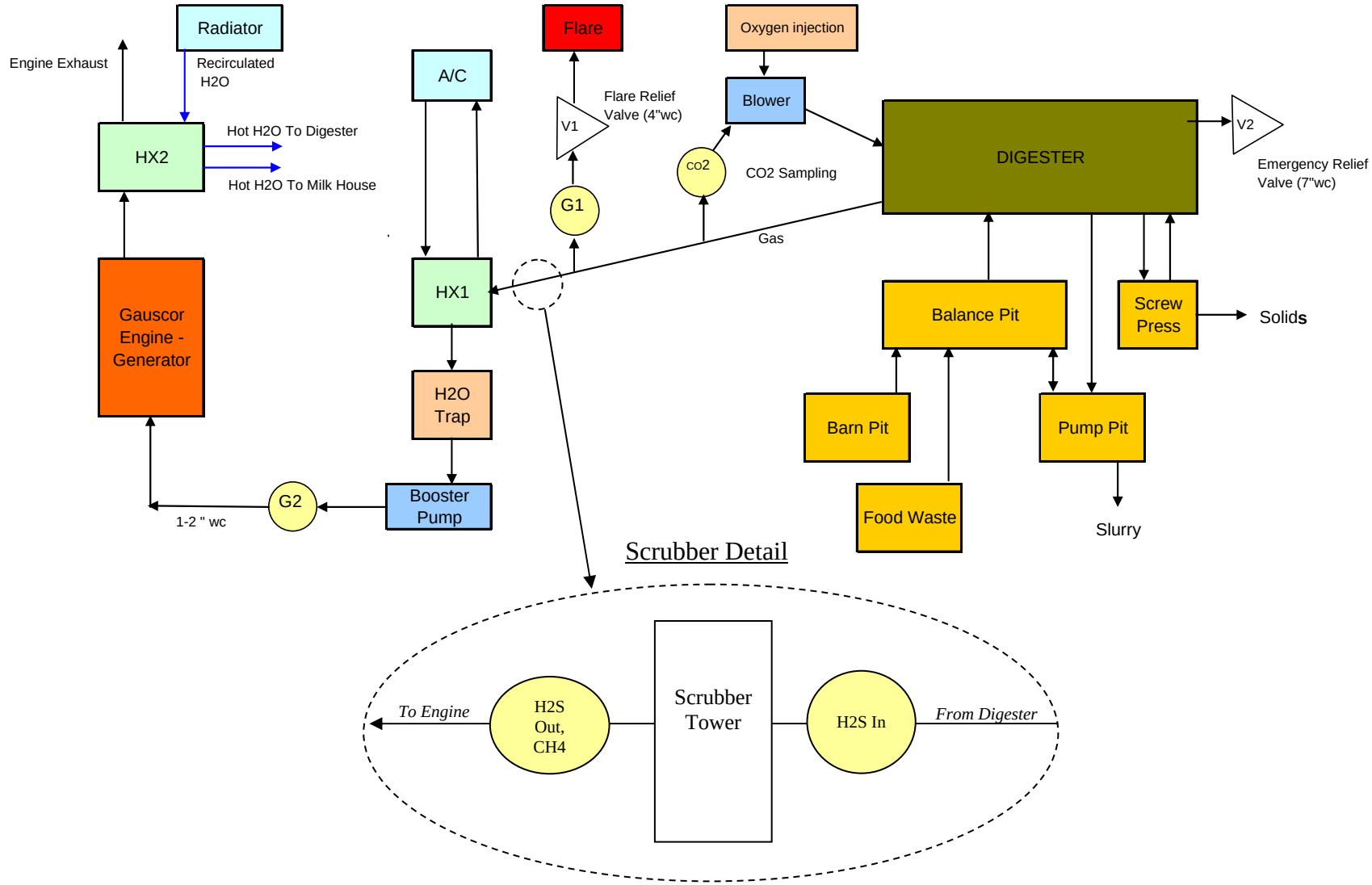

Figure 3. Schematic of ADG System

Capacity Payment Descriptions

This Section describes the Capacity Incentive Payments included in the Agreement, the payment milestones to be achieved in order to receive payment, and the deliverables to be provided in achieving these milestones. For a biological scrubber system, the available Capacity Payments are Capacity Payments 1, 4, 5, and 6, which are presented below.

Capacity Payment #1: Up to 15% of Total Capacity Incentive is payable for reimbursement of project costs once the Contractor provides evidence sufficient to demonstrate payments for major equipment (e.g. power generation system, anaerobic digester system, biogas clean-up and handling systems etc.) and/or engineering design.

Capacity Payment #4: Up to 45% of the Project Enhancement Component of the Total Capacity Incentive is payable once NYSERDA's designated technical consultant has verified that construction/installation of the Project Enhancement has been completed or the required documentation for the Project Enhancement, according to applicable sections of *Using the Incentive Calculation Tool* of Exhibit D has been submitted to NYSERDA. The Contractor may request payment at this time for any Project Enhancements that have been completed and verified. Payment for Project Enhancements completed and verified after the request for Capacity Payment #4 had been made may be requested with the Capacity Payment #6.

Capacity Payment #5: 20% of Total Capacity Incentive is payable once documentation has been provided to NYSERDA that sufficiently verifies successful operation of the newly installed system and completion of interconnection, if applicable (e.g. interconnection acceptance test documentation from the utility). Verification of successful operation, for example, may include documentation of operation of the equipment with data from meters or hand-held biogas measurement equipment or other methods of documentation satisfactory to NYSERDA.

Capacity Payment #6: Up to 100% of the Total Capacity Incentive is payable once the newly installed system is successfully commissioned. Commissioning includes operating the ADG-fueled energy generation system at a minimum of 75% average capacity factor over seven (7) consecutive days, and demonstrating the ability to upload data generated by the system to NYSERDA's CHP website, if applicable. A project Commissioning Report must also be completed detailing the installation and commissioning activities and include design updates and as-built diagrams. Any project Enhancements payments that were not made with the Capacity Payment #4 may be requested with this payment.

Monitoring System Equipment, Installation, Operation, and Maintenance

Payment for this incentive shall ultimately be based on the ability of the biological scrubber to reduce H_2S levels to less than 400 ppmv, as supported by collected data. Measurements will be made with continuous automatic gas sampling and analysis, or by other methods found acceptable to NYSERDA. For this project a Union Instruments GmbH INCA4003 biogas analyzer will be used to measure the H_2S concentrations and CH_4 percentage.

Figure 3 shows the locations of the three (3) new biogas measurements. The gas analyzer measures H_2S levels prior to the biological scrubber (**H2S_IN**), H_2S levels after the biological scrubber (**H2S_OUT**). Information on these data points is shown in Table 2.

Table 2. Monitored Points for Biological Scrubber System

Point Name	Description	Instrument	Engineering Units	Expected Range
H2S_IN	H_2S Before Scrubber	Union Instruments GmbH INCA4003	ppm	0 – 10,000 ppm (± 3% full scale)
H2S_OUT	H_2S After Scrubber	Union Instruments GmbH INCA4003	ppm	0 – 10,000 ppm (± 3% full scale)
CH_4	CH_4 After Scrubber	Union Instruments GmbH INCA4003	%	0-100 % (± 1 % full scale)

Maintenance activities will be performed in accordance with the instructions in the O&M manual. A log of maintenance activities for the meter will be maintained at the site.

The Union Instruments GmbH INCA4003 updates readings for CH_4, H_2S before scrubber, and H_2S after scrubber every 30 minutes. The Red Lion data logger, installed in the Scrubber Control Panel (separate from the Red Lion providing gas flow and generator power data), is recording the gas analyzer readings. The data logger is programmed to write 1-minute readings got each monitoring point. 15-minutes samples are taken by CDH, from the Red Lion 1-minute data, and loaded into a database. The 15-minute CDH database values are then averaged to calculate the hourly values that are displayed on the NYSERDA Data Integrator website.

The data logger will be connected to an uninterruptible power supply (UPS) to ensure the data logger retains its settings and data in the event of a power outage. The UPS is capable of powering the data logger for at least one day. The farm will provide a static IP address (or Ethernet connection if static IP is unavailable) that will be used for data logger communications. CDH Energy Corp. will set up automated processes to extract monitored data from the data logger and transfer the data to the NYSERDA Integrated Data System website on a nightly basis. The data logger is capable of holding at least 6 months of 1-minute interval data, so if communications are lost, back data will be able to be downloaded once communications are restored.

The worksheet in Appendix B will be used as a template for documenting the capabilities of the biological scrubber system. Biogas flow and H_2S input to and output from the biological scrubber will be documented for each hour of the year that samples are taken. The percentage of cumulative outlet H_2S samples (up to a maximum of 90% of the hours in a year) with 399 ppm H_2S and below will be submitted to document adequate compliance with the requirement for payment. The summary of samples will show the percentage of cumulative samples with 399 ppm H_2S and below as well as the percentage of cumulative samples with 400 ppm H_2S and above.

Incentive calculation methods for the 6th Capacity Incentive Payment and the annual Performance Payments, which are based on H_2S data, are as follows:

- To satisfy requirements for the 6th Capacity Incentive payment 111 hourly H_2S outlet data values (representing 75% of the 148 hours in a week) in a consecutive 7-day period must be below 400 ppm, and the generator output must be above 50% of the contracted capacity, or other documentation must be provided that is satisfactory to NYSERDA.

- The annual Performance Incentive payment for H_2S reduction is determined by multiplying the Contract Capacity (300kW), times the factor of 75% divided by 90%, times the verified hourly samples below the minimum H_2S threshold while the generator output is greater than 50% of the contracted capacity, times the H_2S Performance Incentive variable for a biological scrubber ($0.0023/kWh). NYSERDA will consider other formulations for calculating the Performance Incentive, in the event that the biological scrubber is unable to operate due to reasons outside of the operation of the scrubber itself. NYSERDA may direct its technical contractors to sample the biogas, determine H_2S removal efficiency, and compare the results to the data originally provided by the operator.

Management of Monitoring System Data (Farm Responsibilities)

The farm staff will perform the following quality assurance and quality control measures to ensure the data produced from the monitoring system accurately describes system performance.

On a daily basis, the farm equipment manager (or other specified employee) will perform inspections of the biological scrubber equipment and record findings into the project log.

On a weekly basis, the farm equipment manager (or other specified employee) will perform inspections of the QA/QC biogas analyzer installations and complete the routine maintenance on the analyzer, noting any abnormalities or unexpected readings.

On a weekly basis, the farm staff will review the data stored on the NYSERDA Integrated Data System website (chp.nyserda.org) to ensure it is consistent with their observed performance of the biological scrubber system and logged readings. The farm will review the data using the reporting features at the website, including:

- Monitored Data – Plots and Graphs
- Monitored Data – Download (CSV File)

In addition, the farm staff will also setup and use the email reports that are available at the Integrated Data System website to help the track system performance, including:

- A periodic email report summarizing performance and the estimated incentive,
- An email report will be sent out if data are not received at web site or do not pass the quality checks.

The website will automatically evaluate the quality of the collected data using range and relational checks. The expected ranges for the sensors (Table 2) will be used for the range checks. The relational check will compare the H_2S ppm data to ensure the gas analyzer is providing valid readings at the same time (ex; H2S_IN should always be greater than H2S_OUT). An additional relational check will compare the H2S_OUT data with the hourly kWh output data (or biogas flow to engine if kWh data unavailable) to confirm that biogas is flowing through the scrubber on its way to the engine generator. Data that passes the range and relational quality checks can be used in the incentive reports listed above. However, all hourly data are available from the NYSERDA Integrated Data System website using the "Download (CSV file)" reporting option. Further details on range and relational data quality checks, including site specific ranges and relations, can be found in the sites "Database Notes" document on the NYSERDA CHP website.

In the event of a communications or analyzer failure, the farm personnel will work with CDH to resolve the issue.

If unanticipated loss of data occurs when the biological scrubber is operational, the farm will follow the procedures outlined in Exhibit D of their contract, i.e. using data from similar periods – either just before or after the outage – to replace the lost data. Farm personnel understand that they can use this approach for up to two (2) 36-hour periods within each 12-month performance reporting period. If more than two (2) such data outages occur, farm personnel will provide information from other acceptable data sources (e.g., weekly recorded logs) to definitively determine the H_2S levels of the biogas during the period in question.

Appendix A

Cut sheets and Manuals for:

- **Red Lion Controls G306A000 Data Logger with Graphic Interface**

  http://www.redlion.net/products/groups/operatorinterface/g306/docs/07037.pdf

- **Universal Instruments INCA GmbH 4003 Gas Analyzer**

  engl.union-instruments.com/tl_files/downloads/Infomaterial/INCA_english.pdf

- **Draeger Tubes / Pump**

  http://www.buydraegertubes.com/accuropump.aspx

  www.buydraegertubes.com/ds/8101831.pdf

  www.buydraegertubes.com/ds/6728821.pdf

Appendix B

H_2S Reduction Spreadsheet

Worksheet to Document Ability of Biological Scrubber to Produce Measured H_2S Concentrations Less then 400 ppmv for 75% of Samples									
Data to be Completed by Operator					Analysis which can be done by Technical Consultant				
A	B	C	D		E	F	G	H	I
Hour	Date of Sample	H_2S in Biogas Before Cleanup (ppm)	H_2S in Biogas After Cleanup (ppm)		Sorted H_2S Data	Range of H_2S Concentrations (ppm)	Number of Samples in Each Range	Cumulative Number of Samples less than Range Maximum	Percentage of Cumulative Samples Less than Range Maximum
12:00:00 AM	1	1,500	50			0 to 399	18	18	75%
1:00:00 AM	1	1,600	50			400 or higher	6	24	100%
2:00:00 AM	1	2,000	250				Total Samples:	24	
3:00:00 AM	1	1,600	250						
4:00:00 AM	1	1,400	400						
5:00:00 AM	1	1,250	150						
6:00:00 AM	1	1,300	150						
7:00:00 AM	1	1,500	150						
8:00:00 AM	1	2,000	200						
9:00:00 AM	1	1,500	250						
10:00:00 AM	1	1,500	250						
11:00:00 AM	1	1,600	150						
12:00:00 PM	1	800	250						
1:00:00 PM	1	800	350						
2:00:00 PM	1	1,200	350						
3:00:00 PM	1	1,100	450						
4:00:00 PM	1	1,300	350						
5:00:00 PM	1	1,400	350						
6:00:00 PM	1	1,500	350						
7:00:00 PM	1	1,400	550						
8:00:00 PM	1	1,300	550						
9:00:00 PM	1	1,500	350						
10:00:00 PM	1	2,000	950						
11:00:00 PM	1	800	550						
NOTE: This is an example for 1 days worth of data. This table will need to be extended to 7 days for the 6th Capacity Payment and 365 days for the Annual Performance Payments.									