MEASUREMENT AND VERIFICATION (M&V) PLAN

FOR

PATTERSON FARMS BIOLOGICAL SCRUBBER SYSTEM

Agreement # - 42045

Revised

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Submitted to:

New York State Energy Research and Development Authority
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Introduction

Patterson Farms is a dairy farm located in Cayuga county. The farm consists of approximately 1,800 milking cows. In 2005 Patterson Farms installed a mixed flow, soft covered, anaerobic digester, and 180 kW Cat G379 engine and generator. The system was designed by RCM and was installed to treat manure produced on site and accept food processing waste totaling approximately 360 milking cow equivalents. In 2009 Patterson Farms installed a second, 225 kW Guascor SFGLD 180, engine and generator in order to take advantage of surplus biogas being produced. Around the same time the farm also installed an RCM biological scrubber system.

The original RCM biological scrubber system consisted of four (4) scrubber vessels and a foam reducer. The system worked well for a period of time however there were some operational issues. Hydrogen sulfide (H_2S) removed from the biogas would plug the scrubber vessels and prevent biogas from flowing thru. This resulted in the need to disassemble the scrubber vessels in order to manually clean and empty them of accumulated H_2S every 6 to 12 months. After nearly 5 years of operation two (2) of the scrubber vessels were removed due to reoccurring maintenance issues. The two (2) remaining scrubber vessels were capable of only scrubbing enough biogas for one of the engines.

The old scrubbers were still functioning in 2015, however the operation and maintenance required to keep them running was the deciding factor for installing the new American Biogas Conditioning Scrubber system.

This plan describes the approach to monitor the performance of the biological scrubber system that has been installed by Patterson 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 Patterson 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 American Biogas Conditioning, LLC. The scrubber is designed for a typical biogas flow rate of 210 standard cubic feet per minute (scfm) containing up to 4,000 parts per million (ppm) of H_2S.

Table 1. Biological Scrubber System Design Specifications

Biological Scrubber	American Biogas Conditioning, LLC
Scrubber Design Operation	Bioreactor Temperature: 90 °F PH: 1.3
Designed Biogas Flowrate	210 cfm
Biogas Pressure	Inlet: -2" to 16" WC Outlet : -2" to 16 WC
Biogas Composition (est.)	CH4 Inlet: 55% to 58% CH4 Outlet: 48% to 50% O2 Inlet : < 1% O2 Outlet: < 2% H2S Inlet (max): 4,000 ppm H2S Outlet: < 200 ppm

The biological scrubber system consists of the following major components; bioreactor, gas testing equipment, technical building, and control switchbox (PLC).

Bioreactor

The bioreactor is a 9' 2" diameter, 38' tall cylindrical tower with a conical roof and flat bottom. The tower is made of corrosion proof fiberglass or polypropylene and is located adjacent to the existing scrubber equipment. The bioreactor houses the packing media on which the bacteria grows, which is distributed among a top and bottom deck. The bottom of the bioreactor, below the two media decks, serves as a collection basin for the nutrient and water mixture and the sulfur that is removed from the bioags. The bottom level is separated from the first deck, and the first deck is separated from the second deck, by perforated flooring; this allows the water nutrient mixture and sulfur rinsed from the media to pass through but keeps the packing material in the upper two levels.

The decks of the bioreactor are identical and consist of the packing material and vertical PVC piping. The piping sprays the packing material with the nutrient mixture in order to feed the bacteria and rinse the packing material in order to prevent sulfur accumulation.

Technical Building

The technical building is an 8' x 16' lighted, climate controlled space with ventilation, heating, and a locking door. The building consists of two separate spaces; the Utility Room and Technical Room.

The utility room houses the process power panel, control switchbox, and the nutrient storage tote. The technical room houses all the systems process instrumentation and control equipment. This includes circulation pumps, process air blower, automated nutrient dosing pump, heating pump, plant instrumentation and controls, gas analyzer, climate control system, and human machine interface (HMI).

Fresh water is heated with hot water from the engine loop, mixed with nutrients, and sprayed into the bioreactor. The control system alternates between circulating the water and nutrients and spraying the media in each individual deck. The bottom of the bioreactor has an overflow drain which keeps the water level from exceeding a certain height.

Biogas flows into the first deck of the bioreactor. It then flows up and back down thru the media, out the same side of the bioreactor, and thru the existing foam reducer, which has been repurposed as a mist eliminator. 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

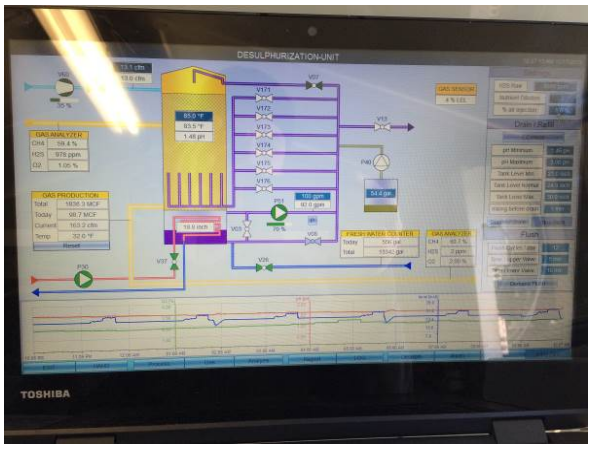
Gas monitoring equipment for the scrubber is located left of the door to the technical room in the utility building. This equipment includes an INCA 4003 gas analyzer, two solenoids for taking samples, and necessary tubing for sampling the biogas.

Control Switchbox

The control switchbox (PLC) is located in the utility room on the external wall of the technical room. The PLC includes the I/O bus, controls, and CPU that controls the automatic operation of the scrubber. The CPU also communicates the control parameters to the HMI located in tehe technical room, via TCP/IP. This allows for remote access to the scrubber controls for remote management in addition to allowing for automated transfer of data files as required by NYSERDA.

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

American Biogas Conditioning bioreactor (left) and technical building (right).



Scrubber HMI, located in the technical room of the technical building.

INCA 4003 gas analyzer.

Gas sampling solenoids for gas analyzer.

Scrubber biogas flow meter; measures biogas leaving scrubber (biogas + air injection).

Bioreactor packing material.

Dosing pump; injects nutrients into feedwater to bioreactor.

First deck of bioreactor looking up towards second deck (without packing material) – vertical PVC piping for feeding bacteria and rinsing packing material.

Figure 1. Photos of System Components

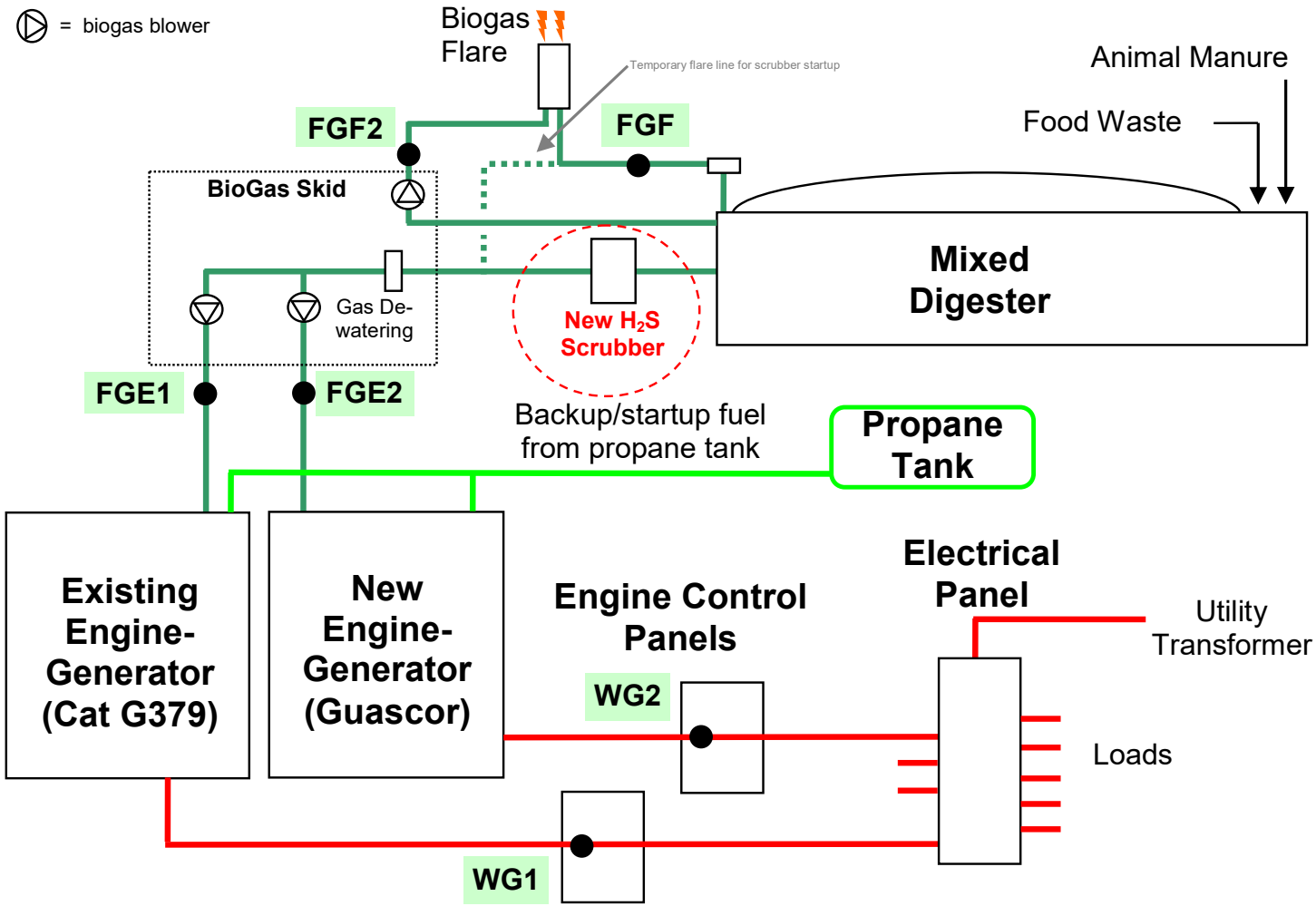


Figure 2. Schematic of ADG System

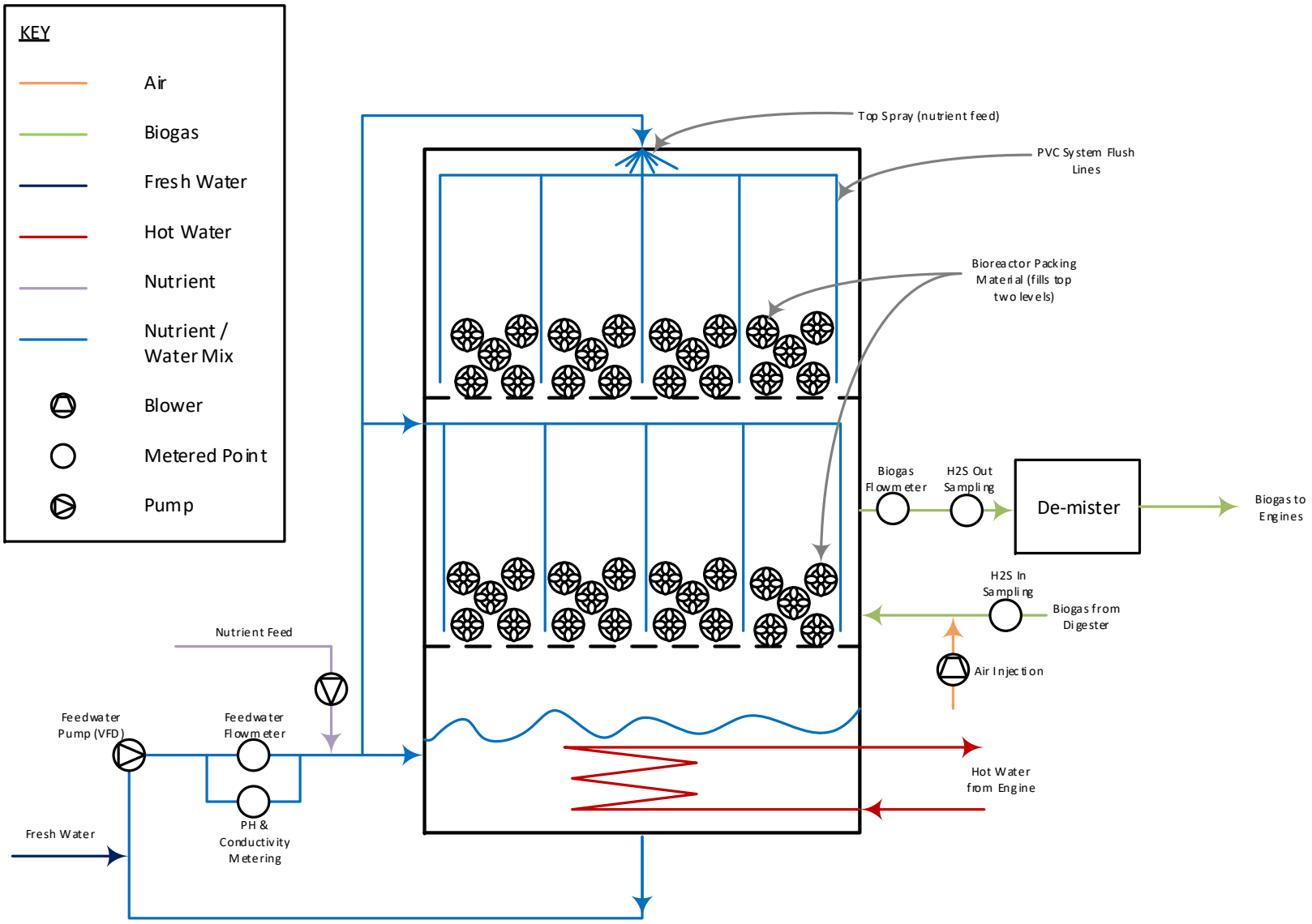


Figure 3. Schematic of New H_2S Scrubber

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 2 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 PLC, located in the technical room, is recording the gas analyzer readings. The PLC is programmed to write 15-minute readings for each monitoring point. The 15-minute are loaded into a local CDH database. These 15-minute values are then averaged to calculate the hourly values that are displayed on the NYSERDA Data Integrator website.

The farm will set up automated uploads to the CDH FTP server. The farm will also provide CDH appropriate VPN credentials so that the PLC can be accessed remotely in order to update the automated uploading script if needed. The PLC has ample storage and is capable of storing months of the 15-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 (475 kW), 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.

    - NYSERDA has approved an alternative method (amended 4/12/18) of calculating the farms annual incentive due to the fact that one of the two (2) generators are no longer in operation. Instead of using 50% of the contracted kW capacity as the threshold for operation 50% of the currently operating 225 kW engine generator's rated fuel requirement flow (2,050 cubic feet biogas per hour based on engine specs and 530 Btu/cf) ***or*** 50% of the engine generator's electrical capacity of 112.5 kW will be used. Any hour in which either of these requirements are met and a reading of less than 400 ppm H2S is recorded shall be counted toward the annual incentive calculation applied to the method described above. Flow thru the scrubber is calculated as the sum of the biogas flow to engine 1, engine 2, and the pressurize flare flow.

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). 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:

- **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.									