Description of and Data Regarding Animal Waste Gasification
NRCS Conservation Practice Code 735 (see attached)

1) Recommended nitrogen, phosphorus, and sediment loading or effectiveness estimates. Discussion may include alternative modeling approaches if appropriate.

The most accurate and appropriate way to measure the effectiveness of manure or poultry litter gasification is to conduct periodic lab analyses of the nitrogen and phosphorus concentrations in manure or poultry litter just before it is fed into gasifier, conduct periodic lab analyses of the biochar as it exits the gasifier, and real time or periodic stack (air) emissions. The biochar will be approximately 21% of the mass of the manure or poultry litter that is fed into the gasifier, but it will capture virtually 100% of the phosphorus (see attached estimate for poultry litter).

2) Justification for the selected effectiveness estimates, including
- List of references used (peer-reviewed, etc.)
- Detailed discussion of how each reference was considered

The two animal waste gasification systems that have been deployed by private industry have not been peer-reviewed. However, they have both been visited and reviewed by Jeff Porter, the Head of the Manure Management Team at the NRCS East National Technical Center in Greensboro.

A review and compilation of the lab analysis of grab samples of manure or poultry litter just before it is augered into the gasifier, lab analysis of grab samples of the biochar as it exits the gasifier, and lab analysis of air emissions from the thermal oxidizer are the three most appropriate and accurate methods for calculating the nutrient removal efficacy of NRCS Conservation Practice Code 735.

The concentration of P_2O_5 and nitrogen in raw manure and poultry litter is well known. During gasification, the biochar or ash captures virtually 100% of the phosphorus in the raw manure or poultry litter, and when a thermal oxidizer is part of an oxygen-starved animal waste gasification system, the vast majority of the nitrogen in the manure or poultry litter is driven off as N_2. The use of a thermal oxidizer in conjunction with a waste gasification system was the rationale for the EPA issuing a December 13, 2013 letter ruling that such gasification systems have a far lower emissions profile than incinerators.

3) Land uses and manure types to which the BMP is applied.

Gasification can be used to process any type of animal waste and it eliminates the need for CAFOs to store poultry litter or manure on the farm.

Since manure gasification is an exothermic process (i.e. uses the manure or litter as a fuel), and since it generates 3,200 to 5,680 Btu per pound of the animal waste being gasified (depending on the moisture and ash content of the manure), the waste heat can be used to dry high-moisture manures such as dairy manure solids, or hog waste solids. Poultry manure and poultry litter are dry enough to be fed directly into the gasifier at up to 30% moisture.

4) Load sources that the BMP will address and potential interactions with other practices.

Animal waste gasification systems will address high levels of atmospheric ammonia or soils with high concentrations of nitrogen or phosphorus in any watershed within the Chesapeake Bay. Animal waste gasification eliminates the land application of large tonnages of raw manure or poultry litter, and significantly reduces the need to install costly and uncertain land-based BMPs.

5) Description of pre-BMP and post-BMP circumstances, including the baseline conditions for individual practices.

Pre-BMP circumstances - The gasification of manure generates a substantial amount of useable energy that can be used in a variety of applications; including drying. Poultry litter and layer manure are dry enough to be augered directly into the gasifier without being pre-dried. Raw dairy manure and hog waste solids have to be dried to 20-30% moisture before being augered into the gasifier, thus when gasifying 2.0 tons per hour of dried manure, for example, a portion of the 12.8 to 22.7 million Btu per hour of waste heat from the gasifier / thermal oxidizer is captured and used to dry the raw dairy manure or hog manure solids using either a rotary drum dryer or a hot-oil auger screw dryer. Excess waste heat can be used to generate electricity, produce steam, or provide heat to farm buildings. Additionally, the gasification process can be used in conjunction with other valuable processes. For example, solids separation systems usually are used when handling liquid manures with less than 10% solids. The solids fraction from these systems is typically about 65 to 70% moisture – which becomes a suitable fuel for a gasification/drying system as mentioned above. The combination of these technology greatly increases the removal of nutrient discharge as the levels of soluble Phosphorus in these liquid manures are much greater than in manures with lower moisture contents.

Post-BMP circumstances: Since the only by-product of manure gasification is phosphorus-rich biochar, the final disposition of the biochar needs to be monitored, and if the biochar is transported out of the Bay watershed, the mass of phosphorus in the biochar could be utilized to help calculate trading credits in the relevant watershed (see attached estimates based on litter gasified in Rockingham Co. VA).

6) Conditions under which the BMP works:

- This should include conditions where the BMP will not work, or will be less effective. An example is large storms that overwhelm the design.
- Any variations in BMP effectiveness across the watershed due to climate, hydrogeomorphic region, or other measureable factors.

Refractory brick-lined manure gasification / thermal oxidizer systems are installed in a covered building or shed, and operate 24 hours per day, ~350 days per year. The gasifiers can operate in any location, halting operation only for routine maintenance of the system. Gasification is not restricted by geography, and neither weather nor climate has an impact on its around-the-clock operation.

7) Temporal performance of the BMP including lag times between establishment and full functioning (if applicable).

Full functioning and efficacy of manure gasification begins with the first load of dried manure or poultry litter that is placed in the moving-floor feed-in hopper and operation continues around-the-clock.

8) Unit of measure (e.g., feet, acres)

Tonnage of raw manure or poultry litter processed by the gasifier, and the pounds of lab-verifiable phosphorus and nitrogen removed from the Bay watershed.

9) Locations within the Chesapeake Bay watershed where this practice is applicable.

Gasification can be practiced anyplace within the Chesapeake Bay watershed where excess manure and excess concentrations of phosphorus and nitrogen exist.

10) Useful life; effectiveness of practice over time.

Refractory brick-lined gasifier / thermal oxidizer systems are very costly and they are built to operate for more than 30 years, remaining lab-verifiably effective over a long period of time.

11) Cumulative or annual practice.

NRCS Conservation practice is a continuous, real-time, internet-connected and laboratory-verifiable BMP.

12) Description of how the BMP will be tracked and reported. Include a clear indication that this BMP will be used and reported by jurisdictions.

As mentioned above, the most accurate and appropriate method for tracking and reporting manure gasification's nutrient removal efficacy is to require reports of the tonnage of manure being processed, and periodic lab analysis of the manure or poultry litter, the biochar (i.e. by-product) and stack air emissions from the thermal oxidizer. Animal waste gasification is a point-source nutrient removal technology, and it allows states to incorporate this BMP in their measurement and verification plans, including watershed implementation and other reports to the EPA.

13) Identification of any ancillary benefits or unintended consequences beyond impacts on nitrogen, phosphorus and sediment loads. Examples include increased, or reduced, air emissions.

Since almost all of the ammonia in the manure or poultry litter is combusted and converted to N_2, and since the volatile organic compounds (VOCs) in the manure are combusted during oxygen-starved gasification of the manure and oxygen-enriched thermal oxidation of the syngases, the release of ammonia and VOCs from the raw manure or litter into the atmosphere is eliminated. From a nutrient-capture and energy-capture perspective, the fresher the manure or poultry litter, the better. As with any combustion process, carbon dioxide, SOx and NOx are emitted, but the levels are very low per ton of manure being processed, and they represent a lower threat to the atmosphere than the ammonia and VOCs in the raw manure or litter when it is stored and land applied.

14) Suggestion for a review timeline; When will additional information be available that may warrant a re-evaluation of the estimate.

As mentioned above, the two animal waste gasification systems that have been deployed by private industry have been visited and reviewed by Jeff Porter, the Head of the Manure Management Team at the NRCS East National Technical Center in Greensboro. An on-site visit by the Bay Manure Expert Panel to either of these regional-scale manure gasification systems can be arranged at the Panel's convenience.

15) Outstanding issues that need to be resolved in the future and a list of ongoing studies, if any.

Studies of manure gasification systems are not necessary, since the technology is already operating in large-CAFO settings by private industry.

16) Operation and maintenance requirements and how neglect alters performance.

Like any costly technology with moving parts (e.g. augers operating in a high-temperature environment), routine maintenance is required. Because a large-CAFO or regional-scale manure or litter gasifier / thermal oxidizer facility (land, equipment, buildings, etc.) costs more than $2 million, there is a very strong incentive to operate it as many hours as possible and for as many years as possible.

17) Discussion of how the practice will be verified.

Since large CAFO-scale manure gasifiers are currently operating, due diligence visits can be conducted on-site. Since the systems are fully automated and connected to the internet, manure or litter gasification systems that are installed in the Chesapeake Bay watershed can be monitored in real-time by the appropriate department of environmental quality. In addition, periodic reports of how much manure has been processed and periodic lab analysis of the raw animal waste, biochar output and air emissions can be reported to the appropriate regulatory authorities.

Postscript: It should be noted that alternative methods for calculating large volumes of nutrient credits will need to be adopted for regional-scale poultry litter gasification systems, since the poultry litter will be received from dozens of farms and the farms supplying the litter will vary slightly from one year to another. Many poultry farms supplying litter to a regional-scale gasification facility do not have a baseline practice in which the litter was formerly land-applied only to their land or within the farm's sub-basin watershed, but was instead sold to third parties and applied elsewhere, usually within the same HUC-4 or HUC-6 watershed.

NATURAL RESOURCES CONSERVATION SERVICE

VIRGINIA CONSERVATION PRACTICE STANDARD

INTERIM STANDARD

WASTE GASIFICATION FACILITY

(No.)

CODE 735

DEFINITION

Thermo-chemical treatment facility for animal and agricultural waste in an oxygen starved environment.

PURPOSE

Gasification of animal manure and other agricultural by-products to address one or more of the following:

- To improve ground and surface water quality by reducing or concentrating the nutrient content, reducing organic strength, and/or reducing pathogen levels of agricultural operations
- To improve air quality by reducing odors and gaseous emissions
- To produce syngas for energy production and other value added by-products
- To facilitate desirable waste handling, storage, efficient transfer or land application alternatives for nutrients

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where:

- The facility and associated components are part of an agricultural waste management system.
- Raw agricultural waste contains excess nutrients for land application based on crop utilization requirements or nutrient ratios need to be modified to be more consistent with crop utilization requirements. There is a need to reduce the potential for leaching or runoff of nutrients.
- Reduction of pathogens is desired.
- Odors and/or gaseous emissions from livestock production facilities and waste storage/treatment system components must be reduced.
- Syngas and/or process heat can be captured and used to dry manure or other agricultural products and/or generate electricity.
- Value-added byproducts can be produced to offset treatment costs.

CRITERIA

General Criteria Applicable to All Gasification Treatment Systems.

Laws and Regulations. Agricultural waste gasification facilities must be planned, designed, and constructed to meet all Federal/State/Tribal/Local laws and regulations.

Feasibility Study. The system provider shall conduct a feasibility study to determine whether the proposed project is feasible and meets the landowner's objectives. Identify the components of the proposed system and provide the costs, in time, money, or other resources, of the installation, start-up, and operation of the facility. Include information on feedstock availability, marketing the products and by-products, and the anticipated return on the investment. Identify any parts of the system that would require a commitment from an outside entity if their actions would impact feasibility. Include a clear identification of the resource concerns to be addressed and the anticipated effects on the environment.

Design. The system provider will complete and supply to the landowner/operator a detailed design of the gasification system. If needed for proper operation, include designs for pre-processing and post-processing facilities such as solid/liquid separation and pelletizers.

As a minimum, include a process diagram in the design documentation along with the following information:

1. The volume and characteristics of the feedstock and of the anticipated products and by-products.

2. Projections of pre-processing and post-processing requirements, including storage, handling, transfer and utilization.

3. Expected air emissions from the system.

4. Nutrient fate projections within the system.

5. Expected pathogen reductions.

6. Process monitoring and control system requirements as described below in the monitoring section.

Feedstock Pre-processing. For the gasification system to function efficiently, pre-processing of the manure such as solid/liquid separation, drying and/or particle size manipulation may be required. Consult the Virginia NRCS Conservation Practice Standards *Solid/Liquid Separation Facility (Code 632)* or *Waste Treatment (Code 629)* for pre-processing guidance.

Components. The gasification system provider will furnish a minimum one year warranty on all construction or applied processes. In addition, the manufacturer will provide a warranty with documentation that describes the service life of each component and what the warranty covers.

The minimum practice life for a gasification system is ten years. Clearly identify in the Operation and Maintenance Plan the expected replacement of any components which have less than a 10 year service life.

Monitoring. Install the necessary equipment to properly monitor and control the waste stream as part of the gasification system.

Monitor the process control parameters identified in the design documentation.

If the gasification unit is located in a confined facility, environmental monitoring must be maintained to ensure proper air quality for working conditions.

Monitor the run status of critical equipment and unit processes.

The landowner/operator must have the interest and skills to monitor and maintain processes or contract with a consultant to provide these services.

Gasification By-Products. Properly dispose of or beneficially use all gasification by-products in a safe and environmentally sensitive manner.

Handle and store all by-products in such a manner as to prevent nuisances to neighbors or to the public at large.

Use Virginia NRCS Conservation Practice Standard *Nutrient Management (Code 590)* when by-products are land applied to supply plant nutrients.

Some of the potential gasification by-products include:

- Syngas. If the syngas is not self-consumed through the gasification process, it can be used for electricity generation, heating, cooling and/or pipeline quality gas. Additional processing of the syngas may be necessary for it to be properly utilized.
- Ash. Through complete gasification, most nitrogen and carbon is converted to a gas phase, while many of the other nutrients (i.e. phosphorus and potassium) remain in a concentrated form in the ash. Use of this material can reduce transportation costs for land application and improve nutrient placement.
- Biochar. Depending on the operating temperature, pressure and other parameters, the resulting ash may qualify as biochar, which is a carbon rich product. Biochar can be used as a soil amendment, carbon source or filtration medium for soil water. Evaluate the biochar produced to ensure it meets the desired use.

- Heat. One by-product of gasification is heat which can be used for drying, heating, cooling, and/or electricity generation.
- Liquid Fuels. Through further processing of the syngas, various types of liquid fuels can also be produced.

Structural Design. Design roofs and enclosures in accordance with the requirements of Virginia NRCS Conservation Practice Standards *Roofs and Covers (Code 367)* and *Waste Storage Facility (Code 313)*.

Facility Closure. Prepare a plan that describes the procedures required to close the facility.

Outside Fuel Source. Identify needed start-up or supplemental energy sources and provide appropriate storage and handling plans.

Safety. Include adequate safety features in the design of the gasification system to minimize hazards. Provide guards and shields for moving parts of the equipment used in the gasification process.

A considerable amount of heat is generated by gasification. Use of proper protective equipment such as gloves and insulated clothes is required.

Ensure that the gasifier and associated appurtenances are gas tight to avoid gas escape and air intake which could lead to the release of toxic gases and/or accumulation of flammable gases.

If the gasification system will create a safety hazard, fence the area and post warning signs to prevent usage for purposes other than intended.

As a minimum, post “Warning-Flammable Gas” and “No Smoking” signs. Provide appropriate fire protection equipment and syngas leak detection sensors, especially in confined areas.

Design the ventilation controls to maintain an environment that will prevent the release of smoke, gas or potential blow out from the system.

Carry out all treatment processes in accordance with all safety regulations.

Mark the location of underground gas lines with signs to prevent accidental disturbance or rupture. Properly label any exposed pipe.

Additional Criteria for Gasifiers that Do Not Self-Consume Syngas.

Syngas is flammable, highly toxic and potentially explosive. The design of a gasification system, including gas collection, control, storage and utilization processes, must address the hazards associated with normal operation and maintenance. Provide adequate safety measures and be in accordance with standard engineering practice for handling a flammable gas and to prevent undue safety hazards. As a minimum:

- Locate flares an appropriate distance from syngas sources and storage. Place enclosed flares as recommended by the manufacturer. The minimum distance of open flares from the syngas source or storage area is 95 feet. Maintain a minimum flare height of 10 feet. Ensure that flares are grounded or otherwise protected to minimize the chance of lightning strikes.
- Equip the flare with automatic ignition and powered by battery/solar or direct connection to electrical service. Ensure that the flare has a capacity equal to or greater than the anticipated maximum syngas production. Install a windshield to protect an open flare against wind.
- Install a flame trap device in the syngas line between the gasifier and sources of ignition or as recommended by the flame arrester manufacturer.

Gas Collection, Transfer, and Control System. Design the syngas collection, transfer, and control system to convey captured gas from the gasification unit to gas utilization equipment/devices (flare, boiler, engine, etc.) or storage.

1. Gas collection and transfer – Meet the following for pipe and/or appurtenances:
   - Securely anchor pipe and components to prevent displacement from normal forces and loads.
   - Pipe used for transfer of gas must include provisions for drainage of

condensate, pressure and vacuum relief, and flame traps.

- For steel pipe meet the requirements of AWWA Specification C-200 or ASTM A53/A211 for stainless steel.
- For plastic pipe meet the requirements of AWWA Specification C-906 or ASTM D-3350 for HDPE.
- Install pipes to enable all sections to be safely isolated and cleaned as part of routine maintenance.

2. Gas Control

- Locate and shelter equipment and components from the elements along with making them readily accessible for replacement or repair.
- Ensure that the size of equipment and connecting pipe has a capacity consistent with its intended use.
- Where electrical service is required at the control facility, meet the National Electrical Code, state and local requirements for all electrical wire, fixtures, and equipment.

3. Syngas Storage

If syngas is to be stored for future use or post-processing, provide adequate volume to meet the requirements for its final use.

Incorporate necessary safety precautions to prevent excess pressure in the gas storage area.

Follow the guidelines outlined for the use of flares and flame traps for syngas storage units.

Gas Utilization. Design and install gas utilization equipment in accordance with standard engineering practice and the manufacturer's recommendations. Include a flare to burn off excess gas.

- Design gas-fired boilers, fuel cells, turbines, and internal combustion engines, when a component of the system, for burning syngas directly or burning as a mix with other fuel. Some equipment may require the removal of H_2S and other contaminants from the syngas before it will operate properly.
- Install and maintain a gas meter, suitable for measuring syngas.

CONSIDERATIONS

Location. Consider locating the gasification facility as near the source of manure or other waste as practicable and as far from neighboring dwellings or public areas as possible. Proper location should also consider slope, distance of manure and other waste transmission, vehicle access, wind direction, proximity of streams and flood plains, and visibility.

Visual Screening. Evaluate the visual impact of the gasification facility within the overall landscape context. Screening with vegetative plantings, landforms, or other measures may be implemented to alleviate a negative impact or enhance the view.

PLANS AND SPECIFICATIONS

Plans shall include all engineering drawings and supporting documentation as well as other plans required to manage the system such as a nutrient management plan for proper land application of by-products.

Prepare plans and specifications for gasification facilities in accordance with the criteria of this standard and good engineering practice.

As a minimum, provide the following in the plans and specifications:

1. Environmental Evaluation
2. Layout and installation details of livestock facilities, waste collection points, waste transfer components, storage facilities and gasification system.
3. Documentation that all necessary outside commitments have been confirmed.
4. Location of all inflow and discharge pipes, construction materials, and necessary appurtenances.
5. Details of support systems for all components of the gasification facility.
6. Fencing and signage as appropriate for safety purposes.

OPERATION AND MAINTENANCE

Develop an operation and maintenance (O&M) plan and review it with the owner/operator prior to construction of a gasification facility. Identify parameters considered critical to proper system function in the Operation and Maintenance Plan. Ensure that the O&M plan is consistent with the proper operation of all system components and contains requirements including but not limited to:

- Recommended loading rates and capacities of the gasification system.
- Proper operating procedures for the gasification system.
- Operation and maintenance manuals for pumps, blowers, instrumentation and control devices, and other equipment used as components of the gasification system.
- Description of the planned startup procedures, normal operation, safety issues, and normal maintenance items. This includes procedures for the planned replacement of components with less than a ten year service life.
- Alternative operation procedures in the event of equipment malfunction.
- Shut-down procedures for both maintenance and for permanent closure.
- Troubleshooting guide.
- Monitoring and reporting plan designed to demonstrate system performance on an ongoing basis.

REFERENCES

Biochar for Environmental Management. Lehmann and Joseph. Earthscan. 2009.

Biomethane from Dairy Waste. A Sourcebook for the Production and Use of Renewable Natural Gas in California. Western United Dairymen. 2005. http://www.suscon.org/news/biomethane_report/Full_Report.pdf

Guide For Siting Small-Scale Biomass Projects in New York State. New York State Energy Research and Development Authority. 2009. http://www.nyserda.org/publications/Report09-07

Guideline for Safe and Eco-friendly Biomass Gasification – Gasification Guide. Intelligent Energy Europe – European Commission. 2009. http://gasification-guide.eu/gsg_uploads/documenten/D10_Final-Guideline.pdf

USDA-Natural Resources Conservation Service. Virginia Electronic Field Office Technical Guide (eFOTG), Section IV. [On-line]. Available at http://www/nrcs.usda.gov/technical/eFOTG

Estimated phosphorus captured on-site via poultry litter gasification assuming 50 tons processed per day

• Average of 52 lbs of P_2O_5 per ton of "as delivered" poultry litter* x 0.4364 = 22.7 lbs of total P per ton of litter as delivered on site.*

• 50 tons of litter per day fed into the gasifier x 22.7 lbs P = approximately 1,135 lbs of total P captured per day on site.**

• 1,135 lbs of P captured on-site per day x 350 days of operation per year = 397,250 lbs of total P captured on-site per year.

*** Source**: Table 16, page 23 of Virginia Tech Report to Virginia DEQ entitled "Evaluating Net Benefits/Impacts of a Shenandoah Valley Poultry Litter to Energy Power Plant" by James Pease, Ph.D. *et al* (April 17, 2012)

** To be confirmed by periodic lab analysis of grab samples of poultry litter and grab samples of biochar made from the same load of poultry litter.