United States Department of Agriculture

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

ANAEROBIC DIGESTER

CODE 366

(no)

DEFINITION

A component of a waste management system in which biological treatment breaks down animal manure and other organic materials in the absence of oxygen.

PURPOSE

Use this practice to accomplish one or more of the following purposes:

- Improve air quality by reducing greenhouse gas emissions and objectionable odors from manure or agricultural waste.
- Reduce transport of pathogens to surface water.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where:

- Biogas production and capture are components of a waste management system plan or a Comprehensive Nutrient Management Plan (CNMP).
- Sufficient and suitable organic feedstocks are readily available.

CRITERIA

General Criteria Applicable to All Purposes

Laws and Regulations
Plan, design, and construct the anaerobic digester to meet all Federal, State, Tribal, and local laws and regulations.

Location
Use location criteria from NRCS Conservation Practice Standard (CPS) Waste Storage Facility (Code 313).

Feedstock Characteristics
Digester design must account for varying feedstock properties. Depending on the system design, extraneous material such as fibrous bedding material (including clumps of straw), soil, sand, or stones may need to be ground (if appropriate), removed, reduced, or otherwise handled. Ensure that the total solids of feedstock influent match the digester type and process design. Food waste, wastewater from food processing operations, and other allowable organic substrates may be added as supplemental feedstock to a digester when the digester is designed to treat such wastes, as described in the operation and maintenance plan. The facility must account for disposal of all feedstocks, including supplemental feedstocks, according to the requirements in NRCS CPS Nutrient Management (Code 590). Exclude excess water and foreign material from the digester.

Design

Follow the documented design and performance requirements of the proposed anaerobic digester and according to the criteria below, as applicable.

- Design digesters to meet “General Criteria Applicable to All Purposes” and either “Additional Criteria for Liquid Waste Storage Impoundments” or “Additional Criteria for Fabricated Structures” in NRCS CPS Waste Storage Facility (Code 313), based on whether the digester is an earthen structure or tank, respectively.
- Design tanks and internal components, including heat pipes, to facilitate periodic removal of accumulated solids and for corrosion protection.
- Design the digester and biogas system components to meet the requirements of State and local seismic codes, as applicable.
- Design the digester cover, materials, anchorage, and all appurtenances, such as weights and floats, to capture and convey biogas to the gas collection system. The digester cover and associated materials must meet the requirements of NRCS CPS Roofs and Covers (Code 367).
- Operating Volume and Retention Time. Size the digester to retain the design requirements to meet the hydraulic and solids retention times (days). Design the digester with appropriate freeboard and overflow or automatic shutdown devices to prevent accidental spillage of effluent or discharge into the gas collection system.
    - For complete mix digesters, minimum digester retention time is 17 days.
    - For covered lagoon digesters, base the design operating volume either on the daily volatile solids (VS) loading rate per 1,000 ft3 or the minimum hydraulic retention time (HRT) adequate for methane production, whichever volume is greater. Select and apply the maximum daily VS loading rate from the values listed on the map in figure 1. Select and apply the minimum HRT from values indicated on the map in figure 2.
    - For plug flow digesters, the digester flow path must have a minimum length to width ratio of 3.5:1, a maximum ratio of flow path width to fluid depth of 2.5:1, and a minimum digester retention time of 20 days.
- Inlet and Outlet. Locate the inlet and outlet devices as far apart as practical to minimize “short circuiting” and to facilitate process flow. Design inlets and outlets of any permanent material to resist corrosion, plugging, freeze damage, and prevent gas loss. Equip the digester with an outflow device, such as an underflow weir that maintains the digester liquid surface at its design operating level. On covered lagoons, locate the inlet discharge a minimum of 12 inches below the digester liquid surface.
- Design the digester to facilitate the movement of all material through the digester to minimize short-circuiting flow (e.g., floor and wall shapes); with appropriate devices, as necessary, to assure a continuous flowing and mixing process; to maintain a gas seal under the cover; and to release effluent directly to separation, storage, or other treatment facility in order to maintain the proper operating conditions.
- Design and install the heating system, if required, to maintain proper digester temperature and to minimize corrosive attack and scalding build-up on the heated surfaces.

Figure 1. Covered lagoons - maximum loading rate (lb VS/1,000 cf/day)

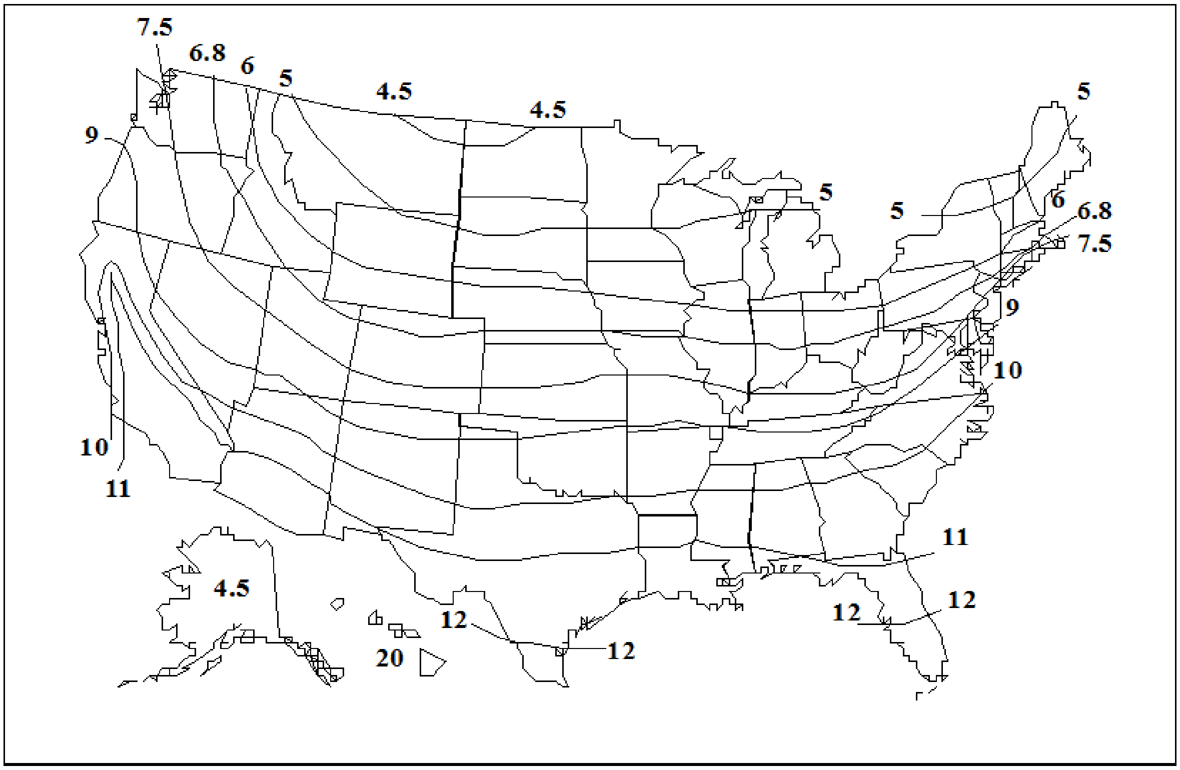
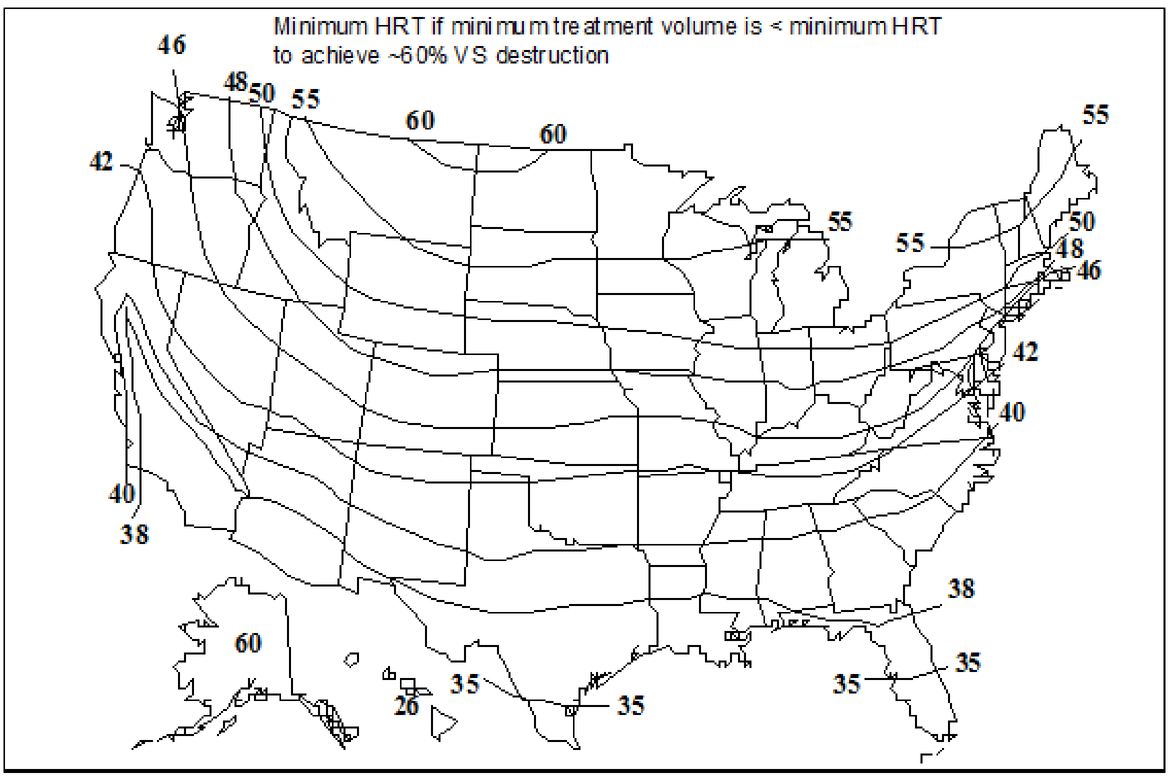


Figure 2. Covered lagoons - minimum hydraulic retention times (MINHRT) in days.



Connections
Ensure that all connections and fittings are properly sized and installed for design flows and vibrations.

Electrical Component Protection
Very small concentrations of biogas can corrode electrical hardware. Protect electrical controls from corrosion due to exposure to biogas or locate them in a separate room or building away from the digester and generator, if applicable.

Gas Collection, Transfer, Control and Utilization System
Gas Collection and Transfer
Meet the following for pipe and/or appurtenances:

- Design the gas collection system within the digester to minimize plugging or install cleanout ports as needed.
- Design the collection and transfer pipe for wet biogas. In colder climates, protect the pipe to prevent frost buildup. Use a minimum of 3-inch diameter pipe, unless a detailed design is performed to account for frost buildup and pressure drop in a low-pressure system.
- Design aboveground pipe for biogas transfer with fitting for expansion and contraction effects.
- For pipes used to transfer biogas include provisions for drainage of condensate, pressure and vacuum relief.
- Provide a flame trap device in the biogas line between the digester and sources of ignition to prevent flame migration from the flare to the gas source or as otherwise recommended by the flame arrester manufacturer.
- For steel pipe meet the requirements of American Water Works Association (AWWA) Specification C-200, or American Society for Testing and Materials (ASTM) Specification A53 or A106; or AWWA C-220 or ASTM A312 for stainless steel.
- For plastic pipe meet the requirements of AWWA Specification C-906 or ASTM D-3350 for high-density polyethylene (HDPE).
- Securely anchor pipe and components within the digester to prevent displacement or damage from normal forces including loads from accumulated scum.
- Install pipes to ensure all sections can be safely isolated and cleaned as part of routine maintenance.

Gas Control and Utilization
- Locate and shelter all equipment and components from the elements.
- Design and install gas utilization equipment in accordance with standard engineering practice and the manufacturer’s specifications.
- Design all equipment and components for a minimum service life of 2 years or more. Provide easy access for replacement or repair of components.
- Base the size of equipment and connecting pipe based on head loss, cost of energy, cost of components, and manufacturers’ recommendations.
- Where electrical service is required at the control facility, follow the National Electrical Code and local and State requirements for the installation and all electrical wire, fixtures, and equipment.
- Install a flare for the anaerobic digestion system either as the primary biogas control device or as a back-up to the biogas utilization equipment. Install flares a minimum of 10 feet above the ground. Locate open flares a minimum distance of 50 feet from the biogas source or per manufacturer’s specifications, whichever is further. Properly ground flares or protect to minimize potential damage caused by lightning strikes.
- Equip flares with automatic ignition and power them by solar-charged battery or direct connection to electrical service. Ensure that the flare capacity is equal to or greater than the anticipated maximum biogas production. Install a windshield or other device to protect an open flare against wind.
- As needed, design appropriate facilities to store excess gas.

- Biogas treatment or conditioning equipment, including, but not limited to hydrogen sulfide removal, must meet gas utilization requirements.
- Install and maintain a gas meter, suitable for measuring biogas.

Monitoring for Mesophilic and Thermophilic Digesters
Install equipment needed to properly monitor the digester and gas production as part of the system. As a minimum, temperature sensors and readout devices to measure (1) internal temperature of digester and (2) inflow and outflow temperatures of digester heat exchanger are required.

Safety
Install fence meeting the requirements of NRCS CPS Fence (Code 382) and post warning signs to indicate hazards. Include appropriate safety features to minimize the hazards of the facility (refer to American Society of Agricultural and Biological Engineers (ASABE) Standard EP470, Manure Storage Safety for guidance, as needed).

Biogas is flammable, highly toxic, and potentially explosive. Design the digester and gas components with adequate safety measures and install components in accordance with standard engineering practice for handling a flammable gas and preventing undue safety hazards. As a minimum -

- Post “Warning Flammable Gas” and “No Smoking” signs.
- Provide appropriate fire protection equipment and biogas leak detection sensors, especially in confined areas.
- Provide adequate ventilation for confined areas where gases can accumulate.
- Use explosion-proof motors, switches and other spark producing devices on all biogas blowers or other equipment installed where biogas is present.
- Provide and maintain above-ground permanent markers to indicate the location of underground gas lines to prevent accidental disturbance or rupture. Mark exposed pipe to indicate type of pipe whether gas or other. Exposed pipe conveying flammable gas is generally painted yellow, per ASME A13.1-2020.

Agricultural Waste Management System Plan
Do not consider the volume of the digester in determining the storage requirement of the waste storage facility.

Additional Criteria for Maintenance of Air Quality
If the digester is located in an area designated as nonattainment or maintenance for National Ambient Air Quality Standards, where emergency flares are not feasible due to their potential for emissions of criteria air pollutants or their precursors, another option must be provided by the manufacturer which adequately addresses conditions to prevent biogas release into the atmosphere, as required or allowed by State and local regulations. In these cases, a digester designed and operated to capture biogas for energy production may provide for emergency biogas release through a vent pipe stack in lieu of flaring provided the anaerobic digestion system meets the following criteria:

- Provides adequate biogas storage for normal operating conditions and reserve biogas storage to prevent biogas release for the duration of routine system maintenance, as specified in the Operations and Maintenance plan.
- Hydrogen sulfide concentrations in untreated biogas does not exceed 6,000 ppm.
- Biogas release is via a minimum 12-inch diameter vent pipe stack with a minimum outlet height of 20 feet above the ground elevation that is immediately adjacent to the pipe’s outlet.
- Biogas release flow rate does not exceed 1,000 cubic feet per minute (CFM).

CONSIDERATIONS

General Considerations

Location
Locate the digester as near the source of manure and as far from neighboring dwellings or public areas as practicable. Consider slope, distance of manure transmission, vehicle access, prevailing wind direction, proximity to hydrologically sensitive areas, and visibility for proper location. Locate the digester near a suitable site for energy utilization equipment. Minimize distances for the transmission of biogas through buried pipe. Locate the waste storage facility, considering elevation and distance from the digester, to take advantage of gravity flow.

Siting and Vegetation
Analyze the visual impact of the digester within the overall landscape context and effects on aesthetics. Consider screening with vegetative plantings, landscaping, or other measures to alleviate a negative impact or enhance the view. In addition, vegetate disturbed areas as soon as possible. Consider the use of other NRCS CPSs such as Critical Area Planting (Code 342), Hedgerow Planting (Code 422), or Windbreak-Shelterbelt Establishment and Renovation (Code 380).

Manure Characteristics
Consider using only fresh manure which has the highest energy content.

Chemicals and Amendments
Consider potential inhibitory effects on gas production of any antimicrobial agents in the manure or waste stream.

Waste Separation
Consider use of NRCS CPS Waste Separation (Code 632) to prepare the waste stream for introduction to the anaerobic digester or for post-digestion treatment.

Collection/Mix Tank
Consider using a collection/mix tank to accumulate manure, settle and separate foreign material, pre-heat, and/or pretreat influent waste to the appropriate total solids concentration. A volume of 1 to 3 days of manure collection, depending on the planned system management, is often used.

Digester Type
The type of digester selected may be affected by geographical location (figure 3), energy considerations, wastewater properties, and other design considerations (figure 4).

Figure 3. Covered lagoons - locations suitable for biogas to energy conversion generally fall below the 40th parallel.

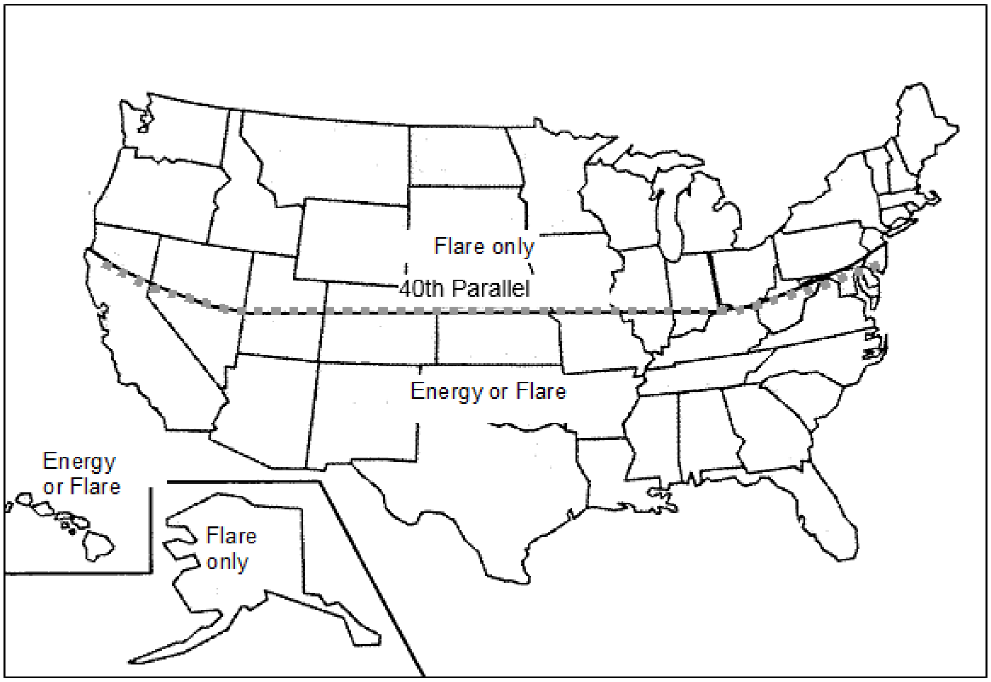
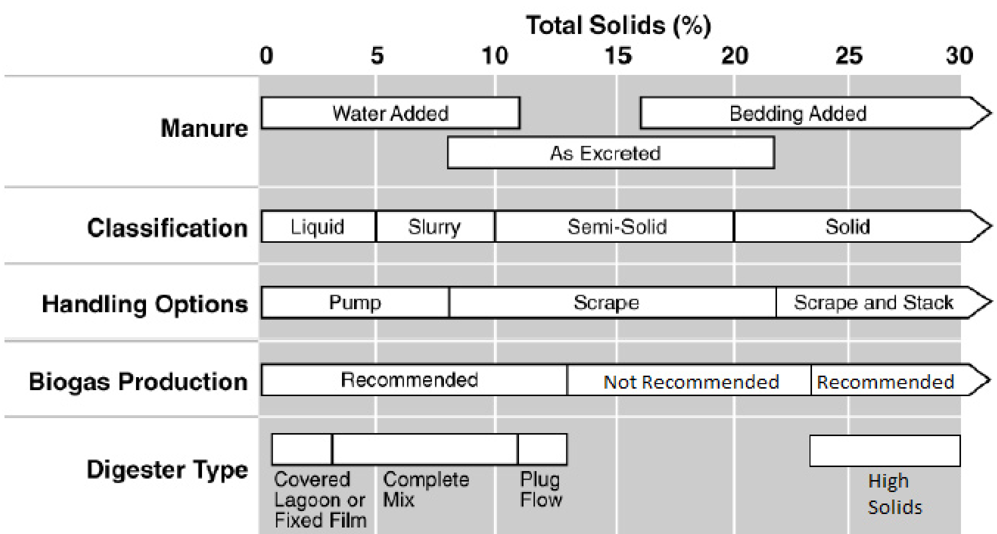


Figure 4. The type of digester selected is affected by multiple parameters and subject to specific design considerations (US EPA - AgSTAR).



Digester Design

A digester operating fluid depth of 8 feet or greater is usually more economical for tank design. Tank dividers or flow separators may be utilized to increase efficiency and prevent short-circuiting. Install interior slopes as steep as permitted by soil properties and construction techniques.

Overflow Protection
In case of digester equipment failure, consider designing the transfer system with the capability to bypass the digester, going directly to storage or land application equipment.

Digestate Processing
Digestate is the residual material left after the digestion process. It is composed of liquid and solid portions. These are often separated and handled independently, as each have value that can be realized with varying degrees of post processing. With appropriate treatment, both the solid and liquid portions of digestate can be used in many beneficial applications. Examples include animal bedding (solids), nutrient-rich fertilizer (liquids and solids), a foundation material for bio-based products (e.g., bioplastics), organic-rich compost (solids), and/or simply as soil amendment (solids). The latter may include spreading the digestate on the field as fertilizer. Digestate products can be a source of revenue or cost savings, and are often pursued to increase the financial and net-environmental benefit of an AD/biogas project.

The digestate has increased potential for some air and nutrient emissions compared to raw manure (see Air Quality and Nutrient Availability considerations). Consider the need to incorporate additional equipment, processes or technologies that may be necessary or useful to treat digestate to reduce emissions and the potential for groundwater and surface water contamination during digestate storage and land application based on its intended use.

Effluent Tank
Consider utilizing an effluent tank to hold digester effluent for subsequent mechanical solid-liquid separation to recover digested separated solids for bedding or soil amendment.

Grounding and Cathodic Protection
Stray voltage, electrolysis and galvanic corrosion can damage pipes inside digesters. Consider the design requirements for electrodes and anodes.

Gas Collection Cover
In areas of extreme wind or excessive snow, consider installing structures to protect inflatable and floating digester covers from damage.

Gas Utilization
Investigate and select the most beneficial and economical use of the biogas energy. Depending on the design and climate, digesters may require more than 50 percent of the biogas heat value to maintain the design temperature in the winter. Digesters can be heated by hot water from boilers burning biogas or by heat recovery from internal combustion engines and micro turbines burning biogas for power generation.

Methane Monitoring and Leak Detection
Consider installing methane leak detection systems and regularly monitoring methane emissions from all components of the system, including the digester, gas collection, transfer, control and utilization system, and digestate storage. If methane leaks are identified, promptly initiate repairs.

Air Quality
There is potential for methane and ammonia emissions from the storage of digester effluent. Consider covering digestate storages and incorporating the resulting biogas into the gas collection, transfer, control and utilization system or incorporating other measures to reduce the potential for emissions. Anaerobic digestion of livestock waste can increase amount of nitrogen that is converted to ammonia and subsequently emitted from the resulting wastewater.Recovering energy could reduce fossil fuel combustion and associated emissions, thereby reducing the net effect of greenhouse gases and improving air quality. Some energy recovery options, such as the use of internal combustion engines to convert biogas to energy, may also result in additional emissions of some air pollutants.

Nutrient Availability
Consider the effects of digestion on nutrient availability. While anaerobic digestion creates a more consistent nutrient supply and can increase management options for the digestate, land application of

digester effluent, compared with fresh manure, may have a higher risk for both ground and surface water quality problems. Compounds such as nitrogen, phosphorus, and other elements become more soluble due to anaerobic digestion and therefore have higher potential to move with water.

Safety Training

Operating and maintaining anaerobic digesters presents unique safety risks. Ensure that all personnel working on or near an anaerobic digester have the safety information, training, and equipment necessary to safely and effectively complete their assigned tasks.

PLANS AND SPECIFICATIONS

Prepare plans and specifications that describe the requirements for applying the practice according to this standard. As a minimum, include—

- Plan view of the system layout and location of livestock facilities, waste collection points, waste transfer pipe, digester, biogas utilization facilities, and digester effluent storage. Include utilities and structures on the site.
- Grading plan showing excavation, fill, and drainage, as appropriate.
- Materials and structural details of the digester, including all premixing tanks, inlets, outlets, pipes, concrete, pumps, valves, and appurtenances as appropriate for the complete system.
- Requirements for foundation, including preparation and treatment.
- Details of biogas collection, control, and utilization system including type of materials for pipe, valves, regulators, pressure gages, electrical power and interface (as appropriate), flow meters, flare, utilization equipment, and associated appurtenances.
- Specify insulation, heat exchanger capacity, and energy requirements as appropriate for maintaining the digester operating temperature within acceptable limits.
- Provide a process flow diagram with the following design information:
  - Flow rates of influent, effluent, and biogas.
  - Design total and volatile solids content of influent and effluent.
  - Digester volume.
  - Hydraulic and solids retention times.
  - When applicable, heating system type and capacity, control, and monitoring.
  - Biogas production, including methane yield.
  - 12-month energy budget when applicable.
  - Safety features.

OPERATION AND MAINTENANCE

Prepare an operation and maintenance plan for the operator. As a minimum, include the following items in the operation and maintenance plan:

- Proper loading rates of the digester and total solids content of the influent.
- Accounting for the nutrient impact of all feedstock in the farm’s nutrient management plan.
- Description of the planned startup procedures.
- Proper operating procedures for the digester, including appropriate operating temperature ranges.
- Digester and other component maintenance, including typical length of downtime due to maintenance.
- Estimates of biogas production, methane content, and potential energy recovery.
- Instructions for safe use and flaring of biogas.
- Monitoring plan with frequency of measuring and recording digester inflow, operating temperatures, biogas yield, and/or other information as appropriate.
- Description of safety issues with the anaerobic digester and associated biogas system. Instructions,

as needed, for ventilating confined spaces according to ASABE standard S607, Ventilating Manure Storages to Reduce Entry Risk.

- Troubleshooting guide.
- Alternative operation procedures in the event of equipment failure.

Establish and maintain emergency contact information for consultation with qualified experts.

REFERENCES

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