**NATURAL RESOURCES CONSERVATION SERVICE**
**CONSERVATION PRACTICE STANDARD**

# ANAEROBIC DIGESTER

**(No.)**
**Code 366**

## DEFINITION

A component of a waste management system that provides biological treatment in the absence of oxygen.

## PURPOSE

For the treatment of manure and other byproducts of agricultural operations in order to:

- capture biogas for energy production
- manage odors
- reduce the net effect of greenhouse gas emissions
- reduce pathogens

## CONDITIONS WHERE PRACTICE APPLIES

This practice applies where:

- Biogas production and capture are components of a planned animal waste management system, and
- Sufficient and suitable organic feedstocks are readily available, and
- Existing facilities can be modified to the requirements of this standard or for new construction, and
- The operator has the interest and skills to monitor and maintain processes or contracts with a consultant to provide these services.

## CRITERIA

### General Criteria Applicable to All Purposes

**Laws and regulations**. Plan, design, and construct digesters and ensure that the handling of feedstock meet all Federal, state, and local regulations.

Evaluate and avoid or minimize impact to cultural resources, wetlands and Federal and state protected species to the extent practicable during planning, design and implementation of this conservation practice in accordance with established National and Florida policy, General Manual (GM) Title 420-Part 401; Title 450-Part 401, Title 190-Parts 410.22 and 410.26, National Planning Procedures Handbook (NPPH) Florida Supplements to Parts 600.1 and 600.6, National Cultural Resources Procedures Handbook (NCRPH), National Food Security Act Manual (NFSAM), and the National Environmental Compliance Handbook (NECH).

**Feedstock characteristics.** The design of the digester needs to take feedstock properties into account. Extraneous material such as soil, sand, stones or fibrous bedding material (including clumps of straw), must be ground, removed, reduced, or otherwise handled. The total solids of feedstock influent to the digester shall be as required by the digester type and process design. Exclude excess water and material from the digester.

Food waste and wastewater from food processing operations may be added as

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

supplemental feedstock to a digester when the digester is designed to treat such wastes, as described in the operation and maintenance plan. Account for the nutrient impact of food waste ad wastewater from food processing operations in the farm's nutrient management plan.

**Safety**. If the digester will create a safety hazard, fence the digester and post warning signs to prevent others from using it for purposes other than intended.

Biogas is flammable, highly toxic, and potentially explosive. When designing the digester and gas components, consider the hazards associated with normal operation and maintenance and provide adequate safety measures Design the digester in accordance with standard engineering practice for handling a flammable gas an to prevent 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.
- Locate flares a minimum distance of 95 feet (30 m) from the biogas source. The flares shall have a minimum height of 10 ft and shall be grounded or otherwise protected to minimize the chance of lightning strikes.
- Provide a flame trap device in the gas line between the digester and sources of ignition or as recommended by the flame arrester manufacturer.
- Mark the location of underground gas lines with signs to prevent accidental disturbance or rupture. Mark exposed pipe to indicate whether gas line or other.

**Digester types.**

Plug Flow Digester

1. The total solids concentration of influent shall be 11 to 14 percent.
2. Digester retention time shall be a minimum of 20 days.
3. Operational temperature shall be mesophilic (ranging from 35 – 40 ºC or 95 – 104 ºF).
4. The length to width ratio of digester flow path shall be a minimum of 3.5:1.
5. The ratio of flow path width to fluid depth shall be less than 2.5:1.
6. The shape of the floor and walls shall facilitate the movement of all material through the digester.

Complete Mix Digester

1. Total solids concentration of manure influent shall be less than 11 percent.
2. Digester retention time shall be a minimum of 17 days.
3. Operational temperature shall be mesophilic (ranging from 35 – 40 ºC or 95 – 104 ºF).
4. Appropriate mixing devices shall be provided to assure a complete mix process.

Covered Lagoon

1. The digester shall meet the General Criteria for All Lagoons given in Florida NRCS conservation practice standard Waste Treatment Lagoon, Code 359, as appropriate, and the following additional requirements:
2. Minimum Design Operating Volume. The design operating volume shall be based either on the daily volatile solids (VS) loading rate per 1,000 $ft^3$ or the minimum hydraulic retention time (HRT) adequate for methane production, whichever is greater. The maximum daily VS loading rate shall be selected from the values listed on the map in Figure 1. The minimum HRT shall be selected from values indicated on the map in Figure 2.
3. Required Total Volume. The required total volume of the digester shall be equal to the minimum design operating volume except where waste storage is included in the design, in which case the volume shall meet the criteria for Design Storage Volume in Florida NRCS conservation practice standard Waste Storage Facility, Code 313, as appropriate.
4. The digester storage volume does not need to account for rainfall in completely covered digesters.
5. Provide a minimum of 2 feet of freeboard above the digester design water surface; if rainfall is included in determining the operating volume, only 1 foot of freeboard is required.


Figure 1. Covered anaerobic digester maximum loading rate (lb VS/1000 $ft^3$/day)

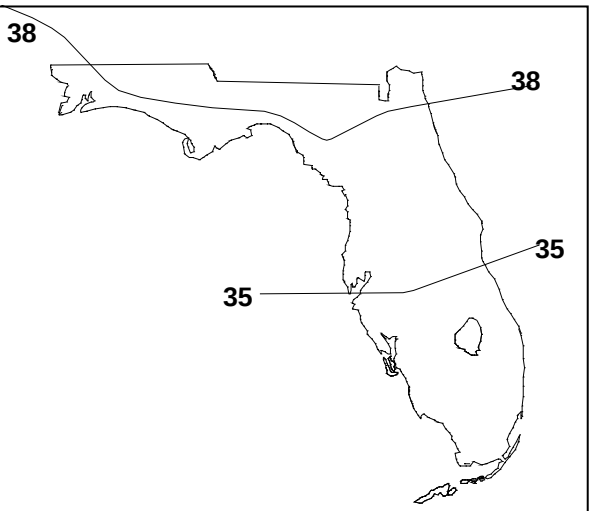


Figure 2. Covered anaerobic digester minimum hydraulic retention times (MINHRT), in days

6. Operating Depth. The operating depth of the digester shall be at least 8 feet over 50 percent or more of the bottom area.
7. Inlet and Outlet. Locate the inlet and outlet devices as far apart as practical to minimize "short circuiting." The inlet shall discharge a minimum of 12 inches below the digester liquid surface. Equip the digester with an outflow device that maintains the digester liquid surface at its design operating level.
8. Digester Cover. 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 materials shall meet the requirements of Florida NRCS conservation practice standard Waste Facility Cover, Code 367.

Fixed Film Digester

1. Total solids concentration of influent shall be $\leq$ 5%. For total solids concentration $\geq$ 2.5%, the influent particle size shall be $\leq$ 0.25 inch.
2. Digester retention time shall range from 1 to 6 days, depending on waste biodegradability.
3. Operational temperature shall range from 59ºF to 104ºF.
4. Microbial support material with $\geq$ 3 inch openings.

Alternative Type Digester

Types of digesters not meeting the above criteria or for a type other than listed in this standard (such as induced blanket or thermophilic reactors) shall be based on the documented design and performance of such existing animal waste digester and certified as such by a registered professional engineer licensed in the state of the proposed installation

**Digester containment characteristics**.

1. Design earthen structures to meet the general criteria for all lagoons as stated in Florida NRCS conservation practice standard Waste Treatment Lagoon, Code 359 as appropriate.
2. Design tanks and internal components (including heat pipes) to facilitate periodic removal of accumulated solids and for corrosion protection.
3. Design tanks to meet the structural criteria for "Fabricated Structures" in Florida NRCS conservation practice standard Waste Storage Facility, Code 313.
4. The following additional criteria apply:
   - Design Operating Volume. Size the digester to retain the design hydraulic and solids retention times (days).
   - Inlet and Outlet. Locate the inlet and outlet devices to facilitate process flow. Inlets shall be of any permanent type designed to resist corrosion, plugging,

freeze damage, and prevent gas loss. Equip the digester with an outflow device, such as an underflow weir, that will maintain the operating level, maintain a gas seal under the cover, prevent gas loss, and release effluent directly to separation, storage, or other treatment facility.

- Cover. Design covers to meet the requirements of Florida NRCS conservation practice standard Waste Facility Cover, Code 367. Equip tanks with suitable covers designed for accumulation and collection of biogas.
- Heating System (if required). Design and install heating system with consideration for minimizing corrosive attack and scalding build-up on the heated surfaces.

**Gas collection, transfer and control system**. Design the biogas collection, transfer, and control system to convey captured gas from within the digester to gas utilization equipment or devices (flare, boiler, engine, etc.).

1. Gas collection and transfer. Design pipe and/or appurtenances to meet the following:
   - Design the gas collection system within the digester to minimize plugging.
   - Securely anchor pipe and components within the digester to prevent displacement from normal forces including loads from accumulated scum.
   - Design the collection and transfer pipe for wet biogas. In colder climates, protect the pipe as necessary to prevent frost buildup. In no case shall the pipe size be less than 3-inch diameter.
   - Pipe used for transfer of gas must include provisions for drainage of condensate, pressure and vacuum relief, and flame traps.
   - Specify steel pipe to meet the requirements of AWWA Specification C-200 or ASTM A53/A211 for stainless steel.
   - Specify plastic pipe to meet the requirements of AWWA Specification C-906 or ASTM D-3350 for HDPE.
   - Construct pipes to enable all sections to be safely isolated and cleaned as part of routine maintenance.
   - Transfer pipe can be buried or installed above ground. Include provisions for drainage of condensate.
2. Gas Control
   - Locate and shelter equipment and components from the elements in convienent places.
   - Ensure equipment and components have a service life of not less than two years and be readily accessible for replacement or repair.
   - Base the size of equipment and connecting pipe on head loss, cost of energy, cost of components and manufacturer's recommendations.
   - Design gas pipe installed within buildings to be of type approved for combustible gas.
   - Where electrical service is required at the control facility, ensure the installation and all electrical wire, fixtures and equipment meet the National Electrical Code and local and state requirements.

**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 collected gas.

- Equip the flare with automatic ignition, powered by battery/solar or direct connection to electrical service. Design the flare to have a minimum capacity equal to the anticipated maximum biogas production. Install a windshield to protect the flare against wind.
- Design gas fired boilers, fuel cells, turbines, and internal combustion engines, when a component of the system, for burning biogas directly, in a mix with other fuel, or include equipment for removing $H_2S$ and other contaminants from the biogas.
- Install and maintain a gas meter, suitable for measuring biogas.

**Operating temperature**. Maintain digesters at internal temperatures appropriate to the digester

type and design. Include in the design heat loss calculations to determine insulation, heat exchanger capacity, and energy requirements as appropriate for maintaining the digester operating temperature within acceptable limits.

Maintain mesophilic digesters between 35 ºC and 40 ºC (95 ºF-104 ºF) with an optimum of 37.5 ºC (100 ºF) and daily fluctuation of digester temperature limited to less than 0.55 ºC (1 ºF).

**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 the following equipment is required:

- Temperature sensors and readout device to measure internal temperature of digester
- Temperature sensors and readout device to measure inflow and outflow temperature of digester heat exchanger

**Operating level**. Design the operating level of digesters with appropriate freeboard and overflow or automatic shutdown devices to prevent accidental spillage of effluent or discharge into the gas collection system.

**Waste storage facility**. When a waste storage facility is a component of the waste system, design it to meet the requirements of Florida NRCS conservation practice standard Waste Storage Facility, Code 313. Do not include the volume of the digester in determining the storage requirement of the waste storage facility except that the sludge volume can be reduced by the anticipated percent destruction of total solids.

## CONSIDERATIONS

**Location**. Consider locating the digester as near the source of manure as practicable and as far from neighboring dwellings or public areas (minimum distance of 300 ft). Consider slope, distance of manure transmission, vehicle access, wind direction, proximity of hydrologically sensitive area, and visibility when locating the digester. Consider locating the digester near a suitable site for energy utilization equipment. Short distances for the transmission of biogas through buried pipe are preferable. Consider elevation and distance from the digester to take advantage of gravity flow when locating the waste storage facility.

**Manure characteristics**. Fresh manure has the most energy content; however, aged manure can be fed to the digester if properly reconstituted to the digester design total solids content. The biogas yield from aged manure (generally less than 6 months old) is dependent on the biodegradation that has taken place during the storage period. Manure in a warm moist state, could be significantly degraded and biogas production will be substantially reduced. Also, consider potential inhibitory effects of any antimicrobial agents in the manure or waste stream.

**Collection/mix tank**. Consider including a collection/mix tank to accumulate manure, settle foreign material and pre-treat influent waste to the appropriate total solids concentration. A volume of1 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, energy considerations, wastewater properties, and other design considerations (Figure 3).

**Digester design**. Consider designing a digester operating fluid depth of 8 feet or greater for a more economical tank design. Tank dividers or flow separators may be utilized to increase efficiency and prevent short-circuiting. Interior slopes should be as steep as permitted by soil properties and construction techniques.

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

**Electrical component protection.** Very small concentrations of biogas can corrode electrical hardware. Consider locating electrical controls in a separate room or building away from the digester and generator.

**Temperature maintenance**: The design should include a means of maintaining the digester within acceptable operating temperature limits, where appropriate.

**Gas transfer pipe.** Exposed pipe conveying flammable gas is generally painted yellow, per IAW ASME A13.1-2007.

**Gas collection cover**. In areas of extreme wind or excessive snow, appropriate structures may be necessary to protect inflatable and floating digester covers from damage.

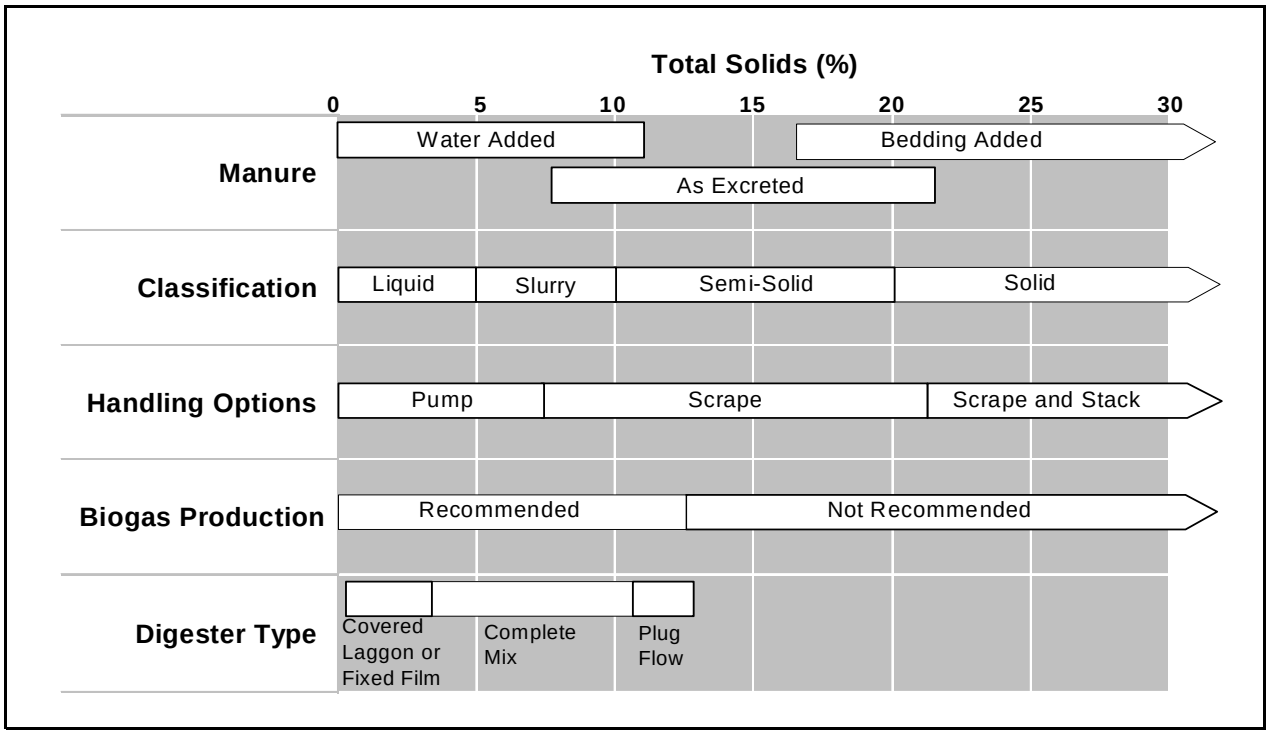


Figure 3. The type of digester selected is affected by multiple parameters (US EPA – AgStar).

**Energy**. To maintain energy production, the temperature will need to remain constantly elevated. To save energy, the biogas energy produced would need to be used, rather than just burned off. Take in consideration of local utility companies need and their infrastructural capacity to use biogas energy as an off-farm product.

**Air quality.** Recovering energy from the biogas may be a preferable alternative to flaring. This could reduce fossil fuel combustion and associated emissions, thereby reducing the net effect of greenhouse gases and improving air quality.

**Gas utilization**. The most beneficial use of the biogas energy must be investigated and selected. Sales of carbon credits may affect the manner of utilization. Depending on the design and climate, digesters may require up to 50 percent of the biogas heat value to maintain the design temperature in the winter season. Digesters can be heated by hot water from boilers burning biogas or by heat recovery from engines burning biogas for power generation.

**Effluent tank**. Consider using an effluent tank to hold digester effluent for solids separation treatment due to the potential value of digested separated solids for bedding or soil amendment.

**Siting and vegetation.** Analyze the visual impact of the digester within the overall landscape context and effects on aesthetics. Screening with vegetative plantings, landscaping, or other measures may be implemented to alleviate a negative impact or enhance the view. In addition, disturbed areas should be vegetated as soon as possible.

**Soil properties**. Consider soil properties such as texture, $K_{sat}$, flooding, slope, water table and depth, as well as limitations related to seepage, corrosivity, or packing of soil material when designing storage structures. Refer to local soil survey information and on-site soil investigations during planning.

**Nutrient availability.** Consider the effects of digestion upon nutrient availability. 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 can become more soluble and therefore have higher potential to move with water.

## PLANS AND SPECIFICATIONS

Prepare plans and specifications in accordance with the criteria of this standard, sound engineering practice, and describe the requirements for applying this practice to achieve its intended use.

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

1. Layout and location of livestock facilities, waste collection points, waste transfer pipe, digester, biogas utilization facilities, and digester effluent storage.
2. Grading plan showing excavation, fill, and drainage, as appropriate.
3. Materials and structural details of the digester, including all premixing tanks, inlets, outlets, pipes, pumps, valves, and appurtenances as appropriate to the complete system.
4. Details of gas 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.
5. For controlled temperature digesters, heat loss calculations to determine insulation, heat exchanger capacity, and energy requirements as appropriate for maintaining the digester operating temperature within acceptable limits.
6. Digester cover material and dimensions of covered surface, if applicable.
7. Details of digester cover anchorage (i.e. location and width of trench, depth, backfill material, and compaction of fill), if applicable.
8. A process flow diagram with the following:
    - 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.
9. Appropriate gas safety equipment or protective measures.
10. Location of utilities and notification requirements.

## OPERATION AND MAINTENANCE

Develop and review with the owner prior to construction an operation and maintenance plan that is consistent with the purposes of the practice, its intended life, safety requirements, and the criteria for its design. Include in the plan the operation and maintenance requirements including but not limited to:

- Proper loading rate of the digester and total solids content of the influent.
- Accounting for the nutrient impact of all feedstock in the farms's nutrient management plan.
- Proper operating procedures for the digester
- Estimates of biogas production, methane content, and potential energy recovery
- Description of the planned startup procedures, normal operation, safety issues, and normal maintenance items.
- Alternative operation procedures in the event of equipment failure.
- Instructions for safe use or flaring of biogas.
- Digester and other component maintenance.
- Trouble shooting guide.
- Monitoring plan with frequency of measuring and recording digester inflow, operating temperatures, biogas yield, and/or other information as appropriate.
- Controlled temperature digesters shall be maintained at internal temperatures appropriate to the digester type and design.
- Description of the operating level of digesters with appropriate freeboard and overflow or automatic shutdown devices to prevent accidental spillage of effluent or discharge into the gas collection system.

## REFERENCES

ASTM A53/A211
ASTM D-3350
AWWA Specification C-200
AWWA Specification C-906
Florida NRCS Conservation Practice Standard
- Waste Facility Cover, Code 367
- Waste Storage Facility, Code 313
- Waste Treatment Lagoon, Code 359

General Manual (GM)
- Title 420-Part 401
- Title 450-Part 401
- Title 190-Parts 410.22 and 410.26

National Cultural Resources Procedures Handbook
National Electrical Code
National Environmental Compliance Handbook (NECH)
National Food Security Act Manual
National Planning Procedures Handbook
- Florida Supplements to Parts 600.1 and 600.6