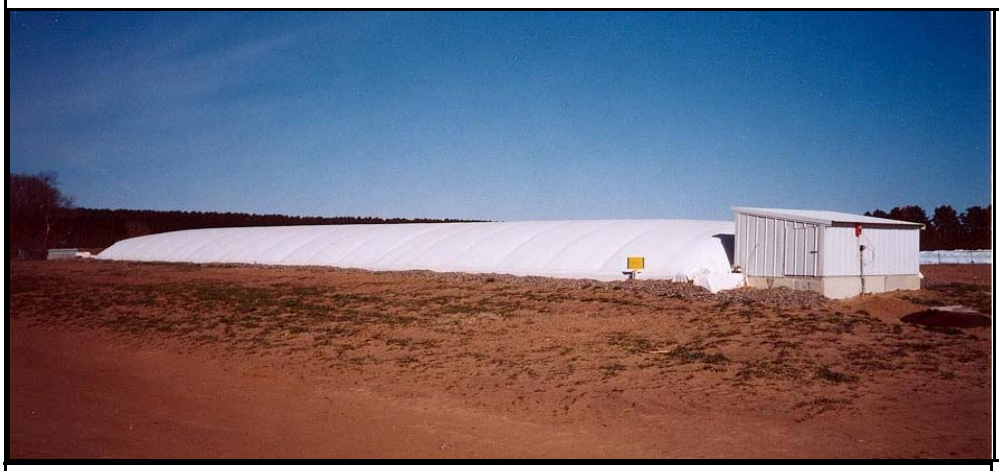
AG Digesters in the Midwest



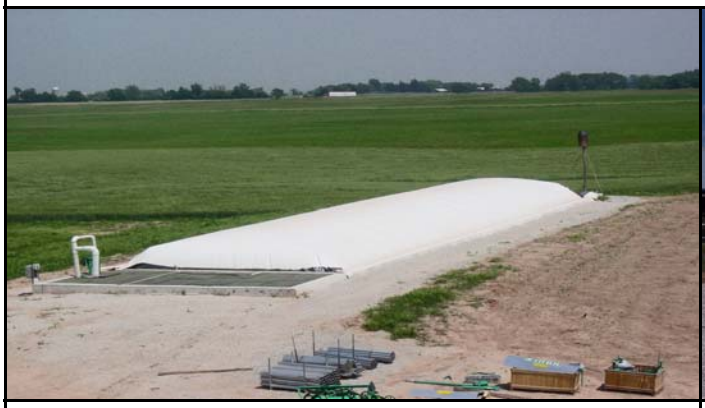
AquaTec DIGESTERS:

- Generate electricity
- Reduce manure treatment costs
- Reduce pathogens
- Reduce odors
- Reduce weed seeds
- Increase manure management flexibility

Haubenschild Dairy - Princeton, Minnesota
1,000 cows, 135 kW, 79,000 ft³ biogas/d

Call AquaTec for Your Digester Needs

THE INDUSTRY STANDARD



Stencil Dairy - Denmark, WI
1,200 cows, 72,000 ft³/d, 140 kW, separator

New Horizons Dairy - Elmwood, IL
2,000 cows, 140,000 ft³/d, 280 kW, separator

Our Customers are Our Best Salesmen

"The whole town knows I am doing something new because the farm is now more nose friendly. The typical smell is gone and the liquid is much easier to handle. - Bob Aman AA Dairy

AquaTec, Inc

1235 Shappert Drive Rockford, IL 815-654-1500 Fax 815-654-0038 http://www.aquatecinc.com

AquaTec Digesters - The Digester That Works

History

AquaTec designs and builds anaerobic digester systems and supplies specialty equipment, employing years of successful experience. AquaTec is a market leader in wastewater anaerobic digestion technology.

Products and Services

- Anaerobic digestion feasibility studies – system layout, costs and benefits
- Complete anaerobic digester design, construction management, startup and troubleshooting
- Power Market Development
- By-Product Market Development
- Regulatory compliance and expert witness

Digester Technology Options

- ***Covered Lagoons*:** For flush collected pig and dairy wastes in warm climates.
- ***Complete Mix Digesters*:** For scraped or pull plug pig or dairy wastes in cold climates.
- ***Heated, Mixed Covered Lagoon*:** For scraped or pull plug pig or dairy wastes in moderate climates where the goal is odor control rather than optimum gas production.
- ***Plug Flow Dairy Digester:*** For scrape-collected dairy manure in any climate.

Gas Use Options

- ***Internal Combustion Engines**:* To produce electricity, AquaTec offers engine generators that are reliable and have local parts and service.
- ***Boilers***: Where heat is the primary energy need, AquaTec offers biogas boilers.
- ***Flares***: Where the primary goal is low cost odor control, AquaTec offers gas collection and flares

International Experience

- AquaTec has provided consulting services in South America, Canada, China, Europe and Throughout USA

Ag-Dairy Digester Cogeneration Systems

Plug Flow Digester

- October 2002 – New Horizons Dairy, Elmwood, IL - 2,000 cows, 200+ kW, building heat, separators
- June 2002 - Stencil Dairy, Denmark, WI, - 1,200 cows, 140 kW, building heat, separator
- January 2002 - Koetsier Dairy, Visalia, CA -1500 cows, rehab digester, 210 kW, separator
- October 2001- DDI, Homer, NY -1,000 cows, boiler, experimental gas turbine, building heat, separator
- September 1999 - ICF Inc./AgSTAR, Haubenschild Dairy, Princeton, MN - 1,000 cows, 135 kW engine, building heat, separator
- September 1997 - ICF Inc./AgSTAR, AA Dairy, Candor, NY - 1,000 cows, 120 kW, boiler, building heat, separator
- December 1996 - Craven Dairy, Cloverdale, OR - 1,000 cows, 120 kW, separator
- December 1985 - Luiz Dairy, Lodi, CA - 900 cows, Rebuild digester, 120 kW, separator
- June, 1983 - Frey Dairy, Conestoga, PA - 600 cows, 100 kW, separator
- December, 1982 - Langerwerf Dairy, Durham, CA - 500 cows, 85 kW, building heat, separator

Complete Mix Digester

- September 2002 - AA Dairy, Candor, NY -250 cows, Rehab generator & heating system of a digester.
- November 2001 - Matlink Dairy, Clymer, NY, 900 cows and organics, 135 kW, building heat, separator

RCM Covered Lagoon

- July 1995 - 1998- Cal Poly Dairy, San Luis Obispo, CA – Process design, 400 cow capacity

ANAEROBIC DIGESTERS AT DAIRIES IN COLD CLIMATES

ABSTRACT

Farmer motivation for building and operating an anaerobic digester includes electricity production, heat production, manure treatment cost savings, nutrient conversion, odor and pathogen control, and byproduct recovery. There is concern for the reliability of these systems in cold climates. Keys to success in cold climates are reviewed. Properly designed units can recover excess heat from engine generators for building, floor and space heat. Commercial scale heated dairy plug flow digesters operating in NY, WI, MN and IL are presented. The only commercial scale mixed dairy and industrial waste digester operating in the US is described. The mixed waste digester is producing 250,000 ft3 of gas a day, which is 400% of the cow manure biogas potential. All systems meet Natural Resources Conservation Service draft standards. System installation and operation are described. A summary table to allow comparisons of costs and benefits is presented. Biogas recovery and use in boilers or engine-generators is discussed for each farm. Anaerobic digesters operate successfully in cold climates and are economically viable for dairy farms.

KEYWORDS

Dairy, cow, manure, residuals management, biogas, methane, odor, anaerobic digestion, digester, plug flow digester, complete mix digester, nutrient management, pathogens, and weedseeds.

INTRODUCTION

Anaerobic digestion is more extensively used outside of the US where treatment of animal waste has been a concern for a longer time. An anaerobic digester is a vessel designed to retain decomposing manure for a sufficient time at the designed operating temperature to allow the growth of methanogenic bacteria in a "steady-state". The bacteria grow without oxygen, decompose the waste, and produce methane as a useable fuel byproduct.

Low ambient temperatures impact manure digestion systems and have the potential for impeding performance. Cold weather system designs will ameliorate the impact of ambient temperature. Several digesters have been operated in US cold climates utilizing these design features. In reviewing operating cold climate digesters, system performance is found to be minimally effected when adequate design precautions are taken.

AgSTAR is a voluntary program sponsored by the US Environmental Protection Agency (EPA), the US Department of Agriculture - Natural Resources Conservation Service (NRCS) and the US Department of Energy (DOE), to encourage methane capture as a part of manure management. Since 1996, AgSTAR provided technical support to 14 AgSTAR Partner farms that were

developing anaerobic digester systems. Several of the digesters reported here were constructed with AgSTAR assistance.

BENEFITS OF DIGESTION SYSTEMS

Farmer's are motivated to build and operate anaerobic digesters due to their inherent benefits including electricity production, heat production, manure treatment cost savings, nutrient conversion, odor and pathogen control, and byproduct recovery. Traditionally, animal production facilities have used their manure digestion facilities as a means to produce electricity, offsetting electric bills, and selling surplus power to their utility. Methane rich biogas from the digesters may also be used to fire boilers, produce hot water for space heating or to meet process heat requirements. Properly designed units can recover excess heat from engine generators for building, floor and space heating

In recent years, digesters have been installed to reduce the odor associated with manure. Naturally occurring organisms in the digester, use the organic material in manure as a substrate for growth. Odor reduction is often in the 90% to 95% range with a properly designed and operated manure methane digester.

A digester is the only treatment system that will pay for itself. An anaerobic digestion system achieves odor reduction as does an aerobic/oxidation system. However, an anaerobic digestion system also produces energy from the treatment process (by generating methane usable as a fuel) whereas aerobic systems consume electrical energy.

Suspended solids may be recovered from raw untreated manure for use as animal bedding or as an ingredient in a soil mix. Usually, additional treatment by chemicals or composting is required to make the raw fiber acceptable for these uses. Suspended solids recovered from anaerobically digested manure have been successfully used for animal bedding with little additional processing. Also when left to compost, the digested solids heat much faster than is customary with raw recovered fiber.

During the digestion process, manure nutrients are "premineralized" in the controlled environment of the digester. Typically, nutrients in raw or incompletely treated manure are made available to soil borne organisms with growth and metabolic rates dependent on ambient temperature. These same nutrients are premineralized in the digester, making them more readily available for plant uptake.

Pathogenic organisms are greatly reduced in a digester. The reduction is observed to be in excess of 99% for fecal indicator organisms. Weedseeds are also observed to be greatly reduced, though the decimation rate is not known. There is also a significant reduction in the number of flies in waste management facilities handling digested manure.

Manure viscosity goes down during the digestion process. Therefore, less power is required to pump or push digested manure through pipelines and irrigation systems.

DIGESTION SYSTEM COMPONENTS

Manure digestion systems consist of 5 subsystems:

1. Mix tank,
2. Digester,
3. Effluent tank,
4. Solids separation,
5. Energy conversion.

Manure is removed from barns and holding areas, frequently with rubber tire "skid steer" tractors with scrapers/buckets, or by mechanical scrapers on chain, cables or metal straps. Manure is placed in a holding tank where it is mixed prior to introduction into the digester. Typically the holding tank has a capacity for 2 or more days. After mixing, the manure is pumped into the digestion vessel, usually sized for about a 20 day manure retention time. The digester is heated, permitting year around bacterial action on organic material in the manure. Manure from a barn cleaned mechanically is typically treated in a "plug flow" digester. Manure collected by "flushing" with water and diluted to 3-8% total solids is treated in a "complete mix" digester. Treated manure is collected in an effluent storage tank, frequently sized for a minimum of 2 days of storage. This effluent is pumped to solids separation equipment, frequently a screw press or a screen separator. Solids are collected and stored or used, liquid is placed in a longer term storage facility. Gas from the digester is pressurized and introduced to a boiler or an engine with an attached generator.

KEYS TO SUCCESSFUL COLD WEATHER OPERATIONS

The digestion system is sensitive to cold temperature and must be designed accordingly. In reviewing successful cold climate digesters, there are found to be certain keys to their successful and reliable operation.

1. Manure Collection
   Frozen manure is managed as a solid not as a liquid and may not be loaded into the digester. Any bypassed manure will neither contribute to energy production nor will it be treated. Fewer digester benefits will be realized in barns which are not constructed or managed to reduce the incidence of freezing.

2. Thermal System Design
   Heating is required to support the metabolic requirements of the anaerobic organisms. This heat may be supplied either by burning commercially available fuel, or biogas. In either case efficient combustion and heat recovery is desirable. Boiler and cogenerator design for maximum heat recovery will assure adequate quantities of heat to support the biological process in the digester.

3. Digester Design
   Digester design considers two basic heat requirements: bringing of incoming fresh manure to digester temperature, and replacement of heat lost through the digester walls, floor and roof. Important considerations are insulation of the digestion vessel and adequate sizing of the digester heating system.

4. Exposed Pipes
   Liquid will freeze in layers as it passes through pipes that have their wall exposed to

winter ambient temperatures. Appropriate measures are to insulate pipes or enclose them in insulated structures.

COLD WEATHER DIGESTER INSTALLATIONS

Five commercial scale plug flow digesters and one commercial scale complete mix digester were built on farms in the northern cold climate regions of the United States. All are heated with hot water brought to temperature by burning biogas. A description of each follows as well as a summary table. Biogas recovery and use in boilers or engine-generators is also discussed for each farm:

New York	Minnesota
Matlink, Clymer	Haubenschild Dairy, Princeton
AA Dairy, Candor	
DDI Dairy, Homer	
Wisconsin	**Illinois**
Stencil Farms, Denmark	New Horizons, Elmsford

CLIMATE

Average temperatures (in degrees Fahrenheit) for six cold weather digesters are noted. Of particular interest are the extremely cold January and February averages.

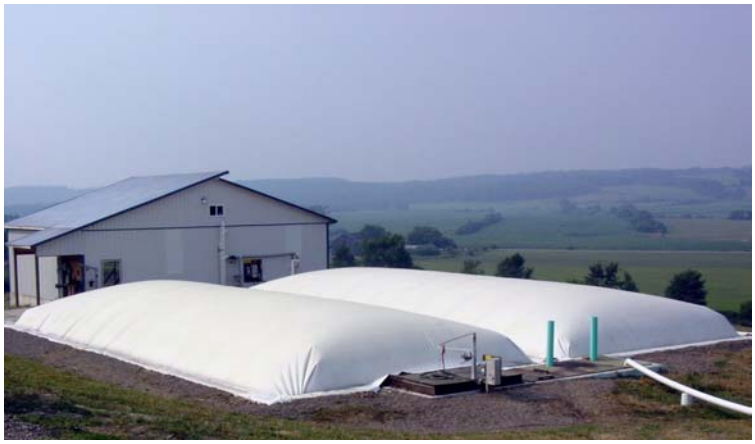
Winter Ambient Temperature for Six Cold Climate Digesters

Month	Matlink	AA	DDI	Haubenschild	Stencil	New Horizons
October	51.0	50.2	48.8	47.0	49.1	55.1
November	40.2	39.6	38.2	30.3	35.1	41.1
December	28.2	27.8	26.1	15.3	22.2	28.7
January	23.0	22.6	21.2	8.6	16.4	23.7
February	24.3	23.8	23.2	14.9	20.0	28.4
March	32.9	32.3	32.0	26.8	29.8	39.0
Winter Average	33.3	32.7	31.6	23.8	28.8	36.0
Annual Average	47.2	46.7	45.6	41.8	44.2	51.6

COMPLETE MIX DIGESTERS

Complete mix digesters are used to treat waste with 3 to 10% total solids and adequate volatile solids to produce enough biogas methane to maintain digester temperature

Matlink Dairy- 700 Head Dairy and Food Waste, Clymer, NY
The only commercial scale mixed dairy and industrial waste digester operating in the US is at Matlink Dairy. The mixed waste digester is producing 250,000 ft3 of gas a day. This is 400% greater than what could be produced by dairy manure alone.



Matlink Dairy has 700 cows housed in 1 freestall barn. The system was designed for manure from the equivalent of 900 cows. Manure is collected continually with cable scrapers to a drop gutter. As much as 12,000 gallons of wastes from a food processor has been received daily including: breaded fish cooker sludge, juice and dairy pipe cleanout, and out of specification foods. Multiple years of seasonal odor episodes from the manure storage pond were not acceptable to downwind neighbors. Consequently, the farm chose the engineering firm to design an innovative, low cost, heated, mixed, concrete digester. The approximately 80' x 70' x 16' deep digester holds roughly 20 days of material.

The digester produces enough methane to fuel a 130 kW Waukesha engine generator set and a food waste dryer. A flare burns the unused biogas. Electricity generated offsets farm electrical requirements, with the utility purchasing the surplus. Cogen hot water maintains digester temperature, heats the calf barn and supplies heat to the barn space and floor heating. Stabilized digester effluent flows to the storage pond. The pond no longer emits odorous gases. The digester is able to accommodate the variation in manure and food waste loading rate.

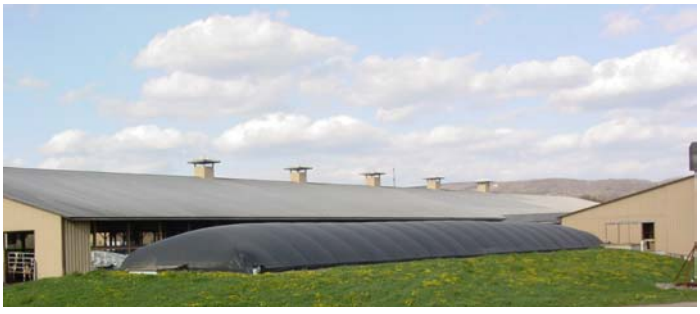
The primary benefits to the owners are odor reduction of stored and field applied manure. A secondary benefit is the substantial reduction in electricity and natural gas purchases. There have been no odor complaints since the digester was installed and compliance investigations by state regulators have stopped. The digester started up in about 30 days switching to biogas from natural gas in November 2001. Within 5 hours of the placement of the digester top, biogas was being flared. The engine has been in operation about 95% of the time since startup.

PLUG FLOW DIGESTERS

Plug flow digesters are used to treat scraped manure (in the 11% to 13% total solids range) from dairies. Since 1997, several 1,000 cow digesters and larger have been built. Five have operated through a winter in areas of the US with extremely cold winters.

AA Dairy, Candor, New York - 1000 cow digester

AA Dairy Farm built and started up their 550 cow anaerobic digestion facility, complete with a boiler fired system in October 1996. The digester is sized for future expansion. AgSTAR provided technical assistance in all phases of



AA Dairy, Candor, NY

the project.

The digester has operated without problems and the engine has had occasional outages for repair. In total the generator is operating over 90% of the time. The system is currently operating at a capacity of 70 kW, as well as producing hot water and about $60/day of digested fiber. Odor has been controlled permitting the dairy to now spray irrigate treated manure, substantially reducing the cost of manure application.

Haubenschild Dairy, Princeton, Minnesota - 1000 cow digester

Haubenschild Dairy Farm started their digestion system September 1999 while populated with only 480 of their current 1,000 cows system. Biogas is being used to fuel a naturally aspirated Caterpillar 3406 engine, producing about 130 kW of power about 98% of the time since startup. Heat recovered from the cogen is supplied to maintain temperature in the digester, parlor, employee areas and the walk area of the newest barn. The dairy has chosen to wait to install a separator to recover solids for resale.

Haubenschild Dairy, Princeton, MN

The local utility, Eastern Electric, has been a promoter of and asset to the project. The project has been well received and promoted within the state, receiving numerous environmental awards.

Odor has been controlled and manure handling is much easier for the owner. The owner is of the opinion that there is a significant increase in nutrient value from the manure as a result of digestion.

Dairy Development International - Homer, NY 1000 cow digester

Dairy Development International (DDI) started up their 1000 cow digester in October 1999. Digested manure is passed through a screw press separator. DDI chose to introduce digester biogas directly into a boiler specifically designed for biogas. All dairy hot water needs are met by the biogas fired boiler. All barn floors are heated as are all office and employee areas. Digester heat also is supplied from the boiler. The plan is for DDI to install four Capstone turbines to produce electricity with biogas. Power produced in excess of the farm's needs will be sold to the utility.

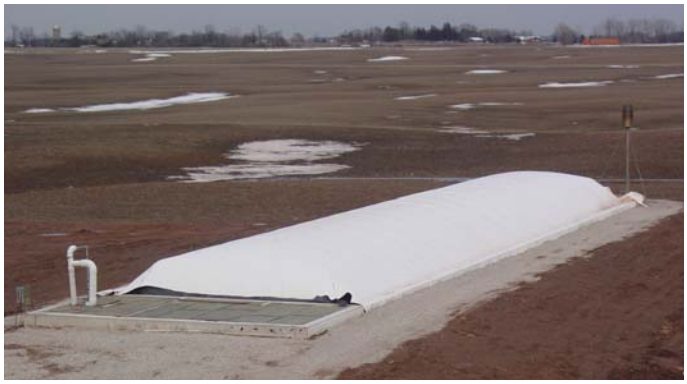
Dairy Development International, Homer, NY

The system was installed to reduce the odors associated with manure storage and

land application. Few complaints have been received in spite of the dairy having been recently constructed in a neighborhood disinclined to its presence.

Stencil Farms – Denmark, WI - 1200 cow digester

Stencil Farm started their digestion system December 2001 while populated with only 1000 of their current 1,200 cows. Biogas has been used to fuel a naturally aspirated Caterpillar 3406 engine, producing about 130 kW of power about 95% of the time since startup. Heat recovered from the cogen is supplied to maintain temperature in the digester and employee areas. The dairy has a separator to recover solids for bedding.



Stencil Farms, Denmark, WI

The utility, Wisconsin Power has been an asset to the project

Stencil Farms installed the digester to improve the bedding quality of the recovered fiber. They had been bedding for more than 5 years with fiber recovered from raw manure. Since bedding with digested fiber, milk somatic cell and plate count values have been dramatically reduced, increasing milk bonuses for milk quality. Manure odor has been controlled and manure handling is much easier for the owner.

New Horizons Dairy – Elmwood, IL - 2400 cow digester

New Horizons started their digestion system in October 2002 while populated with only 1200 of the eventual 2400 cow capacity. Illinois' Attorney General pursued legal action against New Horizons under their previous name of Inwood Dairy, for odor and other related manure issues. The dairy was fined and ordered to redesign the facility. No further action has been taken since installation of the digester.

New Horizons, Elmwood IL

Thirty nine days after the digester was filled, the top was placed. The next day the flare was lit with full gas pressure. Five days later the engines were started on biogas. Biogas has been used to fuel two naturally aspirated Caterpillar 3406 engines, producing about 200 kW of power approximately 95% of the time since startup. Heat recovered from cogeneration is supplied to maintain temperature in the digester. The dairy has installed separators to recover solids for sale.

COST BENEFIT

Construction costs and benefits associated with six cold climate digesters are reported in the following table.

Costs and Benefits of Six Cold Climate Digesters

System	Start Date	Capital Cost	Electric Savings/sales $/Year	Hot Water Savings $/Year	Fiber Value $/Year
Haubenschild	1999	$335,000	$80,000	$20,000	No recovery
Stencil	2001	$450,000	$40,000	$15,000	$40,000
New Horizons	2002	$875,000	$100,000	$19,000	$60,000
AA Dairy	1997	$311,500	$40,000	-	$10,000
DDI	2001	$325,000	none	$30,000	$15,000
Matlink	2001	$625,000	$80,000	$15,000	$30,000

CONCLUSION

Six manure digestion systems have been installed in the cold climate regions of the US. Several have over three years of operating time. One system, AA Dairy in the Finger Lakes Region of Northern New York State, has been in operation since 1997. Manure has been treated in these systems almost continually from the beginning of their operation. Biogas has been used to fuel boilers and cogeneration systems. Electric purchases have been reduced, electric sales made, and fuel purchases for heating reduced. The success of these operations illustrates that anaerobic digesters can operate successfully in cold climates and are economically viable for dairy farms.

ACKNOWLEDGEMENTS

The EPA AgSTAR program initiated a program in the early 1990's to construct full scale commercial manure digestion systems around the US. AgSTAR provided the engineer professional assistance to three of the installations reported here, AA Dairy, Haubenschild Farm and Matlink Dairy. Without the foresight of the AgSTAR program, there would not be the many digestion systems around the US for perspective digester owners to visit.