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PRO-DAIRY

Anaerobic Digestion at AA Dairy: Case Study

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Anaerobic digestion overview

Digester type	Plug-Flow
Digester designer	RCM Digesters, Inc.
Influent	Raw manure
Stall bedding material	Sawdust
Number of cows	600 dairy cows
Rumensin® usage	Yes; dry cows and pre-fresh cows
Dimensions (width, length, height)	30'x 130'x 14'
Cover material	Soft top (Hypalon 45)
Design temperature	100°F
Estimated total loading rate	11,000 gallons per day
Treatment volume	408,436 gallons
Estimated hydraulic retention time	37 days
Solid-liquid separator	Yes; compost produced and sold
Biogas utilization	Caterpillar engine with 130-kW generator
Carbon credits sold/accumulated	No
Monitoring results to date	Yes; see page 6.

Farm overview

- AA Dairy is a 600-cow dairy operation located on 2,200 acres in the town of Candor in Tioga County, New York
- The dairy began operating in the summer of 1993. Odor issues began to cause local concern, and thus, the decision was made to construct an anaerobic digester
- The digester was commissioned in June 1998
- Benefits (other than odor control) derived from this digester include:
    - Electricity and heat generated from the biogas
    - Compost from the post-digested separated solids
    - Irrigation liquid from the separated liquid effluent
- The electricity produced by burning biogas in the engine-generator set, is used for on-farm needs and any excess is sold to New York State Electric and Gas (NYSEG) under the provisions of the New York State Net Metering law (See Fact Sheet NM-1)
- The post-digestion separated solids are cured and marketed as compost to local buyers under the name "Field of Dreams Compost"
- The separated liquid effluent, mixed with milk house wastewater, flows by gravity to an HDPE-lined long-term storage, and is eventually land applied by tanker truck or irrigation by way of underground piping

Figure 1. Ground-level view of AA dairy anaerobic digester in winter

Why the digester?

Before the digester was built, manure and wastewater were stored in an underground pit at the rear of the milking center holding area. Manure was removed from this pit and recycled to the land base daily; however, local residents expressed concerns about odor, truck traffic, and a possible threat to water quality. After some exploration into new manure management options, the farm decided to construct a plug-flow anaerobic digester. The installation of the digester reduced odor, reduced the risk of runoff and leaching, and reduced manure transport over the roadways. Since the digester system was commissioned, liquid effluent, which has greatly reduced odor emissions, has been recycled to cropland.

Digester System

System and process description

A plug-flow digester with a 1,000-cow capacity, designed by RCM Digesters, Inc., was constructed at AA Dairy in 1998. The below-grade cast-in-place concrete digester structure is 130 feet long, 30 feet wide and 14 feet deep. The digester is equipped with an airtight, flexible dome to trap biogas. The manure is kept at approximately 100°F in the digester for optimal biogas production. A 7.5-Hp piston pump sends raw manure mixed with bedding, and if necessary (to dilute manure) milking center wastewater and/or solid-liquid separator liquid effluent, to the digester continuously for 4-6 hours per day. According to the "Big-5 Interim Report[1]", approximately 11,000 gallons of influent are fed to the digester each day. With this daily flow volume, the estimated hydraulic retention time is 40 days, approximately twice that of most other plug flow digesters.

System diagram

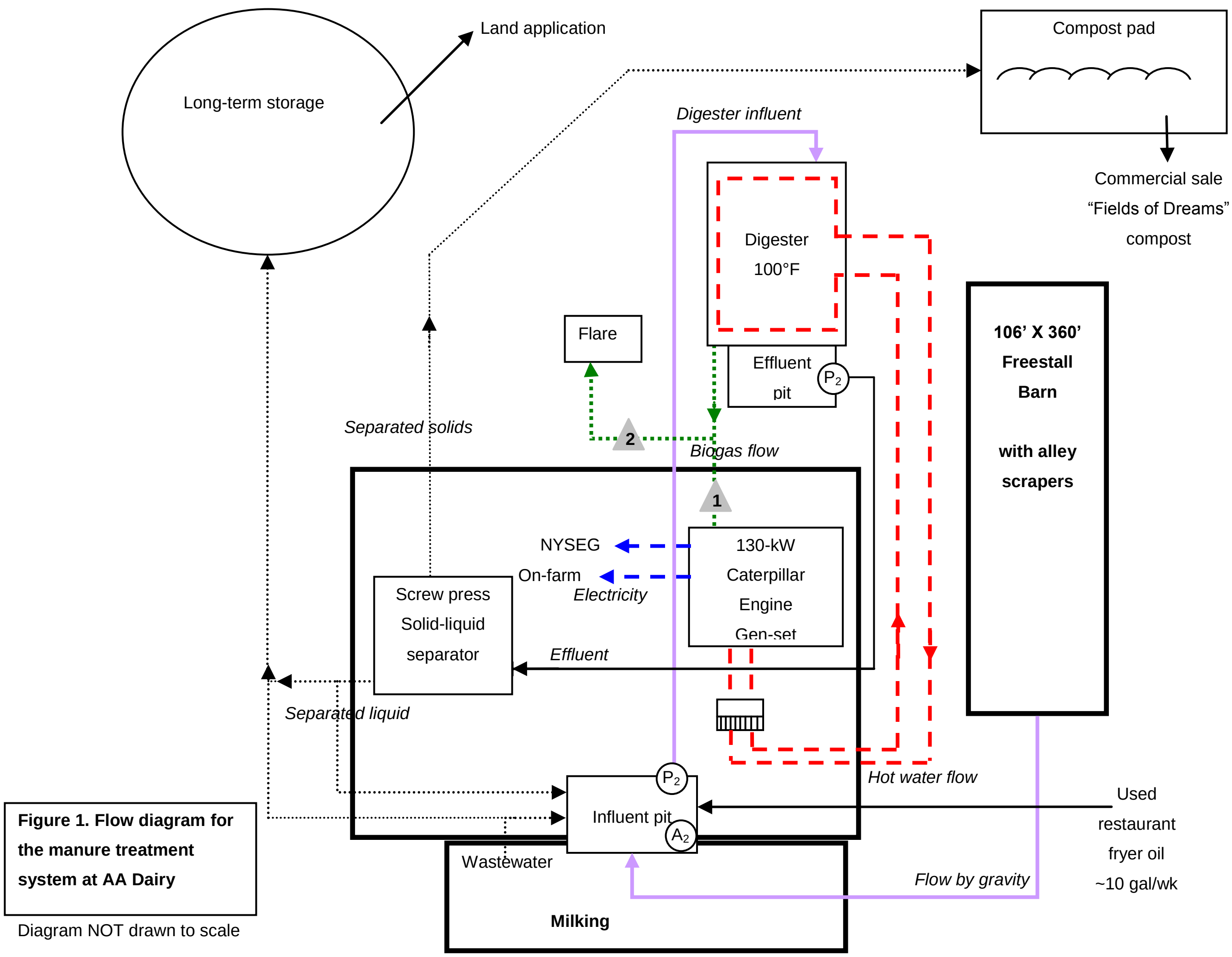

Figure 2: Schematic drawing of AA Dairy manure treatment system

[1]"Big-5 Interim Report": See "Biogas Distributed Generation Systems Evaluation And Technology Transfer - Interim Project Report. April, 2007" Project #: 6597. http://www.manuremanagement.cornell.edu/HTMLs/Project_Reports.htm

Liquids and solids process description

Manure is continuously scraped by alley scrapers from the 106'x 360' freestall barn and is gravity-fed into a cross barn alley. Shredded newspaper, sawdust, and approximately 10 yd^3/week of kiln-dried shavings are used for bedding. Barn effluent (manure + bedding) flows to the influent pit and when necessary, is mixed with milking center wastewater to dilute the digester influent. The farm adds about 10 gallons per week of used restaurant fryer oil, claiming it keeps foaming to a minimum, and prevents crust buildup within the digester.

After digestion, the treated slurry is pumped to a screw-press solid-liquid separator with a 7.5-Hp centrifugal pump. The separated solids are placed in windrows on the compost pad to cure, and the separated liquid flows by gravity to long-term storage.

Finished compost is sold in large and small bulk quantities and in 20-pound bags available at local farm and garden suppliers. The compost has been approved for use in organic food production.

The separated liquid effluent flows by gravity to a 2.4 million gallon HDPE-lined long-term storage. The stored liquid waste is spread on fields via 4000-gallon slurry wagons, or distributed through a pipeline system to irrigate cropland (corn, alfalfa, and grass).

Heat and electricity generation

Biogas is used to fuel a 130-kW (3306 Caterpillar) engine. The engine is a diesel block with a natural gas head that has been converted to run on biogas. The electric power produced is used for on-farm needs, and excess is sold to the local utility, New York State Electric & Gas.

Heat exchangers transfer heat from the engine to water, and the heated water is stored in a 4000-gallon tank. Stored hot water is used to keep the digester at a constant 100°F.

Economics

Initial capital costs

The initial capital costs associated with the digester system in 1997 are shown in Table 1.

Table 1. Initial capital costs for AA Dairy (Source: Wright and Perschke, 1998)

Component	Cost ($)
Digester	
- Manure pump (20 Hp)	9,000
- Engineering design	20,000
- Concrete digester (inc. floating insulation, gas containing cover, 2 hot water heating circuits)	160,000
Subtotal	***189,000***
Energy Conversion	
- Engine generator (used) & switching equipment	15,000
- Rebuild the engine	2,000
- Rebuild the generator	9,000
- Plumbing, electric, and mechanical systems	9,000
- Run cable to utility hook-up	8,000
- Electrical engineer consultant	18,000
Subtotal	***61,000***
Solid-Liquid Separation	
- Effluent pump (7.5 Hp) & variable speed drive	3,000
- Separation equipment	25,000
- Building for separator equipment	25,000
Subtotal	***53,000***
Liquid waste storage lagoon	
- Lagoon (excavation, fence, pipe, outlet structure)	18,000
- Plastic liner	42,000
Subtotal	***60,000***
TOTAL	**363,000**

Lessons Learned

The farm reported that the following lessons were learned as a result of operating their anaerobic digester.

The noise from the engine in an un-insulated pole barn can be loud. Providing a sound insulated engine room reduces the sound on- farm as well as the sound from a distance. People that had been keeping their windows shut from the odor were now complaining about the sound.

The projected savings from hot water use never materialized, since changing from the existing radiant heating system to a hot water heating system in the milking center would have been cost prohibitive. Since electricity produced by on-farm generation can meet the electric needs of the farm, there was not a huge incentive to make an expensive change.

Separated digested manure solids were used as bedding for a short time. Mastitis incidents rose in the milking herd and bedding was the first potential cause that was eliminated. The farm decided the use of manure solids for bedding was a risk of additional mastitis.

Compost marketing has been increasingly successful over time due to repeat customers, word of mouth advertising and the use of a website. Prices vary depending on size of the purchase. All the manure solids produced are able to be sold.

The engine-generator set selected was based primarily on price and not the most efficient size. A used engine-generator set became available and was put into service. An oversized engine will be less efficient in converting fuel to power at lower operating speeds. Designing a digester for 1,000 cows and operating it at half capacity reduces process efficiency.

The weir wall, consisting of wooden boards placed across the concrete opening at the outlet of the digester, eventually failed. Until repairs were made, it was necessary to keep the effluent pit full in order to prevent the loss of biogas.

Service support was found to be lacking for much of the equipment associated with the digester system, including the engine-generator set and electrical connections. At times a small problem that goes unfixed for a long time can lead to a more serious problem. There is demand for maintenance services to assist farms in operating and maintaining digester system components.

When treated digester effluent was added to the heifer barn's manure storage pond, it was found that odor was reduced. The farm deduced that, to control on-farm odors, not all manure has to be digested, and that possibly mixing digester effluent with raw manure may provide some odor control.

Changing the feedstock of the digester too quickly can disrupt the normal functioning of the bacteria and shock the system.

It is not worth it to have an atmospheric heat storage, the heat provided to the digester while the engine is down is not worth all the energy lost while it is in storage.

Do not shut down the engine and re-start it on a continuous basis – some people think shutting down the engine and night and running it during the day will give higher electricity buy back, but this is not good practice for the engine.

Do not put frozen manure in a digester, it takes too long to get it up to temperature and steals heat from the rest of the process.

It may be helpful to put a cathodic rod in the manure to prevent electrolysis of the heating pipes.

Previous testing results

AA Dairy's anaerobic digester system, along with seven others in NY State are in the process of being monitored to determine digestate stabilization, engine-generator set performance, reduction in greenhouse gas emissions, and economic benefit to the farm. AA Dairy and four of the other systems currently being monitored were also monitored in the past. The following data was taken from an interim monitoring report written in 2007. The complete report is available on line at www.manuremanagement.cornell.edu and can also be obtained by contacting the authors of this case study.

Waste stabilization results

Digester influent and effluent samples were collected monthly from 5/2001 to 6/2002 and from 7/2003 to 4/2005 and analyzed by a commercial laboratory. The values in Table 2 are the average (Avg), standard deviation (St. Dev.), 99 percent confidence interval (CI) and the number of samples (n) for the constituents analyzed. A negative value for the percent change in concentration indicates an increase in the constituent concentration as a result of the digestion process, while a positive value represents a constituent concentration reduction.

Solid-liquid separation performance results

Separator influent (digester effluent) and both the solid and liquid effluent flows were sampled monthly and analyzed by a commercial laboratory. The average (Avg), standard deviation (St. Dev.), 99 percent confidence interval (CI), and number of samples (n) for the solid-liquid separator influent stream, liquid effluent stream, and solid effluent stream are shown in Table 2.

Biogas and energy production results

Data on energy production/use was taken between 1/2004 and 5/2005. The total monthly metered biogas data were obtained from the farm log sheets and monthly farm visits. All biogas produced at AA was metered prior to use by the engine-generator set. The average daily biogas production used was divided by the average daily weight of VS consumed by the digester to compare the digester's efficiency in production of biogas. The biogas carbon dioxide concentration was measured using a Bacharach, Inc. FYRITE gas analyzer. The analyzer measured the concentration of biogas CO_2 in a range of 0 - 60 percent. The biogas was tested by the farm or the researchers during farm visits, and the average of the recorded values are shown in Table 3. The electrical energy generated, purchased, sold, displaced, and used is also shown in Table 3. Displaced energy was the energy sold subtracted from the energy produced. Farm utilization was calculated by adding the energy displaced and the energy purchased. Energy generated at AA was obtained every farm visit from the Watt-hour meter included as part of the engine-generator set control panel instrumentation. Energy purchased and sold was obtained from the NYSEG meter. A capacity factor that exceeds 90% is desired. Low monthly capacity factors at AA are the result of an engine-generator sized for a digester processing manure from 1,000 cows, while the digester at AA only processed manure from 600 cows.

Table 2. Anaerobic Digester and Solid – Liquid Separator Performance at AA Dairy

		Anaerobic Digester			Solid-Liquid Separator		
Constituent	**Statistic**	**Influent Constituent Concentration**	**Effluent Constituent Concentration**	**Change in Constituent Concentration**	**Influent Constituent Concentration**	**Liquid Effluent Constituent Concentration**	**Solid Effluent Constituent Concentration**
pH (Std. units)	Avg.	7.24	7.9	--	7.88	7.81	8.46
	St. Dev.	0.32	0.10		0.09	0.12	0.15
	CI	0.07	0.02		0.04	0.05	0.06
	n	75	75		32.5	31.5	31
TS (percent)	Avg.	11.15	8.08	27.5%	7.89	4.6	23.8
	St. Dev.	1.24	1.08		0.93	0.69	1.74
	CI	0.28	0.24		0.37	0.28	0.72
	n	75	75		32.5	31.5	31
TVS (percent)	Avg.	9.44	6.43	31.9%	6.27	3.21	21.25
	St. Dev.	1.05	0.91		0.81	0.46	1.73
	CI	0.24	0.21		0.33	0.19	0.73
	n	75	75		32.5	31.5	31
Volatile acid as Acetic acid (mg/kg)	Avg.	3,273	871	73.3%	--	--	--
	St. Dev.	1,368	1,582		--	--	--
	CI	536	620		--	--	--
	n	25	25		--	--	--
COD (mg/kg)	Avg.	125,875	88,993	29.3%	76,790	46,973	134,614
	St. Dev.	174,622	76,921		18,502	14,123	69,414
	CI	39,520	17,409		6,810	6,211	211,911
	n	75	75		32.5	31.5	31
DCOD	Avg.	24,331	16,053	34.0%	16,644	16,114	15,772

(mg/l)	St. Dev.	8,315	6,555		5,430	8,142	3,997
	CI	1,894	1,494		2,449	2,192	1,086
	n	74	74		32	53	52
Log_{10}MAP (cfu/gram)	Avg.	3.9	1.8	98.7%	1.8	1.55	1.55
	St. Dev.	0.5	0.6		0.5	0.8	0.7
	CI	0.1	0.2		0.35	0.7	0.85
	n	65	59		27.5	19	8
Log_{10}F. Coli. (mpn/gram)	Avg.	6.1	3.1	99.9%	3.25	3.1	2.8
	St. Dev.	0.8	0.7		0.55	0.65	0.45
	CI	0.2	0.2		0.4	0.3	0.35
	n	73	70		31.5	31.5	30

Table continued on next page

	Anaerobic Digester				Solid-Liquid Separator		
Constituent	**Statistic**	**Influent Constituent Concentration**	**Effluent Constituent Concentration**	**Change in Constituent Concentration**	**Influent Constituent Concentration**	**Liquid Effluent Constituent Concentration**	**Solid Effluent Constituent Concentration**
TKN (mg/kg)	Avg.	4,782	5,145	-7.5%	4,869	4,542	5,379
	St. Dev.	1,275	1,292		1,345	1,448	1,521
	CI	289	292		595	642	644
	n	75	75		32.5	31	31
NH3-N (mg/kg)	Avg.	1,876	2,588	-37.9%	2,457	2,403	2,265
	St. Dev.	474	421		391	646	380
	CI	107	95		165	290	170
	n	75	75		32.5	31.5	31
ON (mg/kg)	Avg.	2,908	2,556	12.1%	2,412	2,140	3,114
	St. Dev.	1,167	1,292		1,389	1,239	1,531
	CI	264	292		612	543	619
	n	75	75		32.5	31	31
TP (mg/kg)	Avg.	803	811	-0.93%	730	638	1,036
	St. Dev.	241	220		144	132	284
	CI	55	50		58	52.5	129
	n	75	75		32.5	31.5	31
OP (mg/kg)	Avg.	457	534	-16.7%	490	433	544
	St. Dev.	132	122		78.5	105	133
	CI	30	28		32.5	42.5	54.5
	n	75	75		32.5	31.5	31
K (mg/kg)	Avg.	1,927	2,216	-14.9%	2,234	2,098	1,845
	St. Dev.	299	401		523	308	158
	CI	169	227		388	246	127
	n	12	12		7	6	6
Cu (mg/kg)	Avg.	16.08	31	--	--	--	--
	St. Dev.	8.95	14		--	--	--
	CI	3.92	6.4		--	--	--
	n	20	20		--	--	--

Table 3. Electrical Energy Generated, Purchased, Sold, Displaced and Used at AA Dairy

	Monthly metered biogas (ft^3)	**Biogas produced per pound volatile solids consumed (ft^3/lb)**	**Average biogas CO_2 content (%) [A]**	**Average monthly energy generated, purchased, sold, displaced, utilized (kWh)**	**Capacity factor**	**Energy (Wh) per cubic foot of biogas used**
Average	1,041,585	16.2	34.7	Produced: 20,916 Purchased: 10,064 Sold: 6,512 Displaced: 14,404 Farm used: 24,378	0.294	17.7
Range	396,700 1,455,100	--	34 40	Produced: 0 to 39,900 Purchased: 960 to 19,360 Sold: 0 to 13,600	0.0 0.582	0.2 35.3

				Displaced: 0 to 26,300 Farm used: 19,360 to 31,937		
Number samples	13 months	23	18	10 months	17 months	17 months

[A] Estimated CH_4 concentration is equal to 100 – [CO_2]

Another evaluation of the digester system at AA Dairy has been described in a paper prepared by EPA's AgSTAR program, titled "A Comparison of Dairy Cattle Manure Management with and without Anaerobic Digestion and Biogas Utilization."
It can be found on the website at http://www.epa.gov/agstar/pdf/nydairy2003.pdf

Results from current monitoring project

The monitoring of AA Dairy is continuing, following the national digester performance evaluation protocol, developed to standardize monitoring and reporting of anaerobic digestion evaluations by the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) and the EPA AgSTAR Program.

In keeping with this new protocol, a pump test was conducted at the farm (10/25/2007) by pumping manure from the influent pit to a tanker truck and counting the number of piston pump strokes. Density of the manure was also determined. The results showed the Houle piston pump in the influent pit to have a volumetric pump efficiency of 33% when pumping manure to the digester.

Who to Contact

- Charlie: AA Dairy anaerobic digester operator. Phone: 607-659-3324
- Curt Gooch, Manure Treatment Specialist, PRO-DAIRY Program, Cornell University. Phone: 607-255-2088, Fax: 607-255-4080, Email: cag26@cornell.edu

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