DOE/R6/12085--T1

DE83 017946

TX-81-009

DOE/R6/12085--T1 10/5/83

MASTER

To: Mr. Wayne Missaggia

Subject: Final Report - Project DE-FG46-81R612085

The objective of this grant was to maintain a single stage anaerobic digester at Tarleton State University for the purpose of providing a working prototype for interested people in the area. During the 21 months the project was funded about 310 people visited the project.

The importance of agriculture to the United States economy is illustrated by the fact the 3% of the population produces food for the rest of the people. American agriculture requires intensive energy inputs; therefore, a shortage of energy will have direct effect on food cost which requires 13.5% of each dollar earned. Whereas 25-35% of each dollar equivalent earned is required by western Europeans. Part of the "cheap food" policy in the U.S. has been made possible because of inexpensive fossil fuels of the past. Cost of fossil fuels will no doubt increase at a faster rate in the future. If the U.S. is to maintain a "cheap food" policy, the cost-competitive energy sources must be made feasible and adopted by potential users in agriculture.

During the past decade, farm animal wastes have emerged as a major source of pollution of surface and ground waters. Because extremely cheap commercial fertilizers and energy were readily available, these wastes were viewed by many farmers as a nuisance and often were treated as materials with little or no value. More stringent environmental controls, greater numbers of animals per farm, and widespread urban sprawl have made the management and disposal of manures a problem of major proportions to many farmers.

Three alternatives are generally available to the farmer for disposal of manure:

1. Spread the manure on the land.

This method is practical if large tracts of land with low human population densities are available.

2. Process the manure.

This method may include drying the manure for livestock feed or fertilizer use.

3. Convert by anaerobic digestion.

This method converts manure to a usable source of energy (methane) and produces an effluent which retains all fertilizer values and is environmentally acceptable.

Positive environmental impact on communities will also be significant because livestock operations and people can cohabit the same areas peacefully since odors from livestock wastes can be practically destroyed using the anaerobic concept. Flies that are attracted by other waste disposal procedures will decrease when digester systems are used because excess waste and odors are sealed in the digesters and not exposed for food or as breeding grounds for these aerial pests.

Residues from the digesters may also be used in the area either as supplemental feed for livestock or as fertilizer. Either way, a once useless waste is recycled into food and/or fiber on a cost-competitive basis.

From a farmer's viewpoint, cheaper energy for heating homes, barns, chicken brooders, or swine nurseries will be welcomed. The same energy source may also be used for cooling homes, meat or milk coolers, and egg storage. Cattle feeding, which is the core of agricultural income in many

West Texas communities, may capitalize on anerobic energy for feed processing.

The conversion of organic materials, such as animal wastes, to an easily utilizable form of energy can be accomplished by a number of methods. The process that appears to hold the greatest immediate potential is the anaerobic fermentation by which organic materials are converted to methane and other gases. The extraction of energy from wastes using anaerobic digestion to produce bio-gas is not new, and the general technology is well known. Bio-gas, the main constituents of which are methane and carbon dioxide, has been known for a long time as swamp gas, sewer gas, or fuel gas.

EQUIPMENT AND PROCEDURES

Demonstration Plant Facilities

Figure 1 is a schematic diagram of the demonstration anaerobic digestion plant. Fresh manure is loaded from hogs housed on slatted floored concrete pens which are completely covered. There are between 10,000 and 30,000 pounds of hogs on the floor, depending on the season. Manure is also used from 3,000 laying hens. The birds are housed in cages. No antibiotics or growth stimulants are used in the rations of either the hogs or the poultry.

The manure from the poultry is scraped to a pit at one end of the laying house and dumped into the pit. Water is added to the material to form a slurry of 12 to 14% total solids, so the manure can be pumped out of the pit by a Marlow diaphram mud pump and transported by gravity flow to the sump pit located at the digester. The manure from the swine feeding floor is transported to the anaerobic digester by gravity flow.

After the manure from the poultry or the swine, or poultry and swine manure mixed together in the sump pit, water is added to the material to form a slurry of 9-11% total solids. The slurry is then pumped into a pre-mix tank where it is mixed for about five minutes. The slurry is then allowed to settle for about two minutes. This short period of time is all that is needed to allow feed to settle to the bottom, and for most material that will float to rise to the top. After the short settling period the manure is loaded into the digester by gravity flow.

The anaerobic digester is 14 feet wide, 30 feet long, and 10 feet deep. The walls and floor is concrete and the top is of fiberglass. Fiberglass was used for the top because of its resistance to corrosion, cost, and long life. The temperature within the digester is held at 95 degrees fahrenheit by a heat exchanger. The heat exchanger is powered by some of the gas produced by the digester and solar heating panels. The mixing of slurry within the digester is by recirculating the gas. This is done by using a Root Lobe Compresser, model 315. The compresser is controlled by a time clock which is set a ten minutes per hour of mixing time.

The bio-gas is then passed through a gas scrubber which is packed with iron sponges. After the hydrogen sulfide has been removed, the gas is then stored for use. An air compresser modified to compress combustable gases is used to store the gas at about 125 psi. Propane tanks are used for the storage of the gas that is then used for heating, cooling, and other power needs.

ECONOMIC VALUE

Digester design

The design of an on the farm anaerobic digester should be based on several parameters. Gas production from anaerobic digestion is a biological function and not an engineering problem. The environmental requirments for anaerobic digestion for production of methane is well known (Fulton 1979, Hasimoto et al. 1979). An anaerobic digester operating in the mesophilic temperature range (95 degrees fahrenheit-35 degrees centigrade) would be the most economical in the Southwest United States. Fluctuations of greater than ± 2 can decrease bio-gas production. A higher rate of gas production can be accomplished by mixing the contents of the digester. Mixing prevents formation of an undesirable scum on the surface, and brings bacteria into more immediate contact with the organic matter. PH of the digester should be between 6.8-7.5.

A second major factor in the design of a digester is the quality of labor that will be doing most of the work with the anaerobic digester. The day to day operation of a digester will be done by a farm laborer. This means that the digester must be of simple design. Fischer (1979) lists conditions which would indicate a stable anaerobic digester. The eqipment needed to measure the six conditions he listed are: PH meter, drying oven, gas chromatograph, and an ashing furnace. The average farm laborer could not carry out the six steps suggested by Fischer.

A third major factor is hydraulic retention time. The longer the manure is in the digester the more gas produced per pound of manure, but the longer the unit needs to be. Correct design involves selecting the best trade-off between gas yield per pound of manure and digester construction cost. For mesophilic systems 95 degrees F, retention times of 12 to 16 days are used. Another factor is loading rate which is usually specified in terms of the weight of volatile solids added to the digester daily per unit of digester volume. The typical volatile solids loading rates are 0.2 to 0.3 lbs. vs/day/cu.ft. for mesophilic digesters.

The fourth major factor in digester design and planning is <u>intergrating</u> the anaerobic digester into a commercial poultry swine or dairy farm. A standard plan or design cannot be develped to fit all farms and ranches. Transporting the manure to the digester, removing foreign substances from the manure(dirt, rock, feed, feathers or hay) will be different on each farm. Another problem with a standard design is how the effluent will be handled. Another problem with standard design is energy usage; and energy usage is the key to whether or not anaerobic digestion is economically feasible.

<u>Energy Utilization</u>

Much has been written on the very large anaerobic digesters that utilize the manure from thousands of cattle (Hashimoto, <u>et al</u>, 1978 Sweeten 1980). Two problems seem to arise on all of these studies. The first problem is what to do with the energy produced. Research at Tarleton has shown that if the energy that is produced cannot be used on site in an energy efficient way, the anaerobic digester on that farm is too large. The second problem is that many research workers put a feed value on the digester effluent; but Burford, <u>et al</u>(1979), Maciel (1979), Zinn, <u>et al</u> (1979), Fulton (1980) have reported relatively low nutritional value, poor palatability and or difficulty in the handling of the product. Animal manures do have a feed value, but it is questionable as to whether anaerobic digestion increases this value.

The productive use of the energy produced is the key to the economic feasibility of anaerobic digesters. Anaerobic digesters produce bio-gas constantly throughout each 24 hour day. It is not economically feasible to store large quantities of gas on the farm. This means that the rate of gas usage needs to be roughly equivalent to the rate of gas production. Required storage would need to be large enough in capacity to provide supplementary gas when the rate of usage exceeds the rate of bio-gas production. There are several possibilities for the use of bio-gas at a rate relatively close to the rate of production.

Heating

Given any situation where direct heating is required, bio-gas should be a potential energy source. Possible uses of heat found on most farms would be domestic uses (cooking and hot water), brooding of pigs and chickens, and hot wash water required for poultry or dairy farms.

Cooling

There are a number of cooling needs on farms that require energy where bio-gas use could contribute. Poultry operations require coolers for eggs, and dairies require cooling systems for bulk milk. Milk cooling presents an addtional developmental problem which may require adaptation of equipment to by-pass water heat exchangers which have been developed using traditional design to by-pass water chilling in a conventional milk cooler. This would reduce theoretical energy inputs by approximately 50%.

Feed and Waste Processing

Other potential energy needs on some farms include drying manure waste to eliminate flies and odor, or use as a feed ingredient. Also, bio-gas may become cost prohibitive if considered a part of the same bio-gas energy use system, then the value of two otherwise uneconomical processes may be economically justified.

After personal communication with engineers at a Denver based manufacturing firm, plans for the feasibility of a grain micronizer as a part of the gas use system were concluded. When micronizers are operated, there may be a build-up of excess heat from the micronizing process which can be used to either dry manure or recycle the heat into the digester to support the anaerobic system. Heat returned to the digester will spare bio-gas energy which would otherwise be used for temperature maintenance. Using waste heat energy for maintenance of digester temperature would increase the efficiency of bio-gas output. It is this possibility of recycling excess heat for manure drying or for supporting the bio-gas generating system that can make these mutually supporting systems economically feasible.

Electricity

Many farm operations were developed with equipment dependent upon a source of electrical power produced and distributed by corporate power conglomerates. The cost of electricity is rapidly increasing at a rate comparable to the cost of fuel sources such as natural gas or fuel oil that are used to generate it. Since many farm activities depend on electrical power, bio-gas should be considered an alternative source of energy for on-farm generation of electricity. Farm generation of electrical power could solve some of the inequities in distribution of electricity. As current rates of costs of electrical energy increase, electrical power from bio-gas may be more economical.

On June 2, 1980, a 4000 cubic feet anaerobic digester was put into operation at the Agricultural Center at Tarleton State University, Stephenville, Texas. The design of this anaerobic digester is the result of three and one half years of research in which the major goal was to develope an anaerobic digester that would be practical and economical for farms and ranches in Texas.

This digester can handle the manure from 100 dairy cows or 40 sows farrow to finish or 16,000 laying hens. The digester is fourteen feet wide, thirty feet long and ten feet deep. The walls and floor are concrete and the roof is fiberglass. The liquid level is maintained by a weir which allows volume control and anaerobic conditions. The contents of the digester is mixed by recirculating gas with a lobe compresser. The temperature in the digester is maintained at 95 degrees F by circulating water through a heat exchanger. The digester is loaded daily with a 16 day retention time and 9% to 10% total solids.

The design of this digester minimized labor, management, and maintenance requirements. Because the gas produced by anaerobic digestion is flammable, precautions were taken to eliminate areas where leaking gas might accumulate.

From data collected and information gained from the continual operation of this digester, some rather exact economic values and cost projections can be derived.

To illustrate economic benefits, the following summary shows what can be realized by using the energy produced by digestion of the manure from a 200,000 bird laying operation, or a 1,300 cow dairy operation, or a 530 sow, farrow to finish operation. These figures are based on research results obtained at Tarleton State University.

200,000 Laying Hens

GAS PRODUCTION

Gas production per bird per day	1/3 cubic foot
Gas production per 200,000 bird/day	66,000 cubic feet
25% used to heat digester during winter	16,500 cubic feet
Bio-gas available per day during winter	49,500 cubic feet

ENERGY CONSUMPTION OF THE DIGESTER OPERATION

Pre-mixing	480 Kwhr per month
Mixing of digester	2,800 Kwhr per month
Gas compresser	4,200 Kwhr per month
	7,560 Kwhr
Electricity ($.05/Kwhr)	$378.00 per month
	$4,536.00 per year

The following projections are based on the assumption that natural gas, propane and electricity will increase in price by only 10% per year.

Value of bio-gas 49,500 cu.ft./day

Propane based on 65¢ per gallon (93,000 BTU/gallon)

49,500 cu.ft. x 600 BTU per foot= 29,700,000 BTU

29,700,000 ÷ 93,000= 319.35 gallon of propane per day

319.35 gallon x $.65 (cost of a gallon of propane)=$207. per day

$207.58/day x 365= 75,766.70 first year

Value of bio-gas 49,500 cu.ft./day

Natural gas based on $4.00/1,000,000 BTU

49,500 cu.ft. x 600 BTU per feet= 29,700,000 BTU

29.7 million BTU per day

29.7 x $4.00/million BTU= $118.80 per day

$118.80 x 365 = $43,360 first year

Cost of Anaerobic Digester

45,000 cu.ft. 20 x 15 x 150 ft.

Concrete sides, bottom, reinforced, insulated, buried in the ground

Fiberglass top so as to use solar energy during the summer

Digester contains heat exchanger with boiler modified to use bio-gas

Manure pre-mixing, gas scrubbing, digester mixing, equipment building and a gas compresser

Cost of construction $6.25 per cubic foot of digester $281,250

$281, 250 at 12% interest for 4 years= $350,397

Maintenance interest and debt retirement = $380,397

Maintenance $7,500 per year = $30,000

Value of propane---4 year---$386,767

The greatest demand for energy during the summer in the South and Southwest parts of the U.S. is electricity. Electricity is a major form of energy that is rquired on most farms in Texas. The highest demand occurs during the six warmest months of the year. It is during this period of time that the most energy is available from an anaerobic digester. Data indicates that about 8% of the energy produced is required to maintain digester temperature. Instead of 49,500 Cu.Ft.

of bio-gas available for use, 60,720 cu.ft. would be available. When the need for heat (hot water, brooding chickens, domestic, etc.) would be at a minimum, the bio-gas could be used to fuel an engine to generate electricity. The research at this station has not yet been completed as to measure the economic feasibility of converting the energy in bio-gas to electricity.

If a 22% (Sweeten 1980) conversion efficiency with an internal combustion engine can be reached, the following values can be expected:

Gas Production (60% methane 40% Co_2)	200,000 hens
Gas production/hen/day	1/3 cu.ft.
Gas production/200,000 birds/day	66,000 cu.ft.
8% used to heat digester(summer)	5,280 cu.ft./day
25%used to head digester(winter)	16,500 cu.ft./day
Gas available 180 days summer	60,720 cu.ft./day
Gas available 180 days winter	49,500 cu.ft./day

Using the energy that is available during the summer to generate electricity (22% conversion) and the energy that is available in the winter as a direct source of heat, a value for the energy produced can be estimated.

Electricity has a value of $.05/Kwhr, and the price of propane is $.65/gallon. If the cost of energy increases at a modest 15% annually, the table shows the value of electricity and propane that could be expected over a five year period.

Electricity 2,350 Kwhr/day		Propane 319 gallons/day	
1982	$24,322	$43,565	
1983	$27,960	$50,099	
1984	$32,154	$57,613	
1985	$36,977	$66,254	
1986	$42,523	$76,192	
	$163,936	$293,723	Total=$457,659

Cost of Construction $6.25 per cubic foot

Total $281,250

$281,250 at 12% interest for 5 years $365,625

Maintenance $12,500 per year= $50,000

Maintenance, interest, and debt retirement= $417,351

Value of energy----5 years= $457,659

Conclusions

Anaerobic digestion for the production of energy seems to be affected by the following:

1. The ability to adapt the energy system to the farming operation.
2. Efficient utilization of all energy produced.
3. Heat recycling from internal combustion engines that are used for production of methane.
4. It appears from research data that the minimum size of farms for anaerobic digestion systems are:

   Poultry------40,000 laying hens (cages)

   Swine--------100 sows-farrow to finish--concrete slats

   Dairy Cows---Depends on management of the dairy herd.

BIBLIOGRAPHY

Burford, J. L., F. T. Varani, S. B. Don, and B. Pace. 1979. "Energy Potential Through Bioconversion of Agricultural Wastes; Phase III." Final report to Four Corners Regional Commission, Grant No. 682-366-003, Bio-Gas of Colorado, Inc., Loveland, Colorado, January 14.

Fischer, J. R., E. L. Iannoti, and D. M. Sievers. 1979. "Biological and Chemical Fluctuations During Anaerobic Digestion of Swine manure." (In press). USDA/Agruicultural Research Service, Columbia, Missouri.

Fulton, E. L. 1979. "Methane Generation from Poultry House Wastes." Extension Seminar on Methane Production from Livestock and Poultry Wastes, Texas Agricultural Extension Service, Texas A&M University, and Tarleton State University, Stephenville, Texas, May 23.

Hashimoto, A. G., Y. R. Chen, and R. L. Prior. 1978. "Thermophilic Anaerobic Fermentation of Beef Cattle Residue." In: Symposium Papers, Energy from Biomass and Wastes, Institute of Gas Technology, August 14-18, Washington, D.C.

Hashimoto, A. G., Y. R. Chen, and R. L. Prior. 1979. "Methane and Protein Production from Animal Feedlot Wastes." Journal of Soil and Water Conservation, 34(1):16-19.

Maciel, P. 1979. "Status of the Imperial Valley Biogas Project." Presented at Seminar on Biogas and Alcohol Production, Chicago, Illinois, October 25-26.

Sweeten, J. M., 1980. "Prospects for Methane Production at Cattle Feedlots." Presented at National Cattlemen's Association convention, San Diego, California.