A BIOGASIFICATION SYSTEM AT A DAIRY

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A biogasification system which generates methane from the anaerobic digestion of cow manure has been designed and constructed at a dairy. One objective has been to produce a "package" facility which is easy to install and operate. The system produces and processes methane gas for direct use at a dairy. This package consists of several modular components that can be assembled and put to use much like a "do-it-yourself-kit." Since the biggest deterrent to an on-site means for utilizing animal wastes has always been high cost, work has been aimed at designing a facility which when mass-produced could be available at a low price. At the present project site, where propane is used, the facility is economically attractive. The process design needs further improvement to demonstrate economic feasibility for sites where natural gas and other forms of energy are used. Detailed design descriptions and testing procedures for this unit are presented elsewhere (1).

BIOCONVERSION OF WASTES INTO METHANE

Potential methane production by anaerobic digestion of the manure produced by the 100 million head of cattle in the United States could supply only 2.5 to 3% of the nation's annual demand of 22.8 trillion cubic ft of natural gas (2). Thus, bioconversion can offer only minor alleviation of the energy crisis, but it would have significant ramifications on pollution control. Most current biogasification proposals involve only large-scale facilities. Unfortunately, technology concerning methane production from manure in small-scale units has not been significantly advanced (3). There is more manure available, by far, for bioconversion at the more than 400,000 dairies and farms scattered across the country than in the large feedlots distributed mostly in the Southwest (2). Collection and transportation of manure to a central regional bioconversion plant will probably remain economically unjustified; thus, biogas should be produced and used exclusively on a dairy or farm (4).

In the absence of oxygen, organic materials are decomposed by anaerobic fermentation; such an environment can be established within organic particulates such as natural wastes. According to McCarty (6), the process occurs in three stages which are performed by two different groups of bacteria acting as a coupled system. In the first step, complex organics such as fats, proteins, and carbohydrates are converted by enzymatic hydrolysis to simple soluble organic compounds. In the second step, these simpler compounds are fermented to mostly volatile fatty acids by a group of facultative anaerobic bacteria commonly called "acid formers". The third step involves fermenting the organic acids to carbon dioxide and methane by a group of strictly anaerobic bacteria collectively called "methane formers". Biogas formed in this step is methane-rich, 600-700 Btu/cubic ft gas.

BIOCONVERSION SYSTEM FOR A DAIRY

The system design entails assimilating several modular components into a flexible package. The unit must be easy to construct, operate, and maintain. Furthermore, this facility must be built on a small site for a relatively low cost. Modular design is incorporated so that the facility can be retrofitted to a wide variety of existing farms and dairies. The biosystem package, shown in Figures 1, 2 and 3, consists of a sump, pump, floating covers, fermenter, heat exchanger, drying bed, and a hydrogen sulfide (H_2S) stripper. The existing facility has been constructed at a dairy farm five miles north of Norman, Oklahoma. All specifications and equipment costs are summarized in Table 1.

PROCESS FLOW DESCRIPTION

The bioprocess incorporates a fairly straightforward method for converting raw manure to biogas and fertilizer as shown in Figure 2. Fresh incoming manure is mixed with an equal amount of warm water in a 48 cubic ft concrete sump. The sump is

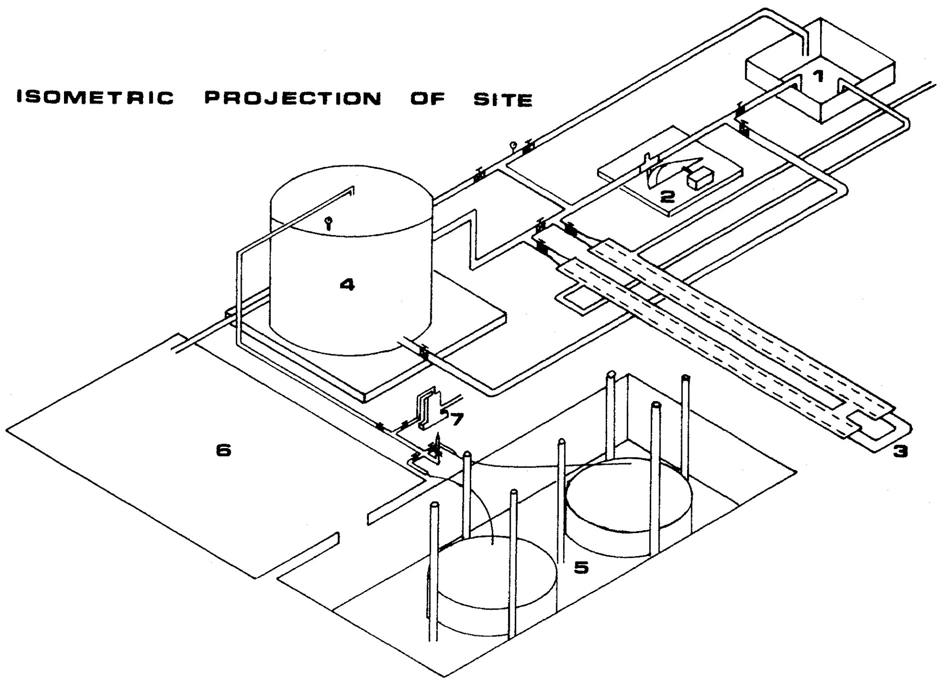

FIGURE 1. Bioconversion system for a dairy; isometric view of the site. Components of the system are: 1, sump; 2, pump; 3, heat exchanger; 4, fermenter or anaerobic digester; 5, floating gas storage covers; 6, drying bed; 7, hydrogen sulfide stripper.

TABLE 1. *Budget for the design and construction of an anaerobic digestion facility at a dairy.*

I. SITE EXCAVATION	
Concrete and forms for sump	$ 50.00
Concrete pads for pump, fermenter, and drying bed	145.00
II. PUMPING EQUIPMENT	
Assume use of highest-priced pump: Peabody-Barnes Model 3SCU sewage pump, 3-inch suction-discharge, cast iron type complete with mechanical seal	956.00
Hammer-Cutler fuse box, manual starter and wiring rated at 45 amps	200.00
III. ANAEROBIC DECAY CHAMBER	
1525-gallon, high-density, cross-linked polyolefin tank from Poly Processing Company	450.00
IV. HEAT EXCHANGE EQUIPMENT	
2/20 ft. joints schedule 40 black steel pipe	180.00
2/20 ft. joints schedule 40 CPVC pipe	82.00
Angle irons, H-X pipe supports	100.00
V. GAS COLLECTION AND STORAGE SYSTEM	
2 high-density, cross-linked polyolefin floating covers, from Poly Processing Company, 400 ft^3 capacity	900.00
Concrete for stabilizing floating covers	50.00
Crane to place floating covers in biopond	80.00
VI. PIPING AND FITTINGS	
2/20 ft. joints schedule 80 ½ inch PVC pipe	28.00
5/20 ft. joints standard 2-inch PVC pipe	150.00
Bulkhead fittings for fermenter and floating covers: 3/2", 3 ½"	90.00
Ells: 8/2", 2/3" black schedule 80	136.00
VII. GAS TREATMENT SYSTEM	
H_2S stripper, 5-gallon plastic cylinder, rated at 10 psig	120.00
Drop-in cartridge, loaded with wood chips impregnated with iron(II) oxide	10.00
VIII. INSTRUMENTATION	
Industrial gas flow meter	60.00
2 pressure gauges	30.00
2 temperature gauges	50.00
IX. INSULATION	
Spray-on polyurethane foam for fermenter and heat exchanger	150.00
X. LABOR	600.00
TOTAL SYSTEM COST	$4617.00

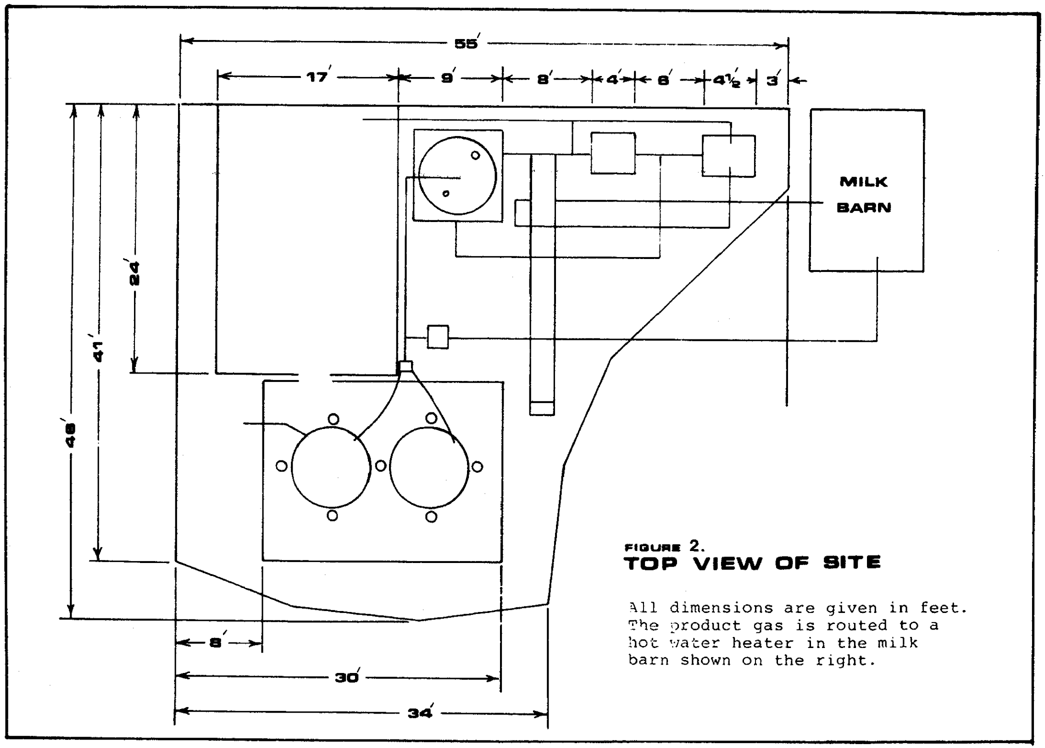

FIGURE 2. Bioconversion system for a dairy; top view of the site. Dimensions are given in feet. The gas produced in the system is used in a water heater which is located in the milk barn (shown on the right of the Figure).

located in the milking area for two reasons. One is the ease with which manure can be collected and transferred to the sump. The other reason is that waste hot water used to clean the milk barn floors can be drained into the sump. Use of this waste hot water minimizes heat exchanger operation and thus partially defrays the cost of warming the manure to digestion temperatures.

Two concrete aprons encompass the site. Manure on the aprons is scraped by tractor into large dirt-free piles and then loaded into the sump. Waste hot water used to wash off the milking room floors is then added and the mixture blended with a shovel to put the manure in a form more conducive to digestion. Approximately one part manure is mixed with one part water to insure a slurry containing about 7 to 9% dry solids by weight. Previously the farmer scraped manure into a drain which was routed to an anaerobic lagoon; thus, no more time is taken for loading the sump than was spent for disposing the manure in the past. The slurry is then pumped through a shell-and-tube heat exchanger (1) in winter or directly into the gas fermenter during summer. During the summer months (about 7 months), the fermenter is able to maintain a 95 F temperature without adding additional heat as a parasitic power requirement. Net biogas production during the winter was calculated to be about 30% less than that of the summer months, owing to the extra hot water required for the heat exchanger.

All piping except the inner sleeve used in the heat exchanger is poly(vinyl chloride) (PVC). The outer sleeve of the heat exchanger is fabricated from chlorinated poly(vinyl chloride) piping, since this is more suited to high-temperature use than PVC. Use of plastic piping made construction of the facility extremely fast and easy. In no more than a few hours, 200 feet of line complete with valves and fittings were installed. The use of plastic piping and polyolefin tanks for the fermenter and floating covers contributed to a nearly three-fold reduction of the cost compared to that for

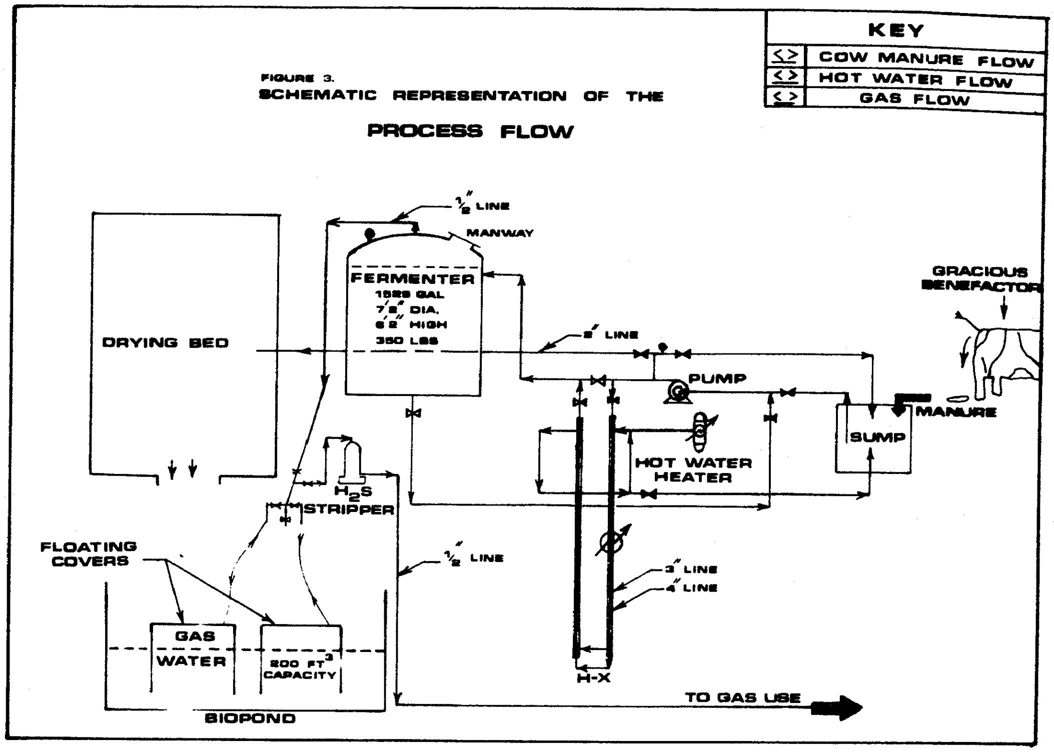

FIGURE 3. Schematic representation of the process flow.

past bioconversion facilities. Methane produced in the fermenter is piped to two gas collection and storage vessels floating in an anaerobic lagoon (biopond) nearby. Open at the bottom, these covers rise in the water as they fill with gas. After digestion the sludge from the fermenter is piped to an adjacent bed where the slurry is dewatered. Once dewatered, the mixture is within EPA guidelines for material to be spread on cultivated pasture land locally.

When needed, the methane is drawn from storage through the H_2S stripper, then piped to the desired location. The present prototype facility is capable of processing 100 gallons of slurry per day and producing 13 cubic ft of methane per hour, which is to be used to fuel a hot water heater.

ECONOMIC EVALUATION AND MARKETABILITY

Anaerobic digestion facilities have not been established at dairies primarily owing to poor economic feasibility. Formerly, the installation of a biogasification system at a 100-cow dairy would encumber 3 to 5 years profit—a capital drain too large for any business. There are about 10,000 farms in Oklahoma which milk from 50 to 100 cows. If only the petroleum fuels used on a dairy were replaced by the use of biogas, a savings of 46 trillion Btu/year would result. At a price of $2.00 per million Btu, the energy saved would be worth $92,000,-000. The total capital required to install the proposed biogasification system would be on the order of $40,000,000; thus, a potentially attractive net annual savings in energy costs could be realized by Oklahoma farmers. In addition, bioconversion systems would provide a substantial reduction of the cost for waste management and pollution control.

The economic studies conducted to evaluate the system described in this paper covered three cases: the first for dairies using propane, the second for dairies using natural gas, and the third for dairies using electricity. The economic analyses of the unit include present worth and rate of return (ROR) calculations. These studies assume a $4,000 capital investment with a 15-year life and an interest rate of 10%, and are based on the net energy produced. The results, presented in graphical form in Figures 4 and 5, show the savings a farmer would realize compared to the cost of currently available forms of energy. For example, Figure 4 indicates that a bioconversion facility for a farm using propane would have a present worth of almost $3,000, assuming an annual propane price rise of 15% per year and a discount rate of 10%. Similarly, Figure 5 indicates that the proposed bioconversion system will earn a 17% rate of return for dairies using propane (15% annual price rise), which corroborates the results found in Figure 4.

Although the capital cost is estimated to be $5,100, the present prototype facility was built for $4,200. This number may be reduced to $4,000 for units sold in "do-it-yourself" forms. The design was conservative in order to allow greater flexibility in changing operating conditions. All cost estimates are in 1975 dollars.

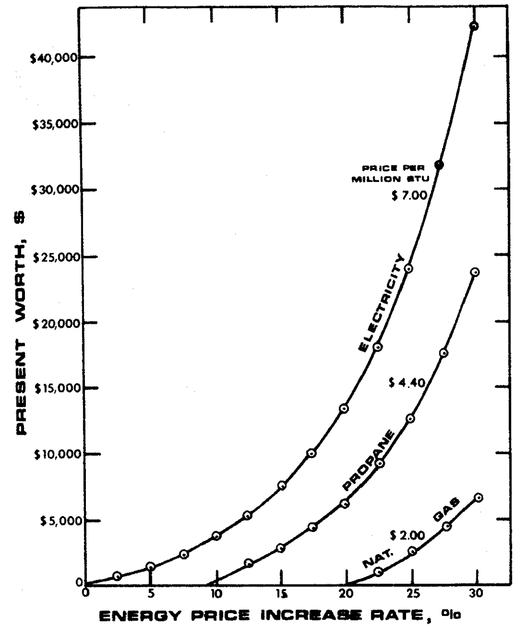

FIGURE 4. Plot of present worth of the bioconversion system *vs.* annual energy price increase rates for electricity, propane, or natural gas.

SYSTEM PERFORMANCE

Testing and data evalution were conducted to assess the performance of the facility (1). Measurements were made over a ten-day period and the results were averaged. Anaerobic systems sometimes undergo cycling; thus, a ten-day period of data tabulation and analysis was necessary to get a realistic view of system performance.

The eight variables measured consisted of biogas production and composition, pH, alkalinity, volatile acids, total and volatile solids, and efficiency; thus the primary factors affecting anaerobic fermentation were examined. For the most part, all the critical parameters measured were found to be well within the limits of normal anaerobic digestion. This observation is contrary to results recorded in the literature.

Most opinions indicate that anaerobic fermentation is very sensitive to operate and difficult to control. However, it should be noted that most of the experience with anaerobic systems has been gained in sewage treatment facilities. Sewage sludge often contains toxic materials such as heavy metals from industrial wastes, which may be part of the reason anaerobic digestion of these sludges is unreliable. Agricultural wastes would probably not pose the toxicity problems met in sewage sludge.

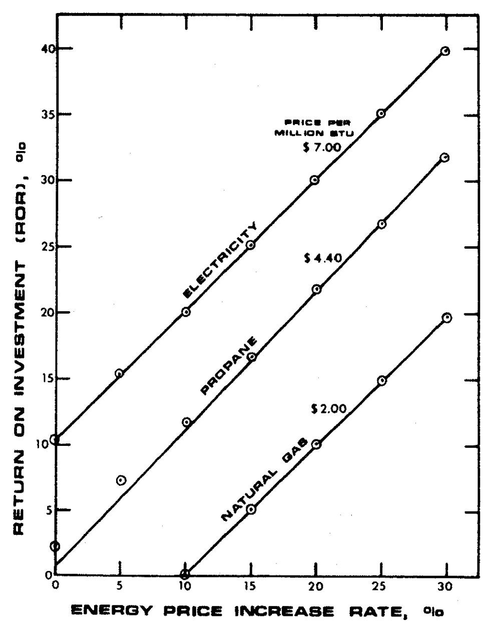

FIGURE 5. Plot of the rate of return on the investment in the bioconversion system *vs.* annual energy price increase rates for electricity, propane, or natural gas.

CONCLUSIONS

A remarkable feature of this system is that its cost is relatively low. Raw materials cost nothing and their abundance is staggering. Furthermore, the by-product can be used as valuable fertilizer sludge. There are many advantages and disadvantages with an on-site anaerobic digestion facility, but the main criterion invariably is economic feasibility. Already farms and dairies are feeling a pinch with increases in feed and maintenance costs. This state of affairs could eventually force the smaller dairies out of business. The proposed bioconversion facility must be designed to keep farms and dairies in business without encumbering too large a capital investment. Economic studies have indicated that the facility can be constructed and operated profitably at dairies utilizing propane, natural gas, or electricity as energy sources. Dairy farmers are somewhat conservative; thus biogasification will have to be made extremely attractive in order to gain any acceptance.

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