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ANEROBIC FERMENTATION OF AGRICULTURAL RESIDUES - POTENTIAL FOR IMPROVEMENT AND IMPLEMENTATION

Sixth Quarter (Third Semi-annual) Progress Report
for period from September 16, 1977 to December 15, 1977

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Anaerobic Fermentation of Agricultural Wastes -
Potential for Improvement and Implementation

SUMMARY

This is the sixth progress report of a three year research effort to promote the development of new and/or improved technology to facilitate and promote the wide spread use of anaerobic fermentation in agriculture as a source of renewable, clean energy. The first year of this effort, extending from June 1, 1976 to May 31, 1977, was concerned with fundamental research into the nature and performance of anaerobic fermentation in the conversion of agricultural residues into "biogas", a mixture consisting mainly of methane and carbon dioxide. Moving into the second year of the project, emphasis has shifted from the laboratory to the full scale and pilot scale demonstration of simplified fermentors characterized by the absence or a limited amount of mixing.

Activities for the sixth quarter year, extending from September 16, 1977 to December 15, 1977, have included the following:

- Completion of the final draft of the final report describing the findings of the first year of the project.
- Excavation and site preparation.
- Construction of the full scale plug flow and pilot scale random mixed fermentors.
- Installation of the ram pump manure delivery system.
- Construction of two buildings to house controls and appurtenances.
- Continued operation of the pilot scale plug flow fermentor.

The overall progress attained with the major components of the project is estimated to be less than one month behind the work plan schedule even though notification of continued support was received three months into the projected time schedule. The status of each major section of the project may be summarized as follows:

- I. Final Report - The final draft has been completed and is presently being typed and prepared in its final form. Target date for submission to D.O.E.: January 9, 1978.
- II. Pilot-scale Random Mixed Fermentor - Construction of this unit is virtually complete and testing is presently under way.

Start up is expected some time in late December or early January. Work on this fermentor has thus far been in close adherence to the work plan schedule.

III. Pilot-scale Plug Flow Fermentor - During most of the sixth quarter, this fermentor was operated at 10 - 12 percent total solids feed, 10 day HRT. The comparatively high hydraulic loading rate and the temperature of the feed material obtained from Barn 2 has made it difficult to replace the amount of heat lost from the system each day and to maintain a temperature of 95°F throughout the fermentor. With the heat demand exceeding the heat transfer capabilities of the PVC heating pipe network within the pilot reactor, fermentor temperatures dropped for a period by about 10 to 25 degrees accompanied by a depression in gas production. It is expected, however, that this problem will soon be alleviated. Despite difficulties with the 10 day HRT operating mode, the pilot scale plug flow study remains close to schedule.

IV. Full-scale Plug Flow Fermentor and Control Unit - Most of the materials and equipment required for the construction of the full scale plug flow and conventional control fermentors have been obtained. Modifications on Tank L2 for conversion to a full scale conventional fermentor are progressing well and the system will soon be ready for testing. The ram pump system which will transport manure residues from Barn 2 to the feed Tank T1 has been installed. Tasks completed in the construction of the full scale plug flow fermentor have included the erection of the dirt shoulder retaining wall, the laying of the feed line, trench excavation and installation of the underdrain system. Work on this unit is presently at a standstill due to the adverse weather conditions and the heavy snow cover received during the first two weeks of December. Plans are presently being made for the removal of snow from the area and for the construction of an inexpensive structure over the plug flow fermentor work site to minimize the effects of the winter weather. The effluent tanks for the plug flow and conventional control systems have been installed and the two buildings adjacent to their respective fermentor units are nearly completed. The overall progress in the construction of the full scale reactors is about 1-1/2 months behind schedule.

INTRODUCTION

In his most recent "energy message" to the American people, President Carter once again stressed the fact that unless significant progress is made in energy conservation and alternative energy development, the United States will continue to become increasingly dependent upon foreign oil. Because the U.S. now imports more than \$40 billion worth of energy annually, the political and economic consequences are easily equal to a state of war. Significantly, the President's address emphasized the need for research into the development of alternative energy sources, among which "methane" generation was specifically mentioned.

Official and unofficial signals throughout the world seem to underscore the fact that as competition for world energy supplies intensifies, increased attention will have to be focused on alternate inexhaustible energy supplies. Among these new sources of energy, those fuels which are inexhaustible or renewable, and hence, least subject to foreign regulation, will be the most advantageous ones, from both an economic and political standpoint. An integral part of the ongoing search for alternative fuels in the U.S. and throughout the world, fuels from biomass should receive increased emphasis since the potential of generating a significant amount of clean, renewable fuel from photo synthetically fixed solar energy appears to be economically and technically feasible in many instances.

The determination of the feasibility of anaerobic fermentation of agricultural wastes for pollution control and energy generation has been under investigation since 1973 at Cornell University. The first project included an in-depth analysis of the practical, technical and economic feasibility of implementing this technology on one-family dairy farms (40 and 100 cows) and medium-sized beef feedlots (1000 head) (Jewell et. al., 1976). The report from this effort emphasized that the technology was poorly defined and unoptimized and that it should be possible to increase the feasibility with additional research and development. A second research effort was then initiated with the general goal of identifying either 1) simple, low cost anaerobic fermentor designs or 2) high rate designs that enable recovery of multiple products from the unit. All of the work was conducted with dairy cow manure. The initial grant stage of this project was primarily concerned with bench and pilot scale experimentation and fundamental research to provide an information base which could facilitate the selection of reactor types for full scale demonstration and serve as a rationale for the design of these units. The present stage of the project focuses on the large scale development and demonstration of certain practical and economically feasible anaerobic fermentation systems.

This study was designed to examine the following reactor types:

1. pilot scale random mix, 3 cow residue handling capacity when operated at a 30 day HRT;
2. pilot scale unmixed horizontal displacement (UHD), 3 cow residue handling capacity when operated at a 30 day HRT;
3. full scale unmixed horizontal displacement (UHD), 65 cow residue handling capacity when operated at a 10 day HRT; and
4. full scale conventional control, same residue handling capacity as the full scale UHD fermentor.

OBJECTIVES

The general approach of this new phase of the project will be to define unique approaches to methane generation that will result in economical methane generation alternatives for small scale agriculture. Specific objectives of this study will be to:

1. develop the basis for minimal acceptable cost and management required for small scale fermentor development;
2. demonstrate cost-effective designs and manageable technology for typical farming operations using the dairy as an example at the 65 head size (about 0.5 tons dry matter feed rate per day);
3. define lower limits for major parameter specification for successful fermentor operation in terms of mixing, insulation, temperature, feed rate, and management requirements in a cold climate with full size fermentors;
4. review alternative construction materials useful for decreased capital cost of fermentor construction and operation; and
5. develop a practical design and operational manual for small scale fermentor design, construction, and operations, using the study results.

PROJECT STATUS

PROPOSED STATUS

The work plan originally drafted and submitted with the proposal is shown in Figure 1. A further breakdown of scheduled tasks and objectives is presented in the bar chart of Figure 2. The work proposed for the sixth quarter year (second quarter of the second year of support) mainly consisted of full and pilot scale fermentor construction and the continued operation of the pilot scale plug flow reactor. Progress on the full scale plug flow and conventional control fermentors was to include the construction of the reactor, the installation of pumps, piping, heating equipment, and controls, and the initiation of testing preparatory to start-up. Detailed work plans proposed for construction phase of the full scale plug flow and conventional control fermentors are shown in Figures 3 and 4, respectively. Also scheduled for the sixth quarter was the completion of the pilot scale random mixed fermentor; testing and start-up of this unit were originally scheduled for the month of December. Finally, the on-going pilot scale plug flow fermentor was to be operated during the sixth quarter under conditions of 10-12% TS manure and the urine feed, 10 day HRT and 35°C.

PRESENT STATUS

On the whole, the methane project is about one month behind the proposed schedule. Most of this delay has been caused by the effect of adverse weather conditions on outdoor construction activities. Very few serious technical obstacles to progress have been encountered during the construction phase of the project. Research staff meetings are held on a weekly basis for continual

Figure 1. Detailed work plan for the development and demonstration of low cost fermentors.

Figure 2

CORNELL UNIVERSITY METHANE PROJECT WORK PLAN FOR 1977-1979

CONSTRUCTION SCHEDULE FOR FULL SCALE PLUG FLOW

No.	List of Tasks	Time Allotted (Days)
1	Stake out site	1
2	Grade and level site	7
3	Excavate trench	6
4	Equipment shed construction	5
5	Install drainage system	4
6	Construct restraining wall	10
7	Preparation of digester bed and roll sand	6
8	Dig hold for effluent tank	3
9	Construct effluent baffle	3
10	Install feed line from TI to the digester	4

No.	List of Tasks	Time Allotted (Days)
11	Install bottom insulation	2
12	Liner installed and anchored	6
13	Install hot water heater, external heat pipes, and sampling pipes	9
14	Install feed baffle	2
15	Place effluent tank and backfill	4
16	Install internal heat pipes	5
17	Install temperature probes and sensors	4
18	Install gas collection system	3
19	Place on digester cover	4
20	Install feed pump	1

Figure 3. Construction schedule for the full scale plug flow fermentor (cross-hatched lines indicate progress made as of Dec. 15, 1977).

CONSTRUCTION SCHEDULE FOR COMPLETELY MIXED CONTROL REACTOR

List of Tasks	Time Allocated (Days)
1. Removal of tank top	1
2. Cleaning of tank L-2	5
3. Plug existing holes intake L-2	3
4. Cutting new holes	6
5. Dig hole for effluent tank	6
6. Building construction	7
7. Install liner	6
8. Install upper heat pipes and probes	3
9. Install sample ports and gas line	2
10. Install Vaughan pump	5

List of Tasks	Time Allocated (Days)
11. Install influent, effluent and recycle lines	5
12. Install hatch cover	5
13. Install probes and sensors	5
14. Install lower heat pipes	2
15. Put back concrete top and install effluent tank	5
16. Install insulation	3
17. Backfill effluent tank	2
18. Install gas and heat system	5

Figure 4. Construction schedule for the full scale conventional control fermentor (cross-hatched lines indicate progress made as of Dec. 15, 1977).

evaluation, planning and identification of problems which impede progress. The minutes of meetings held during the first quarter are included in Appendix A.

The amount of progress attainable, particularly in the construction of the full scale fermentors, has been and will continue to be heavily dependent upon the weather and snow cover. Since funding for the second year of the project was not officially confirmed by the Department of Energy (then ERDA) until August 19, 1977 and since the procurement of large items of equipment and construction could not be initiated until late in the year, it is likely that the project will run into winter weather conditions that will continue to hinder outdoor work activities until late March, 1978. This prospect was mentioned in the "Renewal Proposal", p. 36, submitted May 31, 1977 (see Appendix B). A review of official communications taking place between Cornell University and the Department of Energy during the past nine months in reference to the Methane Project is presented in Table 1.

Final Report

The final draft of the results obtained during the first year of this study is presently being typed and composed into its finished form. It is expected that the final report will be submitted to the Department of Energy by January 9, 1978. The main delay in preparation of this report has occurred as a result of the large amount of data, and difficulty which resulted in interpreting the incomplete data that resulted from the D.O.E. decision to interrupt many phases of this study prior to their completion.

TABLE 1

A Summary of Communications or Actions Initiated in the Conduct of the
Second Year of the Cornell Methane Project

Date	Event	Methane Project Response or Effect
March 4, 1977	First Renewal Proposal Submitted for Second and Third Year Support.	Proposal rejected
April 20, 1977	ERDA urges a shift of emphasis in the Cornell Methane Project from fundamental research to pilot and full scale demonstration of fer- mentation systems. ERDA also requests a final report describing the first year activities.	The Cornell group studied the feasibil- ity of accelerating the Methane Project research effort and elected to submit a new research proposal for second and third year funding which would focus on large scale fermentor research and design.
May 31, 1977	Second Renewal Proposal Submitted for Second and Third Year Support.	
August 19, 1977	Effective date of D.O.E. Agreement for Methane Project Second Year Funding.	Late August - Mater- ials and equipment ordered. Late September - Construction activi- ties initiated. Early November - All materials and equip- ment received.
December 6, 1977	Date of Letter of Intent from ERDA for Second and Third Year Methane Project Funding (See Appendix B).	

Pilot Scale Random Mixed Reactor

Construction of the pilot scale random mixed fermentor is almost completed. This unit is located along side of the pilot scale plug flow fermentor in the Agricultural Research Laboratory of the Teaching and Research Center located at Harford, New York. The random mixed reactor tank consists of a cube-shaped wooden box jacketed with a rubber hypalon liner. A picture of this structure is shown in Photograph No. 10 in Appendix C. Although not shown in the photo, heating pipes, pumps, controls and the hookups to the water heater have since been installed. Initial testing of the various system components has been initiated. Progress in building the pilot scale random mixed fermentor has remained on schedule.

Pilot Scale Plug Flow Fermentor

The pilot scale plug flow fermentor during the sixth quarter was changed in operation from a 15 day HRT to a 10 day HRT while maintaining the same 10-12 percent TS feed concentration. This unit functioned satisfactorily during the first three weeks of operation in October when temperatures of 94 to 95°F were maintained in all monitored sections of the fermentor and when 9-10,000 l/day biogas was produced. It was during this period when a cobalt soluble tracer (CoLi EDTA) was introduced and monitored in the plug flow fermentor for a hydraulic retention time determination; the data from this tracer study have not yet been analyzed. In November, however, the temperature of the plug flow fermentor decreased to 80-85°F and gas production rate decreased accordingly to a low of 5-6,000 l/day. It was assumed at this point that the depression in gas production rate was most probably brought about by the reactor's inability to maintain temperatures favorable to high rate anaerobic fermentation. After an examination of the heating system it

was concluded that neither the external piping, the water heater, nor the solenoid valves were at fault for the decrease in fermentor temperature. It was finally deduced that the heating demand of the low temperature, high hydraulic loading condition of the influent stream probably exceeded the heat transfer rate of the PVC heating pipe network inside the plug flow fermentor. The effect of the heat transfer limitation of the system was not evident until November when ambient air and, hence, influent manure temperatures underwent a sharp decrease of 15 to 20 degrees fahrenheit. To increase heat input to the fermentor, heating pipes have since been added to the influent feed tank and plans to apply a wrapping of heating tape and insulation to the influent tank are presently being considered.

It was expected that if the temperature of the fermentor can soon be recovered and maintained at 95°F while operating in the 10 day HRT mode, the pilot scale plug flow study could continue close to schedule.

Full Scale Plug Flow Fermentor and Control Unit

The key items of materials and equipment necessary to complete construction of the full scale plug flow and control fermentors have been received. The ram pump, one of the largest pieces of equipment ordered, was obtained in its entirety during the month of October and was installed over a period of three weeks. The ram pump will serve to deliver manure material from a conveyor system in Barn 2 to the feed tank (T1). The ram pump hopper was positioned under the Barn 2 conveyor as shown in Photograph No. 11 and a 12 inch line with a gate valve was laid from the ram pump to feed tank T1 and imbedded in concrete as depicted in Photograph No. 12.

The progress made with each task in the construction of the full scale plug flow fermentor is indicated in the work schedule of Figure 3. It can be seen from this chart that the plug flow fermentor construction effort is approximately 1 1/2 months behind schedule.

Major plug flow reactor construction activities have included the installation of the effluent line (Photograph 1) and effluent tank (Photograph 4), the erection of the retaining wall for the dirt shoulder of the trench adjacent to the driveway (Photographs 2 and 3), the initial excavation of the trench (Photograph 5) and the installation of the underdrain system. The equipment shed located nearest to the plug flow fermentor, shed No. 1, is shown in Photograph 6. This structure will house reactor heating equipment, controls and biogas utilization experimental apparatus.

As previously stated, work on the full scale plug flow fermentor has been highly dependent upon weather conditions conducive for excavation. During several weeks of considerably wet weather, in the early part of the sixth quarter, (more than 24 inches of rain in 7 weeks in September and October and 28 inches of snow in November and December), excavation of the plug flow fermentor had to be postponed because of adverse ground moisture conditions. At this time it was decided to channel a considerable amount of manpower into the installation of the ram pump. In addition, construction of the plug flow fermentor ceased during the first two weeks in December due to subzero wind chill temperatures and snow cover totaling more than 25 inches. A large, inexpensive shelter erected over the entire work area of the plug flow reactor work area is presently being considered to minimize the obstacle of snow cover which will, no doubt, be encountered throughout the winter.

The conventional control fermentor consists of a formerly existing concrete tank which will ultimately be converted into an air-tight anaerobic fermentation basin with provisions for heating and mixing. Modifications on Licom Tank L2 to fabricate the conventional control fermentor are nearly completed. This tank is shown in Photograph 7. As discussed in the previous progress report, a hypalon rubber jacket will be supported in the freeboard volume (airspace) of the fermentor tank, the edges of which will be anchored below the liquid level of the basin. This is expected to insure the gas-tight integrity of the system. In order to install the hypalon jacket, the concrete top was removed to allow access into the fermentor tank, as illustrated in Photograph 8. As described in the previous progress report, the hypalon jacket was designed to be suspended by six steel support rods attached to the liner material by hypalon sleeves; the steel rods were, in turn, to be anchored to the concrete wall near the top of the reactor tank.

The effluent tank for the full scale conventional control fermentor has been set in place. The piping and pumps required to waste and feed this unit have also been installed. The Vaughn pump and the above-ground piping servicing the conventional control unit have been located in an equipment shed constructed next to the fermentor tank. The equipment shed, shown in Photograph 7, is in its final stages of fabrication. Despite difficulties with the weather, work connected with the conventional control fermentor has fallen behind schedule by less than one month.

FUTURE ACTIVITIES

Construction of the full scale fermentors will continue well into the seventh quarter of the project. It is expected that the conventional control fermentor will be tested and started before this quarter is ended. Significant progress on the full scale plug flow fermentor, however, may not be realized until March, 1978 as noted in the original proposal. Nevertheless, work on the plug flow system will continue as rapidly as logistically possible throughout the winter months. By the end of the sixth quarter the testing and start up phases for the pilot scale random mixed fermentor should be completed and the pilot scale plug flow fermentor should be progressing through a new set of operating conditions in the fermentation of dairy cow manure and urine at some lower temperature.

REFERENCES

1. Jewell, W. J., H. R. Davis, W. W. Gunkel, D. J. Lathwell, J. H. Martin, Jr., T. R. McCarty, G. R. Morris, D. R. Price and D. W. Williams. "Bioconversion of Agricultural Wastes for Pollution Control and Energy Conversion". Report prepared for U.S. Energy Research and Development Administration, Report No. TID 27164, available through NTIS, Springfield, Virginia, 1976.

APPENDIX A

Agricultural Waste Management

and Rural Environmental Engineering

Department of Agricultural Engineering • Riley-Robb Hall
Ithaca, New York 14853 • (607) 256-2270

15 October 1977

MEMO TO: Methane Project Members

FROM: T.D. Hayes

RE: Minutes of the Methane Project Meeting Held September 19, 1977

PRESENT: R. Cummings, S. Dell'Orto, T. Hayes, W. Jewell, A. Leuschner,
D. Sherman, and M. Wulfe

ABSENT: K. Fanfoni

General Review

D. Sherman: The pilot scale unmixed horizontal displacement (UHD) reactor has been operating for about one month at the 15 day HRT condition (10-12% TS manure feed). Thus far, very little distress has been observed with this unit in terms of a drop in pH, depressed gas production or reduced solids destruction efficiency. On the contrary, decreasing the HRT of this reactor from 30 to 15 days (10-12% TS feed) effected an increase in the gas production rate from 5000-6000 l/day to 9,000-10,000 l/day. During the transition to the new mode of operation, the control reactor was discontinued but has since been started up again to run in parallel with the pilot scale UHD reactor. In addition to performance monitoring, a chloride tracer (NaCl) was introduced into the influent end, when it appeared that the UHD fermentor was approaching steady state in gas production and solids destruction. Effluent samples have been analyzed for chloride periodically to allow an examination of the flow patterns through the reactor and to provide a basis for calculating the effective hydraulic retention time (HRT) for the pilot UHD reactor. Thus far, one theoretical retention time (15 days) has elapsed since tracer infusion. The NaCl tracer dosage employed was approximately the same

as that used in a previous reactor run in which the effluent chloride concentration did not exceed 1700 mg/l.

To insure that the pilot scale UHD reactor temperature would be maintained at 95°F, the temperature of the water heater was increased from 130°F to 140°F to compensate for the drop in the laboratory temperature which is allowed to occur in the fall and winter months.

In the next week A. Leuschner will examine the steady state data obtained from the present pilot UHD reactor condition, 15 day HRT, 10-12% TS feed, and will evaluate the feasibility of further decreasing the HRT to 10 days.

The manure transport system for filling the portable feed tank has been worked out. Manure will be taken from tank T1 with the Vaughn pump using the dilatomatic pump as a backup system as shown in Figure 1. Electrical power hookup for both of these pumps will be easily attained.

There appears to be enough room for locating the pilot scale random mix reactor in the Agricultural Research Laboratory at ASTARC (Harford) even if the pilot-scale UHD reactor is allowed to remain in its present position. Originally it was thought that the pilot UHD reactor would have to be shifted a few feet to make room for the second reactor and yet avoid interference with normal movement through the lab area.

In accordance with the plans for construction, the exact location of the full scale UHD reactor will be staked out and site preparation will soon begin. The large moyno pump to be used in feeding the UHD reactor has been ordered. If delivery of the moyno pump is delayed past the intended start-up date, the Vaughn pump can be used to feed the full-scale UHD fermentor.

- A. Leuschner: The cover has been removed from tank L2, a preliminary step in modifying the structure to serve as the conventional full scale control fermentor. In the next few days the tank will be pumped out and cleaned. Holes in the tank not needed will be sealed with cement. The hypolon liner (Bert Co., 20/40) has been ordered for this unit. Also on order is a steel tank for effluent storage. Once all the materials are obtained, it should not take much more than one week to install the liner and heating pipes. The Vaughn pump, ordered 3 weeks ago, has still not arrived; 5-6 weeks delivery time was predicted by the manufacturer. The top of the digester, when positioned back in place, will be foam-insulated; several local estimates are being obtained.

The final design details of the shed to be located beside the full scale control fermentor are being worked out. This shed will house the pipes and equipment servicing the conventional control reactor. The shed will also have enough space for a heater and an internal combustion engine.

- R. Cummings: The ram pump, which will be used to move manure from Barn 2 to the feed tank T1, has been ordered from Hedlund Inc. Plans and strategies are presently being devised to make the installation of the ram pump as trouble-free and as expedient as possible. In any case, it is expected that installation of this unit will interrupt mechanized manure removal from Barn 2 for several days.

Discussion

It appears that thus far the project has stayed fairly well on schedule. Although delivery of some materials may be delayed, there seems to be several weeks worth of work ahead in site preparation, excavation, shed construction, pipe laying, and other tanks which will not depend on specialized equipment items.

Two different plans for enclosing certain methane project reactor areas with a fence for safety reasons are presently being considered. One option would place a fence only around the full scale UHD digester as shown in Figure 2. The other option suggested by Prof. Samuel Slack involved fencing in the entire complex of 6 tanks and the UHD reactor, also depicted in Figure 2. A decision on this matter will not be needed until reactor construction is completed.

Jewell:

Detailed work plans for the construction phase of the project should be completed soon. For now, a short-termed time diagram of the tasks to be completed in the next two months for the conventional and UHD systems would be very useful.

Martin Wulfe, B.S.M.E., M.S. Architecture, has been hired on a temporary and part-time basis to help out with the large amount of drafting that has to be done to translate detailed designs to working blue prints.

Shortly, a decision should be made on the usefulness of conducting an open workshop in the summer or fall of 1978 concerning the practical design and feasibility of anaerobic fermentation systems on the dairy farm. There are several reasons justifying such an effort:

- 1) We have an obligation to transfer the technology to the public; and
- 2) The preparation for the workshop would provide impetus and a basis for the design manual.

The agenda for the next methane project meeting will include:

1. General review of progress in light of the time schedule.
2. Identification of problems encountered in the preliminary stages of construction.

Figure 1

Pumping System for the Transfer of Manure from Tank 1 to the Mobile Feed Wagon

Figure 2

Agricultural Waste Management

and Rural Environmental Engineering

Department of Agricultural Engineering • Riley-Robb Hall
Ithaca, New York 14853 • (607) 256-2270

28 October 1977

MEMO TO: Methane Project Members

FROM: T. Hayes

RE: Minutes of the Methane Project Meeting Held October 13, 1977

PRESENT: J. Chandler, R. Cummings, S. Dell'Orto, K. Fanfoni, T. Hayes,
W. Jewell, A. Leuschner

ABSENT: D. Sherman

General Review

R. Cummings:

All of the parts to the ram pump have arrived and installation of this unit will be initiated shortly. The first task in setting up the ram pump is to dig the pit in which the pump will be mounted. The locations of all of the lines running through the area have been elucidated with the blueprints of the Barn 2 area of ASTARC (Harford). It is estimated that the pit for the ram mechanism and the trench for the Pipe can be excavated in one day, barring unforeseen complications. It is anticipated that concrete will be poured the next day. The initial segment of pipe extending from the ram pump will be placed on top of a layer of gravel in the trench and imbedded in concrete. The ram pump will essentially be located in a heated shed and the line from the ram pump will be buried below frost line (6 ft. depth).

The hypalon liner has arrived from the Best Co. Fabrication of the hypalon cover for the conventional control digester will be started. This task will mainly consist of fashioning rubber sleeves for the liner to be supported in the full scale conventional control reactor as described in Figure 1 (taken from the minutes of August 31, 1977).

The concrete slab to the shed adjacent to the conventional control reactor has been poured, the piping in this area has been installed and the power line has been laid. The concrete block walls of this structure are

almost completed. The roof of the shed will consist of 2 x 10 lumber. To expedite construction and to minimize costs the shed will probably not be outfitted with windows or clear paneling for the roof to provide natural lighting. The building will, however, be wired for artificial lighting.

A. Leuschner:

The construction of the full scale conventional control unit can be completed with the materials which have arrived, among which includes the hypalon liner material. It has been decided that the same Fenwal temperature controller and sensor probes used to thermostat the pilot UHD reactor will also be employed for the completely mixed reactor. These temperature controls are on order. Lead anchors have been obtained to serve as a means of attaching the hypalon liner support rods to the concrete wall of the conventional control reactor. Work on the conventional control fermentor is roughly 7 to 8 days behind schedule.

K. Fanfoni:

All of the drawings have been completed for all the fermentors to be constructed. The sites for the full scale plug flow fermentor and the equipment shed for this unit have been located and staked out. The shed slab, however, has to be poured before digging can be started on the plug flow reactor.

The anchoring system for securing the hypalon liner is presently being worked out by Jeff Chandler. Materials for the anchoring mechanism will be obtained and tried out before the liner is installed into the excavated trench for the full scale plug flow fermentor.

The operating mode of the pilot scale plug flow fermentor has recently been changed from 15 days HRT to 10 days HRT, while influent feedstock remained at 10-11% TS manure. This lowering of retention time was initially accompanied by a lowering of the gas production rate, from 10,000 l/day at 15 days HRT to 5-6000 l/day at 10 days HRT. It was noted, however, that the increased hydraulic loading to the system made it more difficult for the fermentor to keep the temperature in the first third of the reactor at 95°F. Alternatives for correcting the deteriorating performance of the plug flow fermentor include:

- 1) Recycle
- 2) Increase the retention time (perhaps to 12.5 days)
- 3) Turn the temperature up for the water heater

Discussion

Jewell:

In this particular phase of the project it should be realized that fermentor construction is first priority; building the sheds should be of secondary importance. It is apparent that we now have all of the materials needed to finish construction on all of the proposal fermentors.

In regard to the installation of the ram pump system, it would be desirable to have included in the plans built-in safety measures which could be relied upon as added protection against a freeze-up of the manure-bearing line. Bob C. should keep this in mind as various installation plans are considered.

Now is a good time for K. Fanfoni and A. Leuschner to start thinking about the various fundamental questions raised with the previous year's research and about some areas of additional research which might prove fruitful in answering those questions.

Attention was called to the possible need of additional, temporary construction personnel. It was discussed and decided by Jewell, Hayes, Fanfoni and Leuschner that one more worker would be hired bringing to three the number of temporary construction workers hired.

The agenda for the next methane project meeting will include:

- 1) General review of progress
- 2) Identification of construction problems

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Figure 1. Hypalon Anchoring and Support in the Full Scale Conventional Digester.

Agricultural Waste Management

and Rural Environmental Engineering

Department of Agricultural Engineering • Riley-Robb Hall
Ithaca, New York 14853 • (607) 256-2270

4 November 1977

MEMO TO: Methane Project Members

FROM: T. Hayes

RE: Minutes of the Methane Project Meeting Held October 27, 1977

PRESENT: R. Cummings, S. Dell'Orto, K. Fanfoni, T. Hayes, W. Jewell, A. Leuschner

ABSENT: D. Sherman

General Review

K. Fanfoni: As mentioned at the last methane project meeting, the pilot scale plug flow fermentor was changed in operation, from a 15-day HRT to a 10-day HRT; the concentration of feed remained the same, 10-12% TS. Shortly after the change in operating mode, the fermentor exhibited a decreased rate of gas production (from 10,000 l/day at 15 days HRT to 6000 l/day at 10 days HRT), a rise in volatile acid concentration (from 200 mg/l to 1200 mg/l) with a concomitant drop in pH (from 8.0 to 7.1), and a lower methane content in the digester gas (from 55 to 45% CH₄). It was noted that the increased hydraulic loading to the system made it more difficult for the fermentor to maintain the temperature in the influent third of the basin at 95°F. One of the simpler remedies considered included turning the temperature of the water heater up. While the water heater thermostat control was turned up from 140°F to 150°F feeding was purposely suspended for two days to allow the influent zone to heat up to the correct temperature. This resulted in an increase in gas production rate from 6000 l/day to around 9000 l/day. After feeding was resumed, the methane content of the fermentor gas rebounded from a previous value of 45% to 65% CH₄.

A tracer study will be initiated while the pilot scale plugflow fermentor is at the 10 day HRT, 10-12% TS feed condition.

Lithium-cobalt EDTA will probably be the tracer of choice.

The moyno pump for the full-scale plug flow fermentor has arrived. The drive for this pump is expected to be delivered some time in mid-November. Steady progress has been made in installing the effluent tank and laying out the railroad ties which will serve to contain the dirt shoulder on the side of the plug flow reactor facing the road. The site is almost ready for excavation and the trench construction, drainline installation, insulating and liner placement in the trench should take place within the next three weeks.

The walls of the shed near the plug flow fermentor have been laid up in concrete block. The roof to this building has not yet been built and will take second priority to fermentor construction activities.

A. Leuschner: Sleeves which have been glued on to a piece of the hypalon liner will be tested today for strength. It is expected that if the sleeves hold during testing, the liner can be installed and anchored in the concrete fermentor tank soon thereafter. After installation, plans have been made to test the liner for leaks by filling the rubber jacket with helium and by scanning for helium leakage with the helium gas sensor. Work on the conventional reactor is no more than one and one-half weeks behind schedule.

Separate heating systems will be installed for the full-scale conventional and plug flow fermentors. The water heater that will be used with the conventional control reactor will soon be tested.

Discussion

To keep pace with the manpower requirements of the construction phase of the project, another worker was hired. Ed Grigley will be working on the Methane Project on a temporary basis to assist in the construction of the full-scale systems. This brings to three the number of temporary personnel presently working for the project.

The next methane project meeting will be held around 10 November 1977. The agenda for this meeting will include:

- 1) General review of progress in light of the time schedule.
- 2) A brief evaluation of present and future labor requirements.
- 3) Identification of construction problems.

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28 November 1977

MEMO TO: Methane Project Members

FROM: T. Hayes *Tom Hayes*
Duk

RE: Minutes of the Methane Project Meeting Held November 10, 1977.

PRESENT: R. Cummings, S. Dell'Orto, K. Fanfoni, T. Hayes, A. Leuschner,
W. Jewell, D. Sherman, W. Wujcik.

General Review

K. Fanfoni: The temperature of the first zone of the pilot scale plug flow fermentor has once again fallen significantly. Presently, the temperatures in the influent third of the reactor read 75° F in the top layer and 80°F near the bottom. Gas production has fallen from a previous level of 9000 l/day to a present value of 7000 l/day. Concomitantly, the fraction of methane in the gas has decreased from 60% to 50% CH₄. Since sampling for the tracer study is almost complete, it is proposed that feeding be suspended to the pilot scale plug flow fermentor until temperatures recover to 95° F throughout the reactor.

The tracer study for the pilot scale plug flow fermentor was initiated by the introduction of cobalt lithium EDTA into the influent end of the fermentor on November 4. Preparation of samples for cobalt analysis will merely entail acidification, centrifugation, and filtration of the centrate. The clarified samples will then be analyzed for cobalt by atomic absorption spectrometry.

W. Jewell: It seems fairly clear that the gas production problems now observed with the pilot scale plug flow fermentor stem from difficulties in maintaining temperature in the initial section of the fermentor. In order to boost the heat input to this unit, the feed may have to be preheated. The present situation with the pilot reactor's heating system indicate that estimates of the heat exchange capacity of the pipe

network to be installed in the full scale plug flow fermentor may need to be reviewed. An additional network of heating pipes may have to be added to the fullscale plug flow fermentor to ensure that a temperature of 95°F can be maintained under the lowest of ambient air temperatures. In seeking ways to boost heat transfer capabilities, direct steam injection should be considered as an alternative. This method of fermentor heating has been adopted by a number of installations in Germany.

The construction phase for the pilotscale random mixed reactor should be about 80% complete and, according to the schedule, should be started up in about two or three weeks. Work on this unit should intensify to prevent shipping too far behind. Seed material for the random mixed fermentor will consist of effluent from the pilot-scale plug flow fermentor, previously collected and stored in two fiberglass tanks.

The pilot scale plug flow reactor effluent will also be used as seed material for the fullscale conventional control fermentor. Seed material for the full scale plug flow fermentor, however, will most likely come from the conventional control reactor which is expected to have a 4-6 week head start which is expected to have a 4-6 week head start in operation.

K. Fanfoni: The retaining wall for the dirt shoulder of the full scale plug flow fermentor is nearly complete. More railroad ties are needed, however, for the remaining tiers. Excavation of the trench for the plug flow fermentor has been held up for a few days since the installation of the ram pump required much of the available manpower and equipment.

R. Cummings: Installation of the ram pump should be finished this week. Next week we should be able to concentrate our efforts on the full scale plug flow reactor.

A. Leuschner: Work is continuing on a method of attaching sleeves to the liner which will allow the rubber jacket to be suspended in the conventional control reactor freeboard space with 5 support rods. The adhesives or cements tried thus far have not resulted in a sufficiently strong rubber to rubber bond. A heat seal will be tried next. As soon as the sleeves are fabricated the liner will be placed inside the concrete tank.

It was originally proposed that the full scale conventional control fermentor would be heated with a gas-fired boiler supplying hot water to a network of pvc pipes placed inside the reactor basin. An economical boiler system was sought which would allow for an automatic switch-over from digester gas to propane, or vice versa, whenever needed.

Presently, information about such a boiler (180,000 BTUH), manufactured by the Fulton Co., is being sought. All of the temperature controllers have been ordered and should be here in about one week.

Discussion

W. Jewell:

All sections of the corrected first draft of the final report should be reviewed and turned in for final draft construction by Friday of this week, November 11.

In general, it appears that the construction phase of the project is moving at a rapid pace, especially in the midst of good weather conditions. Bad weather could, however, slow things up considerably. Excavation tasks should be completed as soon as possible before the ground freezes.

The next methane project meeting will be held around November 30. The agenda for this meeting will include:

1. General review of progress.
2. Another look at the time schedule.
3. Further discussion on various fermentor design aspects.

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21 December 1977

MEMO TO: Methane Project Members

FROM: T. D. Hayes

RE: Minutes of the Methane Project Meeting Held November 30, 1977

PRESENT: R. Cummings, S. Dell'Orto, K. Fanfoni, T. Hayes, A. Leuschner

ABSENT: D. Sherman, W. Jewell

General Review

K. Fanfoni: Excavation for the full scale plug flow fermentor has started today and it is expected that the underdrain system, consisting of lines of weeper pipe laid in gravel, will be installed this week. Work is continuing on this unit as rapidly as possible with the realization that the seasonally cold weather will soon freeze the ground, making it difficult to find workable dirt for backfill.

The pilot scale plug flow fermentor is now being fed on a 20 to 30 day HRT basis to reduce the hydraulic loading of the cold influent manure feed material and thus allow the system to heat up to the normal operating temperature of 95°F. Additional heat exchange PVC pipes have been added to the feed tank to increase heat transfer during a relatively high hydraulic loading condition of 10 days HRT. Plans for wrapping the feed tank with heating tape are also being considered.

Work on shed No. 1, located next to the full scale plug flow unit, is continuing. The roof to this structure will be built within the next few weeks.

A. Leuschner: The hypalon jacket for the full scale conventional control fermentor has been installed. This hypalon liner lines the freeboard volume (airspace), the edges of which are

anchored below the liquid level of the fermentor to make this unit gas tight.

The Vaughn feed pump has recently been installed. This piece of equipment, however, cannot be tested until the piping is completed and the feed and conventional fermentor tanks are made ready to fill with liquid manure.

R. Cummings: The pilot scale random mixed fermentor is nearly completed in construction. Seed for start up for this unit is now being accumulated in a fiberglass tank. The seed material will consist of effluent collected from the pilot scale plug flow fermentor.

Plans are presently being made to contract the services of the Thomas Construction Co. to do much of the wiring for the equipment buildings, pumps, lights, electrical outlets, and space heaters. Bob will also assist in this task.

T. Hayes: The final draft of the final report is virtually completed. This report will be typed and figures and schematics will be inked during the month of December.

The next methane project meeting will include the following topics for discussion:

1. General review of progress
2. Estimation of future progress
3. Continued dialogue on various fermentor design aspects.

APPENDIX B

The work plan for the next two years is illustrated in Figures 11 and 12 for the four different major fermentors. The time schedule and work plan raise one critical point - the time schedule is highly critical during the early stages in enabling this work plan to be adhered to. Comprehensive design, development, ordering materials, and the issuing of construction contracts will take between 2 and 4 months. If formal approval of the renewal is not received until August or September, construction of these systems cannot start until December or January. However, it is extremely difficult to begin construction projects during these months and it is likely that little significant progress could be made until late March if this were the time schedule. However, early notice should enable a late Fall 1977 start-up of these systems, provided that no unforeseen difficulties arise.

The existing plug flow 5000 liter pilot plant would continue in operation at 12 percent total solids feed. It would be used to examine major conditions scheduled to be tested in the full-scale operation, prior to actually attempting it with the full-scale systems. After several shorter HRT runs are completed with the 12 percent solids feed (15 day and 10 day), the temperature will be decreased to 25°C and gas production capability will be compared to earlier results. The effects of recycle will be evaluated if the data indicates that this is a useful and sensitive variable. Using a given set of reactor conditions determined from previous experiments testing will be initiated with waste with bedding added to it. One material such as chopped straw, chopped corn stalks or sawdust will be examined, the exact type depending on which practice appears to be the most prevalent and which is available at the time of the study.

UNITED STATES
DEPARTMENT OF ENERGY
CHICAGO OPERATIONS OFFICE
9800 SOUTH CASS AVENUE
ARGONNE, ILLINOIS 60439

December 6, 1977

Mr. Jack W. Lowe, Associate Director
Office of Academic Funding
123 Day Hall
Cornell University
Ithaca, New York 14850

Dear Mr. Lowe:

CONTRACT EY-76-C-02-2981, PROPOSED MODIFICATION A003

This is to advise you that, subject to the execution of a contract document, the Department of Energy can provide support for the renewal of this contract in the amount of \$284,049 for the period August 1, 1978, through July 31, 1979, and the remaining funding of \$170,598 for the period August 1, 1977, through July 31, 1978.

A Special Research Support Agreement is being prepared and will be sent to you for your review and execution.

Sincerely yours,

Dana R. Dixon
Supervisory Contract Specialist
Contracts Management Office

cc: Principal Investigator

APPENDIX C

Photograph No. 1
Plug Flow Fermentor: Effluent Line and Effluent Tank
Installed.

Photograph No. 2
Plug Flow Fermentor: Construction of the Retaining Wall.

Photograph No. 3
Plug Flow Fermentor: Completion of the Retaining Wall.

Photograph No. 4
Plug Flow Fermentor: Effluent Tank Positioned.

Photograph No. 5
Plug Flow Fermentor: Excavation of the Trench.

Photograph No. 6
Construction of Shed No. 1 Adjacent to the Plug Flow Fermentor.

Photograph No. 7
Modifications on the Conventional Control Fermentor
Tank and Construction of Shed No. 2.

Photograph No. 8
Conventional Control Fermentor Concrete Lid Removed to
Allow Access to the Interior of the Tank for Modification
Work.

Photograph No. 9
Top View of Shed No. 2 on the Edge of an Effluent Holding
tank, the Feed Tank T1 (Left) and the Conventional
Control Fermentor (Behind the Shed).

Photograph No. 10
Pilot Scale Random Mixed Fermentor.

Photograph No. 11
Ram Pump Installed Under a Conveyor In Barn 2.

Photograph No. 12
Manure Bearing Line Imbedded in Concrete
Leading from the Ram Pump to Feed Tank T1.