260
10-16-78

COO-2981-7

ANAEROBIC FERMENTATION OF AGRICULTURAL RESIDUES—POTENTIAL FOR IMPROVEMENT AND IMPLEMENTATION

Seventh Quarter Progress Report, December 16, 1977—March 15, 1978

By
W. J. Jewell
R. W. Guest
R. C. Loehr
D. R. Price
W. W. Gunkel
P. J. Van Soest

Work Performed Under Contract No. EY-76-S-02-2981

College of Agriculture and Life Sciences
Cornell University
Ithaca, New York

U.S. Department of Energy

Solar Energy

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Paper Copy $4.50
Microfiche $3.00

COO-2981-7
Distribution Category UC-61

Cornell University
College of Agriculture and Life Sciences
Ithaca, New York 14853

Report Number COO-EY-S-02-2981-7

ANAEROBIC FERMENTATION OF AGRICULTURAL RESIDUES-POTENTIAL FOR IMPROVEMENT AND IMPLEMENTATION

Seventh Quarter Progress Report for period from
December 16, 1977 to March 15, 1978

Principal Investigators and Participants

W.J. Jewell, R.W. Guest, R.C. Loehr, D.R. Price,
W.W. Gunkel, P.J. Van Soest

Cooperators

M.J. Wolin and T.L. Miller
New York State Department of Health
Albany, New York

Full Time Researchers

S. Dell'Orto, K. Fanfoni, T.D. Hayes
A.P. Leuschner and D.F. Sherman

Prepared for

The U.S. Department of Energy
Under Contract No. EY-76-S-02-2981,
Modification A002

Anaerobic Fermentation of Agricultural Wastes -

Potential for Improvement and Implementation

SUMMARY

This is the seventh progress report of an on-going three year research effort to contribute to the development of a new and/or improved technology that will result in wide spread use of anaerobic fermentation in agriculture to generate a renewable clean energy source. During the first year of this project, extending from June 1, 1976 to May 31, 1977, emphasis was given to fundamental research into the nature and performance of anaerobic fermentation in the conversion of agricultural residues into "biogas". In the second year of the project, emphasis was shifted from the laboratory to the full scale and pilot scale demonstration of simplified fermenters characterized by various limitations on the amount of mixing applied.

Activities for the seventh quarter year, extending from December 16, 1977 to March 15, 1978 have included the following:

- Completion of construction of the full scale conventional control fermenter.
- Completion of construction, testing and startup of the random mix fermenter.
- Installation of feed and effluent lines, electrical wiring, boilers, gas lines and controls.
- Successful testing of the ram pump.
- Conclusion of the 35°C studies with the pilot scale plug flow fermenter and the initiation of the low temperature (25°C) studies.
- Preparation of a detailed outline to the design manual.

As of March 15, 1978, the overall progress achieved with the major components of the project was estimated to be about 2.5 months behind the work plan schedule. As detailed in the last progress report, much of this delay has been due to the winter weather (i.e. cold temperatures, snow, frozen ground, etc.) which has interfered with excavation and other outdoor construction activities. Since the procurement of materials and supplies was not initiated until official notice of funding was received from D.O.E. in late August 1977, the construction phase was delayed and consequently ran into the adverse freezing conditions characteristic of Ithaca winters. The status of each major section of the project may be summarized as follows:

I. Final Report - The final draft was completed and submitted to the Department of Energy on January 24, 1978.

II. Pilot-scale Random Mix Fermenter - Construction on this unit has been completed. During the seventh quarter this reactor was tested and then placed on a carefully planned start-up procedure. The random mixed reactor is now out of its start-up phase and into its first operating condition. As of March 15, 1978 this unit was operating at 10-12% TS feed, 30 day HRT and a 3-day intermittant mixing cycle while producing biogas at a rate of 7-8000 ℓ/day. Thus far, the pilot scale random mix fermenter is operating on schedule.

III. Pilot-scale Plug Flow Fermenter - The 35°C studies using a dairy cow manure and urine feed stock have been concluded. The last condition from which steady state data was obtained was an operating mode of 10-12% TS feed, 10 days HRT, 35°C. The operating temperature was then lowered to 25°C. Fermentation will continue at 25°C, 10-12% TS, 30 days HRT until steady state data is collected. The experimental program for this section of the project is about one and a half months behind.

IV. Full-scale Plug Flow Fermenter and Control Unit - Construction on the conventional control fermenter is virtually complete. Testing and shake down of this unit is expected to be concluded by the end of March and start-up should be initiated during the first part of April. The ram pump, which was installed during the sixth quarter, has been tested and was found to operate satisfactorily. The two sheds which house the boilers, pumps, lines, valves, and control panels have been completed in construction. One shed is located adjacent to the conventional control fermenter (shed no. 1) and one near the plug flow fermenter (shed no. 2). Tasks completed in the construction of the plug flow fermenter have included installation of the boiler, assembly of the heating pipe networks, fabrication of the liner, contouring the walls of the trench, placement of the baffles in the trench and the installation of liner anchors. Foam insulation has been applied to the effluent tanks of both full scale reactors and to the conventional control fermenter itself. It is expected that the conventional control fermenter will be operational by April and the full scale plug flow fermenter will be started before May. Despite the adverse working conditions of this winter, the construction phase has taken a timespan no longer than was proposed in the original schedule. This was made possible through the utilization of the project's temporary employment funds for three capable construction workers. Although the pace of construction is proceeding according to expectations, on the absolute time frame of the proposed schedule it appears that construction has slipped behind by 2 1/2 to 3 months. It must be remembered, however, that while the proposed schedule for full scale fermenter construction assumes a beginning date of June 1, 1977. funding from D.O.E. was not received until late August 1977, predisposing a three month delay in equipment and materials procurement.

INTRODUCTION

Among the pages of one of the nations most well read news magazines appeared a short, concise article on the production of methane from agricultural residues. This feature included an animated diagram of the conversion of feedlot manure at Guymon, Oklahoma to biogas, treatment of the biogas, sale of the methane to People's Gas Co., the introduction of this gas into the main lines, and the utilization of the gas by a typical household in Chicago. On the other side of the world, an American president stood gazing at a Gobar fermentation system as it was explained to him that the reactor had the capability of converting agricultural wastes from any one of millions of farmsteds in India to a clean, renewable fuel that could be utilized for cooking. This occasion was brought into the homes of millions of Americans who watched on as President Carter mused aloud over the possibilities of methane fermentation in the U.S. Within the last year, the concept of methane generation from municipal, industrial and agricultural residues has gained considerable visibility with the American public as reflected by its frequency of mention in the news media. Because of the increased publicity over the capabilities and potential benefits of fermentation and because of soaring fuel costs which tend to erode already thin agricultural profit margins, farmers will, no doubt, be among the first groups to reach out for those technologies that appear feasible for reducing dependence on fossil fuels.

The fact that manure residues on many farms are collectable and fermentable should establish a good first impression with farmers of the adaptability of anaerobic fermentation to agricultural residue management systems. Wide acceptance of any "promising" technology, however, is highly improbable unless technical and economic feasibility can be clearly shown. It is for this reason that fuels from biomass demonstration projects should continue to receive a great deal of interest from the agricultural community.

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 fermenter 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 fermenter.

Since the unmixed horizontal displacement reactors to be used in this study were designed to promote the movement of feed segments through the reactor as separate entities to simulate as much as possible the plug flow condition, the terms UHD and plug flow will be used interchangeably in this report.

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 fermenter development;

2. Demonstrate cost-effective designs and manageable technology for typical farming operations using the dairy as an example at the 65 head herd size (about 0.5 tons dry matter feed rate per day);

3. Define lower limits for major parameter specification for successful fermenter operation in terms of mixing, insulation, temperature, feed rate, and management requirements in a cold climate with full size fermenters;

4. Review alternative construction materials useful for decreased capital cost of fermenter construction and operation; and

5. Develop a practical design and operational manual for small scale fermenter design, construction, and operations, using the study results.

PROJECT STATUS

PROPOSED STATUS

The work plan of project activities, drafted and submitted with the original proposal, is shown in Figure 1. A bar chart representation of the time schedule for task completion and experimentation is presented in Figure 2. During the seventh quarter year (third quarter of the second year support) progress was to include the completion of the testing phase and startup for the pilot scale random mix reactor and the full scale conventional control and plug flow fermenters. Also scheduled for this quarter was the initiation of the 35°C operating condition (10-12% TS, 30 day HRT) for the full scale units and the random mix fermenter. Lastly, the on-going pilot scale plug flow fermenter, fed 10-12% TS dairy cow manure and urine, was to conclude its 35°C studies and begin its transition toward operation at a lower temperature, 25°C, with the same substrate. The first feeding mode to be applied to the pilot scale plug flow unit at 25°C was 10-12% TS, 30 days HRT.

PRESENT STATUS

On the average, the methane project is about two and one half months behind the proposed schedule. The full scale fermentation work, in particular, would appear to be several months behind the proposed schedule, but this would not be an entirely accurate assessment of the situation. Rather, evaluation of the large scale demonstration phase of the project should be made in light of the fact that the original agreed-to schedule was predicated upon formal approval of D.O.E. funding before May 31, 1977, in which case procurement of supplies, equipment and materials could have been initiated in June. In actuality, funding did not come until late August 1977, delaying necessary orders by about three months. Hence, construction which should have started in August could not be intensified until late October, 1977. Compounding

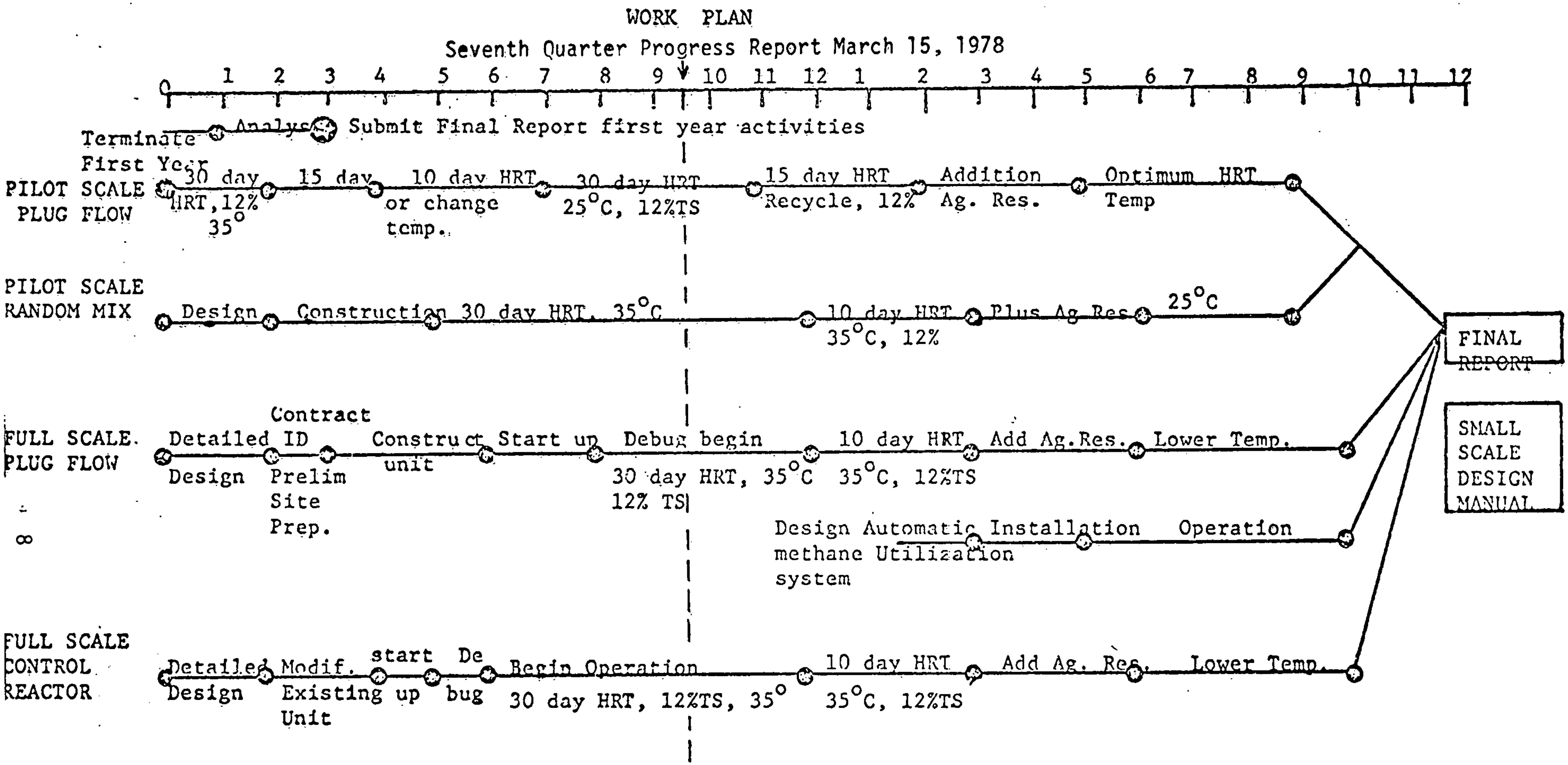
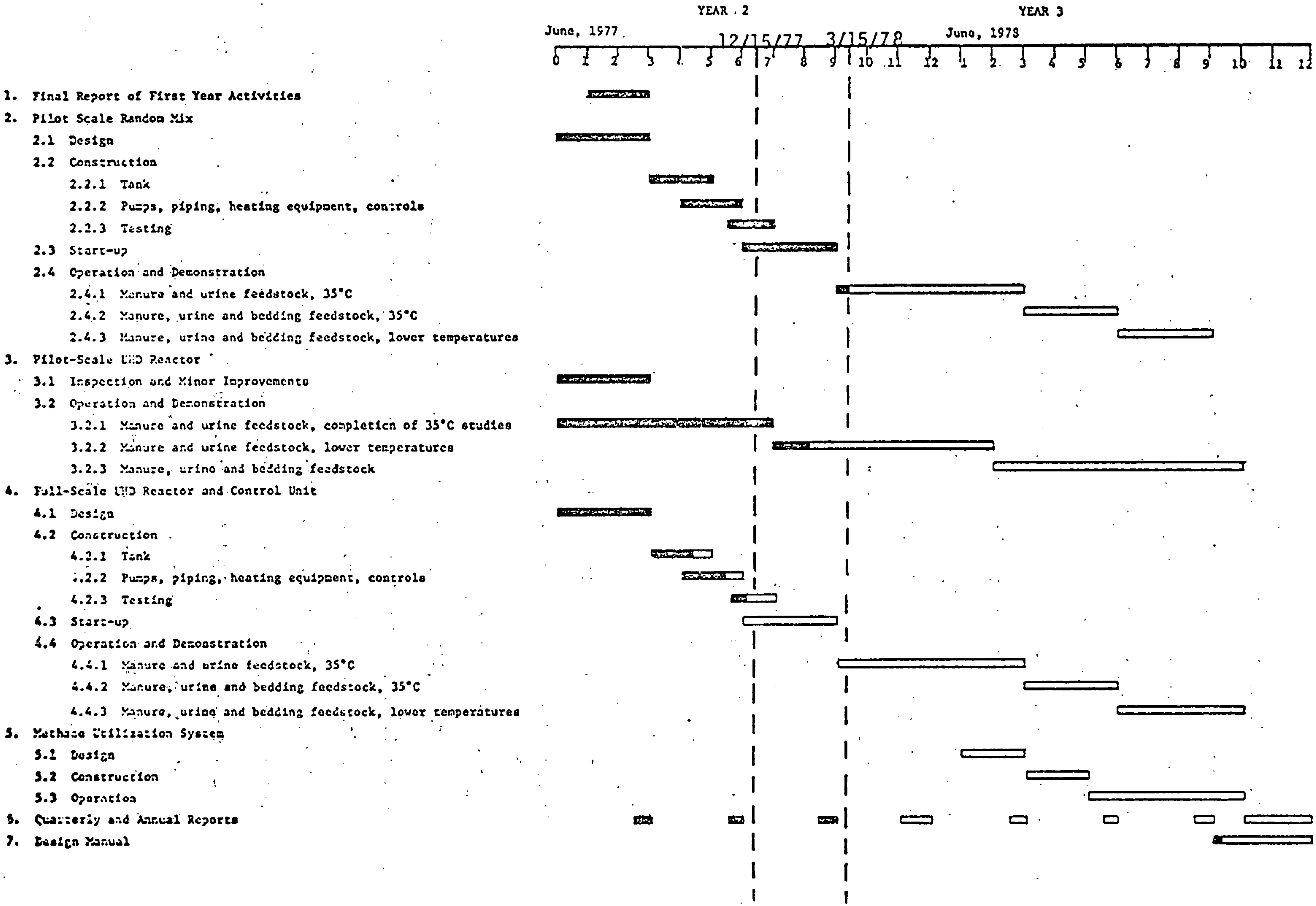


Figure 1. Detailed work plan for the development and demonstration of low cost fermentors.

Figure 2
CORNELL UNIVERSITY METHANE PROJECT WORK PLAN FOR 1977-1979



the difficulties of the situation, the delay in construction predisposed an almost inevitable interference of freezing weather and snow with the outdoor construction work and excavation that had to be done. Utilization of temporary employment funds from the project to hire three additional workers, however, made it possible to continue construction through the winter at a pace close to the rate of progress prescribed by the proposed schedule, taking into account the 2 1/2 month delay in intensive construction. In other words, because of the added manpower the time lost in the construction phase over the winter months was held to a minimum.

Progress during the winter months was continually reviewed and evaluated by the methane project research group which met on a regular basis to identify and discuss the various tasks and problems encountered during this construction period. The minutes of meetings held during the first quarter are included in Appendix A.

Final Report

The final report for the first year research activities of the Cornell Methane Project was submitted to the Department of Energy on January 24, 1978.

Pilot Scale Random Mix Reactor

A 5600 ℓ(1500 gallon) pilot scale random mix reactor, located adjacent to the pilot scale plug flow fermenter in the Agricultural Research Laboratory of the Teaching and Research Center, Harford, N.Y., was completed in construction early in this quarter. This system has long since passed the testing and start up phases and is presently progressing in operation toward steady state at 35°C, 10-12% TS feed and 30 days HRT. Presently, the random mix unit is producing biogas at a rate of about 6000 ℓ/day or 1.00 ℓ/ℓ reactor/day. At one point during this quarter, the random mix fermenter, consisting of a cube-shaped wooden box jacketed with a rubber hypolon liner, developed several cracks in a couple of the support braces (2" x 4") on the wall. This problem was promptly corrected with additional bracing using steel stock and cable.

Pilot Scale Plug Flow Fermenter

The last set of operating conditions applied to the pilot scale plug flow fermenter at 35°C was as follows: 10-12% TS feed, 10 days HRT. In the first half of this quarter steady state data was obtained from this operating mode, thus completing the 35°C studies using manure and urine as the feedstock. Steady state data obtained from this unit in the first and second year of funding are summarized in Table 1. Of particular interest in this table are the gas production rates observed when various operating conditions were applied to the pilot scale plug flow system. The highest rates of methane gas production were obtained at 15 and 10 days HRT under feed concentrations of 10-12% TS, the highest organic loading rate conditions applied. Although improvement in gas production seemed to level off in going from 15 to 10 days HRT, it should be pointed out that no signs of severe stress were noted with the short HRT reactor runs in terms of low effluent pH or alkalinity; the methane fraction in the 10 day HRT fermenter run, however, did appear a bit low. The plot of methane gas production rate versus loading rate for the plug flow fermenter shown in Figure 3 indicates that under a fermentation temperature of 35°C and under liquid dairy cow manure and urine feed concentrations of less than 12% TS, optimum methane gas production may be achieved by operating the plug flow unit at hydraulic retention times between 10 to 15 days. The data implies that a great deal of latitude may be exercised in the design of mesophilic (35°C), liquid-handling plug flow fermenters in that this type of reactor could be sized to handle a wide range of hydraulic loading rates with minimal departure from the optimum in methane gas production with respect to stability, quality and quantity. This kind of flexibility would be particularly useful on farm operations where the efficiency of fermentable residue collection may vary greatly from season to season.

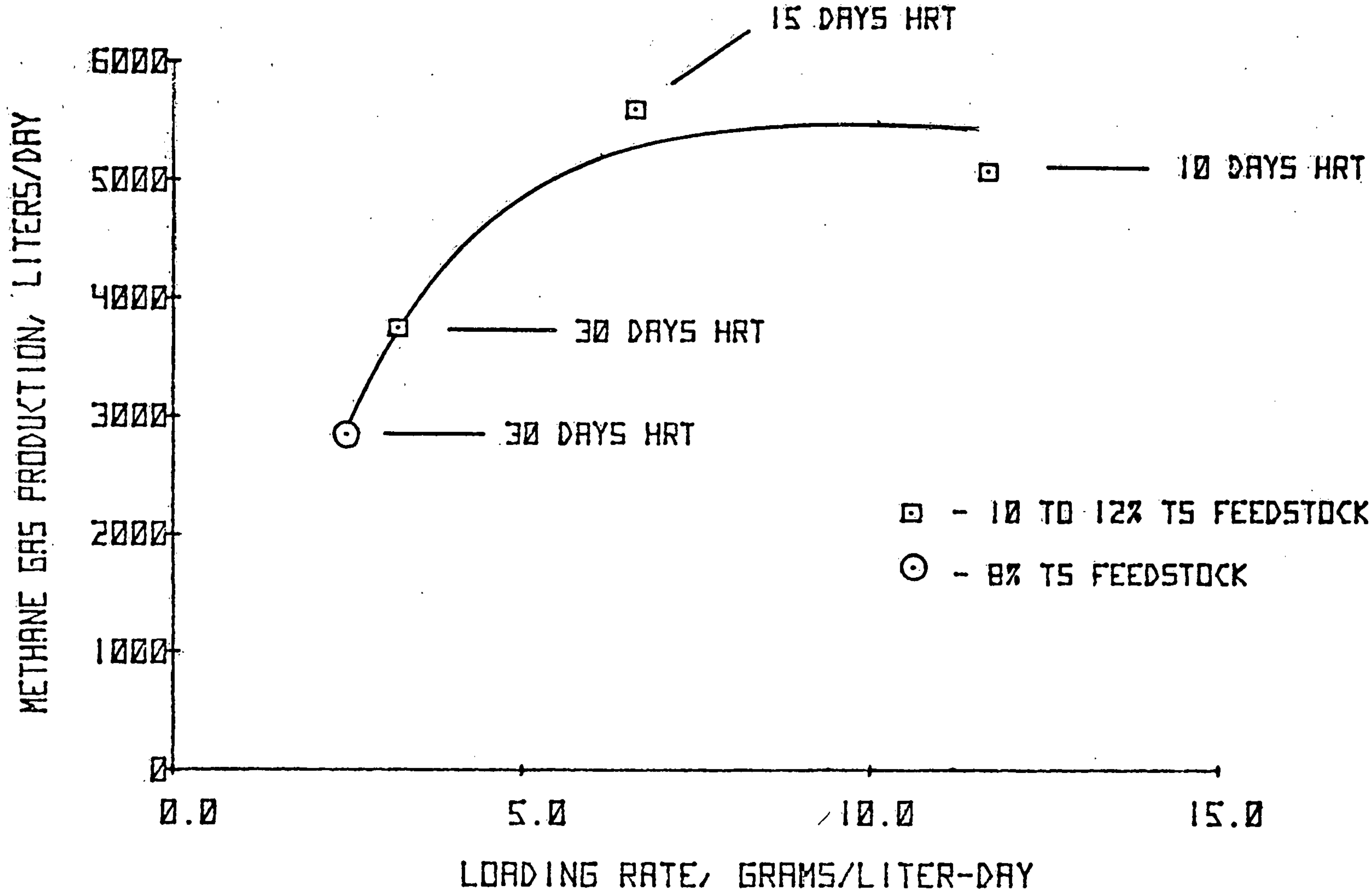


FIGURE 3. METHANE GAS PRODUCTION VERSUS LOADING RATE FOR THE 5600 LITER PILOT SCALE PLUG FLOW FERMENTOR OPERATED AT 35 DEGREES CELSIUS.

Table 1

Performance Data Summary From the Pilot Scale Plug Flow Fermenter Maintained at 35°C

Performance Parameters	Operating Conditions of the Plug Flow Fermenter			
	*30 days HRT 8% TS feed	30 days HRT 10-12% TS feed	15 days HRT 10-12% TS feed	10 days HRT 10-12% TS feed
Days of Operation	120	90	60	120
Loading g TVS/ℓ/day	2.49	3.23	6.63	11.7
lbs TVS/ft^3/day	.16	.20	.41	.73
Influent TS(g/ℓ)	86.4	112.0	112.0	129.0
TVS(g/ℓ)	74.6	97.0	99.5	117.4
pH	7.8	6.5	7.2	7.8
Effluent TS(g/ℓ)	48.7	88.5	87.4	107.2
*TS % Reduced	43.6	21.3	22.0	16.9
TVS (g/ℓ)	38.0	72	72.5	89.2
TVS % Reduced	49.0	25.7	27.1	24.0
pH	7.9	7.7	8.0	7.8
alkalinity, g/ℓ	14.3	16.7	17.9	16.4
volatile acids, g/ℓ	.47	.25	.80	--
Total Ammonia, g/ℓ	2.26	2.71	2.40	3.05
Gas Produced ℓ/day	5065	6145	8878	9383
** ℓ/ℓ day	.91	1.10	1.59	1.68
Gas Composition % CHy/%CO_2	56/44	61/39	63/37	54/46
Methane Produced ℓ/day	2836.4	3748	5593	5067
** ℓ/ℓ/day	.51	.67	1.00	.91
ℓ CH_4/gVS added	.20	.21	.15	.08
ℓ CH_4/g VS destroyed	.41	.79	.55	.32

* Steady state data for this experimental run was obtained during the first year of D.O.E. funding of the Cornell Methane Project.

** Effluent solids data from this experiment are of questionable reliability because of an observed occurence of solids separation (fiber flotation) within the reactor.

*** Liters produced per liter fermenter volume per day.

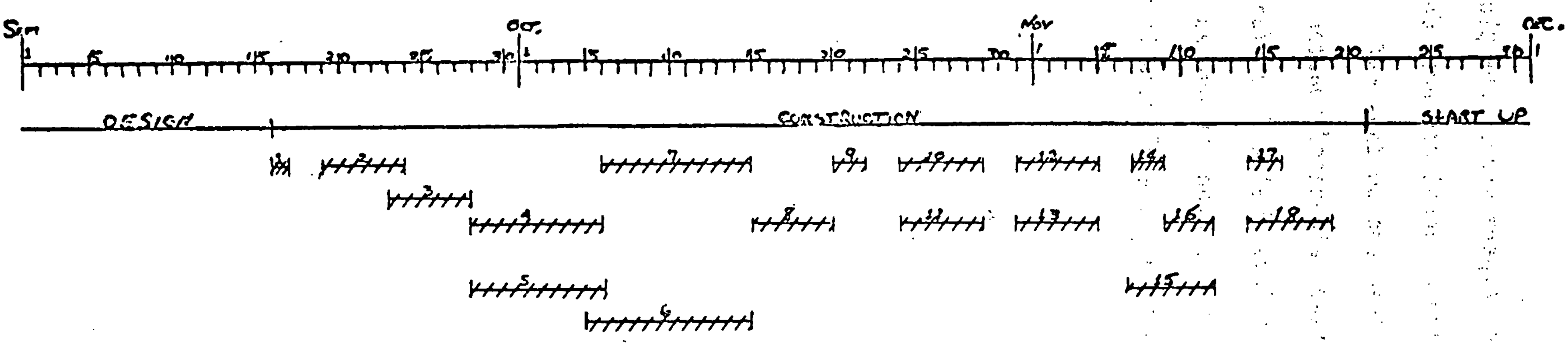
FULL SCALE PLUG FLOW FERMENTER AND CONTROL UNIT

All of the tasks in the construction schedule for the full scale conventional control fermentor, as outlined in Figure 4, have been completed and testing of this unit will soon be initiated. During the seventh quarter attention was focused on completing the effluent line connections, installing the rest of the pvc heat exchanger pipes in the tank, backfilling the effluent tank, insulating the effluent and reactor tanks, and installing and testing the gas lines and heating system. Shed No. 1, located adjacent to the full scale conventional control reactor, was wired for electrical power and outfitted with accessible control panels. It is expected that the full scale control fermenter will be in the testing phase by the end of March and could be initiated into the startup phase by April.

The ram pump that was installed in November, 1977 operated satisfactorily during testing. This pump will transport manure and urine from Barn 2 to Feed Tank T1. Plans are presently being made to place a float control and a timer on the ram pump to turn the pump on for a predetermined interval of time when the hopper is filled to a particular level by the manure conveyor. Another modification planned for the ram pump is a safety mechanism which would automatically shut the system down should a man, small child or animal fall into the hopper.

As previously mentioned, work on the full scale plug flow fermenter has been made more difficult by the cold and deep snow cover which continued throughout the Ithaca winter months of December, January, February, and early March. The utilization of additional manpower, however, allowed construction on the plug flow reactor components to continue, preparing for that period of the spring thaw when excavation could resume and when the prefabricated parts could be quickly assembled and installed into a carefully contoured and insulated trench. Such preparatory work included installation of the

Upon concluding the 35°C studies, the temperature of the plug flow fermenter was lowered to 25°C over a period of about one week under influent conditions of 10-12% TS manure and urine feed and 30 days HRT. During this period, gas production from the unmixed, elongated reactor decreased steadily from 8-10,000 liters per day to a level below 5000 ℓ/day. It is expected that the gas production could decrease even further as the microbial population of the plug flow fermenter continues to acclimate to the new, cooler temperature.



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

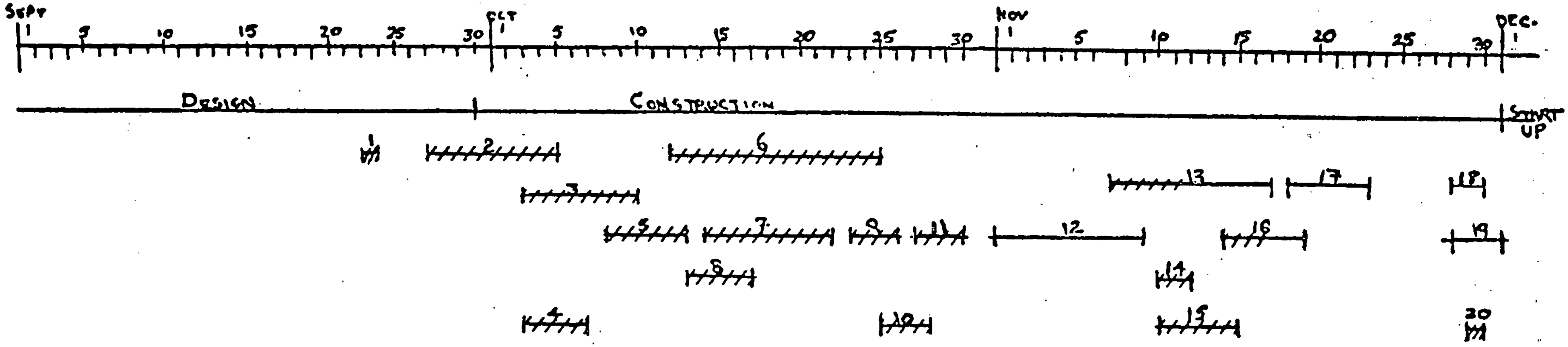
List of Tasks	Time Allocated (Days)
11. Install influent, effluent and recycle lines	5
12. Install hatch cover	5
13. Install probes and sensors	5
14. Install lower heat pipes	2
15. Put back concrete top and install effluent tank	[illegible]
16. Install insulation	3
17. Backfill effluent tank	2
18. Install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

FIGURE 4. Construction schedule for the full scale conventional control fermenter (cross hatched lines indicate progress made as of March 15, 1978).

boiler, electrical wiring of shed No. 2 (the equipment shelter nearest to the plug flow unit), laying of conduit lines to the fermenter site, installation of controls, plumbing, construction of heating pipe networks, and fabrication and sealing of the hypalon liner. The progress of all plug flow fermenter construction tanks is outlined in Figure 5. During the first week of March, the plug flow construction site was cleared of snow and the partially thawed ground was loosened with jack hammers in preparation for excavation. The trench was then shaped with excavated top soil and fill dirt, the baffles were set in place and the hypalon liner anchors were installed. Before the end of March, additional fill dirt will be brought in, trench contouring will be completed, and foam insulation will be applied to the trench walls and bottom. At that time, the trench will be ready for the installation of the hypalon liner, heating pipes, control sensors, sampling lines, gas collection system and digester cover, the last major steps in plug flow fermenter construction.

DESIGN MANUAL

The promotion of a new technology is often largely dependent upon how well the information obtained at the research and development stage is translated into useful design and operating criteria for actual implementation. This was the basic premise in mind when an anaerobic fermentation applications manual was originally proposed as part of the Cornell Methane Project. Although work on this manual was at first proposed for the last three months of the project, March 1 - May 31, 1979, it was decided that preparation of the manual should be initiated immediately to satisfy, as soon as possible, an already growing demand for technology transfer relevant to the practical implementation of anaerobic fermentation processes on small-scale agricultural operations.



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 T1 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 5: Construction schedule for the full scale plug flow fermenter (cross-hatched lines indicate progress made as of March 15, 1978).

In the seventh quarter, meetings were held among project members to decide on some procedural starting points for the design manual. Principal responsibility for the writing of the design manual was accepted by Ken Fanfoni and Don Sherman. During the month of February, an outside consultant, (Tom Abeles, i/e Associates, Minneapolis) was retained to provide input as one who had experienced in the design and installation of an agricultural anaerobic fermenter and as one who could contribute fresh ideas from an outsider's perspective. By the end of the seventh quarter, a detailed outline for the design manual was drafted. It was decided that the manual would directly address the concerns of the farmer and/or would-be installers of farm-based anaerobic fermenters. A new completion date for the design manual has tentatively been set for December 13, 1978.

FUTURE ACTIVITIES

The pilot scale studies on the plug flow and limited mixing concepts will continue throughout the next quarter. During the time, it is expected that steady state data will be obtained from the plug flow fermenter operating at 25°C, 30 days HRT and 10-12% TS dairy cow manure and urine feed and from the random mix fermenter programed for a mode of 35°C, 30 days HRT, 10-12% TS manure and urine feed and mixing every 3 days.

Now that construction of the Conventional Control fermenter has been completed, testing and startup for the unit will occupy a good portion of the eight quarter. With most of the project manpower focused on the construction of the full scale plug flow reactor, it is expected that this unit could be buile and operational by the midpoint of the next quarter (by the end of April perhaps). The overall goal, in any case, is to rapidly complete the construction and testing phases of the plug flow fermenter so both full scale reactors could be in operation by May, 1977.

Appendix A

Minutes of the Methane Project Meetings

Held During the Seventh Quarter Period (Dec. 15, 1977 to March 15, 1978)

Agricultural Waste Management
and Rural Environmental Engineering
Department of Agricultural Engineering • Riley-Robb Hall
Ithaca, New York 14853 • (607) 256-2270

February 6, 1978

MEMO TO: Members of the U.S. Department of Energy Methane Project

RE: Minutes of the Methane Project Meeting Held January 19, 1978

FROM: T.D. Hayes

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

ABSENT: D. Sherman

General Review

K. Fanfoni: For more than two months, the pilot scale plug flow fermentor has been operating at a depressed rate of gas production due to low digester temperatures induced by a high hydraulic loading (10 day HRT) of low temperature influent. This additional heat demand was accommodated by placing the cold influent in a mixed feed tank wrapped with heating tape and waiting until the influent reached a temperature of 70°F before feeding. Since this procedure of feeding has been implemented, the fermentor temperature has in the last few weeks increased from approximately 80°F to 95°F. Accordingly, this increase in fermentor temperature has effected a rise in gas production from 6000 ℓ/day to 8000 ℓ/day. The pilot reactor is expected to reach steady state at the 10 day HRT, 10-12% feed condition by the end of January; steady state data will be taken during the first part of February. Although a change to a new condition was to occur on January 1 in accordance with the proposed schedule, mid-February is the new target date for the planned switch over. Before changing to a lower operating temperature, however, a recycle mode applied to this unit at 95°F, 10 days HRT, is presently being considered to determine whether a still higher gas production rate can be achieved at this temperature.

Cold weather and heavy snow cover continue to hamper outdoor construction activities connected with the full scale plug flow reactor. Work on this fermentor, however, has not come to a standstill. A number of tasks such as liner fabrication, the preparation of heating pipe networks, and the installation of prefabricated components (i.e. water heater, pumps, wiring, etc.) can be performed apart from the excavation which has been stalled by the weather. The completion of these preparatory jobs is expected to expedite the final construction steps when excavation is able to resume in the spring.

A. Leuschner: All fixtures have been installed in the full scale control fermentor and the electrical work should be completed shortly. The effluent line from the reactor tank will soon be installed.

Two 16 ft.-long propane tanks will be installed in the coming weeks at inconspicuous locations near the full scale fermentors. Propane will serve as an auxiliary fuel for the boilers which will heat the fermentors; biogas, however, will be the principal fuel intended for reactor heating. Providing serious complications do not arise upon testing, the full-scale conventional fermentor should be ready for start-up in late February.

S. Dell'Orto: The pilot scale random mix reactor is now in the testing and debugging stage. Apparently the factory seams used on the liner material are not gas tight. The seams will, however, be painted inside and out with a special sealant; this unit will then be retested. It is expected that leakage problems will soon be corrected and that the random mix fermentor will be ready for start-up next week.

R. Cummings: We are presently looking for an adequate diaphram pump which will do a better job of mixing the random mix reactor than the moyno pump used to feed the pilot scale plug flow fermentor. We may be able to purchase such a pump for around $800.

The electricians have finished wiring power to the pumps and shed near Tank P1. The ram pump will be wired for power some time this week.

Discussion

Although various sectors of the project have fallen behind schedule, due mainly to the onslaught of winter, it nevertheless behooves us to construct a revised time schedule of goals for the coming months. It may also be helpful to include in the new projection estimates of temporary manpower requirements for the next three months.

Bart Eshuis, a new graduate student from Holland, has recently joined the methane group and will be working with Jeff Chandler in fermentation areas of toxicity, conservation of nutrients protein yield. We extend a warm welcome to Bart.

W. Jewell: The Fuels from Biomass meeting of January 9 and 10, 1978, was held in Seattle Washington. Some notes and materials from this meeting were passed along to the Cornell methane project group. Highlights of this meeting included a performance description of Ecotope's fermentor which is now receiving residue from 170 beef cattle and operating at a 15 day HRT, a review of the use and acceptance of SI units in technical literature (Ralph Wentworth, Dynatech) a continued discussion of anaerobic fermentation kinetics by Andy Hashimoto, and a description of progress to date on the Monford feedlot fermentor by Warren Coe of Hamilton Standard. Details of these and other topics were included in the prepared summary of the meeting distributed to all Cornell methane project members.

During the months of February and March much of the groundwork for the methane project fermentor design manual should be outlined in significant detail. To facilitate the initial stage of this effort, Tom Abeles will be retained in February as a consultant to identify essential topics and information which should be included in the manual. Additional practical information for design will be provided by Jeff Chandler who will be conducting a review and evaluation of materials and equipment suitable for fermentor construction.

Agricultural Waste Management
and Rural Environmental Engineering
Department of Agricultural Engineering • Riley-Robb Hall
Ithaca, New York 14853 • (607) 256-2270

13, February, 1978

MEMO TO: Members of the U.S. Department of Energy Methane Project

FROM: T.D. Hayes

RE: Minutes of the Methane Project Meeting held February 2, 1978

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

ABSENT: D. Sherman

General Review

S. Dell'Orto: The pilot scale random mix fermentor is now gas tight and is presently in the start-up phase. The random mix fermentor is now being loaded with effluent material from the pilot scale plug flow reactor at a rate that will fill the new reaction vessel within the next ten days. The random mix reactor will then be carefully loaded with dairy cow manure feedstock. A formal start-up strategy for this unit will be worked out this week based on procedures proven successful with other laboratory scale methane project fermentors. The first set of operating conditions which will be applied to this unit are as follows: 35°C, 30 day HRT, 10-12% TS feed, fed daily, mixed three times per detention time.

R. Cummings: Electrical work for the full scale control fermentor should be completed in the next two weeks. Both boilers for the full scale fermentors should also be wired in the next few weeks.

Workmen will be arriving today with their equipment to apply foam insulation to the full scale control fermentor and to two effluent tanks. Also ordered was a diaphram pump for mixing the pilot

New York State College of Agriculture and Life Sciences • A Statutory College of the State University • Cornell University, Ithaca

scale random mix reactor. This pump will cost about $1100.

A. Leuschner: All piping inside the full scale control fermentor is virtually completed. Two lines remain to be installed, however, before testing can begin for this unit. Now that the elbow for the recycle line is in, the control fermentor piping work can be rapidly concluded. Once the recycle line is installed, testing can then begin. Power control panels and electrical wiring for the boiler should be completed in about two weeks.

Testing of the ram pump can begin as soon as the piping is completed and as soon as the feed tank T1 is ready to hold liquid manure. A suggestion by Dr. Jewell will be followed that a formal start-up procedure for the ram pump be obtained from the manufacturer before testing the system.

K. Fanfoni: The pilot scale plug flow fermentor has shown remarkable improvement in gas production ever since the feed tank was outfitted with heat exchange PVC pipes and heating tape wrapped around the exterior of the tank. The additional heat exchange capacity of the feed tank made it possible to heat the cold manure residue to 70°F before feeding. When the pilot scale plug flow fermentor could not maintain temperatures above 85°F, gas production rates hovered around 6000 ℓ/day with a methane content of 48% under reactor operating conditions of 10 days HRT, 10-12% TS feed. When temperature was restored to a more optimum operating level of 95°F, gas production climbed to around 8,000 ℓ/day under the same manure loading conditions. In the last two weeks, gas production experienced further increases to 9-10,000 ℓ/day at 60% CH_4. Solids destruction data now correlates well with gas production. Data collection from the plug flow reactor will begin as soon as steady state with respect to gas production is reached. Presently, the pilot scale plug flow fermentor is producing methane gas at a rate of 1.0 to 1.1 ℓ/ℓ fermentor/day compared to 0.90 to 0.95 ℓ/ℓ/day obtained from a bench scale completely mixed control fermentor operating under similar loading conditions of 10 days HRT and 10-12% TS manure feed.

The next condition for the pilot scale plug flow fermentor will utilize recycle while maintaining a 7.5 day HRT in the fermentor. The reactor will continue to operate at 95°F and 10-12% TS feed through the next condition. The rationale used here was that the effect of recycle on fermentor performance should be investigated and that recycling experiments at 95°F should be conducted before initiating a low temperature study which could possibly alter the biological and physical characteristics of the reactor contents.

Wm. Jewell: There are a number of things we should be thinking about in the coming weeks that will be discussed in fuller detail at future meetings:

1. A schedule of tasks and goals to be for use on for the next 4 or 5 months, particularly with respect to construction, shakedown and start-up of the full scale fermentors and the random mix reactor.

2. Start-up strategies for the pilot and full scale fermentors. Such plans should be <u>based on past experience</u>!

3. Refined estimates and justification for certain temporary man power needs.

4. Future steps which can be taken to improve the appearance of the fermentor site. Though true, the saying "You can't judge a book by its cover..." is not a philosophy universally practice by all potential visitors.

This meeting was concluded with a ten minute review of slides recently taken of methane project construction and research activities at the T & R Center, Harford. Virtually all stages of the second-year methane project research program have thus far been documented with photographs and slides.

Agricultural Waste Management
and Rural Environmental Engineering
Department of Agricultural Engineering • Riley-Robb Hall
Ithaca, New York 14853 • (607) 256-2270

1, March 1978

MEMO TO: All Department of Energy Methane Project Members

FROM: T.D. Hayes

RE: Minutes of the Methane Project Meeting Held February 16, 1978

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

General Review:

S. Dell'Orto: The pilot scale plug flow fermenter is now operating on a recycle mode, maintaining a 7.5 day HRT. This reactor is presently being fed 50 gallons of recycled effluent and 50 gallons of untreated dairy cow manure. The rationale behind this departure from the proposed experimental schedule was that steady state data for a recycle condition at 35°C could be quickly obtained from the plug flow reactor since the system was already acclimated to this temperature while operating at relatively high organic loadings. As soon as the operating mode was changed to the recycle condition, the plug flow fermenter's heating system was hooked up to the random mix fermenter to eliminate the necessity of obtaining another water heater. Theoretically, the water heater had sufficient capacity to handle the heating demands of both reactors. For some reason, however, the dual hookup to the water heater predisposed a significant drop in temperature for the plug flow reactor from 35°C to 29°C. The gas production rate for the plug flow reactor during this period of recycle at 29°C hovered around 7000 ℓ/day. Meanwhile, the temperature of the random mix reactor contents climbed gradually to 35°C where that temperature was steadily maintained. In light of this development and in light of the originally proposed experimental schedule it was decided that if the plug flow fermenter did not recover in temperature to 35°C in three days, the present operating condition would be abandoned for the time being and operating conditions for this unit would be changed over to a single pass mode at 25°C, 30 day HRT and 10-12% TS feed.

Start up for the random mix reactor seems to be going well. The first operating condition for this unit will be as follows: 35°C, 30 day HRT, 10-12% TS feed, mixing three times per detention time. The random mix fermenter will be gradually loaded until the above operating condition is reached. After this unit is thoroughly tested, a tracer study will be initiated to check for short circuiting.

A. Leuschner: The recycle line to the full scale conventional control fermenter has been installed but the effluent line to this unit remains to be finished this week and one hole in the tank wall needs to be sealed up. The boiler is now wired up for service; the propane gas line, the biogas lines and meters will be installed soon. A small tank of propane will be kept on hand to fire the boiler during the start up period and during certain times (if any) when a back-up fuel source is needed. The boiler will be ready for testing as soon as gas and electrical power are supplied to this unit. The conventional fermenter is so close to completion that storage of effluent from the plug flow fermenter should be started now to provide an adequate amount of seed for start-up.

R. Cummings: The power to the shed 1 boiler will be turned on by next Monday or Tuesday. Two pieces of equipment in Barn 2 (ventilation shutters) will have to be temporarily disconnected while the electrical line to the water heater is hooked up to a main power line.

In the last two weeks, the T1 feed tank was patched and the ram pump was then tested. During testing, the ram pump successfully pumped manure from Barn 2 to feed tank T1 at rates specified in the operator's manual. As soon as testing is completed, efforts will be made to provide safety devices for the ram pump to make it difficult for an adult, child or animal to fall into the large hopper of this unit while it is running.

K. Fanfoni: Work on shed 2 is continuing at a steady pace. Presently, emphasis is being placed on boiler installation, wiring, piping and Fenwal thermostat hookups. As mentioned at the last meeting, much of the prefrabricating, component preparation, heating pipe network assembly, and control shed work can be completed during the months of February and March so that as soon as the ground thaws to the point where excavation can resume, total attention can be directed toward installing the trench fermenter.

W.J. Jewell: It could be as late as mid-April before the snow is removed and the ground is thawed. We should perhaps continue to think about possible alternatives which would short-cut this impasse.

Plans are presently being made to initiate graduate student research on ammonia and volatile acid interrelationships in the toxification of anaerobic fermenters. Three graduate students will, in some way, be associated with this effort; Jeff Chandler, Bart Eshuis and James Morris. Included in this study will be serum bottle experiments in which fermentation rates will be measured under concentrations of varied ammonia holding initial carbon (volatile acids) constant, and varied carbon holding initial ammonia constant.

We have with us today Dr. Tom Abeles who will be serving as a consultant to the Methane Project in connection with the preparation of the design manual. Primary responsibility in the drafting of the design manual rests with Ken and Don. However, Tom's experience with the installation of plug flow fermentation systems and his familiarity with the most recent literature and developments in this area warranted his input, starting at the earliest planning stages of the manual. In the coming weeks, Tom will be assisting us in defining the scope, objectives and structure of the manual, and he will be offering some suggestions regarding the content of the manual and where certain items of information can be found. In particular, next week Dr. Abeles will help to organize and construct a detailed outline of the design manual and will have substantial input in defining what kinds of information each component of the outline should include.

The next methane project meeting will be held around March 3 at 8:30 am at T & R, Harford. The agenda will include:

1. A General Review
2. Evaluation of the start-up procedure used for the random mix fermenter.
3. Discussion of the possible use of an inflatable, heated greenhouse structure to allow an early resumption of work on the full scale plug flow fermenter.

Agricultural Waste Management
and Rural Environmental Engineering
Department of Agricultural Engineering • Riley-Robb Hall
Ithaca, New York 14853 • (607) 256-2270

March 14, 1978

MEMO TO: Members of the U.S. Department of Energy Methane Project

FROM: T. Hayes

RE: Minutes of the Methane Project Meeting Held March 3, 1978

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

General Review:

Al Leuschner: Construction on the full scale conventional fermenter is nearly completed. A few tasks remain to be completed including the installation of the effluent line, hook-up of the propane tank to the water boiler, insulation of the effluent tank top and installation of the fermenter hatch cover. In about a week, testing should begin. Gas leak testing will consist of merely pressurizing the system and monitoring the rate at which the pressure drops. The testing and shake down of all major components of the conventional control system should extend for about 1 or 2 weeks, barring any serious problems. Start-up for this unit is targeted for the last week in March.

Ken Fanfoni: During the first week in March operating conditions for the pilot scale plug flow reactor were changed from a 10-day HRT, 35°C, 33% recycle mode to 30-days HRT, 25°C, single pass. It has taken about a week to make the temperature transition but now the plug flow fermenter is presently operating at the lower temperature at a gas production rate of about 4500-5000 ℓ/day.

Wm. Jewell: Perhaps we should try various modes of feeding the pilot scale units since in some cases the farmer who employs anaerobic fermentation for residue handling may choose to load the system once or twice a week. Feeding modes reasonably consistent with those likely to be used by the farmer should be considered for application to the test reactors of this project. For instance, in addition to obtaining steady state data from the random mix fermenter as operated on a daily feed basis, other feeding schedules (maintaining constant hydraulic and feed loadings) should also be tried including once every three days or once per week.

Steve Dell'Orto: The random mix system is now out of the start-up phase, operating now at 30-days HRT, 10-12% TS, 35°C. This system is mixed every three days with a diaphram pump and fed every day. Currently, the random mix fermenter is yielding a gas production rate of about 8-10,000 ℓ/day.

Wm. Jewell: During the last week in February a detailed outline of the design manual was drafted with the help of Dr. Tom Abeles, who was retained as a consultant for this period. The outline has since been distributed among methane project members for their inspection and comment. The next steps in developing the design manual over the coming weeks will include:

1. An expansion of the design manual outline describing the kinds of information to be included under each heading and the sources of such information.

2. An estimation of the manpower required for various design manual tasks.

3. Development of a schedule of tasks relevant to the completion of the design manual.

The next methane project meeting is tentatively scheduled for Thursday, March 16, 8:30 AM, at the T&R Center, Harford.

*U.S. GOVERNMENT PRINTING OFFICE: 1978-740-306/4355. Region 4.