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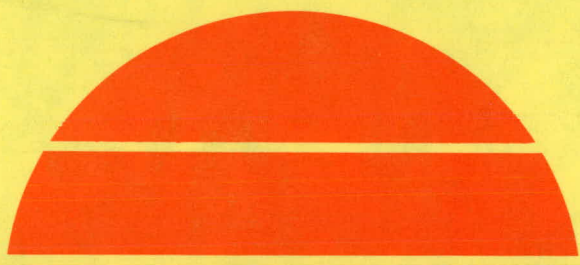
**ANAEROBIC FERMENTATION OF AGRICULTURAL RESIDUES—  
POTENTIAL FOR IMPROVEMENT AND IMPLEMENTATION**

**Eleventh Quarter Progress Report for Period from December 16, 1978—March 15,  
1979**

**By  
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ANAEROBIC FERMENTATION OF AGRICULTURAL RESIDUES--  
POTENTIAL FOR IMPROVEMENT AND IMPLEMENTATION

Tenth Quarter Progress Report for Period From  
September 16, 1978 to December 15, 1978

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## REPORT OUTLINE

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Anaerobic Fermentation of Agricultural Residues--  
Potential for Improvement and Implementation

This is the tenth quarter progress report describing the activities of an on-going three-year research effort to facilitate the development of new and/or improved technology that will result in the widespread implementation of anaerobic fermentation as a source of renewable energy for small-scale agriculture. This report describes the progress of events in the last three months contributing to the continued demonstration of the simplified reactor concept at the full-scale level in the conversion of dairy farm manure residues to methane.

The methane project is now obtaining data from simplified pilot and full-scale fermentors operated on dairy cow manure. The following reactor types have been constructed and operated:

1. Pilot scale randomly fed and mixed, three-cow residue handling capacity when operated at a 30-day HRT;
2. Pilot scale plug flow reactor, three-cow residue handling capacity when operated at a 30-day HRT;
3. Full-scale plug flow reactor, 65-cow residue handling capacity when operated at a 10-day HRT; and
4. Full-scale conventional completely mixed control, same residue handling capacity as the full-scale plug flow fermentor.

The overall progress attained with the major components of the project is estimated to be about 2 1/2 months behind schedule. Scheduled activities in the next quarter should bring the tasks up to the time schedule as originally proposed.

In general, activities for the tenth quarter, extending from September 16, 1978, to December 15, 1978, have included the following:

1. Continued operation of the full-scale plug flow and conventional control fermentors at the 30-day, 35°C, 10-12% TS manure feed condition.

2. The replacement of the flexible cover on the full-scale plug flow reactor.
3. Ongoing experimentation with bedding addition to the dairy manure feedstock of the pilot scale plug flow fermentor operated at 30 days HRT, 35°C and 11-13% TS feed.
4. Completion of the manure feed studies at 35°C for the random mix reactor and the initiation of bedding addition to the manure influent (11-13% TS).

## 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 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 herd 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 submitted with the proposal is presented in Figure 1. A bar chart schedule indicating the proposed and actual progress of certain project components is presented in Figure 2. During the tenth quarter, operation of all pilot and full-scale fermentors continued. The 5.0 m<sup>3</sup> pilot scale random mix reactor was to conclude its experimental testing with manure and bedding at 35°C and a new series of operating modes with the same feed type at lower temperatures was to be initiated. The 5.6 m<sup>3</sup> pilot scale plug flow reactor was also to continue operating with a manure and bedding feed. Also scheduled for the tenth quarter was the completion of the manure and bedding feeding modes at 35°C for the full-scale conventional and plug flow fermentors; during the latter portion of this period testing with the manure and bedding feed at the lower temperatures was to be initiated.

### Present Status

The overall progress of the methane project is presently about two months behind the proposed schedule. Although the operation of the pilot scale reactors has adhered closely to the work plan, the full scale demonstration phase has lagged by about 2 1/2 months. In an effort to accelerate the testing program and to narrow this schedule gap, a revised experimental plan was drafted in August, 1978, as shown in Figure 3. Progress in reference to the new schedule is indicated showing a close adherence to the accelerated work plan.

Progress review meetings were held with the methane project group on a weekly basis throughout the tenth quarter for periodic progress review.

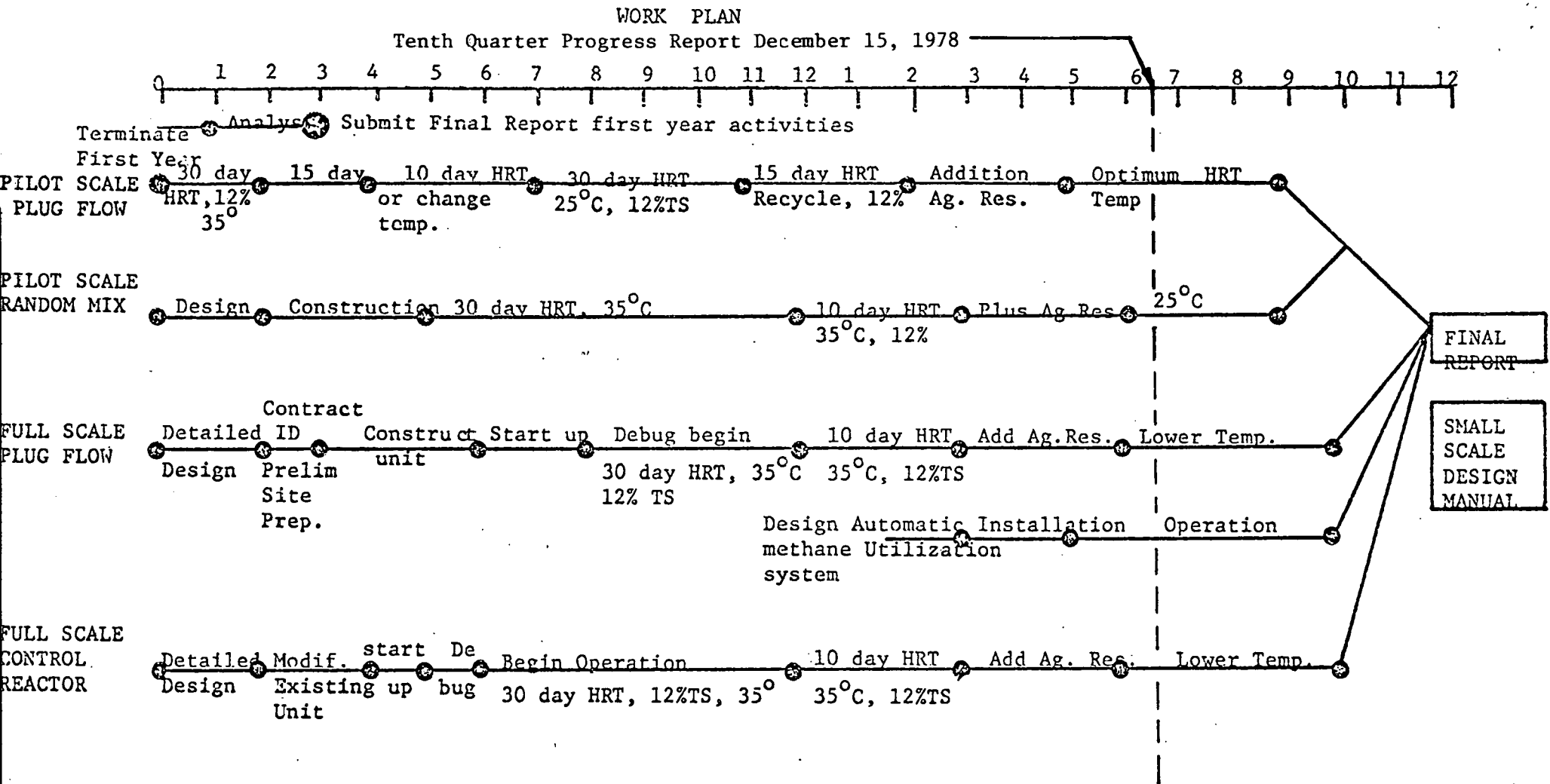


Figure 1. Detailed work plan for the development and demonstration of low cost fermentors.

FIGURE 2.

CORNELL UNIVERSITY METHANE PROJECT WORK PLAN FOR 1977-1979

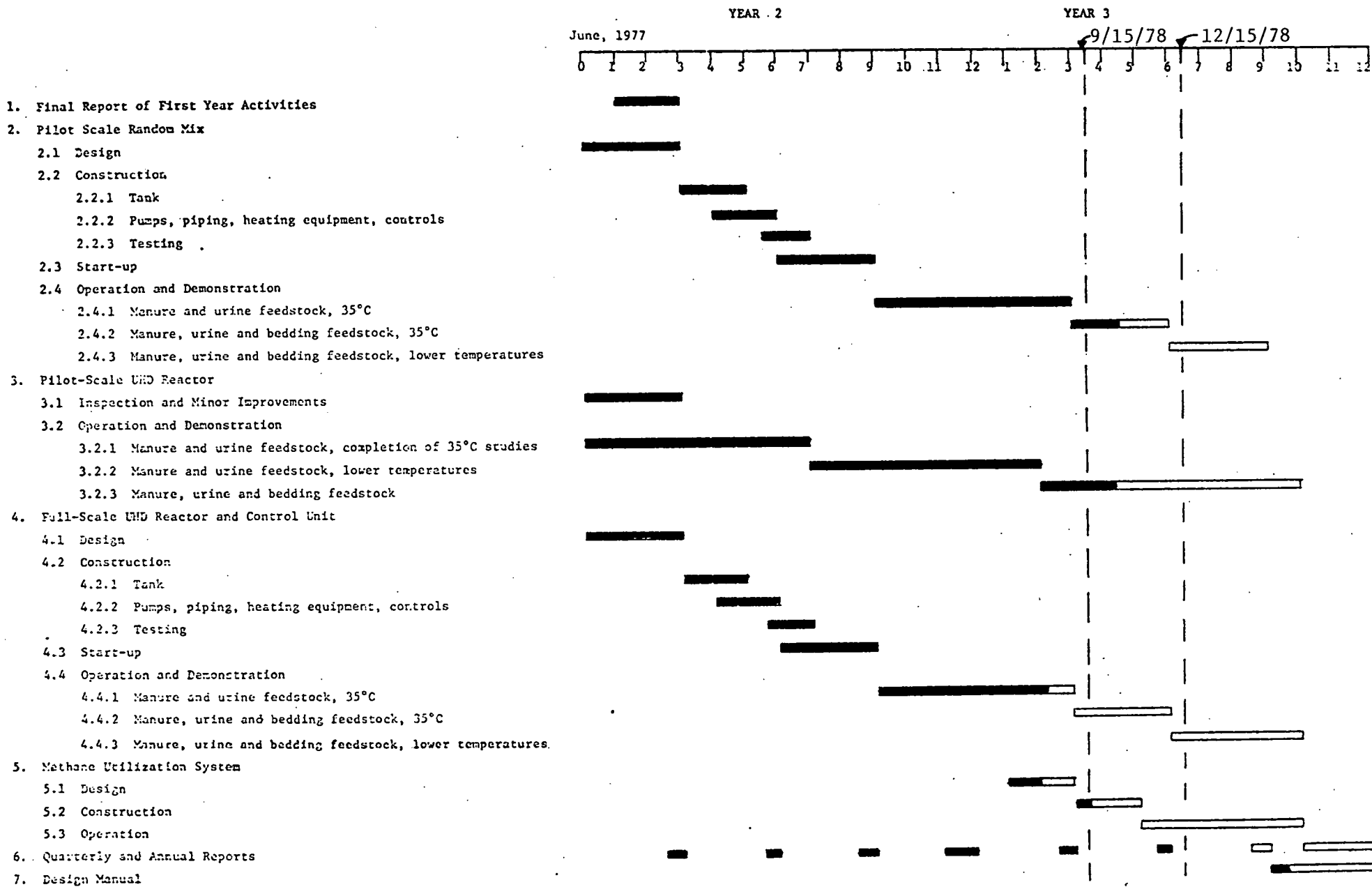
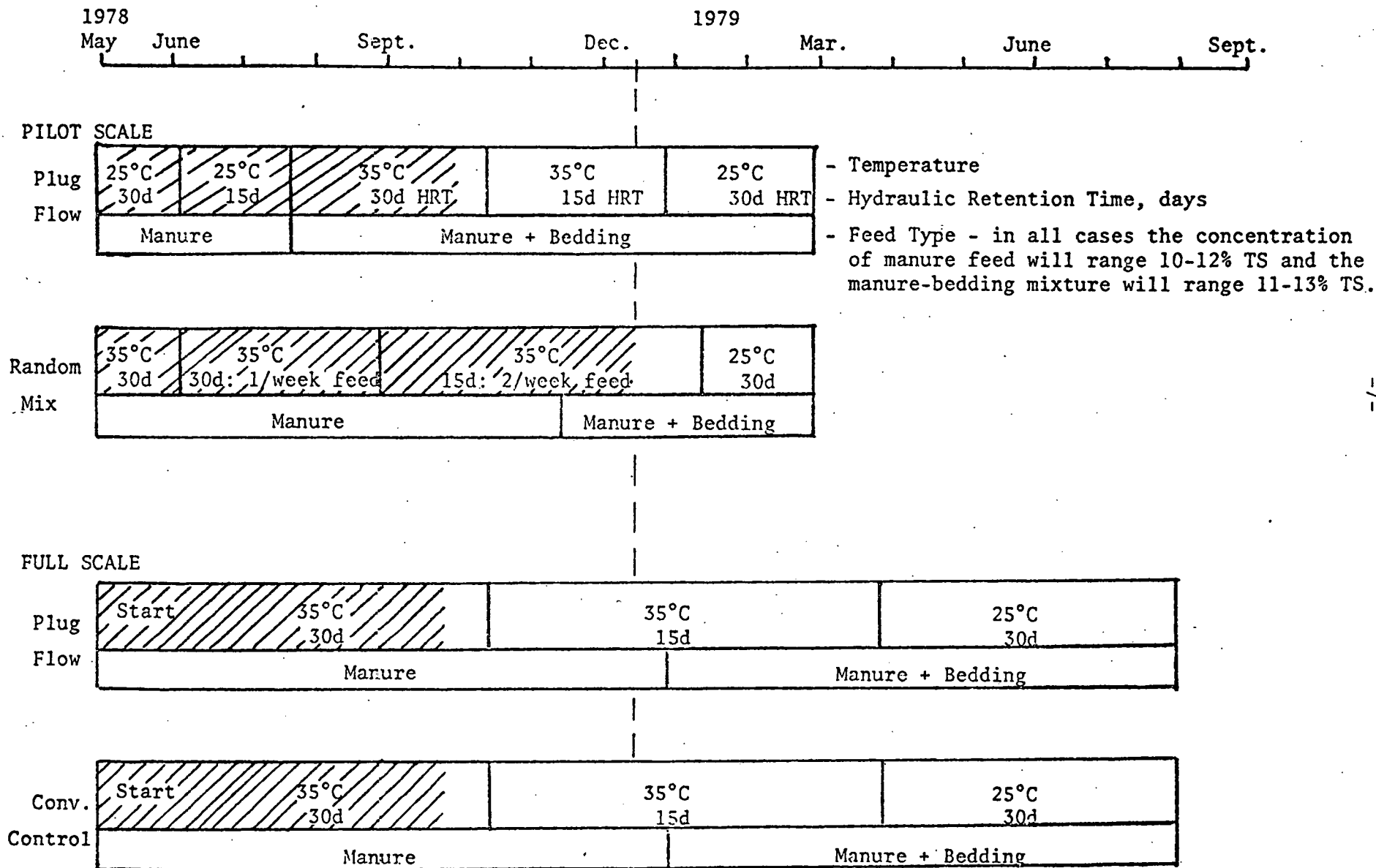


Figure 3. EXPERIMENTAL TESTING PROGRAM



The notes and minutes from these sessions are presented in Appendix A.

#### Pilot Scale Random Mix Reactor

Steady state data was collected from this unit during the last quarter while operating at a 16-day HRT, 35°C, fed 10-12% TS dairy manure at a frequency of once every four days and mixed after every feeding. At this operating mode the random mix reactor produced biogas at an average rate of about  $1.4 \text{ m}^3/\text{m}^3 \text{ reactor/day}$  ( $0.84 \text{ m}^3/\text{m}^3/\text{day CH}_4$ ) with a concomitant TVS destruction efficiency of about 28 percent over the 24-hour period. After feeding, gas production for this  $5.0 \text{ m}^3$  reactor typically peaked at levels over  $11.0 \text{ m}^3$  and decreased over the remainder of the four-day feeding cycle to values below  $6.0 \text{ m}^3$ . This condition indicated that the biological system acclimated to these wide variations in feeding.

Upon collection of steady state data from this condition, the random mix unit was fed a mixture of chopped straw bedding and manure while maintained in the same operating mode. Straw was added to the influent manure on the basis of a bedding utilization rate of 1.4 Kg/cow/day (3.0 lbs/cow/day). During the first feeding period, introduction of the manure-straw material predisposed significant foaming in the reactor, displacing about 25 percent of the volume of the reactor. Due to recent design changes in the reactor, all of the expelled contents were eventually returned to the reactor. The bedding content of the feed was subsequently reduced by 33% and the foaming problem has since subsided.

The first mechanical problem with this system occurred with a break in the pvc heat exchanges grid through which hot water is normally recirculated. After close examination and testing, it was decided that the disconnection occurring in the 2-inch pvc pipe probably resulted from the pulsating

action of the diaphragm feed pump which causes large hydraulic shocks to move through the reactor. Corrective measures have consisted mainly of the installation of a steel heat grid that would be capable of holding together during mixing and feeding periods. Although metal components for the interior of the reactor are not advised for any final full scale fermentor design (due to corrosion problems), the steel heat grid is expected to yield consistent operation for the short term of experimentation with the random mix unit.

The concept of using pvc heat grids for full scale fermentor applications utilizing recirculation mixing is already under observation with the full scale conventional control fermentor now operating.

#### Pilot Scale Plug Flow Fermentor

Throughout the entire tenth quarter, the pilot scale plug flow fermentor has been operating on a dairy cow manure-bedding mixture at a consistency of 11-13% TS, while maintained at 35°C and 30 days HRT. Chopped straw was initially added to the feed, but when float accumulations became noticeable sawdust was substituted as the bedding additive. Midway through the last quarter, a significant float layer of 0.15-0.2m (6-8 inches) had accumulated in the reactor making accurate solids destruction determinations difficult.

Subsequent addition of water for dilution had no significant remedial effect; the float mat continued to grow to 0.2-0.3m (8-12 inches).

In November the float material was removed and feeding was resumed with a manure and wheat straw mixture. Bedding addition to the manure feed was decreased to a blending rate of 0.68 Kg/cow/day (1.5 lbs/cow/day). Straw accumulation in the float will be watched closely over the next few weeks to determine the extent of difficulties that may be expected with bedding addition to the large scale fermentors. Currently, the pilot scale plug flow reactor

is producing about  $1.1 \text{ m}^3/\text{m}^3$  reactor/day of biogas ( $0.65 \text{ m}^3/\text{m}^3$  reactor/day  $\text{CH}_4$ ).

The testing program for the pilot scale reactor is about 1.5 to 2.0 months behind the proposed work plan schedule.

#### Full Scale Plug Flow Fermentor and Control Unit

The full scale plug flow and conventional control reactors have continued to operate at  $35^\circ\text{C}$ , 10-12% TS manure feed and 30 days HRT through all of the tenth quarter.

During the first half of the last quarter, gas leak problems persisted with the hypalon flexible cover originally installed on the full scale plug flow unit; accurate gas production data from this unit could not be obtained during most of this period. The special weather-resistant hypalon cover material ordered early in the summer of 1978 from Cooley Inc. was received in late October. A substitution in the liner order was then made from hypalon at  $\$10.75/\text{m}^2$  ( $\$1.00/\text{ft}^2$ ) to a 45 mil, 2000 denier scrim Estane (Brand) material. (polyurethane, 58630 ether, B.F. Goodrich) at  $\$21.52/\text{m}^2$  ( $\$2.00/\text{ft}^2$ ).

The new liner material was received in late October, but before it was installed the old liner had to be removed and discarded. In light of questions regarding the safety of flexible cover digesters relevant to fire and explosion possibilities, a carefully conducted and controlled fire test was conducted on the old, inflated gas collection cover. A burning cloth dropped on the gas collection bag resulted only in a large flare of biogas which died out as soon as the bag deflated. No explosion occurred. No significant damage was imparted to the reactor or surrounding buildings. Within two days the old hypalon cover was removed, and the Estane material was installed on the plug flow reactor.

During cover replacement it was noticed that manure had filled the pvc

anchoring pipes to which the Estane liner was to be attached, thus making the pipes harder to handle due to the added weight. Design changes will be sought to alleviate this problem. The new gas collection cover has been holding biogas without leakage at pressures exceeding  $1200 \text{ n/m}^2$  (5.0 inches of water column) since mid-November.

The conventional completely mixed control reactor also developed a leak problem that resulted in a noticeable amount of liquid escaping from under the freeboard liner and out the top of the reactor in the form of foam. This fermentor was subsequently repaired by altering the liquid level in the basin and by plugging the source of the liquid leak with concrete. Final adjustments to the liner and to the reactor caused delay in testing of about one month.

The full scale plug flow and conventional control reactors have reached stable operation at the 30-day HRT,  $35^\circ\text{C}$ , 10-12% TS feed mode. A summary of gas production and solids destruction data obtained from these units is presented in Table 1 as compared to performances observed from bench and pilot scale reactors operated in previous phases of the project. The data indicate that full scale plug flow and conventional control fermentors are operating at gas production and solids destruction efficiencies comparable to those obtained with their reactor types at the bench and pilot scale level. Both full scale units are presently producing biogas at rates of 1.1 to  $1.2 \text{ m}^3/\text{m}^3$  reactor/day for the completely mixed and plug flow systems, respectively.

One of the most important aspects of any anaerobic fermentor operated in cold climates is the overall energy balance of the process. The monitoring of gas flows from the full scale reactors and biogas utilization rates of the boilers has been completed with new gas meters during the tenth quarter. Determinations of heat losses from the full scale reactors and of boiler efficiencies have also been planned. Heat and energy balances are incomplete

Table 1

Gas Production and Solids Destruction Data  
from Bench, Pilot and Full Scale Plug Flow  
and Completely Mixed Control Reactors  
Operated at 30 Days HRT and 35°C

Reactor Type and Scale	Biogas Production		Gas Composition Percent Methane	TVS Destruction Percent
	$\frac{m^3}{m^3}$ Reactor/day	$\frac{m^3}{Kg/VS_A}$		
Plug Flow				
Bench <sup>1</sup>	0.91	0.36	56	--
Pilot <sup>2</sup>	1.10	0.33	61	26
Full <sup>2</sup>	1.16	0.38	58	39
Conventional Control				
Bench <sup>2</sup>	0.92	0.25	64	32
Bench <sup>3</sup>	0.81	0.35	63	36
Full <sup>2</sup>	1.08	0.37	59	31

1. Feed Consistency = 8% TS dairy manure.
2. Feed Consistency = 10-12% TS dairy manure.
3. From previous Cornell study, G. Morris thesis, using 8% TS dairy manure feed.

at this time. This will be a major focus in the next quarter.

The full scale fermentation effort is approximately three months behind schedule.

#### Design Manual

The initial outline for the design manual has been prepared and will be used as a guide to format and content. This portion of the study is well ahead of schedule.

### FUTURE ACTIVITIES

The pilot scale random mix reactor will conclude its present operation of feeding and mixing every four days, 16-days HRT, 35°C, and 11-13% TS manure-bedding influent and will complete the next operating mode of 30 days HRT, 25°C, 11-13% TS manure-bedding feed. The pilot scale plug flow reactor operating on manure and bedding will soon be shifted from 30 days HRT at 35°C to 15 days HRT. This operating mode should end within the eleventh quarter and the last condition of 25°C, 30 days HRT and 11-13% TS manure-straw feed will be started. By the end of the eleventh quarter, both pilot reactors should be nearly complete according to their respective testing programs.

In the next quarter the full scale plug flow and conventional control fermentor will both conclude operation at 30 days HRT, 35°C and 10-12% TS manure influent; when steady state data at this condition has been completed, the HRT of these reactors will be changed from 30 to 15 days. Toward the latter portion of the next quarter both reactors will then end their test period on manure and will begin experimentation with bedding additions to manure feedstocks.

Most important, comprehensive energy balance data will be obtained from the operation of the full scale anaerobic reactors as operated at realistic dairy manure loading rates under actual environmental conditions that would be encountered on a farm in a typical northern winter. Information to be collected will include determinations of boiler efficiencies, net gas production rates and conducted heat losses from the fermentor basins. As yet, the full scale plug flow fermentor has not been insulated over its exposed liquid surfaces, nor has the uninsulated flexible cover been protected from winds and weather with any kind of shelter. Closed cell insulation blocks will

be laid over every exposed liquid surface, and additional insulation will be placed over the flexible liner, if required. Heat balances on the plug flow fermentor will be conducted before and after the addition of these features to determine their actual value.

Lastly, a serious effort to initiate preparation of the design manual will be made before the close of the next quarter. It should, however, be emphasized that this document will not be a construction and service manual in a strict sense, but will instead be targeted for farmers to provide a basis for determining the applicability and economic feasibility of implementing anaerobic fermentation on any particular small scale farm.