C00-2917-9

BIOLOGICAL CONVERSION OF BIOMASS TO METHANE
BEEF LOT MANURE STUDIES

REPORT

For Period June 1, 1976 - November 30, 1977

John T. Pfeffer
and
Gerald E. Quindry
Department of Civil Engineering
University of Illinois
Urbana, Illinois 61801

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy nor any of their employees nor any of their contractors, subcontractors or their employees make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Report No. UILU-ENG-78-2011

May 1978

MASTER

Prepared for

THE U.S. DEPARTMENT OF ENERGY
UNDER CONTRACT NO. EY-76-S-02-2917

PORTIONS OF THIS REPORT ARE ILLEGIBLE. It
has been reproduced from the best available
copy to permit the broadest possible avail-
ability.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ABSTRACT

A series of experiments was conducted to determine the performance characteristics of the methane fermentation process using beef feed lot manure as a substrate. Manure was obtained from the University of Illinois beef farm. This manure was processed through four parallel fermentors each having a capacity of 775 liters. A continuous feed system was employed to determine the conversion efficiency. The effluent from the fermentation units was evaluated to determine its dewatering characteristics and the quality of the liquid and solid residues. A simple simulation model was developed to evaluate the effect of various operating conditions on processing costs and the net income.

These studies clearly show that thermophilic fermentation (58-60°C) substantially increase the gas yield and the rate of gas production over that obtained at the mesophilic fermentation temperature. System stability is very good. Substantial decreases in temperature or significant increases in loadings did not disrupt the process. Solids recovery from the fermented slurry was accomplished with screens, vacuum drum filters and centrifuge. Solids capture was poor unless massive dosages of conditioning chemicals were added. In terms of investment and operating costs, simple screens (20 mesh size) would capture 75 to 80 percent of the recoverable suspended solids. Because of the poor solids capture and the relatively low crude protein content of the solids, solids separation for refeed does not appear too promising. Use of screens to recover the coarse solids for use as roughage may be beneficial to the system.

Manure that is obtained from open lots, especially when it has been exposed to the environment for extended periods, offers little potential for methane production. The biodegradability of this material is so low that the cost of producing the gas far exceeds its value. Fresh manure such as that obtained from environmental lots produced significant quantities of gas. It is probable that an economic system can be developed using this material as a substrate.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
DESCRIPTION OF EXPERIMENTAL SYSTEM	2
Continuous Fermentation System	2
Feed Preparation	6
Fermentor Operation	7
Residue Processing and Disposal	8
Fermentor Feed Stock	9
RESULTS AND DISCUSSION	11
Manure Fermentation	11
Reactor Start-up	11
Gas Production Rates	14
Fermentation Kinetics	33
Reactor Stability	41
Nitrogen Level Variations	45
Thermochemical Pretreatment	48
Fermented Slurry Studies	50
Particle Size Distribution	50
Composition of Different Size Fractions	58
Centrifuge Dewatering Study	63
Vacuum Filtration Studies	68
Utilization of Residual Solids	75
Nitrogen Analysis	76
Phosphorus Analysis	78
Computer Simulation Results	82
REFERENCES	90
APPENDIX A	91
APPENDIX B	156
APPENDIX C	175

LIST OF FIGURES

Figure	Page
1. Floor Plan of Building for Housing the Experimental System	3
2. Schematic of One Set of Fermentors	4
3. Details of Reactor and Variable Speed Mixer	5
4. Thermophilic Gas Production	38
5. Mesophilic Gas Production	39
6. The Effect of Temperature Change on Reactor Stability	42
7. The Effect of Temperature Change on Reactor Stability	44
8. Particle Size Distribution at Various Process Stages	57
9. Cake Solids Produced During Centrifuge Tests	65
10. Centrate Solids Produced During Centrifuge Tests	67
11. Cake and Filtrate Solids Obtain with Filter Leaf Test	71
12. Solids Capture Using Filter Leaf Test Procedure	73

LIST OF TABLES

Table	Page
1. Variations in pH, Alkalinity and Volatile Acids	12
2. Gas Production Rates	15
3. Average Weekly Gas Production Data - Reactor 1	18
4. Operating Parameters - Reactor 1	21
5. Average Weekly Gas Production Data - Reactor 2	24
6. Operating Parameters - Reactor 2	26
7. Average Weekly Gas Production Data - Reactor 3	29
8. Operating Parameters - Reactor 3	31
9. Average Weekly Gas Production Data - Reactor 4	34
10. Operating Parameters - Reactor 4	36
11. Evaluation of the Rate Constant	40
12. Average Nitrogen Contents of Feed and Effluent Slurries - mg/l	46
13. Operating Conditions During Residual Processing Tests	52
14. Particle Size Distribution	53
15. Fiber Analysis - Reactor Effluent	60
16. Fiber Analysis - Feed Slurry	60
17. Hardness and Iron Analysis - % Solids Retained on Sieve	62
18. Corrected Fiber Analysis - Reactor Effluent	62
19. Filter Leaf Test Results	69
20. Expected Vacuum Filter Performance	74
21. Nitrogen Distribution, mg N per g Total Solids	77
22. Phosphorus Distribution, mg P per g Total Solids	79
23. Potassium Distribution, mg K per g Total Solids	81
24. Manure Characteristics Used in Simulation	83
25. Effect of Fermentation Temperature and Lot Type on Economics	85
26. Effect of Lot Size on System Economics	87
27. Effect of Retention Time on System Economics	89

INTRODUCTION

Recovery of energy from residual organic materials and from crops grown specifically for their energy content is part of the Fuels from Biomass Program. One of the processes for energy recovery is the methane fermentation system. In order to evaluate the methane yields from various organic materials a small pilot scale experimental system has been established. Construction of this facility was initiated in June of 1976, and it became operational in October 1976.

After the initial shakedown period, tests were conducted on the methane yields from animal manure. This initial substrate was selected to complement the work being conducted on other related projects.

One objective of the proposed research is to provide data on the methane yield for various operating conditions. These data will provide the necessary base from which economic feasibility studies can be conducted. Since a major factor in the economic evaluation is the yield of methane per unit of material processed, these data are essential for the above studies. Additional objectives include the evaluation of the benefits of substrate pretreatment and the evaluation of potential systems for processing and disposing of the fermentor slurry.

DESCRIPTION OF EXPERIMENTAL SYSTEM

1. Continuous Fermentation System

This methane fermentation system is housed in the Department of Civil Engineering's Dynamic Testing Lab. This building is located on the south campus of the University of Illinois at Urbana. A floor plan of this facility is shown in Figure 1. In addition to a large test bay in which the reactors are housed, this facility contained adequate laboratory, office and related space for the research staff.

The fermentation reactors consisted of four completely mixed stainless steel reactors with a total volume of 0.91 m^3 each. The operating level in each reactor was 0.775 m^3 . Heating was provided by circulating hot water from a hot water heater through external jackets on each tank. A temperature controller (TC) opened a solenoid valve (SV) to allow the hot water to circulate through the jacket when the temperature dropped below the set point. Figure 2 shows a schematic of one set of reactors. A second set operated in parallel.

The reactors were initially equipped with variable speed turbine mixers. The mixing speed could be varied from 20 to 120 rpm. Recording watt meters measured the power consumption on each mixer. The mixing power input could be varied from 0.1 kw to 1.0 kw. This is equivalent to mixing power input ranging from 0.13 to 1.3 kw per m^3 of slurry. Because of repeated failure of the variable speed drives, they were removed from the system in April 1977. The mixer speed was fixed at 75 rpm. The dimensions of the reactor and the associated mixer are shown in Figure 3.

Dynamic Test Laboratory Plan

Figure 1. Floor Plan of Building for Housing the Experimental System

Figure 2. Schematic of One Set of Fermentors

Figure 3. Details of Reactor and Variable Speed Mixer

The feed slurry was pumped into the fermentors with a progressing cavity pump (P1). This pump was connected to a time switch (TS) to allow for the approximation of a continuous feed system by pumping a percentage of each hour. Effluent from the reactors was pumped by a similar type pump (P2) that was actuated by a level controller (LC). The effluent was collected in a holding tank (T1) for additional processing. Gas from the reactors was passed through wet test gas meters (M) for determining gas flow rate. The gas was sampled for gas analysis with a Fisher Gas Partitioner.

2. Feed Preparation

The organic materials used in this process had to be prepared for feed into the system. The initial step was one of size reduction. This was accomplished by a "granulator" manufactured by H. C. Davis Sons, Inc. This unit was equipped with three screens, 6.3 mm, 19 mm, and 39mm. The organic material could be ground to either of these three desired sizes. In order to effectively grind this material it had to be relatively dry. This also assisted in storage of significant quantities of feed material. The dry material did not decompose.

After shredding, a predetermined weight of the feed material was added to the slurry tanks (ST). The dry feed was slurried with the desired amount of water. Either recycled liquor or fresh water could be used in the slurry tanks. After completely wetting the organic material, it was then discharged into mixed holding tanks (HT). This provided for storage of the slurry prior to pumping into the reactors. These mixed tanks also provided for a relative uniform feeding of

material into the reactors since they contained approximately two days supply of feed slurry. These tanks were covered primarily for odor control.

3. Fermentor Operation

The loading rate on the reactors was determined by the concentration of organic solids in the feed slurry and the volume of feed slurry pumped per unit time. The predetermined loading rates were set by controlling the feed slurry concentration and varying the pumping time.

The performance of the fermentation system was analyzed on the basis of gas production. This was augmented with analysis of the reactor contents for total and volatile total solids, pH, alkalinity, and volatile acids. These data provided the basis for calculating the conversion efficiencies and methane yields.

Since each reactor was on an independent mixing system, the mixing power could be varied. This permitted evaluation of the effect of mixing intensity on the methane yields. Also each reactor was on an independent temperature control system so that the fermentation temperature could be varied as desired.

There were only two feed slurry holding tanks so two reactors were fed from each tank. However, by varying the throughput, the loading rate and retention time of each reactor could be varied. This arrangement essentially allowed each reactor to operate independent of the others. Therefore, it was possible to evaluate four operating conditions at one time.

4. Residue Processing and Disposal

The effluent from the reactors was collected in an effluent storage tank (T1). These storage tanks were connected to a progressing cavity pump (P3) that fed the centrifuge. The resulting centrifuge cake was collected for either further processing or disposal by landfill. The centrate was discharged into a holding tank. When centrate recycle was employed this liquor was used to make up the feed slurry. Without recycle this material was allowed to flow to the drain.

Two centrifuges were used. One was a Fletcher Mark III. This was a solid bowl basket centrifuge. This unit had a variable speed drive so that it is possible to evaluate the effect of centrifugal force on solids capture and cake moisture. This unit was augmented with a horizontal solid bowl conveyor centrifuge (Sharples P-600) that could be operated continuously. Larger quantities of slurry could be processed with the continuous unit than with the basket unit.

Provisions were made for applying a thermochemical treatment process for either the residue or the feed material. A mixed reactor capable of withstanding an internal pressure of 8 atm was connected to a steam generator. By adding the fibers to this reactor along with an appropriate amount of caustic and water it was possible to heat treat this material prior to fermentation. This permitted evaluation of the effect of thermochemical pretreatment or posttreatment of the residual solids on the fermentation characteristics.

In addition to the dewatering by centrifugation, the effluent was available for additional tests. This slurry can be dewatered by vacuum filtration and filter test leaf studies were available to evaluate

its filtration characteristics. Also, the quality of the effluent liquid and solids was evaluated with respect to its nutrient value both as a possible refeed material or as a soil additive. These evaluations were made with laboratory analyses rather than having actual field tests.

5. Fermentor Feed Stock

The original proposal specified the application of the methane fermentation process to various crop residues and crops grown specifically for biomass production. The actual substrate to be tested was to be selected in consultation with the research sponsor. After discussion of the Fuels from Biomass Program's activities, it was decided that additional information was needed to complement the research on cattle feed lot manure fermentation. Therefore, manure from the College of Agriculture beef cattle feed lots was obtained for the initial substrate investigation.

The manure, which contained some small quantity of bedding, was scraped from the lots with a front end loader and hauled by truck to the laboratory. The moisture content of the manure varied, being dependent upon the temperature and precipitation. In general, the moisture content was too high to permit passage through the 6.3 mm screen on the mill. A fraction of the pile was spread on the floor to allow for some drying. This was passed through the mill without any screen simply to break up the lumps. This material was respread and additional drying allowed passage through the 6.3 mm screen.

Because of the way in which manure was collected and handled, the large piles were relatively compact. The exposed surface dried quickly. Until the surface dried, there was some aerobic decomposition.

However, the bulk of the pile was anaerobic. With the relatively dry nature of the manure and the high ammonia content, biological activity in the pile was limited. However, repeated handling of the manure did allow for stabilization to occur as will be discussed later.

RESULTS AND DISCUSSION

1. Manure Fermentation

Installation of the fermentation system as previously discussed was completed by October 15, 1976. The installation was delayed for some time due to purchasing problems. Requests for prices for the reactors were placed in early May, 1976. There was a 60-day delay in issuing these requests. With the lead time necessary for fabrication of these tanks, they did not arrive on site until September 3, 1976. A contract modification to include variable speed mixers was made in August, 1976. This required redesign of the mixer drives to allow for variable speed operation. Because of the previous delays in the reactor acquisitions, this modification did not cause any additional delays in start-up.

A. Reactor Start-up

The reactors were filled with tap water and allowed to reach the $58^{\circ}\text{C} \pm 2^{\circ}$ operating temperature prior to October 22, 1976 (Day 76296). On this date, 0.115 m^3 of feed slurry at approximately 1.5 percent solids was added to Reactors 1 through 3. This quantity of feed was added daily. As can be seen in Table 1, the pH of all three units dropped below 6.0. The alkalinity of the reactor slurry was very low. On Day 76304, lime was added to the feed tanks to elevate the pH of the feed slurry to 8.5. The pH of the feed slurry was maintained at this level until the reactor pH increased to 6.6.

On Day 76306 (Nov. 1, 1976) the seal on Reactor 2 was damaged. The air leaking by this seal resulted in a low partial pressure of carbon dioxide which resulted in a higher pH in this unit. The seal on this

Table 1. Variations in pH, Alkalinity and Volatile Acids

Date	Reactor #1			Reactor #2			Reactor #3			Reactor #4		
	pH	Alk ¹	V.A. ²	pH	Alk	V.A.	pH	Alk	V.A.	pH	Alk	V.A.
76 296	7.05	129	-	7.37	129	-	7.35	124	-	-	-	-
300	6.32	-	-	6.49	-	-	6.58	-	-	-	-	-
301	5.80	-	-	5.90	-	-	6.30	-	-	-	-	-
302	5.80	319	-	5.90	520	-	6.10	263	-	-	-	-
303	6.72	376	228	6.54	551	192	6.30	324	216	-	-	-
305	5.90	-	-	6.35	-	-	5.90	-	-	-	-	-
306	6.45	-	-	6.90	-	-	6.30	-	-	-	-	-
307	6.30	530	204	6.80	716	264	6.05	592	360	-	-	-
308	6.60	-	-	7.15	-	-	6.20	-	-	-	-	-
309	6.85	422	96	7.35	566	72	6.25	644	192	-	-	-
311	6.70	-	-	6.90	-	-	6.65	-	-	-	-	-
313	6.90	876	192	6.95	1063	288	6.85	891	204	-	-	-
314	6.92	-	-	6.97	-	-	6.79	-	-	-	-	-
316	6.86	1452	-	6.95	1401	-	6.82	1045	-	-	-	-
317	6.95	1421	-	-	-	-	6.90	1164	-	-	-	-
321	6.97	1700	288	6.89	1694	216	6.89	1617	216	-	-	-
323	7.05	2173	336	7.05	2070	240	7.00	2045	197	-	-	-
324	7.00	2070	-	6.95	2199	-	7.10	2366	-	6.95	1931	-
327	7.15	2938	120	7.20	2910	192	7.10	2706	168	7.20	2434	144
328	7.20	3182	-	7.10	3142	-	7.10	3006	-	6.95	2557	-
329	7.22	-	264	7.22	-	144	7.27	-	144	7.18	-	144
330	7.25	-	-	7.22	-	-	7.36	-	-	7.14	-	-
331	7.30	3903	-	7.30	3917	-	7.30	3495	-	7.30	3373	-
332	7.27	4053	120	7.23	4066	216	7.26	3563	216	7.20	3468	264
334	7.20	-	-	7.25	-	-	7.35	-	-	7.40	-	-
335	7.40	4855	-	7.20	4746	-	7.35	4720	-	7.32	4610	-
337	7.20	4869	-	7.25	4896	-	7.25	4461	-	7.25	4502	-
338	7.30	4836	120	7.25	4876	144	7.20	4243	192	7.25	4420	216
339	7.25	-	-	7.20	-	-	7.30	-	-	7.20	-	-

¹mg/l as CaCO₃

²mg/l as acetic acid

unit was replaced and by Day 76316 the pH in all reactors was in an acceptable range. The alkalinity was approximately 900 mg/l and the gas production was increasing. It appeared that a reasonable population of methane bacteria was established since the volatile acids measured less than 400 mg/l in all units.

On Day 76315 the manure was increased to 45 kg per 0.2 m³ of slurry resulting in an increase in the feed slurry solids concentration. The feed rate was set for 0.06 m³ per day to produce a 13.3-day retention time. The actual feed volume varied between .06 to .08 m³ resulting in a retention time between 9.7 and 13 days. With an operating volume of 0.775 m³, the initial solids loading was approximately 0.64 kg VS/m³ day.

The reactors reached an apparent operating equilibrium in mid-November (Day 76320). Because of the variable nature of the feed slurry quantity and concentration, a true equilibrium was not established. It was not possible to obtain representative solids data on the reactor contents due to the difficulty in sampling. This was a continuing problem throughout the study. Several sampling techniques were tried, but none was totally satisfactory until the procedure instituted in May 1977. Solids data for the reactors are reported in Appendix A. However, these data up to Day 77140 may not be accurate.

The sampling technique used consisted of withdrawing approximately one liter of slurry directly from the reactor. This technique provided a representative sample of the reactor contents. However, it was still not possible to obtain a solids balance on the system. A check on the technique employed in sampling the mix tank showed that

the solids concentration measured at the bottom of the tank was as much as 20 to 30 percent greater than at the top of the tank. Because of the inability to obtain representative samples from the top of the tank, a sampling port was inserted at one-third the tank depth. Solids loading and gas production data have been adjusted to account for this sampling error.

The volatile solids loading and gas production during start-up are shown in Table 2. Gas leaks in Reactors 3 and 4 made it impossible to obtain consistent gas readings. However, Reactors 1 and 2 were gas tight and the gas data show a significant conversion of organics to gas. For the period shown in Table 2, Reactors 1 and 2, respectively, produced 0.346 and 0.389 m³ of gas per kg of volatile solids fed. One set of gas analyses showed that the gas from each reactor was 58 percent methane and 42 percent carbon dioxide.

B. Gas Production Rates

After the initial shakedown-period, the loading rate, temperature and retention time was specified for each reactor. In general, Reactor 1 served as a control. It was operated at 58°C, a nominal retention time of 9 days, a moderate solids loading.

This operational pattern was continued until Day 77268. All reactors were operated successfully until the end of December 1976. The manure obtained prior to this time was completely free of bedding. During wet periods, some bedding is added to the pens to reduce the effect of the wet conditions on the animals in each pen. An unusually dry fall accounted for the total absence of bedding in the manure

Table 2. Gas Production Rates
(Nov. 16 through Dec. 3, 1976)

Date	Reactor #1			Reactor #2			Reactor #3			Reactor #4		
	kg VS	Gas Prod.		kg VS	Gas Prod.		kg VS	Gas Prod.		kg VS	Gas Prod.	
	day	ℓ/d	m ³ /kg VS	day	ℓ/d	m ³ /kg VS	day	ℓ/d	m ³ /kg VS	day	ℓ/d	m ³ /kg VS
76321	-	-	-	-	-	-	-	-	-	-	-	-
322	1.52	515	0.339	1.14	665	0.583	2.06	480	-	-	-	-
323	1.36	462	0.339	1.70	780	0.459	1.82	*	-	-	10 ¹	-
324	1.82	775	0.426	1.21	747	0.617	3.90	*	-	-	193	-
325	1.29	938	0.727	1.14	676	0.593	1.82	*	-	1.82	482	0.265
326	1.29	516	0.400	0.83	431	0.519	0	*	-	0	390	-
327	0.99	587	0.592	1.44	621	0.431	2.42	*	-	2.42	501	0.207
328	3.00	1001	0.334	3.00	1138	0.379	2.06	*	-	1.82	559	0.307
329	4.94	1195	0.242	6.52	1836	0.282	2.26	*	-	2.11	622	0.314
330	3.50	881	0.252	3.18	1094	0.344	2.86	730	-	2.56	713	0.279
331	2.57	713	0.277	2.28	898	0.394	1.63	*	-	3.25	653	0.201
332	2.85	936	0.328	2.85	1066	0.374	2.00	730	-	1.88	662	0.352
333	3.26	926	0.284	3.26	1082	0.332	2.07	*	-	2.00	542	0.271
334	3.45	1121	0.325	3.45	994	0.288	2.40	*	-	2.27	590	0.260
335	3.05	497	0.163	4.27	998	0.234	2.00	*	-	2.13	621	0.292
336	2.41	620	0.257	3.00	597	0.199	2.56	*	-	2.94	*	-
337	0	739	-	0	1063	-	0	*	-	0	*	-
338	4.76	797	0.167	6.00	1190	0.198	2.76	*	-	2.76	873	0.316

* Gas leak due to mixer seal problems.

¹ Started operation of #4.

obtained during this period. Since it was unnecessary to reduce the particle size of the manure, the mill was not purchased initially.

When additional manure was obtained in November 1976, it contained a small quantity of straw. It was necessary to chop this manure before it could be used. A mill was ordered, but due to purchasing delays and unusual weather conditions, it did not arrive until mid January 1977. During the interim, frozen dairy manure was used as feedstock. Starting on Day 76348, this was the feed for all four reactors. This manure was exhausted by the beginning of January 1977. At this time feed was discontinued in all units. Extreme weather conditions delayed installation of the mill until the first week of February 1977 (77035). At this time the reactors were restarted and were in equilibrium by 77060.

After about five weeks of operation, severe problems developed with the slurry withdrawal system. Due to the nature of the slurry, it was not possible to obtain gravity flow from the reactors. As soon as flow stopped, the effluent pipe clogged completely. Semi-continuous feeding was impossible. It was necessary to install effluent pumps on the reactors to remove the slurry. Also during this period, excessive foaming developed in the higher loaded reactors. This was a result of the batch feeding necessary since the slurry would not drain from the reactors by gravity. The effluent pumps were installed during this shut down period and the reactors restarted, reaching equilibrium conditions by Day 77140.

Operation was reasonably successful for the balance of the test period. A frequent problem was encountered with grit in the pumps and pipes. When the manure was scraped from the lot, crushed limestone was also picked up with the manure. When passed through the mill, the majority of this rock was broken into small particles that were not effectively removed in the slurry tank. On occasion, the quantity of grit was sufficient to plug the feed lines. This disrupted the feeding schedule and resulted in fluctuations in the data.

In order to reduce the fluctuations in the data, gas composition and gas production data are presented as the average of seven days. The data collected on a daily basis was entered into a data storage program. This program was used to calculate the loading rates and gas production rates. The raw data are given in the Appendix A.

The gas production data, loading rates and retention time data for Reactor 1 are given in Table 3. This reactor operated at $58 \pm 2^\circ\text{C}$ throughout the test period. This reactor initially had a moderate loading rate of 3 to 4 kg of volatile solids per m^3 per day (0.19 to 0.25 lb/cu ft day). This rate was doubled about halfway through the test period.

The average gas production data for 7 day periods was relatively consistent for a given manure. There was significant variation in the gas production resulting from variations in manure characteristics. For example, the addition of the frozen fresh dairy manure on Day 76248 resulted in a two fold increase in gas production over the previous manure. When fresh manure was fed on Day 77156, gas production again increased substantially. However, there was a steady decrease in gas

Table 3. Average Weekly Gas Production Date - Reactor 1

Week Ending	θ Days	Gas LPH	CH ₄ %	Gas Production m ³ /kg V.S. Fed Kg	Loading V.S./m ³ -Day
76326	11.5	21.6	(60)	0.387	1.73
333	10.8	28.6	(60)	0.191	4.63
340	12.0	30.3	(60)	0.281	3.34
347	7.8	33.8	(60)	0.220	4.76
354	8.0	65.9	(60)	0.450	4.53
361	7.3	59.2	(60)	0.419	4.37
77066	9.3	41.5	(60)	0.327	3.94
073	11.6	32.2	(60)	0.312	3.20
080	9.9	(19.9)	(60)	-	3.51
087	9.4	29.4	(60)	0.268	3.39
094	9.4	27.6	(60)	0.261	3.28
148	9.3	20.9	(60)	0.204	3.17
155	9.2	22.2	(60)	0.223	3.08
162	9.3	42.8	60.1	0.411	3.23
169	9.4	53.7	65.4	0.398	4.18
176	9.2	53.4	62.0	0.400	4.13
183	8.6	53.8	62.0	0.247	4.75
190	9.1	36.8	61.3	0.216	6.25
197	9.3	56.4	62.7	0.289	5.05
204	9.3	55.8	62.2	0.270	6.40
211	9.2	50.9	61.2	0.256	6.15
218	10.9	48.2	56.9	0.240	6.21
225	9.1	43.1	61.1	0.214	6.25
232	8.9	47.9	66.1	0.206	7.19
239	8.8	49.9	63.8	0.213	7.26
246	8.7	37.3	63.0	0.171	6.74
253	8.8	(14.1)	56.9	-	5.43

Table 3 - Continued

Week Ending	θ Days	Gas LPH	CH ₄ %	Gas Production m ³ /kg V.S. Fed	Loading Kg V.S./m ³ -Day
260	8.8	(13.3)	53.1	-	5.08
267	5.0	34.8	63.7	0.196	5.50
274 ¹	4.6	21.6	61.4	0.092	7.26
281	4.7	12.8	63.5	0.031	6.36
288	4.6	7.6	66.0	0.061	7.48
295 ²	7.9	11.4	61.4	0.084	4.19
302	7.5	16.9	59.7	0.095	5.48
309	7.3	19.1	55.8	0.102	5.81
316	(7.0)	22.8	54.2	0.119	5.95
323	8.4	26.7	50.6	0.198	4.18
330	7.5	59.5	51.7	0.231	7.96

¹Start feed of digested residue

²Start feed of raw manure

production during the following weeks. By the time a new batch of manure was obtained on Day 77190, the gas production decreased from approximately $0.4 \text{ m}^3/\text{kg V.S. fed}$ to about $0.22 \text{ m}^3/\text{kg V.S. fed}$. The same pattern was exhibited when fresh manure was fed on Day 77197.

This reduction in gas yield is closely correlated with the quality of the manure. The manure was exposed to aerobic stabilization while on the feed lot. Precipitation not only accelerates the biological activity, but also can result in the leaching of organics from the manure. In addition, the handling, storage and preparation of the manure prior to adding to the fermentation system resulted in a loss of biodegradable organics.

The range of operating parameters for Reactor 1 for each week is given in Table 4. The pH was always greater than 7.0. The total volatile acids were generally less than $500 \text{ mg}/\ell$ as acetic acid. The only exception was during the period of Day 76246 to about Day 76274. Prior to this period, the pH was 7.9 to 8.1 with alkalinities of approximately $5.0 \text{ g}/\ell$. The volatile acids reach a high of $1,670 \text{ mg}/\ell$.

The initial methane composition was set at 60 percent. The gas chromatograph did not become operational until the week ending with Day 77162. Prior to that date, one set of gas analysis was conducted on the gas from each reactor. This analysis showed that the gas from each reactor contained 58 percent methane and 42 percent carbon dioxide. The values of 60 percent given in Table 3 are simply so the computer program had a number to use when calculating the methane production.

In order to evaluate the effect, if any, of a mild thermo-chemical treatment step on increased gas yield, a series of tests employing both dewatered fermentor residue and raw manure was undertaken.

Table 4. Operating Parameters - Reactor 1

Week Ending	θ Day	pH Range	Alkalinity Range - g/l	Volatile Acid Range - g/l
76326	11.5	7.0-7.1	1.7-2.2	0.29-0.34
333	10.8	7.2-7.3	2.9-4.1	0.12-0.26
340	12.0	7.2-7.4	4.8-4.9	0.12
347	7.8	7.2-7.3	5.4-5.8	0.17-0.29
354	8.0	7.2-7.3	6.5-7.0	0.29
361	7.3	7.2-7.3	6.8	0.14
77066	9.3	7.1-7.4	4.7-5.2	0.17-0.31
073	11.6	7.3-7.4	4.1-5.8	0.19-0.22
080	9.9	7.1-7.3	4.0-4.7	0.22-0.67
087	9.4	7.2-7.4	3.9-4.3	0.29-0.38
094	9.4	7.3-7.4	4.0-4.1	0.34-0.60
148	9.3	7.1-7.2	2.2-2.5	0.14-0.22
155	9.2	7.2-7.3	2.3-2.5	0.07-0.17
162	9.3	7.0-7.3	2.3-3.0	0.29-0.53
169	9.4	7.0-7.5	3.0-3.7	0.17-0.62
176	9.2	7.5-7.7	3.6-4.5	0.17-0.41
183	8.6	7.3-7.7	4.3-4.6	0.24-0.50
190	9.1	7.6-7.7	4.2-5.0	0.14-0.29
197	9.3	7.6-7.7	4.3-5.0	0.14-0.53
204	9.3	7.6-7.8	4.4-5.0	0.26-0.29
211	9.2	7.6-7.7	4.6-5.5	0.17-0.26
218	10.9	7.5-7.9	4.5-4.8	0.24-0.53
225	9.1	7.5-7.9	4.8-5.1	0.17-0.53
232	8.9	7.9-8.0	4.4-5.3	0.10-0.38
239	8.8	7.9-8.1	4.4-4.8	0.05-0.29
246	8.7	7.9-8.1	4.6-5.2	0.07-0.31
253	8.8	7.5-7.9	3.7-4.3	0.36-1.34

Table 4 - Continued

Week Ending	θ Day	pH Range	Alkalinity Range - g/l	Volatile Acids Range - g/l
260	8.8	7.4-7.6	3.3-4.0	0.36-1.05
267	5.0	7.2-7.5	2.6-2.8	0.22-1.33
274	4.6	7.2-7.5	2.2-2.7	0.22-1.67
281	4.7	7.2-7.6	1.3-1.9	0.02-0.10
288	4.7	7.2-7.3	1.2-1.4	0.05-0.12
295	4.9	7.2-7.3	1.5-2.1	0.02-0.10
302	7.5	7.2-7.4	2.3-3.2	0.05-0.12
309	7.3	7.4-7.6	3.0-3.4	0.05-0.12
316	7.0	7.4-7.5	3.0-3.1	0.05-0.10
323	8.4	7.4-7.5	2.7-3.0	0.07-0.14
330	7.5	7.4-7.4	2.9-3.4	0.12-0.48

On Day 77268, the feed to Reactor 1 was the dewatered residual solids. With a retention time of 5 days, gas production dropped to very low levels. On Day 77289, raw manure was again used in the feed for Reactor 1. There was a significant increase in gas production. During the week ending with Day 77316, the manure supply was exhausted. Reactor 1 did not receive any feed for 5 days. An additional load of manure was obtained in order to collect some additional data on the thermochemical pretreatment.

The summary of the gas production data and loading rates for Reactor 2 is given in Table 5. The operating parameters are shown in Table 6. This reactor was subjected to various loading rates and retention times. The same manure used for Reactor 1 was also fed to Reactor 2. This reactor responded normally even at retention times as low as 3.0 days and loadings $16.65 \text{ kg V.S./m}^3\text{-day}$ ($1.0 \text{ lb/ft}^3\text{-day}$). This high loading rate was not maintained due to temperature control problems during the period from Day 77184 to 77190. The temperature dropped to 50°C two days in succession. As shown in Table 6, the volatile acids increased to greater than 4000 mg/l with the pH decreasing to 6.5. During this period, excessive foaming was experienced. The foam filled the gas handling system, voiding any gas readings obtained.

A reduction in loading during the week ending with Day 77197 did not result in system recovery. The volatile acids increased to 7.26 g/l and the pH decreased to 6.2. At the end of this week, the temperature control malfunctioned again. The temperature in Reactor 2 reached 71°C and the gas production dropped to 0 l/hr . The reactor was reseeded with effluent from Reactor 3 and brought back on line.

Table 5. Average Weekly Gas Production Data - Reactor 2

Week Ending	θ Days	Gas LPH	CH ₄ %	Gas Production m ³ /kg V.S. Fed	Loading Kg V.S./m ³ -Day
76326	12.7	16.0	(60)	0.312	1.59
333	11.3	23.1	(60)	0.195	3.68
340	10.2	23.4	(60)	0.198	3.66
347	7.9	32.7	(60)	0.213	4.76
354	8.3	55.2	(60)	0.366	4.67
361	7.7	59.1	(60)	0.404	4.53
77002	8.8	71.1	(60)	0.511	4.31
066	7.0	43.3	(60)	0.271	4.95
073	6.2	40.1	(60)	0.261	4.76
080	6.9	39.7	(60)	0.239	5.15
087	6.3	32.0	(60)	0.226	5.07
094	6.0	29.6	(60)	0.188	4.88
148	3.7	30.9	(60)	0.120	7.94
155	3.7	35.5	(60)	0.145	7.59
162	3.8	73.4	61.4	0.287	7.91
169	3.8	98.2	63.3	0.293	10.36
176	3.7	98.8	60.8	0.302	10.14
183	3.0	109.0	62.0	0.203	16.65
190	3.8	(59.5)	55.0	-	16.74
197	7.4	(17.9)	53.1	-	5.06
204	11.1	54.8	61.3	0.295	5.75
211	8.9	47.3	60.0	0.254	5.77
218	9.2	43.1	60.2	0.218	6.13
225	7.6	41.5	60.7	0.153	8.41
232	5.0	36.8	62.4	0.096	11.85
239	8.7	29.2	62.2	0.153	5.90
246	4.9	37.5	61.2	0.102	11.42

Table 5 - Continued

Week Ending	θ Days	Gas LPH	CH ₄ %	Gas Production m ³ /kg V.S. Fed	Loading Kg V.S./m ³ -Day
253	4.7	28.5	64.7	0.087	10.12
260	4.5	37.3	62.5	0.108	10.70
267	5.6	-	59.2	-	8.04
274 ¹	4.7	16.4	70.3	0.074	6.86
281	4.9	4.1	77.4	0.023	5.55
288	4.6	3.9	84.6	0.020	6.19
295 ²	12.2	15.8	78.9	0.083	5.88
302	7.5	23.9	61.8	0.112	6.62
309	6.9	35.2	56.9	0.144	7.59
316	(7.5)	32.1	55.2	0.166	3.60
323	10.5	22.8	52.6	0.185	3.82
330	7.6	58.0	53.0	0.244	7.35

¹Start feed of digested residue - caustic pretreatment

²Start feed of raw manure - caustic pretreatment

Table 6 Operating Parameters - Reactor 2

Week Ending	Θ Day	pH Range	Alkalinity Range - g/l	Volatile Acid Range - g/l
76 326	12.7	6.9 - 7.1	1.7 - 2.2	0.22 - 0.24
333	11.3	7.1 - 7.3	2.9 - 4.1	0.14 - 0.22
340	10.2	7.2 - 7.3	4.7 - 4.9	0.14
347	7.9	7.2 - 7.3	5.4 - 6.5	0.12
354	8.3	7.2 - 7.3	5.9 - 6.2	0.31
361	7.7	7.2 - 7.5	5.1 - 6.5	0.14
77 002	8.8	7.3 - 7.4	6.4 - 6.5	0.12
066	7.0	7.1 - 7.3	4.8 - 5.3	0.34 - 0.50
073	6.2	7.1 - 7.4	3.9 - 5.4	0.17 - 0.55
080	6.9	7.1 - 7.2	4.0 - 4.5	0.17 - 0.50
087	6.3	7.2 - 7.3	3.8 - 4.2	0.29 - 0.70
094	6.0	7.2 - 7.3	3.6	0.86
148	3.7	7.0 - 7.1	2.1 - 2.3	0.14 - 0.22
155	3.7	7.1 - 7.2	2.2 - 2.5	0.07 - 0.19
162	3.8	6.8 - 7.2	2.4 - 3.0	0.50 - 1.08
169	3.8	6.9 - 7.5	3.0 - 3.7	0.38 - 1.32
176	3.7	7.4 - 7.7	3.8 - 5.1	0.31 - 1.15
183	3.0	7.2 - 7.7	4.1 - 4.4	0.22 - 1.32
190	3.8	6.5 - 7.7	3.1 - 3.8	0.89 - 4.03
197	7.4	6.2 - 6.5	3.0 - 3.4	1.86 - 7.26
204	11.1	7.5 - 7.8	4.3 - 4.9	0.30 - 1.56
211	8.9	7.6 - 7.8	4.8 - 5.5	0.19 - 0.46
218	9.2	7.5 - 7.8	4.4 - 4.7	0.26 - 0.78

Table 6 - Continued

Week Ending	Ø Day	pH Range	Alkalinity Range - g/l	Volatile Acid Range - g/l
225	7.6	7.5 - 7.8	4.1 - 4.6	0.34 - 1.15
232	5.0	7.4 - 8.0	4.5 - 4.8	0.48 - 1.26
246	8.7	7.6 - 7.8	3.8 - 4.1	0.96 - 1.32
253	4.9	7.3 - 7.7	3.5 - 4.5	0.22 - 0.54
260	4.7	7.2 - 7.2	2.9 - 3.1	0.07 - 0.34
267	4.5	7.4 - 7.6	2.5 - 3.0	0.22 - 0.48
274	5.6	7.4 - 7.7	1.8 - 2.1	0.02 - 0.22
281	4.7	7.7 - 7.9	1.6 - 1.9	0.05 - 0.07
288	4.9	7.5 - 7.9	1.7 - 2.0	0.02 - 0.14
295	12.2	7.5 - 7.8	1.8 - 3.2	0.05 - 0.22
302	7.5	7.5 - 7.7	4.0 - 4.2	0.12 - 0.38
309	6.9	7.5 - 7.7	3.7 - 5.0	0.10 - 0.34
316	7.5	7.5 - 7.6	3.8 - 4.4	0.05 - 0.34
323	10.5	7.4 - 7.6	3.7 - 4.3	0.26 - 0.74
330	7.6	7.4 - 7.5	3.9 - 4.1	----

This reactor continued to operate at the thermophilic temperature until Day 77219 when the temperature was reduced to 40°C. Data were collected on mesophilic digestion until Day 77261. The temperature was increased to 58°C and dewatered fermented residue that was thermochemically treated was the feed. This residue was mixed with 3 g of lime per 100 g dry solids and heated to 110°C for two hours. The gas production decreased to exceptionally low levels. On Day 77289, raw manure was subjected to this pretreatment and used as feed for Reactor 2.

The gas production data and loading rates for Reactor 3 are given in Table 7. The operating parameters for this reactor are given in Table 8. Reactor 3 received the same manure as Reactor 1 except during the thermochemical treatment tests when raw manure was fed to Reactor 3.

This reactor responded normally until an attempt was made to apply a high loading rate. On Day 77177, the feed solids concentration was increased to 10 percent. With an initial retention time of 6 to 7 days, the volatile acids increased to almost 6.0 g/l. Excessive foaming developed and the gas handling equipment was frequently filled with foam. During the week ending on Day 77204, the foaming was so intense that it was not possible to obtain any gas readings. Because of this problem with foam, the feed solids concentration was reduced to 5 percent and the loading reduced. On Day 77219 the temperature was reduced to 40°C for the balance of the study.

The system functioned normally during this period. A gas leak developed during the week ending with Day 77267, resulting in excessively low gas production rates for this week.

Table 7 Average Weekly Gas Production Data - Reactor 3

Week Ending	θ Days	Gas LPH	CH ₄ %	Gas Production m ³ /kg V.S. Fed	Loading kg V.S./m ³ Day
76 326	12.7	----	(60)	-----	2.55
333	12.7	----	(60)	-----	2.55
340	12.6	----	(60)	-----	2.79
347	7.7	32.6	(60)	0.232	4.35
354	8.5	50.9	(60)	0.385	4.09
361	7.8	61.1	(60)	0.443	4.27
77 002	9.3	48.0	(60)	0.346	4.30
066	7.0	47.6	(60)	0.291	5.06
073	6.3	41.2	(60)	0.254	5.02
080	6.1	48.3	(60)	0.307	4.86
087	6.1	31.5	(60)	0.192	5.07
148	4.6	28.5	(60)	0.133	6.62
155	4.7	31.8	(60)	0.165	5.97
162	4.7	60.9	62.9	0.311	6.06
169	4.7	81.0	64.7	0.316	7.94
176	4.7	93.6	63.9	0.357	8.06
183	6.5	70.5	55.0	0.161	13.5
190	7.5	63.1	58.9	0.162	12.1
197	4.9	99.3	61.9	0.163	18.8
204	4.9	----	59.2	-----	19.3
211	5.9	71.6	55.6	0.150	14.8
218	6.1	80.2	55.7	0.169	14.7
225	9.0	62.1	60.4	0.223	8.6

Table 7 - Continued

Week Ending	Θ Days	Gas LPH	CH ₄ %	Gas Production m ³ /kg V.S. Fed	Loading kg V.S./m ³ Day
232	9.4	35.0	63.2	0.166	6.52
239	8.9	37.0	62.2	0.170	6.72
246	8.8	42.6	64.0	0.172	7.63
253	9.2	48.4	64.0	0.178	8.36
260	9.3	57.3	54.1	0.251	7.08
267	9.3	(14.6)	68.7	-----	4.62
274	9.7	22.6	67.3	0.166	4.19
281	9.3	20.9	57.1	0.158	4.12
288	9.3	16.1	62.8	0.110	4.68
295	9.0	17.3	59.3	0.116	4.61
302	13.1	13.9	57.1	0.135	3.16
309	14.3	10.9	56.3	0.137	2.48
316	14.2	12.0	53.0	0.143	2.57

Table 8 Operating Parameters - Reactor 3

Week Ending	Θ Day	pH Range	Alkalinity Range - g/l	Volatile Acid Range - g/l
76 326	12.7	6.9 - 7.1	1.6 - 2.4	0.20 - 0.22
333	12.7	7.1 - 7.4	2.7 - 3.6	0.14 - 0.22
340	12.6	7.2 - 7.4	4.3 - 4.5	0.19
347	7.7	7.2 - 7.4	5.0 - 5.2	0.14 - 0.22
354	8.5	7.2 - 7.5	5.8 - 6.0	0.38
361	7.8	7.2 - 7.5	5.8 - 6.3	0.14
77 002	9.3	7.1 - 7.4	5.7 - 5.8	0.29
066	7.0	7.1 - 7.4	5.1 - 5.9	0.17 - 0.26
073	6.3	7.2 - 7.4	4.2 - 5.1	0.24 - 0.53
080	6.1	7.1 - 7.2	3.9 - 4.0	0.31 - 0.38
087	6.1	7.3 - 7.4	3.6 - 3.8	0.32 - 0.46
148	4.6	7.1 - 7.2	2.0 - 2.7	0.17 - 0.22
155	4.7	7.2 - 7.3	2.0 - 2.3	0.17 - 0.26
162	4.7	6.8 - 7.3	2.4 - 2.8	0.17 - 0.91
169	4.7	7.1 - 7.6	3.0 - 4.0	0.29 - 0.77
176	4.7	7.6 - 7.8	4.1 - 4.7	0.31 - 1.01
183	6.5	7.3 - 7.9	4.8 - 5.4	0.53 - 5.94
190	7.5	7.6 - 7.9	6.3 - 6.9	0.66 - 3.90
197	4.9	7.6 - 7.8	6.3 - 6.9	2.40 - 2.76
204	4.9	7.7 - 7.9	6.8 - 7.9	0.78 - 1.98
211	5.9	7.7 - 7.9	6.5 - 9.1	0.72 - 3.36
218	6.1	7.5 - 8.0	6.7 - 7.1	0.60 - 1.68
225	9.0	7.8 - 7.9	6.9 - 7.0	0.12 - 0.67

Table 8 - Continued

Week Ending	⊙ Day	pH Range	Alkalinity Range - g/l	Volatile Acid Range - g/l
232	9.4	7.6 - 7.8	5.2 - 6.1	0.89 - 1.32
239	8.9	7.4 - 7.6	4.3 - 5.2	1.62 - 3.65
246	8.8	7.6 - 7.8	4.3 - 4.9	0.34 - 1.32
253	9.2	7.7 - 7.8	4.2 - 5.2	0.10 - 0.26
260	9.3	7.3 - 7.6	3.5 - 4.4	0.05 - 0.19
267	9.3	7.4 - 7.5	3.3 - 4.0	0.24 - 0.41
274	9.7	7.4 - 7.5	3.1 - 3.3	0.05 - 0.22
281	9.3	7.3 - 7.6	3.3 - 3.5	0.05 - 0.26
288	9.3	7.4 - 7.5	3.2 - 3.6	0.05 - 0.12
295	9.0	7.2 - 7.3	3.3 - 3.5	0.07 - 0.12
302	13.1	7.2 - 7.3	2.7 - 2.9	0.05 - 0.12
309	14.3	7.2 - 7.3	2.7 - 2.9	0.05 - 0.16
316	14.2	7.0 - 7.3	2.4 - 2.8	0.02 - 0.07

The gas production data and loading rates for Reactor 4 are given in Table 9. The operating parameters for this reactor are given in Table 10. Reactor 4 was subjected to the same feed slurry as Reactor 3. Gas leaks were encountered during the period from 77177 to 77190. The gas production data are in error. This reactor responded reasonably well to high loadings of 20 kg V.S./m³-day (1.25 lb/ft³-day). Gas production was good. The pH and volatile acids were within acceptable ranges. On Day 77219, the temperature was reduced to 40°C for the balance of the study.

Gas production data from Day 77240 to 274 were in error due to gas leaks. The source of the leak could not be found for several weeks. It was finally corrected by adjusting the mixer seal.

C. Fermentation Kinetics

The gas production data collected at the various retention times can be used to determine the fermentation kinetics at 58°C and 40°C. The gas production data expressed as m³ per kg volatile solids added are shown in Figures 4 and 5 as a function of retention time. These data show an extremely wide variation in gas production for given retention times, especially for the 58°C fermentation temperature. This wide variation was caused by changes in the quality of the manure fed to the reactors.

In order to obtain a rate constant for this fermentation, it is necessary to obtain an estimate of the original biodegradable substrate level. The volatile solids as such do not reflect the level of biodegradable organics. The initial substrate level can be estimated

Table 9 Average Weekly Gas Production Data - Reactor 4

Week Ending	Θ Days	Gas LPH	CH ₄ %	Gas Production m ³ /kg V. S. Fed	Loading kg V.S./m ³ Day
76 333	12.1	39.2	(60)	0.384	3.16
340	12.2	23.4	(60)	0.246	2.94
347	7.6	35.2	(60)	0.251	4.35
354	7.9	49.8	(60)	0.346	4.45
361	6.9	60.2	(60)	0.348	5.35
77 002	8.5	70.7	(60)	0.471	4.65
066	6.8	41.8	(60)	0.253	5.10
073	---	----	----	-----	----
148	6.3	27.5	(60)	0.175	4.88
155	6.2	27.2	(60)	0.185	4.55
162	6.2	55.4	60.4	0.368	4.66
169	6.2	74.6	56.6	0.386	5.99
176	6.2	78.0	62.7	0.400	6.04
183	5.9	(79.7)	61.0	-----	14.90
190	8.2	(34.1)	60.7	-----	9.78
197	5.1	100.7	61.2	0.176	17.70
204	4.8	95.0	58.7	0.162	18.10
211	4.5	123.7	58.8	0.190	20.10
218	5.4	78.8	57.6	0.153	15.90
225	11.9	48.6	63.8	0.187	8.10
232	14.0	31.6	64.7	0.220	4.44
239	14.6	30.9	63.3	0.225	4.25
246	14.1	(20.1)	61.1	-----	4.86
253	14.3	(14.1)	61.4	-----	5.60

-35-
Table 9 - Continued

Week Ending	Θ Days	Gas LHP	CH ₄ %	Gas Production m ³ /kg V. S. Fed	Loading kg V.S./m ³ Day
260	14.0	(16.0)	55.3	-----	4.37
267	13.0	(17.7)	57.7	-----	4.14
274	4.6	22.2	65.0	0.109	6.31
281	4.7	25.7	61.6	0.113	7.05
288	6.2	19.8	64.0	0.109	5.64
295	14.6	12.2	58.7	0.143	2.63
302	10.0	15.0	57.9	0.181	2.55

Table 10 Operating Parameters - Reactor 4

Week Ending	θ Days	pH Range	Alkalinity Range - g/l	Volatile Acid Range - g/l
76 333	12.1	7.0 - 7.3	2.4 - 3.5	0.14 - 0.26
340	12.2	7.2 - 7.4	4.4 - 4.6	0.22
347	7.6	7.2 - 7.3	4.9 - 5.6	0.12 - 0.14
354	7.9	7.2 - 7.3	6.1 - 6.3	0.35
361	6.9	7.2 - 7.5	6.1 - 6.2	0.12
77 002	8.5	7.3 - 7.4	6.2 - 6.4	0.12
066	6.8	6.9 - 7.4	3.9 - 6.3	0.67 - 3.00
073	---	6.8 - 6.9	4.5 - 4.7	3.30 - 3.70
148	6.3	7.0 - 7.2	2.0 - 2.4	0.12 - 0.22
155	6.2	7.2 - 7.5	2.4 - 2.5	0.17 - 0.26
162	6.2	6.9 - 7.2	2.5 - 2.8	0.24 - 0.79
169	6.2	7.0 - 7.5	3.0 - 3.9	0.34 - 0.70
176	6.2	7.5 - 7.7	4.2 - 4.9	0.26 - 0.72
183	5.9	7.8 - 8.0	4.7 - 6.3	0.40 - 0.70
190	8.2	7.7 - 7.8	6.3 - 8.1	0.36 - 2.76
197	5.1	7.8 - 8.0	7.0 - 8.6	0.18 - 1.08
204	4.8	7.8 - 8.0	7.0 - 8.5	0.24 - 0.72
211	4.5	7.6 - 8.0	6.8 - 9.9	0.43 - 0.96
218	5.4	7.6 - 8.0	6.7 - 7.8	0.36 - 1.10
225	11.9	7.8 - 7.9	6.3 - 8.1	0.31 - 0.62
232	14.0	7.7 - 7.9	5.7 - 6.3	0.48 - 0.84
239	14.6	7.7 - 7.8	5.1 - 6.0	0.19 - 0.60
246	14.1	7.7 - 7.9	4.6 - 5.8	0.10 - 0.26
253	14.3	7.7 - 7.8	5.1 - 6.0	0.07 - 0.26

Table 10 - Continued

Week Ending	Θ Day	pH Range	Alkalinity Range - g/l	Volatile Acid Range - g/l
260	14.0	7.3 - 7.5	3.8 - 4.8	0.02 - 0.10
267	13.0	7.3 - 7.5	3.6 - 3.9	0.07 - 0.10
274	4.6	7.2 - 7.4	2.5 - 3.8	0.02 - 0.36
281	4.7	7.3 - 7.6	3.2 - 3.5	0.02 - 0.19
288	6.2	7.2 - 7.2	3.1 - 3.2	0.12 - 0.17
295	14.6	7.2 - 7.3	3.0 - 3.4	0.07 - 0.19
302	10.0	7.2 - 7.3	2.7 - 3.1	0.07 - 0.10

Figure 4. Thermophilic Gas Production

Figure 5. Mesophilic Gas Production

by plotting the log of the gas production against the reciprocal of the retention time. The y-axis intercept represents the level of gas production at infinite retention time.

The data shown in Table 11 were used to estimate the initial level of biodegradable organics. These data were taken from Figures 4 and 5 and represent the maximum and minimum gas production levels. After the above graphical analysis was completed, the value for the initial substrate level was then slightly adjusted so the following equation plotted as a straight line was an intercept of 1.0.

$$\frac{S_o}{S_e} = k\theta + 1$$

- where S_o = Initial substrate level
 S_e = Final substrate level
 θ = Fermenter retention time
 k = Rate constant

Table 11. Evaluation of the Rate Constant

θ Days	$\frac{1}{\theta}$	40°C		58°C	
		Gas - m ³ /kg Min	V.S. Fed Max	Gas - m ³ /kg. Min	V.S. Fed Max
3	0.33	0.059	0.090	0.111	0.260
4	0.25	0.070	0.107	0.130	0.320
6	0.17	0.090	0.137	0.160	0.390
8	0.125	0.105	0.162	0.180	0.437
10	0.10	0.119	0.182	0.195	0.437
12	0.083	---	---	0.208	0.500
15	0.067	0.145	0.230	---	---
S_o (Est)		0.250	0.400	0.275	0.650
K (day ⁻¹)		0.081	0.079	0.240	0.250

Thus analysis produced the estimated initial substrate levels and rate constants shown in Table 11. The estimated biodegradability of this manure ranged from 33.1 percent to 78.3 percent for the thermophilic data. This is based on a maximum gas production of 0.83 m^3 per kg volatile solids if these solids were 100 percent biodegradable. The calculated rate constants were 0.240 and 0.250 day^{-1} for the minimum and maximum biodegradability respectively. In a similar manner, the biodegradability for the mesophilic studies ranged from 30.1 to 48.2 percent. The calculated rate constants were 0.081 and 0.079 day^{-1} .

This analysis suggests that thermophilic fermentation results in a high level of biodegradability. However, this conclusion is not necessarily valid since the mesophilic and thermophilic studies were not conducted concurrently, using the same manure feed. However, this analysis does show that the rate constant is three fold higher at the thermophilic temperature than at the mesophilic temperature. These data show that the rate constant determined by this technique did not vary with the biodegradability of the manure.

D. Reactor Stability

One of the concerns with the methane fermentation process is stability of operation. Changes in temperature, loading rate, etc. are thought to cause perturbations in the system that may result in process failure. An unplanned example of reactor stability developed when the hot weather conditions caused repeated thermal overload of the hot water heater used to heat the reactors. As shown in Figure 6, reactor temperature reductions occurred three times, with the temperature dropping to

Figure 6. The Effect of Temperature Change on Reactor Stability

40°C. In addition to the temperature drop, the manure feed was changed to a fresh manure that was more biodegradable.

As a result of this temperature drop and increased loading of biodegradable organics, the volatile acids increased from approximately 200 mg/l to 800 mg/l. When the temperature was increased to 60°C, the acids decreased to less than 400 mg/l. Each time the temperature dropped, this was repeated. Gas production also followed a similar pattern with a net increase resulting from the change in the manure characteristics. Therefore, at a retention time of 9.2 days, the system was extremely stable.

In the reactor operating at a 3.7 day retention time, the same pattern was observed as shown in Figure 7. The response was more extreme with the volatile acids reaching a maximum of 1300 mg/l. Since the system is well buffered, the pH did not drop below 6.8 with the high volatile acids. Therefore, the system was able to recover rapidly when the temperature was increased to the operating level. Very high gas production rates were observed. Gas analysis showed that the methane content was 60 percent or greater, reaching a high of 68 percent.

Day 0 on Figures 6 and 7 corresponds to Day 77151. The data for this period are given in Appendix A, Tables A-1 and A-2.

Figure 7. The Effect of Temperature Change on Reactor Stability

E. Nitrogen Level Variations

Nitrogen is an important parameter in the anaerobic fermentation process. Adequate nitrogen must be maintained in the system to meet the nutritional requirements of the microorganisms. Conversely, excess ammonia (NH_3) levels may be inhibitory to the microorganisms. Therefore, the ammonia nitrogen was monitored in the system. Each week, two to five samples from the feed slurries and each reactor were analyzed for ammonia content. Less frequent measurements of the total Kjeldahl nitrogen were also made. These data are shown in Table 12 as the average value for the seven-day period.

The specific ion probe technique was used for the ammonia determinations. TKN analyses were obtained by the micro-kjeldahl digestion technique. However, with the large number of samples being tested, distillation facilities were not available to recover the ammonia. Instead, the digested liquor from the micro-kjeldahl digestion was subjected to ammonia analysis using the ammonia probe. These analytical procedures are discussed in Appendix B.

The feed slurry samples were taken from the mixing tanks. Feed sample 1 was fed to Reactors 1 and 2 while feed sample 2 was fed to Reactors 3 and 4. These data clearly reflect the quality of the manure and the operating conditions. In general, the TKN values for the reactors were significantly higher than the corresponding feed slurry. This is probably a result of the inability to obtain a representative sample from the feed mixing tanks. Due to the mixing pattern in these tanks, samples taken from the top of the tank contained significantly fewer suspended solids than samples taken from near the tank bottom.

Table 12. Average Nitrogen Contents of Feed and Effluent Slurries - mg/l

Week Ending	Feed Slurry				Reactor Effluent							
	TKN		NH ₃ -N		TKN				NH ₃ -N			
	1	2	1	2	1	2	3	4	1	2	3	4
77162	-	1030	182	174	-	-	1880	1660	205	202	195	195
169	1410	1385	207	216	1980	1920	1920	1990	250	240	243	240
176	-	-	275	300	2200	1830	1670	1360	300	325	370	400
183	1515	3070	320	482	3070	3070	3260	2600	463	402	595	530
190	-	-	215	450	-	-	-	-	450	340	800	610
197	1350	2906	-	-	-	-	-	-	-	-	-	-
204	-	-	405	570	-	-	-	-	460	460	-	-
211	1350	3220	415	450	3490	2310	3310	2630	580	560	960	730
218	1850	4800	410	620	2780	2450	5620	5630	750	670	1215	1110
225	2150	-	350	430	2800	2360	5410	3540	600	460	650	620
232	-	-	-	-	3560	2380	3690	3420	550	570	710	720
239	1400	1440	250	310	2700	2700	2830	2640	590	650	620	615
246	1200	2150	230	245	3810	3340	3300	3200	740	560	505	610
253	1350	1350	230	-	2200	2100	2360	2700	663	373	485	520
260	-	1190	69	105	2480	1900	1850	2000	385	160	257	324
267	1334	1940	111	150	-	-	1780	1415	232	197	216	246
274	-	-	74	100	1600	1360	1530	1530	230	133	235	176
281	-	1580	22	95	-	-	-	1650	122	78	239	188
288	-	-	76	111	-	-	-	-	113	89	177	182
295	-	-	-	82	-	-	-	-	134	102	149	140
302	-	-	51	38	-	-	-	-	173	199	165	159
309	-	-	88	57	-	-	-	-	430	442	273	236
316	-	-	111	81	-	-	-	-	912	820	327	640
323	-	-	170	31	-	-	-	-	-	-	407	640
330	-	-	325	440	-	-	-	-	797	547	342	543

The ammonia samples should be accurate since this nitrogen form is soluble and not subject to mixing problems.

Two periods shown in Table 12 show extreme variations in nitrogen levels. From Day 77179 through 77218, the solids concentration in feed slurry 2 was increased to the 10 percent range. The organic and ammonia nitrogen present in the feed slurry increased accordingly. There was also a significant increase in the organic and ammonia nitrogen level in Reactors 3 and 4. This increase in the reactors did lag the feed slurry increase.

During this period, the ammonia nitrogen reached levels of 1200 mg/l. With a fermentation temperature of 58°C, the unionized ammonia can reach relatively high levels, especially when the associated pH is 8.0 to 8.1. When the effect of the temperature on the ammonium ion dissociation is considered, a pH of 8.0 and a temperature of 58°C will result in a $(\text{NH}_3)/(\text{NH}_4^+)$ ratio of 0.32. Therefore, a total ammonia concentration of 1200 mg/l will produce an NH_3 concentration of 290 mg/l. This level is generally considered to inhibit methane fermentation at mesophilic fermentation temperatures. Of course, the reactors were experiencing significant operational problems during this period as shown in Tables 8 and 10.

During the period 77268 to 281, feed slurry 1 consisted of the previously digested residue. This was the period when Reactor 1 was receiving only this residue while Reactor 2 was receiving this residue after a mild thermochemical pretreatment. The ammonia levels in feed slurry 1 and Reactors 1 and 2 dropped significantly during this period. Most of the nitrogen had been washed from the solids during the previous fermentation. Consequently, very little nitrogen remained.

Feed slurry 2 also had a very low ammonia nitrogen level. However, the ammonia nitrogen in the reactors remained at a satisfactory level. The low nitrogen in the feed slurry was a result of the poor quality manure being processed at this time.

In general, sufficient nitrogen was present in the reactors to maintain adequate levels of nutrients for the microorganism population. Under certain operating conditions, the ammonia reached levels that have been considered inhibitory.

F. Thermochemical Pretreatment

A short test of the effect of thermochemical pretreatment on the gas yield was undertaken. From day 77268 until 289, Reactor 1 was being fed a slurry containing only solids centrifuged from the effluent from Reactors 3 and 4. These same solids, after being mixed with 3 g of lime per 100 g dry solids and heated at 110°C for two hours, were fed to Reactor 2. The gas production in both reactors was exceptionally low. These data are shown in Tables 3 and 5. The methane production from Reactor 1 was greater than Reactor 2 during this period. However, the gas production rates dropped to such low levels that the cost of such gas production would be excessive.

On Day 77289, the previously fermented solids were replaced with raw manure. The thermochemical treatment was continued. Gas production in both reactors increased significantly. A break in the test run occurred during the week ending with day 77316, when the manure supply was exhausted. The reactors were not fed for 5 days. Allowing for equilibrium to be established during the weeks ending with day 77295 and 77323, three weeks of gas production data can be used to compare the

effectiveness of this treatment. The methane production in Reactor 1, the control, was $0.080 \text{ m}^3/\text{kg}$ volatile solids added. The methane production from Reactor 2, the test reactor, was $0.095 \text{ m}^3/\text{kg}$ volatile solids added. This mild treatment appeared to increase the methane yield by 19 percent. However, the quality of this manure was very poor. This percentage is magnified by the low gas production from the control. Using gas production rates from biodegradable manure of 0.20 m^3 of methane per kg volatile solids fed, the percentage increase due to this mild thermochemical pretreatment would only be 7.5 percent. However, if this gas is priced at $\$7/100 \text{ m}^3$ ($\$2/\text{MCF}$) of methane, it will pay the lime cost at $\$53/\text{metric ton}$ ($\$48/\text{ton}$). Therefore, a more careful evaluation of this processing step may be warranted, especially if the price of this gas continues to increase.

2. Fermented Slurry Studies

The fermented slurry presents a major management problem when withdrawn from the reactors. This material must be processed in an acceptable environmental manner. The only viable technique for handling this material is to store it until it can be applied to the land. The solids remaining after fermentation may have some by-product recovery value. In order to better understand the properties of this slurry, various tests were conducted to determine dewatering characteristics of the slurry, particle size distribution and the characteristics of the various size fractions.

A. Particle Size Distribution

The particle size distribution of the solids in the fermented slurry plays a major role in determining the solids recovery potential. The composition of these solids will determine their value in any by-product recovery system. A wet sieve analysis technique (see Appendix 8) was used to obtain the particle size distribution.

A sample volume of 2 liters of effluent slurry was obtained for each run. These samples were withdrawn from the effluent holding tanks while the tanks were being vigorously mixed to insure a representative sample. Wet sieving techniques were used in order to separate the 2 liter sample into six different size fractions. After the sieving was completed, the sieves along with the solids retained on the sieves were dried overnight. The solids concentration of the liquor that passed the 200 mesh sieve and the concentration of solids in the wash water which also passed the 200 sieve were measured. By recording the volume

of liquor and wash water, it was possible to determine the total solids which passed the 200 mesh sieve. These solids were added to those retained on each sieve to determine the total solids concentration of the original 2 liter sample.

After the percent of total solids retained on each sieve was established, the percent of fixed solids was measured on samples taken from each sieve. Samples were also taken at this time for a fiber and nitrogen analysis.

Dry sieving techniques were utilized to determine the particle size distribution for the raw feed manure that had been ground so as to pass a 6.3 mm screen. A sample volume was collected and oven dried. Once the sample was dry, it was weighed and then subjected to a standard sieve analysis. The percentage retained on each sieve was determined.

Samples for the wet sieve analysis were obtained from different reactors at different times. The operating conditions for these reactors and the mixing tanks when samples were taken are shown in Table 13. The test identification is by reactor number and date. The results of these sieve analyses are given in Table 14. These data show the percent of each solids category that was retained on each mesh size. For the purpose of this discussion, the suspended solids are considered to be those solids retained on the 200 mesh sieve. These solids would be 74 μ m or greater in size.

The results in Table 14 provide some interesting information regarding the size distribution of the feed solids and the fermented solids. A significant portion of the total solids and volatile total solids passed the 200 mesh screen. These solids represented the small

Table 13. Operating Conditions During Residue Processing Tests

Reactor Number	Date	Feed Rate l/day	Temperature °C	Total Solids, %	Volatile Solids, %	Feed Total Solids, %
1	6-14-77	80	56	4.58	3.13	4.45
2	6-15-77	200	52	4.90	3.49	4.61
3	6-16-77	167	58	4.21	3.21	5.27
4	6-21-77	120	52	5.30	3.70	5.56
1	6-29-77	80	60	5.34	3.73	5.70
2	7-1-77	300	58	5.30	3.66	5.34
3	7-8-77	120	59	9.18	6.03	9.62
4	7-14-77	160	59	9.11	6.03	10.52
1	7-20-77	80	60	5.11	3.51	5.74
4	7-27-77	197	58	9.93	7.05	9.68
2	9-13-77	160	40	6.23	3.81	4.25
3	9-16-77	80	61	6.52	4.41	4.53
4	9-19-77	55	42	6.26	3.95	6.70
3	10-15-77	80	40	5.88	3.65	6.02
Mixing Tank Number						
2	7-27-77	-	-	4.49	3.34	-
1	10-19-77	-	-	2.93	2.06	-

Table 14. Particle Size Distribution

Sieve Size	Percent of Solids Retained			
	Total Solids	Volatile Total Solids	Suspended* Solids	Volatile* Sus. Solids
Reactor #1 Effluent (6-29-77)				
10	12.1	14.7	25.4	29.5
20	21.9	26.6	46.0	53.2
50	35.0	41.4	74.5	82.6
100	40.6	45.4	85.3	90.6
200	47.6	50.1	100.0	100.0
Pan	100.0	100.0	-	-
Reactor #2 Effluent (7-1-77)				
10	36.3	41.2	65.9	71.3
20	39.0	44.7	70.8	77.3
50	46.6	52.0	84.6	90.1
100	51.1	54.0	92.7	95.0
200	55.1	47.7	100.0	100.0
Pan	100.0	100.0	-	-
Reactor #3 Effluent (7-8-77)				
10	40.8	46.7	77.1	83.4
20	44.5	50.2	84.4	90.0
50	46.1	57.3	87.1	91.5
100	49.2	53.3	93.0	91.5
200	52.9	56.0	100.0	95.0
Pan	100.0	100.0	-	100.0
Reactor #4 Effluent (7-14-77)				
10	41.2	46.9	68.7	75.4
20	43.8	50.0	73.0	80.1
50	51.5	57.0	85.8	91.3
100	55.4	58.6	92.3	93.8
200	60.0	62.4	100.0	100.0
Pan	100.0	100.0	-	-

Table 14. (cont.)

Sieve Size	Percent of Solids Retained			
	Total Solids	Volatile Total Solids	Suspended* Solids	Volatile* Sus. Solids
Reactor #2 (9-13-77)				
10	27.3	32.3	51.4	55.9
20	38.5	44.0	72.5	76.3
50	45.8	51.1	86.3	88.6
100	49.5	54.4	93.2	94.3
200	53.1	57.8	100.0	100.0
Pan	100.0	100.0	-	-
Reactor #3 (9-16-77)				
10	24.9	29.0	44.6	55.5
20	36.9	41.4	66.1	78.7
50	47.7	46.9	85.5	89.7
100	52.4	49.7	93.9	95.2
200	55.8	52.4	100.0	100.0
Pan	100.0	100.0	-	-
Reactor #4 (9-19-77)				
10	14.1	14.5	31.4	30.8
20	25.7	26.5	57.2	55.9
50	35.3	36.5	78.6	77.4
100	39.9	42.1	88.9	89.2
200	44.9	47.2	100.0	100.0
Pan	100.0	100.0	-	-
Reactor #3 (10-15-77)				
10	20.7	23.4	34.6	45.4
20	36.1	37.1	60.4	72.0
50	47.4	44.7	79.3	86.7
100	55.1	48.6	92.1	94.1
200	59.8	51.6	100.0	100.0
Pan	100.0	100.0	-	-

Table 14. (cont.)

Sieve Size	Percent of Solids Retained			
	Total Solids	Volatile Total Solids	Suspended* Solids	Volatile* Sus. Solids
Raw Manure Slurry Mixing Tank #2 (7-27-77)				
10	34.0	35.5	59.6	58.2
20	38.7	41.0	67.9	61.2
50	49.6	52.3	87.0	86.1
100	53.8	57.0	94.4	93.5
200	57.0	60.3	100.0	100.0
Pan	100.0	100.0	-	-
Raw Manure Slurry Mixing Tank #1 (10-19-77)				
10	44.3	42.3	67.0	64.9
20	50.8	42.3	76.9	75.6
50	58.8	51.2	89.0	87.6
100	63.2	61.9	95.6	95.0
200	66.1	65.2	100.0	100.0
Pan	100.0	100.0	-	-

* Suspended solids refer to those solids retained on the 200 mesh screen, i.e. a particle size greater than 74 μm .

suspended and colloidal solids as well as the dissolved solids. Solids from reactors operating at long retention times (Reactor 1 on 6/29/77 and Reactor 4 on 9/19/77) generally had more solids passing the 200 mesh screen than the reactors operating at short retention times. The total solids passing the 200 mesh screen ranged from 40 to 55 percent for the fermented slurry. In the raw manure slurry, the percent of total solids passing the 200 mesh screen was 34 and 43 percent for the two samples tested.

The distribution of suspended solids as defined for this study is of more importance. Removal of insoluble solids passing the 200 mesh screen (74 μm) will generally require chemical treatment. This will greatly increase the cost of processing these solids. The distribution of suspended solids shows that the majority of the solids can be recovered as a relatively large particle. In all fermented slurries tested 90 percent of the solids retained on the 200 mesh screen were retained on the 100 mesh (149 μm) screen. With the exception of the reactors operated at long retention times, 90 percent of the solids retained on the 200 mesh screen were retained on the 50 mesh screen (297 μm). Therefore, a major portion of these solids can be recovered without the use of expensive dewatering systems.

This relationship is shown graphically in Figure 8 where the percent of solids passing a given size screen is plotted against screen size. The dry manure, after passage through the mill with a 6.3 mm screen, was subjected to a dry sieve analysis resulting in the size distribution shown in Figure 8. When the manure was slurried with water, the size distribution changed substantially as shown by the curve for

Figure 8. Particle Size Distribution at Various Process Stages

the feed slurry. This curve is for only those solids that are equal to or greater than the 200 mesh size. This substantial change in size distribution can be attributed in part to an increase in particle size due to absorption of water.

This figure also illustrates the variation in size distribution resulting from increased stabilization. More organics were fermented to gas at the longer retention times resulting in smaller particles. Of the two curves marked as 10-day retention time, the upper curve was for a 58°C fermentation temperature, while the lower curve was for a 40°C temperature. A highly loaded system as evidenced by the curve marked as a 2.5-day retention time shows a particle size distribution only slightly different from the feed slurry.

This analysis suggest that a fermentation system operated to obtain maximum gas production will produce a slurry containing solids that are more difficult to recover. Conversely, a system with a reduced conversion efficiency may be expected to produce a slurry containing solids that are more easily recovered.

B. Composition of Different Size Fractions

The potential for by-product recovery depends upon the composition of the residue from the fermentors. In particular, the composition of the various particle sizes will be of significance in establishment of the type of solids recovery system required. Samples for fiber analysis and nitrogen analyses were taken from the various size sieves after the particle size distribution had been completed. Additional analysis for calcium carbonate and iron were conducted on the filtrate obtained from the cellulose hydrolysis step employed in the fiber analysis.

The results of the fiber analysis are shown in Tables 15 and 16. Table 15 shows the average of 8 sets of analyses conducted on the reactor effluents. The data in Table 16 are the average values of two sets of analyses conducted on the feed slurry. The results of the individual analyses are given in Appendix A. The extractable material as measured by an alcohol-benzene extraction was approximately 1 percent in the reactor effluents. The feed slurry had a significantly higher extractable content.

The composition of the remaining solids is generally considered to be holocellulose, lignin and ash. In any sample containing nitrogenous compounds, a correction for the protein content is applied. There are several techniques for protein determination. However, for this correction, protein was calculated as 6.25 times the organic nitrogen. The protein level of these solids was considerably lower than the data obtained in the centrifuge cake (see Table 21). During the washing process, it is probable that much of the bacterial biomass was dislodged and passed through to the pan. Therefore, these protein values were used only in correcting the fiber composition.

The protein correction is required because the acid hydrolysis of the cellulose will cause the protein molecules to precipitate. Since the organic solids remaining after cellulose hydrolysis are identified as lignin, the protein precipitate will increase the lignin content. Therefore, the correction is necessary.

The fixed solids (ash) content determination was made on samples taken from the sieves. This fixed solids percentage was used to calculate the lignin by deducting this percentage from the solids remaining after

Table 15
Fiber Analysis - Reactor Effluent

Sieve Size	Tot. Solids Retained on Sieve - %	Percent of Solids Retained on Sieve				
		Ext.	Cellulose	Lignin	Protein	Fixed Solids
10	27.2	1.1	54.2	14.6	1.4	30.0
20	8.6	1.4	53.8	9.2	1.8	34.7
50	8.8	1.3	47.8	9.7	2.6	46.1
100	4.7	1.1	43.6	17.3	2.1	55.4
200	4.5	1.0	43.2	12.4	1.5	51.1
Pan	46.4	---	----	----	---	----

Table 16
Fiber Analysis - Feed Slurry

Sieve Size	Tot. Solids Retained on Sieve - %	Percent of Solids Retained on Sieve				
		Ext.	Cellulose	Lignin	Protein	Fixed Solids
10	39.2	1.6	53.3	14.3	1.6	29.3
20	5.6	1.6	53.3	22.4	1.4	21.4
50	9.5	2.4	55.9	16.1	2.4	23.2
100	4.3	3.6	43.0	26.3	3.3	23.8
200	3.0	4.0	47.1	23.1	2.1	23.7
Pan	38.5	---	----	----	---	----

cellulose hydrolysis. As can be seen from Table 15, the sum of the percentage of individual components in the fiber frequently exceeded 100 percent.

An attempt to explain this problem that occurred in the reactor effluent slurry resulted in the following. The manure contained a quantity of crushed limestone that was added to various low areas in the feed lot. When this manure was milled, the limestone was reduced in size. This also resulted in attrition of the mill. As the manure was processed through the system, the large particles of limestone were removed. However, the finer particles passed through the system. This grit caused wear on the various metal surfaces resulting in a measurable quantity of iron. When the limestone and iron were subjected to the acid conditions used in the cellulose hydrolysis, the limestone and iron dissolved also. Analysis of the hardness and iron content of the liquid remaining after cellulose hydrolysis showed a significant calcium and iron content. These data are shown in Table 16.

The calcium and iron content represent a significant contribution to the cellulose content. The data in Table 18 have been corrected by deducting the calcium and iron from the cellulose and recalculating the lignin content. The data in this table show that most of the cellulose and lignin occur in the larger size particles, generally in excess of 0.3 mm size.

These data clearly show that essentially all of the recoverable solids exist as particles greater than 0.3 mm. The ash content of these solids varied from 30 to 46.1 percent. The cellulose and lignin content decreased as the ash content increased with the smaller particles. In

Table 17
Hardness and Iron Analysis - % Solids Retained on Sieve

Sieve Size	Feed Slurry		Reactor Effluent	
	CaCO ₃	Fe	CaCO ₃	Fe
10	0.9	0.3	1.1	0.4
20	1.4	0.3	2.5	0.6
50	2.4	0.3	2.7	0.8
100	2.8	0.4	4.6	0.9
200	7.2	0.4	5.2	1.0

Table 18
Corrected Fiber Analysis - Reactor Effluent

Sieve Size	Tot. Solids Retained on Sieve - %	Percent of Solids Retained on Sieve				
		Ext.	Cellulose	Lignin	Protein	Fixed Solids
10	57.2	1.1	52.7	14.8	1.4	30.0
20	8.6	1.4	50.7	11.7	1.8	34.7
50	8.8	1.3	44.3	5.7	2.6	46.1
100	4.7	1.1	38.1	3.3	2.1	55.4
200	4.5	1.0	37.0	9.4	1.5	51.1
Pan	46.4	---	----	---	---	----

general, the protein content was less than 3 percent. It was, however, relatively uniform with particle size distribution. Based on these analyses, the most practical system for solids recovery is a mechanical screen sized to capture 0.25 mm particles. The screened solids can then be pressed to remove additional water if desired.

C. Centrifuge Dewatering Study

The objective of the centrifuge dewatering study is to evaluate the efficiency of the centrifuge in solids capture and solids dewatering. A Sharpless Mark III solid bowl-basket centrifuge with a variable speed drive was used to conduct the dewatering tests. This unit does not provide for continuous cake discharge; therefore, a predetermined amount of slurry which will insure that the bowl is not overloaded with solids was fed to the centrifuge. The centrate retained in the bowl at the end of the run was withdrawn by the use of a skimmer pipe.

The feed line from the effluent tanks to the centrifuge, as well as the centrifuge itself, was first flushed with clean water to avoid contamination from previous runs. The slurry from one of the four effluent storage tanks was pumped through the feed line to displace the flushing water. Homogeneity of the effluent slurry was insured by vigorous mixing of the effluent tank. There was no chemical addition to the effluent slurry.

The centrifuge was started and adjusted to rotate at a predetermined speed. After the desired speed was attained, the slurry pump was engaged, pumping the effluent slurry directly to the centrifuge. It must be noted here that as the solids in the bowl accumulated, the centrifuge tended to decrease in speed. Therefore, it was necessary to

continuously monitor and readjust the unit to maintain the desired test conditions. The tests were performed at a flow rate of 8 liters per minute, which is recommended for the Sharples Mark III unit.

The centrifuge was then readjusted for the next speed. Speeds of 1000, 1600, 2300, and 3000 rpm were used for each effluent tank. The centrate samples were taken from the unit discharge line after approximately 20 liters had been fed. The centrate was analyzed for both total and volatile solids. Cake samples were obtained after each run. Representative samples were taken after the contents of the entire bowl had been thoroughly mixed by hand. As with the centrate samples, the cake samples were analyzed for total and volatile solids. Duplicate samples were used for all cake samples, and the results were then averaged. Samples of the slurry prior to centrifugation were obtained directly from the effluent tanks.

Separate dewatering tests were performed on the effluent from reactors with varying retention times and feed solids concentrations. The operating conditions for each reactor are listed in Table 13.

The percent solids of the cake are plotted against the centrifuge speed (rpm) and are shown in Figure 9. A curve for both total and volatile solids is presented in this figure. In each case, the ratio of volatile solids to total solids was relatively constant at 60 to 65 percent. At low speeds and g forces, the cake contained a considerable amount of water. At a rotational speed of 1000 rpm, the cake solids were found to be only 16 to 19 percent with a feed solids concentration of approximately 5.0 percent. Increasing the speed to 2300 rpm resulted in cake solids which varied from 22 to 27 percent.

Figure 9. Cake Solids Produced During Centrifuge Tests

The maximum cake solids were obtained at 3000 rpm with a high value of 30 percent. The curves show that very little additional solids capture was gained after approximately 2300 rpm. At the higher speeds the cake was very dry and was not easily removed from the bowl. The fermentor retention time apparently was not a factor in the dewatering tests.

The results for a reactor receiving a feed slurry of approximately 9.0 percent solids are shown for Reactor #4. As one might expect, the solids capture increased with increasing speed. From inspection of this curve, it would appear that the optimum speed was again 3000 rpm or less, as with the 5.0 percent feed slurry.

The centrate percent solids are plotted against rotational speed for the same runs and are shown in Figure 10. Again, both total and volatile solids are plotted. The ratio of volatile solids to total solids was found to be between 65 to 70 percent. This is higher than the ratio for the cake.

With a 5.0 percent feed slurry, the lowest centrate solid percentage of 1.5 to 1.8 percent was obtained at the highest speeds. There was virtually no improvement in centrate solids capture after 2300 rpm. As with the cake solids, the fermentor retention time did not seem to influence centrate solids capture.

However, the concentration of the feed slurry has a pronounced effect upon the capture, as illustrated by Reactor #4 in Figure 10. Doubling the feed concentration has the effect of more than doubling the solids concentration at the lowest speeds, and increasing the values at the higher speeds by at least one half. Inspection of Figure 10

Figure 10. Centrate Solids Produced During Centrifuge Tests

would indicate that the optimum speed was not obtained. The maximum speed of the Mark III unit is 3400 rpm; therefore, tests at higher speeds were not possible.

D. Vacuum Filtration Studies

A common technology for slurry dewatering involves filtration mechanisms ranging from simple screens to filter belt presses. One such system that has evolved is the vacuum filtration process. This process has been widely used to dewater slurries from many sources. A laboratory test procedure has been developed for evaluation of the filtration characteristics of slurries. This procedure, commonly known as the filter leaf test procedure, employs a section of filter cloth that is commercially available for installation on a vacuum filter. The test cloth is subjected to the same sequence of operations encountered in an operating vacuum filter. The data obtained from these tests can be used for predicting the response of the full scale system.

The dewatering characteristics of the slurry can be changed by chemical conditioning. Various chemicals can be used to improve the filtration characteristics. Iron salts, especially ferric chloride, are effective in this chemical conditioning. The addition of organic polymers has also been found to be of assistance.

A series of tests using the filter leaf test procedure was undertaken using three different media as follows. These media were provided by Eimco. In all experiments the iron dosage is expressed as g/l of $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$. For convenience, the water of hydration has been dropped.

- PO-808 - Polyethylene monofilament yarn, 1/1 plain weave, 40 x 23 thread count at 10.5 oz/yd²
- NY-415 - Nylon monofilament yarn, 1/1 plain weave, 40 x 40 thread count at 5.7 oz/yd²
- POPR-859 - Polypropylene monofilament yarn, 2/2 twill weave, 68 x 30 thread count at 8.5 oz/yd²

The NY-415 was the most porous of the three media used, while POPR-859 had the tightest weave. As would be expected, the media plays a key role in determining the response of the slurry to this dewatering technique. The data shown in Table 19 provide some interesting information on the filtrability of this slurry.

Table 19. Filter Leaf Test Results¹

Filter Media	FeCl ₃ g/l	Polyelec. ² mg/l	Cake Solids %	Filtrate Sus. Solids - g/l
POPR-859	7.0	10(A22)	14.6	0.149
PO-808	7.0	10(A22)	21.1	0.694
PO-808	2.1	0	29.2	1.007
PO-808	2.1	5(A23)	21.2	0.884
PO-808	2.1	10(A23)	18.0	0.443
NY-415	1.7	0	24.0	0.920

¹Form time - 30 sec., drying time - 120 sec.

²Polyelectrolyte - Dow Purifloc A22 and A23.

The slurry solids concentration varied somewhat, but in general was in the 40 to 60 g/l range. For the media tested, POPR-859 produced an exceptional filtrate quality, about 150 mg/l of suspended solids.

Unfortunately, this required a massive chemical dose and the resulting filter cake had a very high moisture level. The chemical flocculation of the fine particles results in a large quantity of water that is retained by the cake when removed by this media. The same chemical treatment resulted in a cake of 21.1 percent moisture for the PO-808 medium. However, the filtrate suspended solids concentration was significantly higher. The cake solids content for the PO-808 medium was 29.2 percent with lower chemical addition, but again, the filtrate suspended solids concentration was 1007 mg/l.

These data show that higher cake solids can be obtained with limited chemical addition when using a coarse weave media. The data also show that the higher cake solids are produced at the expense of the solids capture. The filtrate suspended solids are significantly higher when a drier cake is produced. Attempts to use fine media such as the POPR-859 without chemical conditioning were a total failure. The media clogged immediately and it was not possible to pull any liquid through the test leaf.

As a result of several tests, it became apparent that the most effective filter media for solids recovery would be a coarse medium like NY-415. The effect of ferric chloride on this slurry filterability is shown in Figure 11. A cake solids of 20 percent was obtained without any chemical addition. A dosage of 1.7 g/l of FeCl_3 (68 lbs per ton of dry solids) produced the maximum filter cake solids of 25 to 26 percent. The filtrate suspended solids were reduced from 1250 mg/l at 0 mg/l FeCl_3 to 800 mg/l at a FeCl_3 dosage of 1.7 g/l.

Figure 11. Cake and Filtrate Solids Obtain with Filter Leaf Test

Solids capture is one criterion for evaluation of filter performance. The data in Figure 12 show the solids capture obtained with two media with various chemical dosage and form and drying times. In this figure, the open symbols are for 30 second form times while the closed symbols are for 15 second form times. The thicker cake produced with the longer form time resulted in higher solids capture due to the deep media filtration effect of the thicker cake. Longer drying times reduced the solids capture. This may have resulted from the extraction of more water and fine solids from the cake with the longer drying times. High solids capture was possible but at a cost. Large chemical dosages and fine filter media yielded up to 97 percent solids capture.

The expected vacuum filter performance based on the filter leaf test analysis is shown in Table 20. The finer medium, PO-808, provided a higher solids capture when a massive dosage of chemical was added. Filtration rates were low and the cake moisture was low. The coarse medium NY-415 did not yield as high a solids capture, but the cake solids were somewhat higher. The filtration rate was also better than for the finer medium.

Based on the results of this study, it appears that vacuum filtration is not a viable option for dewatering of the fermented slurry. Filtration rates are low even when substantial quantities of chemicals are added to condition the sludge. The most effective solids removal system may well be a coarse mesh filter cloth that captures only the larger particles. The applied vacuum may assist in removing some of the excess water so that the cake is reasonably dry.

Figure 12. Solids Capture Using Filter Leaf Test Procedure

Table 20. Expected Vacuum Filter Performance

Form Time Sec.	Dry Time Sec.	Cake Solids %	Filter Loading kg/m ² -hr	Solids Capture %
NY-415, FeCl ₃ - 1.7 g/l				
15	90	17.6	21.5	78.6
	105	17.0	17.6	77.4
	120	22.2	28.3	83.5
30	90	22.0	32.7	86.1
	105	21.9	28.8	90.2
	120	24.0	24.4	85.5
PO-808, FeCl ₃ - 7 g/l, A 23-10 mg/l				
15	90	19.5	24.4	83.0
	105	21.3	18.1	82.0
30	90	19.4	25.9	93.5
	105	21.9	22.4	97.0
	120	22.3	18.5	96.0
	135	21.0	15.6	85.0

3. Utilization of Residual Solids

The fermentation process removes only carbon, hydrogen and oxygen from the substrate being utilized. All other elements are conserved by this process. The microorganism growth will require certain elements for the synthesis of new cellular protoplasm. As a result of this protoplasm production, the value of the residue may be enhanced. A portion of the ammonia nitrogen present in the manure is synthesized into protein. This protein has potential for recovery as an animal feed supplement. Therefore, not only are all forms of plant nutrients (nitrogen, phosphorus, potassium and minerals) conserved, but the nitrogen is partially upgraded to protein nitrogen in the form of bacterial cells, i.e. single cell protein.

In order to develop information required to evaluate the recovery potential of the residue from the system, one must know if these materials are soluble or insoluble and the associated concentrations. Therefore, a series of tests was conducted to determine the nitrogen, phosphorus and potassium content of the feed and effluent slurries and the centrifuge cake. Also, the nitrogen forms found in these fractions were determined.

The analytical techniques employed are thoroughly described in Appendix B. Total phosphorus and potassium determinations can be made by digesting the sample with various acids or combinations of acids. It has been found that a mixture of periodic and perchloric acid will allow rapid sample digestion at lower temperatures than are possible with other digestion reagents. This method is somewhat safer than higher temperature reactions. Periodic acid is also especially good at fragmenting large molecular species to smaller ones, thus speeding up the oxidation of the organics.

Nitrogen determination by the micro-kjeldahl technique was employed. The ammonia produced upon digestion of the organics was measured with a specific ion electrode. This electrode was routinely used to determine the ammonia concentrations in the fermenters. Because of the large number of samples tested, it was not possible to recover the ammonia by distillation. The concentrated NaOH was added directly to the digesting solution to raise the pH. The ammonia was then measured by the ammonia probe. This procedure was checked on a standard sample of riboflavin. The calculated total kjeldahl nitrogen was 3.96 percent. After digestion, the ammonia probe showed 3.56 percent total kjeldahl nitrogen, approximately a 10 percent loss.

The accuracy of this procedure has been improved. The expanded scale on the specific ion meter allowed for greater accuracy than when the millivolt scale was being used. Also, it was found that the ammonia probe must equilibrate with the particular sample before reproducible results were obtained. There was substantial variation in the nitrogen results. This variation is reflected in the standard deviations reported in Appendix A.

Soluble concentrations were determined by centrifuging the sample for removal of suspended solids. The fine solids present in the samples immediately plugged every type of filter used. It was impossible to obtain a sufficient volume of filtrate to be used in the analyses for soluble compounds.

A. Nitrogen Analysis

A summary of the results of the nitrogen analysis is shown in Table 21. A more detailed breakdown of these data is given in Appendix A. These numbers are the average of four separate samples. The effect of

Table 21. Nitrogen Distribution, mg N per g Total Solids

Temp °C	θ Days	Organic Nitrogen			Ammonia Nitrogen		
		Feed	Eff.	Cake	Feed	Eff.	Cake
40	4.8	15.1	20.7	40.1	0.9	2	0.3
	9.5	18.1	16.9	39.7	1.5	3	0.2
	13.7	28.4	32.7	39.2	1.3	2.3	0.4
58	3.9	29.2	21.8	19.1	2.3	2.4	0.02
	4.7*	54.8	53.8	48.6	3.9	4.0	2.2
	4.9	26.8	21.3	21.3	1.6	2.2	0.01
	5.7*	44.4	53.9	-	4.5	5.5	4.0
	6.4	26.8	19.4	19.3	1.6	2.0	0.02
	9.5	29.2	28.8	22.1	2.3	2.9	0.03

temperature and retention time on the nitrogen distribution does not appear to be significant. As expected, the degradation of organics increases the ammonia content in the effluent. This is the only observation that can be made regarding the effect of the processing on the nitrogen distribution. However, the organic nitrogen content of these streams is significantly affected by the nitrogen content of the feed manure. The two retention times marked with an asterisk in Table 21 received feed manure of different quality than that used for the other four retention times at the 58°C temperature. The high level of organic nitrogen in the feed slurry is reflected in the effluent as well as the centrifuge cake.

The cake contained a reasonable quantity of organic nitrogen, ranging from 1.91 to 4.86 percent of the total solids. The crude protein content of this cake would range from 12.0 to 30.3 percent. Based on the results of the centrifuge tests, approximately 75 percent of the suspended solids was captured in the cake. A mass balance on the organic nitrogen shows that on the average, approximately 60 percent of the input organic nitrogen was present in the centrifuge cake. A similar balance on the total kjeldahl nitrogen (TKN) shows that 55 percent of the TKN was captured in the centrifuge cake. Essentially all of the ammonia nitrogen was present in the liquid portion of the effluent stream. Consequently, the ammonia nitrogen in the cake was present as a result of water being retained by the cake.

The total nitrogen in the effluent ranged from 1.99 to 5.94 percent of the total solids. The effluent from the reactors contained between 4 to 10 percent total solids. The total nitrogen in the effluent could range between 0.08 to 0.6 percent, depending upon the fermentor operating conditions and the quality of the feed manure. The organic nitrogen was approximately 90 percent of the effluent nitrogen. Ammonia nitrogen contributed only 10 percent to the total nitrogen. This liquor will have an ammonia concentration between 200 and 1000 mg/l, depending upon the feed manure and the feed solids concentration (see Table 12).

B. Phosphorus Analysis

A summary of the phosphorus analysis is shown in Table 22. As with the nitrogen data, these values represent the average of four separate samples. Soluble phosphorus was higher in the raw feed than in the effluent from the reactors. It appeared that the phosphorus was

Table 22. Phosphorus Distribution, mg P per g Total Solids

Temp °C	θ Days	Total Phosphorus			Soluble Phosphorus		
		Feed	Eff.	Cake	Feed	Eff.	Cake
40	4.8	8.9	9.4	6.0	1.4	0.8	2.0
	9.5	8.5	9.2	5.8	2.1	0.7	1.4
	13.7	7.8	9.7	6.6	2.0	0.9	2.1
58	3.9	8.6	7.1	5.1	4.8	1.0	1.0
	4.7*	8.8	8.7	6.8	8.4	0.9	3.2
	4.9	7.3	8.0	5.1	2.8	1.5	1.3
	5.7*	9.0	8.9	8.3	7.3	1.0	4.7
	6.4	7.3	7.4	4.4	2.8	1.1	1.4
	9.5	8.6	8.4	4.8	4.8	1.1	0.6

precipitating in the fermentation step. This phosphorus may have been precipitated, but it was not of sufficient size particles to be removed by the centrifuge. In fact, the total phosphorus content of the solids in the centrifuge cake was significantly lower than the solids in the reactor effluents.

Phosphorus recovery will be greatest if the total effluent stream is utilized. Considering a 75 percent recovery of suspended solids in the centrifuge cake, the phosphorus recovery in this cake will be approximately 53 percent. The balance will be retained with the centrate.

C. Potassium Distribution

A summary of the potassium analysis is given in Table 23. These values are the average of four separate samples. Additional data for these analysis is given in Appendix A. Most of the potassium in these samples was in the soluble form. In the feed slurry, the potassium was 72.3 percent soluble. There appeared to be some effect of temperature on the potassium solubility. At the 40°C fermentation temperature, the soluble potassium accounted for 86.9 percent of the total potassium. At 58°C, the soluble potassium was reduced to 72.6 percent of the total K in the effluent slurry.

As a result of the solubility of this element, the potassium content of the centrifuge cake was low. A balance of the potassium in the feed stream shows that with a 75 percent recovery of suspended solids in the centrifuge step, the potassium recovery was 20 percent at 40°C and 23 percent at 58°C fermentation temperature. These variations with temperature probably are not significant. However, it is clear that the potassium recovery with the solids is very low. Effective recovery of the potassium will require use of the entire stream.

Table 23. Potassium Distribution - mg K per g Total Solids

Temp °C	Days	Total Potassium			Soluble Potassium		
		Feed	Eff.	Cake	Feed	Eff.	Cake
40	4.8	31.8	32.6	8.5	23.6	32.9	3.6
	9.5	29.4	34.8	8.9	32.7	34.4	3.9
	13.7	30.7	39.7	6.7	29.5	25.8	5.1
58	3.9	23.0	18.6	7.0	12.0	8.0	5.9
	4.7*	34.7	32.8	10.4	23.9	21.3	6.3
	4.9	25.1	21.1	6.4	10.3	8.2	2.4
	5.7*	38.5	33.7	15.0	34.4	27.4	6.3
	6.4	25.1	22.3	6.2	10.3	12.9	2.6
	9.5	23.0	20.7	5.9	12.0	12.5	8.0

4. Computer Simulation Results

In order to evaluate the economic potential of methane production from beef feedlot residue, a simulation of the processing system was constructed. The computer program is outlined in detail in Appendix C. It is a modification of the program that was developed for refuse fermentation (Quindry et al., 1976). Only gas recovery was evaluated since the data collected during this study do not support attempts to recover protein. The limited protein content of the residue and the various uncertainties relative to refeeding suggest that the process should be evaluated only on the value of the recovered gas. The program has the capacity to evaluate the cost of solids recovery via centrifugation as well as gas cleanup.

A series of runs was made with the simulator to evaluate the economics of this system. The processing system included only the following unit processes:

- Mixed manure storage tank, 24 hour storage
- Heat exchanger for heat recovery from effluent
- Mixed fermentation tank
- Steam boiler for fermentor heating

Dewatering of fermentor effluent was not included and the cost of residue disposal was not considered.

The rationale for the above constraint is as follows. In an enclosed lot in which the manure is collected fresh from trenches under a slotted floor, the moisture content of the manure is sufficiently high to exclude recycle of any liquid separated from the fermentor residue. Therefore, the only justification for solids recovery from the residue stream is the refeeding potential. If refeeding is practical,

then the value of the reclaimed protein plus the elimination of a residue disposal cost will offset the cost of feed recovery. Therefore, the gas production system simply intercepts the manure on its way to disposal and extracts the gas. Also, gas cleanup is not included as it is assumed that the gas can be used locally.

For comparative purposes, the same system is applied to an open lot even though the manure is sufficiently dry to warrant recycle of a significant portion of the water in the fermentor residue. If the gas production warrants additional processing of the residue, it can be accomplished. In this simulator, the manures are assumed to be significantly different. The characteristics are given in Table 24.

Table 24. Manure Characteristics Used in Simulation

	Open Lot		Environmental Lot	
	40°C	58°C	40°C	58°C
Production Rate - Wet (kg/day-animal)	2.64	2.64	4.9	4.9
Total Solids (%)	35	35	15	15
Volatile Solids (% total solids)	67	67	78	78
Biodegradable Solids (% volatile solids)	30	33	48	78
Rate Constant (day ⁻¹)	0.08	0.25	0.08	0.25

The manure production rates, total solids and volatile total solids were obtained from Ashare et al. (1977). The biodegradable solids and rate constants are based on the results of this study. These data are highly significant in determining the net economics of this system.

With these data and appropriate cost curves for the individual processes, it is possible to compute the cost of producing gas from either type of feed lot at either the mesophilic or thermophilic digestion temperature. Capital costs are in 1978 dollars and are assumed available at a 10 percent interest rate. Capital costs are construction costs only and do not include various costs such as land, site related, engineering, etc. Annual costs include only capital amortization and operating and maintenance costs directly related to processing. Taxes, return on investment, labor, etc. are not included.

The results of these runs are shown in the following table. The lot type, i.e., environmental vs. open, and its effect on the economics and energy recovery are shown in Table 25. With gas priced at \$2.10/GJ ($\$2/10^6$ BTU), the open lot, with the manure characteristics listed in Table 24, cannot show a net income. Additional costs associated with labor, taxes, etc. will only increase the loss associated with this substrate. However, the high quality manure from the environmental lot results in a substantial net income when operated at the thermophilic fermentation temperatures. Because of the high rate constant and the percentage of volatile solids that are biodegradable, a large portion of the organic solids is converted to gas. The income is substantially greater than the production costs, suggesting that substantial return on investment is possible.

These data for the 100,000 head lot size clearly show that manure from open lots will not break even. They also show that thermophilic fermentation is necessary for the manure from the environmental lot to be profitable. Clearly, smaller lots will only increase the loss associated with the nonprofitable operations for the large lots. In order to

Table 25. Effect of Fermentation Temperature and Lot Type on Economics
(Lot size = 100,000 head, θ = 8 days)

	Open Lot		Environmental Lot	
	40°C	58°C	40°C	58°C
<u>Fermentor</u>				
Volume - m ³	14,000	14,000	26,130	26,130
Const. cost - 10 ⁶ \$	1.63	1.63	2.99	2.99
Const. cost - \$/hr	22.11	22.11	40.71	40.71
Mixing cost - \$/hr	18.70	18.70	33.89	24.03
<u>Auxiliary System</u>				
Const. cost - 10 ⁶ \$	0.29	0.31	0.42	0.47
Const. cost - \$/hr	3.93	4.30	5.65	6.37
O & M = \$/hr	0.80	0.88	1.15	1.29
<u>Energy Balance</u>				
Consumed - GJ/hr	2.47	2.41	4.38	3.29
Produced - GJ/hr	0.90	5.34	19.52	109.40
<u>Total Costs - \$/hr</u>				
Construction	26.04	26.41	46.36	47.08
O & M	21.89	21.46	38.51	28.79
Labor	-	-	-	-
Misc.	-	-	-	-
Income - \$/hr	1.87	10.12	37.00	207.00
Net Income (Loss) - \$/hr	(46.00)	(38.00)	(48.00)	131.00

determine the effect of economies of scale, a series of runs was made in which the lot size varied from 5000 to 100,000 head. These data are shown in Table 26. The fermentation temperature was 58°C with a retention time of 5 days.

As would be expected, the size of the lot is highly significant in determining the system economics. There are two major factors contributing to the size effect. First, economies of scale result in a construction cost for the 10,000 head lot of only 15 percent greater than for the 5000 head lot. Therefore, it is not surprising that the potential income from the small lot is likely to be negative unless labor, site costs and profit are zero, or the value of the energy is much higher. Based on the economic analysis shown in Table 26, it would appear that the 25,000 head capacity lot is about the size where economies of scale become insignificant. Lot capacities in the 10,000 to 25,000 head range may be economically attractive, but a very careful economic analysis of a specific site would be necessary to determine economic feasibility.

The economics of this system look very attractive for the 25,000 head lots. The construction costs for this simple system (mix tank, heat exchanger, fermentor, and boiler) would be approximately \$760,000. Allowing perhaps \$50,000 annually for labor, the pay back period would be slightly over four years. This is a very crude cost calculation and should be considered as such. Using the costs in Table 26, one can make an economic evaluation to suit the needs of a specific installation. Since these data are for θ of 5 days, the economics will improve at longer retention times.

Table 26. Effect of Lot Size on System Economics (1000 head)

	5	10	25	50	100
<u>Fermentor</u>					
Volume - m ³	817	1,634	4,080	8,170	16,340
Constr. cost - 10 ⁶ \$	0.31	0.33	0.56	0.96	1.88
Constr. cost - \$/hr	4.26	4.52	7.60	13.00	25.60
Mixing cost - \$/hr	0.82	1.64	4.10	8.19	16.39
<u>Auxiliary System</u>					
Constr. cost - 10 ⁶ \$	0.08	0.12	0.20	0.30	0.47
Constr. cost - \$/hr	1.11	1.63	2.76	4.14	6.30
O & M - \$/hr	0.23	0.34	0.56	0.84	1.28
<u>Energy Balance</u>					
Consumed - GJ/hr	0.11	0.23	0.57	1.13	2.27
Produced - GJ/hr	4.40	8.90	22.40	45.20	90.60
<u>Total Cost - \$/hr</u>					
Construction	5.37	6.15	10.36	17.14	31.90
O & M	1.41	2.36	5.31	10.14	19.85
Labor	-	-	-	-	-
Misc.	-	-	-	-	-
Income - \$/hr	8.38	16.90	42.53	85.60	172.00
<u>Net Income - Annual</u>					
\$/year	14,000	73,600	235,600	510,700	1,051,200
\$/head	2.8	7.36	9.43	10.21	10.51

The optimum retention time for the thermophilic fermentation temperature was determined for a 100,000 head lot. It is unlikely that one will have a 100,000 head environmental lot, but this analysis will apply to any size lot since only the ratio of the net income at various retention times is utilized. These data are shown in Table 27. These data show that the net income increases up to a θ of 10 days. However, the data in Table 25 for an environmental lot was an 8 day retention time show a net income of \$131/hr, which is slightly better than the \$130/hr for the 10 day system. Therefore, it would appear that with gas priced at \$2.10/GJ, the optimum retention time would be approximately 8 days. If gas prices increase, then a longer retention time may be more economical.

Table 27. Effect of Retention Time on System Economics
(100,000 head lot, fermentation temperature = 58°C)

	3	4	6	10
<u>Fermentor</u>				
Volume - m ³	9,800	13,067	19,600	32,700
Constr. cost - 10 ⁶ \$	1.14	1.51	2.25	3.73
Constr. cost - \$/hr	15.46	20.54	30.65	50.74
Mixing cost - \$/hr	10.75	13.65	19.01	28.85
<u>Auxiliary System</u>				
Constr. cost - 10 ⁶ \$	0.45	0.46	0.47	0.48
Constr. cost - \$/hr	6.23	6.26	6.32	6.41
O & M - \$/hr	1.25	1.27	1.29	1.30
<u>Energy Balance</u>				
Consumed - GJ/hr	1.59	1.94	2.58	3.77
Produced - GJ/hr	68.90	81.22	98.12	117.30
<u>Total Costs - \$/hr</u>				
Construction	21.69	26.80	36.97	57.15
O & M	13.33	16.67	22.91	34.47
Labor	-	-	-	-
Misc.	-	-	-	-
Income - \$/hr	131.00	154.00	186.00	222.00
Net Income (Loss) - \$/hr	96.00	111.00	126.00	130.00

References

- Ashare, Edward, Donald L. Wise, and Ralph L. Wentworth, Fuel Gas Production From Animal Residue, Dynatech R/D Company, Report No. 1551, Cambridge, Mass., January, 1977.
- Blecker, Herbert G., and Thomas M. Nichols, Capital and Operating Costs of Pollution Control Equipment Modulus, Vol. II, Data Manual, U.S. Environmental Protection Agency, Report Number EPA-R5-73-023b, July 1973.
- Kispert, R. G., S. E. Sadek, L. C. Anderson, and D. L. Wise, Fuel Gas Production from Solid Waste, Dynatech R/D Company, Report No. 1258, Cambridge, Mass., January, 1975.
- McCarty, Perry L., "Anaerobic Waste Treatment Fundamentals," Public Works, November, 1964.
- Patterson, W. L. and R. F. Banker, Estimating Costs and Manpower Requirements for Conventional Wastewater Treatment Facilities, Water Poll. Control Res. Series 17090DAN 10/71, U.S. Environmental Protection Agency, Washington, D.C., October, 1971.
- Quindry, Gerald E., Jon C. Liebman, and John T. Pfeffer, Biological Conversion of Organic Refuse to Methane, Vol. II, Final Report: UIIU-ENG-76-2021, Department of Civil Engineering, University of Illinois at Urbana-Champaign, Urbana, Illinois, November, 1976.

APPENDIX A

The tables in Appendix A present the actual data obtained from the various reactors under the test conditions being employed. The date is designated at the year and the day of the year. For example 76321 is November 16, 1976. The time is listed as the hour of the day. Also, any missing data are recorded as a -1. This technique allows the use of zero when a data point is zero. The gas meter readings are the actual meter readings in liters. The difference between two days readings represent the gas produced during that time period. The alkalinity, solids and volatile acids are all expressed as mg/l of the appropriate constituent.

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EPP. T.S.	EPP. V.S.	EPP. V.A.	CH4 %	
76321	-1.00	-1.00	75.70	6.97	1700.00	32934.00	19711.00	-1.00	-1.00	290.00	-1.00
76322	-1.00	-1.00	68.13	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76323	16.15	1729.00	90.84	7.10	2173.00	-1.00	-1.00	-1.00	-1.00	336.00	-1.00
76324	17.00	2082.00	64.35	7.00	2070.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76325	12.30	2564.00	64.35	7.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76326	10.30	241.00	49.21	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76327	15.45	722.00	64.35	7.20	2938.00	-1.00	-1.00	-1.00	-1.00	120.00	-1.00
76328	16.15	1171.00	105.98	7.20	3182.00	68899.00	46590.00	26972.00	18570.00	-1.00	-1.00
76329	17.45	1981.00	75.70	7.22	-1.00	-1.00	-1.00	-1.00	-1.00	264.00	-1.00
76330	14.45	2801.00	68.13	7.25	-1.00	61343.00	37741.00	30909.00	17584.00	-1.00	-1.00
76331	12.00	411.00	75.70	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76332	14.30	1013.00	60.56	7.27	4053.00	91251.00	53712.00	47050.00	27891.00	120.00	-1.00
76333	15.30	1759.00	64.35	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76334	16.30	2498.00	56.78	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76335	16.00	337.00	56.78	7.40	4855.00	78196.00	46559.00	40552.00	23289.00	-1.00	-1.00
76336	17.00	733.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76337	17.00	1208.00	102.20	7.20	4869.00	-1.00	-1.00	36564.00	20505.00	-1.00	-1.00
76338	17.00	1772.00	60.56	7.30	4836.00	-1.00	-1.00	-1.00	-1.00	120.00	-1.00
76339	13.00	2901.00	60.56	7.25	-1.00	71611.00	41720.00	40257.00	22792.00	-1.00	-1.00
76340	-1.00	-1.00	64.35	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76341	14.45	812.00	52.99	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76342	14.30	1454.00	94.62	7.20	5360.00	59012.00	35249.00	44383.00	24860.00	280.00	-1.00
76343	15.10	2306.00	109.77	7.25	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76344	13.40	232.00	102.20	7.20	5844.00	68847.00	39539.00	48093.00	27839.00	-1.00	-1.00
76345	16.15	1110.00	87.06	7.10	-1.00	-1.00	-1.00	-1.00	-1.00	168.00	-1.00

Table A 1

DEEP MANURE RUN #1 REACTOR #1 START NOV. 16, 1976

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
76346	12.13	1523.00	109.77	7.20	5844.00	80416.00	53674.00	47196.00	26515.00	-1.00	-1.00
76347	11.30	2894.00	94.62	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	60.00
76348	11.40	1370.00	109.77	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76349	14.30	363.00	94.62	7.20	6488.00	76036.00	51387.00	47505.00	27658.00	-1.00	-1.00
76350	14.30	2100.00	87.06	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	288.00	-1.00
76351	10.00	731.00	98.41	7.15	6972.00	30463.00	21958.00	47269.00	28131.00	-1.00	-1.00
76352	14.45	2035.00	87.06	7.25	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76353	9.00	2896.00	94.62	7.15	-1.00	30837.00	23083.00	40697.00	25613.00	-1.00	-1.00
76354	9.30	981.00	102.20	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76355	15.40	221.00	124.91	7.15	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76356	12.40	1624.00	98.41	7.30	6770.00	65668.00	46782.00	35962.00	22566.00	-1.00	-1.00
76357	13.20	190.00	-1.00	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	144.00	-1.00

-93-

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EPP. T.S.	EPP. V.S.	EPP. V.A.	CH4 %	
77060	13.00	1940.00	84.00	7.00	4700.00	57133.00	41451.00	43637.00	28432.00	312.00	-1.00
77061	14.45	99.00	80.50	7.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77062	12.40	1050.00	89.00	7.10	5200.00	46677.00	32253.00	37678.00	24142.00	192.00	-1.00
77063	13.30	2208.00	80.20	7.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77064	9.40	131.00	84.50	7.40	4900.00	49752.00	33242.00	49074.00	30454.00	168.00	-1.00
77065	14.30	873.00	74.30	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77066	14.00	1794.00	79.90	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77067	14.10	2636.00	80.00	7.40	5800.00	44936.00	32200.00	39214.00	28266.00	192.00	-1.00
77068	13.00	450.00	83.60	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77069	13.30	1346.00	85.50	7.30	5000.00	41298.00	28906.00	41774.00	26133.00	192.00	-1.00
77070	14.30	2200.00	77.10	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77071	9.30	2880.00	79.90	7.40	4100.00	47209.00	30024.00	51606.00	30270.00	-1.00	-1.00
77072	9.45	602.00	47.40	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	216.00	-1.00
77073	10.25	1054.00	40.90	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77074	10.00	1340.00	75.20	7.20	4300.00	51456.00	36018.00	41958.00	29205.00	672.00	-1.00
77075	10.00	1031.00	84.50	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77076	10.40	2436.00	85.50	7.30	4700.00	50870.00	33811.00	47626.00	29811.00	-1.00	60.00
77077	10.00	32.00	59.50	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	216.00	-1.00
77078	9.00	502.00	84.50	7.20	4000.00	46429.00	30277.00	49024.00	29361.00	-1.00	-1.00
77079	13.00	627.00	76.20	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	504.00	-1.00
77080	8.10	939.00	79.90	7.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77081	10.30	1862.00	81.80	7.40	4300.00	44889.00	30521.00	42166.00	28621.00	288.00	-1.00
77082	14.30	2583.00	78.00	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77083	11.45	97.00	83.60	7.30	4000.00	53696.00	35457.00	45578.00	29301.00	384.00	-1.00
77084	14.30	835.00	84.50	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-94-

Table A 1

BEEF MANURE RUN 3 REACTOR 1 START FEB 20, 1977 WET STUFF

PAGE 1

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH ₄ %
77085										
12.15	1357.00	79.00	7.40	3900.00	45830.00	30895.00	45861.00	28871.00	312.00	-1.00
77086										
11.00	2026.00	78.00	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77087										
10.30	2661.00	79.96	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77088										
12.30	379.00	78.00	7.30	4100.00	42762.00	29028.00	41846.00	26611.00	336.00	-1.00
77089										
12.50	1214.00	83.50	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77090										
12.50	1722.00	79.90	7.40	4000.00	50948.00	35220.00	40397.00	29345.00	600.00	-1.00

-95-

DATE/TIME		GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %
77145	8.15	2954.00	-1.00	7.00	2306.00	47112.00	28883.00	54454.00	30255.00	216.00	-1.50
77146	8.15	460.00	79.60	7.20	2523.00	34663.00	24066.00	30927.00	18655.00	192.00	-1.50
77147	8.00	883.00	79.60	7.10	2210.00	58770.00	37705.00	29585.00	18413.00	144.00	-1.00
77148	8.00	1386.00	83.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77149	8.45	1988.00	81.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77150	9.24	2521.00	81.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77151	8.15	2964.00	81.50	7.20	2306.00	45306.00	30263.00	50334.00	31969.00	144.00	-1.00
77152	8.10	409.00	81.50	7.30	2436.00	38353.00	25139.00	43350.00	27104.00	168.00	-1.00
77153	8.10	731.00	81.50	7.30	2306.00	45829.00	30045.00	42733.00	25591.00	120.00	-1.00
77154	8.10	1078.00	81.50	7.30	2480.00	49704.00	32651.00	41586.00	26035.00	72.00	-1.00
77155	9.05	1532.00	81.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77156	10.00	2654.00	87.20	7.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77157	8.10	2917.00	81.50	7.20	2480.00	36450.00	26978.00	47202.00	31440.00	408.00	-1.00
77158	8.30	741.00	81.50	7.30	2566.00	40326.00	31504.00	47962.00	31323.00	528.00	-1.00
77159	8.10	2027.00	81.50	7.10	2262.00	36123.00	27626.00	44920.00	28447.00	528.00	-1.00
77160	10.00	376.00	89.10	7.30	2871.00	36639.00	27332.00	44086.00	29116.00	288.00	58.40
77161	8.10	1351.00	79.60	7.20	3002.00	38053.00	28129.00	42976.00	29943.00	408.00	61.80
77162	8.45	2569.00	81.50	7.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77163	8.35	600.00	80.00	7.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77164	8.20	1098.00	80.00	7.00	3002.00	49369.00	36223.00	46324.00	31047.00	168.00	-1.00
77165	8.15	1940.00	80.00	7.10	3088.00	44505.00	33518.00	43784.00	31405.00	432.00	64.50
77166	8.10	223.00	80.00	7.20	1306.00	46101.00	38196.00	45805.00	31312.00	336.00	72.10
77167	8.20	1712.00	83.40	7.50	3480.00	51282.00	39268.00	47666.00	33616.00	388.00	64.50
77168	8.30	151.00	-1.00	7.40	3741.00	55604.00	41684.00	46533.00	33031.00	624.00	65.90
77169	8.25	963.00	81.90	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A 1

DEEP MANURE RUN #4 REACTOR #1 START MAY 25, 1977

PAGE 1

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T. S.	FEED V. S.	EFF. T. S.	EFF. V. S.	EFF. V. A.	CH ₄ %
77170										
8.35	2186.00	80.00	7.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77171										
8.10	726.00	80.00	7.50	3610.00	56778.00	39642.00	50531.00	33430.00	168.00	60.10
77172										
8.10	1960.00	80.00	7.60	4002.00	58569.00	43275.00	49940.00	34577.00	360.00	65.40
77173										
8.45	97.00	87.60	7.60	3735.00	56357.00	40063.00	50405.00	34237.00	192.00	61.00
77174										
8.05	1420.00	80.00	7.70	4365.00	52132.00	39222.00	49739.00	35133.00	216.00	60.50
77175										
8.10	2846.00	80.00	7.70	4500.00	51172.00	37113.00	50589.00	34589.00	408.00	61.20
77176										
9.30	1065.00	80.00	7.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-97-

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. Y.A.	CH4 %
77177										
77178	9.20	1944.00	82.80	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77179	8.15	55.00	82.80	7.70	4590.00	49926.00	35685.00	52103.00	35512.00	384.00
77180	8.15	1691.00	153.50	7.70	4320.00	53570.00	40207.00	52755.00	37006.00	312.00
77181	8.10	174.00	80.00	7.70	4593.00	56971.00	42069.00	53356.00	37348.00	240.00
77182	8.15	1646.00	80.00	7.70	4590.00	53549.00	37986.00	53634.00	35657.00	432.00
77183	8.00	2583.00	80.00	7.60	4635.00	53444.00	39136.00	52629.00	35193.00	504.00
77184	9.50	709.00	80.00	7.70	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77185	10.10	1491.00	80.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77186	11.00	2228.00	80.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77187	9.30	2912.00	80.00	7.70	4545.00	42216.00	27688.00	49577.00	32341.00	144.00
77188	8.30	403.00	80.00	7.70	4230.00	43544.00	31913.00	49124.00	33566.00	264.00
77189	8.10	1553.00	93.00	7.70	4545.00	40290.00	29270.00	54300.00	35523.00	368.00
77190	8.05	2724.00	85.00	7.70	4995.00	41679.00	30675.00	50154.00	33503.00	216.00
77191	9.45	902.00	85.00	7.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77192	9.30	2011.00	85.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77193	1.05	10.00	78.00	7.70	4950.00	54649.00	39246.00	51755.00	33223.00	144.00
77194	8.00	1797.00	80.00	7.70	4365.00	52391.00	40214.00	49253.00	34302.00	240.00
77195	8.15	2426.00	82.00	7.60	4365.00	52636.00	38181.00	52695.00	34706.00	528.00
77196	8.30	936.00	84.00	7.60	4275.00	56218.00	41417.00	51156.00	34716.00	288.00
77197	8.10	2121.00	80.00	7.60	4320.00	52420.00	38508.00	50832.00	34896.00	288.00
77198	8.30	315.00	80.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77199	9.10	1812.00	82.00	7.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77200	9.05	2959.00	87.00	7.70	4410.00	47687.00	36021.00	60814.00	42866.00	264.00
77201	8.10	1402.00	80.00	7.70	4500.00	45442.00	33332.00	54571.00	38067.00	264.00
77202	8.10	2710.00	80.00	7.60	4995.00	57356.00	44335.00	51123.00	35133.00	288.00

-86-

Table A 1

BEEF MANURE REACTOR: START JUNE 26 1977

PAGE 1

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
77202	8.10	962.00	80.00	7.70	4656.00	48167.00	34271.00	52760.00	35753.00	264.00	64.50
77203	8.50	2374.00	80.00	7.70	4656.00	47658.00	36061.00	52491.00	37616.00	264.00	60.20
77204	11.00	847.00	83.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77205	11.30	2289.00	83.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77206	9.05	502.00	85.00	7.60	5280.00	45201.00	34796.00	53587.00	38982.00	168.00	65.30
77207	9.05	1423.00	85.00	7.60	5472.00	49628.00	35626.00	52100.00	34613.00	168.00	61.00
77208	8.05	2674.00	80.00	7.70	4992.00	41935.00	33392.00	52746.00	36659.00	264.00	58.90
77209	8.10	1067.00	87.00	7.70	4608.00	42390.00	33979.00	51734.00	40195.00	864.00	58.20
77210	8.10	2305.00	80.00	7.70	4704.00	40721.00	28531.00	52688.00	34772.00	264.00	62.70
77211	9.10	276.00	90.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77212	10.00	1470.00	92.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77213	8.50	2730.00	80.00	7.70	4656.00	67520.00	53647.00	51938.00	38779.00	504.00	50.50
77214	8.10	2780.00	80.00	7.90	4704.00	40420.00	38413.00	52541.00	40146.00	240.00	55.70
77215	8.10	1649.00	80.00	7.90	4512.00	44230.00	36297.00	52481.00	41828.00	528.00	57.20
77216	9.10	1888.00	87.00	7.70	4512.00	43328.00	34318.00	53627.00	42489.00	-1.00	60.70
77217	8.10	2569.00	-1.00	7.70	4800.00	44714.00	36519.00	55869.00	45135.00	1200.00	69.30
77218	9.45	378.00	37.00	7.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77219	10.55	1293.00	95.00	7.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77220	8.05	2059.00	88.00	7.70	4800.00	47957.00	37562.00	52560.00	40842.00	528.00	61.90
77221	8.05	307.00	80.00	7.80	4800.00	53929.00	43580.00	52191.00	41001.00	72.00	66.80
77222	8.05	1457.80	81.00	7.90	4896.00	52123.00	41495.00	53864.00	41129.00	168.00	60.90
77223	9.00	2553.00	78.00	7.90	4800.00	49257.00	38695.00	52679.00	41659.00	360.00	58.70
77224	8.05	294.00	82.00	7.70	5088.00	45264.00	36744.00	55812.00	46293.00	1104.00	57.20
77225	10.15	1669.00	84.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77226	10.30	2799.00	80.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A 1

DEEP MANURE REACTOR1 START JUNE 26 1977

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CS4 %
77227										
8.40	841.00	83.00	8.00	5200.00	53171.00	43506.00	58413.00	47767.00	384.00	68.10
77228										
8.05	1978.00	80.00	7.90	4416.00	46443.00	37708.00	55546.00	44793.00	264.00	62.20
77229										
8.00	17.00	104.00	8.00	4512.00	50617.00	39873.00	55056.00	41807.00	288.00	55.00
77230										
8.15	1270.00	87.00	7.90	4416.00	49611.00	40975.00	54283.00	44551.00	312.00	68.30
77231										
9.30	2565.00	81.00	7.90	4896.00	52610.00	42880.00	54237.00	43902.00	96.00	-1.00
77232										
12.00	803.00	80.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77233										
11.30	1921.00	85.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77234										
9.20	2989.00	88.00	7.90	4416.00	50087.00	38339.00	58461.00	43083.00	288.00	65.70
77235										
8.15	1500.00	91.00	8.00	4608.00	47309.00	38169.00	57553.00	45785.00	48.00	50.20
77236										
8.15	2391.00	89.00	8.00	4512.00	50730.00	37719.00	60047.00	44167.00	120.00	57.20
77237										
8.15	659.00	87.00	7.90	4800.00	46931.00	37912.00	56339.00	44796.00	192.00	65.40
77238										
8.30	1680.00	82.00	8.10	4416.00	63305.00	50176.00	57407.00	45965.00	108.00	71.70
77239										
10.30	108.00	84.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77240										
10.00	1231.00	89.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77241										
9.05	2146.00	83.00	8.10	4704.00	58898.00	44044.00	55972.00	43204.00	240.00	62.90
77242										
8.35	80.00	90.00	8.00	5184.00	57062.00	43648.00	59269.00	46174.00	312.00	61.30
77243										
8.30	943.00	90.00	7.90	4608.00	45136.00	34433.00	58216.00	45104.00	168.00	62.60
77244										
8.15	1792.00	87.00	8.00	4800.00	44586.00	34068.00	59006.00	46588.00	72.00	64.60
77245										
9.00	2604.00	86.00	8.00	4704.00	43106.00	32265.00	58791.00	45330.00	144.00	61.80
77246										
10.30	334.00	85.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77247										
9.45	807.00	81.00	7.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77248										
10.20	1146.00	92.00	7.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77249										
8.30	1435.00	85.00	7.90	3744.00	63883.00	41411.00	56941.00	41589.00	528.00	65.20
77250										
8.00	1728.00	85.00	7.90	4320.00	88432.00	60192.00	61879.00	44714.00	576.00	52.80
77251										
8.00	1974.00	88.00	7.90	4320.00	72020.00	44342.00	65164.00	43882.00	288.00	50.80

-100-

Table A 1

BEEF MANURE REACTOR1 START JUNE 26 1977

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EPP. T.S.	EPP. V.S.	EPP. F.S.	CH# %	
77252	8.00	2128.00	81.00	7.90	3840.00	82698.00	47310.00	66013.00	43631.00	1344.30	58.70
77253	10.05	2525.00	94.00	7.90	-1.00	105527.00	62092.00	-1.00	-1.00	-1.00	-1.00
77254	10.50	2907.00	82.00	-1.00	-1.00	62642.00	34884.00	-1.00	-1.00	-1.00	-1.00
77255	9.35	163.00	05.00	7.40	3840.00	54680.00	35639.00	68526.00	45343.00	360.00	48.00
77256	8.10	410.00	07.00	7.50	4018.00	50999.00	33823.00	64387.00	42646.00	384.00	49.70
77257	8.00	687.00	09.00	7.50	3724.00	48194.00	31422.00	61501.00	39514.00	1032.00	52.40
77258	8.05	860.00	02.00	7.50	3332.00	67208.00	43868.00	62269.00	39103.00	1056.00	56.20
77259	8.15	1300.00	82.10	7.60	3528.00	45932.00	31152.00	60903.00	41679.00	890.00	57.10
77260	9.20	1604.00	-1.00	7.60	-1.00	39244.00	27832.00	-1.00	-1.00	-1.00	-1.00
77261	10.05	1270.00	128.00	7.50	-1.00	40574.00	27236.00	-1.00	-1.00	-1.00	-1.00
77262	8.10	2110.00	158.00	7.50	2842.00	30555.00	19774.00	50980.00	32441.00	936.00	59.70
77263	11.55	2344.00	168.00	7.40	2744.00	26761.00	13893.00	42076.00	22692.00	1320.00	66.70
77264	8.25	2633.00	145.00	7.50	2744.00	10003.00	5352.00	39984.00	26734.00	480.00	69.90
77265	8.05	2875.00	157.00	7.50	2842.00	55868.00	30671.00	40272.00	26723.00	216.00	68.30
77266	8.05	420.00	160.00	7.40	2646.00	57330.00	41708.00	40307.00	27537.00	432.00	54.00
77267	9.25	798.00	-1.00	7.20	-1.00	44852.00	31770.00	-1.00	-1.00	-1.00	-1.00

-101-

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %
77267										
77268	9.25	798.00	-1.00	7.20	-1.00	44852.00	31770.00	-1.00	-1.00	-1.00
77269	8.20	1374.00	162.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77270	8.05	2142.00	160.00	7.30	2744.00	57040.00	41195.00	44857.00	31162.00	672.00
77271	8.10	2638.00	161.00	7.40	2548.00	41941.00	28962.00	42878.00	29760.00	528.00
77272	9.00	111.00	162.00	7.40	2744.00	40602.00	27676.00	41619.00	20885.00	312.00
77273	8.00	570.00	175.00	7.40	2156.00	54826.00	40340.00	43070.00	30066.00	216.00
77274	8.00	874.00	162.00	7.40	2156.00	57556.00	32988.00	46289.00	26074.00	336.00
77275	9.30	1213.00	161.00	7.50	-1.00	76774.00	52221.00	-1.00	-1.00	-1.00
77276	9.45	1513.00	163.00	7.61	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77277	8.00	1659.00	160.00	7.30	1842.00	24663.00	17357.00	44732.00	28102.00	96.00
77278	8.00	1757.00	159.00	7.30	1666.00	24050.00	13909.00	40362.00	29047.00	96.00
77279	8.00	1884.00	160.00	7.30	1568.00	30528.00	21773.00	38015.00	27016.00	24.00
77280	8.00	2022.00	160.00	7.20	1470.00	38101.00	26534.00	41155.00	29032.00	24.00
77281	8.00	2144.00	160.00	7.20	1274.00	37674.00	23084.00	41204.00	27205.00	24.00
77282	11.00	2302.00	163.00	7.30	-1.00	59557.00	17644.00	-1.00	-1.00	-1.00
77283	9.00	2465.00	161.00	7.20	-1.00	42315.00	27430.00	-1.00	-1.00	-1.00
77284	7.45	2666.00	165.00	7.20	1274.00	64499.00	42375.00	52211.00	34404.00	72.00
77285	8.45	2866.00	163.00	7.20	1176.00	51359.00	34319.00	53572.00	35779.00	72.00
77286	8.00	52.00	162.00	7.20	1372.00	70037.00	47120.00	54838.00	38106.00	96.00
77287	8.10	264.00	163.00	7.20	1372.00	49399.00	34187.00	54131.00	38504.00	48.00
77288	8.10	422.00	160.00	7.30	1372.00	34836.00	22777.00	51492.00	29070.00	120.00
77289	10.00	987.00	160.00	7.30	-1.00	39448.00	23293.00	-1.00	-1.00	-1.00
77290	10.30	739.00	21.00	7.20	-1.00	73423.00	49533.00	-1.00	-1.00	-1.00
77291	8.05	1183.00	44.00	7.20	1470.00	111076.00	67698.00	47739.00	32694.00	48.00
77291	8.00	1416.00	80.00	7.20	1764.00	80539.00	53646.00	50066.00	33715.00	96.00

-102-

Table A 1

DEEP MANURE REACTOR #1 START SEPT. 25 1977

DATE/TIME	GAS FTTFR	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
77292											
77293	8.00	1704.00	100.00	7.20	1862.00	53444.00	39698.00	48033.00	33523.00	48.30	59.40
77294	8.00	2038.00	121.00	7.30	2058.00	29891.00	20912.00	49737.00	33999.00	24.00	60.90
77295	8.00	2326.00	-1.00	-1.00	1960.00	65135.00	35246.00	41623.00	22248.00	72.00	59.40
77296	10.00	2637.00	-1.00	7.30	-1.00	81150.00	55522.00	-1.00	-1.00	-1.00	-1.00
77297	9.30	49.00	100.00	7.40	-1.00	80215.00	52250.00	-1.00	-1.00	-1.00	-1.00
77298	8.45	435.00	99.00	7.40	2254.00	57450.00	40424.00	50444.00	35354.00	48.00	57.00
77299	8.05	820.00	101.00	7.30	2352.00	69349.00	46656.00	50767.00	34907.00	48.00	59.50
77300	8.00	1269.00	105.00	7.40	2744.00	64686.00	45019.00	55271.00	38632.00	120.00	63.20
77301	8.00	1674.00	102.00	7.40	3136.00	125009.00	76311.00	57240.00	39850.00	96.00	59.40
77302	8.00	2154.00	102.00	7.40	2940.00	119560.00	66716.00	61099.00	34752.00	72.00	59.40
77303	9.55	2744.00	106.00	7.40	-1.00	65631.00	38544.00	-1.00	-1.00	-1.00	-1.00
77304	11.05	364.00	133.00	7.50	-1.00	71161.00	47287.00	-1.00	-1.00	-1.00	-1.00
77305	8.35	878.00	97.00	7.40	3430.00	63453.00	45967.00	61163.00	42077.00	96.00	54.50
77306	8.00	1235.00	97.00	7.40	3430.00	39583.00	28009.00	58394.00	37440.00	72.00	53.30
77307	8.00	1630.00	94.00	7.50	3136.00	67721.00	50840.00	52254.00	36234.00	48.00	55.90
77308	8.05	1945.00	105.00	7.40	3038.00	66693.00	48684.00	51712.00	34543.00	72.00	56.10
77309	9.05	2373.00	102.00	7.40	3234.00	60361.00	39769.00	52595.00	33096.00	120.00	56.60
77310	9.50	2925.00	100.00	7.60	-1.00	58686.00	34864.00	-1.00	-1.00	-1.00	-1.00
77311	10.30	493.00	100.00	7.50	-1.00	60079.00	44395.00	-1.00	-1.00	-1.00	-1.00
77312	8.35	998.00	150.00	7.40	3038.00	76557.00	51927.00	49386.00	34551.00	96.00	52.50
77313	8.05	1656.00	95.00	7.40	3136.00	65597.00	47715.00	53556.00	37923.00	96.00	55.30
77314	8.05	2247.00	-1.00	7.40	3039.00	60063.00	42670.00	50269.00	35371.00	96.00	52.50
77315	8.10	2771.00	-1.00	7.40	3136.00	41107.00	30238.00	47902.00	33700.00	96.00	54.20
77316	8.05	291.00	-1.00	7.50	3038.00	43379.00	28648.00	44957.00	26299.00	48.00	-1.00
	9.45	540.00	-1.00	7.40	-1.00	43290.00	31067.00	-1.00	1.00	-1.00	-1.00

-103-

Table A 1

DEEP NATURE REACTOR #1 START SEPT. 25 1977

DATE/TIME	GAS METERS	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CR4 %
77317	10.00	772.00	-1.00	7.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77318	8.15	964.00	-1.00	7.50	-1.00	75871.00	59700.00	-1.00	-1.00	-1.00
77319	8.10	1113.00	61.00	7.50	3038.00	72685.00	56803.00	44664.00	31226.00	96.00
77320	8.10	1775.00	106.00	7.40	2842.00	71639.00	54331.00	47479.00	33526.00	144.00
77321	8.05	2206.00	109.00	7.40	2842.00	-1.00	-1.00	48981.00	35159.00	96.00
77322	8.05	359.00	65.00	7.40	2744.00	97526.00	58700.00	52774.00	29571.00	72.00
77323	8.30	2658.00	103.00	7.40	-1.00	91373.00	56931.00	-1.00	-1.00	-1.00
77324	11.25	2490.00	106.00	7.40	-1.00	94855.00	66677.00	-1.00	-1.00	-1.00
77325	8.10	746.00	103.00	7.40	2940.00	95776.00	70672.00	59406.00	42605.00	120.00
77326	8.10	2216.00	103.00	7.40	3332.00	93740.00	67020.00	59206.00	42902.00	-1.00
77327	8.10	962.00	95.00	7.40	3430.00	89826.00	55474.00	63179.00	36228.00	480.00
77328	8.55	2421.00	98.00	7.40	-1.00	90542.00	55302.00	63417.00	36820.00	-1.00
77329	11.25	1056.00	102.00	7.40	-1.00	82003.00	54537.00	61323.00	39388.00	-1.00
77330	11.45	1653.00	103.00	7.40	-1.00	74354.00	47448.00	61554.00	36125.00	-1.00

-104-

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
76321	-1.00	-1.00	56.78	6.90	1694.00	32934.00	19711.00	-1.00	-1.00	216.00	-1.00
76322	-1.00	-1.00	85.16	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76323	10.15	181.00	60.56	7.10	2070.00	-1.00	-1.00	-1.00	-1.00	240.00	-1.00
76324	17.00	552.00	56.78	7.00	2199.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76325	12.30	987.00	41.64	7.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76326	10.30	1347.00	71.92	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76327	15.45	1652.00	64.35	7.20	2910.00	-1.00	-1.00	-1.00	-1.00	192.00	-1.00
76328	16.15	1987.00	64.35	7.10	3142.00	68899.00	46590.00	20246.00	13236.00	-1.00	-1.00
76329	17.40	2713.00	68.13	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	164.00	-1.00
76330	14.45	106.00	60.56	7.20	-1.00	61343.00	37741.00	23153.00	13255.00	-1.00	-1.00
76331	12.00	682.00	75.70	7.30	3917.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76332	14.30	1257.00	60.56	7.20	4066.00	91251.00	53712.00	41693.00	22914.00	216.00	-1.00
76333	15.30	1897.00	64.35	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76334	16.30	2554.00	79.49	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76335	16.00	118.00	64.35	7.20	4746.00	78196.00	46559.00	39846.00	23280.00	-1.00	-1.00
76336	17.00	722.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76337	17.00	1068.00	128.69	7.30	4896.00	-1.00	-1.00	33942.00	18126.00	-1.00	-1.00
76338	17.00	1685.00	98.41	7.30	4876.00	-1.00	-1.00	-1.00	-1.00	144.00	-1.00
76339	13.00	2263.00	64.35	7.20	-1.00	71611.00	41720.00	38786.00	22265.00	-1.00	-1.00
76340	-1.00	-1.00	64.35	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76341	14.45	699.00	60.56	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76342	14.30	1198.00	94.62	7.30	5441.00	59012.00	35249.00	43208.00	24388.00	-1.00	-1.00
76343	15.10	2233.00	102.20	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76344	15.40	90.00	102.20	7.20	6166.00	68847.00	39539.00	42821.00	25458.00	-1.00	-1.00
76345	16.15	897.00	67.06	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	120.00	-1.00

Table A 2

STEP MANURE RUN #1 REACTOR #2 START NOV. 16, 1976

PAGE 1

DATE/TIME	GAS METER	FED DATE	PH	ALKALINITY	FED T.S.	FED V.S.	EFF. T.S.	EFF. V.S.	EFF. T.S.	EFF. V.S.
76346	12.10	1625.00	103.98	7.25	6468.00	80416.00	53674.00	42262.00	25183.00	-1.00
76347	11.30	2833.00	90.84	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	60.00
76348	11.40	1185.00	94.62	7.15	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76349	14.30	2886.00	102.21	7.25	5964.00	76036.00	51387.00	44303.00	26686.00	-1.00
76350	14.30	1361.00	75.70	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	312.00
76351	13.00	2540.00	90.84	7.30	6206.00	30463.00	21958.00	44063.00	27352.00	-1.00
76352	14.45	630.00	94.62	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76353	9.00	1404.00	94.62	7.30	-1.00	30837.00	23083.00	35357.00	22480.00	-1.00
76354	9.30	2399.00	90.84	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76355	15.40	1131.00	124.91	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76356	12.40	2528.00	83.27	7.15	6166.00	65668.00	46782.00	37295.00	25058.00	-1.00
76357	13.20	1456.00	102.20	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	144.00
76358	16.20	2953.00	102.20	7.30	5964.00	60726.00	43541.00	39083.00	26638.00	-1.00
76359	13.50	1528.00	98.41	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76360	10.50	2890.00	90.84	7.30	-1.00	51414.00	36834.00	36192.00	24010.00	-1.00
76361	10.50	2157.00	94.62	7.50	6488.00	-1.00	-1.00	-1.00	-1.00	-1.00
76362	10.50	694.00	94.62	7.30	-1.00	49005.00	33678.00	35088.00	22039.00	-1.00
76363	10.50	2173.00	98.41	7.40	6529.00	-1.00	-1.00	-1.00	-1.00	120.00
76364	11.20	800.00	98.41	7.40	-1.00	51644.00	35452.00	43569.00	27627.00	-1.00
76365	10.20	2527.00	56.78	7.40	6367.00	-1.00	-1.00	-1.00	-1.00	-1.00

-106-

Table A 2

DAIRY MANURE RUN #2 REACTOR #2 START DEC. 11, 1976

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CRU %	
77060	13.00	1626.00	84.00	7.10	5000.00	57133.00	41451.00	43819.00	28573.00	504.00	-1.00
77061	14.45	2670.00	125.00	7.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77062	12.40	633.00	125.00	7.10	5300.00	46677.00	32253.00	46226.00	28080.00	600.00	-1.00
77063	13.30	1789.00	121.00	7.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77064	9.40	2778.00	120.80	7.30	4800.00	49752.00	33242.00	42071.00	27191.00	336.00	-1.00
77065	14.30	663.00	81.80	7.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77066	14.00	1763.00	126.30	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77067	14.10	2817.00	118.90	7.40	5400.00	44936.00	33208.00	44649.00	30378.00	384.00	-1.00
77068	13.50	602.00	124.50	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77069	13.30	1644.00	120.80	7.30	5100.00	41298.00	28906.00	49165.00	28930.00	168.00	-1.00
77070	14.30	2726.00	120.80	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77071	9.30	547.00	120.80	7.20	3900.00	47209.00	30024.00	56056.00	32800.00	552.00	-1.00
77072	9.45	1521.00	125.40	7.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77073	10.25	2354.00	122.60	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77074	10.00	484.00	117.00	7.20	4000.00	51456.00	36018.00	52777.00	34757.00	312.00	-1.00
77075	10.00	1074.00	120.80	7.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77076	10.40	1989.00	124.50	7.20	4500.00	50870.00	33811.00	46542.00	29117.00	-1.00	60.00
77077	10.00	2880.00	117.00	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	168.00	-1.00
77078	9.00	379.00	117.00	7.20	4200.00	46429.00	30277.00	48839.00	29860.00	-1.00	-1.00
77079	13.00	627.00	76.20	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	504.00	-1.00
77080	8.10	1945.00	117.10	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77081	10.30	450.00	115.20	7.20	4200.00	44889.00	30521.00	42295.00	27355.00	288.00	-1.00
77082	14.30	1395.00	115.20	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77083	11.45	1936.00	130.10	7.20	3900.00	53696.00	35457.00	51681.00	32230.00	696.00	-1.00
77084	2.30	2768.00	118.90	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A 2

BEEF MANURE RUN 3 REACTOR 2 START FEB 21, 1977 WET STUFF

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T. S.	FEED V. S.	EFF. T. S.	EFF. V. S.	EFF. V. A.	CH4 %	
77085	10.15	302.00	110.90	7.30	3800.00	45830.00	30895.00	48659.00	30794.00	672.00	-1.00
77086	11.00	1182.00	120.80	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77087	10.30	1980.00	124.50	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77088	10.30	2826.00	130.10	7.30	3571.00	42762.00	29028.00	43424.00	28885.00	864.00	-1.00
77089	12.50	746.00	122.60	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77090	12.50	1169.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-108-

DATE/TIME	GAS BE12R	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
77145	8.15	294.00	-1.00	7.00	2132.00	47112.00	28663.00	61331.00	33743.00	216.00	-1.00
77146	8.15	989.00	199.00	7.00	2262.00	34663.00	24066.00	55439.00	30517.00	144.00	-1.00
77147	8.00	1572.00	201.00	7.10	2088.00	58770.00	37705.00	48820.00	28122.00	216.00	-1.00
77148	8.00	2403.00	216.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77149	8.45	270.00	201.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77150	9.20	1029.00	201.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77151	8.15	1666.00	201.00	7.20	2436.00	45306.00	30263.00	50757.00	32822.00	192.00	-1.00
77152	8.10	2287.00	201.00	7.20	2489.00	38353.00	25139.00	51956.00	31516.00	144.00	-1.00
77153	8.10	2680.00	201.00	7.10	2218.00	46829.00	35045.00	43037.00	26730.00	168.00	-1.00
77154	8.10	70.00	201.00	7.20	2218.00	49704.00	32651.00	41028.00	26986.00	72.00	-1.00
77155	9.15	793.00	223.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77156	10.00	2387.00	201.00	6.90	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77157	8.10	313.00	201.00	7.00	2480.00	36450.00	26978.00	54274.00	36870.00	600.00	-1.00
77158	8.30	1651.00	201.00	7.00	2654.00	40326.00	31504.00	57330.00	38901.00	1080.00	-1.00
77159	8.10	668.00	201.00	7.00	2784.00	36123.00	27626.00	52665.00	35845.00	960.00	-1.00
77160	10.00	2922.00	201.00	7.10	2871.00	36639.00	27332.00	48657.00	33953.00	816.00	60.40
77161	8.10	1615.00	201.00	7.20	2958.00	38053.00	28129.00	46286.00	32002.00	504.00	62.40
77162	8.45	699.00	201.00	6.80	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77163	8.35	2598.00	203.60	7.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77164	8.20	683.00	200.00	6.90	2956.00	49369.00	36223.00	47829.00	34107.00	384.00	-1.00
77165	8.15	1997.00	200.00	6.90	3045.00	48535.00	33518.00	49038.00	34943.00	1080.00	59.40
77166	8.10	1300.00	200.00	7.10	3088.00	46101.00	38196.00	49864.00	36382.00	1056.00	67.40
77167	8.20	1102.00	200.90	7.50	3436.00	51282.00	39268.00	47786.00	35460.00	528.00	68.00
77168	8.30	49.00	-1.00	7.30	3698.00	55604.00	41684.00	53427.00	38472.00	1320.00	61.60
77169	8.25	1642.00	200.00	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A 2

BEEF MANURE RUN #4 REACTOR #2 START MAY 25, 1977

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %
77170	8.35	1094.00	200.00	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77171	8.10	-1110.00	200.00	7.40	4046.00	56778.00	39642.00	55923.00	39293.00	672.00
77172	8.10	483.00	200.00	7.50	4306.00	58569.00	43275.00	58287.00	41214.00	1152.00
77173	8.05	2679.00	203.00	7.50	3825.00	56357.00	40063.00	56195.00	35254.00	1032.00
77174	8.05	2217.00	200.00	7.70	5175.00	52132.00	39222.00	55456.00	39022.00	696.00
77175	8.10	1595.00	203.00	7.70	4455.00	51172.00	37113.00	56043.00	37878.00	312.00
77176	9.30	1005.00	200.00	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-110-

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFP. T.S.	EFP. V.S.	EFP. V.A.	CH4 %
77177										
9.23	2924.30	200.30	7.20	-1.00	-1.00	-1.30	+1.00	-1.00	-1.00	-1.00
77178										
8.15	2125.00	200.00	7.70	4230.00	49926.00	35685.00	53080.00	36529.00	672.00	60.10
77179										
8.13	1771.00	205.00	7.50	4050.00	53570.00	40207.00	55091.00	30376.00	816.00	62.10
77180										
8.13	1019.30	280.30	7.70	4095.30	56971.00	42069.00	55190.00	38712.00	1320.00	60.80
77181										
8.15	-1278.00	247.00	7.70	4365.00	53549.00	37986.00	54712.00	37777.00	552.00	62.40
77182										
8.00	1020.00	300.00	7.70	4050.00	53444.00	39136.00	53076.00	36584.00	216.00	64.60
77183										
9.53	698.00	304.00	7.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77184										
10.10	2065.00	80.00	-1.00	-1.00	-1.00	-1.30	-1.70	-1.00	-1.00	-1.30
77185										
11.00	476.00	205.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77186										
8.30	1192.00	307.00	7.70	3780.00	42216.00	27688.00	49306.00	31563.00	888.00	60.10
77187										
9.30	-1565.00	200.00	7.40	3105.30	43544.00	31910.00	49076.00	34203.30	1752.30	55.80
77188										
8.30	127.00	300.00	7.40	3285.00	40790.00	28770.00	51500.00	35083.00	2664.00	59.90
77189										
8.25	1118.30	295.00	7.00	3060.00	41679.00	30675.00	49014.00	34551.00	4012.30	44.00
77190										
9.45	1704.00	260.00	6.50	-1.00	-1.00	-1.00	-1.30	-1.00	-1.00	-1.30
77191										
9.30	2113.00	205.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77192										
8.05	2530.00	140.00	6.50	3105.00	54649.00	39246.00	49186.00	33887.00	5520.00	43.40
77193										
8.00	2657.00	83.00	6.40	3105.00	52391.00	40214.00	49845.30	37933.30	1960.00	-1.00
77194										
8.05	2713.00	82.00	6.40	3015.00	52636.00	38181.00	52974.00	37201.00	7260.00	-1.00
77195										
8.30	2878.00	80.00	6.20	3015.00	56218.00	41417.00	48367.00	34777.00	5400.00	62.80
77196										
8.10	14.30	-1.00	6.40	3020.00	52428.00	39508.00	52182.00	37253.00	5640.00	-1.00
77197										
8.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77198										
9.30	1119.00	-1.00	7.50	-1.00	-1.00	-1.00	-1.70	-1.00	-1.00	-1.00
77199										
8.25	2514.00	40.00	7.70	4500.00	47687.00	36021.00	53394.00	37731.00	1560.00	64.80
77200										
8.10	1190.00	77.00	7.80	4860.00	45442.00	33332.00	52000.00	35723.00	720.00	-1.00
77201										
8.10	2447.00	79.00	7.80	4725.00	57356.00	44335.00	53031.00	36449.00	420.00	58.50

Table A 2

DEEP MANURE REACTOR 2 START JUNE 26 1977

PAGE 1

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. Y.A.	CH4 %
77202										
9.10	841.00	80.00	7.80	4320.00	49167.00	34271.00	52253.00	35717.00	300.00	61.70
77203										
9.50	1987.00	80.00	7.70	4416.00	47658.00	36061.00	51798.00	40554.00	480.00	60.20
77204										
11.00	40.00	82.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77205										
11.30	1470.00	96.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77206										
8.05	2692.00	83.00	7.70	4800.00	45201.00	34796.00	52046.00	36659.00	456.00	63.90
77207										
9.05	319.00	81.00	7.60	5472.00	49628.00	35626.00	51504.00	33461.00	264.00	58.50
77208										
8.05	1877.00	80.00	7.70	4512.00	44935.00	33392.00	52880.00	37947.00	264.00	58.90
77209										
8.10	2993.00	76.00	7.70	4992.00	42390.00	33979.00	49790.00	38826.00	288.00	56.80
77210										
8.10	1217.00	88.00	7.75	4896.00	40721.00	28531.00	51761.00	33746.00	192.00	62.00
77211										
9.10	1240.00	95.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77212										
11.00	180.00	93.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77213										
8.50	1206.00	82.00	7.70	4512.00	67520.00	53647.00	50745.00	38625.00	432.00	61.50
77214										
8.10	2303.00	80.00	7.70	4416.00	48420.00	38413.00	51626.00	38764.00	2128.00	57.80
77215										
8.10	455.00	79.00	7.80	4512.00	44230.00	36297.00	53091.00	43253.00	780.00	59.70
77216										
8.10	839.00	84.00	7.80	4512.00	43328.00	34318.00	53503.00	40690.00	264.00	60.25
77217										
8.10	1841.00	81.00	7.70	4704.00	44714.00	36519.00	54095.00	44870.00	1152.00	61.80
77218										
9.45	120.00	81.00	7.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77219										
10.55	1375.00	81.00	7.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77220										
8.05	2297.00	84.00	7.70	4608.00	47957.00	37562.00	53491.00	41446.00	1152.00	59.90
77221										
8.05	427.00	79.00	7.80	4128.00	53929.00	43580.00	56584.00	44828.00	336.00	55.50
77222										
8.05	1366.00	80.00	7.80	4608.00	52123.00	41495.00	54926.00	41962.00	432.00	62.50
77223										
8.00	2382.00	160.00	7.70	4320.00	49257.00	38695.00	58946.00	46604.00	672.00	64.80
77224										
9.05	170.00	165.00	7.70	4512.00	45254.00	36744.00	59500.00	48118.00	912.00	59.90
77225										
10.15	1105.00	120.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77226										
10.30	2017.00	124.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-112-

Table A 2

BEEP MANURE REACTOR 2 START JUNE 24 1977

PAGE 2

DATE/TIME	GAS METERS	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
77227	3.40	10.00	165.00	7.70	4323.00	53171.00	43506.00	61061.00	50732.00	1152.00	67.30
77228	8.05	1700.00	160.00	7.60	3936.00	46043.00	37708.00	57733.00	47373.00	1080.00	60.30
77229	8.10	1980.00	161.00	8.00	4320.00	50617.00	39873.00	61880.00	45071.00	1032.00	61.30
77230	8.15	2409.00	187.00	7.80	4416.00	45611.00	40975.00	61590.00	51382.00	420.00	60.20
77231	9.30	2483.00	134.00	7.40	4416.00	52610.00	42880.00	61304.00	50576.00	2880.00	-1.00
77232	12.00	2485.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77233	11.30	2485.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77234	9.20	2485.00	80.00	7.80	4512.00	50087.00	36339.00	58071.00	42219.00	460.00	60.50
77235	8.15	430.00	80.00	8.00	4416.00	47309.00	38169.00	56930.00	46168.00	900.00	59.50
77236	8.15	1110.00	80.00	8.00	4800.00	50730.00	37919.00	59213.00	41995.00	1440.00	57.60
77237	8.15	1591.00	81.00	7.60	4608.00	46931.00	37912.00	57104.00	45442.00	1260.00	61.30
77238	8.30	2336.00	80.00	7.70	4704.00	63305.00	50176.00	59119.00	46380.00	1140.00	72.00
77239	10.10	47.00	150.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77240	10.00	544.00	121.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77241	8.05	1470.00	160.00	7.80	3936.00	58898.00	44044.00	60394.00	47280.00	1320.00	62.00
77242	8.05	2643.00	160.00	7.80	4032.00	57062.00	43648.00	61540.00	47829.00	1020.00	60.00
77243	8.00	637.00	165.00	7.60	4032.00	45136.00	34437.00	61340.00	47512.00	1020.00	63.10
77244	8.15	837.00	163.00	7.60	4128.00	44586.00	34068.00	61382.00	48234.00	1140.00	60.50
77245	9.00	1607.00	161.00	7.60	3840.00	43106.00	32265.00	58385.00	44323.00	560.00	59.30
77246	10.00	2614.00	159.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77247	9.45	540.00	163.00	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77248	10.20	1438.00	160.00	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77249	8.00	2237.00	155.00	7.60	4512.00	63083.00	41411.00	55089.00	39923.00	540.00	67.10
77250	8.00	2956.00	165.00	7.70	3744.00	68432.00	60192.00	59396.00	42235.00	360.00	63.20
77251	8.00	494.00	159.00	7.60	3552.00	72020.00	44342.00	65664.00	43707.00	216.00	63.90

-113-

Table A 2

BEEP NATURE REACTOR 2 START JUNE 26 1977

PAGE 3

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	REMARKS
77252										
8.00	987.00	166.00	7.60	3264.00	82698.00	47310.00	68020.00	42276.00	264.00	64.70
77253										
10.05	1359.00	162.00	7.60	-1.00	105527.00	62092.00	-1.00	-1.00	-1.00	-1.00
77254										
10.50	1694.00	160.00	-1.00	-1.00	62642.00	34884.00	-1.00	-1.00	-1.00	-1.00
77255										
8.05	1987.00	162.00	7.20	3072.00	54680.00	35639.00	71315.00	44407.00	216.00	63.50
77256										
9.10	2693.00	169.00	7.20	2940.00	54999.00	33323.00	68397.00	44388.00	72.00	60.50
77257										
8.00	2754.00	203.00	7.20	2940.00	48194.00	31422.00	62295.00	38137.00	120.00	63.10
77258										
8.15	808.00	161.00	7.20	2940.00	67208.00	43868.00	60753.00	36610.00	336.00	62.30
77259										
9.15	421.00	158.00	7.20	2940.00	45932.00	31152.00	58037.00	39429.00	240.00	62.90
77260										
9.20	808.00	-1.00	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77261										
10.05	1547.00	79.00	7.40	-1.00	40574.00	27236.00	-1.00	-1.00	-1.00	-1.00
77262										
8.10	2343.00	165.00	7.50	3038.00	30555.00	19774.00	51786.00	33001.00	384.00	58.50
77263										
11.55	2767.00	165.00	7.50	2940.00	26761.00	13693.00	46818.00	24261.00	216.00	54.20
77264										
8.25	2341.00	165.00	7.40	2548.00	10003.00	5352.00	46492.00	31642.00	490.00	56.00
77265										
8.35	2510.00	130.00	7.40	2450.00	55868.00	38671.00	45031.00	30077.00	408.00	60.50
77266										
8.05	2692.00	-1.00	7.40	2450.00	-1.00	-1.00	39616.00	26508.00	360.00	66.60
77267										
9.25	2927.00	163.00	7.60	-1.00	44852.00	31770.00	-1.00	-1.00	-1.00	-1.00

-114-

Table A 2

BEEP MANURE REACTOR 2 START JUNE 26 1977

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %
77267										
9.25	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77268										
8.20	63.00	155.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77269										
8.05	235.00	161.00	7.40	2058.00	-1.00	-1.00	44711.00	29783.00	216.00	64.50
77270										
8.10	321.00	162.00	7.50	1960.00	-1.00	-1.00	44514.00	29296.00	72.00	72.20
77271										
8.00	499.00	167.00	7.50	2058.00	69597.00	45919.00	44832.00	30210.00	24.00	71.40
77272										
9.00	893.00	167.00	7.60	2058.00	56584.00	37160.00	44714.00	30269.00	96.00	72.90
77273										
8.00	1072.00	163.00	7.50	1862.00	48714.00	27042.00	45566.00	23788.00	168.00	73.99
77274										
9.30	1105.00	163.00	7.70	-1.00	49518.00	30079.00	-1.00	-1.00	-1.00	-1.00
77275										
9.45	1348.00	163.00	7.80	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77276										
8.00	1377.00	160.00	7.70	1862.00	-1.00	-1.00	41454.00	26083.00	72.00	65.20
77277										
8.00	1440.00	165.00	7.80	1764.00	50524.00	26939.00	36022.00	21519.00	72.00	88.20
77278										
9.00	1530.00	159.00	7.80	1666.00	45913.00	32681.00	39024.00	26410.00	72.00	88.30
77279										
8.00	1670.00	165.00	7.80	1666.00	38681.00	25699.00	41676.00	28689.00	72.00	71.20
77280										
8.00	1755.00	120.00	7.70	1568.00	-1.00	-1.00	39015.00	24866.00	48.00	83.40
77281										
11.00	1863.00	160.00	7.90	-1.00	39580.00	36634.00	-1.00	-1.00	-1.00	-1.00
77282										
9.00	1943.00	165.00	7.80	-1.00	53940.00	37032.00	-1.00	-1.00	-1.00	-1.00
77283										
7.45	2042.00	165.00	7.70	1666.00	48873.00	35536.00	41982.00	29090.00	144.00	86.20
77284										
8.45	2157.00	165.00	7.50	1960.00	74141.00	29828.00	41363.00	28523.00	72.00	-1.00
77285										
9.00	2242.00	160.00	7.60	1666.00	60937.00	40980.00	43034.00	30072.00	48.00	83.10
77286										
8.10	2325.00	171.00	7.70	1666.00	43925.00	29609.00	43391.00	30213.00	24.00	85.60
77287										
8.10	2406.00	160.00	7.90	1666.00	76439.00	39098.00	41384.00	24056.00	48.00	80.40
77288										
10.00	2485.00	180.00	7.90	-1.00	38354.00	20419.00	-1.00	-1.00	-1.00	-1.00
77289										
10.30	2526.00	21.00	7.80	-1.00	117836.00	67595.00	-1.00	-1.00	-1.00	-1.00
77290										
9.05	2625.00	46.00	7.70	1764.00	91542.00	53258.00	42312.00	28975.00	48.00	83.70
77291										
8.00	2796.00	82.00	7.70	2254.00	105712.00	60997.00	48316.00	32552.00	144.00	84.80

-115-

Table A 2

HEAT TREATED BEEF MANURE REACTOR #2 START SEPT. 25 1977

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH 5
77292										
8.00	112.00	110.00	7.60	2450.00	94114.00	60271.00	52719.00	36362.00	192.00	78.77
77293										
8.00	548.00	121.00	7.50	3038.00	93725.00	52304.00	59257.00	37604.00	216.00	67.10
77294										
8.00	932.00	118.00	7.50	3234.00	101817.00	54207.00	55976.00	28749.00	96.00	60.00
77295										
10.00	1533.00	105.00	7.60	-1.00	82516.00	47461.00	-1.00	-1.00	-1.00	-1.00
77296										
9.30	2092.00	106.00	7.60	-1.00	86868.00	56307.00	-1.00	-1.00	-1.00	-1.00
77297										
8.45	2621.00	95.00	7.60	4018.00	-1.00	-1.00	66984.00	46085.00	192.00	61.20
77298										
9.05	78.00	100.00	7.50	4318.00	96095.00	57558.00	62517.00	42687.00	144.00	61.60
77299										
8.00	453.00	100.00	7.60	4116.00	85601.00	59830.00	66411.00	45063.00	384.00	64.00
77300										
8.00	1149.00	109.00	7.60	4214.00	63712.00	46350.00	69710.00	47169.00	336.00	62.40
77301										
8.00	1959.00	98.00	7.70	4608.00	97849.00	57383.00	69034.00	39569.00	120.00	60.40
77302										
9.55	2785.00	116.00	7.60	-1.00	75124.00	44312.00	-1.00	-1.00	-1.00	-1.00
77303										
11.05	763.00	95.00	7.70	-1.00	237311.00	80662.00	-1.00	-1.00	-1.00	-1.00
77304										
8.05	1209.00	100.00	7.60	4998.00	95288.00	63741.00	67134.00	45259.00	254.00	54.50
77305										
8.00	1987.00	143.00	7.50	4413.00	71653.00	48143.00	63397.00	39903.00	336.00	59.70
77306										
8.00	42.00	101.00	7.60	4312.00	74171.00	53380.00	64870.00	44128.00	240.00	54.60
77307										
8.15	923.00	102.00	7.50	3724.00	73858.00	52347.00	65637.00	43898.00	240.00	55.20
77308										
8.05	1903.00	124.00	7.50	4018.00	25936.00	16654.00	64756.00	40324.00	96.00	55.50
77309										
9.50	2793.00	100.00	7.70	-1.00	65317.00	41034.00	-1.00	-1.00	-1.00	-1.00
77310										
10.00	839.00	107.00	7.60	-1.00	78413.00	56056.00	-1.00	-1.00	-1.00	-1.00
77311										
8.05	1687.00	105.00	7.50	4410.00	69626.00	47214.00	66370.00	44449.00	312.00	52.50
77312										
8.05	2437.00	95.00	7.50	3920.00	53566.00	36926.00	63396.00	43264.00	336.00	55.80
77313										
8.05	125.00	-1.00	7.50	3822.00	48905.00	34110.00	61027.00	40535.00	264.00	57.40
77314										
8.10	787.00	-1.00	7.60	4116.00	52292.00	36667.00	61716.00	41966.00	72.00	54.70
77315										
8.05	1285.00	-1.00	7.60	3724.00	-1.00	-1.00	58582.00	32766.00	48.00	-1.00
77316										
9.45	1593.00	-1.00	7.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A 2

HEAT TREATED BEEF MANURE REACTOR #2 START SEPT. 25 1977

PAGE 2

-116-

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CHG %
77317										
10.00	1975.00	-1.00	7.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77318										
8.15	2175.00	-1.00	7.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77319										
8.17	2642.00	-1.00	7.60	3920.00	-1.00	-1.00	55598.00	36801.00	408.00	-1.00
77320										
8.10	2794.00	56.00	7.50	4312.00	104767.00	79019.00	59214.00	39759.00	264.00	48.30
77321										
8.05	101.00	101.00	7.40	3724.00	-1.00	-1.00	62693.00	43949.00	264.00	47.00
77322										
8.05	1403.00	-1.00	7.50	4018.00	104918.00	69070.00	62607.00	34572.00	744.00	52.60
77323										
9.30	2779.00	100.00	7.50	-1.00	111591.00	64355.00	-1.00	-1.00	-1.00	-1.00
77324										
11.25	1733.00	100.00	7.50	-1.00	105758.00	74028.00	-1.00	-1.00	-1.00	-1.00
77325										
8.10	322.00	96.00	7.50	4116.00	94957.00	72534.00	50612.00	39102.00	720.00	53.20
77326										
8.10	1882.00	101.00	7.50	3920.00	38217.00	29908.00	65684.00	46432.00	1776.00	45.50
77327										
8.10	134.00	96.00	7.50	3920.00	98411.00	56144.00	67484.00	38982.00	2446.00	49.60
77328										
8.55	1146.00	100.00	7.40	-1.00	95451.00	59074.00	66346.00	38238.00	-1.00	51.50
77329										
11.25	2275.00	103.00	7.40	-1.00	81282.00	53123.00	62940.00	39876.00	-1.00	54.50
77330										
11.45	372.00	100.00	7.40	-1.00	62935.00	39566.00	61801.00	36424.00	-1.00	53.00

-117-

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
76321	-1.00	-1.00	64.35	6.90	1617.00	54576.00	32199.00	-1.00	-1.00	216.00	-1.00
76322	-1.00	-1.00	56.78	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76323	16.15	747.00	123.01	7.00	2045.00	-1.00	-1.00	-1.00	-1.00	197.00	-1.00
76324	17.00	-1.00	56.78	7.10	2366.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76325	12.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76326	10.30	-1.00	75.70	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76327	15.45	-1.00	64.35	7.10	2706.00	-1.00	-1.00	-1.00	-1.00	168.00	-1.00
76328	16.15	-1.00	56.78	7.10	3006.00	55543.00	39831.00	20438.00	13609.00	-1.00	-1.00
76329	17.40	-1.00	71.92	7.27	-1.00	-1.00	-1.00	-1.00	-1.00	144.00	-1.00
76330	14.45	-1.00	49.21	7.36	-1.00	52176.00	33032.00	16779.00	9883.00	-1.00	-1.00
76331	12.00	-1.00	60.56	7.30	3495.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76332	14.30	-1.00	58.67	7.26	3563.00	59971.00	35202.00	24652.00	15443.00	316.00	-1.00
76333	15.30	-1.00	68.13	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76334	16.30	-1.00	56.78	7.35	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76335	16.00	-1.00	56.78	7.35	4270.00	73289.00	45598.00	28557.00	17365.00	-1.00	-1.00
76336	17.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76337	17.00	-1.00	60.56	7.25	4461.00	43795.00	26021.00	27846.00	16205.00	-1.00	-1.00
76338	17.00	727.00	60.56	7.20	4243.00	-1.00	-1.00	-1.00	-1.00	192.00	-1.00
76339	13.00	920.00	60.56	7.30	-1.00	66154.00	38493.00	27611.00	16117.00	-1.00	-1.00
76340	-1.00	-1.00	60.56	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76341	14.45	2196.00	60.56	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76342	14.30	2906.00	102.20	7.30	5038.00	54539.00	32030.00	34565.00	19772.00	216.00	-1.00
76343	15.10	776.00	98.41	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76344	15.40	1614.00	94.62	7.25	5239.00	63966.00	36686.00	40795.00	24164.00	-1.00	-1.00
76345	16.15	2380.00	98.41	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	144.00	-1.00

Table A 3

BEEF MANURE RUN #1 REACTOR #3 START NOV. 16, 1976

PAGE 1

DATE/TIME	GAS FLOW	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
76346	12 11	174.00	94.62	7.31	522.00	84672.00	55776.00	38709.00	23176.00	-1.00	-1.00
76347	11 30	912.00	87.06	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	67.00
76348	11 40	2204.00	98.41	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76349	14 31	862.00	87.06	7.30	58.30	75238.00	51629.00	34573.00	27983.00	-1.00	-1.00
76350	14 30	2535.00	83.27	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	384.00	-1.00
76351	10 20	522.00	87.06	7.30	6085.00	29524.00	21242.00	38892.00	24439.00	-1.00	-1.00
76352	14 45	1622.00	91.04	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76353	9 31	2471.00	94.62	7.20	-1.00	26987.00	21270.00	33467.00	21764.00	-1.00	-1.00
76354	9 31	427.00	94.62	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76355	15 40	2331.00	91.04	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76356	2 40	540.00	87.06	7.30	5844.00	61845.00	44300.00	30828.00	20989.00	-1.00	-1.00
76357	13 21	2704.00	113.55	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	144.00	-1.00
76358	16 20	1283.00	102.20	7.40	6327.00	56618.00	40525.00	34935.00	23433.00	-1.00	-1.00
76359	13 51	230.00	112.20	7.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76360	10 50	973.00	87.06	7.40	-1.00	57609.00	41221.00	34262.00	22503.00	-1.00	-1.00
76361	12 50	2884.00	91.04	7.50	5964.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76362	11 50	1474.00	-1.00	7.40	-1.00	49303.00	34156.00	32467.00	20091.00	-1.00	-1.00
76363	13 50	2102.00	94.62	7.30	5844.00	-1.00	-1.00	-1.00	-1.00	288.00	-1.00
76364	11 20	2616.00	90.84	7.10	-1.00	48323.00	33791.00	34333.00	22488.00	-1.00	-1.00
76365	13 20	619.00	56.78	7.10	5723.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A 3

DAIRY MANURE RUN #2 REACTOR #3 START DEC 11, 1976

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	BPP. T.S.	BPP. V.S.	BPP. V.A.	CHG %	
77060	13.00	461.00	84.00	7.20	5800.00	58694.00	41168.00	50192.00	29266.00	216.00	-1.00
77061	14.45	1509.00	125.00	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77062	12.48	2808.00	121.00	7.10	5100.00	50619.00	34284.00	41968.00	25875.00	264.00	-1.00
77063	13.30	1244.00	121.00	7.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77064	9.40	2583.00	124.50	7.40	5500.00	48997.00	33256.00	45930.00	28082.00	168.00	-1.00
77065	14.30	171.00	83.60	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77066	14.00	1193.00	120.80	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77067	14.10	2147.00	120.80	7.40	5900.00	46159.00	34409.00	58629.00	33056.00	264.00	-1.00
77068	13.00	472.00	118.90	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77069	13.30	1466.00	122.60	7.40	5100.00	43053.00	29741.00	48516.00	29225.00	240.00	-1.00
77070	14.30	2326.00	118.90	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77071	9.30	50.00	118.90	7.30	4200.00	50923.00	32420.00	55272.00	32216.00	528.00	-1.00
77072	9.45	1026.00	118.90	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77073	10.25	1958.00	120.80	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77074	10.00	2717.00	124.50	7.20	4200.00	46840.00	33369.00	52735.00	35139.00	384.00	-1.00
77075	10.00	852.00	126.30	7.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77076	10.40	1563.00	125.40	7.10	3950.00	46159.00	30566.00	53769.00	31300.00	-1.00	60.00
77077	10.00	1518.00	125.40	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77078	9.00	2158.00	118.90	7.20	3850.00	42442.00	27834.00	43207.00	26453.00	-1.00	-1.00
77079	13.00	382.00	122.60	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	312.00	-1.00
77080	8.10	986.00	120.80	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77081	10.30	1934.00	126.30	7.30	3700.00	41647.00	28810.00	41494.00	26769.00	324.00	-1.00
77082	14.30	2820.00	126.30	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77083	11.45	477.00	126.30	7.30	3600.00	49822.00	33011.00	42946.00	27605.00	456.00	-1.00
77084	14.30	1347.00	124.50	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-120-

Table A 3

BEEP MANURE RUN 3 REACTOR 3 START FEB 21, 1977 NET STUFF

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. Y.A.	CH4 %
77085										
10.15	1956.00	122.60	7.40	3789.00	48791.00	32360.00	47365.00	29830.00	-1.50	-1.00
77086										
11.00	2653.00	122.60	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77087										
11.30	368.00	122.60	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77088										
11.30	1122.00	-1.00	7.30	3604.00	42732.00	28998.00	44144.00	29994.00	1128.00	-1.00
77089										
-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77090										
-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-121-

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T. S.	FEED V. S.	EFF. T. S.	EFF. V. S.	EFF. V. A.	CH4 %
77145										
8.15	36.00	-1.00	7.10	2306.00	42751.00	20492.00	66341.00	34829.00	216.00	-1.00
77146										
8.15	325.00	167.00	7.20	1958.00	50157.00	31268.00	61167.00	33521.00	168.00	-1.00
77147										
8.00	386.00	163.00	7.10	2566.00	55843.00	34849.00	45050.00	26843.00	192.00	-1.00
77148										
8.00	1081.00	178.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77149										
8.45	1949.00	167.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77150										
9.20	2730.00	159.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77151										
8.15	380.00	159.20	7.30	1958.00	43219.00	28182.00	50729.00	32030.00	264.00	-1.00
77152										
8.10	1053.00	159.20	7.20	2349.00	48664.00	31742.00	52132.00	32549.00	216.00	-1.00
77153										
8.10	1605.00	159.20	7.20	2349.00	43223.00	26273.00	53819.00	32850.00	216.00	-1.00
77154										
8.10	2139.00	159.20	7.20	2349.00	40690.00	25498.00	54014.00	34667.00	168.00	-1.00
77155										
9.05	173.00	183.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77156										
10.00	1445.00	159.20	6.95	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77157										
8.10	1827.00	159.20	7.20	2436.00	48857.00	36031.00	50589.00	33639.00	528.00	-1.00
77158										
8.30	2791.00	159.20	7.10	2523.00	33870.00	25969.00	49559.00	33962.00	912.00	-1.00
77159										
8.10	1453.00	159.20	7.00	2697.00	35486.00	27298.00	46194.00	31292.00	504.00	-1.00
77160										
10.00	470.00	159.20	7.30	2828.00	34680.00	25821.00	43820.00	29727.00	168.00	63.40
77161										
8.10	1541.00	159.20	7.20	2740.00	34841.00	25529.00	40925.00	28463.00	384.00	62.40
77162										
8.45	393.00	159.20	6.80	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77163										
8.35	2116.00	163.80	7.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77164										
8.20	2939.00	160.00	7.00	3002.00	47484.00	35277.00	44898.00	31324.00	288.00	-1.00
77165										
8.15	1073.00	160.00	7.00	3088.00	46485.00	33348.00	44337.00	31924.00	312.00	63.50
77166										
8.10	123.00	165.70	7.10	3219.00	42457.00	29888.00	46037.00	32854.00	528.00	64.10
77167										
8.20	2488.00	166.80	7.60	3524.00	52696.00	40208.00	42085.00	32114.00	768.00	65.50
77168										
8.30	1314.00	-1.00	7.40	3958.00	56512.00	42736.00	50907.00	37267.00	648.00	67.10
77169										
8.25	2342.00	163.80	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A 3

DEEP MANURE RUN #4 REACTOR #3 START MAY 25, 1977

PAGE 1

-122-

DATE/TIME	- GAS METER	FEED RATE	PH	ALKALINITY	FRED T.S.	FRED V.S.	EFP, T.S.	EFP, V.S.	EFP, V.A.	CR4 %
77170	8.35	1564.00	160.00	7.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77171	8.10	1252.00	160.00	7.60	4437.00	57396.00	40831.00	55448.00	38796.00	408.00
77172	8.10	2673.00	160.00	7.60	4654.00	55559.00	40124.00	55520.00	39649.00	768.00
77173	8.15	1602.00	165.70	7.60	4185.00	55979.00	40923.00	56812.00	39095.00	408.00
77174	8.05	1010.00	160.00	7.80	4050.00	50568.00	38415.00	55685.00	39920.00	1008.00
77175	8.10	412.00	160.00	7.80	4545.00	50781.00	36470.00	55579.00	38762.00	312.00
77176	9.30	2600.00	160.00	7.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-123-

DATE/TIME	GAS METER	PCPD RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH ₄ %
77177	9.20	1209.00	165.70	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77178	8.15	645.00	165.00	7.90	4770.00	83173.00	52862.00	66635.00	46266.00	648.00
77179	8.10	-1.00	227.60	7.80	5355.00	98799.00	70307.00	71898.00	49784.00	520.00
77180	8.10	2246.00	220.00	7.60	4935.00	130639.00	70853.00	78410.00	53480.00	1320.00
77181	8.15	-90.00	80.00	7.40	4860.00	106309.00	73888.00	84135.00	56059.00	5940.00
77182	8.00	1945.00	80.00	7.40	5445.00	105209.00	71377.00	78957.00	56138.00	5040.00
77183	9.50	564.00	85.00	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77184	10.10	1833.00	84.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77185	11.00	1219.00	87.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77186	8.30	-1.00	90.00	7.80	6795.00	95720.00	60929.00	88751.00	57954.00	3120.00
77187	8.30	1272.00	80.00	7.80	6930.00	98006.00	65756.00	89973.00	59629.00	660.00
77188	8.30	1762.00	169.00	7.90	6483.00	99932.00	66755.00	95212.00	57464.00	2580.00
77189	8.05	475.00	120.00	7.80	6345.00	96228.00	65771.00	91811.00	58683.00	3900.00
77190	9.45	2380.00	130.00	7.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77191	9.30	1362.00	139.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77192	8.05	2770.00	121.00	7.80	6255.00	100942.00	72345.00	94517.00	60963.00	2760.00
77193	8.00	2244.00	177.00	7.70	6660.00	98175.00	73860.00	93670.00	62533.00	2760.00
77194	8.05	1534.00	158.00	7.60	6570.00	104748.00	72983.00	97272.00	63624.00	2430.00
77195	8.30	-227.00	160.00	7.60	6885.00	105214.00	77559.00	98238.00	67254.00	3000.00
77196	8.10	-592.00	160.00	7.70	6795.00	103753.00	72518.00	98519.00	64684.00	2520.00
77197	8.30	-986.00	260.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77198	9.30	-190.00	178.00	7.80	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77199	8.05	-1455.00	220.00	7.90	7335.00	95029.00	69609.00	95486.00	66790.00	890.00
77200	8.10	-27.00	150.00	7.80	7200.00	93257.00	68975.00	98275.00	67726.00	780.00
77201	8.10	-1861.00	220.00	7.80	7650.00	87146.00	65010.00	97874.00	67724.00	1080.00

-124-

Table A 3

BEEF MANURE REACTOR 3 START JUNE 26 1977

PAGE 1

DATE/TIME	GAS METERS	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
77202	8.10	-355.00	220.00	7.90	7872.00	95989.00	66712.00	97211.00	62330.00	1020.00	62.20
77203	8.50	1338.00	-1.00	7.70	6784.00	95301.00	71111.00	96394.00	67402.00	1980.00	55.40
77204	11.00	-2290.00	80.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77205	11.30	1717.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77206	8.05	445.00	98.00	7.80	7969.00	99701.00	71883.00	99011.00	70404.00	720.00	58.90
77207	8.05	2467.00	160.00	7.70	9120.00	95385.00	64370.00	98276.00	63684.00	1920.00	55.50
77208	8.05	237.00	120.00	7.80	6528.00	96790.00	69245.00	101722.00	71917.00	1740.00	57.80
77209	8.10	832.00	124.00	7.90	7104.00	91736.00	75270.00	1015563.00	79912.00	1980.00	55.00
77210	8.10	279.00	155.00	7.90	7104.00	103871.00	70528.00	103626.00	63975.00	3360.00	50.90
77211	9.10	2160.00	140.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77212	10.00	2784.00	110.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77213	8.50	-445.00	126.00	7.60	6912.00	94924.00	74609.00	107215.00	85556.00	960.00	52.00
77214	8.10	-557.00	100.00	7.80	6912.00	98443.00	73815.00	110940.00	81009.00	600.00	56.30
77215	8.10	-832.00	126.00	8.00	6720.00	93049.00	73974.00	107286.00	82031.00	1680.00	55.90
77216	8.10	725.00	145.00	8.00	6912.00	94029.00	71727.00	109743.00	80630.00	672.00	56.10
77217	9.10	2980.00	150.00	7.80	7104.00	101321.00	86048.00	112505.00	94433.00	1560.00	58.10
77218	9.15	-563.00	124.10	7.50	-1.00	110070.00	72548.00	108798.00	69417.00	-1.00	-1.00
77219	10.55	-790.00	115.00	-1.00	-1.00	81992.00	69031.00	-1.00	-1.00	-1.00	-1.00
77220	8.05	1380.00	79.00	7.90	6912.00	74451.00	58335.00	98740.00	73693.00	677.00	57.90
77221	9.35	1185.00	84.00	7.90	6912.00	72116.00	54010.00	96886.00	73396.00	120.00	58.00
77222	8.05	2457.00	81.00	7.90	7008.00	43407.00	32683.00	90120.00	67389.00	144.00	61.30
77223	8.00	576.00	79.00	7.80	6912.00	44137.00	35834.00	95722.00	70346.00	360.00	64.00
77224	8.05	1242.00	79.00	7.80	6912.00	50954.00	41249.00	91282.00	73117.00	288.00	60.70
77225	10.15	2140.00	80.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77226	10.30	100.00	80.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A 3

BPPF MANURE REACTOR 3 START JUNE 26 1977

DATE/TIME	GAS FETTER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	C-4 %
77227										
8.40	1029.00	82.00	7.80	5376.00	48001.00	39235.00	89670.00	73953.00	898.00	66.70
77228										
8.05	2034.00	80.00	7.70	5664.00	46566.00	37700.00	87304.00	67676.00	940.00	66.60
77229										
8.00	2861.00	84.00	7.70	6144.00	44276.00	33896.00	78183.00	59549.00	1080.00	59.80
77230										
8.15	844.00	80.00	7.70	5856.00	55627.00	46181.00	73512.00	60596.00	1320.00	59.80
77231										
9.30	1447.00	81.00	7.60	5184.00	53124.00	43552.00	74685.00	59556.00	1320.00	-1.00
77232										
12.00	2016.00	79.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77233										
11.30	2777.00	80.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77234										
9.20	781.00	80.00	7.50	4320.00	55559.00	40926.00	71237.00	50912.00	3640.00	61.40
77235										
8.15	1377.00	80.00	7.60	5280.00	54547.00	45320.00	67060.00	53919.00	1520.00	58.70
77236										
8.15	2345.00	80.00	7.60	4608.00	52943.00	38351.00	68691.00	47831.00	1200.00	57.60
77237										
9.15	391.00	93.00	7.40	5184.00	51045.00	41110.00	70627.00	56516.00	1620.00	61.50
77238										
8.30	1469.00	90.00	7.60	4512.00	42500.00	33371.00	63892.00	50117.00	2220.00	73.80
77239										
11.30	2115.00	93.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77240										
10.00	464.00	88.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77241										
8.05	1367.00	91.00	7.75	4896.00	64878.00	46133.00	63884.00	4886.00	1320.00	62.00
77242										
8.05	2221.00	99.00	7.70	4512.00	59599.00	44428.00	64575.00	49831.00	720.00	63.00
77243										
8.00	115.00	83.00	7.60	4512.00	57919.00	43662.00	65255.00	54137.00	1008.00	64.20
77244										
8.15	1588.00	81.00	7.70	4704.00	56028.00	42448.00	67915.00	53532.00	336.00	64.20
77245										
9.00	2412.00	84.00	7.70	4320.00	54320.00	40289.00	62445.00	46512.00	456.00	65.50
77246										
10.00	238.00	90.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77247										
9.45	9.14	81.00	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77248										
10.20	1507.00	80.00	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77249										
8.00	2139.00	84.00	7.70	5184.00	55723.00	39363.00	63442.00	45153.00	96.00	65.80
77250										
8.00	2742.00	83.00	7.80	5088.00	62268.00	44714.00	63070.00	47198.00	240.00	63.70
77251										
8.00	277.00	165.00	7.80	4608.00	98376.00	58144.00	66194.00	46664.00	264.00	62.60

-126-

Table A 3

BEEF MANURE REACTOR 3 START JUNE 26 1977

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
77252	8.00	1145.00	83.00	7.70	4224.00	112052.00	63072.00	66146.00	44392.00	264.00	63.90
77253	10.05	1296.00	82.00	7.80	-1.00	126972.00	67577.00	-1.00	-1.00	-1.00	-1.00
77254	10.50	1775.00	86.00	-1.00	-1.00	80269.00	48599.00	-1.00	-1.00	-1.00	-1.00
77255	8.05	2807.00	80.00	7.30	4416.00	71312.00	45744.00	70644.00	45449.00	192.00	60.10
77256	8.10	2788.00	80.00	7.40	4214.00	66791.00	42414.00	67733.00	44992.00	48.00	50.60
77257	9.00	-462.00	83.00	7.40	3822.00	60668.00	37990.00	65549.00	41086.00	120.00	57.30
77258	8.05	2583.00	85.00	7.50	3528.00	67888.00	42442.00	64770.00	40210.00	72.00	53.30
77259	8.15	1574.00	78.00	7.60	3626.00	59730.00	39196.00	65238.00	44124.00	168.00	49.10
77260	9.20	1833.00	81.00	7.60	-1.00	43106.00	22334.00	-1.00	-1.00	-1.00	-1.00
77261	10.05	2029.00	79.00	7.50	-1.00	51992.00	33862.00	-1.00	-1.00	-1.00	-1.00
77262	8.10	2314.00	83.00	7.40	3822.00	67036.00	38537.00	61095.00	37758.00	240.00	73.60
77263	11.55	2418.00	84.00	7.40	4018.00	40567.00	21329.00	58798.00	29508.00	404.00	70.20
77264	9.25	2604.00	84.00	7.30	3626.00	41536.00	28065.00	56833.00	38667.00	336.00	68.20
77265	8.35	2743.00	80.00	7.35	3528.00	77733.00	49240.00	59250.00	36855.00	336.00	67.10
77266	9.05	56.00	80.00	7.35	3332.00	53629.00	39005.00	51018.00	36235.00	312.00	64.40
77267	9.25	527.00	82.00	7.40	-1.00	47434.00	32382.00	-1.00	-1.00	-1.00	-1.00
77268	9.20	1120.00	115.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77269	9.05	1645.00	80.00	7.50	3332.00	57445.00	41112.00	54351.00	36524.00	216.00	66.60
77270	8.10	1847.00	52.00	7.50	3234.00	30220.00	19592.00	51979.00	35384.00	168.00	59.10
77271	8.00	2298.00	82.00	7.50	3136.00	-1.00	-1.00	48968.00	33334.00	48.00	68.00
77272	9.00	2432.00	85.00	7.50	3136.00	53948.00	41009.00	48346.00	33152.00	120.00	73.20
77273	8.00	2639.00	80.00	7.40	3234.00	84038.00	52176.00	48038.00	27086.00	216.00	69.70
77274	9.30	235.00	79.00	7.50	-1.00	46736.00	33562.00	-1.00	-1.00	-1.00	-1.00

-127-

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	BFP. T.S.	BFP. V.S.	BFP. V.A.	CS4 %
77275	9.45	323.00	80.00	7.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77276	8.00	717.00	84.00	7.30	3332.00	31174.00	21701.00	46714.00	29158.00	264.00
77277	8.00	1158.00	80.00	7.40	3332.00	30664.00	17774.00	43559.00	24053.00	144.00
77278	8.00	1695.00	84.00	7.33	3433.00	59465.00	39836.00	46320.00	32032.00	144.00
77279	8.00	2275.00	75.00	7.40	3528.00	104934.00	68540.00	52652.00	34820.00	72.00
77280	8.00	2911.00	81.00	7.50	3430.00	61975.00	37571.00	52794.00	31835.00	48.00
77281	11.00	345.00	84.00	7.50	-1.00	27576.00	23572.00	-1.00	-1.00	-1.00
77282	9.00	811.00	81.00	7.40	-1.00	36122.00	28400.00	-1.00	-1.00	-1.00
77283	7.45	1091.00	83.00	7.50	3626.00	79774.00	53532.00	53418.00	35253.00	96.00
77284	8.45	1311.00	80.00	7.40	3234.00	56293.00	39812.00	58301.00	39330.00	72.00
77285	8.00	1660.00	80.00	7.40	3332.00	47353.00	32984.00	57957.00	39935.00	120.00
77286	8.10	2054.00	82.00	7.40	3234.00	33383.00	21576.00	59468.00	40961.00	96.00
77287	8.10	2514.00	82.00	7.40	3528.00	32020.00	18889.00	58790.00	36473.00	48.00
77288	10.00	2838.00	80.00	7.40	-1.00	16272.00	10137.00	-1.00	-1.00	-1.00
77289	10.30	2913.00	85.00	7.30	-1.00	60159.00	43634.00	-1.00	-1.00	-1.00
77290	9.05	191.00	84.00	7.30	3528.00	56457.00	37779.00	52067.00	39501.00	72.00
77291	9.00	841.00	77.00	7.30	3332.00	38187.00	26243.00	57961.00	37372.00	120.00
77292	8.00	1260.00	78.00	7.30	3332.00	89808.00	61410.00	60512.00	41883.00	120.00
77293	8.00	2352.00	80.00	7.30	3430.00	42755.00	24728.00	54404.00	28396.00	72.00
77294	8.00	2352.00	80.00	7.30	3430.00	42755.00	24728.00	54404.00	28396.00	72.00
77295	13.00	2745.00	117.00	7.20	-1.00	79152.00	45554.00	-1.00	-1.00	-1.00
77296	9.30	45.00	89.00	7.20	-1.00	108776.00	62430.00	-1.00	-1.00	-1.00
77297	8.45	321.00	81.00	7.30	3234.00	31889.00	22102.00	51523.00	35553.00	72.00
77298	8.05	873.00	54.00	7.20	3234.00	79379.00	49333.00	49437.00	32806.00	72.00
77299	8.00	1125.00	50.00	7.30	3136.00	31792.00	21424.00	49804.00	33134.00	120.00

Table A 3

DEEP MANURE REACTOR 43 START OCT. 3 1977

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
77300	8.00	1364.00	55.00	7.20	2744.00	24952.00	16577.00	47275.00	32193.00	96.00	56.80
77301	8.00	1618.00	51.00	7.30	3038.00	29305.00	18973.00	48264.00	28859.00	48.00	56.80
77302	9.55	1815.00	48.00	7.20	-1.00	28442.00	18369.00	-1.00	-1.00	-1.00	-1.00
77303	11.05	2032.00	52.00	7.20	-1.00	34594.00	23484.00	-1.00	-1.00	-1.00	-1.00
77304	8.05	2241.00	53.00	7.20	2940.00	36137.00	25008.00	45628.00	31364.00	48.00	54.90
77305	8.05	2398.00	53.00	7.20	2940.00	36506.00	25877.00	46467.00	31514.00	72.00	56.00
77306	8.00	2581.00	55.00	7.20	2744.00	43367.00	30460.00	43372.00	28103.00	96.00	55.90
77307	9.05	2757.00	53.00	7.20	2842.00	30374.00	21153.00	42193.00	28729.00	48.00	56.20
77308	8.05	2959.00	54.00	7.20	2940.00	40376.00	27791.00	42242.00	28264.00	96.00	58.50
77309	9.50	240.00	50.00	7.30	-1.00	67153.00	41990.00	-1.00	-1.00	-1.00	-1.00
77310	10.00	451.00	52.00	7.30	-1.00	89554.00	61991.00	-1.00	-1.00	-1.00	-1.00
77311	8.05	696.00	57.00	7.20	2842.00	52411.00	38622.00	45033.00	31141.00	48.00	53.40
77312	8.05	1014.00	55.00	7.20	2548.00	45483.00	33127.00	43675.00	30152.00	72.00	53.50
77313	8.05	1249.00	50.00	7.20	2352.00	41257.00	29530.00	43886.00	30241.00	72.00	53.50
77314	8.10	1529.00	-1.00	7.20	2450.00	-1.00	-1.00	40615.00	27952.00	48.00	53.60
77315	8.05	1732.00	-1.00	7.10	2548.00	-1.00	-1.00	43516.00	24523.00	24.00	-1.00
77316	9.45	1968.00	-1.00	7.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77317	10.00	2179.00	-1.00	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77318	8.15	2352.00	-1.00	7.20	-1.00	87686.00	73238.00	-1.00	-1.00	-1.00	-1.00
77319	9.10	2663.00	51.00	7.20	2744.00	83102.00	66913.00	43108.00	30155.00	72.00	-1.00
77320	9.10	174.00	84.00	7.10	2940.00	86134.00	64530.00	45724.00	32380.00	192.00	45.70
77321	8.05	888.00	56.00	7.20	3038.00	-1.00	-1.00	47728.00	34589.00	192.00	49.60
77322	8.05	1504.00	92.00	7.20	2940.00	102041.00	64391.00	51957.00	29732.00	168.00	50.40
77323	8.30	2983.00	49.00	7.20	-1.00	92603.00	59278.00	-1.00	-1.00	-1.00	-1.00

-129-

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
76321	-1.00	-1.00	-1.00	7.85	-1.00	54576.00	32199.00	-1.00	-1.00	-1.00	-1.00
76322	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	60.00
76323	16.15	328.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76324	17.00	337.00	56.78	6.95	1931.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76325	12.30	477.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76326	10.30	871.00	75.70	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76327	15.45	1295.00	56.78	7.20	2434.00	-1.00	-1.00	-1.00	-1.00	144.00	-1.00
76328	16.15	1742.00	52.99	6.95	2557.00	55543.00	39831.00	16643.00	10834.00	-1.00	-1.00
76329	17.40	2269.00	64.35	7.18	-1.00	-1.00	-1.00	-1.00	-1.00	144.00	-1.00
76330	14.45	2774.00	98.41	7.14	-1.00	52176.00	33032.00	35431.00	19492.00	-1.00	-1.00
76331	12.00	351.00	56.78	7.30	3495.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76332	14.30	102.00	56.78	7.20	3468.00	59971.00	35202.00	36931.00	21646.00	264.00	-1.00
76333	15.30	1608.00	64.35	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76334	16.30	2112.00	60.56	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76335	16.00	2628.00	64.35	7.32	4610.00	73289.00	45596.00	31274.00	19776.00	-1.00	-1.00
76336	17.00	205.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76337	17.00	589.00	60.56	7.25	4502.00	43795.00	26021.00	18057.00	10884.00	-1.00	-1.00
76338	17.00	734.00	56.78	7.25	4420.00	-1.00	-1.00	-1.00	-1.00	216.00	-1.00
76339	13.00	1382.00	60.56	7.20	-1.00	66154.00	38493.00	40397.00	22383.00	-1.00	-1.00
76340	-1.00	-1.00	56.78	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76341	14.45	2204.00	79.49	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76342	14.30	170.00	102.20	7.25	4876.00	54539.00	32030.00	36760.00	21052.00	144.00	-1.00
76343	15.10	953.00	94.62	7.25	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76344	15.40	1832.00	94.62	7.20	5441.00	63966.00	36686.00	38045.00	22771.00	-1.00	-1.00
76345	16.15	2630.00	149.77	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	120.00	-1.00

-130-

Table A 4

EEEP MANURE RUN #1 REACTOR #4 START NOV. 16, 1976

PAGE 1

DATE/TIME	GAS MEYER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
76346	12.10	310.00	90.84	7.30	3561.00	84672.00	55776.00	39987.00	22709.00	-1.00	-1.00
76347	11.30	1062.00	94.62	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	60.00
76348	11.40	2340.00	90.84	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76349	14.30	901.00	94.62	7.30	6126.00	75238.00	51629.00	43359.00	25201.00	-1.00	-1.00
76350	14.30	2507.00	87.06	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	348.00	-1.00
76351	10.00	515.00	94.62	7.30	6327.00	29524.00	21242.00	41098.00	24198.00	-1.00	-1.00
76352	14.45	1585.00	113.55	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76353	9.00	2312.00	94.62	7.20	-1.00	26987.00	20270.00	37152.00	22242.00	-1.00	-1.00
76354	9.30	203.00	94.62	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76355	15.40	2010.00	117.34	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76356	12.40	374.00	109.77	7.20	6126.00	61045.00	44301.00	34516.00	22460.00	-1.00	-1.00
76357	13.20	2393.00	109.77	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	120.00	-1.00
76358	16.20	961.00	140.05	7.40	6105.00	56618.00	40525.00	37345.00	23743.00	-1.00	-1.00
76359	13.50	2695.00	109.77	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76360	13.50	1166.00	105.98	7.40	-1.00	57609.00	41221.00	35297.00	23091.00	-1.00	-1.00
76361	10.50	2831.00	102.20	7.50	6247.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76362	13.50	1503.00	94.62	7.30	-1.00	49303.00	34156.00	35591.00	21721.00	-1.00	-1.00
76363	13.50	72.00	105.98	7.40	6166.00	-1.00	-1.00	-1.00	-1.00	120.00	-1.00
76364	11.20	1676.00	94.62	7.30	-1.00	48323.00	33791.00	35805.00	22775.00	-1.00	-1.00
76365	10.20	616.00	56.78	7.40	6367.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-131-

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFP. T.S.	EFP. V.S.	EFP. V.A.	Wt %	
77060	13.00	1213.00	84.00	7.20	5600.00	58694.00	41168.00	50451.00	33348.00	528.00	-1.00
77061	14.45	2078.00	158.00	7.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77062	12.40	280.00	125.00	7.20	5100.00	50619.00	34284.00	45133.00	29346.00	768.00	-1.00
77063	13.30	1482.00	134.00	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77064	9.40	2478.00	124.50	7.40	5400.00	48997.00	33256.00	52888.00	33959.00	576.00	-1.00
77065	14.30	126.00	78.00	7.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77066	14.00	1116.00	120.80	7.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77067	14.10	2163.00	126.30	7.20	6300.00	46159.00	34409.00	43604.00	31899.00	672.00	-1.00
77068	13.00	2838.00	120.80	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77069	13.30	230.00	130.00	7.10	5100.00	43053.00	29741.00	53979.00	34649.00	1584.00	-1.00
77070	14.30	557.00	-1.00	7.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77071	9.30	666.00	-1.00	7.10	3900.00	-1.00	-1.00	-1.00	-1.00	3024.00	-1.00
77072	9.45	797.00	-1.00	6.90	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77073	10.25	798.00	-1.00	6.90	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77074	10.00	802.00	-1.00	6.90	4500.00	-1.00	-1.00	-1.00	-1.00	3648.00	-1.00
77075	10.00	802.00	-1.00	6.80	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77076	10.40	802.00	-1.00	6.80	4650.00	-1.00	-1.00	-1.00	-1.00	3312.00	60.00
77077	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77078	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77079	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77080	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77081	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77082	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77083	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77084	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A 4

SEEP MANURE RUN 3 REACTOR 4 START FEB 21, 1977 WET STUFF

PAGE 1

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	BPP. T.S.	BPP. V.S.	BPP. V.A.	CH ₄ %
77085	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77086	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77087	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77088	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77089	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77090	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-133-

DATE/TIME	GAS METRO	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFP. T.S.	EFP. V.S.	EFP. V.A.	CL %	
77145	8.15	367.00	-1.00	7.00	2436.00	42751.00	24492.00	62711.00	32657.00	144.00	-1.00
77146	8.15	1117.00	121.80	7.20	2044.00	50157.00	31268.00	40091.00	24059.00	216.00	-1.00
77147	8.00	1856.00	118.00	7.10	2306.00	55843.00	34849.00	52945.00	30094.00	120.00	-1.00
77148	8.00	2546.00	121.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77149	8.45	147.00	121.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77150	8.20	751.00	121.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77151	8.15	1267.00	121.30	7.20	2480.00	43219.00	28182.00	55055.00	34973.00	168.00	-1.00
77152	8.10	1800.00	121.30	7.20	2392.00	48664.00	31742.00	43616.00	27832.00	168.00	-1.00
77153	8.19	2353.00	121.30	7.20	2392.00	43223.00	26273.00	52815.00	31721.00	216.00	-1.00
77154	8.10	2776.00	121.30	7.50	2523.00	40690.00	25498.00	53619.00	33888.00	264.00	-1.00
77155	9.05	384.00	132.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77156	10.00	1393.00	121.30	7.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77157	8.10	1974.00	121.30	7.10	2510.00	48857.00	36031.00	53399.00	34819.00	480.00	-1.00
77158	8.30	2857.00	121.30	7.10	2784.00	33870.00	25969.00	52184.00	35172.00	792.00	-1.00
77159	8.10	1384.00	121.30	7.10	2523.00	35486.00	27298.00	49356.00	32763.00	456.00	-1.00
77160	10.00	21.00	128.90	7.20	2784.00	34688.00	25821.00	47297.00	31322.00	240.00	59.50
77161	8.10	1411.00	125.10	7.20	2740.00	34841.00	25529.00	43774.00	29780.00	336.00	61.20
77162	8.45	2973.00	123.10	6.90	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77163	8.35	1218.00	120.00	7.10	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77164	8.20	1991.00	120.00	7.00	3088.00	47484.00	35277.00	46662.00	31495.00	336.00	-1.00
77165	8.15	152.00	120.00	7.00	3045.00	46485.00	33348.00	48086.00	33943.00	504.00	64.60
77166	8.10	1866.00	120.00	7.10	3132.00	42457.00	29888.00	49557.00	34366.00	480.00	68.40
77167	8.20	987.00	119.40	7.50	3436.00	52696.00	40208.00	47360.00	33746.00	696.00	66.40
77168	8.30	2883.00	-1.00	7.40	3872.00	56512.00	42736.00	50708.00	36739.00	360.00	66.20
77169	8.25	1061.00	120.00	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-134-

Table A 4

DEEP MANURE RUN #4 REACTOR #4 START MAY 25, 1977

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T. S.	FEED, V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CHW %
77170										
8.35	2792.00	123.80	7.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77171										
8.10	2017.00	131.40	7.50	4480.00	57396.00	40831.00	54333.00	36988.00	552.00	62.20
77172										
8.10	671.00	120.00	7.70	4394.00	55559.00	40124.00	53018.00	36975.00	312.00	66.00
77173										
8.05	2282.00	123.00	7.60	4545.00	55979.00	40923.00	54026.00	37921.00	720.00	62.70
77174										
8.05	1042.00	123.80	7.70	4230.00	50568.00	38415.00	52362.00	37210.00	456.00	62.20
77175										
8.10	289.00	120.00	7.70	4905.00	50781.00	36470.00	53407.00	36795.00	264.00	59.50
77176										
9.30	2040.00	148.40	7.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-135-

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH ₄ %
77177										
77178	9.20	581.00	142.70	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77179	8.15	2825.00	142.00	8.00	4725.00	83173.00	52462.00	57420.00	39036.00	480.00
77180	8.10	2244.00	150.00	7.00	4860.00	98799.00	70307.00	65969.00	46656.00	408.00
77181	8.10	1511.00	150.00	8.00	5133.00	100639.00	70853.00	69428.00	46869.00	696.00
77182	8.15	508.00	150.00	7.90	5220.00	106309.00	73888.00	73609.00	49149.00	540.00
77183	8.00	1970.00	130.00	7.90	6345.00	105209.00	71377.00	77200.00	51913.00	540.00
77184	9.50	15.00	82.00	7.80	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77185	10.10	476.00	82.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77186	11.00	578.00	84.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77187	8.30	871.00	90.00	8.00	8130.00	95720.00	60929.00	81333.00	51426.00	1920.00
77188	8.30	2046.00	80.00	8.00	6300.00	98006.00	65756.00	84614.00	54144.00	2760.00
77189	8.30	127.00	88.00	7.90	7200.00	99902.00	66755.00	83157.00	51273.00	360.00
77190	8.05	300.00	120.00	8.00	7425.00	96226.00	65771.00	84122.00	52375.00	480.00
77191	9.45	2109.00	122.00	7.90	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77192	9.10	1077.00	119.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77193	8.05	156.00	142.00	7.80	6975.00	100042.00	72345.00	88484.00	54878.00	430.00
77194	8.00	2191.00	173.00	7.80	7065.00	98175.00	73860.00	88082.00	58414.00	180.00
77195	8.05	1561.00	162.00	7.70	7380.00	104748.00	72983.00	95237.00	59436.00	900.00
77196	8.30	830.00	160.00	7.70	7335.00	105214.00	77559.00	91075.00	60247.00	1080.00
77197	8.10	-985.00	150.00	7.80	8640.00	103753.00	72518.00	90280.00	58809.00	780.00
77198	8.30	914.00	150.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77199	9.30	-1813.00	164.00	7.80	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77200	3.05	695.00	150.00	7.90	7740.00	95029.00	69609.00	91662.00	63389.00	720.00
77201	5.10	2417.00	150.00	7.90	8100.00	93257.00	68975.00	90629.00	63906.00	600.00
77202	8.10	1257.00	150.00	7.90	7380.00	67146.00	65010.00	90929.00	62172.00	240.00

-136-

Table A 4

REDF MANURE REACTOR 4 START JUNE 26 1977

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CE4 %
77202										
8.10	957.00	165.00	8.00	8496.00	95989.00	66712.00	91704.00	59090.00	540.00	61.30
77203										
8.50	1601.00	155.00	7.80	6476.00	95301.00	71111.00	104018.00	61474.00	480.00	58.70
77204										
11.00	-2247.00	175.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77205										
11.30	-2490.00	160.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77206										
9.05	-2728.00	155.00	7.90	8928.00	99701.00	71883.00	96540.00	68021.00	432.00	61.50
77207										
8.05	-2782.00	157.00	7.80	9888.00	95385.00	64376.00	95951.00	62037.00	960.00	59.80
77208										
8.35	-303.00	197.00	7.90	8736.00	96790.00	69245.00	99334.00	70462.00	540.00	57.40
77209										
9.10	-2077.00	185.00	8.00	7008.00	91736.00	75270.00	100361.00	79025.00	660.00	58.20
77210										
8.10	-1027.00	153.00	8.00	6816.00	103871.00	70528.00	107323.00	68408.00	760.00	57.10
77211										
9.10	-1727.00	152.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77212										
10.00	2576.00	160.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77213										
8.50	-21.00	160.00	7.80	7104.00	94924.00	74609.00	107235.00	80237.00	360.00	56.60
77214										
8.10	2918.00	160.00	7.80	7008.00	98443.00	73815.00	103280.00	74802.00	792.00	56.30
77215										
8.10	2712.00	160.00	7.90	6720.00	93049.00	73974.00	106734.00	83140.00	288.00	56.70
77216										
8.10	2499.00	159.00	8.00	7488.00	94029.00	71727.00	104816.00	783.2.00	552.00	58.20
77217										
8.10	1012.00	175.00	7.90	7872.00	101321.00	86048.00	109796.00	91838.00	1104.00	60.20
77218										
9.45	1012.00	80.00	7.60	-1.00	110070.00	72548.00	-1.00	-1.00	-1.00	-1.00
77219										
10.55	1012.00	112.00	7.30	-1.00	81992.00	69031.00	-1.00	-1.00	-1.00	-1.00
77220										
8.05	1442.00	83.00	7.80	8064.00	74451.00	58335.00	100858.00	73420.00	624.00	57.60
77221										
8.15	1012.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77222										
8.05	1201.00	51.00	7.80	6816.00	43407.00	32683.00	90612.00	68385.00	312.00	73.50
77223										
8.00	1203.00	80.00	7.90	6336.00	44137.00	35834.00	91340.00	68140.00	360.00	62.30
77224										
9.35	1957.00	55.00	7.90	6720.00	50954.00	41248.00	88183.00	68137.00	408.00	61.90
77225										
10.15	2885.00	56.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77226										
10.30	772.00	51.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-137-

Table A 4

BEEF MANURE REACTOR * START JUNE 26 1977

DATE/TIME	GAS METER	FEED RATE	pH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CE. %
77227										
8.40	1495.79	54.00	7.90	6336.00	48901.00	39235.00	86359.00	71290.00	480.00	59.30
77228										
8.05	2256.00	60.00	7.80	6048.00	46566.00	37790.00	86183.00	69199.30	840.00	60.80
77229										
8.00	71.00	52.00	7.80	6624.00	44276.00	33896.00	80345.00	60750.00	456.00	60.20
77230										
8.15	795.30	57.00	7.80	5664.00	55527.00	46181.00	75899.00	63225.00	648.00	60.30
77231										
9.30	1433.00	53.00	7.70	6240.00	53124.00	43552.00	73531.00	58877.30	624.30	-1.00
77232										
12.00	2245.00	51.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77233										
11.30	2962.70	50.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77234										
8.20	641.00	55.00	7.70	5472.00	55559.00	40926.30	73896.00	53021.30	792.00	61.90
77235										
8.15	1420.00	55.00	7.80	5952.00	54547.00	45320.00	69361.00	55714.00	192.00	59.30
77236										
8.15	2133.00	53.00	7.80	5856.00	52943.00	38351.00	66521.00	46727.00	600.00	59.60
77237										
8.15	2875.00	51.00	7.70	5280.30	51045.00	41110.00	68192.00	54580.00	264.30	61.30
77238										
8.30	666.00	51.00	7.70	5088.00	42580.00	33371.00	65546.00	51853.00	336.00	74.40
77239										
10.30	1372.30	49.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77240										
10.00	1924.00	49.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77241										
8.05	2183.00	59.30	7.90	5856.00	64878.00	46133.00	67134.00	51666.00	168.00	61.50
77242										
8.05	2893.00	50.30	7.80	5280.00	59599.00	44428.00	67531.00	52614.00	96.00	61.10
77243										
8.00	415.00	65.00	7.70	5568.00	57919.00	43662.00	67038.00	51728.00	144.00	60.80
77244										
8.15	964.00	54.00	7.80	5376.00	56028.00	42448.00	69049.00	54965.00	264.00	60.70
77245										
9.00	1446.00	51.00	7.80	4608.00	54320.00	40289.00	65847.00	50068.00	96.00	61.50
77246										
10.30	1727.00	52.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77247										
9.45	1962.00	50.00	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77248										
10.20	2196.00	55.00	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77249										
8.30	2386.30	49.00	7.70	5088.00	55723.00	39363.00	61823.00	46349.00	72.00	63.50
77250										
8.00	2657.00	59.00	7.80	4896.00	62269.00	44714.00	62712.00	47906.00	168.00	62.20
77251										
8.00	2988.00	50.00	7.70	4896.00	98376.00	44714.00	64588.00	48095.00	216.00	61.60

-130-

Table A 4 BEEF MANURE REACTOR 4 START JUNE 26 1977

DATE/TIME	GAS MEIEN	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %	
77252	8.30	325.00	56.00	7.70	4704.00	112052.00	63072.00	65886.00	45731.00	264.70	58.10
77253	10.25	774.00	54.00	7.80	-1.00	126972.00	67577.00	-1.00	-1.00	-1.00	-1.00
77254	10.50	1165.00	53.00	-1.00	-1.00	80269.00	48599.00	-1.00	-1.00	-1.00	-1.00
77255	8.35	1562.00	50.00	7.30	4800.70	71312.00	45744.00	69423.00	49351.00	24.00	57.50
77256	8.10	1910.00	50.00	7.40	4606.00	66791.00	42414.00	67508.00	46754.00	96.00	55.50
77257	8.00	2301.00	55.00	7.30	4508.00	60668.00	37980.00	68021.00	44049.00	48.00	55.60
77258	8.35	2652.00	54.00	7.40	4312.00	67888.00	42442.00	66712.00	43232.00	48.00	55.90
77259	8.15	41.00	73.00	7.50	3822.00	59730.00	39196.00	63223.00	44848.00	96.00	51.90
77260	9.20	450.00	50.00	7.40	-1.00	43106.00	22334.00	-1.00	-1.00	-1.00	-1.00
77261	12.25	830.70	57.00	7.30	-1.00	51992.00	33862.00	-1.00	-1.00	-1.00	-1.00
77262	8.10	1480.00	56.00	7.50	3528.00	67036.00	38537.00	62613.00	39482.00	96.00	58.70
77263	11.55	1635.00	53.00	7.30	3626.00	40567.00	21329.00	58790.00	30959.00	96.00	58.10
77264	8.25	1877.00	57.00	7.30	3822.00	41536.00	28065.00	58940.00	40442.00	60.00	55.70
77265	8.35	2234.00	61.00	7.35	3920.00	77733.00	49240.00	60233.00	39906.00	48.00	56.40
77266	8.05	2647.00	49.00	7.30	3626.00	53629.00	39005.00	57651.00	40387.00	72.00	59.80
77267	9.25	80.00	85.00	7.30	-1.00	47434.00	32382.00	-1.00	-1.00	-1.00	-1.00
77268	8.25	440.00	120.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

-139-

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CF4 %	
77269	9.05	866.00	160.00	7.20	3626.00	57045.00	41112.00	59022.00	40266.00	96.00	60.30
77270	8.10	1375.00	180.00	7.30	3842.00	33220.00	19592.00	53905.00	37405.00	216.00	65.80
77271	9.00	1678.00	160.00	7.40	2842.00	5836.00	3295.00	46340.00	31770.00	24.00	68.70
77272	8.00	2055.00	162.00	7.30	2744.00	53948.00	41009.00	42347.00	29533.00	192.00	65.10
77273	8.30	2651.00	160.00	7.20	2548.00	88038.00	52176.00	47374.00	26854.00	360.00	60.50
77274	9.10	392.00	161.00	7.40	-1.00	46736.00	33562.00	-1.00	-1.00	-1.00	-1.00
77275	9.45	1119.00	160.00	7.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77276	8.00	1711.00	163.00	7.30	3528.00	31178.00	21704.00	46548.00	29260.00	192.00	60.50
77277	8.00	2520.00	161.00	7.30	3234.00	30664.00	17774.00	44388.00	25308.00	48.00	62.80
77278	8.00	100.00	160.00	7.30	3430.00	58465.00	39836.00	48575.00	33881.00	19.00	62.20
77279	8.30	654.00	163.00	7.30	3430.00	104984.00	68540.00	57652.00	39630.00	72.00	61.90
77280	8.00	1248.00	161.00	7.30	3430.00	61975.00	37571.00	59045.00	36860.00	120.00	60.80
77281	11.00	1970.00	157.00	7.30	-1.00	27576.00	23572.00	-1.00	-1.00	-1.00	-1.00
77282	9.00	2425.00	160.00	7.20	-1.00	36122.00	28400.00	-1.00	-1.00	-1.00	-1.00
77283	7.45	2915.00	161.00	7.40	3234.00	79774.00	53532.00	58891.00	38368.00	144.00	65.20
77284	8.45	454.00	160.00	7.30	3234.00	56293.00	39812.00	67861.00	45347.00	144.00	64.60
77285	8.00	974.00	161.00	7.30	3234.00	47353.00	32994.00	66893.00	46480.00	168.00	63.00
77286	9.10	1527.00	161.00	7.30	3136.00	33383.00	21576.00	65517.00	45844.00	120.00	62.00
77287	8.10	2069.00	160.00	7.30	3234.00	32020.00	18889.00	57520.00	35491.00	120.00	65.20
77288	10.01	2499.00	158.00	7.40	-1.00	16272.00	10137.00	-1.00	-1.00	-1.00	-1.00
77289	10.30	2770.00	50.00	7.30	-1.00	60159.00	43634.00	-1.00	-1.00	-1.00	-1.00
77290	8.05	19.00	59.00	7.20	3234.00	56457.00	37779.00	59354.00	39757.00	96.00	56.90
77291	8.00	325.00	50.00	7.30	3430.00	39187.00	26243.00	56890.00	37551.00	72.00	56.80
77292	8.30	622.00	51.00	7.30	3234.00	89808.00	61410.00	56261.00	38222.00	96.00	59.50
77293	9.00	842.00	51.00	7.30	3430.00	29263.00	20625.00	56240.00	37422.00	72.00	59.50

-140-

Table A 4

BREF MANURE REACTOR #4 START SEPT 27 1977

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF.-V.A.	CH4 %	
77294	8.00	1062.00	49.00	7.30	3030.00	42755.00	24728.00	45370.00	23422.00	192.00	60.60
77295	10.00	1260.00	-1.00	7.30	-1.00	79152.00	45554.00	-1.00	-1.00	-1.00	-1.00
77296	9.30	1451.00	53.00	7.30	-1.00	108706.00	62430.00	-1.00	-1.00	-1.00	-1.00
77297	8.45	1617.00	52.00	7.30	3136.00	31889.00	22102.00	51307.00	34965.00	72.00	61.40
77298	8.05	1762.00	79.00	7.20	3234.00	79379.00	49333.00	49241.00	33259.00	72.00	58.20
77299	8.00	1966.00	84.00	7.20	2842.00	31792.00	21424.00	48210.00	32974.00	96.00	57.70
77300	8.00	2327.00	85.00	7.30	2940.00	24952.00	16577.00	47323.00	32341.00	72.00	50.70
77301	8.00	2511.00	85.00	7.30	2744.00	28305.00	18973.00	45464.00	26726.00	72.00	61.40
77302	9.55	2628.00	-1.00	7.30	-1.00	28942.00	18369.00	-1.00	-1.00	-1.00	-1.00
77303	11.05	2746.00	85.00	7.30	-1.00	34594.00	23484.00	-1.00	-1.00	-1.00	-1.00
77304	8.05	2960.00	83.00	7.20	2940.00	36137.00	25008.00	43790.00	29771.00	120.00	51.80
77305	8.00	217.00	99.00	7.20	2646.00	36506.00	25877.00	42513.00	29120.00	96.00	54.90
77306	8.00	431.00	90.00	7.20	2548.00	43367.00	30460.00	39925.00	27453.00	168.00	54.90
77307	8.05	907.00	118.00	7.30	2450.00	33374.00	21153.00	39741.00	27241.00	120.00	50.10
77308	8.05	1209.00	84.00	7.30	2548.00	40376.00	27791.00	39217.00	26595.00	288.00	48.50
77309	9.50	1420.00	50.00	7.40	-1.00	67153.00	41990.00	-1.00	-1.00	-1.00	-1.00
77310	10.10	1774.00	86.00	7.50	-1.00	89554.00	61991.00	-1.00	-1.00	-1.00	-1.00
77311	8.05	2228.00	54.00	7.40	2646.00	52411.00	38622.00	40313.00	27803.00	192.00	54.80
77312	8.05	2632.00	23.00	7.50	2646.00	45483.00	33127.00	39312.00	27180.00	120.00	54.00

-141-

Table A 5. Fiber Analysis

Sieve Size	% Total Solids Retained on Sieve	Percent of T.S. Retained on Sieve				
		Extracted Material	Cellulose	Lignin	Protein	Fixed Solids
Reactor #1 Effluent (6-29-77)						
10	12.1	0.9	58.9	11.9	1.4	26.9
20	9.8	1.0	58.9	10.1	1.4	28.6
50	13.1	1.5	54.1	10.6	1.2	32.6
100*	5.6	1.8	46.6	-	0.4	56.4
200*	7.0	0.8	44.5	-	1.0	59.8
Pan	52.4	-	-	-	-	-
Reactor #2 Effluent (7-1-77)						
10	36.3	1.4	56.1	16.9	1.1	24.5
20	2.7	2.3	56.0	26.7	1.1	13.9
50	7.6	1.5	54.6	6.9	1.2	35.8
100*	4.5	0.2	44.1	-	0.8	59.1
200*	4.0	0.1	45.1	-	1.7	53.1
Pan	44.9	-	-	-	-	-
Reactor #3 Effluent (7-8-77)						
10	40.8	0.9	56.1	17.8	0.6	24.4
20	3.7	0.9	54.8	4.0	1.5	38.8
50	1.6	0.9	42.9	3.7	0.4	52.1
100*	3.1	0.7	43.1	-	0.4	60.2
200*	3.7	0.9	41.7	5.7	1.8	49.9
Pan	47.1	-	-	-	-	-
Reactor #4 Effluent (7-14-77)						
10	41.2	1.8	56.4	18.5	1.8	21.5
20	2.6	2.2	57.6	16.7	1.0	22.5
50	7.7	2.6	51.7	7.5	0.9	37.7
100*	3.9	1.6	44.9	-	0.7	58.1
200*	4.6	2.2	43.3	-	0.5	55.1
Pan	40.0	-	-	-	-	-

*Lignin percent negative due to high fixed solids percentage.

Table A 5 (cont.)

Sieve Size	% Total Solids Retained on Sieve	Percent of T.S. Retained on Sieve				
		Extracted Material	Cellulose	Lignin	Protein	Fixed Solids
Reactor #4 Effluent (9-19-77)						
10	14.1	2.4	52.9	7.0	2.4	35.3
20	11.6	0.4	54.7	7.6	1.4	35.9
50	9.6	0.1	51.7	13.3	0.9	34.0
100	4.5	0.5	46.9	24.5	5.5	22.6
200	5.1	0.8	45.5	13.5	2.9	37.3
Pan	55.1	-	-	-	-	-
Reactor #3 Effluent (10-15-77)						
10	20.7	1.5	50.7	0.4	2.3	45.1
20*	15.4	1.4	48.5	-	2.8	55.9
50*	11.3	1.6	42.9	-	5.3	67.4
100*	7.7	1.1	37.6	-	4.2	76.2
200**	4.7	-	-	-	-	-
Pan	40.2	-	-	-	-	-
Reactor #2 Effluent (9-13-77)						
10	27.3	1.4	51.5	21.3	0.6	25.2
20	11.3	1.8	48.6	11.6	3.9	34.1
50	7.3	1.7	47.4	10.4	2.3	38.2
100	3.6	1.5	43.4	10.0	2.4	42.7
200	3.6	1.1	42.9	11.2	1.3	43.5
Pan	46.9	-	-	-	-	-
Reactor #3 Effluent (9-16-77)						
10	24.8	1.5	51.1	8.7	0.8	37.9
20*	12.1	1.1	50.9	-	1.1	47.3
50*	10.8	0.3	42.7	-	4.2	71.0
100*	4.7	0.4	37.1	-	2.1	68.2
200*	3.4	0.7	39.7	-	1.4	59.3
Pan	44.2	-	-	-	-	-

*Lignin percent negative due to high fixed solids percentage.

**Condenser broke-Sample destroyed.

Table A 5 (cont.)

		Percent of T.S. Retained on Sieve				
Sieve Size	% Total Solids Retained on Sieve	Extracted Material	Cellulose	Lignin	Protein	Fixed Solids
Raw Manure Slurry Mixing Tank #2 (7-27-77)						
10	34.0	2.3	53.8	25.6	1.8	16.5
20	4.7	1.9	55.8	33.7	1.9	6.7
50	11.0	3.5	60.0	17.9	1.3	17.3
100	4.2	3.7	35.7	48.1	1.6	10.9
200	3.1	4.3	46.2	33.8	1.1	14.6
Pan	43.0	-	-	-	-	-
Raw Manure Slurry Mixing Tank #1 (10-19-77)						
10	44.3	1.0	52.8	2.9	1.3	42.0
20	6.5	1.3	50.8	11.0	0.8	36.1
50	8.0	1.4	51.7	14.2	3.6	29.1
100	4.4	3.5	50.4	4.5	4.9	36.7
200	2.0	3.6	48.0	12.5	3.2	32.7
Pan	33.9	-	-	-	-	-

Table A 6
Hardness and Iron Analysis

Sieve Size	% Total Solids Retained on Sieve	Percent of T.S. Retained on Sieve	
		Hardness	Iron
Reactor #2 Effluent (9-13-77)			
10	27.3	1.9	0.4
20	11.3	2.3	0.6
50	7.3	3.6	0.7
100	3.6	6.1	0.8
200	3.6	4.6	0.8
Pan	46.9	---	---
Reactor #3 Effluent (9-16-77)			
10	24.8	0.9	0.4
20	12.1	2.4	0.6
50	10.8	2.5	0.9
100	4.7	4.4	1.0
200	3.4	4.6	1.4
Pan	44.2	---	---
Reactor #4 Effluent (9-19-77)			
10	14.1	0.7	0.3
20	11.6	2.4	0.4
50	9.6	1.9	0.5
100	4.5	5.1	0.6
200	5.1	6.3	0.7
Pan	55.1	---	---
Reactor #3 Effluent (10-15-77)			
10	20.7	0.9	0.5
20	15.4	2.7	0.7
50	11.3	2.7	0.9
100	7.7	2.8	1.0
200**	4.7	---	---
Pan	40.2	---	---

**Condenser broke-Sample destroyed.

Table A 6
(cont.)

		Percent of T.S. Retained on Sieve	
Sieve Size	% Total Solids Retained on Sieve	Hardness	Iron
Raw Manure Slurry Mixing Tank #2 (7-27-77)			
10	34.0	---	0.1
20	4.7	---	0.1
50	11.0	---	0.1
100	4.2	2.2	0.3
200	3.1	9.4	0.2
Pan	43.0	---	---
Raw Manure Slurry Mixing Tank #1 (10-19-77)			
10	44.3	0.9	0.5
20	6.5	1.4	0.4
50	8.0	2.4	0.4
100	4.4	3.4	0.5
200	2.9	4.9	0.6
Pan	33.9	---	---

Table A 7 Summary of Average Nitrogen Concentrations

Date		Total Kjeldahl mg/l as N (N as %TS)	Ammonia mg/l as N (N as %TS)	Organic mg/l as N (N as %TS)
<u>Reactor #2: θ = 4.8 Days; FS = 6.35%; ES = 6.51%; CS = 27.2%</u>				
9/7- 9/10/77	Feed Slurry	1017 $\pm$ 252 (1.60)	56 $\pm$ 10 (0.09)	961 (1.51)
	Effluent Slurry	1485 $\pm$ 239 (2.27)	128 $\pm$ 24 (0.20)	1347 (2.07)
	Cake	10,536 $\pm$ 1852 (4.04)	68 $\pm$ 65 (0.03)	10,469 (4.01)
<u>Reactor #3: θ = 9.5 Days; FS = 5.19%; ES = 6.70%; CS = 27.6%</u>				
9/12- 9/15/77	Feed Slurry	999 $\pm$ 165 (1.96)	78 $\pm$ 17 (0.15)	982 (1.81)
	Effluent Slurry	1344 $\pm$ 310 (1.99)	201 $\pm$ 33 (0.30)	1143 (1.69)
	Cake	10,403 $\pm$ 678 (3.99)	48 $\pm$ 27 (0.02)	10,355 (3.97)
<u>Reactor #4: θ = 13.7 Days; FS = 5.67%; ES = 5.98%; CS = 26.0%</u>				
9/19- 9/22/77	Feed Slurry	1529 $\pm$ 174 (2.97)	71 $\pm$ 2 (0.13)	1458 (2.84)
	Effluent Slurry	2104 $\pm$ 801 (3.50)	136 $\pm$ 16 (0.23)	1968 (3.27)
	Cake	10,129 $\pm$ 1417 (3.96)	88 $\pm$ 31 (0.04)	10,041 (3.92)

Table A 7 (continued)

Date		Total Kjeldahl mg/l as N (N as %TS)	Ammonia mg/l as N (N as %TS)	Organic mg/l as N (N as %TS)
<u>Reactor #2: θ = 3.9 Days; FS = 4.12%; ES = 4.99%; CS = 24.5%</u>				
5/29- 6/8/77	Feed Slurry	1256 $\pm$ 267 (3.15)	90 $\pm$ 31 (0.23)	1166 (2.92) ⁱ
	Effluent Slurry	1211 $\pm$ 333 (2.42)	119 $\pm$ 18 (0.24)	1092 (2.18)
	Cake	4476 $\pm$ 515 (1.91)	3.4 $\pm$ 1.8 (0.0015)	4473 (1.91)
<u>Reactor #3: θ = 4.9 Days; FS = 4.11%; ES = 4.98%; CS = 24.0%</u>				
5/29- 6/8/77	Feed Slurry	1122 $\pm$ 341 (2.84)	63 $\pm$ 36 (0.16)	1059 (2.68)
	Effluent Slurry	1171 $\pm$ 187 (2.35)	111 $\pm$ 15 (0.22)	1060 (2.13)
	Cake	4624 $\pm$ 634 (2.13)	3.1 $\pm$ 0.6 (0.0014)	4621 (2.13)
<u>Reactor #4: θ = 6.4 Days; FS = 4.11%; ES = 5.06%; CS = 23.9%</u>				
5/29- 6/8/77	Feed Slurry	1122 $\pm$ 341 (2.84)	63 $\pm$ 36 (0.16)	1059 (2.68)
	Effluent Slurry	1076 $\pm$ 184 (2.14)	100 $\pm$ 14 (0.20)	976 (1.94)
	Cake	4177 $\pm$ 869 (1.93)	3.4 $\pm$ 0.5 (0.0016)	4174 (1.93)
<u>Reactor #1: θ = 9.5 Days; FS = 4.12%; ES = 4.19%; CS = 24.9%</u>				
5/29- 6/8/77	Feed Slurry	1256 $\pm$ 267 (3.15)	90 $\pm$ 31 (0.23)	1166 (2.29)
	Effluent Slurry	1426 $\pm$ 76 (2.17)	130 $\pm$ 12 (0.29)	1296 (2.88)
	Cake	5328 $\pm$ 1293 (2.21)	6 $\pm$ 4.7 (0.0025)	5322 (2.21)

Table A 7 (continued)

Date		Total Kjeldahl mg/l as N (N as %TS)	Ammonia mg/l as N (N as %TS)	Organic mg/l as N (N as %TS)
<u>Reactor #4: = 4.7 Days; FS = 10.08%; ES = 9.70%; CS = 24.7%</u>				
7/21- 7/25/77	Feed Slurry	5861 967 (5.87)	391 67 (0.39)	5470 (5.48)
	Effluent Slurry	5559 860 (5.78)	390 77 (0.40)	5169 (5.38)
	Cake	11,866 1639 (2.08)	516 189 (0.22)	11,350 (4.86)
<u>Reactor #3: = 5.7 Days; FS = 9.35%; ES = 10.98%; CS = 24.7%</u>				
8/3- 8/5/77	Feed Slurry	4939 170 (5.07)	437 21 (0.45)	4502 (4.44)
	Effluent Slurry	6530 1344 (5.94)	601 43 (0.55)	5929 (5.39)
	Cake	16,942 725 (7.32)	911 394 (0.40)	16,031 (6.92)
<u>Reactor #2: = 4.7 Days; FS = 5.96%; ES = 4.23%; CS = 26.8%</u>				
10/10- 10/13/77	Lime-Treated Feed Slurry	2463 771 (4.10)	77 16 (0.12)	2386 (3.98)
	Effluent Slurry	2670 348 (4.48)	111 3 (0.19)	2559 (4.29)
	Cake	9543 530 (3.57)	2.4 0.44 (0.0009)	9541 (3.57)
<u>Reactor #1: = 4.7 Days; FS = 5.42; ES = 6.51%; CS = 24.3%</u>				
10/10- 10/13/77	Non-Treated Feed Slurry	3040 1012 (5.69)	65 11 (0.12)	2975 (5.57)
	Effluent Slurry	1727 128 (2.66)	141 8 (0.22)	1586 (2.44)
	Cake	8137 275 (3.35)	2.05 0.45 (0.0008)	8135 (3.35)

Table A 8 Summary of Average Phosphorus Concentration

Date		Total P mg/l as P (P as %TS)	Soluble P mg/l as P (P as %TS)	Precipitated P mg/l as P (P as %TS)
<u>Reactor #2: θ = 4.8 Days; FS = 6.35%; ES = 6.51%; CS = 27.2%</u>				
9/7- 9/10/77	Feed Slurry	565 $\pm$ 147 (0.89)	88 $\pm$ 41 (0.14)	477 (0.75)
	Effluent Slurry	610 $\pm$ 100 (0.94)	51 $\pm$ 15 (0.08)	559 (0.86)
	Cake	1612 $\pm$ 162 (0.60)	505 $\pm$ 265 (0.20)	1107 (0.40)
<u>Reactor #3: θ = 9.5 Days; FS = 5.19%; ES = 6.70%; CS = 27.6%</u>				
9/12- 9/15/77	Feed Slurry	432 $\pm$ 62 (0.85)	109 $\pm$ 25 (0.21)	323 (0.64)
	Effluent Slurry	616 $\pm$ 89 (0.92)	45 $\pm$ 8 (0.07)	571 (0.85)
	Cake	1599 $\pm$ 403 (0.58)	376 $\pm$ 85 (0.14)	1223 (0.44)
<u>Reactor #4: θ = 13.7 Days; FS = 5.67%; ES = 5.98%; CS = 26.0%</u>				
9/19- 9/22/77	Feed Slurry	421 $\pm$ 63 (0.78)	97 $\pm$ 31 (0.20)	324 (0.58)
	Effluent Slurry	580 $\pm$ 152 (0.97)	52 $\pm$ 9 (0.09)	528 (0.88)
	Cake	1716 $\pm$ 202 (0.66)	537 $\pm$ 57 (0.21)	1179 (0.45)

Table A 8 (continued)

Date		Total P mg/l as P (P as %TS)	Soluble P mg/l as P (P as %TS)	Precipitated P mg/l as P (P as %TS)
<u>Reactor #2: θ = 3.9 Days; FS = 4.12%; ES = 4.99%; CS = 24.5%</u>				
5/29- 6/8/77	Feed Slurry	350 $\pm$ 64 (0.86)	187 $\pm$ 97 (0.48)	163 (0.38)
	Effluent Slurry	354 $\pm$ 68 (0.71)	51 $\pm$ 20 (0.10)	303 (0.61)
	Cake	1240 $\pm$ 98 (0.51)	237 $\pm$ 115 (0.10)	1003 (0.41)
<u>Reactor #3: θ = 4.9 Days; FS = 4.11%; ES = 4.98%; CS = 24.0%</u>				
5/29- 6/8/77	Feed Slurry	298 $\pm$ 50 (0.73)	112 $\pm$ 44 (0.28)	186 (0.45)
	Effluent Slurry	400 $\pm$ 28 (0.80)	74 $\pm$ 45 (0.15)	326 (0.65)
	Cake	1201 $\pm$ 109 (0.51)	284 $\pm$ 35 (0.13)	917 (0.38)
<u>Reactor #4: θ = 6.4 Days; FS = 4.11%; ES = 5.06%; CS = 23.9%</u>				
5/29- 6/8/77	Feed Slurry	298 $\pm$ 50 (0.73)	112 $\pm$ 44 (0.28)	186 (0.45)
	Effluent Slurry	376 $\pm$ 36 (0.74)	54 $\pm$ 35 (0.11)	322 (0.63)
	Cake	1060 $\pm$ 156 (0.44)	300 $\pm$ 52 (0.14)	760 (0.30)
<u>Reactor #1: θ = 9.5 Days; FS = 4.12%; ES = 4.19%; CS = 24.9%</u>				
5/29- 6/8/77	Feed Slurry	350 $\pm$ 64 (0.86)	187 $\pm$ 97 (0.48)	163 (0.38)
	Effluent Slurry	377 $\pm$ 33 (0.84)	51 $\pm$ 36 (0.11)	326 (0.73)
	Cake	1194 $\pm$ 122 (0.48)	135 $\pm$ 62 (0.06)	1059 (0.42)

Table A 8 (continued)

Date		Total P mg/l as P (P as %TS)	Soluble P mg/l as P (P as %TS)	Precipitated P mg/l as P (P as %TS)
<u>Reactor #4: θ = 4.7 Days; FS = 10.08%; ES = 9.07%; CS = 24.7%</u>				
7/21- 7/25/77	Feed Slurry	883 $\pm$ 102 (0.88)	847 $\pm$ 62 (0.84)	36 (0.04)
	Effluent Slurry	847 $\pm$ 93 (0.87)	88 $\pm$ 12 (0.09)	759 (0.78)
	Cake	1668 $\pm$ 183 (0.68)	743 $\pm$ 215 (0.32)	925 (0.36)
<u>Reactor #3: θ = 5.7 Days; FS = 9.3%; ES = 10.98%; CS = 24.7%</u>				
8/3- 8/5/77	Feed Slurry	866 $\pm$ 53 (0.90)	700 $\pm$ 90 (0.73)	166 (0.17)
	Effluent Slurry	972 $\pm$ 98 (0.89)	107 $\pm$ 14 (0.10)	865 (0.79)
	Cake	2056 $\pm$ 102 (0.83)	1092 $\pm$ 193 (0.47)	964 (0.36)
<u>Reactor #4: θ = 4.7 Days; FS = 5.96%; ES = 4.23%; CS = 26.8%</u>				
10/10- 10/13/77	Lime-Treated Feed Slurry	268 $\pm$ 53 (0.50)	14 $\pm$ 3 (0.03)	254 (0.47)
	Effluent Slurry	237 $\pm$ 34 (0.56)	12 $\pm$ 3 (0.03)	225 (0.53)
	Cake	1095 $\pm$ 132 (0.71)	131 $\pm$ 26 (0.05)	1774 (0.66)
<u>Reactor #1: θ = 4.7 Days; FS = 5.42%; ES = 6.51%; CS = 24.3%</u>				
10/10- 10/13/77	Non-Treated Feed Slurry	397 $\pm$ 108 (0.75)	93 $\pm$ 11 (0.19)	304 (0.56)
	Effluent Slurry	397 $\pm$ 78 (0.61)	56 $\pm$ 10 (0.09)	341 (0.52)
	Cake	1751 $\pm$ 105 (0.72)	270 $\pm$ 138 (0.11)	1481 (0.61)

Table A 9 Summary of Average Potassium Concentrations

Date		Total K mg/l as K (K as %TS)	Soluble K mg/l as K (K as %TS)	Precipitated K mg/l as K (K as %TS)
<u>Reactor #2: θ = 4.8 Days; FS = 6.35%; ES = 6.51%; CS = 27.2%</u>				
9/7- 9/10/77	Feed Slurry	2009 $\pm$ 355 (3.18)	1499 $\pm$ 123 (2.36)	510 (0.82)
	Effluent Slurry	2122 $\pm$ 194 (3.26)	2151 $\pm$ 190 (3.29)	0 (0.00)
	Cake	2311 $\pm$ 185 (0.85)	918 $\pm$ 357 (0.36)	1393 (0.49)
<u>Reactor #3: θ = 9.5 Days; FS = 5.19%; ES = 6.70%; CS = 27.6%</u>				
9/12- 9/15/77	Feed Slurry	1530 $\pm$ 325 (2.94)	1698 $\pm$ 337 (3.27)	0 (0.00)
	Effluent Slurry	2336 $\pm$ 232 (3.48)	2326 $\pm$ 855 (3.44)	10 (0.04)
	Cake	2452 $\pm$ 243 (0.89)	1012 $\pm$ 445 (0.39)	1440 (0.50)
<u>Reactor #4: θ = 13.7 Days; FS = 5.67%; ES = 5.98%; CS = 26.0%</u>				
9/19- 9/22/77	Feed Slurry	1613 $\pm$ 153 (3.07)	1570 $\pm$ 263 (2.95)	43 (0.12)
	Effluent Slurry	2364 $\pm$ 620 (3.97)	1538 $\pm$ 186 (2.58)	826 (1.39)
	Cake	1718 $\pm$ 275 (0.67)	1299 $\pm$ 398 (0.51)	419 (0.16)

Table A 9 (continued)

Date		Total K mg/l as K (K as %TS)	Soluble K mg/l as K (K as %TS)	Precipitated K mg/l as K (K as %TS)
<u>Reactor #2: θ = 3.9 Days; FS = 4.12%; ES = 4.99%; CS = 24.5%</u>				
5/29- 6/8/77	Feed Slurry	939 $\pm$ 132 (2.30)	486 $\pm$ 140 (1.20)	453 (1.10)
	Effluent Slurry	919 $\pm$ 157 (1.86)	402 $\pm$ 112 (0.80)	517 (1.06)
	Cake	1668 $\pm$ 227 (0.70)	1342 $\pm$ 789 (0.59)	326 (0.11)
<u>Reactor #3: θ = 4.9 Days; FS = 4.11%; ES = 4.98%; CS = 24.0%</u>				
5/29- 6/8/77	Feed Slurry	1024 $\pm$ 107 (2.51)	423 $\pm$ 123 (1.03)	601 (1.48)
	Effluent Slurry	1052 $\pm$ 99 (2.11)	410 $\pm$ 109 (0.82)	642 (1.29)
	Cake	1518 $\pm$ 185 (0.64)	514 $\pm$ 160 (0.24)	1004 (0.40)
<u>Reactor #4: θ = 6.4 Days; FS = 4.11%; ES = 5.06%; CS = 23.0%</u>				
5/29- 6/8/77	Feed Slurry	1024 $\pm$ 107 (2.51)	423 $\pm$ 123 (1.03)	601 (1.48)
	Effluent Slurry	1129 $\pm$ 150 (2.23)	661 $\pm$ 217 (1.29)	468 (0.94)
	Cake	1474 $\pm$ 268 (0.62)	563 $\pm$ 182 (0.26)	911 (0.36)
<u>Reactor #1: θ = 9.5 Days; FS = 4.12%; ES = 4.19%; CS = 24.9%</u>				
5/29- 6/8/77	Feed Slurry	939 $\pm$ 132 (2.30)	486 $\pm$ 140 (1.20)	453 (1.10)
	Effluent Slurry	936 $\pm$ 134 (2.07)	565 $\pm$ 219 (1.25)	371 (0.82)
	Cake	1465 $\pm$ 211 (0.59)	434 $\pm$ 79 (0.18)	1031 (0.41)

Table A 9 (continued)

Date		Total K mg/l as K (K as %TS)	Soluble K mg/l as K (K as %TS)	Precipitated K mg/l as K (K as %TS)
<u>Reactor #4: θ = 4.7 Days; FS = 10.08%; ES = 9.70%; CS = 24.7%</u>				
7/21- 7/25/77	Feed Slurry	3485 $\pm$ 212 (3.47)	2389 $\pm$ 367 (2.39)	1096 (1.08)
	Effluent Slurry	3169 $\pm$ 372 (3.28)	2060 $\pm$ 309 (2.13)	1109 (1.15)
	Cake	2559 $\pm$ 299 (1.04)	1461 $\pm$ 391 (0.63)	1098 (0.41)
<u>Reactor #3: θ = 5.7 Days; FS = 9.35%; ES = 10.98%; CS = 24.7%</u>				
8/3- 8/5/77	Feed Slurry	3689 $\pm$ 546 (3.85)	3316 $\pm$ 424 (3.44)	373 (0.41)
	Effluent Slurry	3707 $\pm$ 583 (3.37)	3008 $\pm$ 164 (2.74)	699 (0.63)
	Cake	3688 $\pm$ 388 (1.50)	1962 $\pm$ 528 (0.85)	1726 (0.65)
<u>Reactor #2: θ = 4.7 Days; FS = 5.96%; ES = 4.23%; CS = 26.8%</u>				
10/10- 10/13/77	Lime-Treated Feed Slurry	357 $\pm$ 47 (0.66)	303 $\pm$ 40 (0.56)	54 (0.10)
	Effluent Slurry	387 $\pm$ 35 (0.91)	347 $\pm$ 31 (0.82)	40 (0.09)
	Cake	858 $\pm$ 126 (0.32)	325 $\pm$ 67 (0.12)	533 (0.20)
<u>Reactor #1: θ = 4.7 Days; FS = 5.42%; ES = 6.51%; CS = 24.3%</u>				
10/10- 10/13/77	Non-Treated Feed Slurry	486 $\pm$ 66 (0.95)	366 $\pm$ 88 (0.71)	120 (0.24)
	Effluent Slurry	543 $\pm$ 13 (0.84)	354 $\pm$ 34 (0.55)	189 (0.29)
	Cake	1102 $\pm$ 94 (0.46)	623 $\pm$ 151 (0.26)	479 (0.20)

1. Wet Sieve Analysis

The wet sieve analysis was used to separate a sample of slurry into various size fractions.

Apparatus:

Standard sieves - sizes:

- #10 - 1.981 mm
- #20 - 0.840 mm
- #50 - 0.297 mm
- #100 - 0.149 mm
- #200 - 0.074 mm

Procedure:

1. Dry and tare sieves to within ± 0.5 grams.
2. Collect and measure two liters of slurry.
3. Allow slurry to settle for at least ten minutes.
4. Pass supernatant through #10 and #20 mesh sieves. Rotate sieves to encourage passage of solids. Transfer settled solids to screen and allow to drain.
5. Set liquid aside and allow solids to settle for 15 to 20 minutes.
6. Wash solids on first two screens with small quantities of water. Wash until clean water passes screen (less than four liters). Collect wash water.
7. Pass wash water through the remaining screens. Collect wash water and use to wash accumulated solids on the remaining sieves.

8. Pour supernatant from step five through the next two finer screens. Collect liquid. Transfer settled solids to screens and allow to drain.
9. Using wash water from step seven, wash accumulated solids.
10. Pour remaining liquid to other screens and repeat steps eight and nine.
11. After above steps have been performed for all sieves, collect and measure volume of passed liquid and wash water.
12. Allow solids on screens to dry in 103°C oven and weigh when dry.

2. Fiber Analysis

This test measures the Hemicellulose and Cellulose as Holocellulose. The fats, oils, waxes, etc., are extracted with an organic solvent. Acid hydrolysis removes the Holo-cellulose and the remaining solids are ignited at 600°C to measure the inorganic solids.

Apparatus:

Soxhlet extraction apparatus

250 ml soxhlet extraction flask

100 ml soxhlet extraction tube

Coolwater condensers

25 x 80 mm Cellulose crucibles, hot plate

1 liter side arm erlenmeyer flasks

25 ml Gooch crucibles w/asbestos pads

32 mm filtration holders for Gooch crucibles

125 ml erlenmeyer flasks

Reagents:

Alcohol-benzene solution (1 volume ethyl alcohol to 2 volumes of c.p. Benzene), sulfuric acid (72 percent)

Procedure:

1. Grind test samples to a size of less than 1 mm by passing it through a Wiley Mill.
2. Determine percent fixed solids of sample material. Dry and weigh a crucible without lid on it. Place dry sample in crucible and reweigh. The difference gives the weight of

the sample. Combust the sample at 600°C for 2-3 hours with the lid on. Remove the lid from the crucible and let stand at 600°C for 4-5 hours for complete combustion. Cool the crucible in a dessicator and weigh it without the lid. Subtract the weight of the crucible to obtain the fixed solids remaining. Divide this remaining weight by the initial weight of the sample to obtain the percentage fixed solids in the sample.

3. Place 120 ml of alcohol-benzene solution in extraction flask. Connect flask, tube with cellulose crucibles, and condensor and place in water bath. Extract empty crucibles for 4 hours to remove any extractables in the crucible.
4. Dry and weigh empty crucibles. Fill crucibles with sample and dry and weigh. Difference gives the weight of the sample. Follow extraction procedure as given for empty crucibles.
5. Dry and weigh crucibles and extracted sample. Weight lost is the weight of the extractable material.
6. Dry and weigh 125 ml flasks. Add approximately 1 g of extracted sample of flask, dry and weigh again. Add 15 ml of cold sulfuric acid to flask while stirring. Place flask in cool water bath (20°C) for 2 hours and stir frequently. Wash material from flask into 1 liter beaker with distilled water. Add 500 ml of distilled water to beaker and boil for 4 hours keeping volume constant.

7. Dry and weigh Gooch crucibles with asbestos pad. Filter beaker contents through Gooch crucibles. Dry and weigh crucibles. Material in crucible is lignin and fixed solids.
8. Subtract percent of fixed solids from percent of lignin and fixed solids.

As in step 7, the material not only contains lignin and fixed solids; but protein present in the residue precipitates and is measured as part of the residue which is designated as lignin. Total nitrogen of the residue is determined to correct for protein which is 6.25 times total nitrogen. Therefore, net lignin = (weight in step 7) - fixed solid - protein.

3. Nitrogen Analysis

Equipment:

- a) Micro-Kjeldahl flasks (100 ml)
- b) Specific ion analyzer (Orion model 407A)
- c) Magnetic stirrer with stirring bars
- d) 10 ml and 100 ml graduated cylinders
- e) 20 ml pipette
- f) 10 ml graduated pipette
- g) squeeze bulb
- h) Micro-Kjeldahl digestion burner and manifold

Reagents:

- a) Digestion Reagent: Dissolve 134 g K_2SO_4 in 650 ml ammonia-free distilled water and 200 ml conc. H_2SO_4 . Add, with stirring, a solution prepared by dissolving 2 g red mercuric oxide, HgO , in 25 ml 6N H_2SO_4 . Dilute the combined solution to 1 liter.
- b) Ammonia-free water: Distilled water which has been placed in flasks containing Dowex 150, a cation exchange resin for the removal of NH_3 .
- c) Sodium Hydroxide: Dissolved 400 g NaOH in 1 liter of ammonia-free water. NaOH ~ 10N.
- d) NH_3 -N Standards: Dissolved 3.819 g NH_4Cl in 1 liter of ammonia-free water. This results in a solution with 1 ml = 1 mg NH_3 -N.

		NH ₃ -N
1000 ml standard	=	1000 mg/l
100 ml standard + 900 ml H ₂ O	=	100 mg/l
10 ml standard + 990 ml H ₂ O	=	10 mg/l
1 ml standard + 999 ml H ₂ O	=	1 mg/l

A. Procedure: Total Kjeldahl:

1. Weigh out approximately 0.25 g (dry weight of sample. Sample can have any moisture content as long as the dry weight is approximately 0.25 g. Measure the moisture content to obtain percent TS.
2. Place sample in micro-kjeldahl flask (use squirt bottle full of ammonia-free water to wash all liquid sample into the flask).
3. Add 20 ml of digestion reagent to the flask.
4. Place in digestion rack with hood vent and aspirator turned on. Turn burner on to 2.
5. When white gas begins to come off of sample, turn heat up to 6.
6. When solution turns light green, swirl flask to get solids off of walls. It may be necessary to wash solids down neck of flask with ammonia-free water. Do this with cooled sample only!!
7. Digestion is complete when no solids exist and the solution is light green. This takes about 5 hours. Turn burners off.
8. Fill a 100 ml graduated cylinder with ammonia-free water to the 90 ml mark. Add about 20 ml of this to the Kjeldahl flask. Transfer the contents of the flask back to the graduated cylinder. Fill to the 100 ml mark with ammonia-free water. Pour the contents of the graduated cylinder back into the Kjeldahl flask and then pour the solution into a 500 ml beaker. Let cool.

9. Pipette 20 ml from the 100 ml beaker into a 100 ml beaker.
10. Calibrate the ion analyzer using the X^- scale. The center division should be calibrated first. This should be near the expected average concentration of the samples to be tested. Pour approximately 20 ml of this standard for the center division into a 100 ml beaker containing a clean stirring bar. Rinse the probe with ammonia-free water and immerse it in the solution in the beaker on top of the stirrer. Turn on the magnetic stirrer. Using the 10 ml graduated pipette, pipette 1/2 ml of 10N NaOH into the standard. Set the center division for the standard using the knob in the lower left corner of the ion analyzer.
11. Do the same thing for a standard 10 times larger for the right edge of the scale using the temperature knob to adjust the needle.
12. The probe must now become acclimated to the digested samples, otherwise the readings obtained from the X^- scale will be too high. Four (4) equilibrating samples should be run before actually recording values from the X^- scale. Since more than one digestion is done at a time, take 20 ml from each of the first four beakers and place a clean stirring bar in each. Rinse the probe before each reading and pull the black cord attached to the probe gently before adding 10 ml of 10N NaOH to the sample. Do this for all four samples and note the values read off of the X^- scale. If they have stabilized, repeat the procedure for the samples you wish to record data for.

13. Rinse probe and place it back in its 0.05N buffer solution.
Turn setting to off and turn off the magnetic stirrer.

Example Calculation:

Reactor #1: $\theta = 4.7$ Days; ES = 5.89% Date: 10/10/77

Weight of effluent slurry sample: 8.9 grams

$$\text{Dilution} = \frac{100 \times 30 \times 1}{20 \times 8.9} = 16.9$$

$$X^- \text{ reading} = 112 \text{ mg/l}$$

$$\text{mg/l as N} = 16.9 \times 112 = \underline{1888 \text{ mg/l}}$$

$$\text{N as \%TS} = \frac{1888}{58,900} = \underline{3.20\%}$$

B. Procedure: Ammonia

1. Pour approximately 20 ml of sample into a 100 ml beaker containing a clean stirring bar. In the case of cake solids add a measured weight of cake to 25 ml of ammonia-free water.
2. Calibrate ion analyzer as in steps 10 and 11 above.
3. Place rinsed probe into beaker containing sample. Add 1/2 ml of 10N NaOH. Record X^- scale reading.

Example Ammonia Calculations:

Reactor #1: $\theta = 4.7$ Days; ES = 5.8%; Date: 10/10/77

Using 20 ml of sample:

$$X^- \text{ reading} = \underline{130 \text{ mg/l as N}}$$

$$\text{N as \%TS} = \frac{130}{58,900} = \underline{0.221\%}$$

Using Centrifuged Cake:

1.75 grams is weighed out and added to 25 ml of ammonia-free water.

Taking 20 ml of this sample after centrifuging for 75 minutes in a CU-5000 general purpose centrifuge the following X^- reading was obtained:

$$X^- = 0.17 \text{ mg/l}$$

$$\text{Dilute} = \frac{25}{1.75} = 14.3$$

$$\text{mg/l as N} = 14.3 \times 0.17 = \underline{2.43 \text{ mg/l}}$$

$$\text{N as \%TS} = \frac{2.43}{239,000} = \underline{0.0010\%TS}$$

C. Procedure: Organic N:

To obtain organic N simply subtract ammonia N from total Kjeldahl N.

4. Phosphorus Analysis

Equipment:

- a) Micro-Kjeldahl digestion unit
- b) Micro-Kjeldahl flasks
- c) Burette for periodic-perchloric acid mixture
- d) Squeeze bottle filled with distilled water
- e) 50 ml volumetric test tubes
- f) 50 ml volumetric flasks
- g) 1,2,5,10 ml pipettes
- h) Spec 20 or equivalent
- i) Spec 20 sample tubes
- j) 100 and 1000 ml volumetric flasks
- k) kimwipes

Reagents:

- a) Periodic acid ($\text{HIO}_4 \cdot 2\text{H}_2\text{O}$)-perchloric (70%) acid mixture:
Dissolve 50 g of periodic acid in 1000 ml of perchloric acid by gently heating the mixture.
- b) Blank P. solution: Add 92 ml of 70% perchloric acid to a 1000 ml flask. Fill to 1 liter with distilled water.
- c) Vanado-Molybdate Color Reagent:

Solution A:

- 1) Add 1.25 g of ammonium vanadate (NH_4VO_3) to 300 ml of water heated to approximately 95°C. Mix until solution is complete. Let cool.
- 2) Add 100 ml conc. perchloric acid. Let cool.

- 3) Add solution A to a 1000 volumetric flask.

Solution B:

- 1) Add 25 g of ammonium molybdate $((\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O})$ to 400 ml of water. Dissolve by stirring.
- 2) Add solution B to solution A in the 1000 ml volumetric flask. Add solution B slowly with swirling. Bring up to volume with distilled water.

- d) 50 mg/l Standard P Solution: Dissolve 0.2196 g KH_2PO_4 in 1 liter of distilled water. Pipette 0,1,2,3,4 and 5 ml portions of 50 mg/l stock solution into 50 ml volumetric flasks containing a pipetted 10 ml of blank. Then pipette 10 ml of vanado-molybdate solution into each flask and bring to volume with distilled water and mix. This gives 0,1,2,3,4 and 5 mg/l phosphorus solutions respectively.

A. Procedure: Total Phosphorus:

1. Weight out approximately 0.25 grams (dry weight) of sample into a 100 ml micro-kjeldahl flask.
2. Add 5 ml of periodic-perchloric acid and mix.
3. Measure the moisture content of the sample to obtain the %TS.
4. Digest on a micro-kjeldahl digester until liquid is clear and fairly colorless. Let cool. Sometimes liquid will turn a light green after the heat is turned off. This color usually will disappear upon further cooling. If the color does not disappear, the liquid will have to be reheated until clear.

5. Transfer all contents of the micro-kjeldahl flask into a 50 ml volumetric test tube. Rinse the kjeldahl flask quantitatively into the test tube. Let the contents cool and bring up to volume with distilled water. Mix well. Let all suspended inerts settle out.
6. Take a 10 ml aliquot from the 50 ml volumetric test tube and add it to a 50 ml volumetric flask, then add 10 ml of vanado-molybdate color reagent and bring up to volume with distilled water. Mix well. Let color develop for at least 10 minutes. Read color versus the 0 mg/l phosphorus standard adjusted to 100% transmission (0 absorbance) on the spectrophotometer. Use the 410 mμ filter adjustment. From a curve of standard P solutions read in a similar fashion, mg/l P in the unknown can be determined.

Example Calculation:

Reactor #1: $\theta = 9.5$ Days; ES = 5.03%; Date 5/29/77

Weight of effluent slurry sample = 4.9 grams

$$\text{Dilution} = \frac{50 \times 50 \times 2}{4.9 \times 10} = 102.0$$

The dilution factor of 2 is thrown in because the sample had to be diluted once more than normal to be in the 0-5 mg/l range.

Spec 20 Reading = 0.261

mg/l from standard P curve = 3.41 mg/l

$$\text{mg/l as P} = 102.0 \times 3.41 = \underline{348 \text{ mg/l}}$$

$$\text{P as \%TS} = \frac{348}{50,300} = \underline{0.69\%}$$

B. Procedure: Soluble P:

1. For slurried samples, centrifuge for 75 minutes in the CU-5000 general purpose centrifuge. Then analyze the centrate as in steps 1-6 above.
2. For a cake or dry sample, measure out a portion (1-2 grams) and dissolve it in 25 ml of distilled water, centrifuge and proceed as in step 1 above.

Example Calculations:

Reactor #1: θ = 9.5 Days; ES = 5.03%; Date 5/29/77

Weight of effluent slurry sample after centrifuging
= 8.5 grams.

$$\text{Dilution} = \frac{50 \times 50}{8.5 \times 10} = 29.4$$

Spec 20 Reading = 0.025

mg/l from standard P curve = 0.31

$$\text{mg/l as P} = 29.4 \times 0.31 = \underline{9.1 \text{ mg/l}}$$

$$\text{P as \%TS} = \frac{9.1}{50,300} = \underline{0.018\% \text{TS}}$$

Reactor #1 θ = 9.5 Days; CS = 25.7%; Date 5/29/77

1.60 grams of cake is weighed out and added to 25 ml of distilled water. This is mixed in a 35 ml glass sample bottle and allowed to stand in a refrigerator overnight.

This sample is then centrifuged for 75 minutes and a 6.1 gram sample from the centrate is weighed out.

$$\text{Dilution} = \frac{25 \times 60 \times 50}{1.6 \times 6.1 \times 10} = 640.4$$

Spec 20 Reading = 0.013

mg/l from standard P curve = 0.19

mg/l as P = $640.4 \times 0.19 = \underline{121.6 \text{ mg/l}}$

P as %TS = $\frac{121.6}{257,000} = \underline{\underline{0.047\%TS}}$

C. Procedure: Precipitated P:

1. Simply subtract soluble P from total P.

5. Potassium Analysis

Equipment:

- a) Same as for the phosphorus determination, except replace the Spec 20 with:
- b) Flame Photometer (Junior Spectrophotometer model 6-C; Coleman Instruments, Inc. was used for these potassium determinations.)
- c) K filter

Reagents:

- a) Periodic acid ($\text{HIO}_4 \cdot 2\text{H}_2\text{O}$)-perchloric (70%) acid mixture: Dissolve 50 grams of periodic acid in 1000 ml of perchloric acid by gently heating the mixture.
- b) Blank K solution: Add 46 ml of 70% perchloric acid to a 1000 ml flask. Fill to 1 liter with distilled water.
- c) 100 mg/l Standard K solution: Dissolve 0.1907 grams pure dry KCl in 1 liter of blank K solution. Pipette 80, 60, 40, and 20 ml portions of 100 mg/l K standard solution into 100 ml volumetric flasks. Bring up to volume with blank K solution.
- d) 0 mg/l K standard: Use Blank K solution from part b.

A. Procedure: Total Potassium: (to be run simultaneously with phosphorus determinations)

- 1. Follow steps 1-5 of phosphorus procedure.
- 2. Pipette a 5 ml aliquot from the 50 ml volumetric test tube into a 25 ml plastic vial. Add 5 ml of distilled water, label and cap vial.

3. Using the flame photometer fitted with the K filter, form a standard curve from the standard of 0, 20, 40, 60, 80 and 100 mg/l K.
4. Read flame photometer scale for sample and obtain mg/l in sample from the standard curve.

Example Calculation:

Reactor #1: θ = 9.5 Days; ES = 5.03%; Date 5/29/77

Weight of effluent slurry sample = 4.9 grams

$$\text{Dilution} = \frac{50 \times 10}{4.9 \times 5} = 20.4$$

Flame photometer reading = 57

mg/l from standard K curve = 50

$$\text{mg/l as K} = 20.4 \times 50 = \underline{1020 \text{ mg/l}}$$

$$\text{K as \%TS} = \frac{1020}{50,300} = \underline{2.03\%}$$

B. Procedure: Soluble K:

1. For slurried samples, centrifuge for 75 minutes in the CU-5000 general purpose centrifuge. Then analyze the centrate as in steps 1-4 above.
2. For a cake or dry sample, measure out a portion (1-2 grams) and dissolve it in 25 ml of distilled water, centrifuge and proceed as in step 1.

Example Calculations:

Reactor #1: θ = 9.5 Days; ES = 5.03%; Date 5/29/77

Weight of effluent slurry sample after centrifuging = 8.5 grams

$$\text{Dilution} = \frac{50 \times 10}{8.5 \times 5} = 11.8$$

Flame photometer reading = 21

mg/l from standard K curve = 20

$$\text{mg/l as K} = 11.8 \times 20 = \underline{235 \text{ mg/l}}$$

$$\text{K as \%TS} = \frac{235}{50,300} = \underline{0.47\%TS}$$

Reactor #1: θ = 9.5 Days; CS = 25.7%; Date 5/29/77

1.60 grams of cake is weighed out and added to 25 ml of distilled water. This is mixed in a 35 ml glass sample bottle and allowed to stand in a refrigerator overnight.

This sample is then centrifuged for 75 minutes and a 6.1 gram sample from the centrate is weighed out.

$$\text{Dilute} = \frac{25 \times 50 \times 10}{1.6 \times 6.1 \times 5} = 256.1$$

Flame photometer reading = 3.5

mg/l from standard K curve = 1.5

$$\text{mg/l as K} = 256.1 \times 1.5 = \underline{384 \text{ mg/l}}$$

$$\text{K as \%TS} = \frac{384}{257,000} = \underline{0.15\%TS}$$

C. Procedures: Precipitated K

1. Simply subtract soluble K from Total K.

Appendix C - Computer Program and Documentation

This appendix contains detailed information on the simulation program. It is divided into four major sections: logic flow and notes, definition of major program variables, program listing, and sample output. The program has been implemented on the University of Illinois CDC CYBER-175 computer system in a time-sharing mode.

1. Logic Flow and Notes

1.1 Overview of Simulation Program

The overall structure of the system being simulated is shown in Figure C-1. The computer program consists of a separate subroutine for each of the operations shown in the figure, plus the necessary data initialization, output and control routines. Major emphasis has been placed on the construction of the model of the anaerobic digester, with less importance attached to the system components before and after digestion. This distribution of effort is the result of the dependence of all other components on the design parameters of the digesters, the large effect these parameters have on overall system economics, and, as a result of the laboratory portion of this study, an improved method of modeling the effects of digester temperature, retention time and manure biodegradability on the production rate of methane.

Major portions of this simulation program are alterations of an existing model of an organic refuse digestion system [Quindry, Liebman and Pfeffer, 1976]. Other portions are based on a manure digestion program developed by Dynatech R/D Company [Ashare, Wise, and Wentworth, 1977].

Figure C-1 Overall Structure of Computer Program

1.2 Data Input and Initialization

Data input for the simulation program consists of both a file of parameters (named FRONT) and free-format interactive data that is input during execution of the program. Many parameters which would be changed only rarely are initialized in DATA statements at the beginning of the subroutine in which the parameters are used.

File FRONT consists of information which can be changed more readily, and includes such items as interest rate, inflation adjustments for the capital cost items, mixing horsepower requirements, electricity cost and methane selling price.

Selection of system options, reactor temperature, heat exchanger temperature gradient, and many other parameters is accomplished through the prompting by the simulation program for the desired information when it is needed. These parameters can be changed for each simulation run, and several simulation runs can be done with a single execution of the program.

1.3 Pre-digestion Systems: Mixing and Heat Exchange

Before digestion can take place, the manure must be brought to the desired input solids concentration and, in order to facilitate 24-hour operation of the digester feed system, some storage of the feed slurry is desirable. Also, if the feed slurry temperature can be increased using the heat of the digester effluent in a heat exchanger, a considerable amount of energy can be saved, thus improving system economics.

Subroutine MIX includes the material and energy balances for these pre-digestion systems, and the sizing and cost calculations for the necessary equipment. The slurry solids concentration (CONC) is variable

(line 2100), and the capacity of the mix tank, which provides the desired storage capacity, can be changed by altering (in line 33800) the value of the variable DAMIX, which is the retention time of the mix tank.

The inclusion of a heat exchanger is optional, and, if added, the temperature gradient across the exchanger is variable (lines 36900-37150). The heat exchanger area and capital costs are based on a similar portion of the Dynatech model.

1.4 Anaerobic Digester Model

The important parameters for the digestion system are temperature, retention time and slurry concentration; and the rate of input of biodegradable solids, alkalinity and ammonia in the feed stream. From the retention time, concentration and solids input rate, the volume required for digestion can be calculated (line 41500). This volume is then divided into the number of digesters required according to the data in Table C-1. Digester dimensions are then chosen to minimize the surface area, which will reduce digester heat loss (lines 50100-50900).

Table C-1
Number of Digesters Required

Total Volume cubic meters	Number of Digesters
0 to 3,682	2
3,682 to 14,160	3
14,160 to 35,400	4
35,400 to 48,144	5
48,144 to 56,640	6
more than 56,640	7

1.4.1 Volatile Solids Destruction and Gas Production

The total amount of CO_2 and CH_4 produced by the bacteria is calculated using the digester temperature, retention time and volume, and the biodegradability factor and kinetic constant as shown on page 40 of this report. All of the carbon dioxide produced by the fermentation of the manure is not discharged in the gas phase. Because of the relatively high solubility of carbon dioxide, and its reaction with water to produce carbonic acid, a portion of the CO_2 is removed from the digester in the liquid effluent. The quantity of CO_2 removed in this manner depends on the digester temperature and the rate of input of alkalinity and ammonia from the input slurry. Digester temperature affects the dissociation constant of carbonic acid (K_1), the dissociation constant of ammonia (K_N), Henry's Constant (H_K) and the vapor pressure of water (V_p) as shown in Table C-2 for the two possible digester temperatures.

Table C-2
Effect of Temperature on Digester Constants

Constant	40°C	58°C
K_1	5.04×10^{-7}	5.178×10^{-7}
K_N	1.57×10^{-9}	6.136×10^{-9}
H_K	1.39×10^6	2.5×10^6
V_p (atmos.)	.0728	.1790

SOURCE: Handbook of Chemistry and Physics, 48th ed., CRC Publishing Co.

The actual rate of gaseous CO_2 production can be estimated by calculating the equilibrium conditions in the digester, and subtracting the soluble CO_2 from the total CO_2 input. The reaction of CO_2 in water to produce carbonic acid is given as:

Carbonic acid dissociates readily to form a hydrogen ion and bicarbonate:

The degree of dissociation is dependent on temperature and pH,

$$K_1 = [\text{H}^+] \times [\text{HCO}_3^-] / [\text{H}_2\text{CO}_3] \quad (\text{C-3})$$

where K_1 varies with temperature according to Table C-2. The reaction between carbon dioxide and water is essentially complete and the concentration of carbon dioxide in solution is assumed equal to the concentration of bicarbonate.

Alkalinity is added to the digester from sources other than carbon dioxide production. Other sources that must be included are the dilution water added with the manure, the recycled water from the dewatering step, and the alkalinity of the manure itself. Calculations in the program are based on the estimated alkalinities given in Table C-3.

Table C-3
Estimated Alkalinities for Input Streams

Material	Alkalinity g/l as CaCO_3
Dilution water	0.1
Recycled Centrate	6.0
Manure	3.0

The alkalinity contribution (in moles per liter of digester per day) is calculated by dividing the values in Table C-3 by 100 (to convert from grams as CaCO_3 to moles) and dividing by the total digester volume.

The amount of CO_2 in the liquid phase is also affected by the ammonia concentration in the input. Ammonia reacts with water to produce NH_4^+ and OH^- .

The production of hydroxide affects the pH of the digester, which in turn alters the CO_2 solubility. For the purpose of calculating the equilibrium conditions in the digester, each mole of hydroxide adds an equivalent of one mole of alkalinity to the digester (line 45900).

If the digester pH is known, it is possible to calculate all the remaining unknowns by solving a quadratic equation (lines 46000 to 47100 in the program). The procedure used to calculate the equilibrium pH is to assume a very low pH, do all the required calculations for determining ammonium ion, bicarbonate alkalinity, gaseous CO_2 , and soluble CO_2 concentrations (lines 4500 to 47000) and to then calculate the amount of hydroxide ion addition that is required to maintain the assumed pH. For the low pH that is initially assumed this value will be negative, indicating that the pH should be raised. The pH is then incremented upward and the calculations are done again. This sequence is repeated until the hydroxide requirement becomes slightly positive. Once the equilibrium concentrations for all the end products are known, it is possible to calculate volatile solids destruction, volatile solids remaining, effluent slurry concentration and the methane content of the

gas stream (lines 47800-48200). An additional result of finding the equilibrium conditions in the digester is a prediction of possible ammonia toxicity problems which might occur in a heavily loaded manure digester. Since NH_3 is more toxic to the anaerobic bacteria than NH_4^+ , [McCarty, 1964] the operating pH can become important. The equilibrium concentration of NH_3 is reported as "Undissociated Ammonia" in the program output after calculation at line 45700.

1.4.2 Cost Calculations

The total cost of the digester system depends on both the capital cost and the operating cost. Capital cost is calculated from data presented by Patterson and Banker [1971]. The costs given in that publication have been fitted to equations as shown in Table C-4 (lines 48300-49300 of the program).

Table C-4
Capital Cost for Digesters

Digester Volume (TVD) (Meters ³)			Capital Cost (1971 dollars)
0	TVD	1416	\$165,000
1416	TVD	2832	$45.9 \times \text{TVD} + 100,000$
2832	TVD	8496	$51.2 \times \text{TVD} + 85,000$
8496	TVD		$1,000 \times 10^{(.987 \log (.0531 \text{ TVD}) + .271)}$

Annual Maintenance Cost is assumed to be one percent of the installed capital cost (line 49400). Mixing costs are assumed to be linear with volume and solids concentration. An empirically chosen energy requirement (.475 horsepower per 1000 cubic feet at 4 percent solids) is multiplied by the existing concentration and volume ratios. The volume of the mixing energy requirement is then converted to the metric system.

1.4.3 Energy Requirements

A significant amount of energy is required to maintain digester temperature at the desired level. This requirement is the sum of three components:

- a) Heatloss through digester walls.

Three separate equations are used, for the sides, top and bottom. Each is of the form:

$$HL = \frac{1.8(A)(T-T_0)}{(1/FI + B/K + 1/FO)} \quad (C-5)$$

where

HL = heatloss - BTU/hr

A = area - square feet

T = digester temperature - °C

T₀ = ambient temperature - °C

FI = inside transmittance coefficient

FO = outside transmittance coefficient

B = length of heat flow path - inches

K = conductance coefficient for wall

After calculation of the heatloss in BTU/hr (lines 5100-51500) the value is converted to Joules/hr (line 53810).

b) Heat required to increase the temperature of the incoming slurry is calculated using the output temperature from the heat exchanger and an assumed specific heat constant for the slurry solids (line 51700).

c) Heatloss in water vapor is calculated by using an empirical equation developed for the refuse digestion program [Quindry, et al., 1976].

1.5 Boiler System

In order to provide the heat required for the digesters and gas cleanup, a boiler system using raw digester gas is included. The heat requirement for the digester is known from the digester subroutine. If a gas cleanup system is to be included, the energy required to regenerate the monoethanolamine (MEA) used in the regeneration process is estimated, and the amount of gas containing this energy is removed from the gas stream. The boiler system is sized to produce the required energy output, and cost figures are calculated from available estimates [Blecker and Nichols, 1973].

1.6 Gas Cleanup

The optional gas cleanup system is intended to remove both the large quantity of carbon dioxide and the relatively small quantities of hydrogen sulfide that may be present in the gas stream. The process essentially consists of an absorber containing lean MEA, which, after removing the gas impurities from the methane, is regenerated by heating. This system is based on Kispert et al. [1975] and is the same as the system used in the refuse digestion model [Quindry et al., 1976].

1.7 Dewatering

Dewatering of the digester effluent is accomplished by centrifuges in the subroutine CENTR. This routine may be included on an optional basis. Calculation of the number of centrifuges required, their capital and operating costs, and their energy requirements is based on the previously modeled refuse digestion system.

2. Definition of Major Program Variables

A(1)	Roof surface area of digester
A(2)	Wall surface area of digester
A(3)	Bottom surface area of digester
AANBIO	Percent biodegradable solids (see Table 24)
AANPRO	Manure production rate (see Table 24)
AANTS	Manure total solids (see Table 24)
AANVS	Manure volatile solids (see Table 24)
AANW	Manure water content (see Table 24)
AHEAT	Area of heat exchanger
AJUSE	Energy used (Joules)
AK	Rate constant table (see Table 24)
AKN	Ammonia dissociation constant (see Table C-2)
AKTHS	Substrate utilization (see page 40)
AKI	Rate constant at correct digester temperature
AL	Biodegradability for low temperature digestion
ALATHT	Latent heat vaporization of water
ALK	Alkalinity (g/l as CaCO_3)
ALKD	Alkalinity of dilution water
ALKM	Alkalinity of manure
ALKREC	Alkalinity of recycled centrate
ALR	Liquid limiting flow rate for centrifuge
AMCAP	Amortized capital
AMCR	Maintenance cost/capital cost ratio
AMM	Ammonia input with manure
AMON	Ammonia concentration in digester

ANH3	NH ₃ concentration (moles)
ANH3N	NH ₃ concentration (mg/l as N)
ANH4	NH ₄ ⁺ concentration (moles)
APCOST	Amortized pump cost
ASH	Ash in feed stream (kg/hr)
B	Digester wall thickness (inches)
BICO	Bicarbonate alkalinity (moles/l)
BIOD	Biodegradable solids flow rate (kg/hr)
BOIOP	Boiler operation and maintenance cost
BTUUSE	Boiler capacity (BTU/hr)
CAKE	Total centrifuge solids discharged
CAKEMO	Centrifuge cake moisture
CAKETS	Centrifuge cake solids
CAKEVS	Centrifuge cake volatile solids
CAP	Total capital required
CCAKE	Centrifuge cake solids concentration (percent)
CCBLD	Centrifuge building capital cost
CCBOI	Boiler capital cost
CCBOIA	Amortized boiler capital cost
CCEN	Centrate solids concentration (percent)
CCENT	Capital cost of centrifuges
CCINST	Centrifuge installation costs
CCXCH	Heat exchanger capital costs
CCXCHA	Amortized heat exchanger capital costs
CCWAT	Capital cost of boiler water treatment system
CCWATA	Amortized cost of boiler water treatment system

CEN	Total centrate
CENCCA	Amortized centrifuge capital cost
CENMC	Maintenance cost for centrifuges
CENMO	Centrate moisture
CENTS	Total centrate solids
CH4	Methane production (M^3/hr)
CH4BEN	Credit for methane (\$/hr)
CH4BTU	Heat value of methane (BTU/hr)
CH4CH	Same as CH4
CH4HOU	Heat value of methane (Joules/hr)
CONC	Digester solids concentration (percent)
CO2	Carbon dioxide in gas phase - final value (M^3/hr)
CO2B	Carbon dioxide added to digester by fermentation (Moles/l/day)
CO2G	Equilibrium carbon dioxide concentration
CO2CH	Gaseous carbon dioxide flow rate
CO2GCH	Same as CO2CH
CO2P	Total carbon dioxide produced
CO2S	Dissolved carbon dioxide
CRR	Capital recovery factor
C4	Mixing power requirement at 4 percent solids
C5	Conversion factor HP to KW
C6	Cost of electricity (\$/KWH)
C9	Methane value
C10	Conversion factor HP to BTU/hr
C16	Constant for centrifuge loading calculation

C17	Constant for centrifuge loading calculation
DAMIX	Retention time in mix tank
DD	Digester diameter
DH	Digester height
DIGCON	Solids concentration out of digester
DIGMC	Digester maintenance cost
DLIFE	Design life for system components
DPROF	Value of recovered gas (\$/hr)
ENREM	Energy content of feed stream (BTU/hr)
ENREMJ	Energy content of feed stream (Joules/hr)
ENREQ	Energy required for system operation (BTU/hr)
ENREQJ	Energy required for system operation (Joules/hr)
FI	Heat transmittance coefficient, inside
FO	Heat transmittance coefficient, outside
FRAC	Methane fraction of gas stream
GASCH	Total gas produced (ft^3/hr)
GAST	Total gas produced (M^3/hr)
GCLIFE	Gas cleanup system design life
HCOST	Hourly cost of individual processes
HC03D	Bicarbonate alkalinity added with dilution water
HC03M	Bicarbonate alkalinity added with manure
HK	Henry's Constant
HL	Heat loss in digester
HLT	Total heat loss in digester
HR	Heat required for digester (BTU/hr)
HRJ	Heat required for digester (Joules/hr)

HVAL	Heat value of gas stream (BTU/SCF)
HVALJ	Heat value of gas stream (Joules/SCM)
HVGC	Heat required for gas cleanup (BTU/hr)
HVGCJ	Heat required for gas cleanup (Joules/hr)
H2O	Water in gas stream
H2OFR	Water fraction of gas stream
K	Conductance coefficient for digester
MEACC	Gas cleanup capital cost
MEACCA	Amortized gas cleanup capital cost
MEAOMC	Gas cleanup operating and maintenance costs
MIXBTU	Mixing energy required
MIXCC	Mix tank capital cost
MIXCCA	Amortized mix tank capital cost
MIXHP	Mix tank motor size
MIXOMC	Mix tank operation and maintenance cost
MIXVOL	Mix tank volume
MUMEA	Make-up MEA
MUMEAC	Make-up MEA cost
MWMEA	Molecular weight of MEA
NUMBR	Herd size
NU	Number of digesters required
OANDM	Total cost of operation and maintenance
OH	Hydroxide requirement
OMCCR	Operation and maintenance/capital cost ratio
PBTUR	Pumping energy requirement
PC	Centrifuge power cost
PCOST	Pumping capital cost

PH	Digester pH
PHP	Pump horsepower
POMC	Pumping operation and maintenance cost
QLIMIT	Centrate limiting flow rate
RATIO	Digester height/radius ratio
RD	Digester radius
RET	Digester retention time (days)
RINST	Installation cost/machine cost for centrifuge
SCOUT	Solids concentration in digester effluent (kg/kg)
SLTEMP	Slurry temperature (°C)
SMEAC	MEA circulation rate
S01	Initial substrate level
SPHWV	Specific heat of water vapor
SR	Solids flow rate in each centrifuge
SRATE	Limiting solids flow rate
STCI	Current inflation index
STCmyy	Inflation index for month m of year yy
STEAM	Gas clean-up steam requirement
STEP	Character array
TBTUC	Total energy consumed
TCAPT	Total capital cost for centrifugation
TCCD	Total capital cost of digesters
TCCDA	Amortized digester capital cost
TDIF	Heat exchanger temperature gradient (°C)
TEMP	Slurry temperature (°C)
THLD	Total heat loss in digesters (BTU/hr)

THR	Total heat required (BTU/hr)
THRJ	Total heat required (Joules/hr)
TO	Temperature of incoming slurry to heat exchanger
TOTVOL	Total mix tank volume
TS	Total solids in slurry
TSREM	Total solids in slurry after digestion
TUD	Total digester volume
VAREA	Unit centrifuge area
UCBLD	Unit cost of centrifuge building
UCCENT	Unit cost of centrifuge
UP	Power requirement for unit centrifuge
VOLD	Volume of each digester
VP	Vapor pressure of water
VS	Volatile solids in slurry (kg/hr)
VSD	Volatile solids destroyed (kg/hr)
USREM	Volatile solids in slurry after digestion (kg/hr)
WATIN	Water input in manure (l/hr)
WATNED	Make-up water required (l/hr)
WATR	Total water input to system (l/hr)
XINT	Interest rate (fraction)
XINTP	Interest rate (percent)
X1	Quadratic equation solution
X2	Quadratic equation solution

3. Program Listing

```

00100      PROGRAM DIGEST (INPUT, OUTPUT, FRONT, POUT, TAPES=INPUT, TAPES=OUTPUT,
00200      1TAPES=FRONT, TAPES=POUT)
00300      COMMON/UCOM1/WATE, TS, VS, BIOD, ASH, AMM, ALK, PH, DIGCON, VOLD, CD4, CO2,
00400      2 H2O,
00500      1 BVAL, C4, AMC4, OAND4, DPROP, ENREQ, ENREN, WATNEO, WATIN
00600      COMMON/UCOM2/XINT, STC767, STC772, STC773, STC174, STC175, STC775, STC1,
00700      2 STC771,
00800      1 C4, C5, C6, C9, C10, S01, AK1, RET, CONC, TEMP
00900      2 WRITE (6,5)
01000      5 FORMAT(1,"ANNURE DIGESTION PROGRAM"/)
01100      PRINT (6,4) "HERD SIZE",
01200      READ (5,*) NUMBR
01300      WRITE (6,8)
01400      8 FORMAT(1,"TYPE OF LOT: "/,5X,"1) ENVIRONMENTAL"/,
01500      1 5X,"2) OPEN"/)
01600      READ (5,*) LTYPE
01700      PRINT (6,*) "CONCENTRATION INPUT TO DIGESTER (X) AND TEMP. (DEG. C)"
01800      READ (5,*) CONC, TEMP
01900      PRINT (6,*) "DESIRED DAYS RETENTION",
02000      READ (5,*) RET
02100      PRINT (6,*) "DESIRED RECYCLE RATE",
02200      READ (5,*) RECY
02300      WRITE (J,9) NUMBR, CONC, TEMP, RET, RECY
02400      9 FORMAT(1,"ANNURE DIGESTION SIMULATION"/)
02500      14X,"HERD SIZE.....",I12," ANIMALS"/,
02600      24X,"DIGESTER INPUT CONCENTRATION.....",7X,F5.2," PERCENT"/,
02700      34X,"DIGESTER TEMPERATURE.....",7X,F5.2," DEG. C"/,
02800      44X,"RETENTION TIME REQUESTED.....",7X,F5.2," DAYS"/,
02900      54X,"RECYCLE RATE FOR CENTRATE.....",7X,F5.2," PERCENT"/)
03000      IF (LTYPE.EQ.2) GO TO 11
03100      PRINT (3,*) " ENVIRONMENTAL LOT"
03200      GO TO 12
03300      11 CONTINUE
03400      PRINT (3,*) " OPEN LOT"
03500      12 CONTINUE
03600      PRINT (3,*) " "
03700      READ (9,*) XINT, STC767, STC771, STC172, STC772, STC773, STC174, STC175,
03800      1STC775, STC1, C4, C5, C6, C9, C10
03900      CALL INITIAL (LTYPE, NUMBR)
04000      CALL PRINT (1)
04100      CALL MIX (NUMBR, RECY, SLTEMP)
04200      CALL PRINT (2)
04300      CALL DIGES (RECY, SLTEMP, THR)
04400      CALL PRINT (3)
04500      CALL READ (THR, ISC)
04600      CALL PRINT (6)
04700      IF (ISC.NE.1) GO TO 15
04800      CALL CLFAN
04900      CALL PP T (5)
05000      15 CONTINUE
05100      PRINT (5,*) "INCLUDE DEWATERING 1) YES, 2) NO",
05200      READ (6,*) IDW
05300      IF (IDW.NE.1) GO TO 17
05400      33 CALL CDCTR
05500      CALL PRINT (4)
05600      17 CALL FINAL
05700      PRINT (6,*) "1) REPEAT ANALYSIS OR 2) STOP",
05800      READ (5,*) ISTOP
05900      IF (ISTOP.EQ.1) GO TO 20
06000      STOP

```

```

05700 20 REMIND 9
05800 GO TO 2
05900 END
10000 SUBROUTINE INICAL(LTYPE,NUMBR)
10200 COMMON/UCON1/WATR,TS,VS,BLOD,ASH,AMN,ALK,PH,DIGCON,VOLD,CH4,CO2,
10250 2 H2O,
10300 1 HVAL,CAP,ANCAP,OLANDM,DPROP,ENREQ,ENREN,WATKED,WATIN
10500 COMMON/UCON2/XINT,STC767,STC772,STC773,STC174,STC175,STC775,
10600 1 STCI,ST(771,C4,C5,C6,C9,C10,501,AK1,EST,CONC,TEMP
10800 DIMENSION CHAR(2,5),AK(2),AL(2)
10900 DATA CHAR/85.,65.,15.,35.,78.,67.,78.,33.,9.9,2.64/
11025 DATA AL/48.,30./
11050 DATA VSRTD/11750./
11100 DATA AK/.25,.03/
11200 IF (CONC.LT.CHAR(LTYPE,2)) GO TO 100
11300 WRITE(6,70) CONC,CHAR(LTYPE,2)
11400 10 FORMAT(1X,"INPUT CONCENTRATION OF ",P5.2," PERCENT IS ABOVE "
11500 1"THE"/,1X,"MANURE SOLIDS CONCENTRATION OF" P6.2" PERCENT")
11600 STOP
11700 100 CONTINUE
11800 C ****SET VARIABLES TO INITIAL VALUES
12800 ENREQ=0.
13000 CAP=0.
13100 ANCAP=0.
13200 OLANDM=0.
13300 CH4=0.
13400 CO2=0.
13500 H2O=0.
13600 ALK=0.
13700 PH=0.
13800 VOLD=0.
13900 DIGCON=0.
14000 HVAL=0.
14100 DPROP=0.
14250 AK1=AK(1)
14275 IF (TEMP.GT.50.) GO TO 11
14280 CHAR(LTYPE,4)=AL(LTYPE)
14300 AK1=AK(2)
14325 11 CONTINUE
14327 WRITE(6,72) AK1, (CHAR(LTYPE,I),I=1,5)
14329 72 FORMAT("PARAMETERS USED FOR SOLIDS DESTRUCTION"/,
14335 34X," K.....",8X,P4.2," PER DAY"/,
14337 44X,"COMPOSITION OF MANURE"/,
14339 54X," WATER.....",7X,P5.2," PERCENT"/,
14341 64X," TOTAL SOLIDS.....",7X,P5.2," PERCENT"/,
14343 74X," VOLATILE SOLIDS.....",7X,P5.2," PERCENT T.S."/,
14345 84X," BIODEGRADABLE SOLIDS.....",7X,P5.2," PERCENT V. S."/,
14347 94X," PRODUCTION RATE.....",7X,P5.2," KG/ANIMAL/DAY"/)
14349 PRINT(6,*) "DO YOU WANT TO CHANGE ANY OF THESE VALUES"
14351 PRINT(6,*) "1-YES 0-NO"
14353 READ(5,*) IANS
14355 IF (IANS.EQ.0) GO TO 74
14357 PRINT(6,*) "INPUT ALL 6 VALUES IN THE ABOVE ORDER"
14359 READ(5,*) AK1, (CHAR(LTYPE,I),I=1,5)
14361 74 WRITE(3,72) AK1, (CHAR(LTYPE,I),I=1,5)
14400 AANW=CHAR(LTYPE,1)
14500 AANTS=CHAR(LTYPE,2)
14600 AANVS=CHAR(LTYPE,3)
14700 AANBID=CHAR(LTYPE,4)
14800 AANPRO=CHAR(LTYPE,5)
14805 SQ1=.83*CHAR(LTYPE,4)/100.

```



```

14810 ENREN=NUMBR*ANPRO*ANVS*VSBTU/100./24.
14820 TS=NUMBR*ANPRO/24.
14830 VS=TS*ANVS/100.
14835 ASH=TS-VS
14840 BIOD=ANBIO/100.*VS
14850 WATR=TS/(ANVS/100.)-TS
14860 ANM=.0093*VS
14900 RETURN
15000 END
20000 SUBROUTINE PRNT(I)
20100 CONCON/COM1/WATR,TS,VS,BIOD,ASH,ANB,ALK,PH,DIGCON,VOLD,CH4,CO2,
20150 2 H2O,
20200 1 HVAL,CAP,ANCAP,ANADM,DPROP,ENREQ,ENREN,WATMED,WATIN
20400 COMMON/COM2/XINT,STC767,STC772,STC773,STC174,STC175,STC775,STCI,
20450 2 STC771,
20500 1 C4,C5,C6,C9,C10,SO1,AK1,RET,CONC,TEMP
20700 DIMENSION STEP(2,6)
20800 DATA STEP/10HDATA INITI,10HALIZATION,10HSLURRY MIX,10HING
20900 1,10HDICTION,10H,10HDEWATERING,10H
21000 210HGAS CLEANU,10H,10HBOILER,10H
21100 WRITE(3,10) STEP(1,1),STEP(2,1)
21200 10 FORMAT(1X,"MATERIAL BALANCE AFTER "2A10.//)
21300 WRITE(3,11)WATR,TS,VS,BIOD,ASH,ANM
21400 11 FORMAT(1X,"WATER IN FEED STREAM.....",G12.5," L/HR",/
21500 14X,"TOTAL SOLIDS IN FEED STREAM.....",G12.5," KG/HR",/
21600 24X,"VOLATILE SOLIDS IN FEED STREAM.....",G12.5," KG/HR",/
21700 34X,"BIODEGRADABLE SOLIDS IN FEED STREAM",G12.5," KG/HR",/
21800 44X,"ASH IN FEED STREAM.....",G12.5," KG/HR",/
21900 54X,"AMMONIA NITROGEN IN FEED STREAM....",G12.5," KG/HR AS N"///)
22200 IF(I.LE.2.OR.I.GE.4) GO TO 100
22300 WRITE(3,14) ALK,PH,DIGCON,VOLD
22400 14 FORMAT(1X,"DIGESTER EQUILIBRIUM CONDITIONS"//,
22500 14X,"ALKALINITY ADDED WITH INPUT STREAMS",G12.5," G/L PER DAY",/
22600 24X,"DIGESTER PH.....",7X,P5.2,/
22700 34X,"EFFLUENT SLURRY CONCENTRATION.....",7X,P5.2," PERCENT",/
22800 44X,"TOTAL DIGESTION VOLUME.....",G12.5," CUBIC METERS"///)
22900 100 IF(I.LE.2.OR.I.GE.4) GO TO 110
22950 HVALJ=HVAL*1055.
23000 WRITE(3,15)CH4,CO2,H2O,HVALJ
23100 15 FORMAT(1X,"GAS STREAM CONSTITUENTS"//,
23200 14X,"METHANE.....",G12.5," SCM/HR",/
23300 24X,"CARBON DIOXIDE.....",G12.5," SCM/HR",/
23400 34X,"WATER VAPOR.....",G12.5," SCM/HR",/
23500 44X,"HEAT VALUE OF GAS.....",J12.5," JOULES/SCM"///)
23550 110 XINTP=XINT*100.
23600 WRITE(3,16) CAP,XINTP,ANCAP,ANADM,DPROP
23700 16 FORMAT(1X,"ECONOMIC SUMMARY"//
23800 14X,"TOTAL CAPITAL REQUIRED.....",F12.2," $"/
23900 24X,"AMORTIZED AT "P5.2," PERCENT.....",F12.2," $/HR"/
24000 34X,"OPERATION AND MAINTENANCE.....",F12.2," $/HR"/
24100 44X,"VALUE OF RECOVERED MATERIAL AND GAS",F12.2," $/HR"///)
24120 ENREQJ=ENREQ*1055.
24150 ENRFQJ=ENREN*1055.
24200 WRITE(3,17) ENREQJ,ENRENJ
24300 17 FORMAT(1X,"ENERGY BALANCE"/
24400 14X,"ENERGY REQUIRED FOR PROCESSES.....",G12.5," JOULES/HR"/
24500 24X,"ENERGY AVAILABLE IN SYSTEM.....",G12.5," JOULES/HR"///)
24600 RETURN
24700 END
30000 SUBROUTINE MIX(NUMBR,RECY,SITEMP)
30100 IMPLICIT REAL(N)

```

```

30300      COMMON/UCOM1/WATR,TS,VS,BIOD,ASH,AMH,ALK,PH,DIGCOM,VOLD,CH4,CO2,
30350      2 W2O,
30400      1 HVAL,CAP,AMCAP,OANDN,DPROF,ENREQ,ENREM,WATNED,WATIN
30600      COMMON/UCOM2/XINT,STC767,STC772,STC773,STC174,STC175,STC775,STCI,
30650      2 STC771,
30700      1 C4,C5,C6,C9,C10,S01,AK1,RET,CONC,TEMP
30900      DATA OMCCR,PH2/0.2,85./
31000 C ****NEED WATER ADDITION, NEGLECT SOLIDS IN RECYCLE
31800      WATOUT=TS/(CONC/100.)-TS
31900      WATNED=WATOUT-WATR
31910      WATIN=WATR
32000      WRITE(3,7)
32100      7 FORMAT(///,1X,"MIX TANK OUTPUTS"///)
32200      WRITE(3,10) CONC,WATNED
32300      10 FORMAT(4X,"TOTAL WATER REQUIREMENTS FROM RECYCLE AND"/,
32400      14X,"MARKUP FOR ",F5.2," PERCENT INPUT SOLIDS:"/,
32500      246X,G12.5," L/HR")
32600      ENGL=WATNED/1.78
32700      WRITE(3,11) ENGL
32800      11 FORMAT(46X,G12.5," GAL/HR"///)
32900      SLTEMP=10.
32950      RECUAT=0.
33000      IF(RECY.LE.0) GO TO 100
33100 C ****ADD WATER, HEAT FROM RECYCLE
33200      RECWAT=RECY/100.*WATNED
33300      SLTEMP=SLTEMP+(TEMP-20.)*RECWAT/(WATOUT+TS)
33400 C ****CALCULATE MIXING EQUIPMENT SIZE
33500 C ****ASSUME 1 DAY HOLDING IN MIX TANK
33600 C ****VOLUMES IN LITERS
33700      100 TOTVOL=(WATOUT+TS)*24.
33800      DAMIX=1.
33900      MIXVOL=DAMIX*TOTVOL
34000 C ****CALCULATE MIXER CAPITAL COST
34100 C ****REFERENCE DYNATECH, PG. 167
34200      MIXCC=STCI/STC771*13722*(MIXVOL/28316.)**.52
34300 C ****AMORTIZE CAPITAL COST OVER 20 YEARS
34400      MIXCCA=MIXCC/360./24.*XINT/(1.-(1.+XINT)**(-20))
34500 C ****OP. AND MAINTENANCE IS A FRACTION OF AMORTIZED CAPITAL COST
34600      MIXCAC=OMCCR*MIXCCA
34700 C ****ASSUME .2 HP REQUIRED PER MCF FOR MIXING
34800 C ****REFERENCE DYNATECH
34900      MIXHP=0.2*MIXVOL/28320.
35000 C ****CONVERT TO BTU/HR
35100      MIXBTU=MIXHP*.10
35200 C ****GET PUMPING POWER REQUIREMENT BY SCALING UP OR DOWN
35300 C ****REFERENCE REFUSE DIGESTER PROGRAM
35400      PAPREQ=PH2*TS/20416.66
35500      PBTU=PAPREQ*PH2*24.
35600 C ****PUMP COSTS ASSUME $75./HP AT 1973 COSTS
35700      PCOST=75.*PAPREQ*STCI/STC773
35800      APCOST=PCOST/360./24.*XINT/(1.-(1.+XINT)**(-20))
35900      POYC=OMCCR*APCOST
36000 C ****ADD TO TOTALS FOR PRINT SUBROUTINE
36100      CAP=CAP+MIXCC+PCOST
36200      AMCAP=AMCAP+MIXCCA+APCOST
36300      OANDN=OANDN+MIXCAC+POYC
36400      WATR=WATOUT
36500      ENREQ=ENREQ+PBTU+MIXBTU
36800      ASH=TS-VS
36900      PRINT(6,*) "ADD HEAT EXCHANGER? 1=YES, 0=NO",
37000      READ(5,*) IAND

```

```

37100 IF (IAND,NE,1) RETURN
37125 PRINT (6,*) "TEMPERATURE GRADIENT FOR EXCHANGER (DEG. C) ",
37150 READ (5,*) TDIF
37200 WRITE (3,78)
37300 78 FORMAT(1X,"HEAT EXCHANGER PARAMETERS"//)
37400 AHEAT=.00115*(WATR+TS)*24.*(TEMP-SLTEMP-TDIF)/TDIF
37500 CCXCH=26.*STCI/STC767*(AHEAT)**.75
37600 C ***CONVERT TO SQUARE METRES
37700 AHEAT=AHEAT*.0929
37800 CCXCHA=CCXCH/360./24.*XINT/(1.-(1.*XINT)**(-20.))
37900 XCHONC=OMCCR*CCXCHA
38000 WRITE (3,79) AHEAT,TDIF,CCXCH,CCXCHA,XCHONC
38100 79 FORMAT(4X,"SURFACE AREA....." G12.5," SQ. M. "/
38150 4X,"TEMPERATURE GRADIENT.....",7X,F5.1," DEG. C"/,
38200 14X,"CAPITAL COST.....",F12.2," $"/
38300 24X,"ANNUALIZED CAPITAL COST.....",F12.2," $/HR"/,
38400 34X,"OPERATION AND MAINTENANCE.....",F12.2," $/HR"//)
38500 CAP=CAP+CCXCH
38600 ANCAP=ANCAP+CCXCHA
38700 SLTEMP=TEMP-TDIF
38800 OANDM=OANDM+XCHONC
38900 RETURN
39000 END
40000 SUBROUTINE DIGES (RLCY,SLTEMP,THR)
40100 REAL MP,102,103,K,K1,MCR
40200 COMMON/UCOM1/WATR,TS,VS,BIOD,ASH,AMM,ALK,PH,SCOUT,TVD,CH4CH,
40300 1 CO2GCH,120,HVAL,CAP,ANCAP,OANDM,DPROP,SHREQ,ENR23,WATRED,WATLN
40400 COMMON/UCOM2/XINT,STC767,STC772,STC773,STC174,STC175,STC775,STCI,
40500 1 STC771,C4,C5,C6,C9,C10,SO1,AK1,RLT,CONC,TMP
40600 DIMENSION V4(5),TO(3),A(3),RL(1),FI(3),B(3),K(1),PO(1)
40700 DATA FI,B/3*2.,0.,18.,12./
40800 DATA K,PO,B/3*8.3,2*1.3,2.,2*12.5,15./
40900 DATA HVDATA,VR/5,3681.6,14160.,35400.,48144.,56640./
41000 DATA TO/12.5,12.5,15./
41100 C ***VOLUME OF DIGESTER(S) AND NUMBER
41200 TVD=(WATR+TS)*24.*RET/1000.
41300 IF (TVD.LT.VR(1)) GO TO 1015
41400 IF (TVD.GE.VR(MVDATA)) GO TO 1017
41500 GO TO 1020
41600 1015 NV=2
41700 GO TO 1026
41800 1017 NV=7
41900 GO TO 1026
42000 1020 DO 1025 N=2,MVDATA
42100 IF (TVD.LT.VR(N)) GO TO 1023
42200 GO TO 1025
42300 1023 NV=N+1
42400 GO TO 1026
42500 1025 CONTINUE
42600 1026 VB=TVD/NV
42700 C ***CALCULATE VOLATILE SOLIDS DESTRUCTION AND GAS PRODUCTION
42800 SOUT=SO1/(AK1*RET+1.)
42900 AKTHS=AK1*RET*SOUT
43000 GAST=AKTHS*BIOD
43100 CH4CH=GAST*.6
43200 CO2P=CH4CH
43300 C ***CARBONATE EQUILIBRIUM CALCULATIONS
43400 C ***ASSUME A PH AND CALCULATE CONDITIONS
43500 PH=6.8
43600 CO2B=CO2P/TVD*1.071
43700 HK=.139E07

```

```

44100      AK=5.04E-07
44200      VP=.0728
44300      IF (TEMP.LT.50) GO TO 700
44400      HK=.25E07
44500      AK=5.178E-07
44600      VP=.179
44700  700 CONTINUE
44800      ALXREC=6.
44900      ALAB=0.1*(1.-RECY/100.)*ALKREC*(RECY/100.)
44925      ALX=3.0
44975      HCO3H=(ALKH/100.)*WATIN*24./(TVD*1000.)
45000      HCO3D=(ALKD/100.)*WATNED*24./(TVD*1000.)
45100      AMO=AKH*24./(TVD*10.)
45200      AKK=1.57E-09
45300      IF (TEMP.LT.50.) GO TO 701
45400      AKK=6.136E-09
45500  701 CONTINUE
45600      ANH4=(AMH4*10.**(-PH)/AKH)/(1.+10.**(-PH)/AKH)
45700      AM3=AMGN-ANH4
45800      ANH3=ANH3*14000.*RET
45900      BICO=ANH4+HCO3D+HCO3H
46000      AA=18.*HK*10.**(-PH)*RET/(7.6205*(10.**(-PH)+AK))
46100      BB=1.-VP-AA*BICO/RET
46200      CC=(-AA)*(CO2S**2+CO2B*BICO/RET)
46300      DD=SQRT(BB**2-4.*AA*CC)
46400      X1=(-BB+DD)/(2.*AA)
46500      X2=(-BB-DD)/(2.*AA)
46600      IF (X1.GT.(2) GO TO 865
46700      CO2G=X2
46800      GO TO 870
46900  865 CO2G=X1
47000  970 CO2S=7.6205*CO2G*(1.-VP)/(10.*HK*(CO2B+CO2G))
47100      OH=CO2B-CO2G+0.2/(60.*RET)-CO2S/RET-BICO
47200      IF (OH.GE.0.) GO TO 871
47300      PH=PH+.05
47400      IF (PH.GT.8.5) STOP
47500      WRITE(6,27) PH
47600  27 FORMAT(1X,"PH INCREASED TO ",F5.2)
47700      GO TO 701
47800  871 CO2GH=CO2G*TVB*22.4/24.
47900      GASCH=CO2GH+CH4CH
48000      VSD=CH4CH*44.64*.162/3.
48100      BIOD=BIOD-VSD
48200      ALK=BICO
48300      VSRI=VS-VSD
48400      TSREN=TS-150
48500      IF (TVB.GT.1416.) GO TO 910
48600      TCCD=1650(0.*STCI/STC771
48700      GO TO 917
48800  910 IF (TVD.LT.2812.) GO TO 914
48900      IF (TVD.LT.8490.) GO TO 916
49000      TCCD=10.**{0.987*ALOG10(TVB*35.31/1000.)+.271}*1000.*STCI/STC771
49100      GO TO 917
49200  914 TCCD=(1.3*TVB*35.31/1000.+100.)*1000.*STCI/STC771
49300      GO TO 917
49400  916 TCCD=(1.45*TVB*35.31/1000.+85.)*1000.*STCI/STC771
49500  917 TCCD=TCCD/360./24.*XINT/(1.-(1.+XINT)**(-20.))
49600      DIGHC=0.01*TCCD/24./360.
49700      CH4BTU=CH4CH*35.31*1000.
49800      CH4DEN=CH4BTU/1.0L+06*C9
49900      SCOUT=TSREN/(TSREN+WATR)*100.

```

```

49600      NP=0.475*SCOUT/4.00*TVD/1000.*35.31
49900      NP=C10*NP
50000      EPC=KPC*CS*CS
50100      DH=48.
50200  518  A(1)=VD*35.31/DH
50300      A(2)=A(1)
50400      RD=SQRT(A(1)/3.14)
50500      RATIO="H/RD
50600      IF (RATIO.LT.2.1) GO TO 920
50700      DH=DH-1.
50800      IF (DH.LT.10.) STOP
50900      GO TO 918
51000  920  HLT=0.
51100      A(2)=2.*3.14*RD*DH
51200      DO 1220 I=1,3
51300      EL(I)=A(I)*1.8*(TEMP-TO(I))/(1./FI(I))+B(I)/K(I)+1./PO(I)
51400      HLT=HLT+HL(I)
51500  1220  CONTINUE
51600      THLD=HV+HLT
51700      HR=(TEMP-SLTEMP)*7.8*(.54*TS*2.205+7.*WATR*2.205)
51800      WHL=.433872*1.05752** (TEMP)*(GASCH)*35.31
51900      THR=THLD+HR+WHL
52000      TBTUC=1HR+NP*E
52100      DPROP=DPROP+CH4BEM
52200      ANCAP=ANCAP+TCCDA
52300      QANDR=QANDR+DIGNC+MPC
52400      CAP=CAP+TCCD
52500      DH=DH*.3048
52600      RD=RD*.3048
52700      ENREX=CH4BTU
52710      HVAL=CH4BTU/GASCH
52730      H2O=GASCH/(1.-VP).-GASCH
52740      ENREQ=ENREQ+TDUC
52800      WRITE(J,1299)SLTEMP,TEMP,PH,RET,ANHL3H,VSD,TS,VS,TSREN
52900  1299  FORMAT("DIGESTER PARAMETERS"//
53000      14X,"INCOMING SLURRY TEMPERATURE...",7X,F5.2," DEG. C",/
53100      24X,"TEMPERATURE IN DIGESTER...",7X,F5.2," DEG. C",/
53200      34X,"DIGESTER PH...",7X,F5.2,/
53300      44X,"DIGESTER RETENTION TIME...",7X,F5.2," DAYS",/
53400      54X,"UNDISSOCIATED AMMONIA...",312.5," MG/L NH3 AS N",/
53500      64X,"VOLATILE SOLIDS DESTROYED...",612.5," KG/HR",/
53600      74X,"TOTAL SOLIDS INPUT...",312.5," KG/HR",/
53700      84X,"VOLATILE SOLIDS INPUT...",312.5," KG/HR",/
53800      94X,"TOTAL SOLIDS IN EFFLUENT...",312.5," KG/HR")
53810      THLDJ=THLD*1055.
53820      HRJ=HR*1055.
53830      WHLJ=WHL*1055.
53840      THRJ=THR*1055.
53900      WRITE(I,1300)SCOUT,HV,DH,RD,VD,TVD,THLDJ,HRJ,WHLJ,THRJ
54000  1300  FORMAT(35X,"AT",F6.2," PERCENT SOLIDS"////
54100      11X,I4," DIGESTER(S) REQUIRED"/4X"WITH HEIGHT OF....."
54200      27X,F5.2," METERS"/4X"AND RADIUS OF.....",7X,
54300      3F5.2," METERS"/4X,"VOLUME OF EACH DIGESTER.....",612.5,
54400      4," CUBIC METERS"/4X,"TOTAL VOLUME OF DIGESTER(S)..."
54500      5612.5," CUBIC METERS",/
54600      64X,"HEAT LOSS THROUGH DIGESTER(S).",612.5," JOULES/HR",/
54700      74X,"HEAT REQUIRED TO HEAT SLURRY...",312.5," JOULES/HR",/
54800      84X,"WATER VAPOR HEAT LOSS.....",612.5," JOULES/HR",/
54900      94X,"TOTAL HEAT REQUIREMENT.....",312.5," JOULES/HR")
54950      XINTP=XINT*100.
54975      CH4JOU=CH4BTU*1055.

```

```

5500C WRITE(3,1301) TCCO2,XINT,TCCO2A,HPC,DIGCH,GASCH,CO2CH,CH4CH,CH4JOU
5510C 1301 FORMAT(4X,"DIGESTER CAPITAL COST.....",F12.2," $"/
5520C 14X,"AMORTIZED AT "F5.2" PERCENT INTEREST...."F12.2" $/HR"/
5530C 24X,"MIXING POWER COST....."F12.2" $/HR"/
5540C 34X,"DIGESTER MAINTENANCE COST....."F12.2" $/HR"///
5550C 44X,"GAS PRODUCTION"/
5560C 54X,"TOTAL GAS....."G12.5" CUBIC METERS/HR"/
5570C 64X,"CARBON DIOXIDE....."G12.5" CUBIC METERS/HR"/
5580C 74X,"METHANE....."G12.5" CUBIC METERS/HR"/
5590C 84X,"TOTAL METHANE ENERGY AVAILABLE"G12.5" JOULES/HR"///)
5592C VS=VSREQ
5597C TS=TSREQ
5600C RETURN
5610C END
5600C SUBROUTINE CLEAN
5605C IMPLICIT REAL (*)
5610C COMMON/UCON1/WATR,TS,VS,BIOD,ASH,ANA,ALK,PH,DIGCON,VOLD,CB4CH,
5615C 2 CO2CH,H2O,
5620C 1 HVAL,CAP,AMCAP,OLMDH,DPROF,ENREQ,ENREN,WATRED,WATIN
5640C COMMON/UCON2/XINT,STC767,STC772,STC773,STC174,STC175,STC775,STC1,
5650C 1 STC771,C4,C5,C6,C9,C10,S01,AK1,BET,CONC,TBMP
5680C DATA MWEA,SPHNV,ALANT,GCLIFE/61.08,0.5,1050.,15./
5685C DATA CMEA/0.50/
5690C C ****CALCULATE THE WEIGHT AND VOLUME OF MEA BEING CIRCULATED
5695C C ****WEAC IS KG/HR SREAC IS L/HR
5698C GASCH=CH4CH+CO2CH
5700C WEAC=(CO2CH*35.31/359.)*1.5*MWEA*.4536
5705C SREAC=(WEAC/0.2)
5710C C ****FACUP MEA IS 2% OF MEA CIRCULATED
5715C MUREA=GASCH*1.121E-04
5720C C ****COST OF MEA MAKEUP IS CMEA $/KG
5725C MEAC=MUREA*CMEA
5730C STOR=1.1/3.785*SREAC
5735C HVGC=STAM*(SREAC*(300.-212.)+(212.-120.)+ALANT)
5740C MEACC=113200.*(GASCH*24.*30.*35.31/(359.*2000.))/350.)*.5
5745C 1*STC1/STC773
5750C MEACC2=MEACC*(1/(1.-(1.+XINT)**(-GCLIFE)))/(360.*24)
5755C MEAOMC=0.1*MEACC/360./24.
5760C ECOST=MEACC2+MEACC2*MUREA
5765C ENREQ=ENREQ+HVGC
5770C AMCAP=1101P+MEACC2
5775C OLMDH=OLMDH+MEAOMC+MUREA
5780C CAP=CAP+MEACC
5785C H2O=0.
5790C HVAL=35310.
5795C HVGCJ=HVGC*1055.
5800C WRITE(3,2920) GASCH,CH4CH,CO2CH,WEAC,MUREA,HVGCJ,MEACC,ECOST,
5805C MEACCA,MEAOMC,MUREA
5810C 2920 FORMAT("1 GAS CLEAN-UP SYSTEM OUTPUTS"///,
5815C 14X,"TOTAL GAS IN....."G12.5," CUBIC METERS/HR"/
5820C 24X,"METHANE....."G12.5," CUBIC METERS/HR"/
5830C 34X,"CARBON DIOXIDE....."G12.5," CUBIC METERS/HR"///
5840C 44X,"MEA REQUIRED....."G12.5," KG/HR"/
5850C 54X,"MAKE-UP MEA....."G12.5," KG/HR"/
5860C 64X,"HEAT REQUIRED....."G12.5," JOULES/HR"///
5870C 74X,"CAPITAL INVESTMENT.....",F12.2," $"/
5880C 84X,"HOURLY COST TOTAL.....",F12.2," $"/
5890C 94X," AMORTIZED CAPITAL.....",F12.2," $"/
5900C 14X," OP. AND MAINT.....",F12.2," $"/
5910C 24X," MAKE-UP MEA COST.....",F12.2," $"///)
5915C CO2CH=0.

```

```

64200      RETURN
64300      END
70000      SUBROUTINE CENTR
70020      COMMON/UCOM1/WATR,TS,VS,BIOD,ASH,AMM,ALK,PH,DIGCON,VOLD,CH*CH,
70040      ICORCH,N2O,HVAL,CAP,ANCAP,OANDN,DPRCF,ENREQ,ENREQ,ENREQ,WATMED,WATIN
70060      COMAGN/UCOM2/KINT,STC767,STC772,STC773,STC174,STC175,STC775,STCI,
70080      1 STC771,C4,C5,C6,C9,C10,S01,AK1,RET,CONC,TEMP
70100      DATA C16,C17,QLINT/10722.727,-214.545,51094.8/
70120      DATA UCCENT,JCBLD,VARBA,RINST/125000.,40.,1000.,0.5/
70140      DATA DLIPE,UP,ANCR/10.,200.,.05/
70160      CCAKE=35.
70180      CCEM=.1
70200      CRB=XINT/(1.-(1.+XINT)**(-DLIPE))
70220      SBATE=(C16+C17*CCAKE)/2.205
70240      NCRUN=INT(TS/SBATE+.001)
70260      N=WATR/QLIN
70280      IF(N.LT.1)N=1
70300      IF(N.LD.NCRUN) GO TO 400
70320      NCRUN=N
70340      400 NCACT=NCRUN+1
70360      SR=TS/NCRUN
70380      ALR=WATR/NCRUN
70400      C ****
70420      C **** CALCULATE CAPITAL COST
70440      C ****
70460      CCENT=NCACT*UCCENT*STCI/STC174
70480      CCINST=RINST*CCENT
70500      CCBLD=VARBA*NCACT*UCBLD*STCI/STC174
70520      TCAPT=CCENT*CCINST+CCBLD
70540      CENCCA=TCAPT*CRB/(360.*24.)
70560      C ****
70580      C **** POWER REQUIREMENTS AND COSTS
70600      C ***
70620      P=UP*NCRUN*C10
70640      PC=UP*NCRUN*C5*C6
70660      C **** MAINTENANCE COST
70680      CENMC=(ANCR*TCAPT)/(360.*24.)
70700      HCOST=CENCCA+PC+CENMC
70720      CCEM=CCEM/100.
70740      CCAKE2=CCAKE/100.
70760      C ****
70780      C **** CALCULATE OUTPUTS FROM CENTRIFUGES
70800      C ****
70820      CENTS=CCEM*(WATR-TS*(1.-CCAKE)/CCAKL)/(1.-CCEM-
70840      1 CCEM*(1.-CCAKE)/CCAKE)
70860      CENAO=CENTS*(1.-CCEM)/CCEM
70880      CEN=CENIS+CENAO
70900      CAK2TS=TS-CENTS
70920      CAKEVS=CAKETS*(VS/TS)
70940      CAKEVO=CAKETS*(1.-CCAKE)/CCAKE
70960      CAKE=C2ETS+CAKEVO
70980      ENREQ=ENREQ+P
71000      ANCAP=ANCAP+CENCCA
71020      OANDN=OANDN+PC+CENMC
71040      CAP=CAP+TCAPT
71060      BIOD=BIOD*CENTS/TS
71080      ASH=ASH*CENTS/TS
71100      AMM=AMM*CENTS/TS
71110      VS=VS*CENTS/TS
71120      TS=CENTS
71140      WRITE(3,70) NCRUN,NCACT,SR,ALR

```

```

71160 70 FORMAT(//," CENTRIFUGE OUTPUTS",
71180 14X,"NO. CENTRIFUGES RUNNING.....",8X,14," UNITS",/,
71200 14X,"NO. CENTRIFUGES INCLD. BACKUP.",8X,14," UNITS",/,
71220 14X,"SILIOS FLOW RATE IN EACH.....",F12.2," KG/HR",/,
71240 14X,"LIQUID FLOW RATE IN EACH.....",F12.2," L/HR")
71260 WRITE(3,71) TCAPT,ACOST,CENCCA,PC,CENMC
71280 71 FORMAT(//," COST SUMMARY FOR CENTRIFUGES",/,
71300 14X,"CAPITAL COST TOTAL.....",F12.2," $",/,
71320 14X,"HOURLY COST TOTAL.....",F12.2," $/HR",/,
71340 14X," AMORTIZED CAPITAL.....",F12.2," $/HR",/,
71360 14X," POWER COST.....",F12.2," $/HR",/,
71380 14X," MAINTENANCE COST.....",F12.2," $/HR")
71400 RETURN
71580 END
80000 SUBROUTINE FINAL
80100 X=1.
80200 RETURN
80300 END
85000 SUBROUTINE HEAT(THR,IGC)
85100 COMMON/UCOM1/WATR,T5,V5,BIOD,ASH,AMM,ALK,PH,DIGCON,VOLD,CH4CH,
85200 1 CO2CH,H2O,HVAL,CAP,ANCAP,QANDH,DPROF,ENREQ,EMREN,AINED,WATIN
85300 COMMON/UCOM2/XINT,STC767,STC772,STC773,STC174,STC175,STC775,STCI,
85400 1 STC771,C4,C5,C6,C9,C10,S01,AK1,RET,COMC,TEMP
85500 GASCH=CH4CH+CO2CH
85600 FRAC=CH4CH/GASCH
85650 H2OPR=H2O/GASCH
85700 GASCH=GASCH-THR/HVAL
85800 PRINT(6,*) "INCLUDE GAS CLEANUP? 1=YES 0=NO",
85900 READ(5,*) IGC
86000 IF(IGC.NE.1) GO TO 100
86100 GASCH=GASCH/(1.+7044.46*(1.-FRAC)/HVAL)
100 BTUUSE=CH4CH-GASCH*HVAL
86300 ZH=CH4-GASCH*HVAL
86400 ENR30=INR30-BTUUSE
86500 CH4CH=GASCH*FRAC
86600 CO2CH=GASCH-CH4CH
86650 H2O=H2OPR*GASCH
86700 STEAM=BTUUSE/1186.
86800 CCB01=10.** (ALOG10(STEAM)*.6648+.75)*STCI/STC772
86900 CCB01A=CCB01/360./24.*XINT/(1.-(1.+XINT)**(-20.))
87000 BOIOP=.05*CCB01/360./24.
87100 WAT=STEAM/60./8.34
87200 CCWAT=10.** (ALOG10(WAT)*1.42+2.239)*STCI/STC772
87300 CCWATA=CCWAT/24./360.*XINT/(1.-(1.+XINT)**(-20.))
87400 WATOP=.02*CCWAT/24./360.
87500 CAP=CAP+CCB01+CCWAT
87600 ANCAP=ANCAP+CCB01A+CCWATA
87700 QANDH=QANDH+WATOP+BOIOP
87800 WAT=WAT*60.*3.785
87850 DPROF=DPROF-BTUUSE*C9/1.E06
87870 AJUSE=BTUUSE*1055.
87900 WRITE(3,27) AJUSE,CCB01,CCB01A,BOIOP,WAT,CCWAT,CCWATA,WATOP
27 FORMAT("1BOILER SYSTEM OUTPUTS",/,
88100 14X,"BOILER CAPACITY.....",G12.5," JOULES/HR",/,
88200 24X," CAPITAL COST.....",F12.2," $",/,
88300 34X," AMORTIZED CAPITAL.....",F12.2," $/HR",/,
88400 44X," OP. AND MAINT.....",F12.2," $/HR",/,
88500 54X,"DEMINERALIZATION SYSTEM",/,
88600 64X,"CAPACITY.....",G12.5," L/HR",/,
88700 74X," CAPITAL COST.....",F12.2," $",/,
88800 84X," AMORTIZED CAPITAL.....",F12.2," $/HR",/

```



```
889CC 90Y," OP. AND MAINT,.....",P12.2," S/HR"///}  
890CC RETURN  
891CC END
```

4. Sample Output

MANURE DIGESTION SIMULATION

HERD SIZE.....	100000 ANIMALS
DIGESTER INPUT CONCENTRATION.....	15.00 PERCENT
DIGESTER TEMPERATURE.....	58.00 DEG. C
RETENTION TIME REQUESTED.....	8.00 DAYS
RECYCLE RATE FOR CENTRATE.....	0.00 PERCENT

ENVIRONMENTAL LOT PARAMETERS USED FOR SOLIDS DESTRUCTION

K.....	.25 PER DAY
COMPOSITION OF MANURE	
WATER.....	85.00 PERCENT
TOTAL SOLIDS.....	15.00 PERCENT
VOLATILE SOLIDS.....	78.00 PERCENT T.S.
BIODEGRADABLE SOLIDS.....	78.00 PERCENT V. S.
PRODUCTION RATE.....	4.90 KG/ANIMAL/DAY

MATERIAL BALANCE AFTER DATA INITIALIZATION

WATER IN FEED STREAM.....	.11569E+06 L/HR
TOTAL SOLIDS IN FEED STREAM.....	20417. KG/HR
VOLATILE SOLIDS IN FEED STREAM.....	15925. KG/HR
BIODEGRADABLE SOLIDS IN FEED STREAM	12422. KG/HR
ASH IN FEED STREAM.....	4491.7 KG/HR
AMMONIA NITROGEN IN FEED STREAM....	148.10 KG/HR AS N

ECONOMIC SUMMARY

TOTAL CAPITAL REQUIRED.....	0.00 \$
AMORTIZED AT 10.00 PERCENT.....	0.00 \$/HR
OPERATION AND MAINTENANCE.....	0.00 \$/HR
VALUE OF RECOVERED MATERIAL AND GAS	0.00 \$/HR

ENERGY BALANCE

ENERGY REQUIRED FOR PROCESSES.....	0. JOULES/HR
ENERGY AVAILABLE IN SYSTEM.....	.19741E+12 JOULES/HR

MIX TANK OUTPUTS

TOTAL WATER REQUIREMENTS FROM RECYCLE AND
MAKEUP FOR 15.00 PERCENT INPUT SOLIDS:

0.	L/HR
0.	GAL/HR

HEAT EXCHANGER PARAMETERS

SURFACE AREA.....	1326.2	SQ. M.
TEMPERATURE GRADIENT.....	10.0	DEG. C
CAPITAL COST.....	96773.82	\$
AMORTIZED CAPITAL COST.....	1.32	\$/HR
OPERATION AND MAINTENANCE.....	.26	\$/HR

MATERIAL BALANCE AFTER SLURRY MIXING

WATER IN FEED STREAM.....	.11569E+06	L/HR
TOTAL SOLIDS IN FEED STREAM.....	20417.	KG/HR
VOLATILE SOLIDS IN FEED STREAM.....	15925.	KG/HR
BIODEGRADABLE SOLIDS IN FEED STREAM	12422.	KG/HR
ASH IN FEED STREAM.....	4491.7	KG/HR
AMMONIA NITROGEN IN FEED STREAM....	148.10	KG/HR AS N

ECONOMIC SUMMARY

TOTAL CAPITAL REQUIRED.....	414592.10	\$
AMORTIZED AT 10.00 PERCENT.....	5.64	\$/HR
OPERATION AND MAINTENANCE.....	1.13	\$/HR
VALUE OF RECOVERED MATERIAL AND GAS	0.00	\$/HR

ENERGY BALANCE

ENERGY REQUIRED FOR PROCESSES.....	.28988E+09	JOULES/HR
ENERGY AVAILABLE IN SYSTEM.....	.19741E+12	JOULES/HR

DIGESTER PARAMETERS

INCOMING SLURRY TEMPERATURE...	48.00	DEG. C
TEMPERATURE IN DIGESTER.....	58.00	DEG. C
DIGESTER PH.....	7.50	
DIGESTER RETENTION TIME.....	8.00	DAYS
UNDISSOCIATED AMMONIA.....	176.82	MG/L NH3 AS N
VOLATILE SOLIDS DESTROYED.....	7754.0	KG/HR
TOTAL SOLIDS INPT.....	20417.	KG/HR
VOLATILE SOLIDS INPUT.....	15925.	KG/HR
TOTAL SOLIDS IN EFFLUENT.....	12663.	KG/HR

AT 9.87 PERCENT SOLIDS

4 DIGESTER(S) REQUIRED

WITH HEIGHT OF.....	14.63	METERS
AND RADIUS OF.....	11.92	METERS
VOLUME OF EACH DIGESTER.....	6533.3	CUBIC METERS
TOTAL VOLUME OF DIGESTER(S)...	26133.	CUBIC METERS
HEAT LOSS THROUGH DIGESTER(S)...	.26264E+10	JOULES/HR
HEAT REQUIRED TO HEAT SLURRY..	.53061E+10	JOULES/HR
WATER VAPOF HEAT LOSS.....	.25344E+10	JOULES/HR
TOTAL HEAT REQUIREMENT.....	.10467E+11	JOULES/HR

DIGESTER CAPITAL COST.....	2994331.81	\$
AMORTIZED AT 10.00 PERCENT INTEREST....		40.71 \$/HR
MIXING POWER COST.....	24.03	\$/HR
DIGESTER MAINTENANCE COST.....	3.47	\$/HR

GAS PRODUCTION

TOTAL GAS.....	6118.2	CUBIC METERS/HR
CARBON DIOXIDE.....	2901.5	CUBIC METERS/HR
METHANE.....	3216.7	CUBIC METERS/HR
TOTAL METHANE ENERGY AVAILABLE	.11983E+12	JOULES/HR

MATERIAL BALANCE AFTER DIGESTION

WATER IN FEED STREAM.....	.11569E+06	L/HR
TOTAL SOLIDS IN FEED STREAM.....	12663.	KG/HR

VOLATILE SOLIDS IN FEED STREAM.....	8171.0	KG/HR
BIODEGRADABLE SOLIDS IN FEED STREAM	4667.5	KG/HR
ASH IN FEED STREAM.....	4491.7	KG/HR
AMMONIA NITROGEN IN FEED STREAM....	148.10	KG/HR AS N

DIGESTER EQUILIBRIUM CONDITIONS

ALKALINITY ADDED WITH INPUT STREAMS	.11324E-01	G/L PER DAY
DIGESTER PH.....	7.50	
EFFLUENT SLURRY CONCENTRATION.....	9.87	PERCENT
TOTAL DIGESTER VOLUME.....	26133.	CUBIC METERS

GAS STREAM CONSTITUENTS

METHANE.....	3216.7	SCM/HR
CARBON DIOXIDE.....	2901.5	SCM/HR
WATER VAPOR.....	1333.9	SCM/HR
HEAT VALUE OF GAS.....	.19586E+08	JOULES/SCM

ECONOMIC SUMMARY

TOTAL CAPITAL REQUIRED.....	3408923.90	\$
AMORTIZED AT 10.00 PERCENT.....	46.34	\$/HR
OPERATION AND MAINTENANCE.....	28.62	\$/HR
VALUE OF RECOVERED MATERIAL AND GAS	227.16	\$/HR

ENERGY BALANCE

ENERGY REQUIRED FOR PROCESSES.....	.13656E+11	JOULES/HR
ENERGY AVAILABLE IN SYSTEM.....	.11983E+12	JOULES/HR

BOILER SYSTEM OUTPUTS

BOILER CAPACITY.....	.27146E+11	JOULES/HR
CAPITAL COST.....	71979.62	\$
AMORTIZED CAPITAL.....	.98	\$/HR
OP. AND MAINT.....	.25	\$/HR

DESUPERHEATING SYSTEM

CAPACITY.....	9846.0	L/HR
CAPITAL COST.....	61376.16	\$
AMORTIZED CAPITAL.....	.83	\$/HR
OP. AND MAINT.....	.14	\$/HR

MATERIAL BALANCE AFTER BOILER

WATER IN FEED STREAM.....	.11569E+06	L/HR
TOTAL SOLIDS IN FEED STREAM.....	12663.	KG/HR
VOLATILE SOLIDS IN FEED STREAM.....	8171.0	KG/HR
BIODEGRADABLE SOLIDS IN FEED STREAM	4667.5	KG/HR
ASH IN FEED STREAM.....	4491.7	KG/HR
AMMONIA NITROGEN IN FEED STREAM....	148.10	KG/HR AS N

GAS STREAM CONSTITUENTS

METHANE.....	2498.0	SCM/HR
CARBON DIOXIDE.....	2244.2	SCM/HR
WATER VAPOR.....	1031.7	SCM/HR
HEAT VALUE OF GAS.....	.19586E+08	JOULES/SCM

ECONOMIC SUMMARY

TOTAL CAPITAL REQUIRED.....	3542279.68	\$
AMORTIZED AT 10.00 PERCENT.....	48.16	\$/HR
OPERATION AND MAINTENANCE.....	29.02	\$/HR
VALUE OF RECOVERED MATERIAL AND GAS	175.70	\$/HR

ENERGY BALANCE

ENERGY REQUIRED FOR PROCESSES.....	-.13489E+11	JOULES/HR
ENERGY AVAILABLE IN SYSTEM.....	.92682E+11	JOULES/HR

GAS CLEAN-UP SYSTEM OUTPUTS

TOTAL GAS IN.....	4732.2	CUBIC METERS/HR
METHANE.....	2488.0	CUBIC METERS/HR
CARBON DIOXIDE.....	2244.2	CUBIC METERS/HR

MEA REQUIRED.....	9173.4	KG/HR
MAKE-UP MEA.....	.53057	KG/HR
HEAT REQUIRED.....	.16679E+11	JOULES/HR

CAPITAL INVESTMENT.....	1215153.88	\$
HOURLY COST TOTAL.....	32.82	\$
AMORTIZED CAPITAL.....	18.49	\$
OP. AND MAINT.....	14.06	\$
MAKE-UP MEA COST.....	.27	\$

MATERIAL BALANCE AFTER GAS CLEANUP

WATER IN FEED STREAM.....	.11569E+06	L/HR
TOTAL SOLIDS IN FEED STREAM.....	12663.	KG/HR
VOLATILE SOLIDS IN FEED STREAM.....	8171.0	KG/HR
BIODEGRADABLE SOLIDS IN FEED STREAM	4667.5	KG/HR
ASH IN FEED STREAM.....	4491.7	KG/HR
AMMONIA NITROGEN IN FEED STREAM....	148.10	KG/HR AS N

GAS STREAM CONSTITUENTS

METHANE.....	2488.0	SCM/HR
CARBON DIOXIDE.....	0.	SCM/HR
WATER VAPOR.....	0.	SCM/HR
HEAT VALUE OF GAS.....	.37252E+08	JOULES/SCM

ECONOMIC SUMMARY

TOTAL CAPITAL REQUIRED.....	4757433.56	\$
AMORTIZED AT 10.00 PERCENT.....	66.65	\$/HR
OPERATION AND MAINTENANCE.....	43.35	\$/HR
VALUE OF RECOVERED MATERIAL AND GAS	175.70	\$/HR

ENERGY BALANCE

ENERGY REQUIRED FOR PROCESSES.....	.31895E+10	JOULES/HR
ENERGY AVAILABLE IN SYSTEM.....	.92682E+11	JOULES/HR