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BIOLOGICAL CONVERSION OF BIOMASS TO METHANE

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ABSTRACT

A large scale laboratory system has been constructed to evaluate the methane yields from various organic material. The initial substrate for these studies was beef feed lot manure. Methane yields ranged from 0.11 to 0.259 m^3 per kg volatile solids fed with a fermentation temperature of 58°C. The gas yield for a given manure was a function of retention time. However, fresh manure produced substantially more gas than manure that had been on the lots for several months. Retention times of 3.7 days and loadings of 8.76 kg per m^3 per day resulted in stable operation.

The results of a separate study of the effect of reactor type on methane production showed that if a balanced population of organisms can be maintained in the initial stage, a multi-stage fermentation is more efficient than a complete-mix system. However, when the system is stressed, failure of the multi-stage system is more rapid. If the objective is to maximize the conversion of solids to methane, a staged system will produce more methane per unit volume of reactor. If the objective is to maximize methane production per unit volume of reactor, a single stage complete-mix reactor operating at near the critical retention time is required.

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INTRODUCTION

Recovery of energy from residual organic materials and from crops grown specifically for their energy content is part of ERDA's 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 ERDA projects.

The effect of the type of reactor on methane fermentation has been discussed extensively in the literature. An addendum to the initial proposal provided for the evaluation of methane fermentation in complete mixed, two-stage and plug flow reactors. The objective of this phase of the present study is to determine the desired reactor type to maximize gas production.

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 various substrate pretreatment and the evaluation of potential systems for processing and disposing of the fermentor slurry.

DESCRIPTION OF EXPERIMENTAL SYSTEM

I. 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 in 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 contains adequate laboratory, office and related space for the research staff.

The fermentation reactors consist of four completely mixed stainless steel reactors with a total volume of 910 ℓ each. The operating level in each reactor is 775 ℓ. Heating is provided by circulating hot water from a hot water heater through external jackets on each tank. A temperature controller (TC) opens a solenoid valve (SV) to allow the hot water to circulate through the jacket when the temperature drops below the set point. Figure 2 shows a schematic of one set of reactors. A second set operates in parallel.

The reactors are mixed with a variable speed turbine mixer. The mixing speed can be varied from 20 to 120 rpm. Recording watt meters measure the power consumption on each mixer. The mixing power input can 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. The dimensions of the reactor and the associated mixer are shown in Figure 3.

The feed slurry is pumped into the fermentors with a progressing cavity pump (P1). This pump is 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 is pumped by a

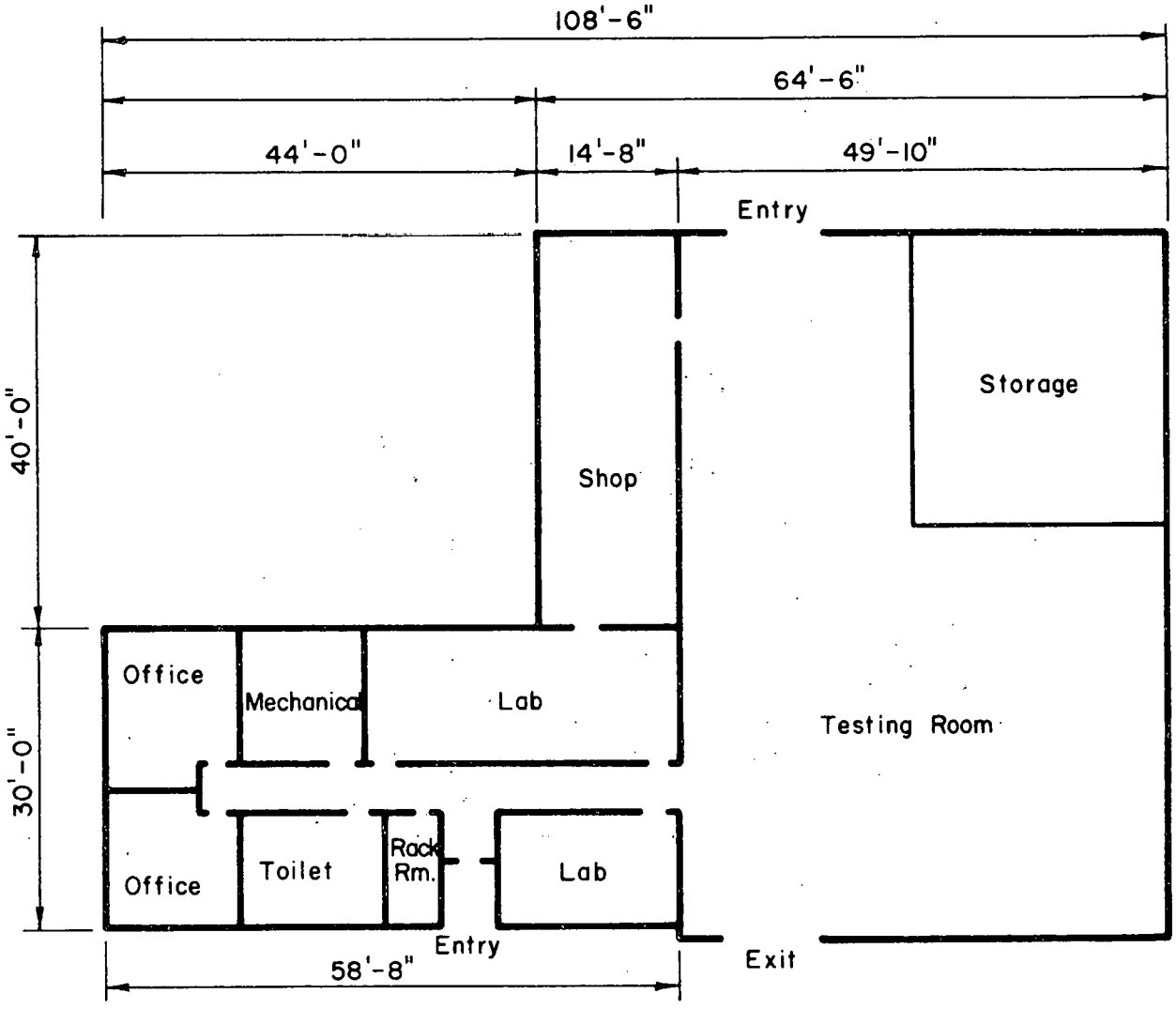

Figure 1. Floor Plan of Building for Housing the Experimental System

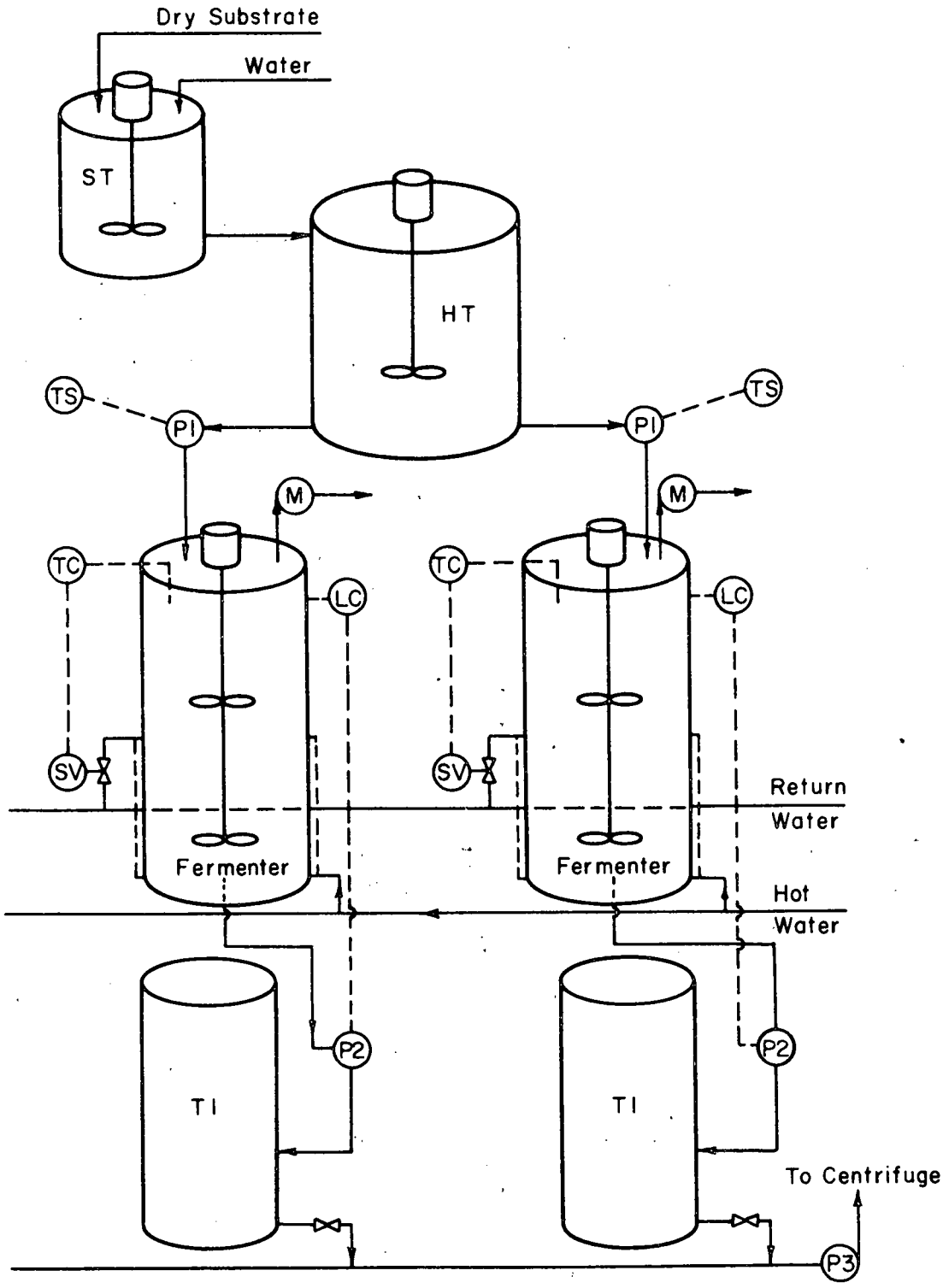

Figure 2. Schematic of One Set of Fermentors

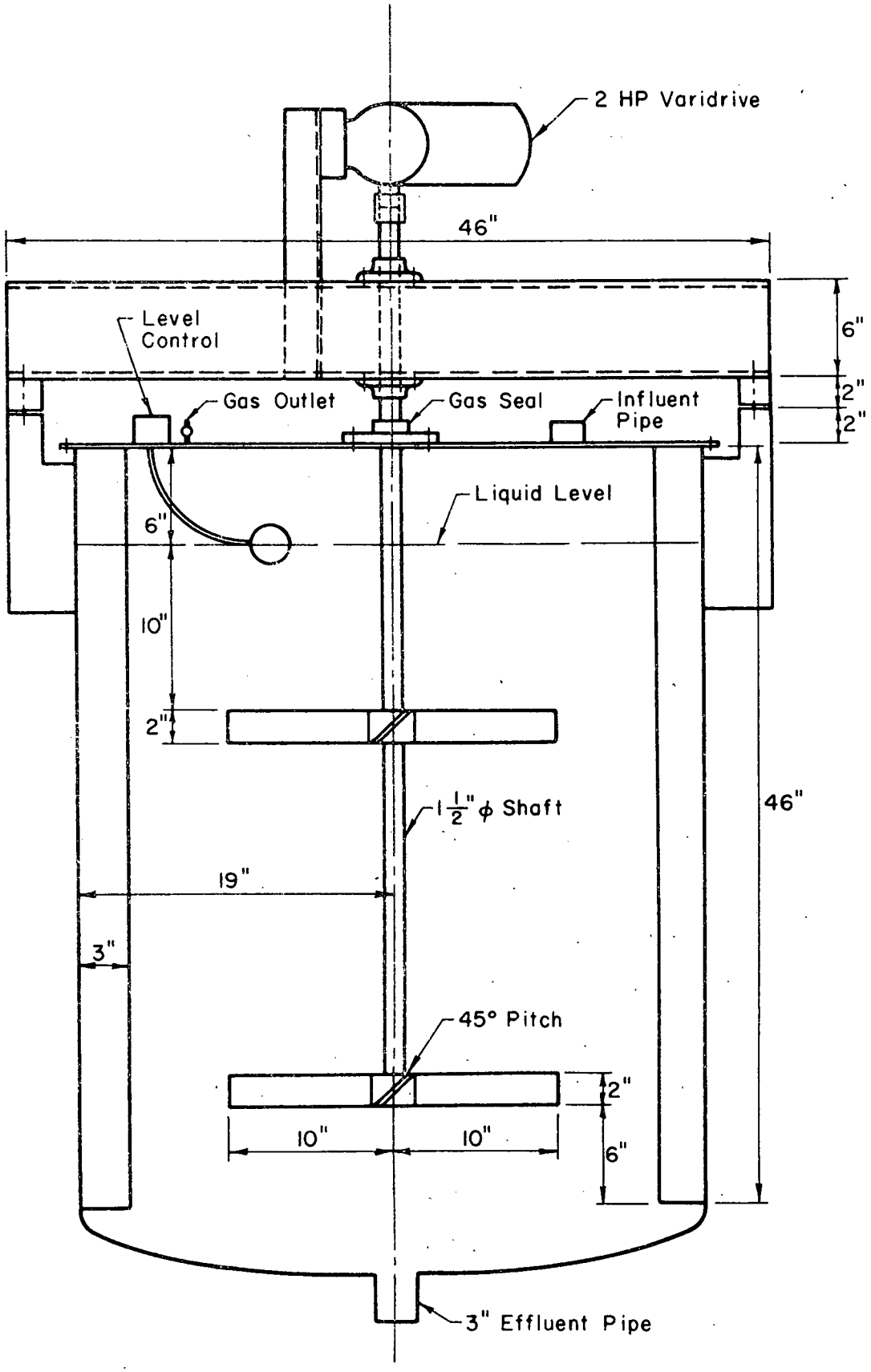

Figure 3. Details of Reactor and Variable Speed Mixer

similar type pump (P2) that is actuated by a level controller (LC). The effluent is collected in a holding tank (T1) for additional processing. Gas from the reactors is passed through wet test gas meters (M) for determining gas flow rate. The gas can then be sampled for gas analysis with a Fisher Gas Partitioner.

A. Feed Preparation

The organic materials used in this process must be prepared for feed into the system. The initial step is one of size reduction. This is accomplished by a "granulator" manufactured by H. C. Davis Sons, Inc. This unit is equipped with three screens, 1/4 in., 3/4 in., and 1-1/2 in. The organic material can be ground to either of these three desired sizes. In order to effectively grind this material it must be relatively dry. This also assists in storage of significant quantities of feed material. The dry material does not decompose.

After shredding, a predetermined weight of the feed material is added to the slurry tanks (ST). The dry feed is slurried with the desired amount of water. Either recycled liquor or fresh water can be used in the slurry tanks. After completely wetting the organic material, it is then discharged into mixed holding tanks (HT). This provides for storage of the slurry prior to pumping into the reactors. These mixed tanks also provide for a relative uniform feeding of material into the reactors since they contain approximately two days supply of feed slurry. These tanks are covered primarily for odor control.

B. Fermentor Operation

The loading rate on the reactors is 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 are set by controlling the feed slurry concentration and varying the pumping time.

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

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

There are only two feed slurry holding tanks so two reactors are fed from each tank. However, by varying the throughput, the loading rate and retention time of each reactor can be varied. This arrangement essentially allows each reactor to operate independent of the others. Therefore, it is possible to evaluate four variables at one time.

C. Residue Processing and Disposal

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

this material is allowed to flow to the drain.

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

Provisions have been 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 125 psi is connected to a steam generator. By adding the fibers to this reactor along with an appropriate amount of caustic and water it is possible to heat treat this material prior to fermentation. This permits evaluation of the effect of thermo chemical pretreatment or posttreatment of the residual solids on the fermentation characteristics.

In addition to the dewatering by centrifugation, the effluent is available for additional tests. This material can be dewatered by vacuum filtration and filter test leaf studies are available to evaluate its filtration characteristics. Also, the quality of the effluent liquid and solids can be evaluated with respect to its nutrient value both as a possible refeed material or as a soil additive. These evaluations are made with laboratory analyses rather than having actual field tests.

II. Laboratory Fermentation Units

These studies were conducted in laboratory reactors designed to allow for the evaluation of single stage complete mix, two stage and

plug flow reactors simultaneously. Figure 4 shows the type of reactor constructed. Three such reactors were used, each having an operating liquid volume of 43 ℓ. Mixing was provided with flat blade pitched impellers fixed to the horizontal shaft. These impellers operated at low speed, approximately 30 rpm. The reactors were operated on a semi-continuous feed schedule with appropriate volumes of substrate added once daily.

One reactor contained four compartments as shown in Figure 4. Four mixed reactors in series provide a reasonable approximation to plug flow. The second reactor operated as a two stage reactor. The volume of the first stage could be varied from 25 to 33 or 50 percent of the total volume. The balance of the reactor volume was used as the second stage. In the third unit, all four compartments were combined into a single reactor. This served as the single stage complete mixing unit.

Flow from one compartment to the next was through a port cut in the dividing walls. When substrate was added to the first compartment, the difference in head caused the contents to flow into the next compartment. It was planned to have these ports open at all times. However, it was recognized the intermixing of the contents of the compartments is possible. A tracer study showed that there was some intermixing between the compartments in the two stage and four stage reactors. Therefore, it was necessary to keep these ports closed except during substrate addition.

Wet test gas meters were used to measure the total gas flow from each reactor routinely. Provisions were made to allow for measuring the gas generated by each compartment during certain tests. The entire system was housed in a constant temperature room.

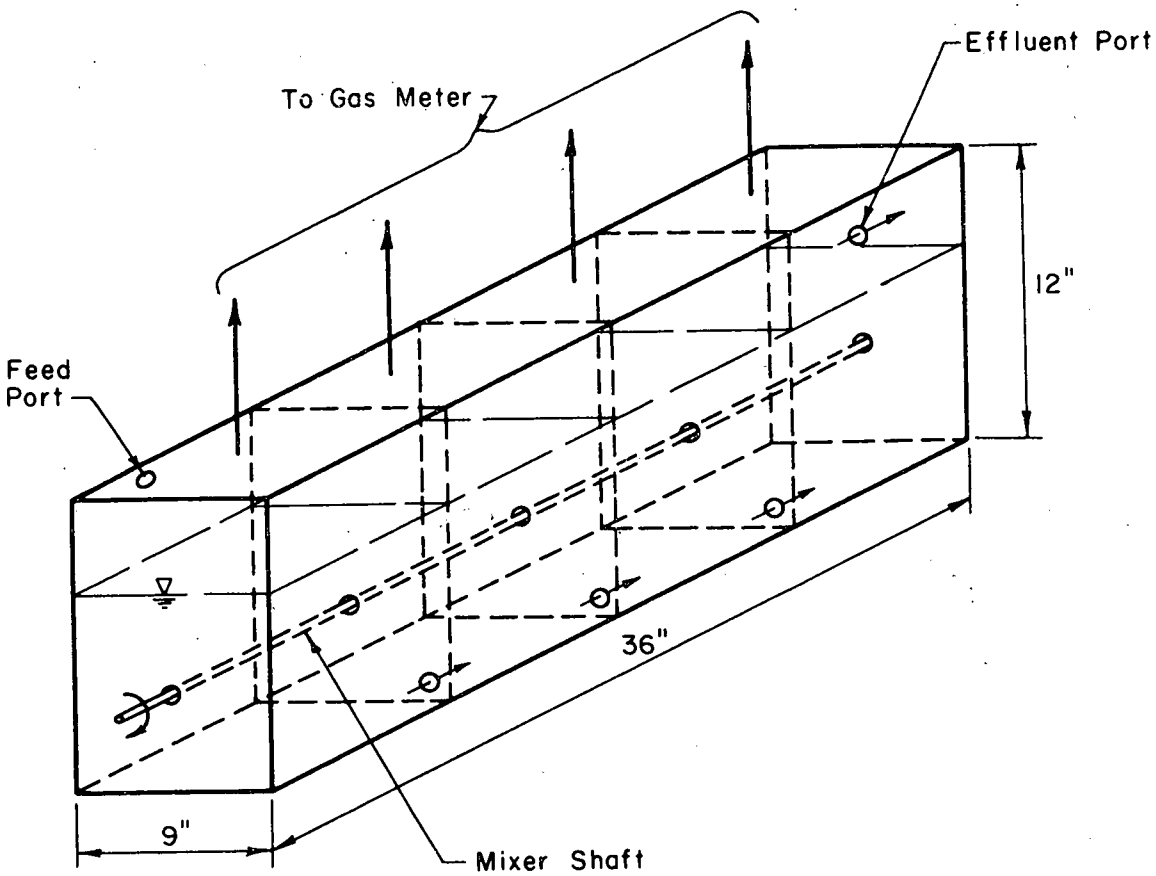

Figure 4. Schematic of Laboratory Fermentation Reactors

III. Fermentor Feed Stock

A. Continuous Fermentation System

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 ERDA Fuels for Biomass Program Manager. After discussion of the current program 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 1/4 in. 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 1/4 in. 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. Consequently, only limited stabilization of the manure occurred in storage.

Table 1 shows the volatile solids content of the manure used in this study. Short term storage does not appear to significantly change the volatile solids. Beef manure 2 was collected on Day 76 344 (Dec. 12, 1976). The moisture in the manure was frozen so the manure was exceptionally wet when the water thawed. It was not possible to process this manure through the shredder. The dairy manure, which did not contain any bedding, was obtained for use while this manure was drying. Extreme weather conditions and mechanical problems caused shut down of the fermentors in January and February. In mid-February, portions of this manure were spread on the test bay floor to assist in drying. When this spread manure was dry, it was processed and additional manure spread. As the data in Table 1 show, there was a significant drop in the volatile solids content of the raw manure during this period of time.

B. Laboratory Fermentation Units

In order to maintain a uniform feed stock for this phase of the study, shredded computer paper was selected as the carbon source. This material is more biodegradable than newsprint and is a more uniform quality. The composition of the feed slurry is given in Table 2. In Run 1, the supplement was raw sewage sludge obtained from the Urbana-Champaign Sanitary District. This was added to provide micronutrients and a continued inoculum of microorganisms. During this run, it was observed that the systems were stressed. The addition of beef manure improved the systems operation. Therefore, during the second run, this manure was substituted for the sewage sludge.

Additional nitrogen and phosphorus were added to insure adequate nutrients. Also, calcium oxide and sodium hydroxide were added to provide

Table 1. Raw Manure Volatile Solids Content

Source	Date Collected	Date* Sampled	Volatile Solids %
Beef 1	76293	76327	59.9
		76334	61.0
		76341	58.9
Dairy	76344	76352	68.0
		76359	72.1
		76366	69.7
Beef 2	76338	77059	70.6
		77066	69.6
		77073	68.3
		77080	67.3
		77087	66.7
Beef 3	77074	77144	61.3
		77151	63.2
		77158	67.6

* Average for week ending on date shown.

the alkalinity required for pH control. If needed, additional caustic was added to the reactors. The constituents listed in Table 2 were added to tap water to provide the desired feed solids concentration.

Table 2. Composition of Feed Slurry

Constituent	Concentration - g/ℓ	
	Run 1	Run 2
Paper	22.3	44.6
NH_4Cl	0.55	1.11
K_2HPO_4	0.19	0.37
CaO	2.9	2.9
NaOH	1.0	1.0
Supplement (dry solids)	3.0	5.9

RESULTS AND DISCUSSION

This project contained two separate studies. Because of the marked difference in these studies, the results will be presented separately and discussed separately.

I. 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°C ± 2° operating temperature prior to October 22, 1976 (Day 76296). On this date, 115 ℓ 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 3, 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.

Table 3. 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	-	-

[1] mg/l as $CaCO_3$

[2] mg/l as acetic acid

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 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 200 ℓ of slurry resulting in an increase in the feed slurry solids concentration. The feed rate was set for 60 ℓ per day to produce a 13.3-day retention time. The actual feed volume varied between 60 to 80 ℓ resulting in a retention time between 9.7 and 13 days. With an operating volume of 775 ℓ, the initial solids loading was approximately 0.64 kg VS/m^3 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 has been a continuing problem throughout the study. Several sampling techniques have been tried, but none has been totally satisfactory. Solids data for the reactors are reported in Appendix A. However, these data are not accurate.

The volatile solids loading and gas production during start-up are shown in Table 4. 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.

Table 4. Gas Production Rates
(Nov. 16 through Dec. 3, 1976)

	Reactor #1			Reactor #2			Reactor #3			Reactor #4		
	kg VS	Gas Prod.		kg VS	Gas Prod.		kg VS	Gas Prod.		kg VS	Gas Prod.	
Date	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.

For the period shown in Table 4, reactor 1 produced 0.260 m^3 of gas per kg of volatile solids feed. The composition of the gas from both reactors was 58 percent methane and 42 percent carbon dioxide.

B. Gas Production Rates

A summary of the results of four separate runs is given in Table 5. The temperature for these runs was set at 58°C. The normal temperature variation was ± 2°C. Run 1 was the initial shakedown run and numerous physical and mechanical problems were identified and corrected. All reactors were operated at approximately 10-day retention time. The reactors were fed daily on a fill and draw basis. The measured gas production was erratic due to gas leaks, meter calibration problems and loading rate. Therefore, the data from this run should be used accordingly.

This range of fermentor operating parameters is shown in Table 6. The volatile acids were always low. The pH and alkalinity were low during the initial part of the run. The pH and alkalinity increased significantly during this time period. This was a result of the washout of the water added to the reactors during start-up. The data collected during this run are given in Appendix A, Table A-1.

Two truck loads of frozen manure from a dairy cow barn was obtained for Run 2. The second batch of beef manure intended for use at this time contained some straw bedding. The high moisture content of this beef manure prevented shredding. Therefore, the dairy manure was used to keep the system operating until the beef manure could be processed.

The gas production from the dairy manure was exceptionally good as shown in Table 5. This was due to the fresh nature of the manure.

Table 5. Loading and Gas Production Rates

Run No. (Date)	Reactor No.	θ Day	VS Load kg/m^3-D	$\frac{m^3\ CH_4}{kg\ VS\ Add}$	$\frac{m^3\ CH_4}{m^3\text{-}D}$	CH_4 %
Beef 1	1	10.8	4.40	0.124	0.54	(60)
(76320-345)	2	10.9	4.07	0.110	0.45	(60)
Run 1	3	11.4	3.17	0.196	0.62	(60)
	4	11.2	3.46	0.175	0.61	(60)
Dairy	1	7.7	4.60	0.259	1.20	(60)
(76345-365)	2	8.3	4.60	0.251	1.15	(60)
Run 2	3	8.5	4.29	0.233	1.01	(60)
	4	7.8	5.01	0.220	1.10	(60)
Beef 2	1	9.9	3.56	0.167	0.593	(60)
(77052-090)	2	6.6	5.10	0.146	0.744	(60)
Run 3	3	6.5	5.12	0.155	0.793	(60)
	4	6.6	5.31	0.128	0.682	(60)
Beef 3	1	9.3	3.59	0.208	0.746	63.2
(77144-172)	2	3.7	8.76	0.139	1.222	61.9
Run 4	3	4.7	6.94	0.160	1.108	64.1
	4	6.2	5.25	0.186	0.973	63.9

Table 6. Average Fermenter Operating Parameters

Run No. (Date)	Reactor No.	θ Day	pH Range	Alkalinity Range - g/ℓ	Volatile Acids Range - g/ℓ
Beef 1	1	10.8	6.9-7.4	1.45-5.84	0.24-0.34
(76320-345)	2	10.9	6.9-7.3	1.40-6.17	0.14-0.24
Run 1	3	11.4	6.8-7.4	1.05-5.24	0.14-0.23
	4	11.2	6.9-7.4	1.93-5.44	0.14-0.26
Dairy	1	7.7	7.1-7.3	6.49-6.97	0.12-0.29
(76345-365)	2	8.3	7.1-7.5	5.96-6.53	0.12-0.31
Run 2	3	8.5	7.1-7.5	5.80-6.33	0.14-0.38
	4	7.8	7.2-7.5	6.10-6.37	0.12-0.35
Beef 2	1	9.9	7.0-7.4	4.00-7.37	0.17-0.67
(77052-090)	2	6.6	7.0-7.5	3.57-6.40	0.17-0.86
Run 3	3	6.5	7.1-7.5	3.60-6.10	0.17-0.53
	4	6.6	7.1-7.7	5.10-8.00	0.41-1.58
Beef 3	1	9.3	7.1-7.7	2.21-4.50	0.07-0.53
(77144-172)	2	3.7	6.8-7.7	2.09-5.18	0.14-1.30
Run 4	3	4.7	6.8-7.8	1.95-4.50	0.16-1.08
	4	6.2	6.9-7.7	2.40-4.90	0.16-0.72

The dairy barn was cleaned daily and the manure was stored in an outside pit. The manure was frozen until it was brought to the test facility. Consequently, it was quite fresh. During the period, the pH was in the 7.1 to 7.5 range, with alkalinities in the 6 to 7 g/ℓ range. The volatile acids were less than 400 mg/ℓ (see Table 6). The data collected during this run are given in Appendix A, Table A-2.

The system was on standby during January 1977. This was necessitated by several factors, including extreme weather conditions that isolated the test facility for several days as well as delay in receiving the shredder required to process the manure that contained bedding. The systems were reactivated in February. The feed pumps were controlled with the time switches. Because the retention times were reasonably long, the feed was pumped in over an 8-hour period. The system was operated in this mode until late March 1977 when temperature control problems caused wide fluctuations in temperature. Excessive foaming resulted. The foam flooded the gas line and completely disrupted the operation of the system.

The gas production was substantially less than that obtained with the dairy manure (see Table 5). The manure had been stored for several months and the organic content was decreasing with time (see Table 1). The pH, alkalinity and volatile acids were as expected except when the temperature began to vary (see Table 6). The data collected during this run are given in Appendix A, Table A-3.

After the temperature control problem was corrected, Run 4 was initiated. The retention time was varied from 3.7 to 9.3 days. The system operated well under these conditions. As expected, the gas

production varied with the retention time and loading rate. A short retention time and high loading rate produced 1.22 m^3 of methane per m^3 of reactor per day but only 0.139 m^3 of methane per kg volatile solid fed. At the long retention time, the opposite condition was observed. The pH, alkalinity and volatile acids were all within an acceptable range. The volatile acids did increase at times, but this was due to temperature variations. This will be discussed later. The data collected during this period are given in Appendix A, Table A-4.

The retention time, loading rate and gas production rates for reactors 1 through 4 are shown in Figures 5 through 8, respectively. The data points shown are the average value of each parameter for the 7 day time period ending on the date shown. The change in loading rates or retention time is reflected in the gas production rate. The quality of the manure also influences the gas production as shown by comparison of the beef and dairy manure. Also, the changing characteristics of the manure show a change in gas production. In particular, beef manure 2 in Figure 6 shows a decrease in gas production. During this period, the retention time was reasonably constant as was the loading rate. However, as shown in Table 1, the volatile solids decreased from 70.6 to 66.7 percent. This emphasizes the importance of the manure quality in determining the gas production.

C. 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

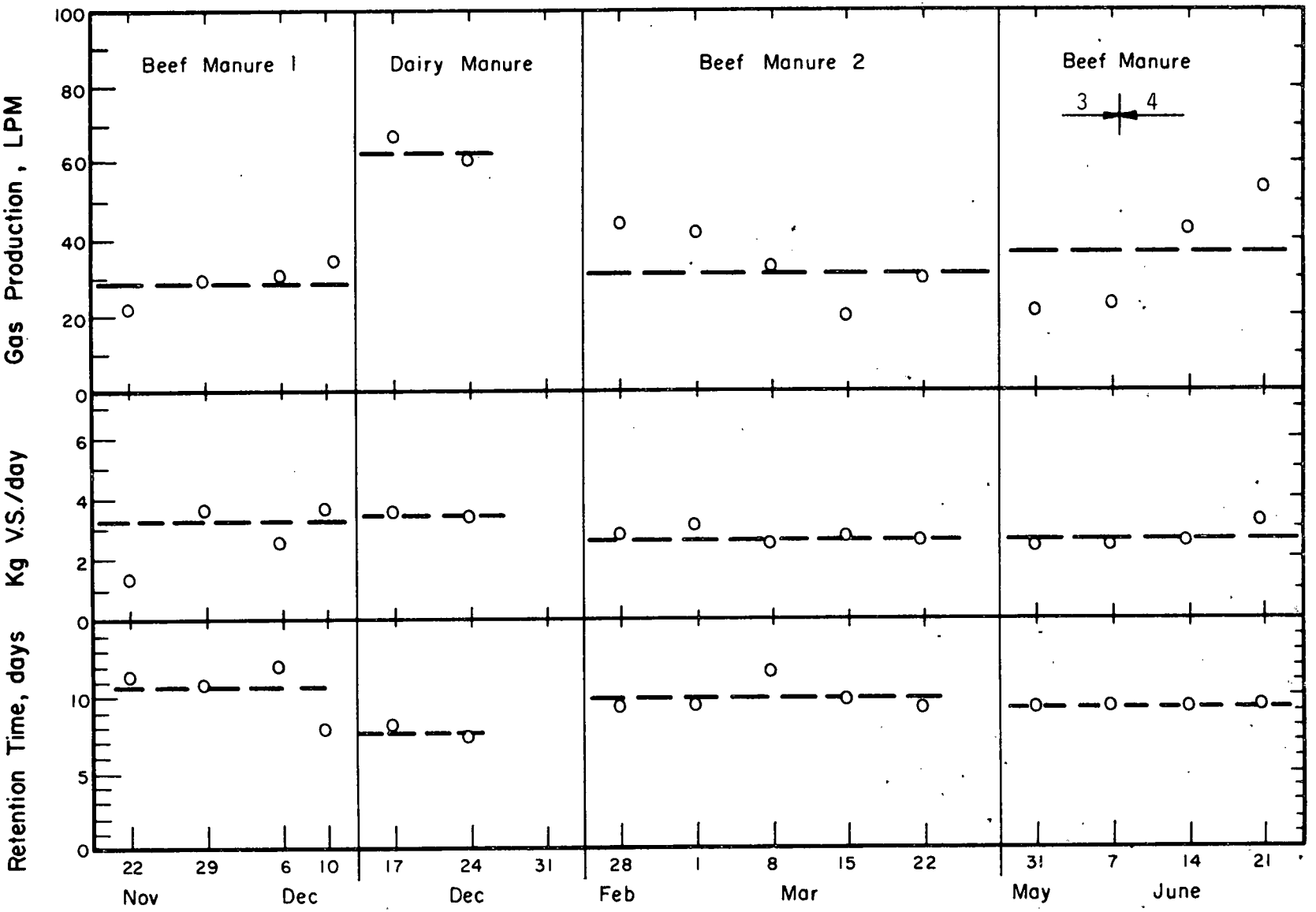

Figure 5. Variation in Retention Time, Loading Rate and Gas Production for Reactor 1

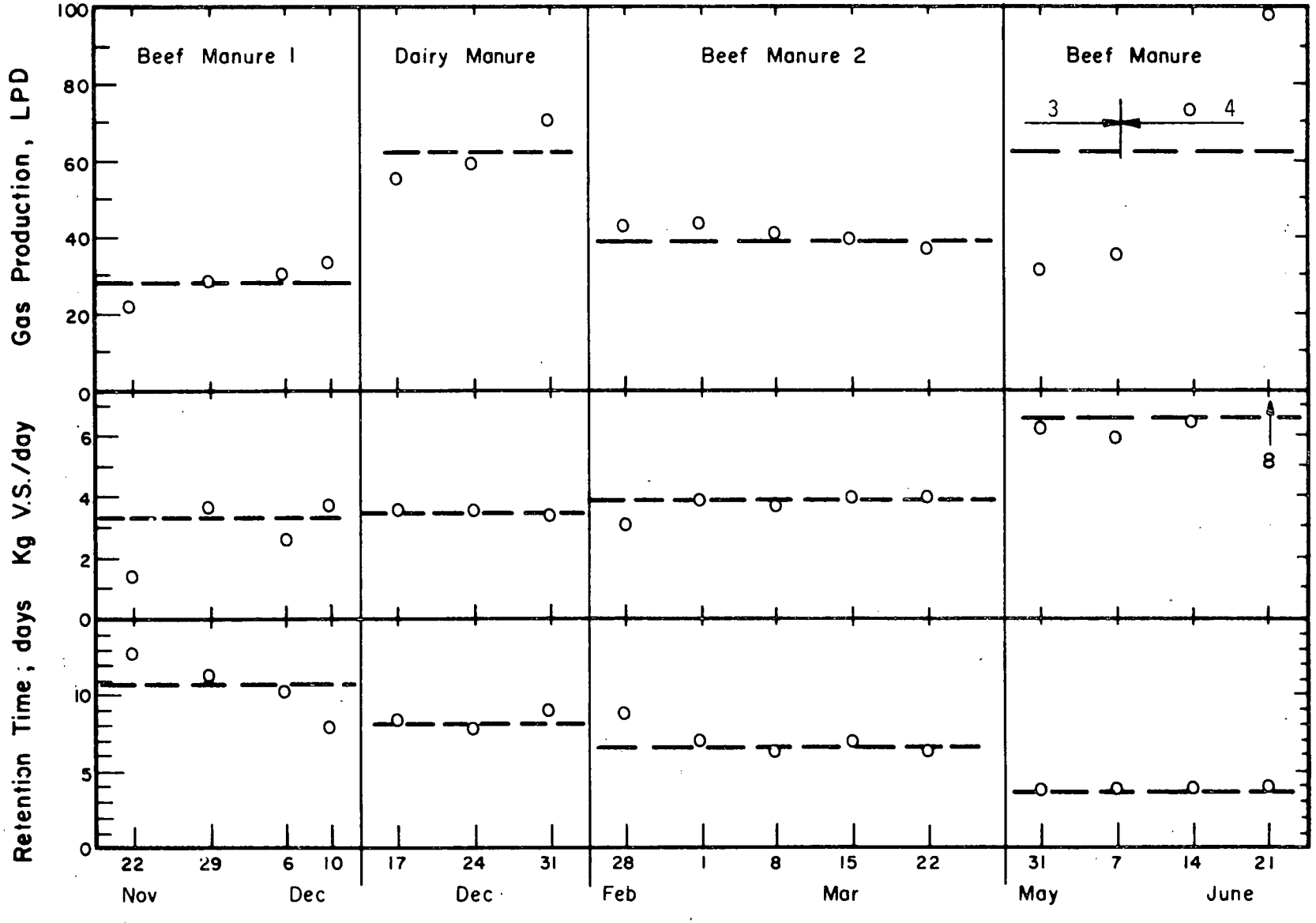

Figure 6. Variation in Retention Time, Loading Rate and Gas Production for Reactor 2

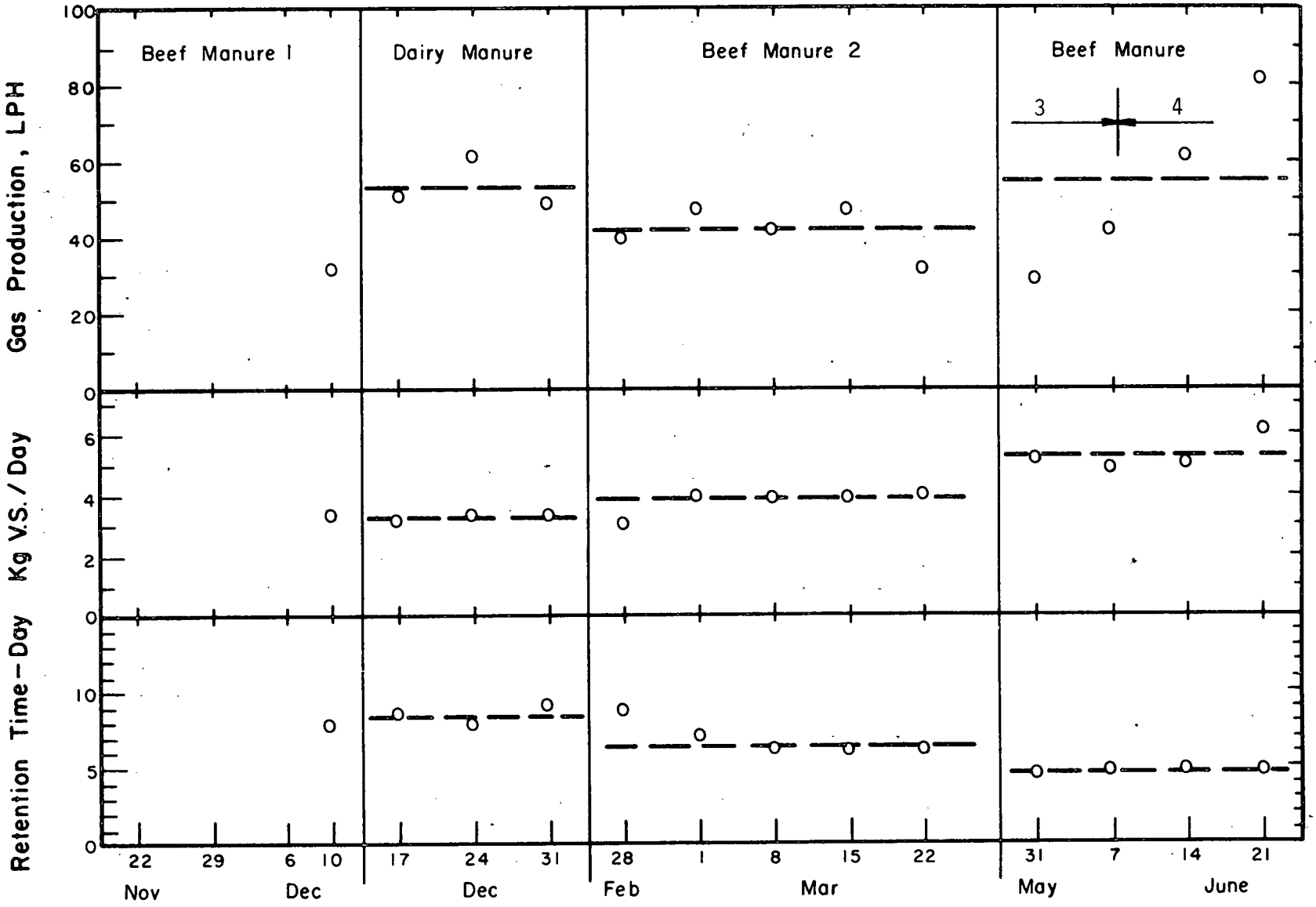

Figure 7. Variation in Retention Time, Loading Rate and Gas Production for Reactor 3

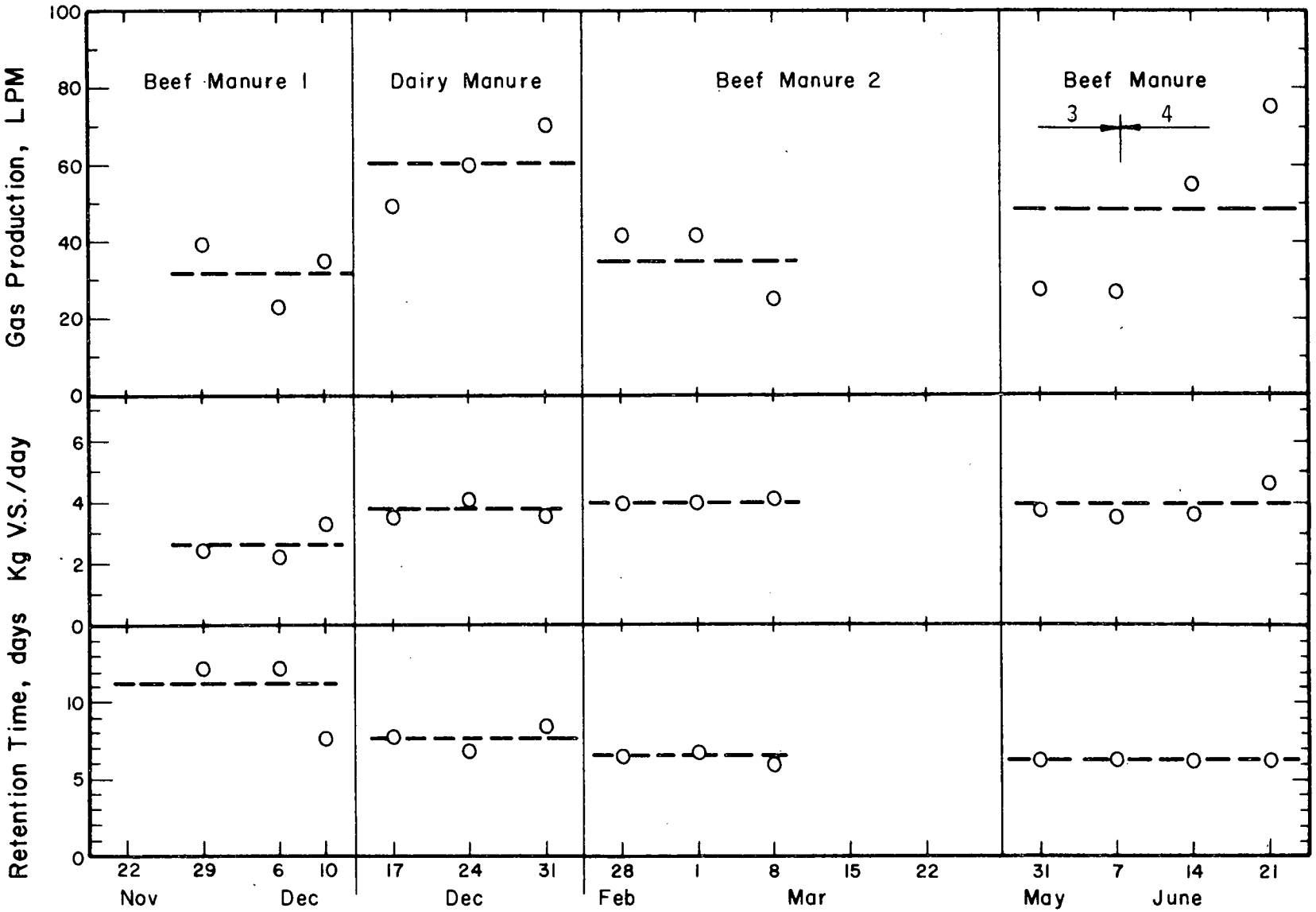

Figure 8. Variation in Retention Time, Loading Rate and Gas Production for Reactor 4

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 9, reactor temperature reductions occurred three times, with the temperature dropping to 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 10. 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 9 and 10 corresponds to Day 77151. The data for this period are given in Appendix A, Tables A-4.1 and A-4.2.

D. Nitrogen Analysis

The organic content of the manure used to date has been relatively high. The beef manure was obtained from open lots. The second

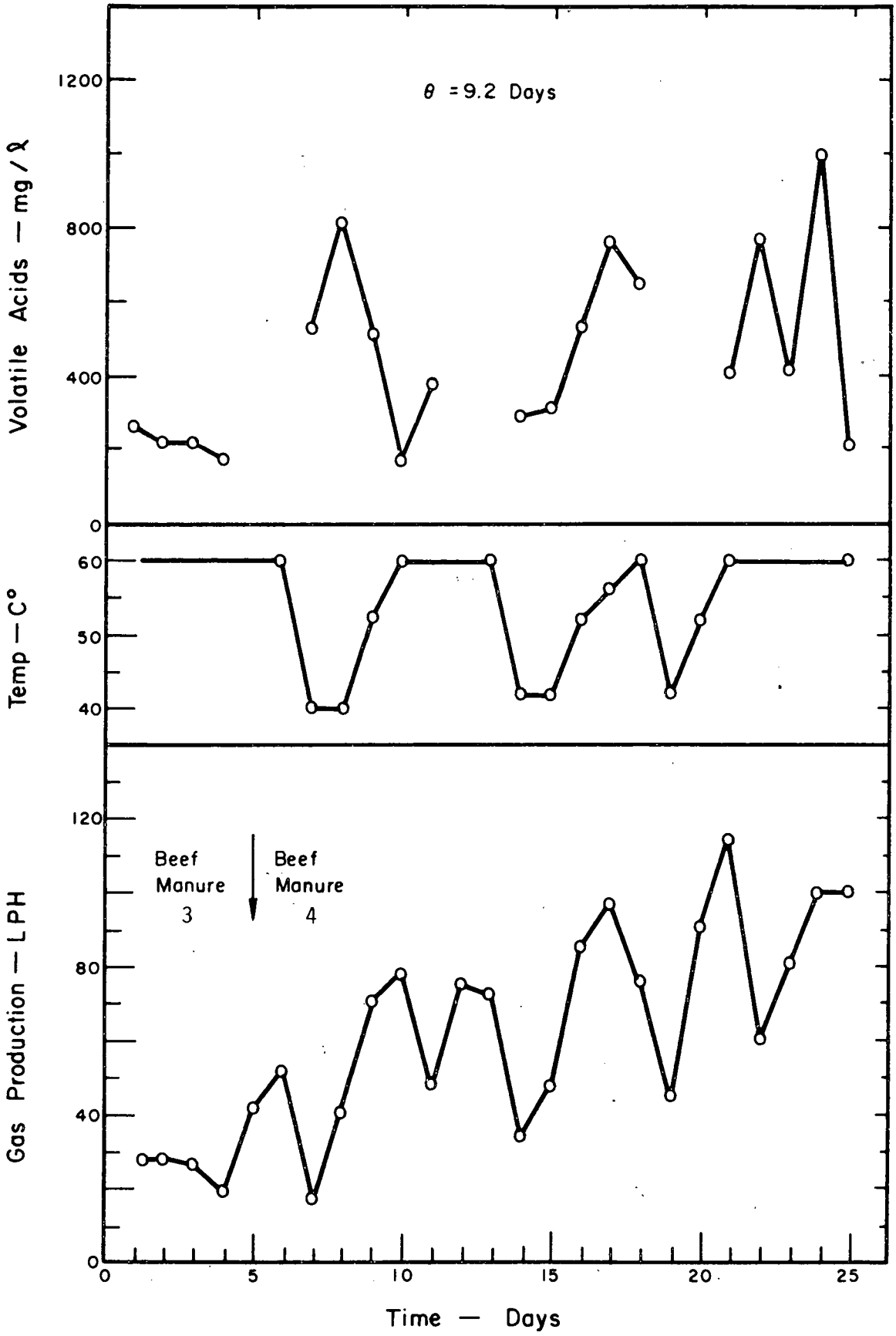

Figure 9. The Effect of Temperature Change on Reactor Stability

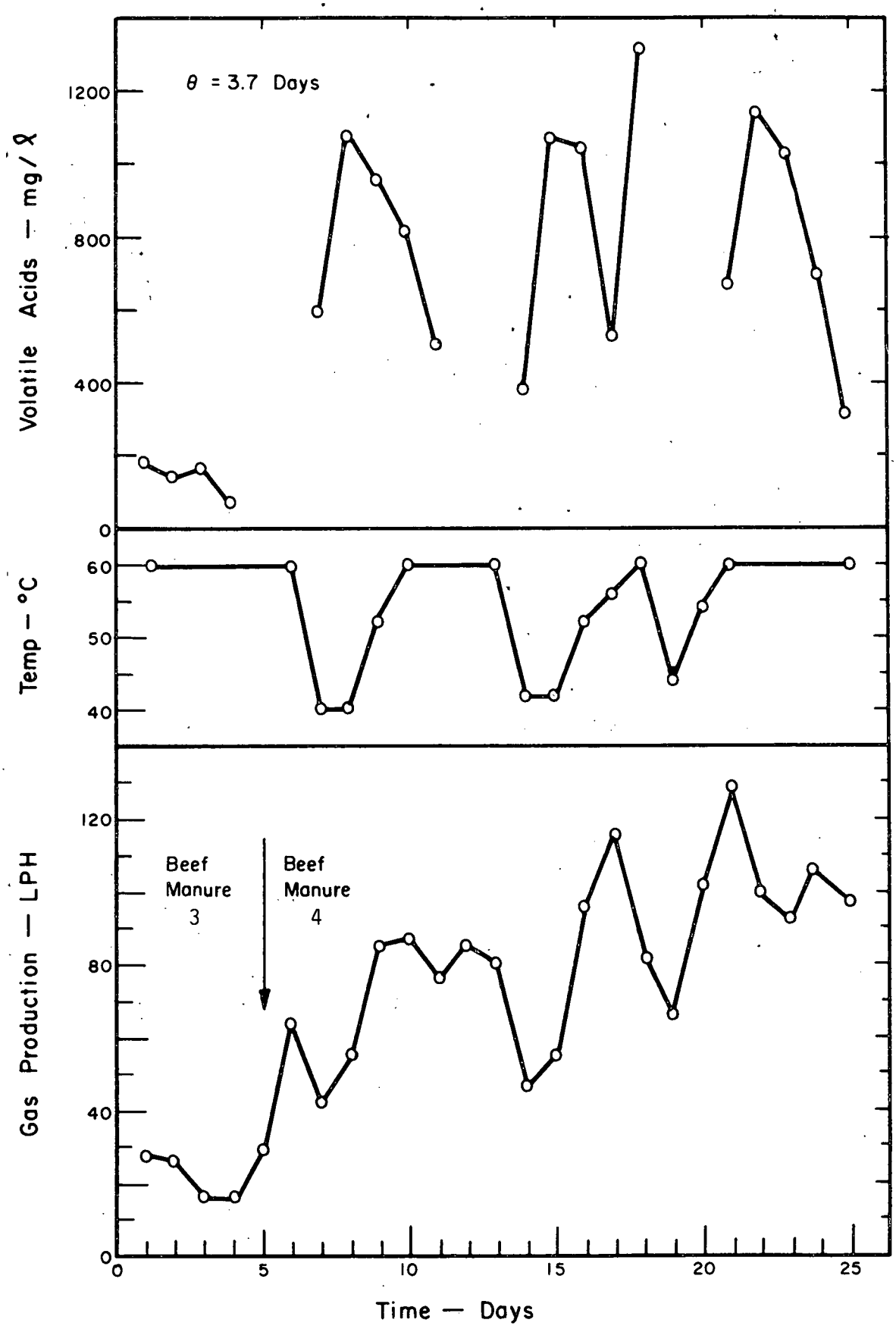

Figure 10. The Effect of Temperature Change on Reactor Stability

and third batches did contain a small amount of bedding. The volatile solids content of the manure ranged from 60 to 72 percent with the dairy manure producing the highest volatile solids.

The nitrogen content in the feed slurry is given in Table 7. These data represent only one set of analyses. The TKN does not exhibit much variation for the three different manures. However, there is a substantial variation in the ammonia content. This variation was also observed by the intense ammonia odor associated with the first beef lot manure stored in the test bay.

Table 7. Nitrogen Content in the Feed Slurry

	Vol. Solids - %	TKN - mg/ℓ N	NH_3 - mg/ℓ N
	Beef Lot Manure 1		
Holding Tank 1	3.67	1679	1180
Holding Tank 2	3.95	2001	1008
	Dairy Manure		
Holding Tank 1	3.38	1134	280
Holding Tank 2	3.54	1652	454
	Beef Lot Manure 2		
Holding Tank 1	3.06	1624	353
Holding Tank 2	3.38	1736	302

The nitrogen content in the reactors was determined at the same time the feed slurry was analyzed. These data are shown in Table 8 and represent the results of only one analysis on each reactor.

Table 8. Nitrogen Content in Fermentors

Fermentor	Vol. Solids - %	TKN - mg/ℓ N	NH_3 - mg/ℓ N
	Beef Lot Manure 1		
1	2.56	1548	1054
2	2.24	1666	850
3	2.18	1694	848
4	2.12	1409	731
	Dairy Manure		
1	2.51	1680	920
2	2.39	1666	1025
3	2.03	1554	781
4	2.40	1638	645

The TKN of the feed slurry is essentially equal to the TKN in the fermentors. In the first beef lot manure tested, the high ammonia in the feed slurry did not change significantly in the fermentor. This would suggest that a substantial portion of the organic nitrogen had been hydrolyzed to ammonia before the manure was fed to the fermentation system. The converse was true for the dairy manure. A significant amount of TKN was organic nitrogen. The dairy manure was freshly collected and processed.

II. Results of Plug-Flow, Two-Stage and Complete-Mix Reactor Studies

Three laboratory scale reactors with a volume of 43 ℓ have been constructed for this phase of the study. One reactor (A) was completely mixed. The second reactor (B) was a two-stage system with the first stage accounting for one-third of the total reactor volume. Both stages are completely mixed. The third reactor (C) consisted of four

complete mixed compartments in series.

Substrate for this study was shredded computer paper plus a small quantity of sewage sludge or beef manure added for microorganism seed and micronutrients (see Table 2). Additional nitrogen and phosphorus were added to provide a balanced substrate. An appropriate quantity of base was added to the substrate to maintain the pH at 6.8 to 7.0 in the completely mixed reactor. The reactors were initially seeded with cultures from the larger manure fermentation system. The initial pH in all reactor stages was in the 7.2 to 7.5 range. The alkalinity was approximately 2700 to 2800 mg/ℓ and the volatile acids were approximately 300 mg/ℓ. This run was initiated on January 15, 1977. The total retention time in all three reactors was 10 days with a fermentation temperature of 60°C.

The amount of caustic added to the substrate was sufficient to maintain the pH in reactor A at 6.7 or greater under normal operating conditions. While this caustic was adequate to maintain the pH in reactor A, the pH in all other reactors eventually dropped to inhibitory levels. These data are shown in Figure 11. Reactor C failed in a short period due to these inhibitory pH levels. The pH in the first stage of reactor B dropped to low levels, but it was only after about 30 days that pH in the second stage began to drop. The associated alkalinity and volatile acids are shown in Figure 12.

After about 30 days after start-up, the pH in both reactors A and B-2 began to decrease. Apparently some micronutrient was missing in the feed slurry. Additional caustic was required to maintain the pH in reactor A. As a result of the increased caustic addition, the pH in

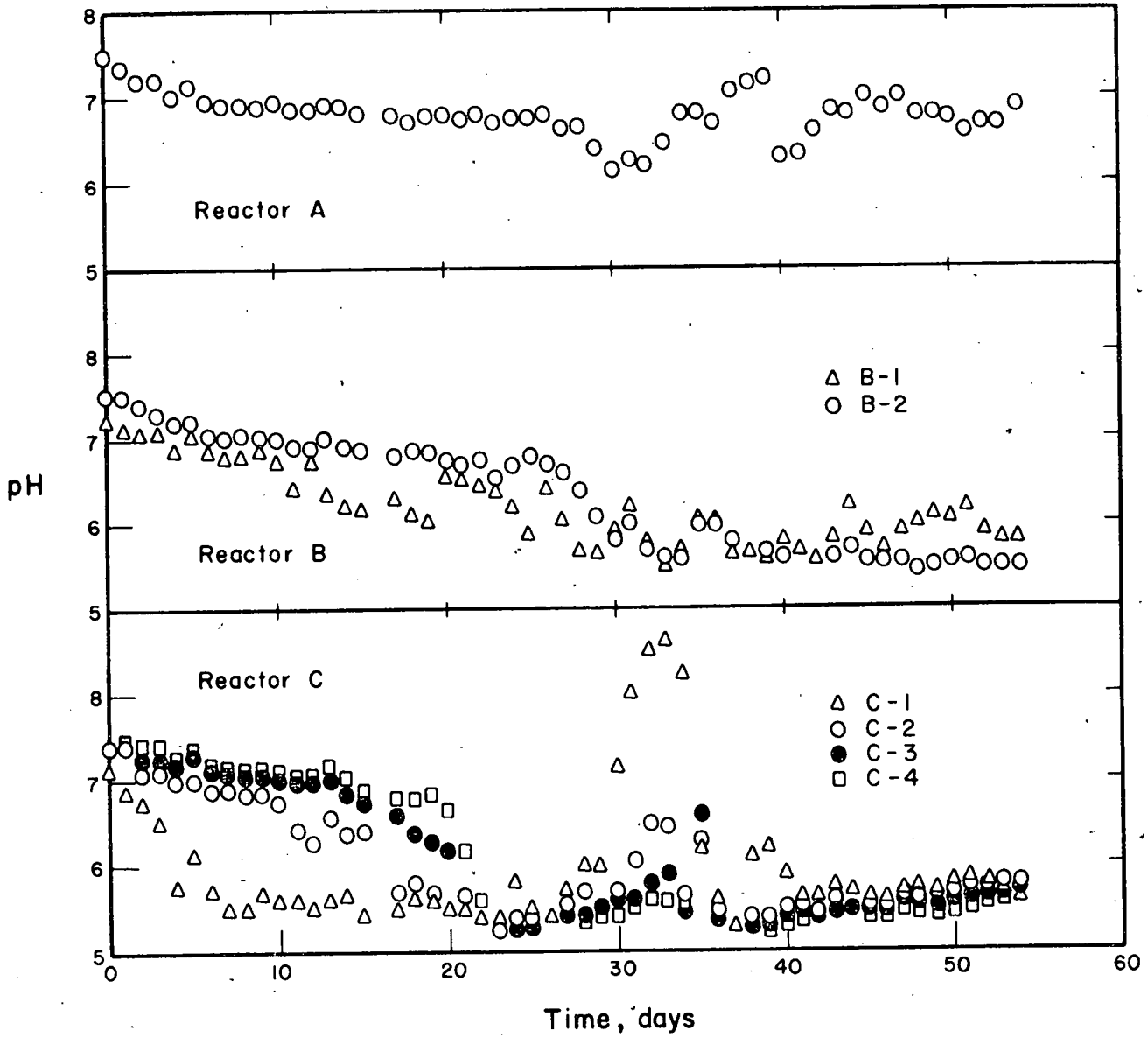

Figure 11. Variation in pH in Reactors A, B and C

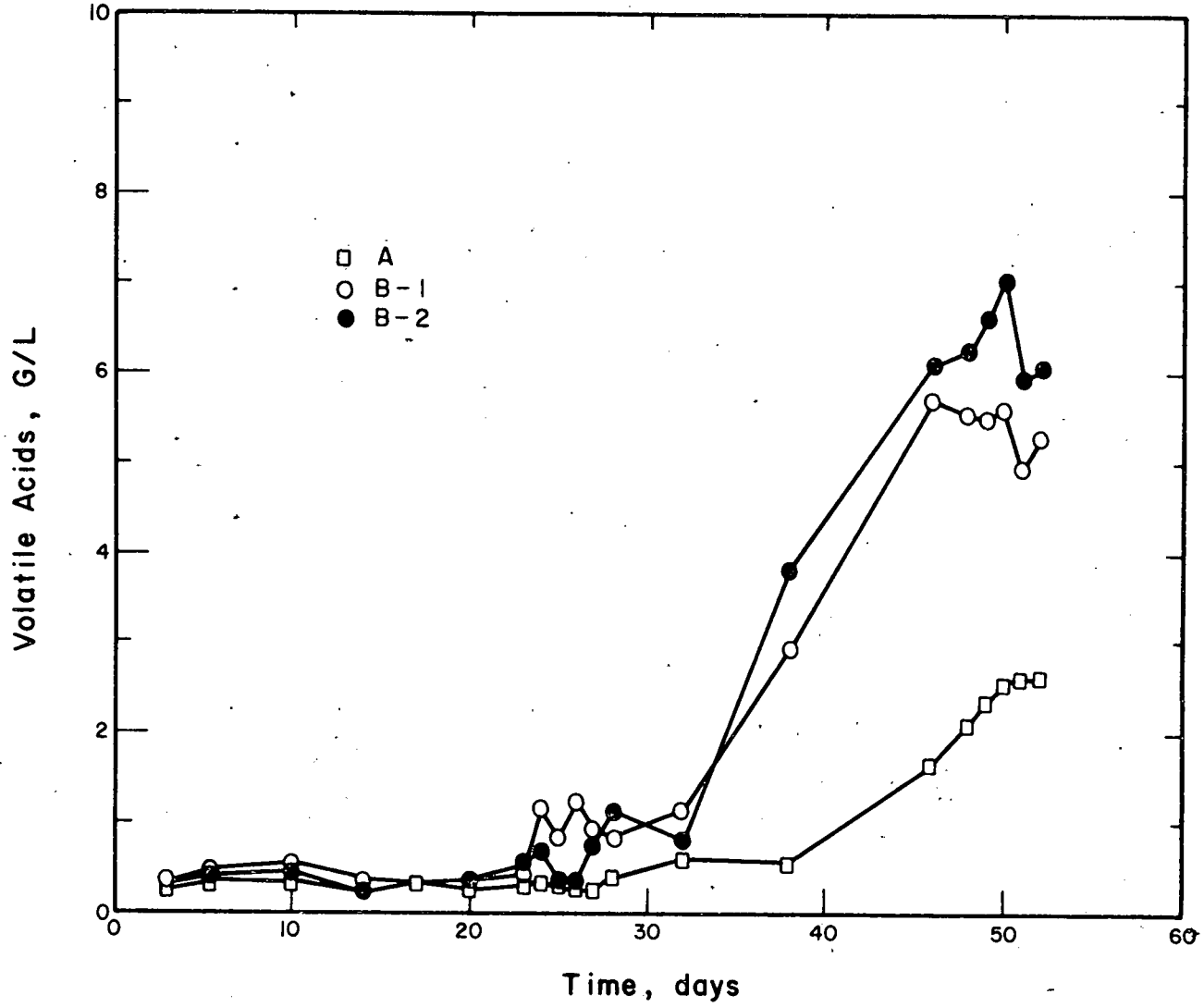

Figure 12. Volatile Acids Concentration in Reactor A and Reactors B-1 and B-2

reactors B-1 and C-1 increased significantly. The volatile acids are shown in Figures 12 and 13.

The volatile acids in reactor A increased slightly during this period. In reactors B-1 and B-2, there was a significant increase in volatile acids. In reactor C, the volatile acids started to increase in stage 1 after about 10 days. A continued increase was observed in all stages during the balance of the run, reaching levels in excess of 6000 mg/ℓ as acetic acid.

On about day 30, a small quantity of sewage sludge was added to the feed slurry to supplement the trace nutrients. Reactor A responded favorably for about 15 days. The volatile acids began to increase again. During this period, the volatile acids in reactor B-1 increased to greater than 6000 mg/ℓ while B-2 increased to about 5500 mg/ℓ. These data show that the two-stage system functioned reasonably well when the system was not stressed. However, when a stress was applied, the two-stage system failed rapidly. The complete mix reactor was considerably more stable. Complete failure occurred in reactor C in about 20 days.

The volatile solids destruction and gas production are shown in Table 9. The feed slurry to the reactors contained 29.9 g/ℓ total solids and 24.5 g/ℓ volatile solids. The COD of the feed slurry was 29.1 g/ℓ. These data clearly show that the complete mix reactor produces a higher gas production than either of the other two reactor designs. The methane production per kg of volatile solids added in reactor A appears to be low. The measured methane production was 0.229 m^3/kg volatile solids added for reactor A, 0.126 m^3/kg volatile solids added for reactor B and 0.06 m^3/kg volatile solids added for reactor C. Based on a measured COD

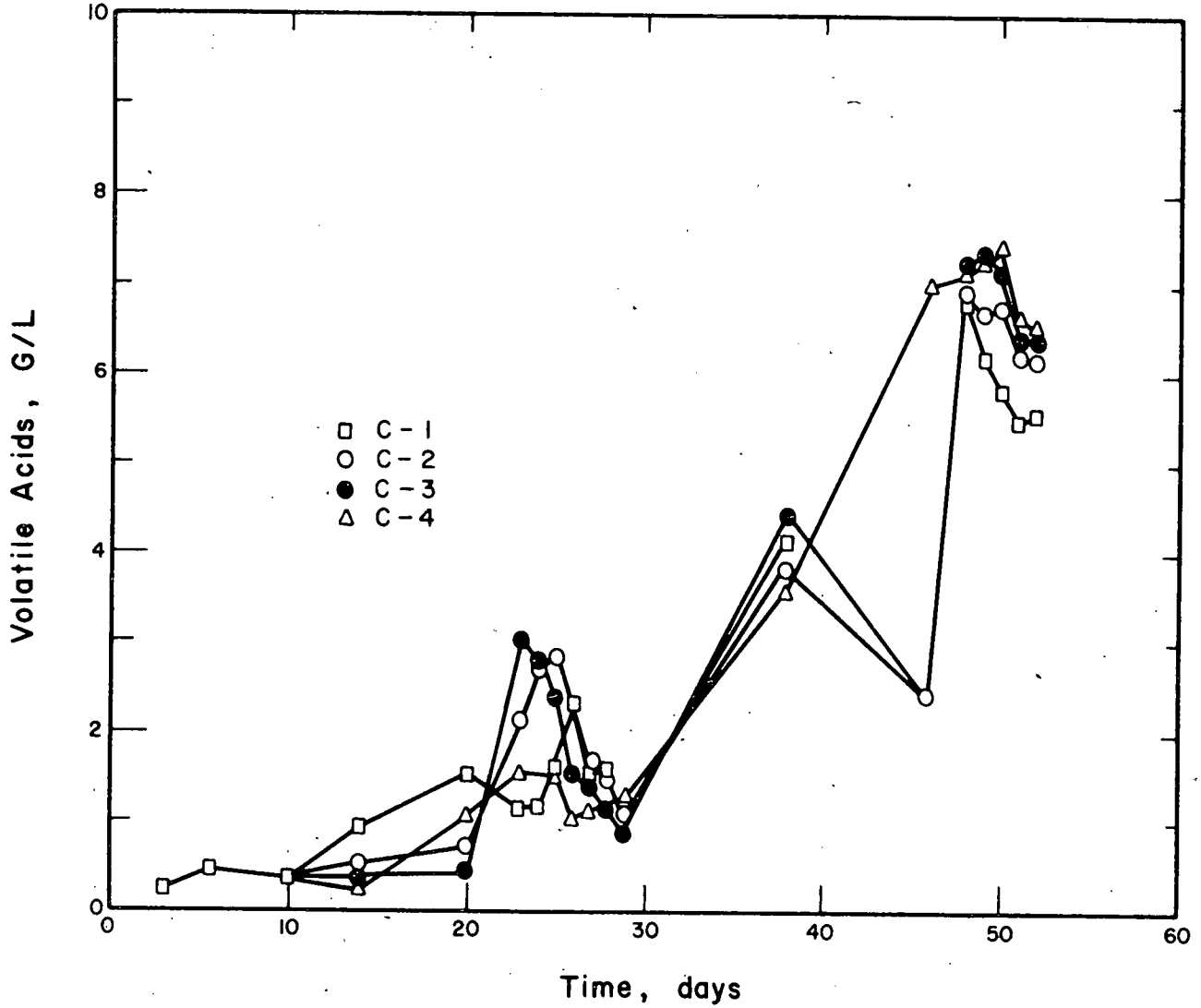

Figure 13. Volatile Acids Concentration in Reactors C-1, C-2, C-3 and C-4

Table 9. COD and Volatile Solids Reduction

Reactor	θ Days	Vol. Solids - g/ℓ S_o	Vol. Solids - g/ℓ S_e	COD - g/ℓ S_o	COD - g/ℓ S_e	K - Day^{-1} Vol. Sol.	K - Day^{-1} COD
A	10	24.5	6.3	29.9	7.6	0.289	0.293
B-1	5	24.5	13.4	29.9	23.1	0.166	0.059
B-2	5	13.4	7.8	23.1	21.7	0.144	0.013
C-1	2.5	24.5	20.1	29.9	26.9	0.088	0.045
C-2	2.5	20.1	14.1	26.9	27.0	0.170	-
C-3	2.5	14.1	12.9	27.0	26.9	0.037	-
C-4	2.5	12.9	12.0	26.9	25.8	0.030	0.017

reduction of 73.8 percent in reactor A, the calculated methane production is 0.306 m^3/ kg VS added. In reactor B, the calculated methane production based on COD reduction is 0.106 m^3/kg VS added. For reactor C, this calculated methane production is 0.047 m^3/kg VS added.

The calculated rate constants from $S_e/S_o = 1/(1 + K\theta)$ for reactor A are comparable based on either volatile solids or COD. However, in reactors B and C, there is no comparison between the constants. It is clear that the volatile solids destruction results from hydrolysis of the solids to volatile compounds that are lost when the solids analyses are performed. These constants show severe inhibition of organic stabilization in both reactors B and C.

Although these data show that the complete mix reactor operates more efficiently than the two-stage or plug-flow units, it appears that the microbial system was stressed. Reactor A did not operate as efficiently as expected. At 60°C and 10-day retention time, the volatile

acids should be low, less than 500 mg/ℓ. Prior experience with 5-day retention times show efficient operation. Therefore, reactor B should not have failed.

A second run was made with a modification of the substrate and a longer total retention time. When the retention time was increased to 14.6 days, reactors A and B began to recover slowly as evidenced by all parameters. This is shown by the first 30 days in Figures 14 through 17. On Day 35, the manure supplement was started. The operation of reactors A and B further improved. Also, once the manure addition was started reactor C improved significantly in all four stages. As shown in Figure 18, the volatile acids ranged from 2000 mg/ℓ in the first stage to 200 mg/ℓ in the last stage.

Initially both reactors B and C required caustic in addition to that present in the feed slurry. The volatile acids in reactor B improved so that on Day 14, additional caustic was not required for pH control. On Day 33, the caustic addition to reactor C was reduced to 10 g/day. By Day 54, it was no longer necessary to add any additional caustic to reactor C.

Figure 14 shows the gas production from all three reactors. The gas from reactor A was consistently in the range of 60 ℓ per day. The dip in gas production for Days 40 through 60 was the result of a decrease in the concentration of the feed solids. Shortly after Day 50, the mixer in reactor B failed. Additional data could not be collected from this unit. During the period from Day 60 to 80, the gas production from reactors A and C were reasonably constant, with C producing slightly more gas.

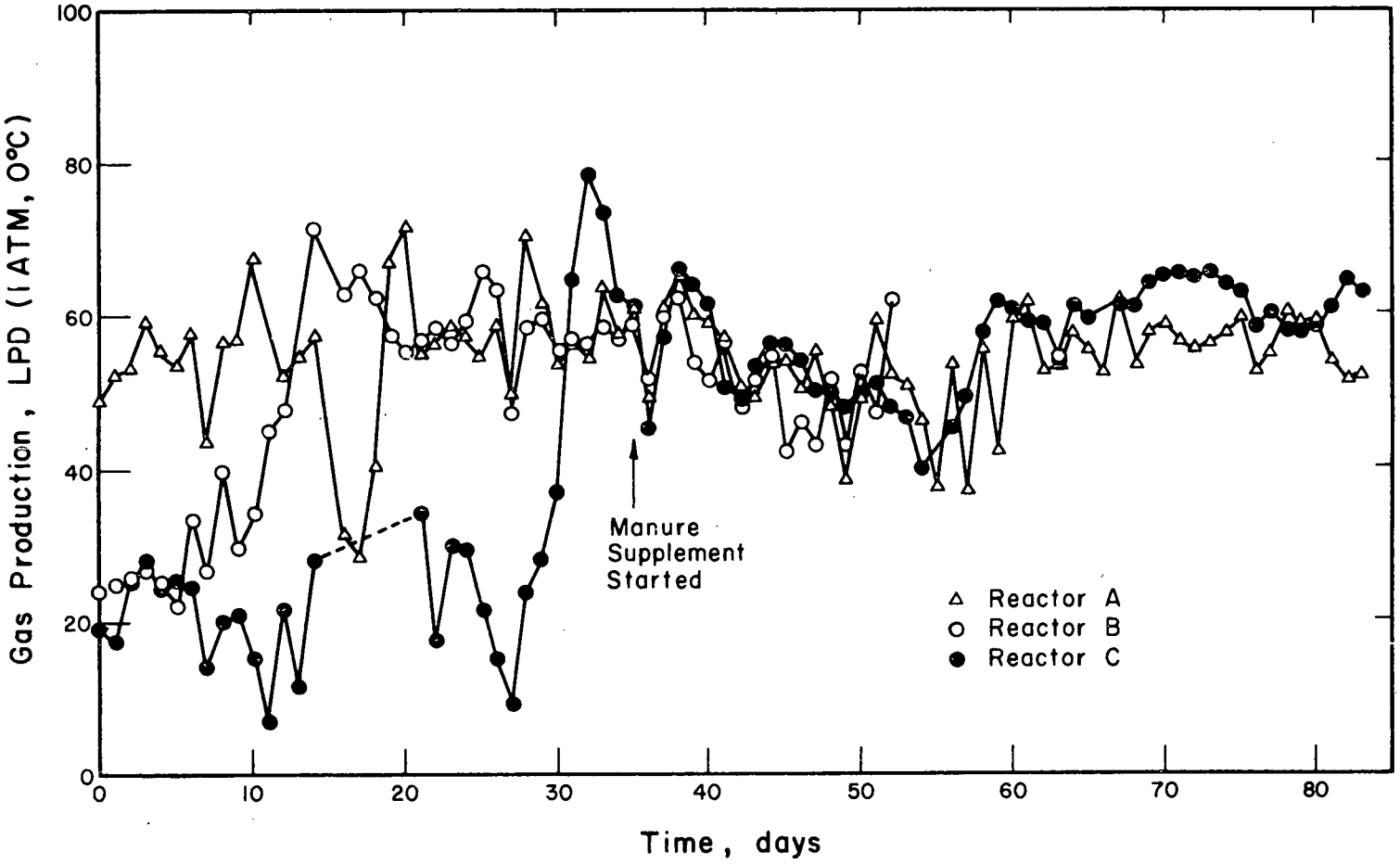

Figure 14. Gas Production from Reactors A, B and C

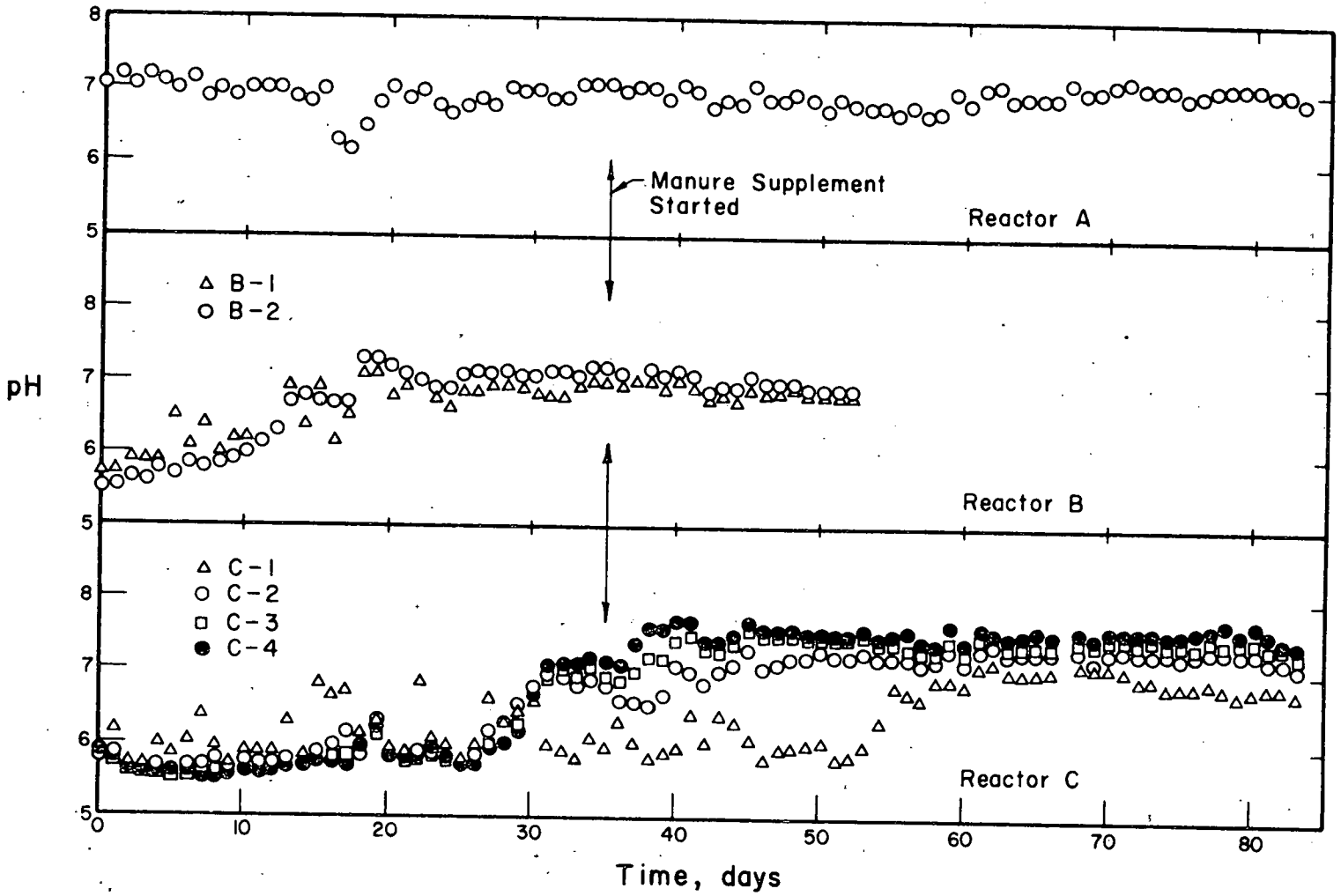

Figure 15. Variation in pH for Reactors A, B and C

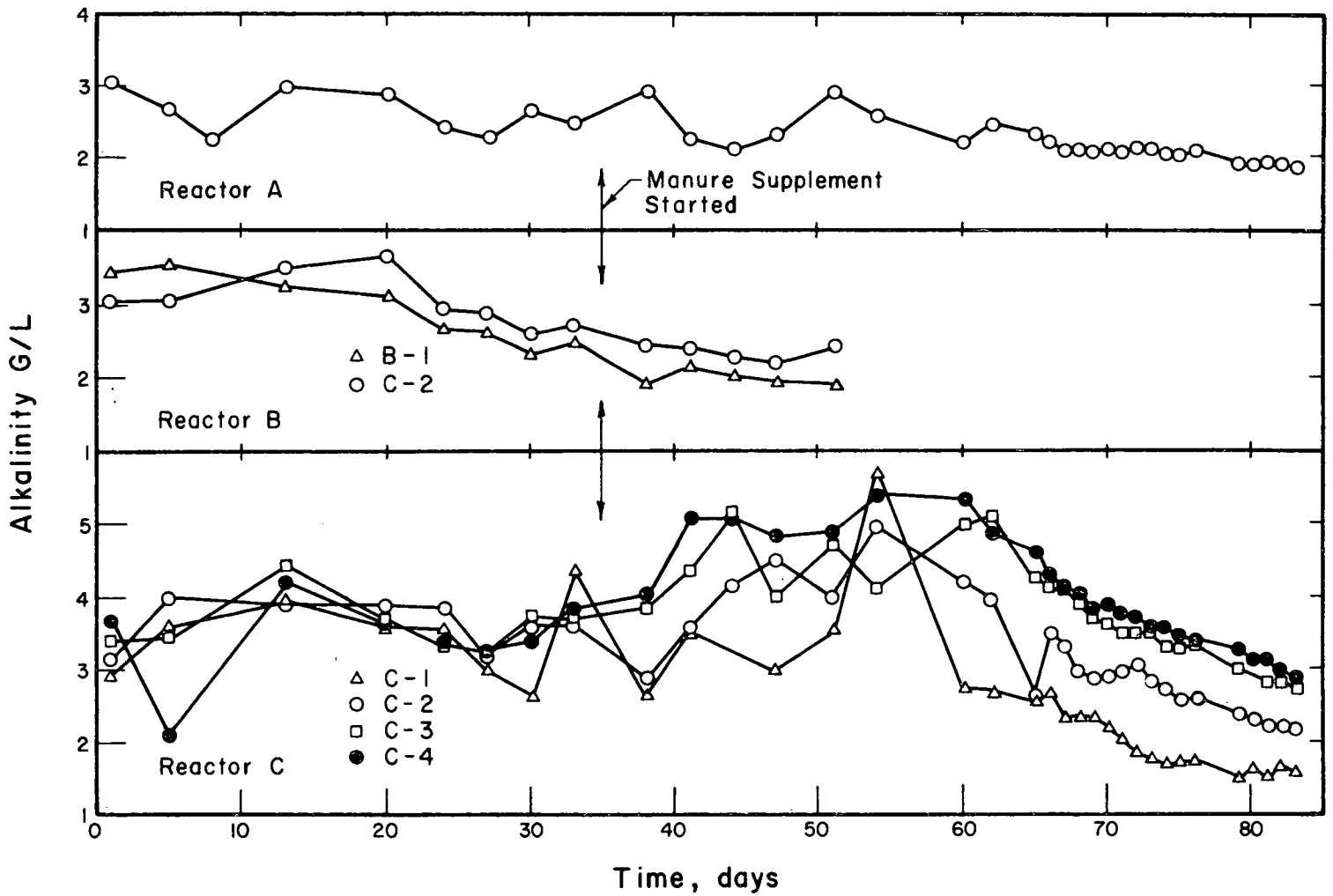

Figure 16. Variation in Alkalinity for Reactors A, B and C

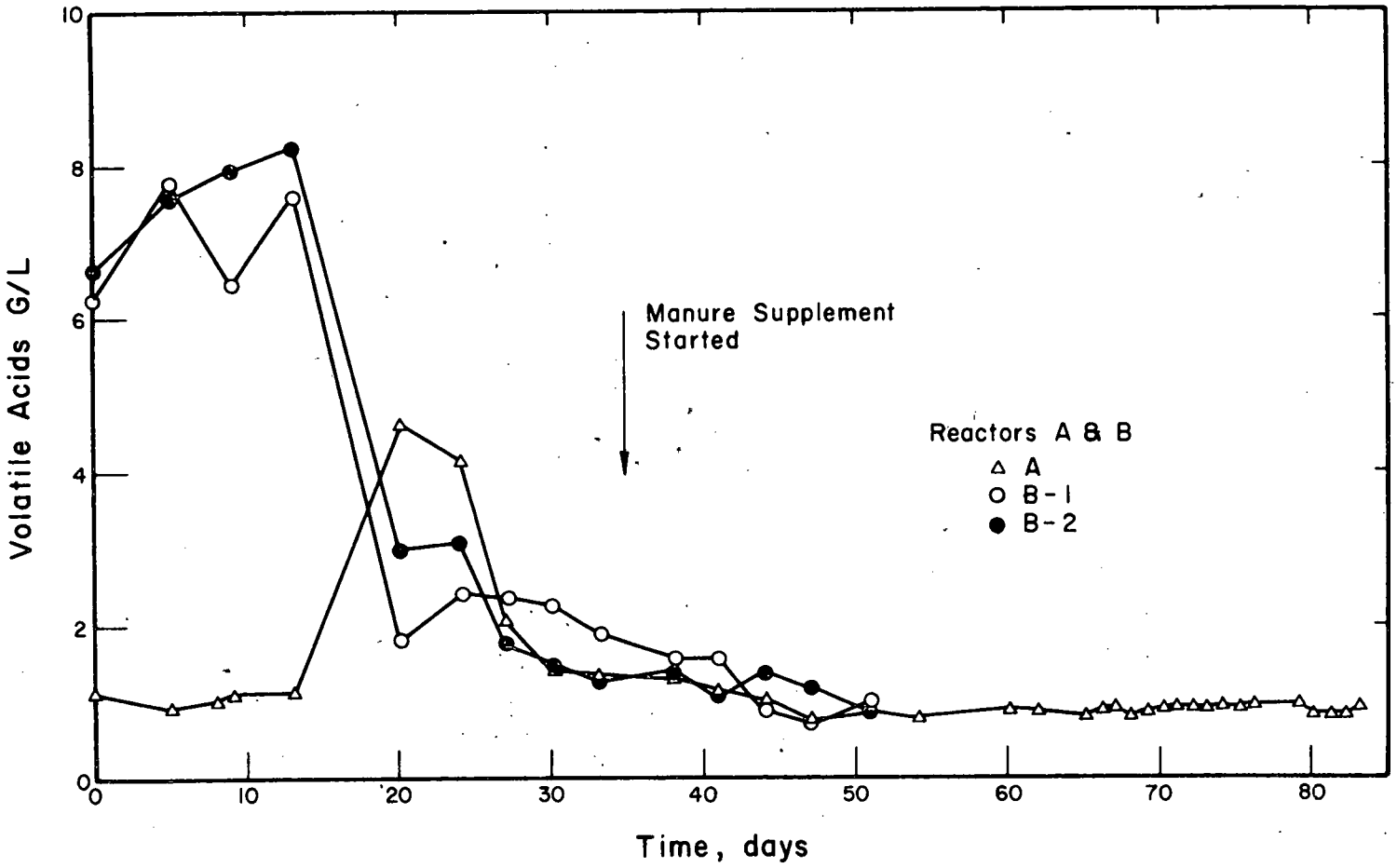

Figure 17. Variation in Volatile Acids for Reactors A and B

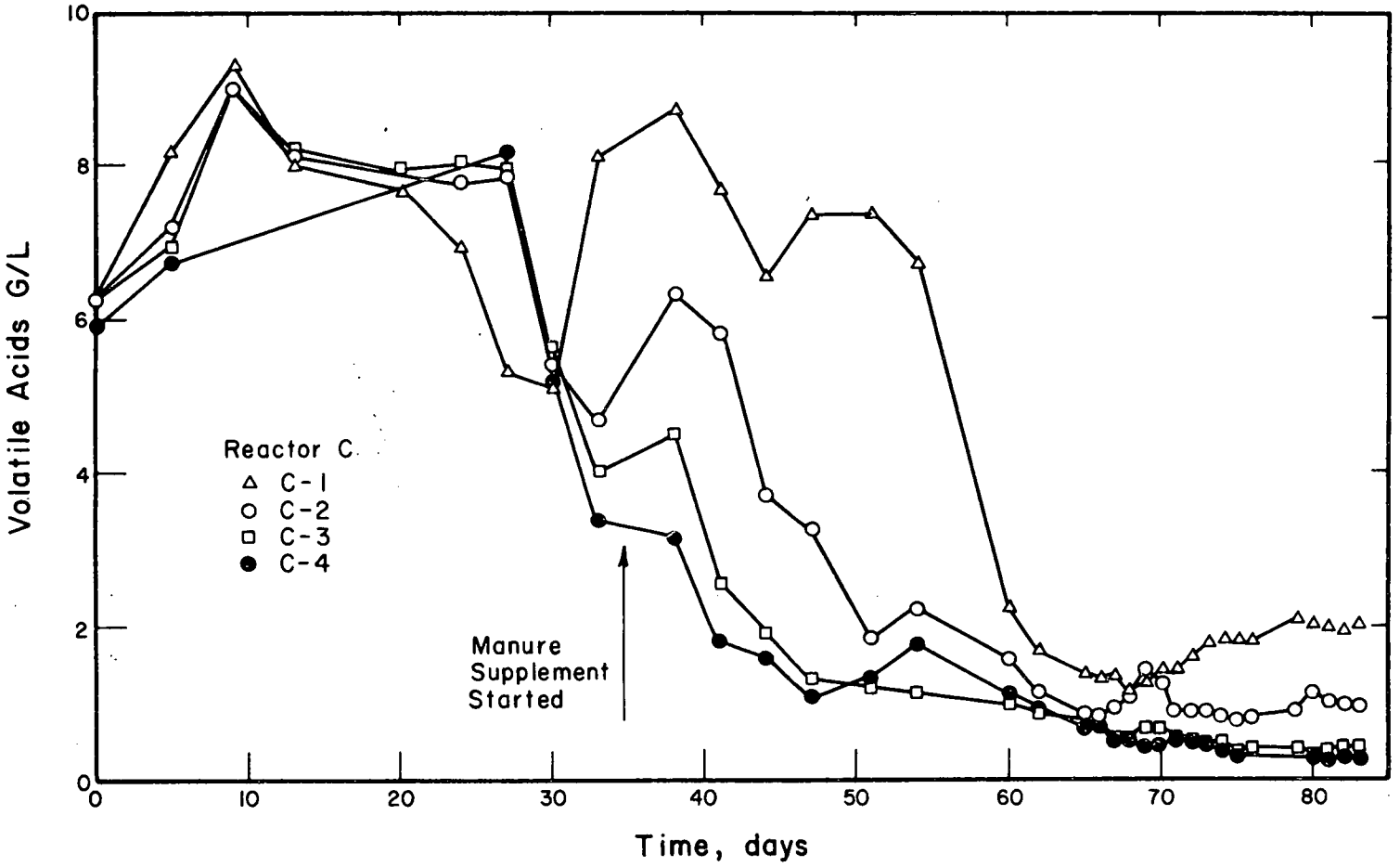

Figure 18. Variation in Volatile Acids for Reactor C

An intensive sampling period was initiated on Day 60. The average of 13 analyses for volatile solids concentration and chemical oxygen demand (COD) is shown in Table 10. Using these data and the kinetic relationship $S_e/S_o = 1/(1 + K\theta)$, the rate constant K for each chamber was calculated. These data are very interesting. The total volatile solids destruction and COD reduction was higher in reactor C than in reactor A. In fact, the effluent from the second stage with a total retention time of 7.32 days was superior to the effluent from reactor A with a 14.6 day retention time.

Table 10. COD and Volatile Solids Reduction

Reactor	θ Days	Vol. Solids - g/ℓ		COD - g/ℓ		K - Day^{-1}	
		S_o	S_e	S_o	S_e	Vol. Sol.	COD
A	14.63	41.54	10.7	51.0	15.15	0.197	0.162
C-1	3.66	41.54	19.5	51.0	25.3	0.309	0.278
C-2	3.66	19.5	10.5	25.3	14.3	0.234	0.210
C-3	3.66	10.5	9.2	14.3	12.4	0.039	0.042
C-4	3.66	9.2	9.1	12.4	12.2	0.003	0.004

As shown in Table 11, the gas production in m^3/kg volatile solids fed and m^3/m^3 of reactor volume was greater in reactor C than in reactor A. As expected, the gas production per kg of volatile solids destroyed is constant. The methane production is given in Table 12. The measured methane production is in close agreement with the theoretical gas production as calculated from the COD reduction.

Table 11. Gas Production

Reactor	m^3/m^3-Day	m^3/kg VS Fed	m^3/kg VS Destroyed
A	1.3	0.456(7.32 SCF)	0.75
C	1.5	0.517(8.30 SCF)	0.77

Table 12. Methane Production - lpd

	Measured	Theor. (COD Red.)
A	37.0	36.89
C	41.3	40.32

The results of these two runs clearly show that if a balanced population of organisms can be maintained in the initial stage, a multi-stage fermentation is more efficient than a complete-mix system. However, if the system is stressed, failure of the multistage system is more rapid. Consequently, care must be exercised in the design of these units. If the objective is to maximize the conversion of solids to methane, a staged system will produce more methane per unit volume of reactor. If the objective is to maximize methane production per unit volume of reactor, a single stage reactor operating at near the critical retention time is required. Based on the COD reduction, 66.3 percent of the methane was produced in the first stage. The methane produced in the second stage was 28.4 percent of the total.

APPENDIX

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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	75.70	6.97	1700.00	32934.00	19711.00	-1.00	-1.00	288.00	-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	17.40	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	288.00	-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	15.40	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	7.18	-1.00	-1.00	-1.00	-1.00	-1.00	168.00	-1.00

Table A-1.1. BEEF 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 %
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										
16.15	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	144.00	-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	41893.00	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										
17.30	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	87.06	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	120.00	-1.00

Table A-1.2. EPRP MANURE RUN #1 REACTOR #2 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 %
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	216.00	-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	36606.00	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-1.3. BEEF MANURE RUN #1 REACTOR #3 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 %
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	52.39	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	45598.00	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										
15.00	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	109.77	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	120.00	-1.00

Table A-1.4. BEEF MANURE RUN #1 REACTOR #4 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 12.10	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

Table A-2.1. DAIRY MANURE RUN #2 REACTOR #1 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. [illegible]	[illegible]
76346 12.10	1625.00	105.98	7.25	6468.00	80416.00	53674.00	42262.00	25183.00	-1.00	-1.00
76347 11.30	2833.00	90.84	7.30	-1.00	-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	-1.00
76349 14.30	2886.00	102.20	7.25	5964.00	76036.00	51387.00	44303.00	26686.00	-1.00	-1.00
76350 14.30	1361.00	75.70	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	312.00	-1.00
76351 10.00	2540.00	90.84	7.30	6206.00	30463.00	21958.00	44063.00	27352.00	-1.00	-1.00
76352 14.45	630.00	94.62	7.30	-1.00	-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	-1.00
76354 9.30	2399.00	90.84	7.20	-1.00	-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	-1.00
76356 12.40	2528.00	83.27	7.15	6166.00	65668.00	46782.00	37295.00	25058.00	-1.00	-1.00
76357 13.20	1456.00	102.20	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	144.00	-1.00
76358 16.20	2953.00	102.20	7.30	5964.00	60728.00	43541.00	39083.00	26638.00	-1.00	-1.00
76359 13.50	1528.00	98.41	7.40	-1.00	-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	-1.00
76361 10.50	2157.00	94.62	7.50	6488.00	-1.00	-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	-1.00
76363 10.50	2173.00	98.41	7.40	6529.00	-1.00	-1.00	-1.00	-1.00	120.00	-1.00
76364 11.20	800.00	98.41	7.40	-1.00	51644.00	35452.00	43569.00	27627.00	-1.00	-1.00
76365 10.20	2527.00	56.78	7.40	6367.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A-2.2. 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.	CH4 %
76346 12 13	174.00	94.62	7.30	5324.00	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	60.00
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 30	862.00	87.06	7.30	5813.00	75238.00	51629.00	34573.00	20983.00	-1.00	-1.00
7635 14 30	2535.00	83.27	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	384.00	-1.00
76351 10 30	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	94.84	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76353 9 00	2471.00	94.62	7.20	-1.00	26987.00	20270.00	33467.00	21764.00	-1.00	-1.00
76354 9 3.	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	94.84	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76356 12 4.	542.00	87.06	7.30	5844.00	61845.00	44391.00	30828.00	20989.00	-1.00	-1.00
76357 13 2.	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	102.23	7.40	6327.00	56618.00	40525.00	34935.00	23433.00	-1.00	-1.00
76359 13.5.	2904.00	102.23	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 10 50	2884.00	94.84	7.50	5964.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
76362 10.50	1474.00	-1.00	7.40	-1.00	49303.00	34156.00	32467.00	20091.00	-1.00	-1.00
76363 10 50	2142.00	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 10 20	619.00	56.78	7.10	5723.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A-2.3. DAIRY MANURE RUN #2 REACTOR #3 START DEC 11, 1976

DATE/TIME	GAS METER	FEED RATE	PH	ALKALINITY	FEED T.S.	FEED V.S.	EFF. T.S.	EFF. V.S.	EFF. V.A.	CH4 %
76346 12.10	318.00	90.84	7.30	5561.00	84672.00	55776.00	39387.00	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	60.30
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	87.96	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	61845.00	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 15.20	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 10.50	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 10.50	1503.00	94.62	7.30	-1.00	49303.00	34156.00	35591.00	21721.00	-1.00	-1.00
76363 10.50	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

Table A-2.4. DAIRY MANURE RUN #2 REACTOR #4 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.	CH4 %
77060 13.00	1944.00	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	80.00	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	32208.00	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	1831.00	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

Table A-3.1. BEEF MANURE RUN 3 REACTOR 1 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	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	79.90	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77088 10.30	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	83.60	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	44397.00	29345.00	600.00	-1.00

Table A-3.1. (continued) BEEF MANURE RUN 3 REACTOR 1 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 %
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 13.00	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	49185.00	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-3.2. 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	118.90	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	1189.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A-3.2. (continued) 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 %
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 12.40	2808.00	121.00	7.10	5100.00	50619.00	34284.00	41988.00	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

Table A-3.3. BEEF MANURE RUN 3 REACTOR 3 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	1956.00	122.60	7.40	3789.00	48791.00	32360.00	47365.00	29830.00	-1.00	-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 10.30	368.00	122.60	7.30	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
77088 10.30	1122.00	-1.00	7.30	3684.00	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

Table A-3.3. (continued) BEEF MANURE RUN 3 REACTOR 3 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 %
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-3.4. BEEF MANURE RUN 3 REACTOR 4 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	-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

Table A-3.4. (continued) BEEP MANURE RUN 3 REACTOR 4 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 %
77145 8.15	2954.00	-1.00	7.00	2306.00	47112.00	28883.00	54454.00	30255.00	216.00	-1.00
77146 8.15	460.00	79.60	7.20	2523.00	34663.00	24066.00	30927.00	18655.00	192.00	-1.00
77147 8.00	883.00	79.60	7.10	2218.00	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 9.20	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	26835.00	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	2020.00	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	42978.00	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	64.40
77166 8.10	223.00	80.00	7.20	3306.00	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	384.00	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-4.1. BEEF MANURE RUN #4 REACTOR #1 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	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 8.05	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	49700.00	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

Table A-4.1. (continued) BEEF MANURE RUN #4 REACTOR #1 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 %
77145 8.15	294.00	-1.00	7.00	2132.00	47112.00	28883.00	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	2480.00	38353.00	25139.00	51056.00	31516.00	144.00	-1.00
77153 8.10	2680.00	201.00	7.10	2218.00	46829.00	30045.00	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 9.05	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	205.60	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	2958.00	49369.00	36223.00	47829.00	34107.00	384.00	-1.00
77165 8.15	1997.00	200.00	6.90	3045.00	44505.00	33518.00	49038.00	34943.00	1080.00	59.40
77166 8.10	1300.00	200.00	7.10	3088.00	46101.00	36196.00	49864.00	36382.00	1056.00	67.40
77167 8.20	1102.00	200.90	7.50	3436.00	51282.00	39268.00	47788.00	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-4.2. 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	-1.00
77171 8.10	-1110.00	200.00	7.40	4046.00	56778.00	39642.00	55923.00	39293.00	672.00	60.10
77172 8.10	483.00	200.00	7.50	4306.00	58569.00	43275.00	58287.00	41214.00	1152.00	61.70
77173 8.05	2679.00	203.80	7.50	3825.00	56357.00	40063.00	56195.00	35254.00	1032.00	59.30
77174 8.05	2217.00	200.00	7.70	5175.00	52132.00	39222.00	55456.00	39022.00	696.00	61.10
77175 8.10	1595.00	203.80	7.70	4455.00	51172.00	37113.00	56043.00	37878.00	312.00	61.20
77176 9.30	1005.00	200.00	7.40	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A-4.2. (continued) 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 %
77145 8.15	38.00	-1.00	7.10	2306.00	42751.00	24492.00	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	32034.00	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	1685.00	159.20	7.20	2349.00	43223.00	26273.00	53819.00	32854.00	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	34688.00	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	2382.00	163.80	7.20	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A-4.3. BEEF MANURE RUN #4 REACTOR #3 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	1564.00	160.00	7.60	-1.00	-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	63.10
77172 8.10	2673.00	160.00	7.60	4654.00	55559.00	40124.00	55520.00	39649.00	768.00	68.20
77173 8.05	1602.00	165.70	7.60	4185.00	55979.00	40923.00	56812.00	39095.00	408.00	63.30
77174 8.05	1010.00	160.00	7.80	4050.00	50568.00	38415.00	55685.00	39920.00	1008.00	62.20
77175 8.10	412.00	160.00	7.80	4545.00	50781.00	36470.00	55579.00	38762.00	312.00	62.00
77176 9.30	2600.00	160.00	7.60	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00

Table A-4.3. (continued) BEEF MANURE RUN #4 REACTOR #3 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 %
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 9.20	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 8.10	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

Table A-4.4. BEEF 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.	CH4 %
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	66.40
77173 8.35	2282.00	120.00	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

Table A-4.4. (continued) BEEF MANURE RUN #4 REACTOR #4 START MAY 25, 1977