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BIOLOGICAL CONVERSION OF BIOMASS TO METHANE

QUARTERLY PROGRESS REPORT
for Period September 1, 1976 - November 30, 1976

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DISCLAIMER

Introduction

During the past quarter all experimental systems have become operational. The earlier problems with equipment acquisition have delayed the progress somewhat. However, most of these problems have been overcome such that the experimental programs have been initiated. This report will concentrate on the manure fermentation portion of this project. The study relating to the effect of reactor design is underway, but the results are too preliminary to evaluate. Therefore, no data from this activity will be reported.

Manure Fermentation System

The fermentation system shown in Figure 1 has been completely assembled and is operational. An operational problem has developed that prevents operation of the system on a continuous feed basis. The manure used as feed material contains soil and sand particles plus hulls and husks that settle in the pipe if a minimum flow velocity is not maintained. The feed pumps can pump the material into the reactors, but the effluent lines plug as a result of these particles settling in the effluent lines. The effluent lines must be cleaned prior to pumping the feed into the reactors. The system will be modified by providing effluent pumps that operate on a float control switch.

A variable speed mixer with a recording watt meter has been installed in each reactor. The reactor and mixer design is shown in Figure 2. Power measurements were made with the reactors empty, filled with tap water at $20^{o}C\pm$ and $45^{o}C\pm$. Power draw for the reactors is shown in Figure 3. The fourth reactor was not operational at the time the no load and tap water measurements were made because of a missing bushing for the motor drive shaft. These curves will be developed when the reactor is emptied for installation of the effluent pump.

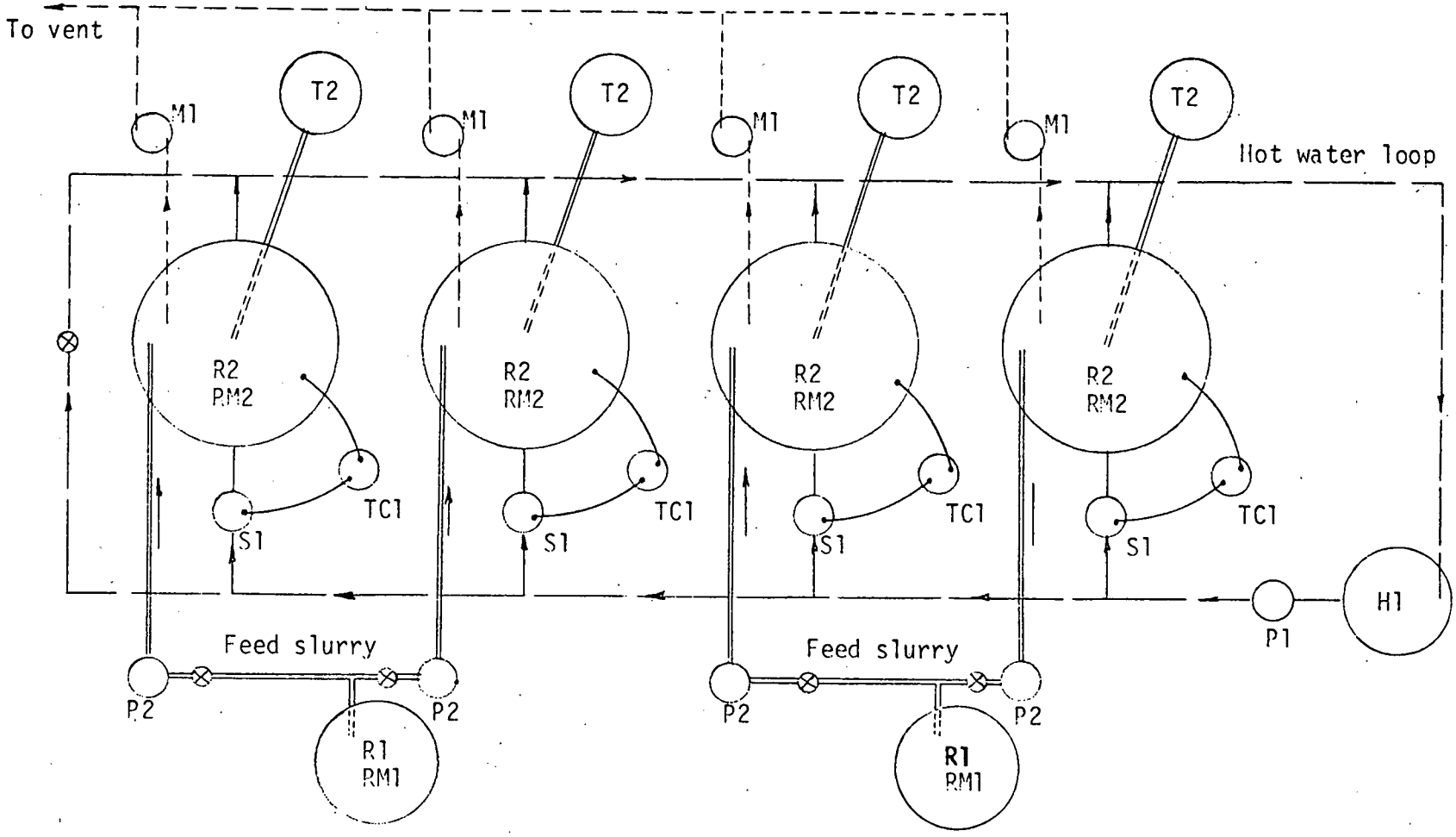


Figure 1. Schematic of experimental processing system

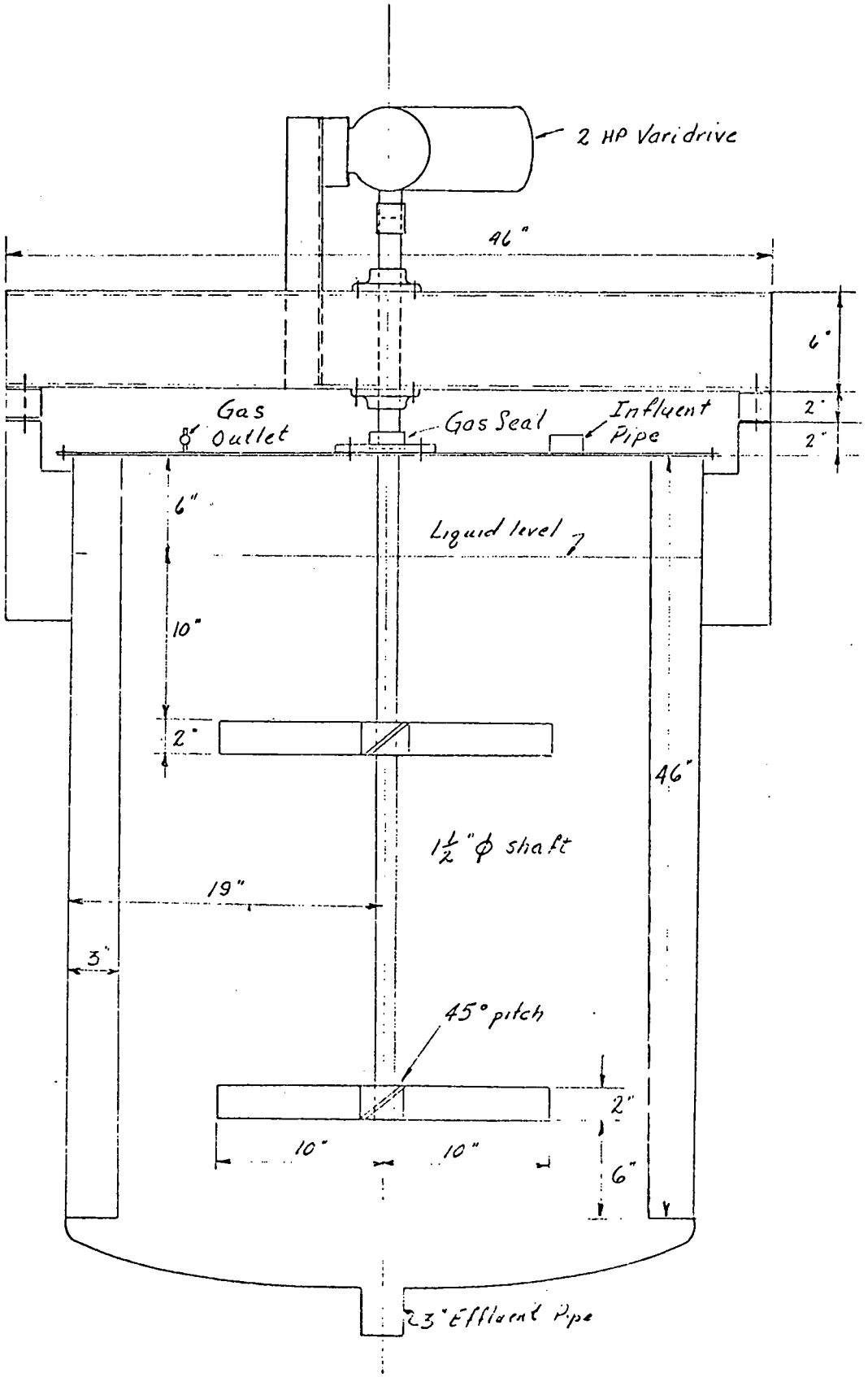
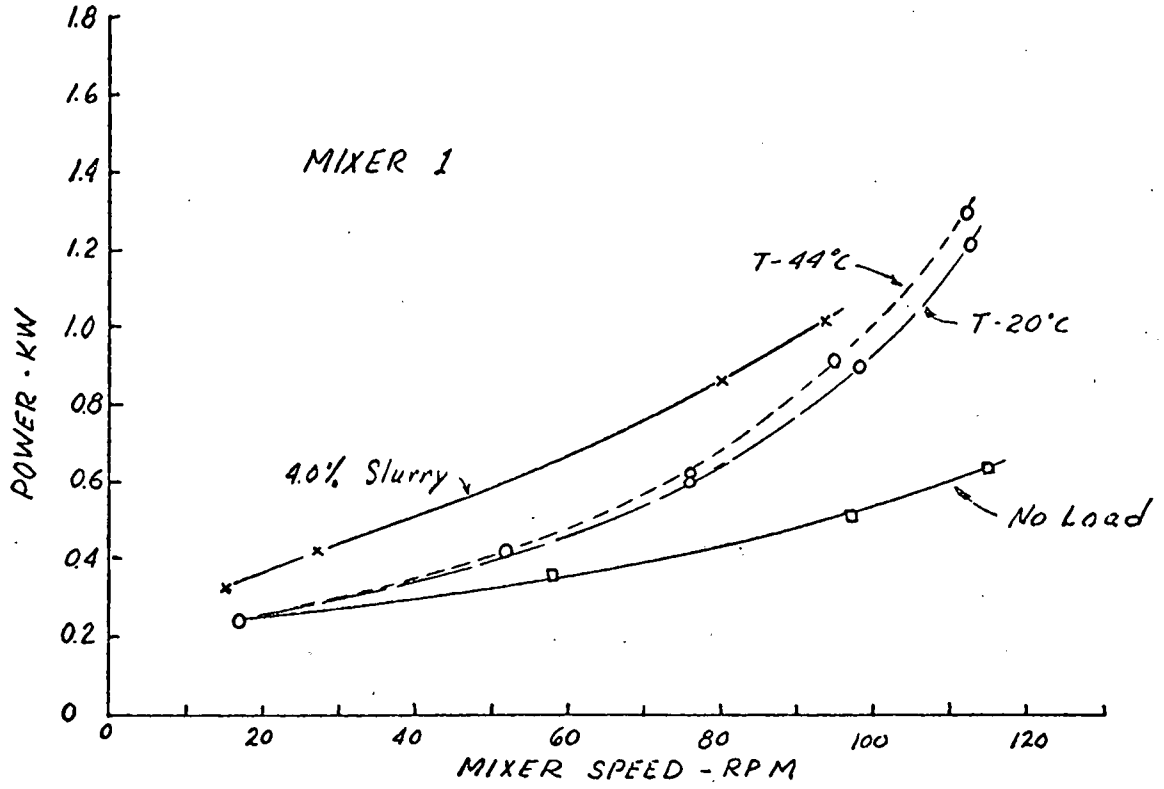


Figure 2. Details of Reactor and Variable Speed Mixer



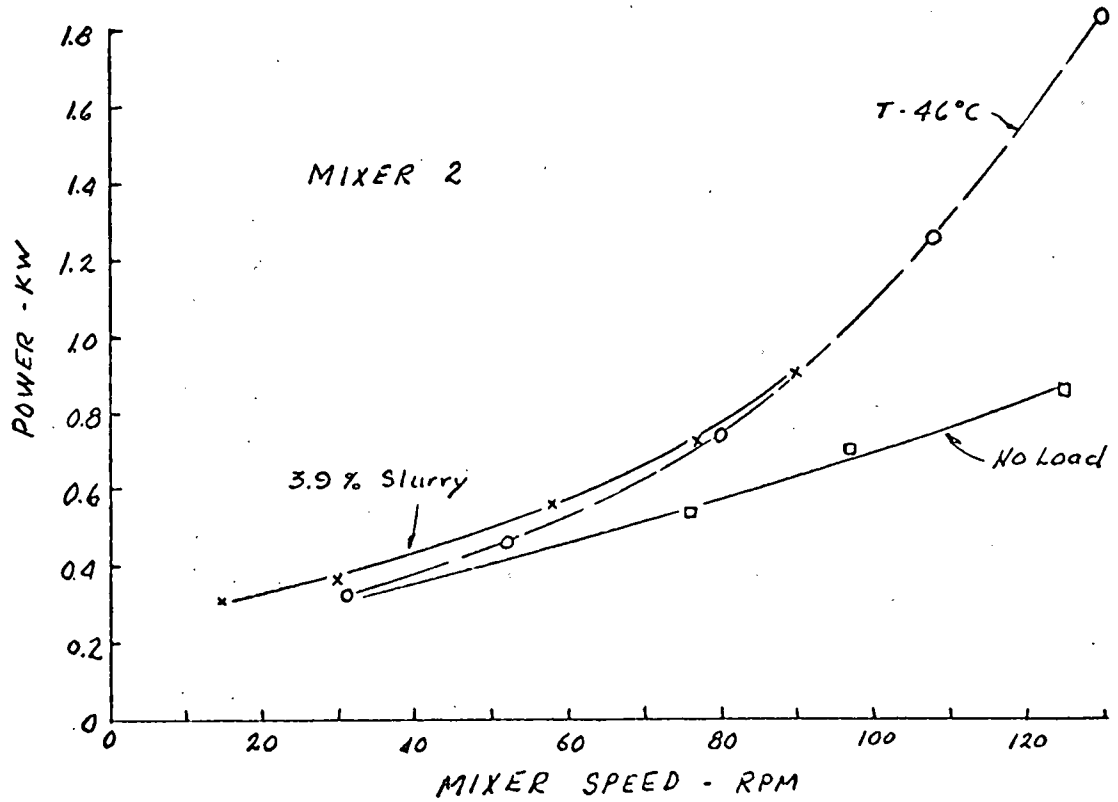
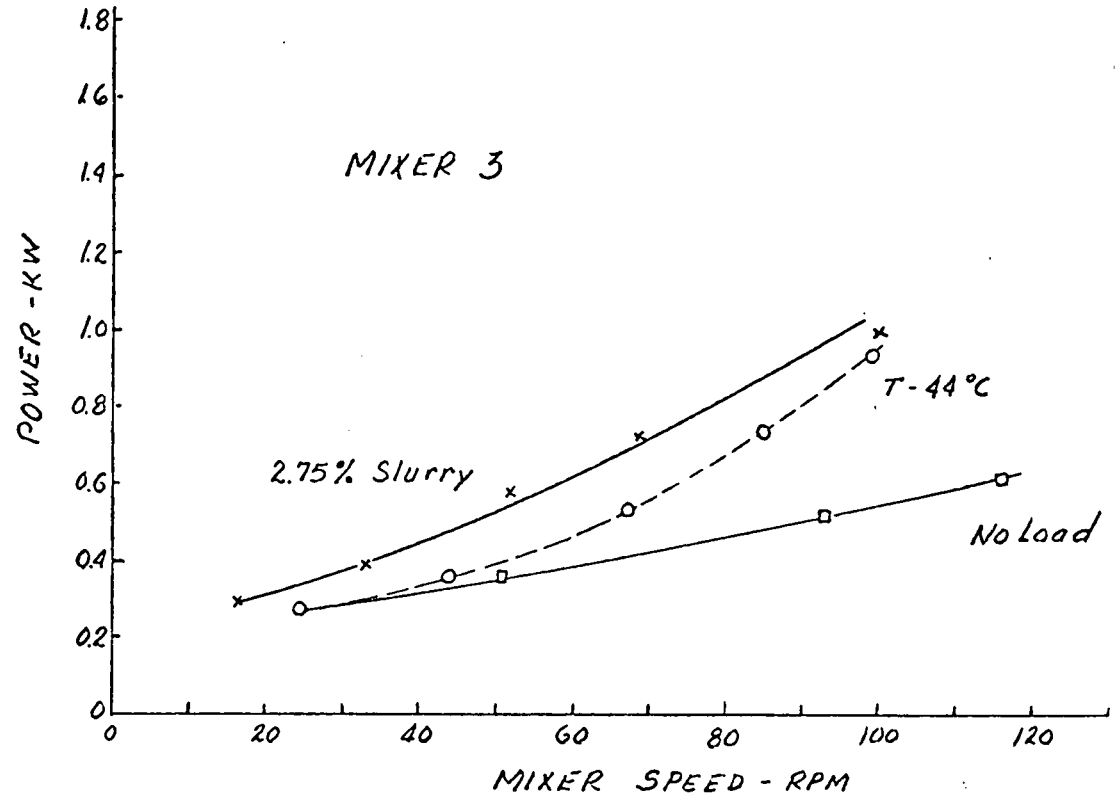


Figure 3. Power draw at various mixing conditions



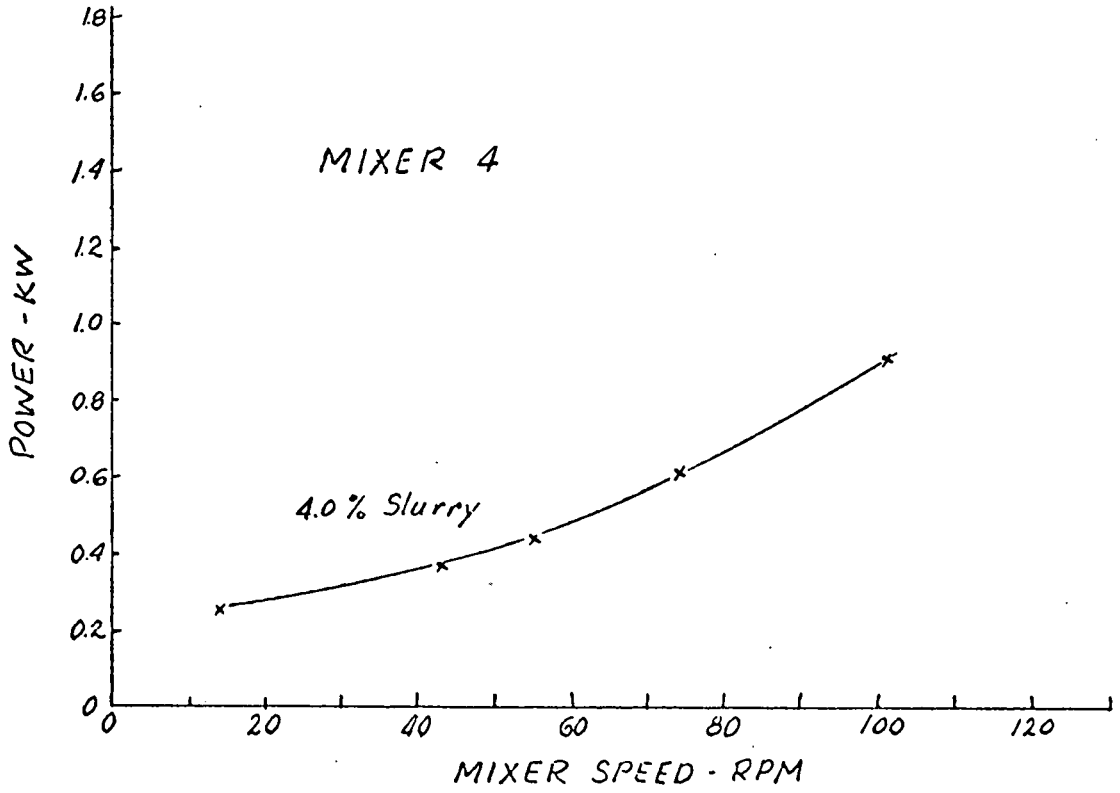


Figure 3. - Continued

These curves show the added power draw due to the water is considerable at the higher mixing speeds. The manure slurry also adds additional power requirements due to the consistancy of this liquid. Mixer 2 does not exhibit a significant increase due to the slurry. These tests will be repeated for all reactors. Also, the no load and tap water power draw will be checked when these units are empty for installation of the effluent pumps.

The only significant operational problem that has developed has been the effluent pipe clogging. Operation of the feed pump with this line plugged will fill the reactor completely causing pressure to be applied to the gas seal. This has caused seal failure on three of the reactors. Problems still exist with adjustment of the gas seal on Reactors 3 and 4. Gas data for these reactors have been erratic as will be shown later.

Substrate

Manure for this system was obtained from the Department of Animal Science beef feeding lots. A truck load free of any bedding was obtained from an open lot. This lot had a very good manure pack, so little or no soil was obtained with the manure. The manure had accumulated for approximately three months, prior to being collected on October 14, 1976. It should be noted that the prior three months had been unusually dry. The manure did not appear to have undergone extensive aerobic stabilization. It was very dry when collected from the lot. In fact, it was dusty. However, moisture analysis showed that the manure was only 30 percent solids on the average.

Feed for the feed tanks had to be slurried prior to dumping into these tanks. The manure contained some stones that probably originated from the driveways. These stones ranged in size from pea gravel to bricks. In order to protect the pumps, it was necessary to slurry this material to allow for

these larger stones to be removed prior to adding to the feed tanks. This process did not remove grit or soil in any quantity.

During start-up, 25 pounds of manure was mixed with 50 gallons of water. This produced a feed slurry containing approximately 1.5 percent total solids and 1.0 percent volatile solids. This practice was continued until November 10, 1976. At this time, 100 lbs. of manure was added to 50 gallons of water. This produced a slurry solids in excess of 5 percent. The actual solids concentrations measured in the feed tanks are shown in Table 1. Mix tank 1 fed reactors 3 and 4 while mix tank 2 fed reactors 1 and 2. The slurry solids concentration varied somewhat due to the need to use water for flushing some of the feed lines. An attempt is being made to keep the feed slurry at about 5 percent solids.

TABLE 1 Feed Slurry Characteristics

	#1		#2	
DATE	% T.S.	% V.S.	% T.S.	% V.S.
11/4	1.39	0.92	1.48	1.01
11/16	5.46	3.20	3.29	2.00
11/23	5.55	3.98	6.89	4.66
11/25	5.21	3.30	6.13	3.77
11/27	5.60	3.52	9.13	5.37
11/30	7.33	4.56	7.82	4.66
12/2	6.62	3.85	7.16	4.17

The manure was of good quality, having a volatile solids of 63.0 percent of total solids in mix tank 1 and 61.2 percent of total solids in mix tank 2.

This variation can only be experimental error since the same manure was added to both mix tanks.

No other analyses have been conducted on the manure. Samples have been collected for nitrogen analysis. Samples will also be kept for fiber analyses to be conducted at a later date.

Reactor Start-up

The reactors were filled with tap water and allowed to reach the $58^{o}C \pm 2^{o}$ operating temperature prior to October 22, 1976. On this date, 30 gallons 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 2, the pH of all three units dropped below 6.0. The alkalinity of the reactor slurry was very low. On October 30, 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 November 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 on November 5, 1976. By November 11, 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 400 mg/l in all units.

On November 10, 1976, the manure was increased to 100 lbs. per 50 gallons of slurry resulting in an increase in the feed slurry solids concentration. The feed rate was set for 15 gallons per day to produce a 13.3-day retention time. The actual feed volume varied between 15 and 20 gallons resulting in a retention time between 10 and 13.3 days. With an operating volume of 200 gallons, the initial solids loading was approximately 0.04 lb V.S./cu ft day.

TABLE 2 Variations in pH, Alkalinity and Volatile Acids

DATE	Reactor #1			Reactor #2			Reactor #3			Reactor #4		
	pH	Alk	V.A.	pH	Alk	V.A.	pH	Alk	V.A.	pH	Alk	V.A.
Oct 22	7.05	129	-	7.37	129	-	7.35	124	-	-	-	-
26	6.32	-	-	6.49	-	-	6.58	-	-	-	-	-
27	5.80	-	-	5.90	-	-	6.30	-	-	-	-	-
28	5.80	319	-	5.90	520	-	6.10	263	-	-	-	-
29	6.72	376	228	6.54	551	192	6.30	324	216	-	-	-
31	5.90	-	-	6.35	-	-	5.90	-	-	-	-	-
Nov 1	6.45	-	-	6.90	-	-	6.30	-	-	-	-	-
2	6.30	530	204	6.80	716	264	6.05	592	360	-	-	-
3	6.60	-	-	7.15	-	-	6.20	-	-	-	-	-
4	6.85	422	96	7.35	566	72	6.25	644	192	-	-	-
6	6.70	-	-	6.90	-	-	6.65	-	-	-	-	-
8	6.90	876	192	6.95	1063	288	6.85	891	204	-	-	-
9	6.92	-	-	6.97	-	-	6.79	-	-	-	-	-
11	6.86	1452	-	6.95	1401	-	6.82	1045	-	-	-	-
12	6.95	1421	-	-	-	-	6.90	1164	-	-	-	-
16	6.97	1700	288	6.89	1694	216	6.89	1617	216	-	-	-
18	7.05	2173	336	7.05	2070	240	7.00	2045	197	-	-	-
19	7.00	2070	-	6.95	2199	-	7.10	2366	-	6.95	1931	-
22	7.15	2938	120	7.20	2910	192	7.10	2706	168	7.20	2434	144
23	7.20	3182	-	7.10	3142	-	7.10	3006	-	6.95	2557	-
24	7.22	-	264	7.22	-	144	7.27	-	144	7.18	-	144
25	7.25	-	-	7.22	-	-	7.36	-	-	7.14	-	-
26	7.30	3903	-	7.30	3917	-	7.30	3495	-	7.30	3373	-
27	7.27	4053	120	7.23	4066	216	7.26	3563	216	7.20	3468	264
29	7.20	-	-	7.25	-	-	7.35	-	-	7.40	-	-
30	7.40	4855	-	7.20	4746	-	7.35	4720	-	7.32	4610	-
Dec 2	7.20	4869	-	7.25	4896	-	7.25	4461	-	7.25	4502	-
3	7.30	4836	120	7.25	4876	144	7.20	4243	192	7.25	4420	216
4	7.25	-	-	7.20	-	-	7.30	-	-	7.20	-	-

Gas Production and Stabilization of Volatile Solids

The reactors reached an operating equilibrium in mid-November. Because of the variable nature of the feed quantity and concentrations, a true equilibrium can not be established. The reactor solid concentrations are shown in Table 3. These data are not as accurate as desired. The problem of effluent line plugging makes it difficult to obtain representative samples from the reactors. Therefore, until a better technique for obtaining these samples is developed, these data are suspect. The reduction in volatile solids is not as great as might be expected. This is due in part to the separation of the grit, etc. in the effluent lines prior to obtaining the samples. The volatile solids in the effluents from reactors 1, 2, 3 and 4 were 59.2, 57.0, 62.0 and 59.6 percent respectively. This is not a significant reduction in the volatile solids content of the feed solids.

The volatile solids loading and gas production are shown in Table 4. Gas leaks in reactor 3 and 4 have made it difficult to obtain gas readings from these units. However, reactors 1 and 2 have not been leaking and the gas data show a significant conversion of organics to gas. For the period shown in Table 4, reactor 1 produced 5 SCF of gas per pound of volatile solids feed. The gas production in reactor 2 was 5.6 SCF per pound of volatile solids added. The gas composition was not determined due to a delay in receiving the gas partitioner. Based on a pH of 7.3 and an alkalinity of 4500 mg/l, the methane content should be between 50 and 60 percent.

The gas production was reasonably good, but higher gas yields should be possible if the organics have not been stabilized excessively while on the lot. It would appear that some stabilization has occurred with this manure.

TABLE 4 Gas Production Rates

DATE	Reactor #1			Reactor #2			Reactor #3			Reactor #4		
	lb.VS	Gas prod.		lb.VS	Gas prod.		lb.VS	Gas prod.		lb.VS	Gas prod.	
	day	ℓ/d	CF/lb.VS	day	ℓ/d	CF/lb.VS	day	ℓ/d	CF/lb.VS	day	ℓ/d	CF/lb.VS
Nov 16	-	-	-	-	-	-	-	-	-	-	-	-
17	3.34	515	5.45	2.50	665	9.40	4.54	480	3.74	-	-	-
18	3.00	462	5.44	3.75	780	7.35	4.00	*	-	-	10[1]	-
19	4.00	775	6.85	2.67	747	9.89	8.60	*	-	-	193	-
20	2.84	938	11.67	2.50	676	9.55	4.00	*	-	4.00	482	4.26
21	2.84	516	6.42	1.83	431	8.32	0	*	-	0	390	-
22	2.17	587	9.56	3.17	621	6.92	5.34	*	-	5.34	501	3.32
23	6.60	1001	5.36	6.60	1138	6.09	4.54	*	-	4.00	559	4.94
24	10.88	1195	3.88	14.37	1836	4.52	4.98	*	-	4.65	622	4.73
25	7.72	881	4.03	7.00	1094	5.22	6.31	730	4.09	5.64	713	4.47
26	5.66	713	4.45	5.03	898	6.31	3.58	*	-	7.16	653	3.22
27	6.28	936	5.27	6.28	1066	6.00	4.40	730	5.65	4.13	662	5.66
28	7.17	926	4.56	7.17	1082	5.33	4.55	*	-	4.40	542	4.35
29	7.60	1121	5.21	7.60	994	4.62	5.28	*	-	4.99	590	4.18
30	6.72	497	2.52	9.41	998	3.75	4.40	*	-	4.70	621	4.67
Dec 1	5.83	620	3.76	6.60	597	3.19	5.70	*	-	6.47	*	-
2	0	739	-	0	1063	-	0	*	-	0	*	-
3	10.49	797	2.68	13.21	1190	3.18	6.08	*	-	6.08	873	5.07
Σ	93.14	13219	-	99.68	15876	-						

* Gas leak due to gas seal problems.

[1] Started operation of #4

Future Studies

With the system operational, a series of runs will be made to determine if the level of mixing has any effect on the gas production rates. In addition, the effects of retention time and temperature on the fermentation rates will be determined. Residue characteristics and quality will be analyzed to evaluate potential uses of this material, as well as to establish design parameters for effluent processing systems.

Acknowledgement

Appreciation is expressed to Dr. E.E. Hatfield, Department of Animal Science and Dr. D.L. Day, Department of Agricultural Engineering for their assistance in obtaining the feed stock for these studies.

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