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MONFORT DIRT LOT EXPERIMENTS

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HAMILTON STANDARD
DIVISION OF UNITED TECHNOLOGIES
Windsor Locks, Connecticut

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ABSTRACT

In order to investigate the feasibility of producing fuel gas and an energy-intensive refeed product from dirt feedlot residues by anaerobic fermentation the Department of Energy awarded Hamilton Standard a contract to operate the Hamilton Standard mobile processing unit at the Monfort of Colorado Kuner feedlot. Results to date have shown that:

- A stable fermentation can be achieved utilizing aged feedlot pen residue if a sufficient adaptation period is provided.
- Methane yields of 2.75 $ft.^3$/pound volatile solids fed (Note: the term "volatile solids" is interchangable with "total volatile solids") can be attained at a loading rate of 0.25 pounds volatile solids/$ft.^3$, 10 day retention time and thermophilic temperature of 57°C.
- The fermentor liquid effluent is acceptable to cattle as a feed ingredient and has been used to provide one-half the daily supplemental protein for twenty steers.
- Residual pharmaceuticals and low levels of heavy metals as well as various anions and cations may possibly impose some additional stress upon the system but do not present a significant detriment to successful operation.
- Feedlot residue is highly variable in both dry matter and inert content with typical particle size in the micron range.

Future efforts will continue to document the variability of residues obtained from feedlots in the Kuner area as well as the effluent gaseous yields from those substrates. Separate evaluations will be conducted dealing with increasing the organic loading rate and the effect of centrate recycle upon the fermentation. Additionally acceptability testing of the dewatered fermentor effluent as a cattle feed supplement will be conducted. As an outgrowth of the residue characteristics study an evaluation of commercially available methods for removing sand and grit inclusions from the collected residue will be performed.

1.0 INTRODUCTION

1.1 Background

Hamilton Standard has been involved in the anaerobic fermentation of animal residues to produce a fuel gas and a refeed product since the beginning of 1970. Laboratory and pilot scale work, conducted by Hamilton Standard and funded by the company, initially demonstrated (and provided the basis for granting of patent #3838199) that high gaseous yields, as well as a highly proteinaceous material suitable for refeeding, were obtainable from the thermophilic fermentation of these residues. These data indicated the economic viability of the system process. These company-sponsored efforts were augmented (1971-1974) by funding provided by the Agricultural Research Service of the United States Department of Agriculture. These studies provided confirmation of the stability, reliability and economic potential of thermophilic fermentation for use in an agricultural environment. During a company sponsored program in 1974 and 1975, Hamilton Standard designed and fabricated a mobile fermentation system capable of processing up to 300 lbs/day (dry matter basis) of animal residue. The system was then operated at an "environmental" feedlot at Kaplan Industries using "as collected" residues. This operational program demonstrated an average methane gas production of 4.4 standard cubic feet per pound of organic material processed. The product gas showed slightly under 1% each of hydrogen sulfide (H_2S) and ammonia (NH_3). The discharge from the fermentor contained about 6% dry matter (Note: the term "dry matter" is interchangeable with "total solids") while the dewatered fermentor discharge over a 28 day test period averaged 25% crude protein and 23% dry matter content. This protein fermentation product (PFP) was utilized in an experimental cattle feed diet as a protein replacement for 51% crude protein cottonseed meal (CSM). These tests indicated the feasibility of utilizing the organic residue to produce enough fuel to make the feedlot energy self-sufficient (or possibly allow for the export of fuel gas from the feedlot) and, at the same time, provide a protein-rich residue, equal in digestibility to that of cottonseed meal, that made system economics very attractive. In 1975-1976, the United States Department of Agriculture and the Department of Energy and its predecessors funded Hamilton Standard to design and build a pilot scale fermentation system at the Meat Animal Research Center (Clay Center, Nebraska) capable of processing 100 pounds/day of residue.

Presently, state-of-the-art research is currently underway investigating mixing dynamics and effects of reduced retention time upon the fermentor performance.

1.2 Program Objectives

All of the prior work, however, was with "fresh" residues available from concrete floors. In order to evaluate the potential of producing fuel and a refeed product from "dirt" feedlots, which provide a residue that is aged and mixed with sand, DOE awarded Hamilton Standard a contract to operate the company owned mobile system at the Monfort feedlot in Colorado. It was anticipated that operation at a dirt feedlot would entail certain difficulties not present with the residues previously tested. The test program objective is, therefore, to determine the performance and stability of the anaerobic fermentation process by operating, under field conditions typical of those at this operational dirt feedlot, with a pilot scale system utilizing commercially available equipment and processing significant quantities of beef cattle residues which have been collected in a realistic manner. This testing will, in turn, confirm the yield and quality of output fuel gas generated by the process. In addition, it will establish the yield and potential value of the effluent solids as a high protein feed ingredient by conducting feeding experiments with cattle. The specific test program objectives are to:

- Evaluate the waste characteristics of the available residue.
- Demonstrate the technical feasibility and stability of the anaerobic fermentation process under operational feedlot conditions.
- Quantify and analyze the output fermentation gas produced.
- Confirm the operational characteristics of the system.
- Analyze the output solid residue fertilizer/ nutritional value.

The results of this program will then allow an assessment to be made of the technical and economic viability of utilizing the anaerobic process at dirt feedlots.

2.0 EXPERIMENTAL SYSTEM

The Hamilton Standard mobile fermentation system was set up at the Monfort Kuner feedlots as shown in Figure 1. The system consists of a mobile laboratory/equipment trailer, an external fermentation vessel, and hardware for processing residue. A simplified block diagram of the system is shown in Figure 2.

The fermentor is a vertical cylindrical steel vessel of 1500 gallon capacity. This tank is set on four post legs and is located adjacent to the trailer. The contents of the fermentor are mixed by pumped recirculation through a pair of 3 inch lines connected to the trailer. Product fuel gas leaves the top of the fermentor and is piped into the trailer for control and measurement. The fermentor is equipped with a viewport for inspecting the fermentation liquid surface and a level gauge for determining liquid volume. There is a 2 inch polyurethane insulation jacket on the fermentation tanks.

The waste preparation hardware consists of two steel tanks, a mixing pump and a loading pump. One tank is used to prepare the initial slurry of cattle residue and to allow sand and gravel to settle out. This is called the mix and degritting tank and is a "vee" bottom carbon steel tank. The mixing pump is a 3-inch diaphragm pump which recirculates the cattle residue and liquids within the mix and degritting tank. After allowing settling, this pump is again used to transfer the residue slurry to the second tank. The sand and gravel left on the bottom of the mix and degritting tanks is cleaned out manually and weighed. The second tank, called the load and metering tank, is suspended on a chain slung from a gantry with a crane-type scale which allows the measurement of the total weight of material loaded. A variable speed, positive displacement, progressing cavity type pump is used to meter the waste load into the system. A comminutor is included between the load and metering tank and the pump inlet to ensure that all solids entering the system are reduced in size to a maximum of about 1/4 of an inch.

The trailer contains all of the additional supporting equipment for the system. The fermentor contents are pump recirculated by a recessed impeller trash type centrifugal pump displacing 100 gpm. A hot water heater, heat exchanger and water heat heat transfer loop, and a temperature control valve are all part of the system used to control the fermentor temperatures. This heating system is capable of delivering 50,000 Btu/hr and controlling system temperatures over the range of 100-140°F. The heat exchanger is located in line with,

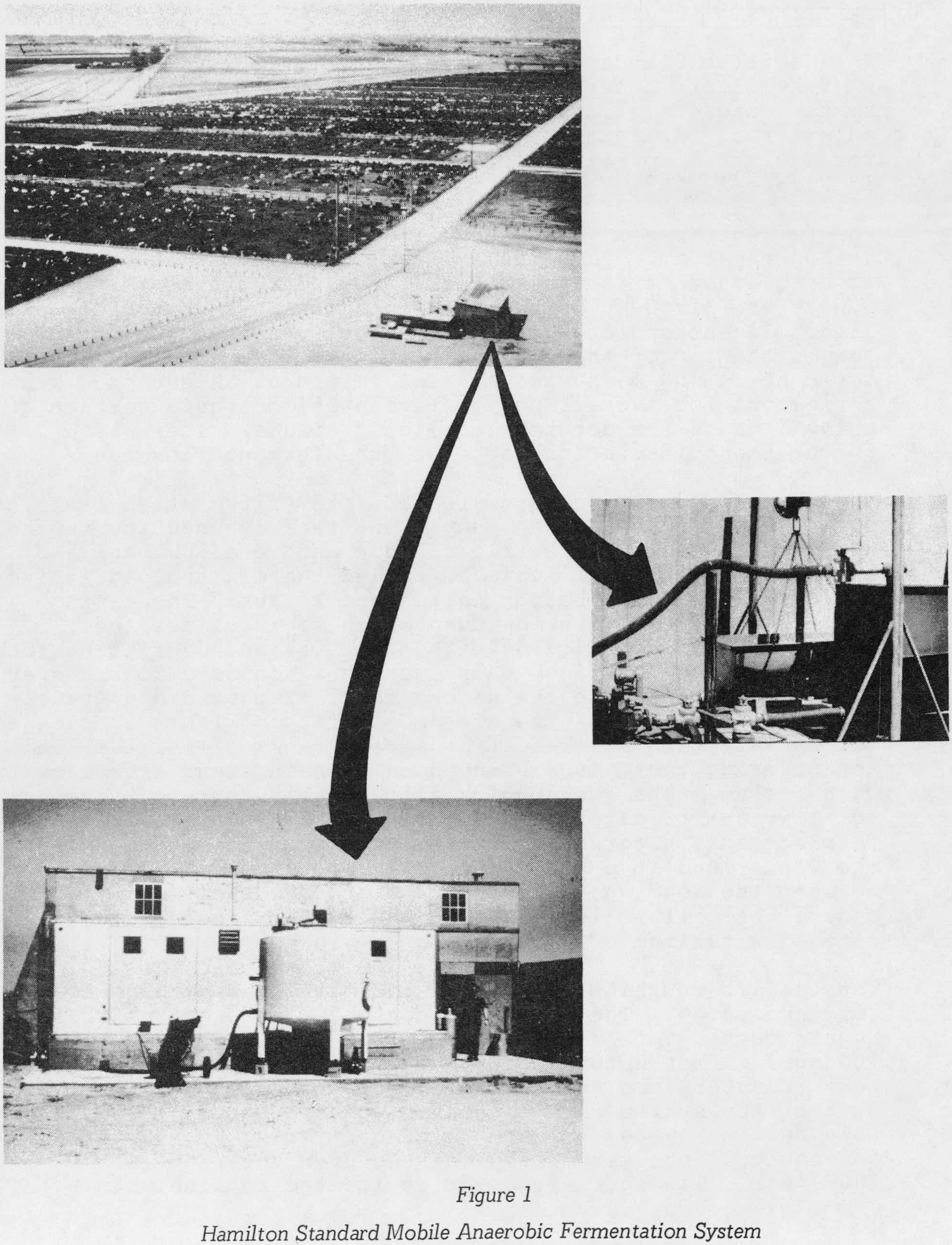


Figure 1

Hamilton Standard Mobile Anaerobic Fermentation System at the Monfort Kuner Feedlot

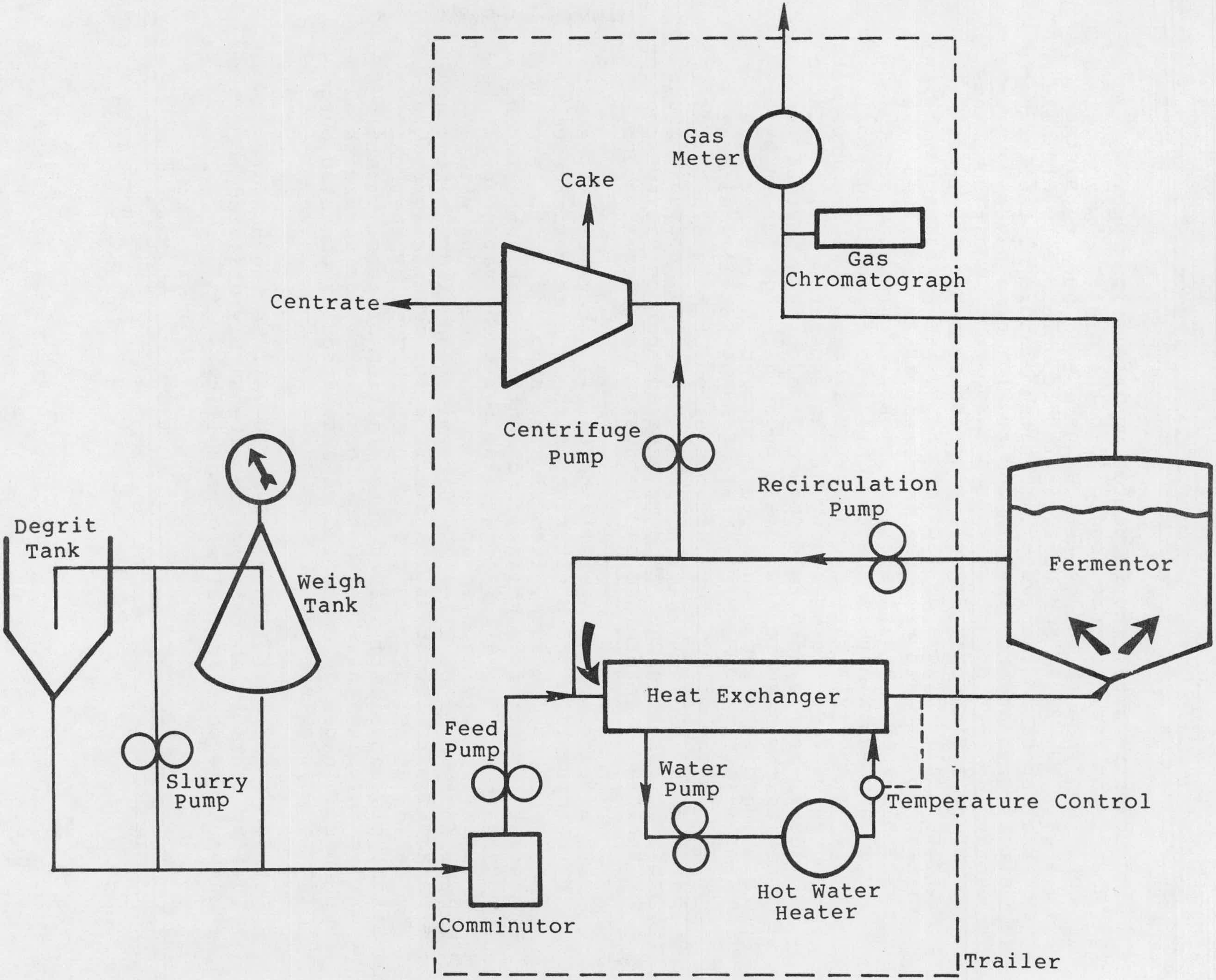


Figure 2

Simplified Block Diagram of the Hamilton Standard Mobile Fermentation System and downstream of, the fermentor recirculation pump. When fresh residues are loaded into the system, they enter upstream of the heat exchanger. The heating system preheats the fluid and controls its temperature to minimize thermal shock to the system. The temperature of the fermentor is monitored and recorded in the trailer on a seven day continuous recording temperature indicator. Additional temperature indicators, as well as pressure indicators, are strategically placed to monitor the system performance. Withdrawal of contents from the fermentor is accomplished by a variable speed, positive displacement, progressing cavity type pump which meters the contents into a centrifuge for solids recovery. The centrifuge is a solid bowl decanter with a screw conveyor for recovery of the separated solids. These solids are conveyed onto a "beach," which is a part of the rotating bowl, where they drain under high "g" forces prior to being discharged down a chute through the trailer floor. The trailer also contains chemical conditioning equipment to aid in the solids recovery operation. The gas produced is measured by means of the system gas meter, pressure gauge, and temperature gauge. The methane and carbon dioxide content of the gas is determined by the system gas chromatograph.

The trailer contains a small analytical laboratory to assist in the operation and monitoring of the system performance. Samples of raw residue, feed slurry, sand and grit, fermentor contents, centrifuge solids, and centrate liquid are taken and stored in a small refrigerator for preservation prior to analysis. A drying oven and ashing furnace along with a laboratory balance allow the determination of dry matter and volatile matter content. A specific ion meter allows determination of pH, NH_3, Na^+, K^+, and Cl^-. Trailer chemical analysis capability allows determination of total volatile acids and alkalinity. The trailer is also equipped with a combustible gas detector and an automatically operated purge fan for system safety.

Outside commercial laboratories, as well as the Monfort Quality Control laboratory, are extensively utilized to support the on-site analysis capability.

3.0 OPERATIONAL RESULTS

Residue from the Monfort-Kuner feedlot averages 50% ash, with particle sizes ranging down to the sub-micron level that are difficult to remove using simple settling. Low levels of pharmaceuticals and heavy metals also exist, but have not been found to have a significant effect on the fermentation. Stable fermentation has been achieved and maintained for 6 months with TVA levels remaining at higher levels (~2500, mg/L) than traditionally considered "normal." Methane yields of 2.75 $ft.^3$ per pound of volatile solids loaded have been consistently obtained from 6 to 9 month old residues. Fermentor contents were used to supply 50% of the supplemental protein to twenty cattle during a fattening period; weight gain matched that of control cattle.

3.1 Residue Characteristics

During the early stages of the experimental program it became evident that manure collected from certain areas of the Monfort facility contained large amounts of inerts (mainly sand and grit). These manures had been collected from the stockpile as well as individual feedlot pens. Because of these findings, an extensive sampling program was begun to evaluate the extent of this high grit condition. Samples of manure collected from various pens on the Kuner facility (Ref. Figs. 3 & 4), as well as from the Monfort-Gilcrest feedlot and some other area feedlots, have since been analyzed for dry matter (DM) and ash content. The results of these analyses have been reported in the quarterly reports submitted to DOE. A summary of these results indicates the following:

(DM) avg	= 58%
(DM) range	= 31-81%
(Ash) avg	= 50%
(Ash) range	= 25-85%

It is evident from these data that "typical" dirt feedlot manure is highly variable.

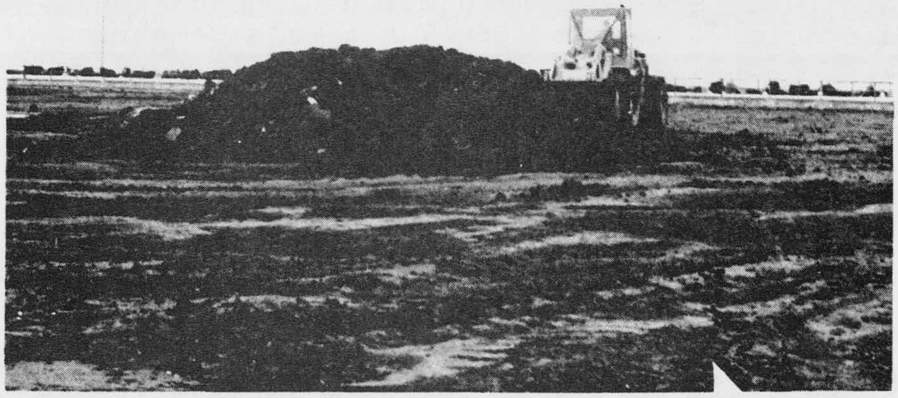


Figure 3

Cleaning of Feedlot Pen

Figure 4

Typical Dirt Feedlot Manure After Scraping

As an additional result of this evaluation, it has been found that the material collected from the back fences (furthest from the feed bunk) have higher ash content. Values for the fence areas and the bunk areas are shown below:

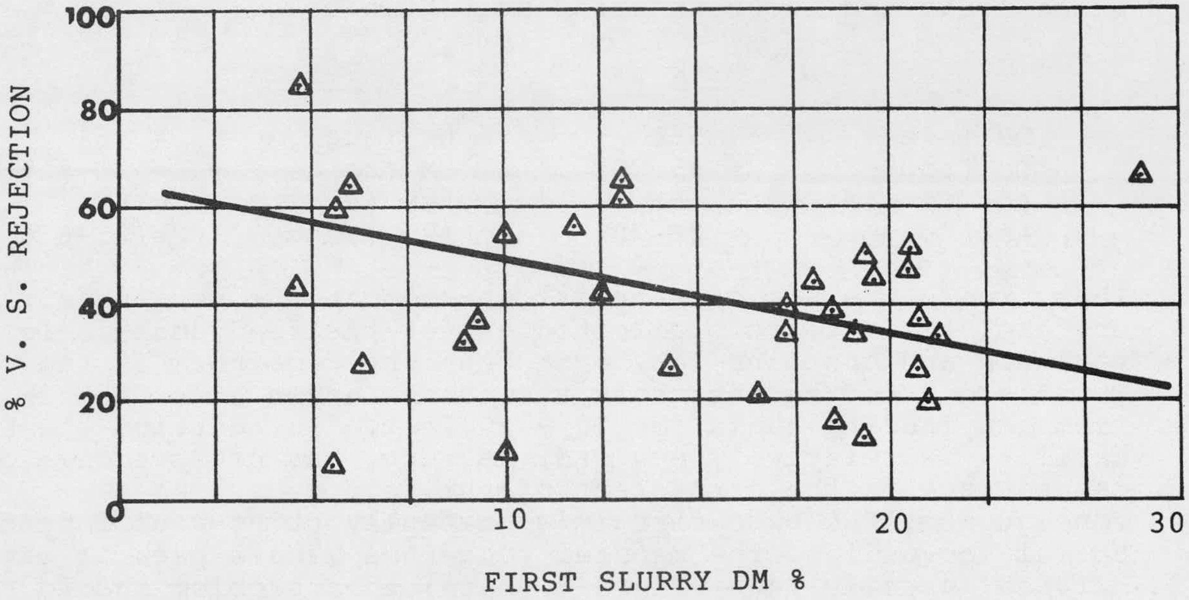
Bunk		Fence	
DM (avg)	= 55%	DM (avg)	= 66%
DM (range)	= 45-70%	DM (range)	= 31-81%
Ash (avg)	= 45%	Ash (avg)	= 60%
Ash (range)	= 28-70%	Ash (range)	= 25-85%

Thus, while the age of material throughout the pen is fairly uniform, the material collected nearer the feed bunk is less variable and contains less grit than the remainder of the pen. This is due to the fact that a concrete apron extends back from the feeding bunks for 10 - 20 feet. In addition the Kuner facility is relatively new and, as such, has not yet developed a manure pack in the dirt areas of the feed pens. As a consequence, the base dirt is continually being worked by the animal hooves into the manure. Once the manure pack is established (usually requiring 3-4 years) this problem should abate. The high inert fraction is caused by a) degradation of the more readily fermentable fraction and b) inclusion of sand and grit.

Early attempts at degritting this substrate involved successive periods of mixing, settling, and transfer between two tanks. While removing a large percentage of the initial ash (70-90%), approximately 40% of the organics were also removed in this fashion when reasonable first slurry concentrations were used (Ref. Figure 5).

This technique still left a slurry high in ash content. Additional efforts are needed in this area to reduce the economic liability imposed by discarding large amounts of organics during preparation of the residue for loading into the fermentor.

To evaluate the type of particle passing through the degritting operation, a sample of ash from the fermentor was subjected to analysis by a scanning electron microscope. The photomicrograph, Figure 6, reveals several particles in the five micron range. The particles shown are clumps of particles (as shown by increased magnification), thereby indicating that the individual particle sizes are smaller than one micron. More recently, manure collections have



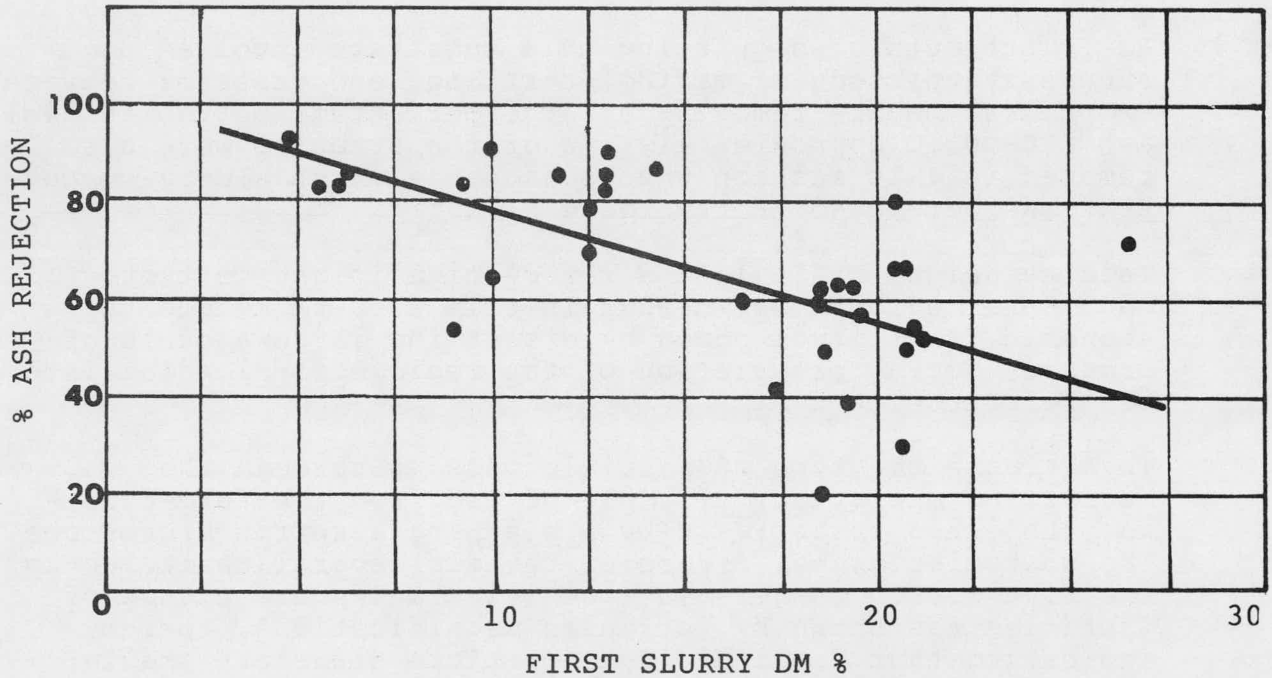


Figure 5

Refractory Removal Efficiency

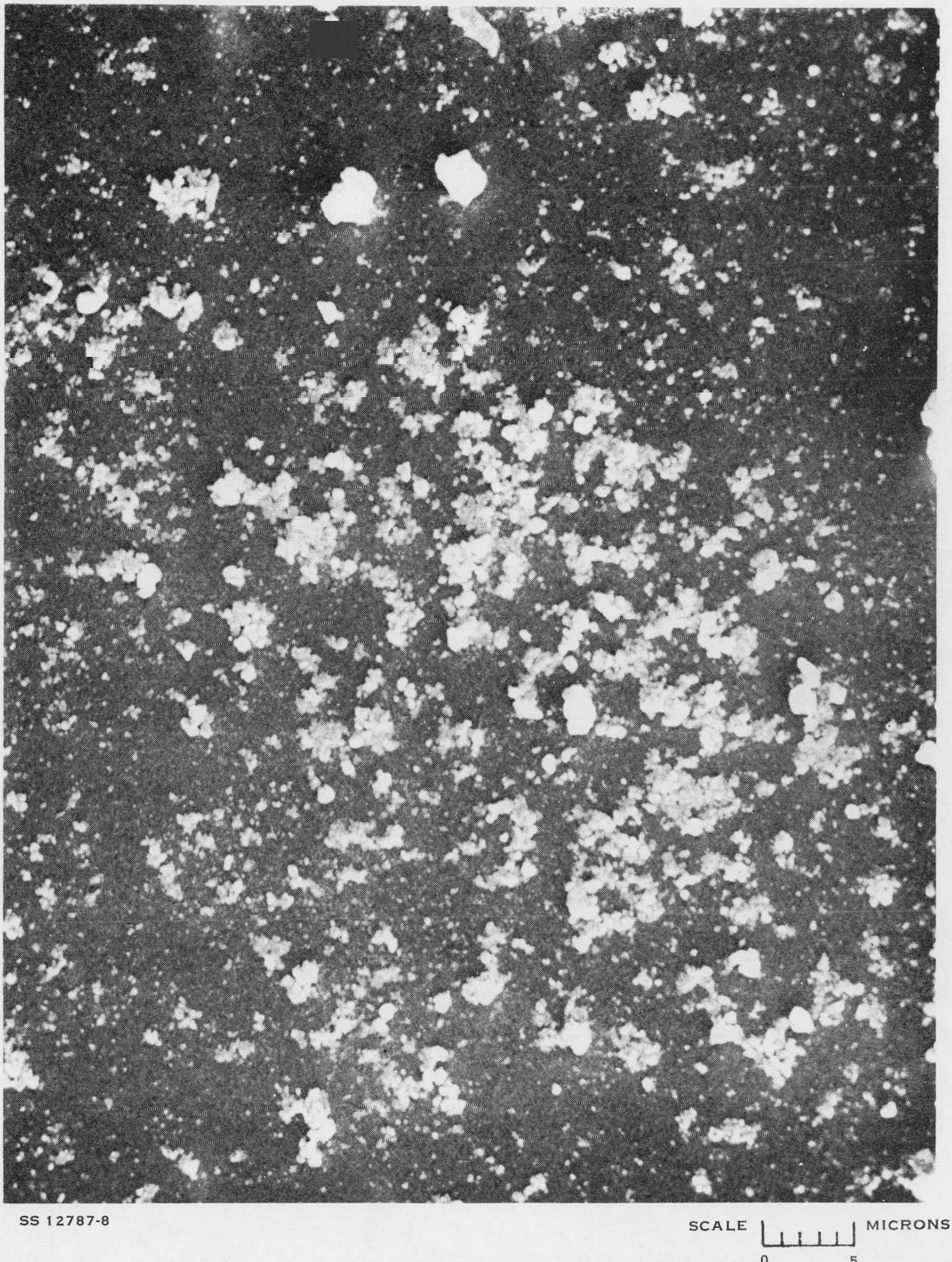


Figure 6

Photograph of Fermentor Ash

been from the first third of the pen area (closest to the feed bunks). While the material thus collected was representative of the pen as a whole as far as average age, it did not include as much grit. The material thus collected did not require the extensive degritting that the manures collected early in the program had. A study will be conducted during the latter stages of this program evaluating various commercially available methods for removing grit.

When early attempts to maintain traditionally low TVA levels were unsuccessful, a number of investigations were begun. Analyses for heavy metals (Zn, Pb, Cu, etc.) did not reveal any potentially inhibiting concentrations. In order to prove that heavy metals were not a causative agent, soluble sulfide was added in sufficient quantity to precipitate the existing heavy metal concentration as well as provide an excess concentration. No effect upon system performance was noted. Continuing analyses have not indicated any inhibitory concentrations of the commonly evaluated heavy metals.

Feeding of pharmaceuticals for preventive medication as well as growth stimulation has become widespread throughout the cattle feeding industry. Some of the more commonly utilized compounds are: Chlortetracycline, oxytetracycline, zinc bacitracin, monensin sodium and DES. Laboratory analyses for the presence of these materials in cattle residue is very difficult and the results not very reliable. The performance of the fermentor did appear to be adversely affected when fresh cattle residue with potentially high levels of pharmaceuticals was used. Repeated analyses of aged cattle residue showed these wastes to have either very low levels of pharmaceuticals or none at all. In addition, the performance of the fermentor with the aged wastes did not indicate significant decreases in performance that could be attributed to the pharmaceuticals.

In summary, these investigations have indicated that:

a. Newer feedlots will present a more severe problem with sand and grit inclusion vis-a-vis older feedlots due to the hoof action working dirt in the manure until a sufficiently thick manure pack is established.

b. Sufficient degradation of residual pharmaceuticals occurs with time and exposure on the feedlot floor which greatly reduces any influences they might have had upon fermentor performance. In addition, previous work done by Hamilton Standard has shown that thermophilic temperatures aid in reducing the effectiveness of some of these compounds.

c. Heavy metal concentrations do not appear to present any difficulties.

d. Geographic location, soil composition, and frequency of collection will greatly influence the size of the sand and grit problem to be overcome.

3.2 Process Stability

The system initially utilized manure obtained either from the stockpile at Kuner or from pens being cleaned. This material was approximately 6-9 months old and, as previously noted, contained abnormally large amounts of sand and grit (70-80% ash). Utilizing this material as substrate gas production during start-up levelled off at approximately 1 ft.^{3}/lb. volatile solids fed. Freshly excreted cattle residue was added to the fermentor to provide a supply of viable organisms and resulted in a significant increase in gas production to about 4 ft.^{3}/pound v.s. fed until the accidental inclusion of residue from cattle which were being fed pharmaceuticals almost caused a complete process failure.

Repeated attempts to switch the process from the fresh pharmaceutical free residue to the aged pen residue resulted in the inability to maintain a stable fermentation process.

Additions of readily available carbohydrates such as steam flaked corn and powdered alpha cellulose were made to the fermentor, on separate occasions, in order to test the fermentative process and demonstrate that the necessary biological populations and chemical factors were present and could properly function in the existing environment.

The rapid and dramatic response of a minimum of 8 ft.^{3} of gas from each pound of volatile solids added, for both the corn and cellulose, showed that a healthy fermentation existed and indicated that the poor performance with the aged pen residue was probably due to its biological unavailability.

Comparison of the residue characteristics for the material selected for this initial testing with the data being collected on the feedlot sampling program showed this initial material to be exceedingly high in inert material and not representative of the material generally available from the feedlot.

Considering the poor quality of the material used to initiate fermentor start-up, the resulting instability in performance and the inability to consistently obtain fresh beef cattle wastes free from pharmaceuticals, it was decided to drain and clean the system and restart and stabilize the process utilizing locally available pharmaceutically free fresh dairy residue.

While this dairy residue provided satisfactory gas production attempts to maintain the low TVA concentrations traditionally believed necessary for successful operation could only be achieved with unacceptably low loading rates.

After successful stabilization had been achieved with the dairy residue the substrate was changed to material collected from a "typical" feedlot pen and the system parameters allowed to establish whatever steady state conditions internal factors dictated. This substrate, while initially causing a drop in performance, subsequently stabilized yielding 2.5 $ft.^3$ CH_4/pound v.s. fed. During this period no attempts were made to control TVA concentrations which rose to 4000 - 5000 mg/L. Loading of this substrate continued unabated except for two days (not consecutive) in September/October 1977. Concurrent with these missed loadings, the TVA started a rapid decline stabilizing at 1500-2500 mg/L. Specific methane yield stabilized, and remains to date, at 2.5-3.0 $ft.^3$/pound v.s. fed at a loading rate of 0.25 pound vs./$ft.^3$/day. Steady-state operation of the system has continued since October 1977. During those six months a number of feedlot pens have provided system substrate. All system parameters indicate a healthy active fermentation capable of yielding 60% of the gas production obtained from fresh dairy residue. Considering the average age of the feedlot manure, and the degradation that can occur after deposit by the steers, these values are most encouraging.

In summary, it appears that aged waste, low levels of residual pharmaceuticals, low levels of various anions and cations all act separately or in concert to cause some additional stress upon the total system. However, it is possible to achieve a stable fermentation and reasonable gas yields from dirt lot residues if a sufficient adaptation period is provided. Care has to be taken to ensure that the system is not "pushed" too quickly initially and that a truly viable methanogenic colony does, in fact, exist before increases in organic loading are imposed. Once operating, the system exhibits the high degree of stability and reliability necessary for successful operation of a processing plant of this nature.

3.3 Gas Yields

Once stability was achieved in the fermentor, specific methane yields became a meaningful parameter. Several different pens have provided the substrate since October 1977. The daily specific methane yields are used to maintain a running 10-day average.

The data obtained from fermentation testing can be evaluated by comparison with an analytical model for the process.

The fraction (fc) of the biologically available substrate converted in the process will be a function of the process rate of reaction (k) and the amount of time (HRT) the substrate is retained in the reactor, as given by:

$$fc = 1 - [1 + k\ HRT]^{-1}$$

for a continually stirred tank reactor (CSTR)

where HRT is the system retention time (days)
k is the process rate of reaction ($days^{-1}$)

Dynatech Corporation has correlated the test data from a number of investigators and has expressed the process rate of reaction (k) as a function of process temperature(T) as follows:

$$k = 3.3 \times 10^9\ e^{-\frac{15000}{RT}}$$

where T is the operational temperature (°K)
R is the universal gas constant (1.987 cal/°Kgram mole)

The gas yield for the system can be predicted from:

$$GA = GT\ (1-R)\ fc$$

where GA = Actual methane produced ($ft.^3$/pound v.s.)
GT = Theoretical methane produced (7.1 $ft.^3$ pound v.s. for cellulose)
1-R= fraction of volatile solids capable of biodegradation

Figure 7 illustrates the expected fermentation peformance from a CSTR for operating temperatures of 48.9°C, 50.3°C and 57.2°C; and for a substrate with a nonbiodegradable fraction (R) of 0.22.

Hamilton Standard's 1971 test data for fresh residues collected from the University of Connecticut Beef Cattle Barn and the 1975 test data for the fresh residue available at the Kaplan Industries "environmental" feedlot are also presented on Figure 7. As shown, these two different sources of fresh waste showed performance which compares very favorably with that predicted by the model, and thereby confirming the use of R = 0.22.

The performance obtained with both fresh and aged residues from the Monfort feed lot during this program is also shown. The fresh residue performance (3.98 $ft.^3$ CH_4/pound v.s.) appears to be slightly lower from that which would be predicted. A slightly higher value of R ($\sim$.29) or a slight inaccuracy in the model's temperature corelation could account for the discrepancy.

The performance obtained with the typical aged pen residue (2.75 $ft.^3$ CH_4/pound v.s.) is significantly lower than that obtained for the fresh Monfort residue. If this aged pen residue had a non biodegradable fraction of 0.51 instead of the 0.29 used for the fresh waste the results would agree with the model.

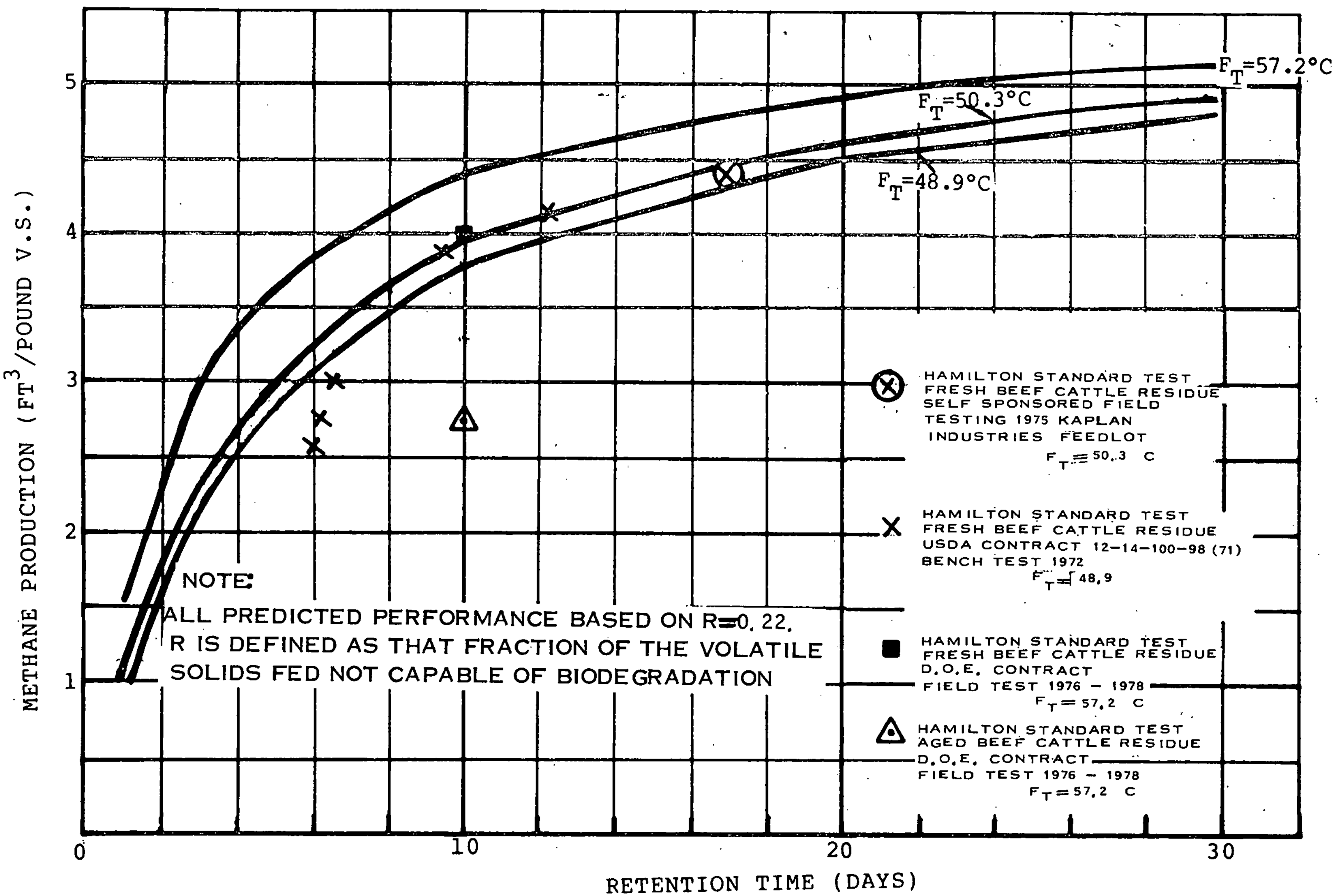


Figure 7
Test Data Correlation with Dynatech Model

3.4 Refeed Value of Fermentation Product

The residual biomass from the anaerobic fermentation of organics has the potential to provide an economic benefit in addition to the fuel gas generated. Previous work by Hamilton Standard has indicated that one dry ton of organics can yield 8,000,000 BTU of gas and 280 pounds of crude protein. In addition, preliminary feeding trials performed by Hamilton Standard at Kaplan Industries several years ago, previously noted in Section 1.0 of this report, indicated that the crude protein so produced was as digestible as cottonseed meal (a standard protein supplement). Based upon natural gas prices of $2 per million BTU and cottonseed meal prices of $150 per ton, this represents product values of $16 worth of fuel and $51 worth of protein per dry ton of organics. If the "average" residue, noted in Section 3.1 available at Monfort is considered (58% dry matter, 50% ash), these values become $4.64 worth of fuel and $14.79 worth of protein per ton of residue collected. The product utilized for these other studies had been dewatered by centrifugation. If dewatering could be eliminated, while still retaining the nutritional value of the effluent without any potential adverse effects from the liquid or its dissolved salts, the beneficial effects upon the total system economics would be substantial.

An objective of the dirt lot experimental program was to establish the dietary usefulness of the effluent protein generated by the fermentation of typical residues from the Monfort feed lot. The use of a liquid refeed product was selected for the first experimental evaluation. Twenty feedlot steers were set aside for the controlled evaluation of the fermentor effluent as a refeed ingredient. The fermentor effluent was mixed with the standard feed ingredients in a mix/feed truck prior to discharge into the feed bunk (Ref. Figures 8, 9). The amount of protein available relative to the effluent moisture content dictated that about 1/2 of the 0.7 pound of supplemental crude protein/head/day normally provided to the steers could be replaced before the diet became too moist. In addition, all other normal pharmaceuticals, vitamins and salts were provided to the test cattle. The test period was December 1977 through January 1978. During this time occasional difficulties with feed freezing in the bunks was encountered. However, acceptance of the mixed feed product was excellent and feeding did not appear affected by the presence of the non-dewatered product (Ref. Figure 10). Preliminary results indicate that the average daily rate of gain of the test cattle was 3.7 pounds per animal which compares favorably with the Monfort control cattle (expected gain of 3.5 - 4.0 pounds per day for the initial 69 days of a feeding period). Based upon these preliminary results it

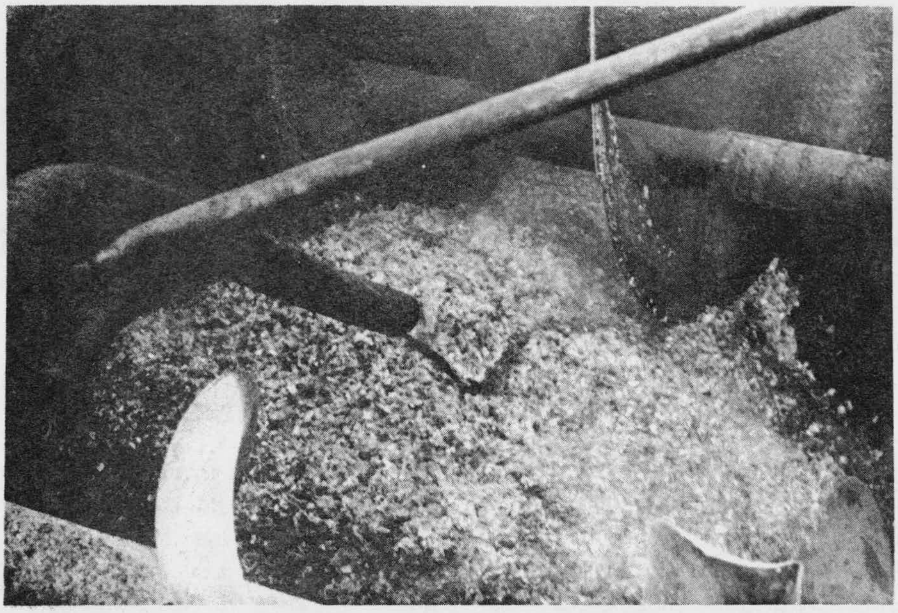


Figure 8

Mixing Fermentor Effluent With Standard Feed Ingredients

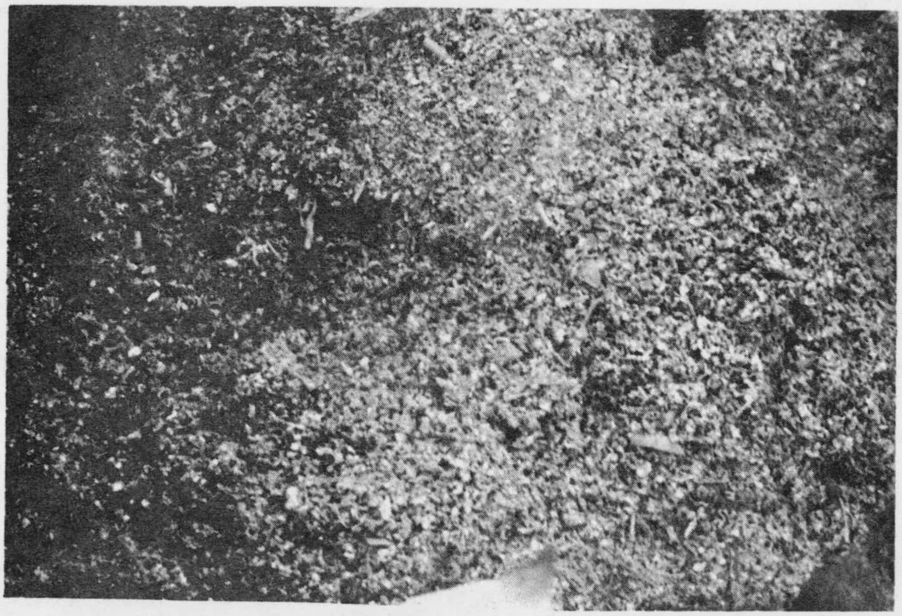


Figure 9

Combined Effluent/Feed Ingredients

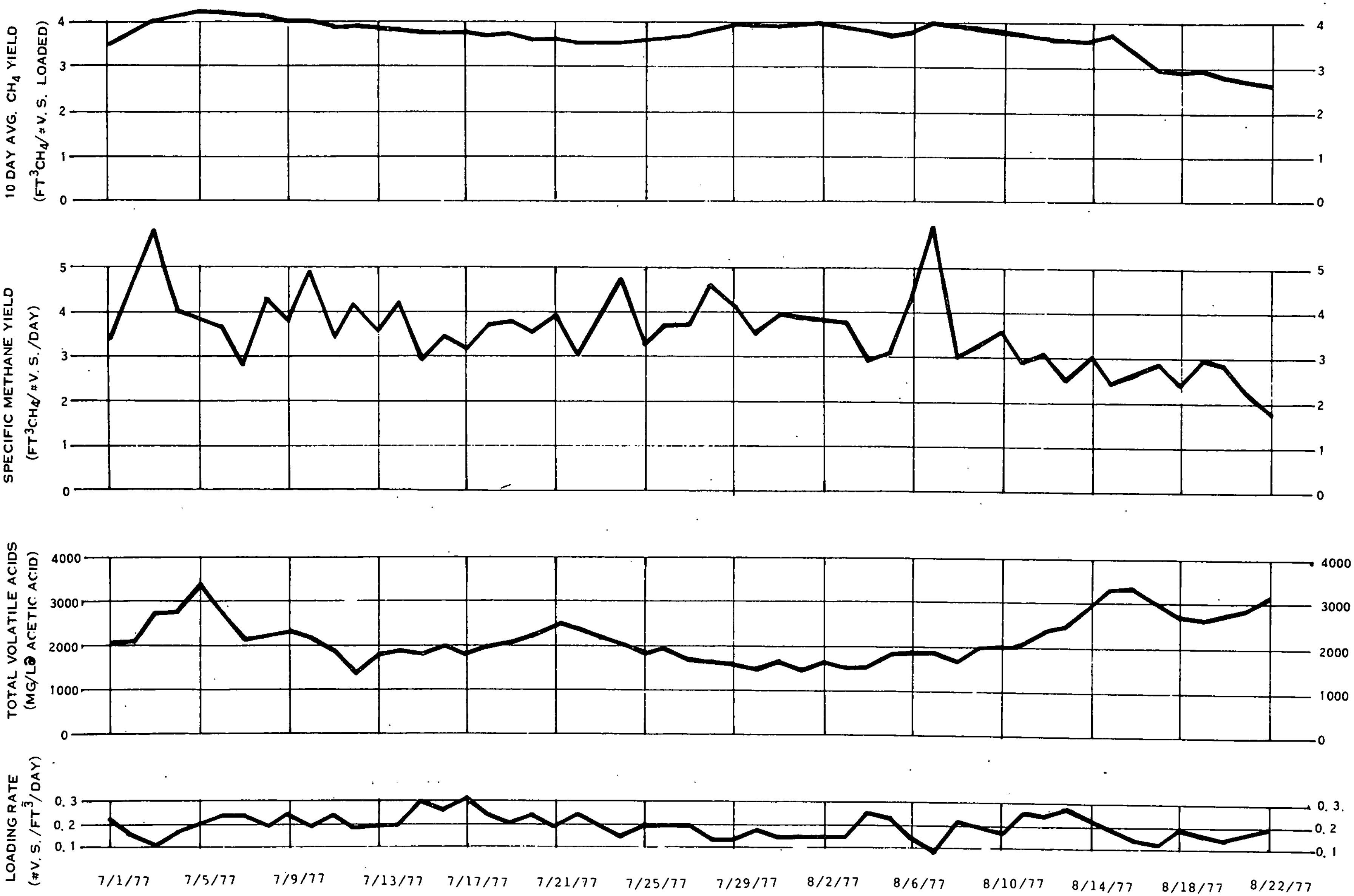
Figure 10

Cattle at Bunk Immediately After Filling With Test Diet may be calculated that utilization of the non-dewatered product as a source of supplemented protein would result in a daily cost savings of approximately $0.06/head/day. Using average prices for feed grains and feeder steers as of December 1977 and slaughter cattle as of April 1978 the profitability of feeding cattle can be calculated as follows: a 700 pound feeder steer would have cost $301 (700 lb x $0.43/lb), the slaughter steer would have sold for $530 (1061 lbs x $0.50/lb), the cattle feed would have cost $155 ($1.20/day x 129 day), and the management costs would have been $19 (15 cents/day x 129 days), resulting in a net profit of $55 ($530 - $19 - $155 - $301). The potential savings of $0.06 per day in feed costs indicated by this preliminary test represents a decrease in feeding costs of $8 or an increased profit of 15%. This increase profit is significant even in the light of the high profit margins realized during this recent time period. During periods of normal profitability which is about $15-$25 per head, this $8 decreased cost represents a significantly higher increased profitability.

3.5 Data Summary

Figures 11 through 15 present those parameters that most clearly indicate the present operating status of the fermentor.

Fresh beef cattle residue was used as substrate until August 11, 1977 at which time use of typical aged manure was initiated. Stable operating conditions were achieved in mid October and since that time various pens have provided aged manure for use as system substrate. While minor fluctuations in performance are noticed when substrates are changed, stable operating conditons of $\sim$ 2000 mg/L TVA concentration and a total gas yield of 5.1 $ft.^3$ gas/pound v.s. loaded at 54% methane resulting ina specific gas yield of 2.75 $ft.^3$ CH_4/pound v.s. loaded have ensued. This effluent gas has, therefore, an energy content of 547 Btu/$ft.^3$. A loading rate of 0.25 pound v.s./ft^3/day coupled with a retention time of 10 days have been maintained throughout this period. While the TVA concentrations has not been maintained at less than 1000 mg/L (as generally thought necessary for stable operation), operating conditions continue to yield encouraging results.


10 DAY AVG. CH4 YIELD
(FT3CH4/#V.S. LOADED)
SPECIFIC METHANE YIELD
(FT3CH4/#V.S./DAY)
TOTAL VOLATILE ACIDS
(MG/L@ ACETIC ACID)
LOADING RATE
(#V.S./FT3/DAY)
7/1/77
7/5/77
7/9/77
7/13/77
7/17/77
7/21/77
7/25/77
7/29/77
8/2/77
8/6/77
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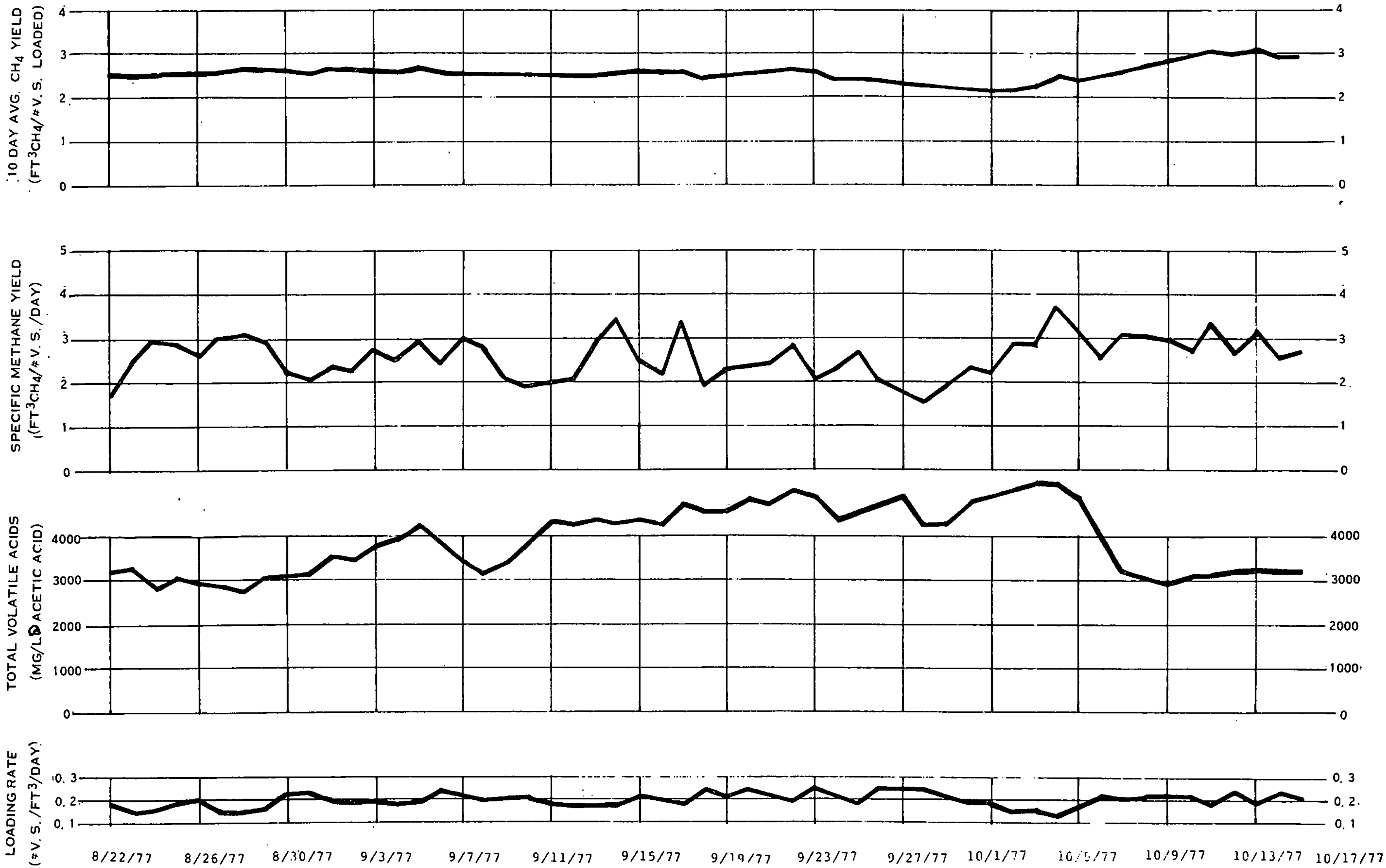
8/22/77

Figure 11


10 DAY AVG. CH_4 YIELD
(FT^3CH_4/#V. S. LOADED)
SPECIFIC METHANE YIELD
(FT^3CH_4/#V. S./DAY)
TOTAL VOLATILE ACIDS
(MG/L AS ACETIC ACID)
LOADING RATE
(#V. S./FT^3/DAY)
8/22/77
8/26/77
8/30/77
9/3/77
9/7/77
9/11/77
9/15/77
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10/17/77

Figure 12

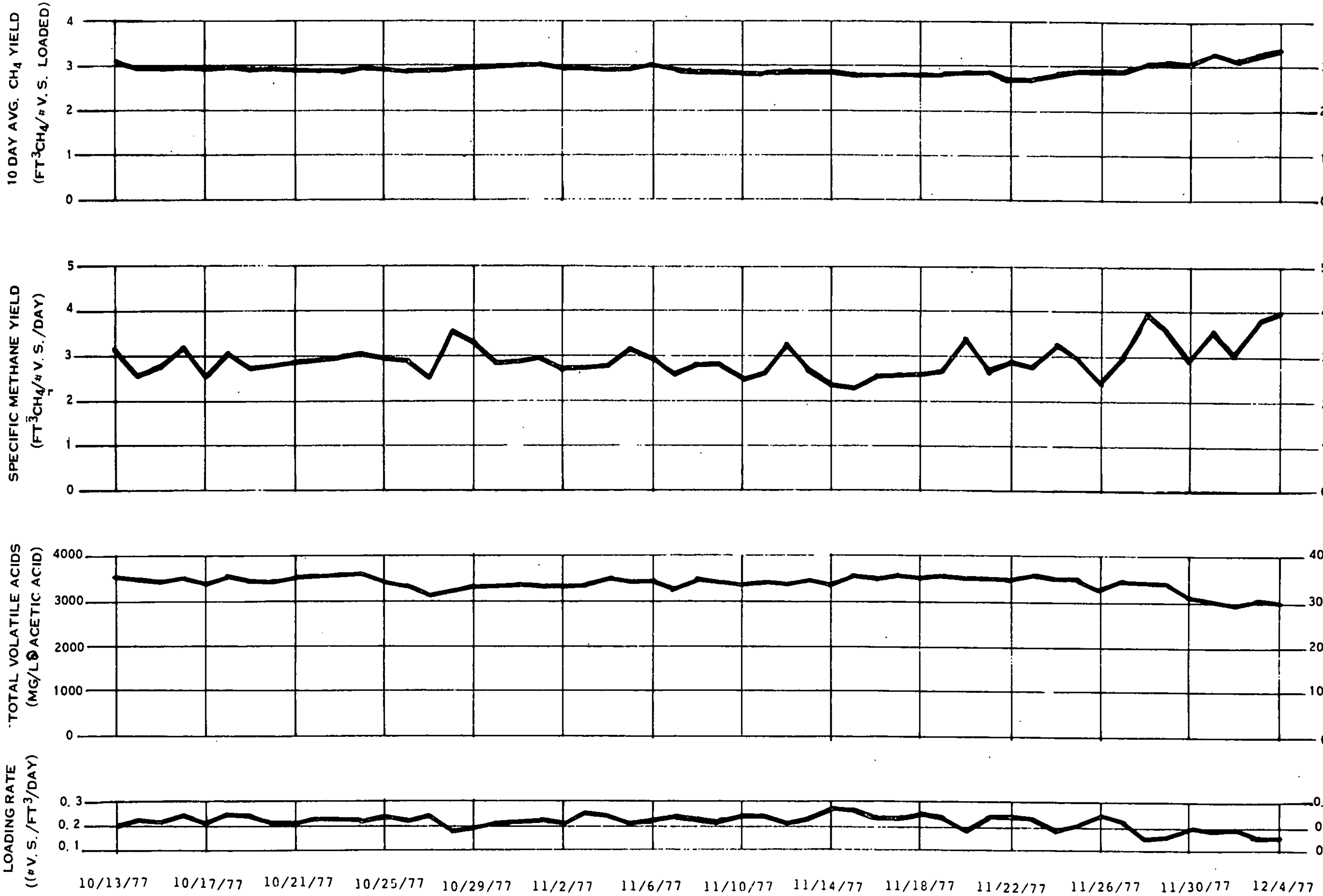

10 DAY AVG. CH_4 YIELD
(FT^3CH_4/# V.S. LOADED)
0
1
2
3
4
SPECIFIC METHANE YIELD
(FT^3CH_4/# V.S./DAY)
0
1
2
3
4
5
TOTAL VOLATILE ACIDS
(MG/L AS ACETIC ACID)
0
1000
2000
3000
4000
LOADING RATE
((# V.S./FT^3/DAY)
0.1
0.2
0.3
10/13/77
10/17/77
10/21/77
10/25/77
10/29/77
11/2/77
11/6/77
11/10/77
11/14/77
11/18/77
11/22/77
11/26/77
11/30/77
12/4/77

Figure 13

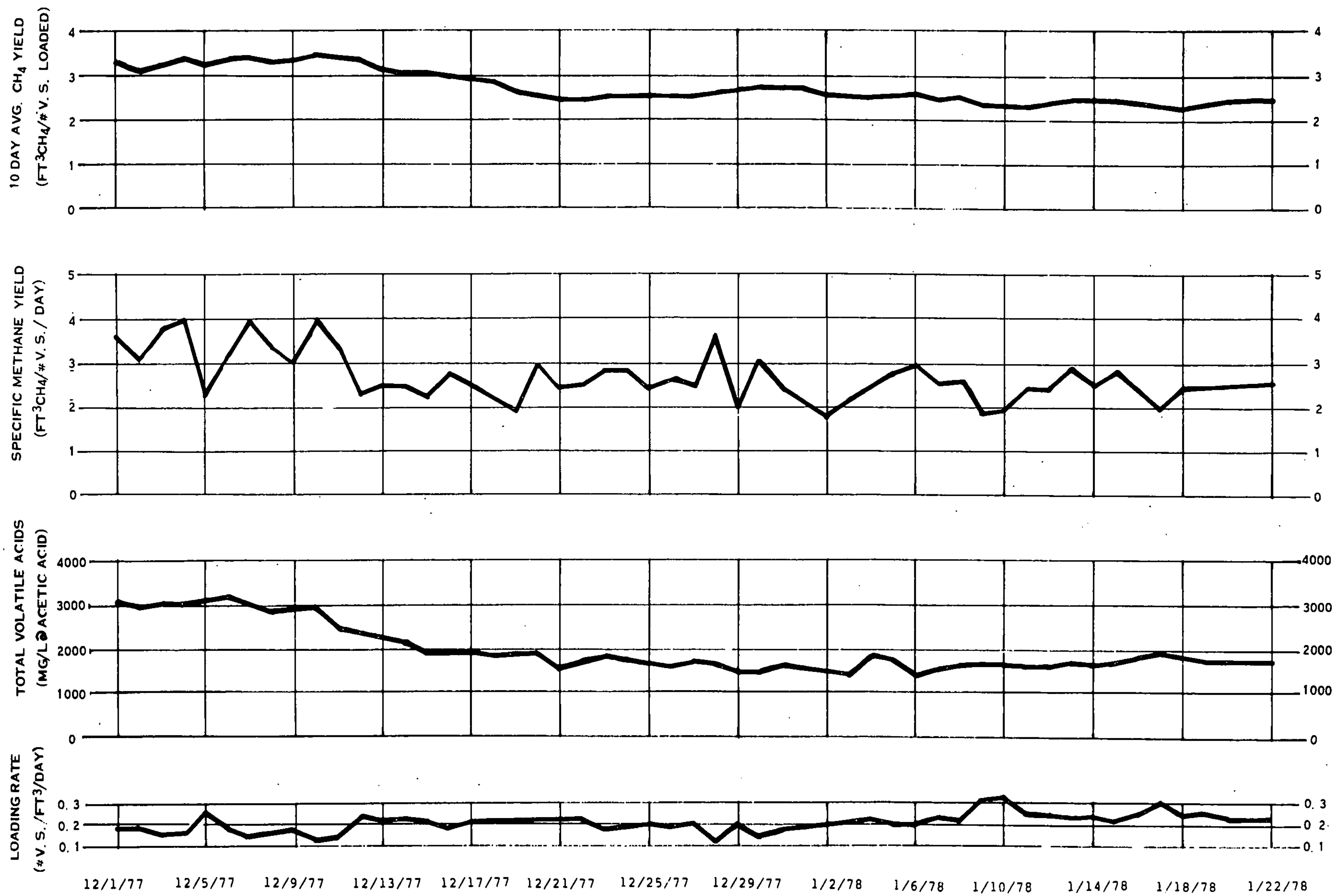
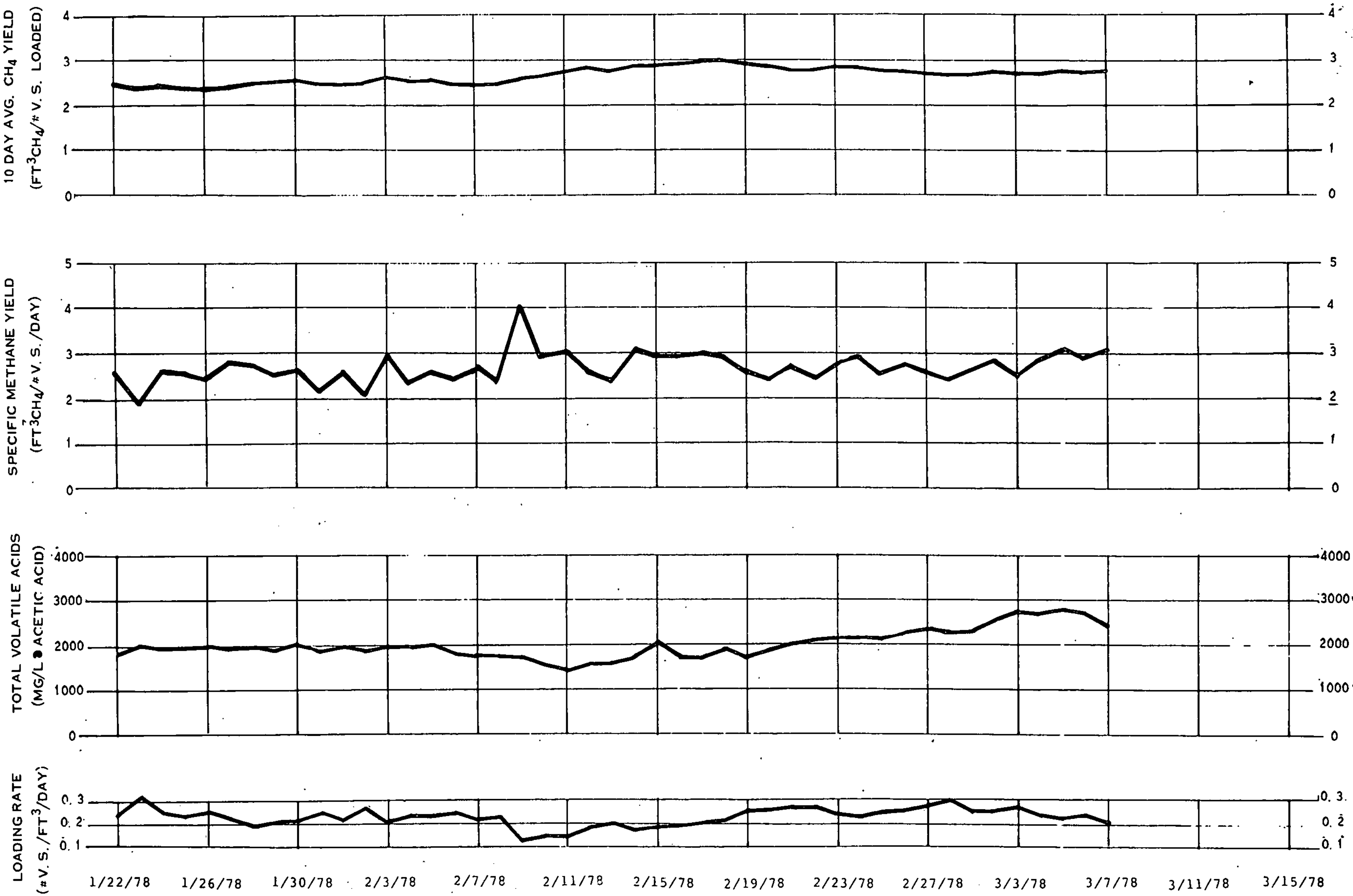

10 DAY AVG. CH4 YIELD
(FT3CH4/# V.S. LOADED)
SPECIFIC METHANE YIELD
(FT3CH4/# V.S./ DAY)
TOTAL VOLATILE ACIDS
(MG/L @ ACETIC ACID)
LOADING RATE
(# V.S./FT3/DAY)
12/1/77
12/5/77
12/9/77
12/13/77
12/17/77
12/21/77
12/25/77
12/29/77
1/2/78
1/6/78
1/10/78
1/14/78
1/18/78
1/22/78

Figure 14



10 DAY AVG. CH4 YIELD
(FT3CH4/#V.S. LOADED)
SPECIFIC METHANE YIELD
(FT3CH4/#V.S./DAY)
TOTAL VOLATILE ACIDS
(MG/L ● ACETIC ACID)
LOADING RATE
(#V.S./FT3/DAY)
1/22/78
1/26/78
1/30/78
2/3/78
2/7/78
2/11/78
2/15/78
2/19/78
2/23/78
2/27/78
3/3/78
3/7/78
3/11/78
3/15/78

Figure 15

4.0 FUTURE ACTIVITIES

For the remainder of the program (until August, 1978), the mobile facility will be operated at the Kuner feedlot to:

- Continue the determination of the methane gas yields from the residue from a number of additional dirt lot pens.
- Continue to document the variability of residue feedstocks from a wide variety of pens both at Monfort and from a number of area feedlots.
- Evaluate the effects of increasing organic loading upon system performance.
- Conduct acceptability tests with centrifuge cake as a cattle feed supplement.
- Evaluate the effect of centrate recycle upon fermentor performance.
- Study and determine what separation techniques are generally applicable to the removal of the sand and grit type inert material and what hardware is commercially available to implement the removal.

The experimental system will be operated for periods of approximately 90 days each on the residues collected from different feedlot pens. The system will be maintained at an operational temperature of 57°C and a retention time of 10 days. The gas yield and composition will be documented along with the normal operational parameters such as dry matter, volatile matter, volatile acids, pH and alkalinity in addition to analyses for specific chemical constituents (as necessary).

The variability of the residue will be documented by a continuation of the present sampling and analysis procedure which periodically collects residue from a number of feed pens randomly distributed on the Kuner feedlot for determination of dry matter and volatile fraction. This analysis will be extended to samples from other feedlots in the general area.

In order to establish the acceptability of the fermentor effluent to cattle as a feed ingredient, it will be included in the daily ration for a limited number of cattle. This material will be used in the form of the solid cake discharged from the centrifuge.

The incoming residue to the facility normally is mixed into a slurry with feedmill quality water. In order to evaluate the practicality of utilizing the liquid centrate from the system for this purpose a 90 day test will be conducted during the last dirt pen test substituting the centrate for the water normally used. During this evaluation analyses will be performed to monitor the potential build up of various chemical constituents.

Cattle residue from the Monfort feedlot which is typically high in a nonorganic sand and grit fraction will be collected and shipped to Windsor Locks. A laboratory program will be conducted to establish the amount of inert material and organic material which will settle within the fermentation tank and is capable of being removed. The effluent material from the tank will be collected and used to evaluate various means of extracting the remaining inert materials prior to the harvesting of the refeed ingredient. Evaluations of various commercial techniques will be performed to identify feasible removal methods. In addition, attempts will be made to have testing performed by equipment manufacturers on a no-cost basis.

The results of the complete program will culminate in a final report that will identify the technical and economic feasibility of producing fuel gas and a refeed product from dirt feedlot residues.

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