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Biological Conversion of Biomass to Methane

Final Subcontract Report
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Prepared under Subcontract No. XB-9-8357-1

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A Division of Midwest Research Institute

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SERI TECHNICAL MONITOR

DAN JANTZEN

FOREWORD

This report describes the results of a research project to determine the effectiveness of thermochemical treatment to enhance the rates of production and yields of methane from crop residues by a fermentation process. While some of the results of this research are negative, it is expected that this report will be of interest to researchers working on fermentation and pretreatment processes.

Funds to support this research were provided by the Biomass Energy Systems Division of the U.S. Department of Energy.

Dan Jantzen, Project Manager
Biomass Program Office.

Abstract

The production of a fuel gas by the anaerobic digestion of crop residues is economically unattractive because of the poor conversion efficiencies experienced with high rate methane fermentation processes. Pretreatment of the residue prior to fermentation has been found to substantially improve the biodegradability of the ligno-cellulose fibers. Thermo-chemical pretreatment using NaOH at temperatures up to 200°C has been found to be effective for laboratory-scale studies. The effectiveness of this pretreatment was evaluated using 0.775-m^3 methane fermentation reactors. A minimum feed slurry solids concentration of five percent was used.

Pretreatment conditions tested included NaOH concentrations ranging from 1.33 to 13.3% by weight, treatment temperature ranging from 106 to 160°C, solids concentration during pretreatment ranging from 16.8 to 33.2% and pretreatment time ranging from 0.316 to 3.16 hours. The solids concentration and pretreatment temperature did not have a significant effect on the gas yield from corn stover. Increases in caustic dosage and pretreatment time increased the gas yield until inhibitory conditions developed. Caustic levels above 7.33% and pretreatment times greater than 120 minutes produced products that caused severe inhibition of the methanogenic bacteria when processing corn stover. When processing wheat straw, all pretreatment conditions resulted in inhibition of the methanogenic microorganisms. The first-order rate constant based on COD reduction for corn stover was increased from 0.25 day^{-1} for untreated stover to 0.51 day^{-1} for pretreatment conditions of 4.33% caustic and a one-hour pretreatment time. The stover biodegradability was increased from 36% to 78%. Because of the high cost of caustic, the improved conversion efficiencies will not be cost-effective. High rate methane fermentation of corn stover and wheat straw does not appear to be economically feasible.

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1. INTRODUCTION

In 1978, approximately 380 million dry tons of crop residues were produced in the United States and this figure is expected to increase over the next 40 years (Ashare et al., 1979). There is much interest in using this material for energy production and one option available is the generation of methane by anaerobic digestion. However, these lignocellulosic materials are resistant to biodegradation and unless some form on pretreatment is employed, the methane generated is unlikely to be economic as large digesters operating at long retention times will be required.

The research presented in this report has been conducted to determine thermochemical pretreatment conditions capable of improving the digestibility of crop residues. Corn stover and wheat straw, which are presently the most abundant crop residues produced in the USA (Ashare et al., 1979), were selected for this investigation.

2. CROP RESIDUE COMPOSITION

The composition of corn stover and wheat straw from various sources is presented in Tables 1 and 2. Both substances have an approximate composition of 40% cellulose, 30% hemicellulose, 15% lignin and 4% protein with the remainder ash.

The fine structure of plant cell walls, the structural importance of cellulose and the factors affecting its biodegradability have been well described in the literature (Cowling, 1963 and 1975; Cowling and Brown, 1969). Cellulose is a high molecular weight polymer of D-anhydroglucopyranose units connected by β, 1-4 glycosidic bonds. Although the degree of crystallinity of cellulose fibers may vary from one plant to another, its chemical composition is constant.

Table 1. The Composition of Corn Stover

	Cell Wall Constituent (w/w% TS)						
Reference	Cell-ulose	Hemi-cellulose	Lig-nin	Protein	Ash	Nitro-gen	Phos-phorus
Lipinsky et al. (1977b)	32.8	28.3	8.7	3.1	4.9	-	-
Miller (1958)	-	-	-	6.4	6.8	-	0.09
National Academy of Science (1971)	-	-	-	-	6.2	0.91	0.08
Pfeffer & Quindry (1979)	46.6	-	23.5	-	20.2	0.63	0.11
Wilke (1978)	-	-	13.7	4.2	5.3	-	-
Wilke (1978)	37.7	-	10.5	-	7.0	-	-
Wilke et al. (1978)	-	-	15.1	4.0	4.3	-	-

Table 2. The Composition of Wheat Straw

Reference	Cell Wall Constituent (w/w% TS)						
	Cell-ulose	Hemi-cellulose	Lig-nin	Protein	Ash	Nitro-gen	Phos-phorus
Agricultural Research Council (1976)	43.5	-	9.9	1.7-3.4	-	-	-
Gaden (1976)	40.0	29.2	13.6	3	-	-	-
Goering et al. (1973)	49	27	12.5	-	-	-	-
Miller (1958)	50.1	-	13.7	3.6	8.1	-	0.08
National Academy of Science (1971)	-	-	-	-	6.3	0.51	0.07
O'Neil et al. (1979)	32.9	21.9	14.5	3.0	9.6	-	-

Lignin has also been studied in detail (Pearl, 1967; Sarkanen and Ludwig, 1971) but due to its complexity and the various forms it takes in different plant fibers, no one structural formula has been accepted. The class monocotylendonous angiosperm, which includes the crop residues used in this study, contains lignin formed from the precursor trans-coniferyl, trans-sinapyl and trans-p-coumaryl alcohols (Pearl, 1967).

The term hemicellulose incorporates a variety of different organic compounds. Originally the readily hydrolysable carbohydrates were named hemicellulose to differentiate them from cellulose (Wenzl, 1970). Three well-defined groups of hemicelluloses, the xylans, mannans and galactans are now recognized as components in all lignified plants. In coniferous woods, mannose is the major monomer while in deciduous woods xylose predominates. Galactose and rhamnose are found in lesser quantities in deciduous woods while arabinose and glucuronic acid are minor components of hemicellulose for both coniferous and deciduous species. Xylan is the major constituent of hemicellulose in corn stover and wheat straw, with arabanan, galactan and mannan present in lesser quantities (Table 3).

Table 3. Assay of Hemicellulose Constituents in Corn Stover and Wheat Straw. (Wilke et al., 1978)

Hemicellulose Constituent (%w/w TS)	Crop Residue: Corn Stover	Crop Residue: Wheat Straw
Xylan	13.0	16.9
Arabanan	2.8	2.1
Mannan	0.25	0.72
Galactan	0.75	2.16

The composition of the crop residue and the biodegradability of its major components will determine the quantity and composition of the gas produced. The following equation was developed to allow the prediction of the gas composition from a knowledge of the feedstock composition (Buswell and Mueller, 1952):

$$C_nH_aO_b + \left(n - \frac{a}{4} - \frac{b}{2}\right) H_2O \rightarrow \left(\frac{n}{2} - \frac{a}{8} + \frac{b}{4}\right) CO_2 + \left(\frac{n}{2} + \frac{a}{8} - \frac{b}{4}\right) CH_4 \qquad (1)$$

With organic substrates, such as crop residues, it is usual to assume that the biodegradable volatile solids (VS) consist entirely of cellulose. Thus, each kilogram of volatile solids removed by fermentation will produce .415 m^3 CH_4 at STP or 0.453 m^3 CH_4 at 25°C. This practice assumes:

(a) The biodegradability of lignin is negligible.

(b) The gas yield per gram of hemicellulose is similar to that per gram of cellulose metabolized.

Both assumptions appear valid for crop residues that have not undergone pretreatment prior to digestion. McCarty et al. (1978), demonstrated that Klason lignin that had not undergone thermochemical pretreatment was 2% convertible to methane.

If it is assumed that the hemicellulose in crop residues is 100% pentose (molecular formula - $(C_5H_8O_4)_n$, Vines and Rees, 1968) then a theoretical methane yield of 0.424 m^3 CH_4/kg hemicellulose fermented is obtained at STP. As xylan and arabanan, which are pentose polymers, account for 87-94% of the hemicellulose of corn stover and wheat straw (Table 3), the validity of these assumptions seems established.

However, the assumption that the biodegradable volatile solids are cellulose may not give an accurate estimate of the gas yield from thermochemically pretreated lignocellulosic materials. Klason lignin heat treated at 250°C and exposed to a Biochemical Methane Potential (BMP) test, at a concentration below 500 mg/l to prevent inhibition, demonstrated a 26% bioconvertibility to methane. Assuming an average molecular formula of lignin to be a polymer based upon a $C_9H_9O_3$ (OCH_3) monomer (Kirk, 1971), 0.629 m^3 CH_4 will be produced at STP per kg lignin metabolized. Also, it will be shown that at elevated temperatures under alkaline conditions, humic substances can be formed from both hemicellulose and cellulose (Section 3.2.2).

The occurrence of these ill-defined chemical reactions with their unknown effects on the biodegradability, volatility and oxidation state of the products makes it very difficult to predict a methane yield per kilogram of volatile solids fermented for thermochemically pretreated lignocellulosics.

3. CROP RESIDUE PRETREATMENT

3.1 Introduction

The objective of crop residue pretreatment is to provide increased methane yields from the digestion process thereby reducing the unit cost of the energy produced. Pretreatment may affect two parameters used to model the anaerobic digestion process:

(a) S_o, the ultimate biodegradability (usually expressed as % VS)

(b) K, the first-order rate constant (d^{-1})

For a completely-mixed reactor, as employed in these studies, and assuming first-order kinetics, these variables are related by the following equation:

$$\frac{S}{S_o} = \frac{1}{1+K\theta} \qquad (2)$$

where:

θ = hydraulic retention time (d)

S = effluent substrate concentration (usually expressed as % VS).

At a constant K value, Equation 2 indicates that a high S_o offers the following benefits:

(a) Greater quantities of methane are produced per kg VS added.

(b) The quantity of residue for disposal is minimized.

(c) Higher solids destruction will be achieved allowing a more concentrated feed slurry to be used. This reduces the reactor size as well as the heat and power requirements.

A high rate constant is desirable as it indicates that the substrate is readily converted to methane and volatile solids removals approaching S_o may be achieved at relatively short retention times. A high rate constant therefore offers the following advantages:

(a) Increased quantities of gas are produced per unit of digester volume.

(b) Smaller digester volumes may be used to achieve a given volatile solids reduction thereby reducing heat and power requirements. The quantity of residue for disposal is also minimized.

Typical values of S_0 and K reported for various substrates used for thermophilic anaerobic digestion are presented in Table 4. The data on domestic refuse and feedlot manure are included to demonstrate values of S_0 and K which allow anaerobic digestion to provide a potentially economic source of methane. The positive results obtained in pilot-plant studies with these substrates have prompted the Department of Energy to fund larger proof-of-concept studies to confirm this potential (Lizdas and Coe, 1979; Ware, 1979).

Table 4. Design Data for the Thermophilic Anaerobic Digestion of Various Substrates

Substrate	Pretreatment Conditions (NaOH conc., temp., time)	S_0 (% VS)	K (d^{-1})	Reference
Domestic Refuse	None	51-55	.78-.95	Pfeffer, 1974
Beef Manure	None	27.5-65.0	.24-.25	Pfeffer and Quindry, 1978
Corn Stover	None	36	.25	Pfeffer and Quindry, 1979
Corn Stover	5% NaOH, 115°C, 4 hrs	71-73	-	Pfeffer, 1979
Wheat Straw	No NaOH, 115°C, 4 hrs	49	.23	Pfeffer, 1979

When digested under thermophilic conditions at retention times of 15 days or less, untreated corn stover demonstrated a very low ultimate biodegradability of 36% VS (Pfeffer and Quindry, 1979). However, recent BMP studies performed under mesophilic conditions have yielded S_0 values in excess of 50% VS (Colberg et al., 1980a).

The rate constant for untreated corn stover is comparable to that for beef manure but only one third to one quarter of that obtained with domestic refuse (Table 4).

Pfeffer (1979) considered an ultimate biodegradability of 55% VS, as observed with domestic refuse, to be marginal from an economic viewpoint. Also, in this instance, the high K value will partially compensate for the low S_0 value and improve the economic prognosis.

Therefore, the low biodegradability of corn stover, combined with its average K value, is likely to render it an uneconomic substrate for methane generation. This is especially true when the substrate acquisition costs are considered. Domestic refuse and feedlot manure have a zero or negative acquisition cost (Pfeffer, 1979) while in most instances crop residues will exhibit a positive cost. Ashare et al. (1979), concluded that typical acquisition costs would vary from \$5 - 20/ton accounting for an increase in the unit gas cost of \$1 - $5/10^6$ BTU. Actual acquisition costs may be even higher than the figures cited by Ashare et al. (1979), with costs as high as \$35 - 45/ton of dry matter delivered to the processing plant being mentioned (Jewell, 1980; Lipinsky et al., 1977a).

However, an alkaline/heat pretreatment process prior to digestion can substantially improve the biodegradability of crop residues (Pfeffer, 1979). It is therefore important to study this thermochemical pretreatment process to determine its potential for improving gas yields and to enable its effects on the economics of methane generation from crop residues to be assessed.

3.2 Thermochemical Pretreatment Process

Much of the difficulty in digesting the cellulose in untreated crop residues is due to its close association with lignin. The digestibility of cellulose has been negatively correlated with the lignin content of the fiber for both ruminants (Tomlin et al., 1965) and anaerobic digesters (Chandler and Jewell, 1980).

Whether the cellulose degradation is limited by the existence of a lignin-cellulose bond or whether the three dimensional lignin network physically protects the cell wall carbohydrates has yet to be elucidated (Millett et al., 1975). However, to improve the degradability of any lignocellulosic material two factors should ideally be achieved:

(a) The fine structure of the cellulose molecule should be altered. The conversion of crystalline to amorphous cellulose will generally assist enzymatic hydrolyses.

(b) The lignin-cellulose complex should be disrupted or, at least, the pore size increased to improve the accessibility of the cellulose to enzymatic attack.

The objective of many pretreatment processes which have been investigated is to maximize these two effects. Many of these processes have been reviewed by Gossett and McCarty (1975), Kitts et al. (1968), and Millett et al., (1975).

In this report, the term thermochemical pretreatment will refer to a process using sodium hydroxide and heat to treat crop residue fibers.

Subsequent comments will be directed by describing the reactions which occur during this process. To clarify these reactions, data pertinent to steam pretreatment and alkaline pretreatment will be considered in separate sections.

3.2.1 Steam Pretreatment

The treatment of a lignocellulosic slurry at elevated temperatures and pressures without chemical addition has been defined as autohydrolysis (Colberg et al., 1980c). Autohydrolysis is equivalent to a very mild acid and heat pretreatment as carbohydrate hydrolysis results in the formation of acid end-products which lower the pH of the sample (Colberg et al., 1980a).

As hemicellulose is the most readily hydrolyzed fiber component. Autohydrolysis is effective in solubilizing much of this compound as demonstrated by the data of Ulmer et al. (1980), using feedlot waste as a substrate (Table 5). With increasingly severe steam treatment, the hemicellulose content of the fibers steadily decreased and a concomitant increase in soluble cellular material was observed. Negligible amounts of cellulose, lignin and protein were solubilized.

Steam treatment improved the biodegradability of the fibers as measured by the *in vitro* rumen digestibility (IVRD) and although *Chaetomium cellulolyticum* grew adequately on fibers treated as 170-190°C, fibers treated at 200°C for 10 minutes failed to support the growth of this fungus. Similarly, attempts to ferment steam-exploded fibers failed. Washing the fibers twice with water failed to remove the growth-inhibiting compound(s) and no attempt was made to chemically define the cause of the inhibition.

Table 5. Effect of Steam Treatment on the Composition and Digestibility of Feedlot Waste Fibers[a] (Ulmer et al., 1980)

	Percent of Dry Weight						
Treatment	Crude[b] Protein	Soluble Cellular Material	cellulose	Hemicellulose	Lignin	Ash[c]	IRVD[d]
None	7.9	21.4	33.8	29.8	10.0	4.9	38.0
170°C/10 min	7.8	27.2	32.2	24.0	12.9	4.1	39.3
180°C/10 min	7.8	31.3	33.8	18.5	12.1	4.2	40.5
190°C/10 min	7.5	39.2	33.3	12.4	11.7	3.8	48.1
200°C/10 min	7.8	47.5	33.6	2.8	11.8	4.2	54.0

[a] Fibers initially 30% (w/w) dry matter prior to steam treatment.

[b] Protein content estimated by nitrogen x 6.25.

[c] Acid insoluble ash.

[d] in vitro rumen digestibility.

The effect of an identical steam explosion process on poplar wood chips has also been studied (O'Neil et al., 1979). This is a proprietary process patented by the Iotech Corporation, Canada and specific details of the process have not been published in the available literature. The major function of steam explosion is to break the lignin-cellulose-hemicellulose complex and increase the accessibility of cellulose to enzymes and chemicals thereby improving its rate of hydrolysis. Also, substantial saccharification of cellulose, in addition to hemicellulose, occurs and a significant depolymerization of lignin occurs as evidenced by its improved extractability in a variety of solvents (O'Neil et al., 1979). This is in agreement with earlier data on the autohydrolysis of wood. Lora and Wagman (1978) have reported that during this process lignin undergoes depolymerization and repolymerization reactions. The former results in the production of an extractable lignin while the latter forms a condensed, unextractable lignin. At any temperature, the lignin solubility is determined by a time/temperature relationship and the amount of extractable lignin is greater at higher temperatures (Lora and Wagman, 1978).

Professor P. L. McCarty's group at Stanford University has also been studying the stage-wise autohydrolysis of wood, in this case white fir (Colberg et al., 1980a, b, c). Their results indicate that a significant proportion of the hydrolyzable carbohydrates (primarily hemicellulose plus some cellulose) are solubilized under relatively mild pretreatment conditions (175-200°C, 0-30 minutes). The remaining carbohydrates require harsher treatment conditions (225°C, 60-120 minutes) to bring about their hydrolysis but the use of the more severe conditions reduces the biodegradability of the resulting material (Colberg et al., 1980b).

An understanding of the hydrolytic reactions occurring may be obtained by a study of the results obtained from the autohydrolysis of a 6% Total Solids (TS) white fir slurry at 175°C for 30 minutes (Colberg et al., 1980c). Monosaccharides accounted for 21% of the COD, oligosaccharides 64% and unidentified compounds the remaining 15% of the COD. From the composition of the sugars it was concluded that hemicellulose was the major component hydrolyzed. It is probable that furfural and hydroxymethyl furfural, the hydrolysis products of pentoses and hexoses respectively, account for much of the unknown COD. In addition, levulinic acid, formic acid and some lignin hydrolysis products may be present (Wenzl, 1970).

In summary, steam treatment of wood primarily solubilizes the hemicellulose component of the fiber resulting in the formation of pentoses and hexoses in the treatment liquor. A proportion of these undergo dehydration to form furfural and hydroxymethyl furfural respectively. In addition, a small quantity of lignin may be solubilized. The use of higher autohydrolysis temperatures results in a greater hydrolysis of cellulose but also increases the dehydration reactions of the hexoses formed, thereby decreasing their biodegradability. It is also likely that increased solubilization of lignin will occur.

3.2.2 Alkaline Pretreatment

Cellulose is an acetal and, as such, it is stable towards alkaline hydrolysis. Alkaline pretreatment, therefore, solubilizes much of the hemicellulose, lignin and protein, resulting in a cellulose enriched fiber. This is demonstrated by the data of Chen and Anderson (1980) (Table 6) who investigated the effects of pretreatment on the various components of rice straw. At room temperature using a 4% w/v NaOH solution, most of the hemicellulose and protein were solubilized along with half the lignin and a fifth of the cellulose.

In the reaction between sodium hydroxide and hemicellulose, sugar acids, lactones, simple organic acids and humic substances are ultimately formed. Only after a considerable amount of hemicellulose is dissolved does the solubilization of lignin proceed. Subsequently, the cellulose itself is attacked (Wenzl, 1970).

Table 6. Effect of Alkali Pretreatment on the Components of Rice Straw Fibers* (Calculated from the data of Chen and Anderson, 1980).

Component	Untreated Fibers (% TS)	Treated Fibers (% TS)	% Solubilization of each Component
Cellulose	41.9	66.6	20.5
Cell Solubles	28.2	15.9	71.6
Hemicellulose	26.3	11.0	79.1
Lignin	6.9	7.1	47.8
Protein	3.8	1.0	86.8
Ash	1.0	0.6	30.0

* One part of ryegrass straw was pretreated with 10 parts 4% w/v NaOH at room temperature for 24 hours.

Wenzl (1970) has also described the events occurring during the soda wood pulping process in which NaOH is the only added chemical. At temperatures below 100°C, 30-40% of the added alkali is consumed, but the dissolution of carbohydrates and lignin is insignificant. Between 100°C and 150°C, about 70% of the glucomannan (a constituent of hemicellulose) originally present is dissolved. At 140-150°C dissolution of lignin begins and, at 170°C, about 50% of the latter is solubilized.

With isolated lignin, alkaline solutions cause the cleavage of the alkyl-aryl ether linkages at the para-position of the phenyl ring. At temperatures of 160°C or greater liberation of some phenolic hydroxyl groups occur and some carbon-to-carbon bonds also become sensitive to hydrolysis. There are also some indications the linkages between the β and δ carbon atoms of the propyl side-chain become partially split (Wenzl, 1970).

Thus lignin hydrolysis produces a large number of complex molecules and, under suitable conditions, more complex molecules may be formed by condensation reactions (Wenzl, 1970). Among the products of alkaline hydrolysis of wood lignins that have been identified are vanillin, vanillic acid, p-hydroxybenzoic acid, syringaldehyde, syringic acid, acetaldehyde, guaiacylethane and the 1,3-dimethyl ether of pyrogallylethane (Pearl, 1967).

The degradation of cellulose in alkaline solution proceeds by an end-wise peeling reaction from the reducing group end of the molecule and isosaccharinic acid may be produced by rearrangement to form α- and β-glucometasaccharinic acids which are stable in alkaline solution and prevent further degradation of the cellulose (Wenzl, 1970). On average, about 50 D-glucose units are peeled off each cellulose molecule before the reaction is terminated (Whistler and BeMiller, 1958).

At temperatures above about 170°C, the cleavage of the glycosidic bond occurs and more reducing end groups are exposed, allowing an increase in the extent of peeling that occurs (Proctor and Wiekenkamp, 1969).

The free sugars produced by hydrolysis are not stable and lactic, formic, glycolic, dihydroxybutyric and acetic acids may be formed from glucose (Pigman and Horton, 1972). Also, at pretreatment temperatures above 170°C, hydroxylated aromatics, such as humic substances, may be produced from cellulose (Gossett et al., 1976b).

The results obtained with wood must be applied somewhat loosely to the thermochemical pretreatment of crop residues. Although it is likely a similar sequence of reaction will occur, the differences between the substrates will cause variations in the specific reactions observed. For example, the data of Chen and Anderson (1980) indicate that substantial solubilization of hemicellulose and lignin occurs at room temperature using NaOH concentrations comparable to those used in the pulp and paper industry. As previously discussed, wood lignin is only dissolved at elevated temperatures.

Also, xylan is the predominant constituent of the hemicellulose of crop residues (Wilke et al., 1978) (Table 3) whereas glucomannans are the major component of coniferous woods (Wenzl, 1979). As glucomannans are more stable to alkali pretreatment than xylans (Wenzl, 1970), substantial solubilization of crop residue hemicelluloses may be expected at lower temperatures than for coniferous woods.

The structure of lignin also varies from one lignocellulosic material to the next. Although there are only three major precursors of lignin (Pearl, 1967) (trans-coniferyl, trans-sinapyl and trans-p-coumaryl alcohols), these monomers may be joined together by a large number of different bonds (Kirk, 1971) leading to a variety of final structures. The class monocotyledonous angiosperm, which includes both corn and wheat straw, contains lignin formed from all three precursors (Pearl, 1967) so the thermochemical pretreatment of crop residues may be expected to result in a wide variety of lignin solubilization products. Although some monomeric compounds will be formed, a number of more complex soluble products may be expected. Sarkanen and Ludwig (1971) noted that "all known methods of chemical degradation [of lignin] yield small molecular weight products in modest yields only."

In addition to the chemical reactions which partially separate cellulose and lignin, physical changes occur during the hot alkali treatment of lignocellulosics which may also improve their biodegradability. The dilute NaOH treatment of hardwood results in a substantial swelling of the fibers making the carbohydrates more accessible to enzymatic attack (Tarkow and Feist, 1969). Although this mechanism is undoubtedly important in improving the degradability of wood in which the microcapillaries are very small (Cowling, 1975), its relevance to improving the biodegradability of crop residues, which may be presumed to possess much larger microcapillaries, has yet to be established.

4. ANAEROBIC DIGESTION OF THERMOCHEMICALLY PRETREATED LIGNOCELLULOSIC MATERIALS

As described in Section 3, the thermochemical pretreatment of lignocellulosic materials results in the solubilization of numerous complex chemical compounds. The exact nature of many of these compounds is unknown and the situation is further complicated by the dependence of the solubilization products on the hydroxide concentration and the pretreatment temperature. Many of the simple compounds formed from the degradation of sugars, such as lactic, formic, glycolic and acetic acids are known to be converted to methane by a consortium of bacteria which includes species of the *Methanobacteriaceae*.

Also, it has been demonstrated that simple aromatic compounds, including lignin precursors and possible products of alkaline degradation, may be fermented to yield approximately stoichiometric quantities of CH_4 and CO_2. (Clark and Fina, 1952; Ferry and Wolfe, 1976; Healy and Young, 1979; Nottingham and Hungate, 1969; Tarvin and Buswell, 1934).

However, such results cannot be directly applied to the anaerobic digestion of thermochemically pretreated crop residues. Firstly, the products formed by alkaline pretreatment are complex, ill-defined and will vary with the pretreatment conditions used. The extent to which monomeric aromatic compounds are formed is unknown but, as previously noted, lignin is a very difficult compound to chemically degrade to low molecular weight products. A substantial fraction of the lignin solubilized may be in the form of medium molecular weight oligoaromatic compounds. Little is known about the biodegradability of such molecules.

Secondly, the research into the formation of methane from simple aromatic compounds has been performed at relatively low substrate concentrations. For example, Healy and Young (1979) used a concentration of 300 mg/l to investigate the digestibility of a wide range of aromatic compounds. Nottingham and Hungate (1969) studied benzoate at a low concentration of 0.02% and at higher concentrations of 0.5-1%. Although stoichiometric conversion of benzoate to methane was obtained at the lowest concentration, complete inhibition of the methanogenic fermentation was observed at the higher concentrations.

Similar results have been obtained using more complex lignocellulosic substrates. Gossett et al. (1976b), used the BMP test to evaluate the effect of thermochemical pretreatment on several lignocellulosic materials. Douglas fir, newsprint, cardboard, office bond paper, raw domestic refuse and digested domestic refuse were studied at an initial total solids concentration of 25 g/l. Inhibition of methanogenesis was observed when the lignin content in the sample was greater than approximately 1,000 mg/l. Subsequently, it has been reported that the soluble products resulting from the heat treatment of 500-1,000 mg/l lignin are inhibitory to methanogenic cultures (McCarty et al., 1978). Boruff and Buswell (1934) reported that 2,500 mg/l of lignin isolated from corn cobs completely inhibited the formation of methane from glucose.

Gossett et al. (1976b), observed that 12.5 g/l of alkali lignin inhibited the methane fermentation of cellulose, xylan and bacterial cells pretreated with 300 meq/l NaOH at various temperatures for one hour. The methane fermentation was not completely inhibited, but less gas was produced than from a control fed substrate that had not been thermochemically pretreated. The degree of inhibition was more severe at high pretreatment temperatures.

In addition to the inhibition from the soluble lignin degradation products, the methane fermentation may be retarded by the humic substances formed by the heat treatment of cellulose and hemicellulose. The sugars and decomposition products of the carbohydrates may also react with the solubilized lignin as demonstrated by the data of Gossett et al. (1976b). By treating 12.5 g/l of cellulose and 12.5 g/l of alkali lignin with 300 meq/l NaOH for one hour at temperatures of 135-225°C, 13-16 g/l of soluble hydroxylated aromatic compounds were formed. The treatment of 12.5 g/l of xylan and 12.5 g/l of alkali lignin under identical conditions yielded 14-18 g/l of soluble hydroxylated aromatic compounds. A mass balance indicates that some carbohydrate degradation products must have reacted with the products of lignin solubilization. These reactions may account for the inhibition observed when steam-exploded feedlot manure was fermented by *Chaetomium cellulolyticum* (Ulmer et al., 1980).

The digestion studies contained in this report have been performed at a total solids concentration of approximately 50 g/l and, as crop residues contain approximately 15% w/w lignin, the digesters were fed a slurry containing approximately 7.5 g/l of thermochemically treated lignin. Severe inhibition of methanogenesis may be expected under these conditions. To reach a level of heat-treated lignin of 500 mg/l would require a 3.33 g/l of total solids in the feed slurry. At such dilute substrate concentrations the need for larger digesters and the specific heat requirements of the influent would render the generation of methane uneconomical.

The objective of this reasearch is therefore to assess the practicality of thermochemical pretreatment for improving the yields of methane from crop residues and to elucidate the optimum pretreatment conditions. It is evident that ideal pretreatment would consist of solubilizing the hemicellulose and swelling the fibers to improve enzyme accessibility to the cellulose while solubilizing as little of the lignin and cellulose as possible.

5. EXPERIMENTAL APPARATUS AND METHODS OF ANALYSIS

5.1 Experimental Fermentation System

This methane fermentation system was housed in the Department of Civil Engineering's Dynamic Testing Lab. The fermentation reactors consisted of four completely mixed stainless steel reactors with a total volume of 0.91 m^3 each. The operating level in each reactor was 0.775 m^3. Each digester was mixed at 75 rpm. The dimensions of the reactor and its associated mixer are shown in Figure 1. Heating was provided by circulating hot water from a water heater through external jackets on each tank. A temperature controller (TC) opened a solenoid valve (SV) to allow the hot water to circulate through the jacket when the temperature dropped below the set point. Figure 2 shows a schematic diagram for two digesters. A second pair of digesters were operated in parallel.

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

5.2 Crop Residue Preparation Equipment

Prior to thermochemical pretreatment, the crop residues underwent size reduction. This was accomplished with a "granulator" (H. C. Davis and Sons Inc., Bonner Springs, Kansas) equipped with a 3.2 mm screen. To be effectively milled, the crop residue had to be relatively dry. This assisted

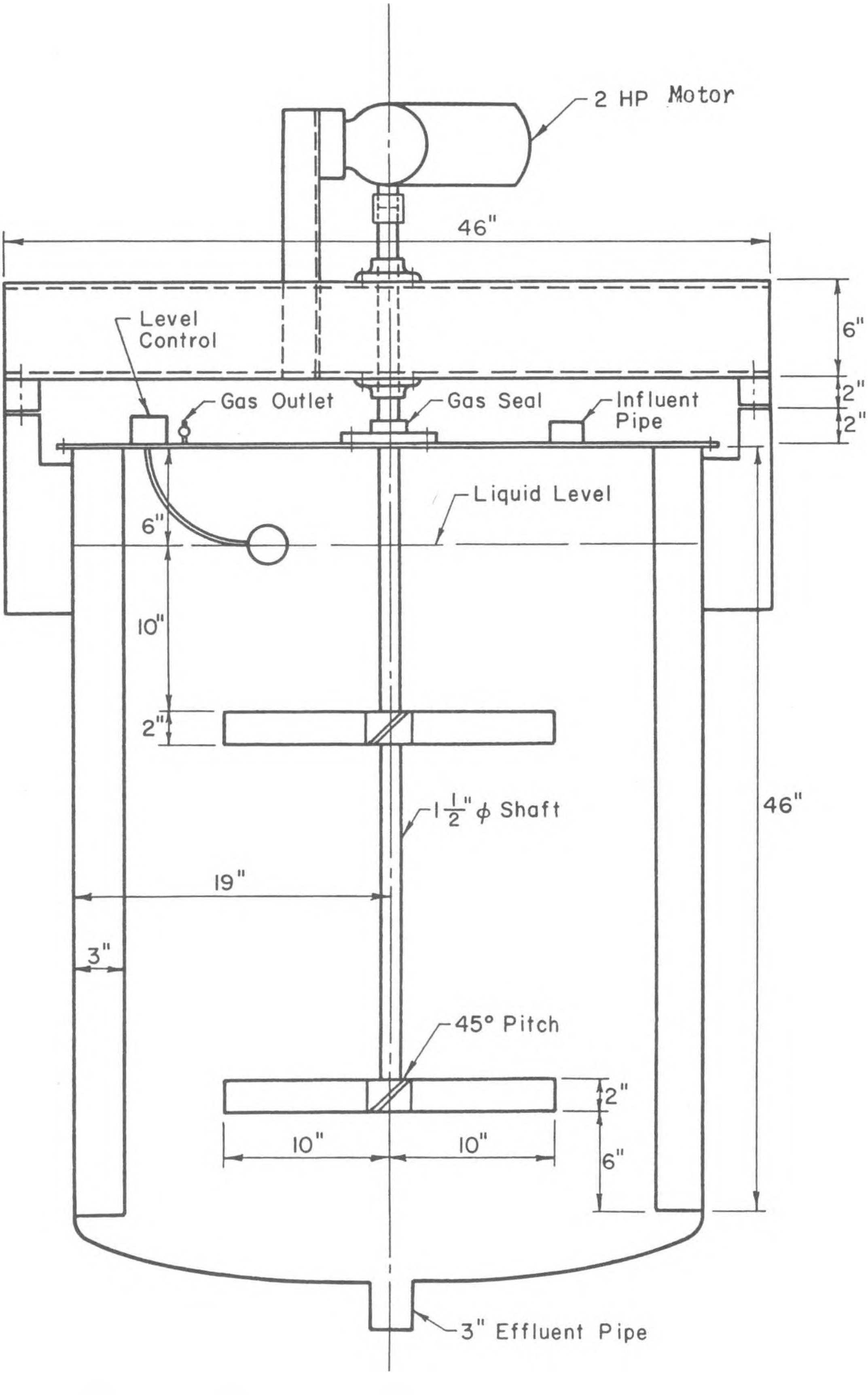

Figure 1. Details of Reactor and Mixer

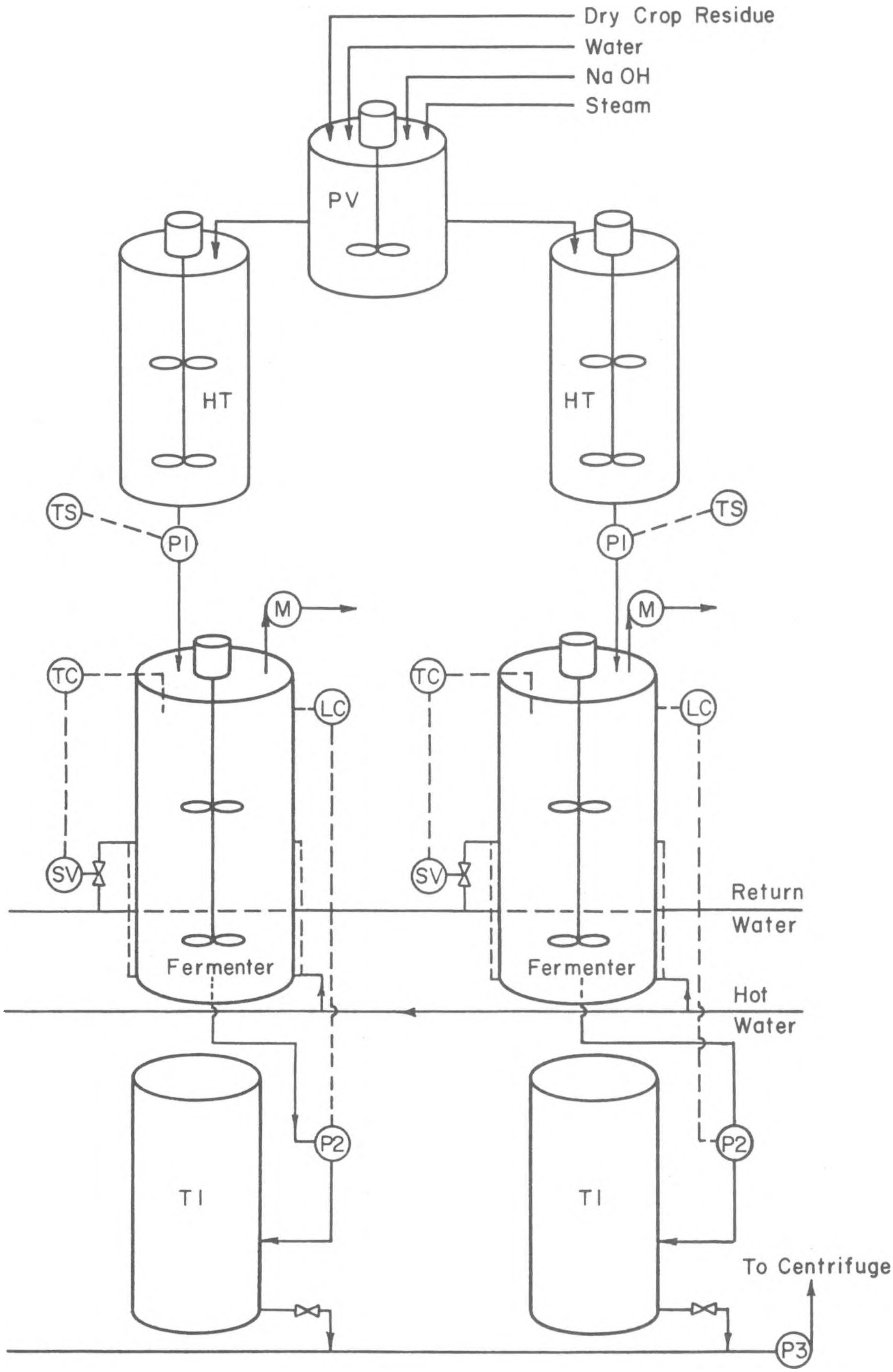

Figure 2. Schematic of Fermentation System

in the storage of substantial quantities of the feedstock as the dry material did not decompose. Details of the particle size distribution after milling have been described elsewhere (Pfeffer and Quindry, 1979).

After size reduction, the crop residue was thermochemically processed in the pretreatment vessel (PV). The dry residue was slurried with the desired amount of water and sodium hydroxide was added as required. The pretreatment temperature and time were set in accordance with the planned experimental design used (Section 6).

During this study, two different pretreatment vessels were used. Initially a 400 ℓ vessel with a helical screw impeller and four baffles was employed. The mixing regime in this reactor was poor. Although the material in the center was adequately mixed by the impeller, the material in the zone of influence of the baffles was held in place on the walls. Thus, the only way in which chemicals and water could reach these fibers was by diffusion. As this reactor was also unable to withstand pressures greater than 30 psig, a second reactor was purchased and placed in operation on day 172. This vessel had a volume of 760 ℓ and was agitated by a mixer rotating at 17 rpm equipped with two impellers each consisting of four flat blades canted at a 45° angle. By ensuring that the blades on the upper impeller swept the reactor wall, dead spots were eliminated and good mixing was obtained at solids concentrations in excess of 30% w/w.

The heat for the pretreatment reactor was initially provided by a Sussmann Model ES-12 boiler (Automatic Steam Products Corp., Long Island City, New York) rated at 12 kW. However, once the second pretreatment vessel was installed, the heating capacity of this boiler diminished rapidly. No electrical problem was evident and an evaluation of the boiler blow-down water demonstrated that it was contaminated with liquid from the pretreatment vessel.

Two factors caused this problem. The first was the method of supplying water to the boiler. Once the water level in the boiler dropped to a predesignated level, a pump was activated to refill the boiler. This resulted in a temporary decrease in water temperature and pressure in the boiler and permitted a flow of material from the pretreatment vessel to the boiler.

Secondly, this problem was intensified by the relocation of the steam entry point on the new pretreatment vessel. In the old vessel, the steam line entered the head-space and, therefore, only vapors were able to be transferred to the boiler. However, to obtain better heat transfer with the new pretreatment vessel, live steam was injected into the bottom of the tank beneath the impeller. Hence, a decrease in boiler pressure resulted in the transfer of a quantity of pretreatment liquor to the boiler.

This problem was remedied by placing a check valve in the steam line to the pretreatment vessel. Because of the diminished performance of the old boiler, a new one was purchased. The new unit (Sussmann Model ES-16) was rated at 16 kW compared to the old boiler's 12 kW capacity, and the time to achieve the required pretreatment pressure was reduced by approximately 70% thereby substantially affecting the total heating time to which the substrate was exposed.

Following pretreatment, the slurry was pumped to the completely mixed holding tanks (HT) and diluted to approximately 5% TS. These holding tanks provided a relatively uniform feeding of material to the digesters as they contained up to six days supply of feed slurry. These tanks were covered primarily to prevent entry of foreign material that may plug the pipes or pumps.

The use of four separate slurry tanks allowed four different pretreatment conditions to be evaluated simultaneously. This provided greater flexibility than the system previously used which operated with only two holding tanks (Pfeffer and Quindry, 1979).

5.3 System Operation

The system performance was assessed by analyzing for the dependent variables presented in Table 7. Total and volatile solids analyses were performed as described in Standard Methods (1975). The pH was measured using a Fisher Accumet Model 325 pH meter. The chemical oxygen demand (COD) was performed in accordance with Standard Methods (1975).

Samples were prepared for the remaining analyses by centrifugation at 5,500 rpm for 30 minutes. The total volatile acid concentration was determined using the column chromatographic technique (Standard Methods 1975). The sample used for the soluble COD was filtered through a Whatman GA/A glass microfiber filter paper prior to analysis.

The corn stover was analyzed for cellulose, hemicellulose and lignin using the procedures described by Chandler and Jewell (1980).

Initially, reliable data collection for the pretreatment variables presented a problem. As the degree of solubilization achieved was dependent upon the pretreatment conditions, some thermochemically treated stover was difficult to pump into the holding tanks and the addition of substantial quantities of water was required to facilitate the transfer. The total solids concentration entering the holding tank was therefore highly variable. However, by taking a cumulative sample during pumping, reproducible results were obtained. A portion of this sample was refrigerated overnight and a solids analysis performed on the remainder. The following day, the solids

Table 7. Dependent Variables Studied

(all data collected following pretreatment)

A. Pretreatment Variables

1. pH
2. Total Alkalinity
3. Total COD
4. Soluble COD

B. Holding Tank Variables

1. pH
2. Total Solids
3. Volatile Solids
4. Total Alkalinity
5. Total COD
6. Soluble COD

C. Digester Variables

1. pH
2. Total Solids
3. Volatile Solids
4. Total Alkalinity
5. Gas Production
6. Gas Composition
7. Total Volatile Acids

concentration of the pretreated stover was calculated and the refrigerated sample diluted to 5% TS. All pretreatment analyses were performed on this 5% TS sample allowing a direct comparison to be made with the holding tank variables.

Also, because of variations in the solids concentration in the holding tanks, their total and soluble COD concentrations were corrected to an equivalent 5% TS value.

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

As corn stover and wheat straw are deficient in both nitrogen and phosphorus, supplemental addition of these nutrients was necessary. Ammonium chloride was added directly to the digesters to maintain a level of approximately 200 mg/l ammoniacal nitrogen. In prior studies, ammonium chloride was added to the holding tanks but this was prevented by the substantial volatilization of ammonia that occurred when an alkaline, pretreated batch of crop residue was added to these tanks. Phosphorus was added to the holding tanks at a rate equal to 0.2 of the nitrogen addition.

Only data collected under steady-state conditions were used to assess the digesters performance. For this study, steady-state was defined as a uniform gas production (m^3 CH_4/kg VS loaded). A stable total volatile acid concentration was used to confirm the attainment of steady-state. The digesters were operated for a minimum of three hydraulic retention times at each pretreatment condition unless early process failure resulted from the pretreatment conditions.

6. EXPERIMENTAL PROCEDURE

6.1 Experimental Design

In order to optimize the thermochemical pretreatment of corn stover, an experimental design was selected with the variables of temperature, alkali dosage, solids concentration and pretreatment time being considered worthy of investigation.

A 2^4 central composite design was selected for this study. Central composite designs are comprised of three sets of points (John, 1971):

i. The cube points at $X_i = \pm 1$. As four independent variables were investigated, there were $2^4 = 16$ cube points (i.e., $n_c = 16$).

ii. The star, or axial points (n_a), are located two per axis at a distance $\pm\alpha$ from the origin. With four independent variables, $n_a = 8$.

iii. The center points (n_o) are located at the origin. To achieve orthogonality,

$$n_o + n_a = \frac{4\,\alpha^2\,(n_c + \alpha^2)}{n_c} \tag{3}$$

and to achieve rotatability

$$\alpha^4 = n_c. \tag{4}$$

Rotatability and near orthogonality was obtained by setting $n_o = 6$ and $\alpha = 2$ (Cochran and Cox, 1957).

The experimental design, therefore, required thirty trials (Table 8).

The design used offered the benefit of economy while estimating the second-order effects allowing an empirical mathematical model of the following form to be fitted to the data:

$$y = \beta_o + \beta_i X_i + \beta_{ij}\, X_i X_j + \beta_{ii}\, X_i^2. \tag{5}$$

Table 8. Experimental Design Used for Corn Stover Studies (Cochran and Cox, 1957)

		Coded Independent Variable			
Block Number	Trial Number	X_1 Temperature	X_2 NaOH Dose	X_3 Solids Concentration	X_4 Pretreatment Time
	1	-1	-1	-1	-1
	2	1	-1	-1	1
	3	-1	1	-1	1
	4	1	1	-1	-1
1	5	-1	-1	1	1
	6	1	-1	1	-1
	7	-1	1	1	-1
	8	1	1	1	1
	9	0	0	0	0
	10	0	0	0	0
	11	-1	-1	-1	1
	12	1	-1	-1	-1
	13	-1	1	-1	-1
	14	1	1	-1	1
2	15	-1	-1	1	-1
	16	1	-1	1	1
	17	-1	1	1	1
	18	1	1	1	-1
	19	0	0	0	0
	20	0	0	0	0
	21	-2	0	0	0
	22	2	0	0	0
	23	0	-2	0	0
	24	0	2	0	0
3	25	0	0	-2	0
	26	0	0	2	0
	27	0	0	0	-2
	28	0	0	0	2
	29	0	0	0	0
	30	0	0	0	0

β_0 is a constant.

β_i is a coefficient describing the linear response to the independent variable X_i.

β_{ij} is a coefficient describing the interaction of the two independent variables X_i and X_j.

β_{ii} is a coefficient describing the quadratic response of the independent variable X_i.

By fitting such a model to the observed data, the effectiveness of the pretreatment procedure, within the field of the independent variables considered, may be mathematically described.

6.2 Independent Variables Studied - Corn Stover

The available equipment constrained the maximum temperature that could initially be achieved. The boiler, rated at 100 psig, restricted the temperature to less than 169°C. This was substantially below the temperature optimum of 200°C observed by Gossett et al. (1975), for the heat treatment of digested refuse at an initial pH of 13. However, the temperature range selected for study (Table 9) will allow the suitability of low pressure reactors to be evaluated.

Table 9. Definition and Levels of Independent Variables Used in Corn Stover Experimental Design

Independent Variable	Coded Symbol	Coded Level -2	-1	0	1	2
Pretreatment Temperature (°C)	X_1	106	119	133	147	160
NaOH Dose (w/w%)	X_2	1.33	4.33	7.33	10.3	13.3
Pretreatment Solids Concentration (w/w%)	X_3	16.8	20.9	25	29.1	33.2
Pretreatment Time ($\log_{10}$)(hr)	X_4	.316	.562	1.0	1.77	3.16

Sodium hydroxide was selected as the alkali as previous research had indicated the unsuitability of lime (Pfeffer and Quindry, 1979). Gossett et al. (1975), demonstrated that the effectiveness of the alkali was correlated with its post-treatment concentration. However, such a parameter is impractical in an experimental design where predesignated levels of the independent variables are required. A weight basis was therefore used as a measure of alkali addition, i.e., g NaOH/g dry solids. A suitable range of NaOH addition was calculated from the data of Gossett et al. (1976b), who presented two equations for NaOH consumption during the pretreatment of digested refuse:

$$\text{At } 133°\text{C},\ Nr = 0.921Na - 0.0497 \quad (6)$$

$$\text{At } 200°\text{C},\ Nr = 0.945Na - 0.110 \quad (7)$$

Where, Na = NaOH added (g NaOH/g TS)

Nr = NaOH remaining after pretreatment (g NaOH/g TS).

By assuming a linear relationship between alkali consumption at 133°C and 200°C, Figure 3 was plotted. Within the confines of the temperature range of this study, it is evident that alkali dosages of at least 10% w/w NaOH should be investigated. Preliminary experiments demonstrated that there were substantial problems pumping a 5% TS slurry of corn stover heat-treated in the absence of NaOH. A 1% w/w NaOH treatment was therefore used as the lowest alkali dosage.

The adverse economic effect of a high NaOH dosage and the potential problem of Na^+ toxicity resulted in the highest alkali dosage being restricted to 13.3%, w/w NaOH. The intermediate values studied are presented in Table 9.

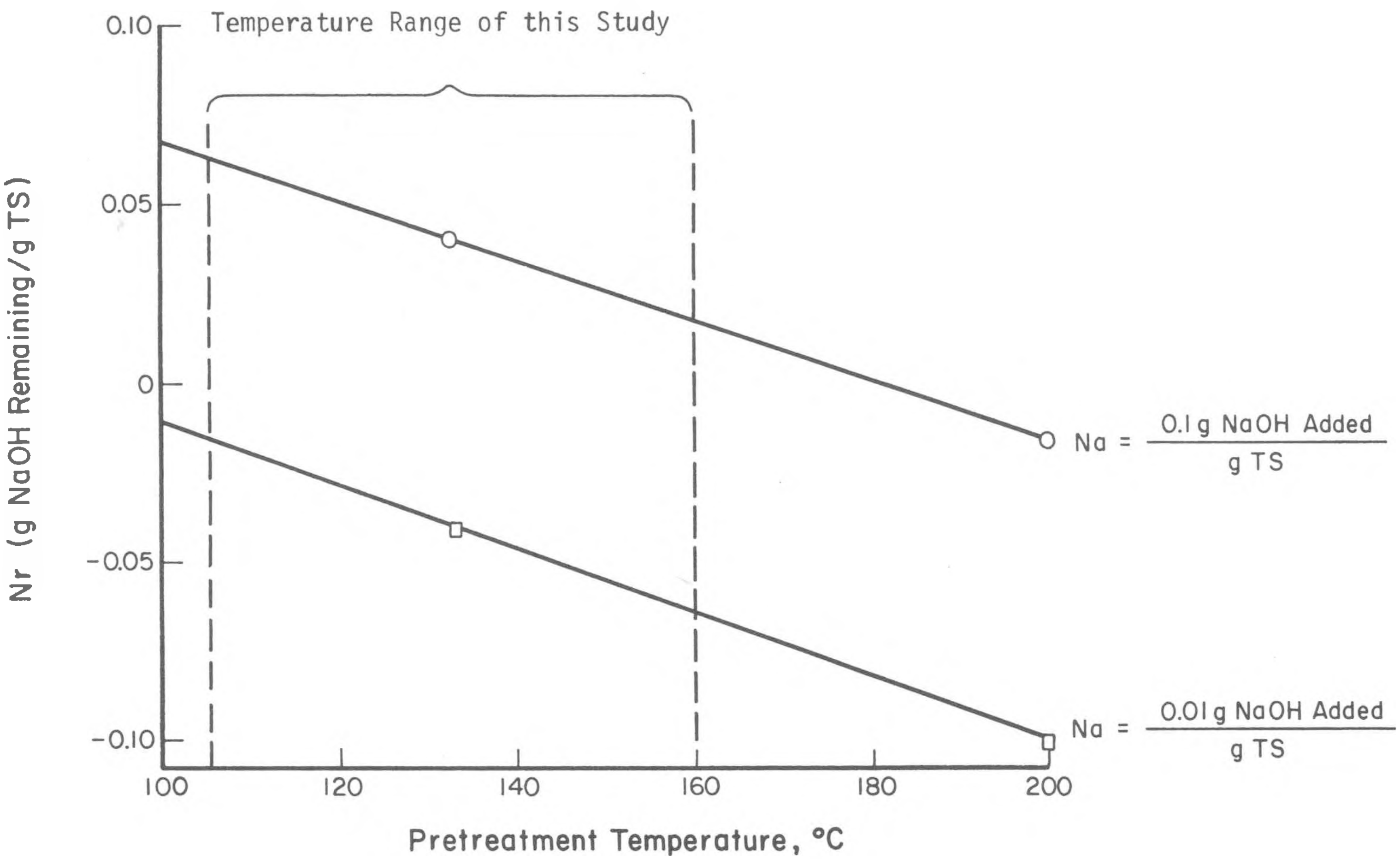

Figure 3. NaOH Remaining as a Function of Pretreatment Temperature and NaOH Added

The pretreatment solids concentration was the third independent variable studied. Gossett et al. (1975), performed much of their work using a 2-5% TS concentration, although they subsequently studied concentrations up to 10% TS (Gossett et al., 1976a). Although their results indicated that the residual NaOH concentration was the major factor determining biodegradability, thermochemical pretreatment at these solids concentrations is unlikely to be economic due to the quantity of water which must be heated with the substrate. Therefore, substantially higher solids concentrations and their effect on the pretreatment efficiency were investigated in this study. Preliminary research indicated that a 25% w/w stover slurry could be pretreated effectively. This concentration was therefore selected as the mid-point with the upper and lower limits set at 33.2% and 16.8% w/w solids (Table 9).

The final independent variable studied was the pretreatment time. This is defined as the time the slurry is held at the designated pretreatment temperature. It does not include the time required for heating up to, and cooling down from, the pretreatment temperature. Although little difference in the biodegradability of domestic refuse was observed between pretreatment times of 45 min and 3 hrs (Gossett et al., 1975) earlier research demonstrated a 17% increase in COD solubilization between the same pretreatment times (Gossett and McCarty, 1975).

These observations demonstrate the importance of this variable and indicate that increasing the pretreatment time may be an economic method of improving COD solubilization and, possibly, gas yields. This is due to the fact that with a well-insulated reactor, only a small increase in energy consumption will occur between short and long pretreatment times. However, at extended pretreatment times, the substrate biodegradability may become impaired due to increased lignin solubilization and extensive carbohydrate degradation. To evaluate the effect of this variable, times ranging from 0.316 hrs to 3.16 hrs were evaluated (Table 9). To study such a span of times while keeping the coded variables an equal increment apart, a $\log_{10}$ scaling mechanism was employed.

6.3 Range of Independent Variables Studied - Wheat Straw

The experimental design for the wheat straw studies was developed similar to the design used for the corn stover (see Section 6.1). Only a relatively short time was available for the study of the thermochemical pretreatment of wheat straw. Consequently, the number of variables had to be limited. Results from the corn stover studies showed that the pretreatment temperature and NaOH dosage had the major impact on the fiber characteristics. These variables were studied in a full 3^2 factorial design with replicated center points. This design is shown in Table 10.

Table 10. Experimental Design Used for Wheat Straw Studies

	Coded Independent Variables	
Trial No.	X_1 (Temperature)	X_2 (NaOH Dosage)
1	-1	-1
2	0	-1
3	1	-1
4	-1	0
5	0	0
6	1	0
7	-1	1
8	0	1
9	1	1
10	0	0
11	0	0

In order to make a comparison between the wheat straw study and the corn stover study, the uncoded levels of the independent variables were selected to be compatible with those used in the stover experimental design. These variables are shown in Table 11. For all trials a pretreatment time of one hour at a temperature and a solids concentration of 25% w/w were used. These values correspond to the center point values used in the corn stover experimental design. The dependent variables studied are listed in Table 7.

Table 11. Definition and Levels of Independent Variables Used in Wheat Straw Experimental Design

Independent Variable	Coded Symbol	Coded Level		
		-1	0	1
Pretreatment Temperature (°C)	X_1	106	125	144
NaOH Dosage (w/w%)	X_2	4.33	7.33	10.3

The results of the trials clearly showed that extreme inhibition resulted when the straw was pretreated at all but the lowest NaOH dosage. Three additional trials were added to evaluate the effect of pretreatment at high temperature on the gas yield. The pretreatment conditions for Trials 12, 13, and 14 were 155°C and 4.33% NaOH, 175°C and 4.33% NaOH, and 175°C and 3% NaOH, respectively. These trials were not part of the experimental design and will be evaluated separately in the results section.

7. RESULTS AND DISCUSSION

7.1 Pretreatment of Corn Stover

Samples of the slurry from the pretreatment vessel were taken to determine the characteristics of the slurry after being subjected to the various treatment techniques. These data are shown in Table 12. The pH of this slurry varied substantially, depending upon the caustic dosage, solids concentration and caustic consumption as determined by the treatment temperature and time. The pH was always above 7.0 and most often in the 9.0 to 10.0 range. As would be expected, the alkalinity values were in concert with the pH levels.

The parameter of particular interest was the degree of COD solubilization. Dry stover was added to tap water containing essentially no soluble COD. Soaking the stover in water could solubilize some COD. However, any significant degree of solubilization requires a more rigorous treatment. Trials No. 1 and 23 exhibited the lower solubilization. These were the mildest treatment conditions as shown in Table 8 and Table 9. Higher caustic dosage and higher temperatures resulted in substantially higher levels of COD solubilization.

Additional changes in the slurry occurred while being stored in the holding tanks. Approximately 600 ℓ of slurry were pretreated and transferred to the appropriate holding tank. With a feed rate to digesters of 100 lpd, the turnover time in each holding tank was about six days. Significant biological activity was occurring in most of these holding tanks. Fermentative bacteria produced acids that reduced the pH to values in the 5.5 to 7.5 range. The pH change in Trial 24 was less, dropping from 12.2 to 11.4. This high initial pH was probably inhibitory to the fermentative bacteria. Atmospheric carbon dioxide could contribute to the above pH drop.

Table 12. Data for Corn Stover Slurry After Thermochemical Pretreatment

Parameter	Trial Number 1	2	3	4	5	6	7	8	9	10	11
pH	8.7	7.2	10.7	10.1	8.4	7.2	11.4	10.0	9.4	9.4	9.6
Alkalinity (mg/l as $CaCO_3$)	1,510	1,490	4,460	3,990	1,180	1,270	4,710	5,000	2,160	2,370	1,750
Total COD (g/l)	63.3	64.5	59.3	58.2	61.5	63.0	58.3	59.1	61.8	59.9	62.7
Soluble COD(g/l)	11.5	15.0	28.8	28.4	13.9	14.6	23.4	28.9	23.1	22.3	15.7
COD Solubilization (%)	18.2	23.3	48.6	48.8	22.6	23.2	40.1	48.9	37.4	37.2	25.0

Parameter	Trial Number 12	13	14	15	16	17	18	19	20	21	22
pH	7.2	11.6	10.2	9.4	7.2	11.3	10.0	10.4	10.4	11.3	9.4
Alkalinity (mg/l as $CaCO_3$)	1,190	4,770	4,130	1,960	1,360	4,380	3,200	2,530	2,070	3,050	2,340
Total COD (g/l)	61.0	57.1	63.7	56.9	62.3	54.5	59.9	62.7	62.0	64.4	59.7
Soluble COD (g/l)	15.0	23.2	31.4	15.3	16.0	23.6	26.6	20.7	20.2	19.3	24.3
COD Solubilization (%)	24.6	40.6	49.3	26.9	25.7	43.3	44.4	33.0	32.6	30.9	40.7

Parameter	Trial Number 23	24	25	26	27	28	29	30
pH	7.1	12.2	10.4	10.6	10.7	10.0	10.3	10.6
Alkalinity (mg/l as $CaCO_3$)	730	5,710	3,290	3,350	2,790	2,840	2,970	3,000
Total COD (g/l)	53.5	62.5	59.1	58.7	61.8	61.0	65.8	63.7
Soluble COD (g/l)	7.82	22.9	22.3	18.8	19.9	22.6	20.7	19.3
COD Solubilization (%)	14.6	36.6	37.7	32.0	32.3	37.0	31.5	30.3

The microbial action in the holding tanks did increase the soluble COD. This increase was small with the maximum being only from 24.6 to 29.8% for Trial 12. In some cases, this increase was slightly negative. This was probably due to experimental error. The analysis did show variability due to sampling and sample preparation problems. There was no apparent loss of COD in the holding tank due to aerobic stabilization. The total COD data in Table 12 and Table 13 did not show any significant difference. The difference was due to experimental variability (See Table 13).

The experimental design separates the independent variables such that the effect of each can be evaluated. The results are shown in Figure 4 and Figure 5. The effects of solids concentration and pretreatment time are shown in Figure 4. The soluble COD level was relatively insensitive to both variables. A slight increase in soluble COD did occur when the treatment time increased from 19 to 190 minutes. Also the soluble COD was slightly higher when the slurry solids concentration in the pretreatment tank was low.

Figure 5 shows the effect of pretreatment temperature and caustic dosage on the soluble COD. The pretreatment temperature did not have an effect on the COD solubilization until the temperature reached 140°C. At the higher temperatures, there was a noticeable increase in the soluble COD. However, the caustic dosage was the variable that had the most significant effect. At the low dosage rates, the soluble COD was only about 7.5 g/l (about 15% of the total COD). The soluble COD increased until the NaOH dosage reached 10%. Higher caustic dosages did not increase the COD solubilization.

Table 13. Data for Corn Stover Slurry in Holding Tank

Parameter	Trial Number 1	2	3	4	5	6	7	8	9	10	11
Ph	6.1	5.6	6.8	7.8	5.9	5.6	7.7	7.6	5.9	6.4	6.0
Alkalinity (mg/l as $CaCO_3$)	2,270	1,660	4,780	4,730	2,460	2,740	4,930	4,510	3,140	3,090	2,670
Total COD (g/l)	65.2	63.4	60.1	59.2	68.6	65.1	53.9	57.9	66.3	63.1	59.7
Soluble COD (g/l)	14.6	19.1	31.3	30.8	17.1	18.4	23.7	28.5	24.7	25.4	16.5
COD Solubilization (%)	22.4	30.1	52.1	52.0	24.9	28.3	44.0	49.2	37.2	40.2	27.6
Δ Soluble COD (mg/l)	3.1	4.1	2.5	2.4	3.2	3.8	0.3	-0.4	1.6	3.1	0.8

Parameter	Trial Number 12	13	14	15	16	17	18	19	20	21	22
pH	5.9	7.8	7.0	6.1	5.7	7.8	7.4	6.7	6.1	7.0	6.3
Alkalinity (mg/l as $CaCO_3$)	2,250	4,890	4,940	2,650	2,230	4,740	4,280	3,850	3,440	3,400	3,550
Total COD (g/l)	65.0	55.1	59.6	59.8	60.5	57.3	57.2	60.6	58.1	66.6	63.7
Soluble COD (g/l)	19.4	24.6	30.6	15.5	17.1	24.7	29.1	22.1	22.0	21.1	27.0
COD Solubilization (%)	29.8	44.6	51.3	25.9	28.3	43.1	50.9	36.5	37.9	31.7	42.4
Δ Soluble COD (mg/l)	4.4	1.4	-0.8	0.2	1.1	1.1	2.5	1.4	1.8	1.8	2.7

Parameter	Trial Number 23	24	25	26	27	28	29	30
pH	5.8	11.4	7.4	7.4	6.7	6.9	6.6	7.1
Alkalinity (mg/l as $CaCO_3$	1,310	6,400	3,630	3,770	3,780	3,870	3,790	3,800
Total COD (g/l)	57.7	54.3	68.6	61.5	57.7	58.1	67.4	61.6
Soluble COD (g/l)	7.45	26.3	24.9	22.1	22.1	23.9	23.2	21.9
COD Solubilization (%)	12.9	48.4	36.3	35.9	38.3	41.1	34.4	35.5
Δ Soluble COD (mg/l)	-.37	3.4	2.6	3.3	2.2	1.3	2.5	2.6

Δ Soluble COD = Holding Tank Soluble COD - Pretreatment Soluble COD

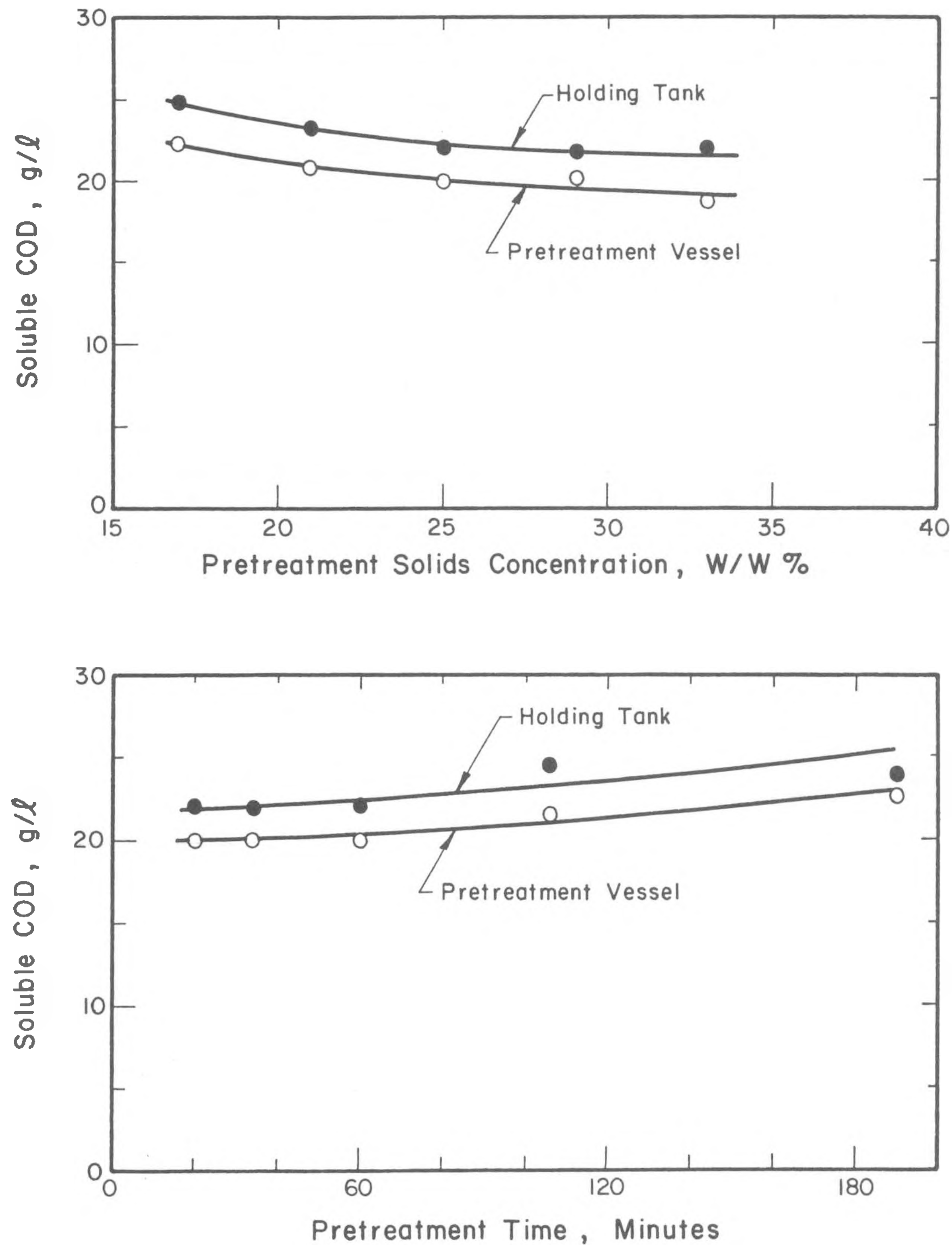

Figure 4. Effect of Solids Concentration and Pretreatment Time on COD Solubilization.

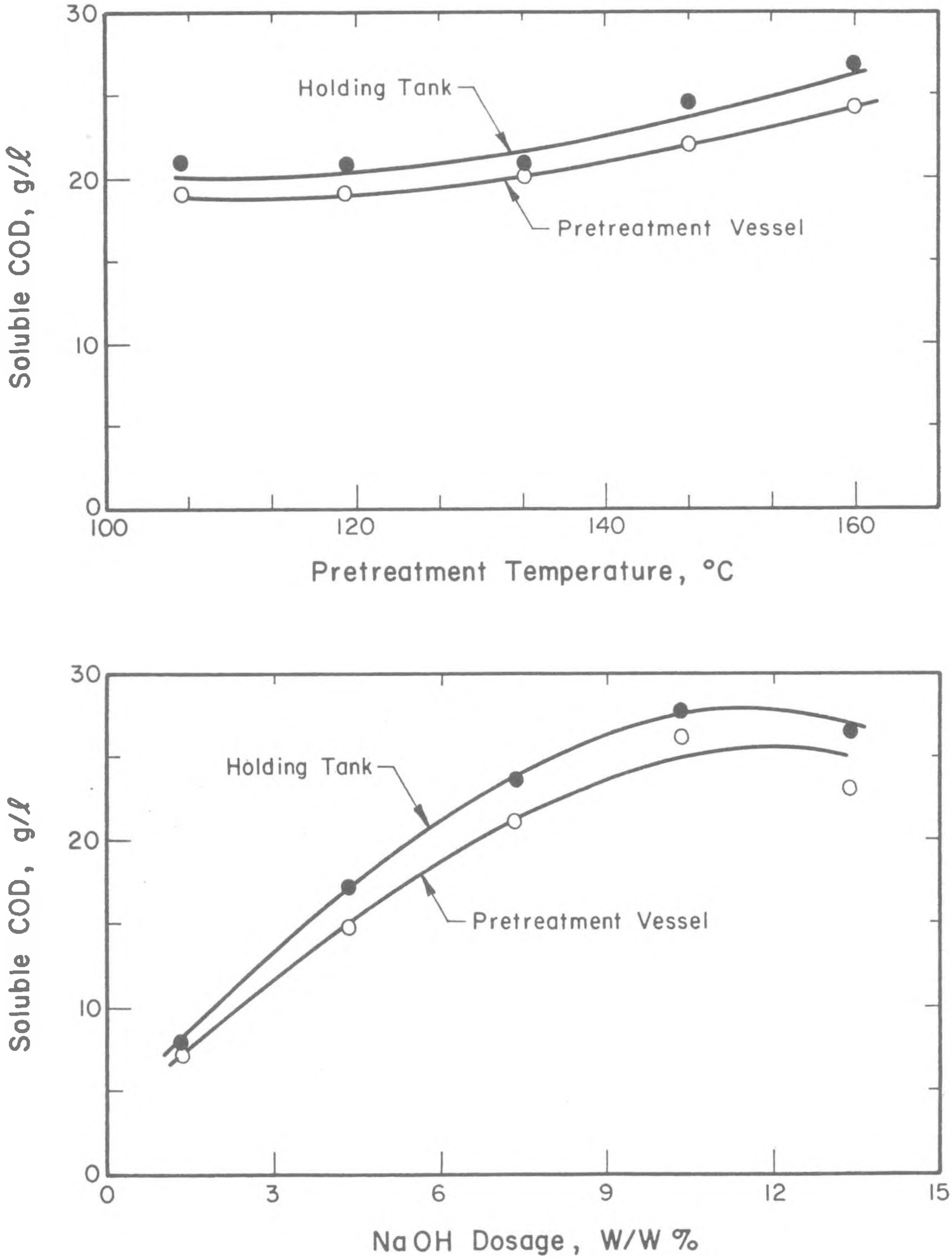

Figure 5. Effect of Pretreatment Temperature and NaOH Dosage on COD Solubilization.

In both Figures 4 and 5, data for the pretreatment vessel and the holding tanks are shown. The soluble COD was always higher in the holding tank. This represents the COD solubilization caused by the microbial activity in these tanks. This difference was not influence by any of the independent variables. It was essentially constant for all conditions except for the lowest caustic level. There was no significant increase in the soluble COD in the holding tank. However, only one trial was conducted at this low caustic dosage.

7.2 Corn Stover Digestion

The primary objective of pretreatment of the stover is to improve the biodegradability of the fibers. The results of these trials are shown in Table 14. These data show the loading parameters and the efficiency of conversion of stover to gas. The basis for this evaluation is both COD and volatile solids. All data were collected at steady-state as determined by the operating parameters in the digester. Figure 6 shows the digester response as it achieved steady-state. This plot is for Trial 9. Steady-state was not always possible to achieve. In Trials 13, 17, and 24, the volatile acids did not plateau, but continued a slow increase. Had the trials been extended sufficiently, failure would probably have resulted. These trials were conducted at the 10.3 and 13.3% caustic dose.

In Trials 4, 7, 8, 14, 18, and 28, steady-state could not be achieved. When the trial was initiated, the volatile acid started to increase and continued upward until they reached a level of approximately 8,000 mg/l. Large quantities of lime were required to maintain the pH in an acceptable range. Gas production rates were substantially lower than obtained in the other trials. Consequently, the trial was assumed to be a failure. The digester performance under conditions of failure is shown in Figure 7.

Table 14. Summary of Data for Steady-State Operation of Digesters Using Corn Stover as a Substrate

Parameter	Trial Number 1	2	3	4	5	6	7	8	9	10	11	12	13*	14	15
Hydraulic Retention Time (d)	7.73	7.78	7.60	8.48	7.54	7.77	9.31	7.86	7.71	7.60	7.60	7.92	7.76	7.88	7.60
Temperature (°C)	57.4	57.3	57.6	56.8	57.4	57.8	58.8	57.4	58.3	58.3	58.4	59.9	58.7	59.4	58.8
Volatile Solids Load (kg VS/m^3 d)	4.89	4.14	5.63	5.03	5.12	4.88	4.50	5.12	5.18	5.11	5.27	4.45	5.26	5.11	5.25
COD Load (kg COD/m^3 d)	8.23	8.01	7.96	6.81	8.91	8.34	6.27	7.61	8.42	8.07	7.85	8.30	7.21	7.86	7.36
pH	7.5	7.3	7.6		7.5	7.2			7.3	7.3	7.0	6.9	7.2		7.0
Alkalinity (mg/l as $CaCO_3$)	4,280	3,400	6,780		5,400	3,450			4,590	4,080	2,940	2,740	5,870		2,650
Feed Total Solids (g/l)	44.4	38.7	53.6	unable	46.3	45.6	unable	unable	48.6	48.1	49.2	41.8	52.2	unable	47.8
Feed Volstile Solids (g/l)	37.8	32.2	42.9	to	38.7	38.0	to	to	40.0	38.9	40.1	35.2	40.8	to	39.9
Effluent Total Solids (g/l)	27.1	23.6	29.9	attain	26.8	26.2	attain	attain	30.1	29.6	33.3	26.5	35.5	attain	31.6
Effluent Volatile Solids (g/l)	18.8	15.8	19.5	steady	18.0	18.3	steady	steady	20.2	19.9	22.1	18.7	22.9	steady-	21.2
Total Volatile Acids (mg/l as acetate)	480	430	2,960	state	2,250	1,730	state	state	1,930	1,530	1,630	2,620	4,900	state	1,440
Methane Content of Gas (%)	57.7	57.4	57.5	opera-	57.6	57.3	opera-	opera-	56.2	56.9	55.1	56.9	54.3	opera-	55.5
Volatile Solids Destruction (%)	50.3	50.9	56.2	tion	53.5	51.8	tion	tion	49.5	48.8	44.9	44.9	43.9	tion	46.9
Gas Production (m^3CH_4/kg VS loaded)	.267	.304	.314		.278	.279			.282	.280	.246	.217	.249		.200
Gas Production (m^3CH_4/kg COD loaded)	.160	.158	.224		.159	.166			.175	.179	.166	.115	.182		.144

Parameter	Trial Number 16	17*	18	19	20	21	22	23	24*	25	26	27	28	29	30
Hydraulic Retention Time (d)	7.79	7.45	10.5	7.77	7.76	7.76	7.77	7.52	7.67	7.76	7.75	7.76	7.71	7.52	7.79
Temperature (°C)	59.1	59.6	58.4	59.1	58.7	58.4	58.1	59.1	58.9	58.8	58.3	58.9	57.3	58.2	58.5
Volatile Solids Load (kg VS/m^3 d)	4.63	5.74	4.23	5.56	5.30	5.36	5.01	5.37	5.82	5.13	5.15	5.31	5.23	5.64	5.23
COD Load (kg COD/m^3 d)	7.80	7.73	5.48	7.60	7.51	8.09	8.09	8.08	7.24	8.45	7.92	7.25	7.62	8.79	8.36
pH	7.2	6.9		7.0	7.3	7.4	7.3	6.9	7.4	7.3	6.9	7.2		7.0	7.3
Alkalinity (mg/l as $CaCO_3$)	2,890	5,450		4,150	4,410	4,290	4,500	1,690	6,750	4,210	4,260	4,110		3,900	4,380
Feed Total Solids (g/l)	43.8	54.5	unable	53.9	49.7	52.5	48.3	47.6	58.1	49.9	49.9	51.0	unable	53.1	51.3
Feed Volatile Solids (g/l)	36.1	42.8	to	43.3	41.1	41.6	39.0	40.4	44.6	39.8	39.8	41.2	to	42.5	40.8
Effluent Total Solids (g/l)	27.3	37.2	attain	34.7	29.6	32.2	30.1	25.4	32.5	31.1	33.9	32.1	attain	34.9	31.8
Effluent Volatile Solids (g/l)	19.3	24.6	steady-	22.5	20.9	20.4	20.6	17.3	19.6	19.5	22.2	20.4	steady-	23.2	20.2
Total Volatile Acids (mg/l as acetate)	1,570	6,510	state	2,710	1,600	1,430	2,450	380	3,430	1,710	2,750	1,940	state	2,930	1,550
Methane Content of Gas (%)	56.8	51.5	opera-	53.8	55.3	56.5	54.9	53.1	53.1	54.0	52.2	54.2	opera-	53.3	55.1
Volatile Solids Destruction (%)	46.5	41.5	tion	48.0	49.1	51.0	47.2	57.2	56.0	51.0	44.2	50.5	tion	45.4	50.5
Gas Production (m^3CH_4/kg VS loaded)	.234	.207		.237	.276	.291	.264	.189	.235	.292	.192	.312		.229	.288
Gas Production (m^3CH_4/kg COD loaded)	.139	.154		.176	.195	.194	.164	.132	.189	.178	.126	.230		.151	.181

* TVA accumulation observed during period of uniform gas production.

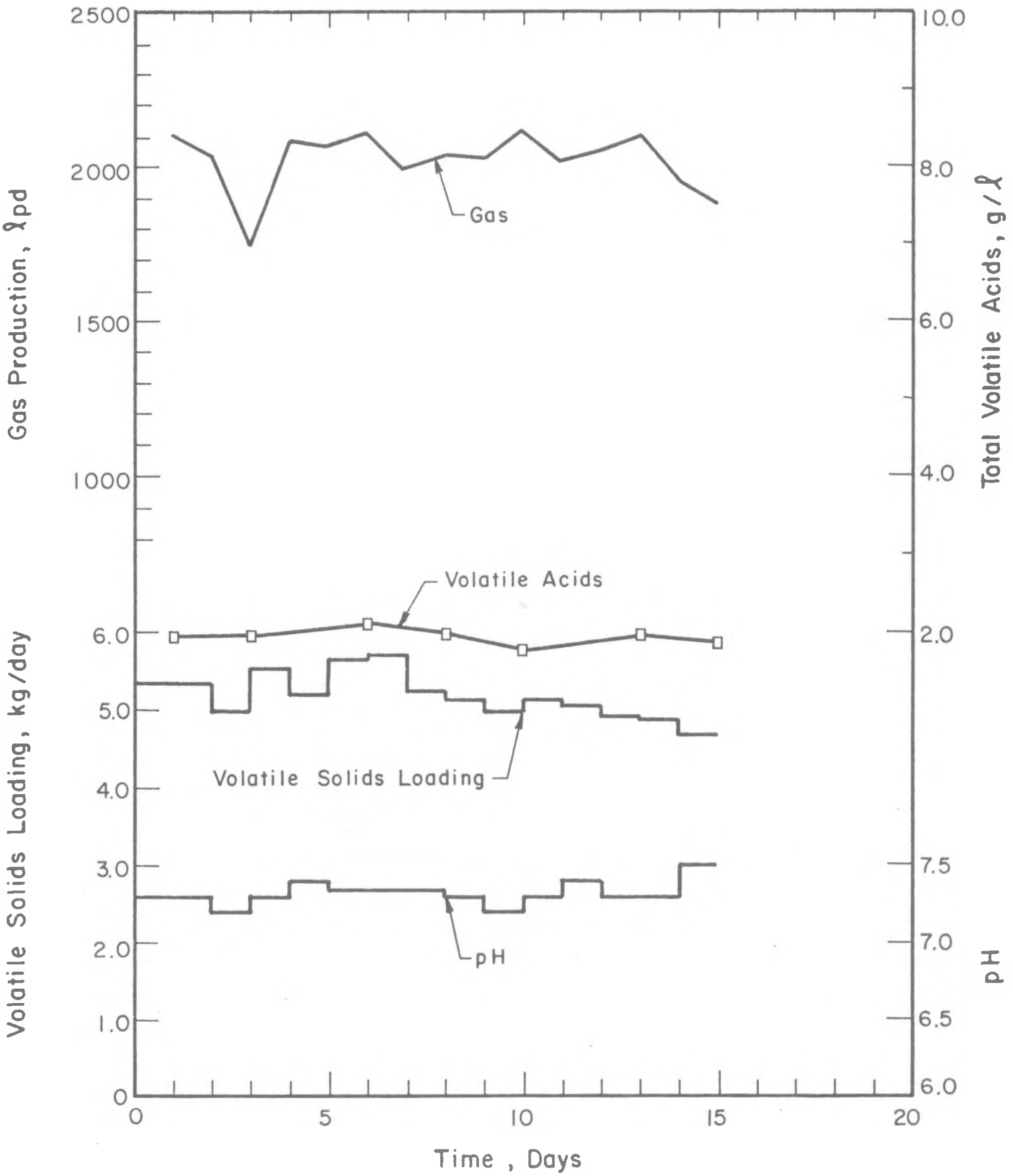

Figure 6. Digester Performance at Steady-State Operation.

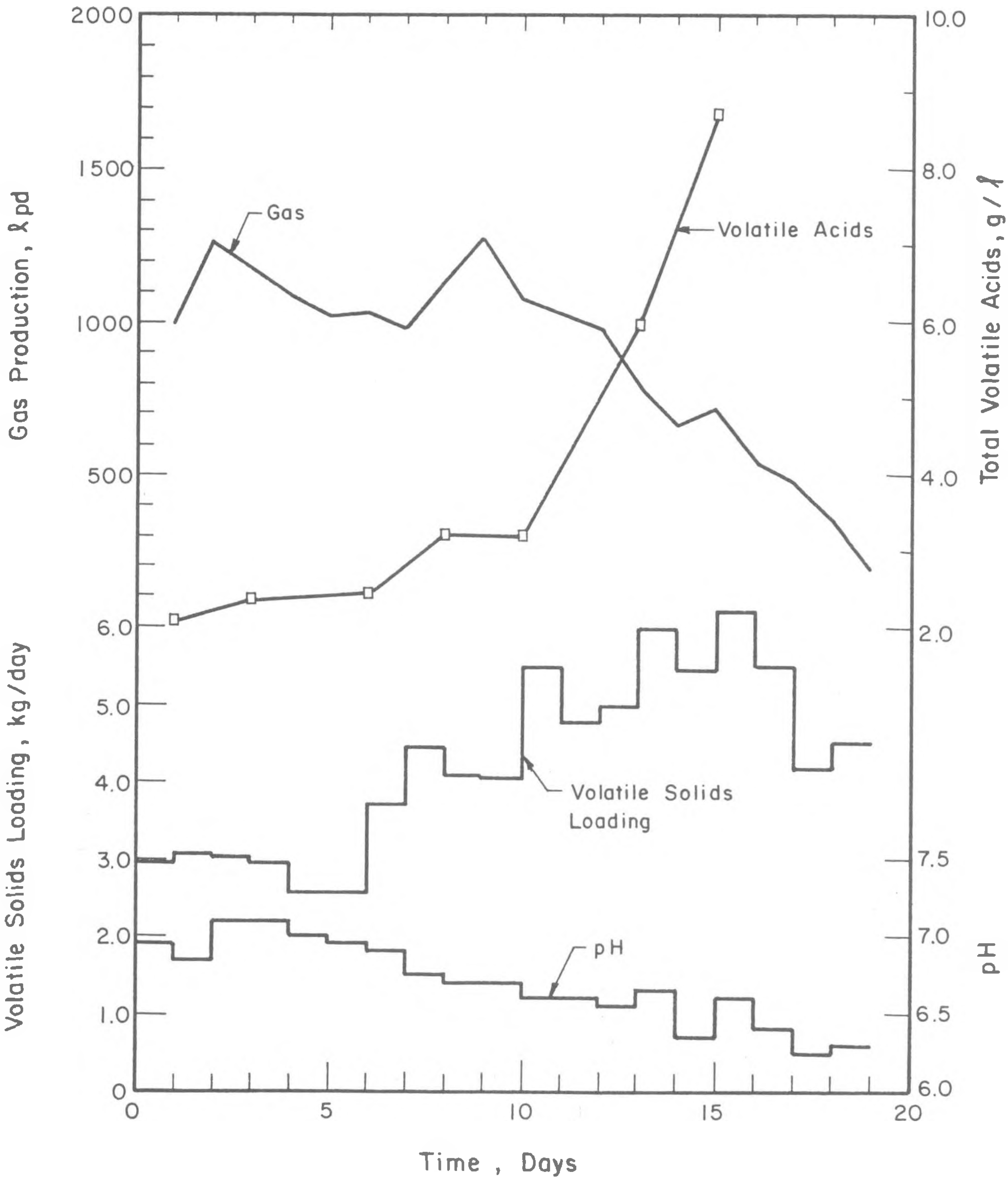

Figure 7. Digester Performance Under Failure Conditions.

The primary measure of the effectiveness of the pretreatment was the gas yield per unit of organic material fed. Both the COD loading and volatile solids loading were determined so the gas production could be expressed in terms of either of these parameters. Volatile solids have traditionally been the basis for gas production. With certain substrates, significant quantities of volatile organics are lost during the sample drying. Short chain organic acids and volatile organics produced during the thermochemical pretreatment are volatilized during sample analysis. This loss can result in a reduction of the measured feed volatile solids by as much as 10%. COD analyses are not subject to this loss. Consequently, the COD is a better parameter for measuring the organic loading rate. However, data for both parameters will be presented.

The analysis of the data generated by the trials is complicated by the 0, 1 results. For the trials receiving the more severe pretreatment, failure resulted in zero gas production. Successful runs did yield variations in methane production ranging from 0.13 to 0.23 m^3/kg COD added and 0.19 to 0.31 m^3/kg vs fed. When the zero value for an unsuccessful trial is averaged with one or two numbers from successful trials, the resultant number does not correlate well with conditions in which no zero values occurred. Consequently, it was necessary to drop some of the zero values from the data analysis.

The effects of the independent variables are shown in Figure 8 and Figure 9. These data show that the methane yield is relatively insensitive to pretreatment temperature up to 160°C. The concentration of solids in the slurry during pretreatment does affect the methane yield. Higher methane yields were obtained at the lower solids concentration. The cause of this

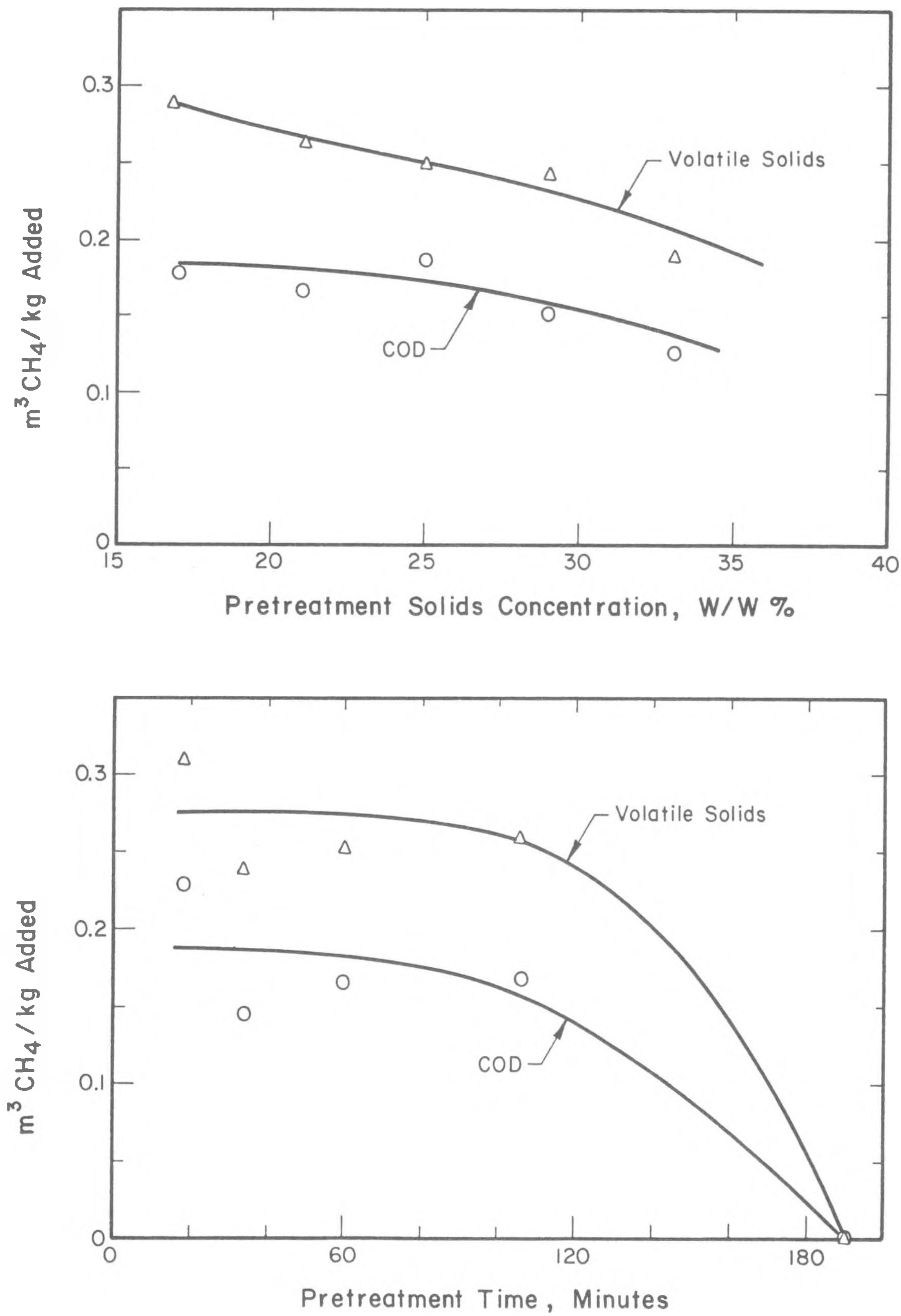

Figure 8. Gas Yields as a Function of Pretreatment Time and Pretreatment Slurry Solids Concentration.

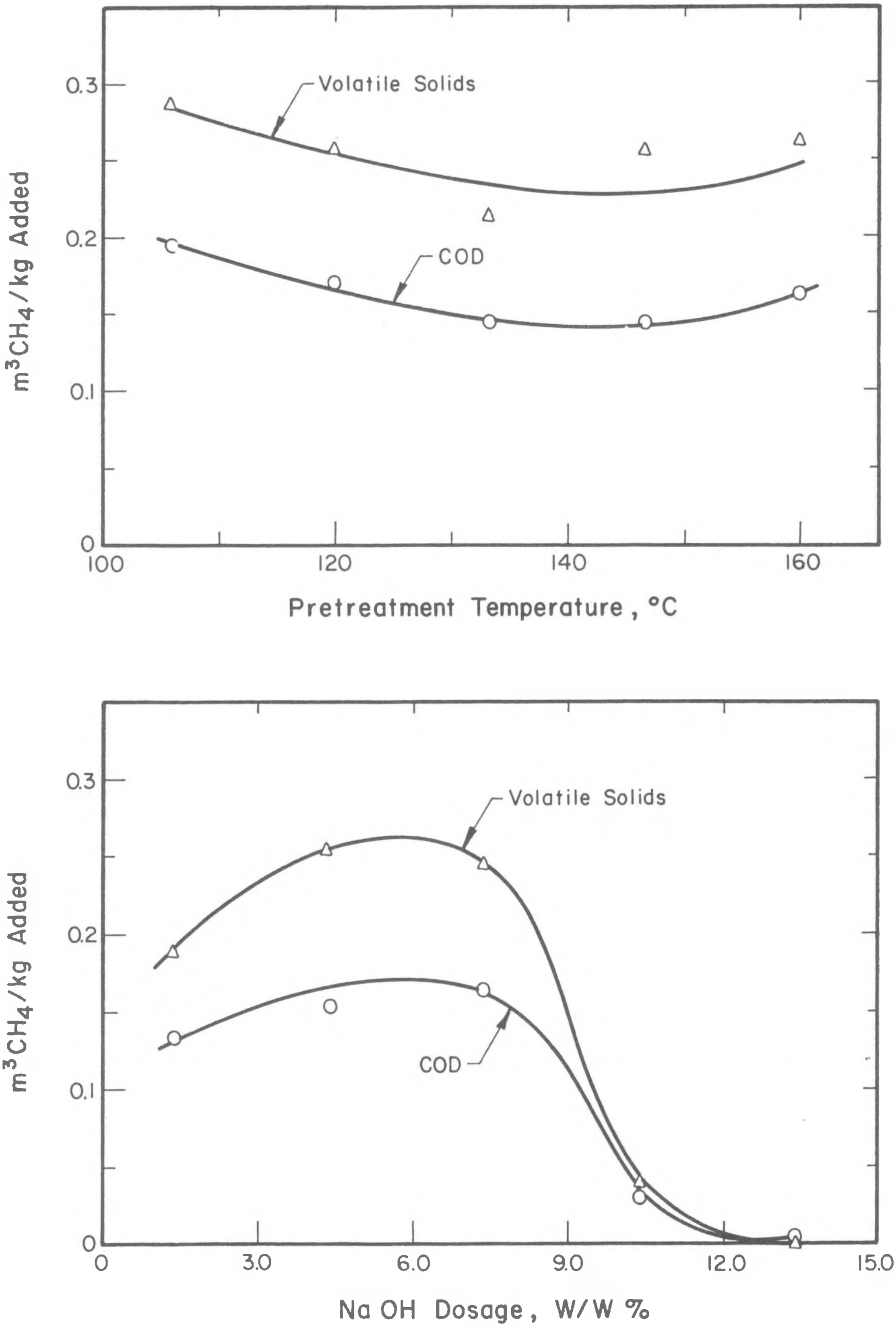

Figure 9. Gas Yields as a Function of Pretreatment Temperature and NaOH Dosage.

effect was not determined. At the higher solids level, the solids were not really in a slurry. The water was almost completely absorbed by the solids. This condition did result in lower soluble COD levels. It also may have affected the degree of swelling of the fibers and separation of the lignin-cellulose fibers.

Pretreatment time and caustic dosage had a major effect on the gas yield. The gas yield was reasonably constant with a pretreatment time up to two hours. However, at the highest time (3.16 hours) process failure resulted. Toxic materials were being produced by the thermochemical decomposition of the lignins. The caustic dosage also had a significant impact on gas production. Increasing this dosage to about 7% resulted in a slight improvement in the gas yield. Higher dosages resulted in process failure. Again, the production of toxic materials from the lignin decomposition was the expected cause of failure.

The slight increase in methane yield with caustic dosages in excess of about one percent does not justify the added cost of the caustic. Figure 10 is a plot of methane yield per kg caustic added as a function of caustic addition. This curve drops off sharply showing that the optimum caustic dosage would be the lower levels. With the high cost of caustic, there is no economic justification for operation at more than the minimum dosage.

The apparent optimum pretreatment conditions as determined by these studies would be the following:

Pretreatment temperature	-	115-160°C
Pretreatment time	-	1-2 hours
Slurry solids concentration	-	15%
Caustic dosage	-	1.3%

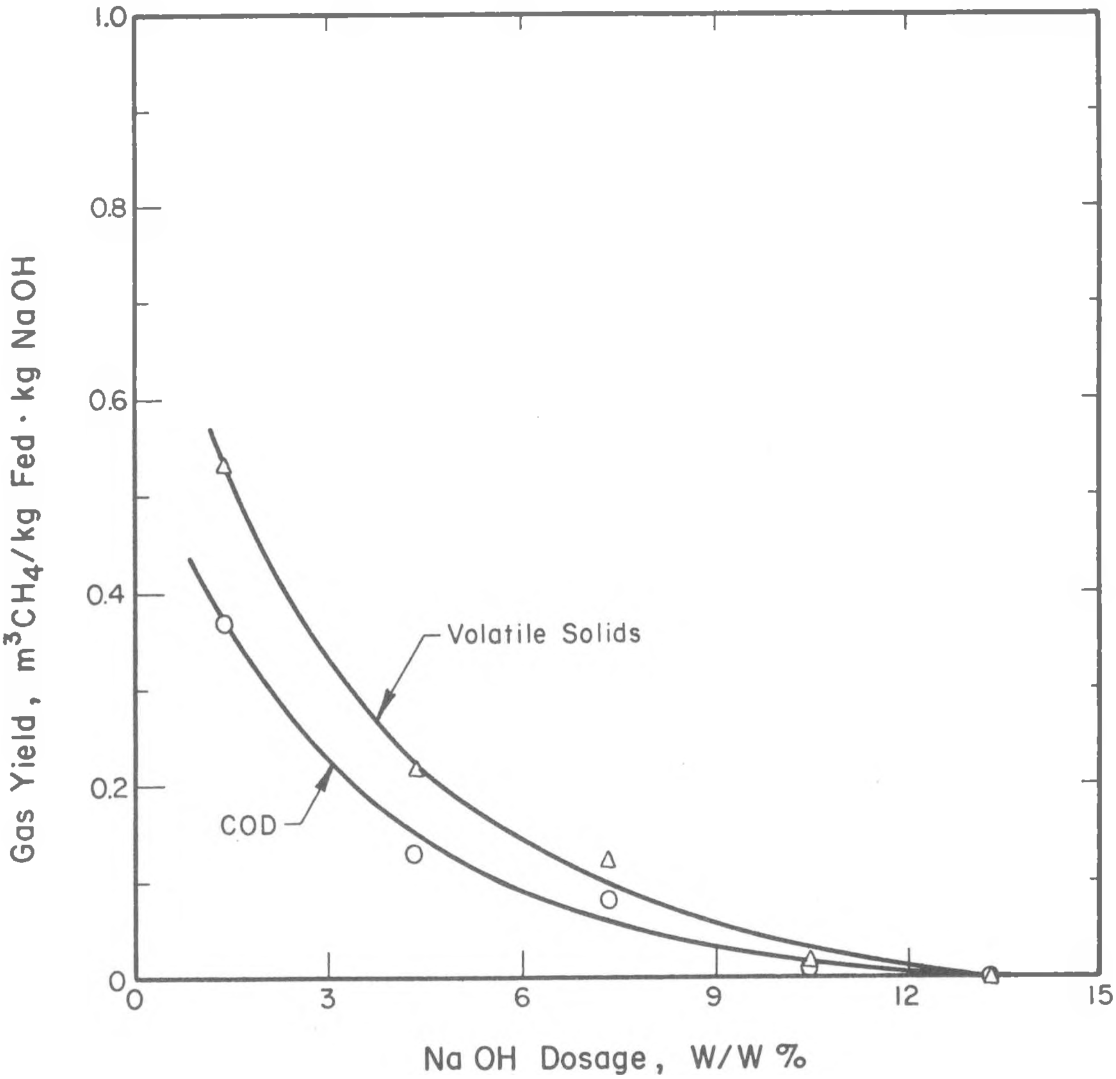

Figure 10. Methane Yield per kg Caustic Added as a Function of Caustic Addition.

Under these pretreatment conditions, lignin hydrolysis would be nonexistent. It would appear that essentially all of the hemicellulose was hydrolyzed. There may have been swelling of the cellulose-lignin fibrils that would enhance enzyme penetration. Digestion of this pretreatment slurry would probably result in nearly complete conversion of the hemicellulose and partial conversion of the cellulose.

Expected gas production can be estimated from the stoichiometric relationship for the fermentation of hemicellulose and cellulose. Each mole of cellulose $(C_6H_{10}O_5)_x$ fermented will yield three moles of methane. This is equivalent to 0.415 m^3/kg of cellulose at 0°C and one atmosphere, or 0.446 m^3/kg at 20°C. If one assumes that hemicellulose is composed of primarily pentosans $(C_5H_3O_4)$, then the methane production would be 0.421 m^3CH/kg of hemicellulose fermented. At 20°C, the methane volume becomes 0.452 m^3/kg. Assuming that the hemicellulose is 100% fermented and cellulose is approximately 50 to 60% fermented, the weighted methane production would be approximately 0.45 m^3/kg volatile solid fermented. This gas volume is measured at 20°C.

The theoretical methane production per kg of COD fermented can be calculated from the stoichiometry of methane oxidation. Each mole of methane requires two moles of molecular oxygen for oxidation. This calculates to 0.357 m^3/kg COD at 0°C and one atmosphere. This is equivalent to 0.384 m^3/kg COD at 20°C.

The maximum methane production obtained in any trial was 0.31 m^3/kg V.S. and 0.23 m^3/kg COD. Using the above figures for theoretical gas production, the solids destruction at the retention time tested was 60% based on the COD data and 69% based on the volatile solids data. The 9% difference would be the result of the loss of volatile organics when the solids samples were dried. The COD data are more realistic.

7.3 Biodegradability Factor and Rate Constant for Corn Stover

After completion of the trials for the evaluation of the pretreatment effects, the reactors were set at retention times of 3.8, 7.5, 15, and 30 days. These tests were initiated prior to completion of the data analyses of the pretreatment effects. Based on the preliminary evaluation of the pretreatment data, the following pretreatment conditions were set:

Caustic dosage - 4.33% w/w

Temperature - 147°C

Time at temperature - 1 hour

Slurry solids - 25%

Loss of the mixer seal on the reactor operating at the 3.8 day retention time prevented completion of this run. However, the other runs did reach steady state and the data in Table 15 were obtained. This fermentation was conducted at 58 and 60°C.

Table 15. Effect of Retention Time on Methane Production

θ Days	Methane Production	
	m^3/kg COD Fed.	m^3/kg Vol. Solids Fed.
7.6	0.224	0.314
15.3	0.260	0.342
29.5	0.279	0.354

These data can be used to obtain an estimate of the biodegradability of the treated stover and a first order rate constant. A plot of log m^3 CH_4 per kg COD fed and m^3 CH_4 per kg volatile solids fed vs the recipricol of retention time ($1/\theta$) will yield the ultimate gas production. When θ approaches infinity, ($1/\theta$) approaches zero. At this point, the substrate remaining, S, will approach zero. The gas yield, S_o-S, is then an estimate of the maximum gas yield where the plot intersects the abscissa. The S_o value for this pretreated corn stover was found to be 0.30 m^3 CH_4 per kg COD fed and 0.37 m^3 CH_4/kg volatile solids fed. These solids exhibited a biodegradability of 78% based in COD and 82% based on volatile solids. The higher percentage for the volatile solids data reflects the error associated with this analysis as previously discussed.

Once the S_o value has been determined, the first order rate constant, K, is easily obtained from a plot of S_o/S vs θ. When this is done, K is found to be 0.51 day^{-1} based on COD reduction. When using the volatile solids data, the value of K is 1.01 day^{-1}. This number is questionable because of the difficulty in obtaining accurate data on the volatile solids. As shown in Table 15, the variation in gas production in going from a retention time of 7.6 days to 29.5 days was small. A small error in the measurement of volatile solids loading will result in substantial change in K. One can have more confidence in the COD data. Consequently, all analysis should be made with the K value determined from the COD data.

This high rate of gas production clearly shows the need to operate at short hydraulic retention times. A 3 day retention will yield 61% of the methane. Increasing to 5 days results in 72% of the gas, while 10 days accounts for 84%. Retention times greater than 10 days yield very little additional gas. This relationship is shown in Figure 11.

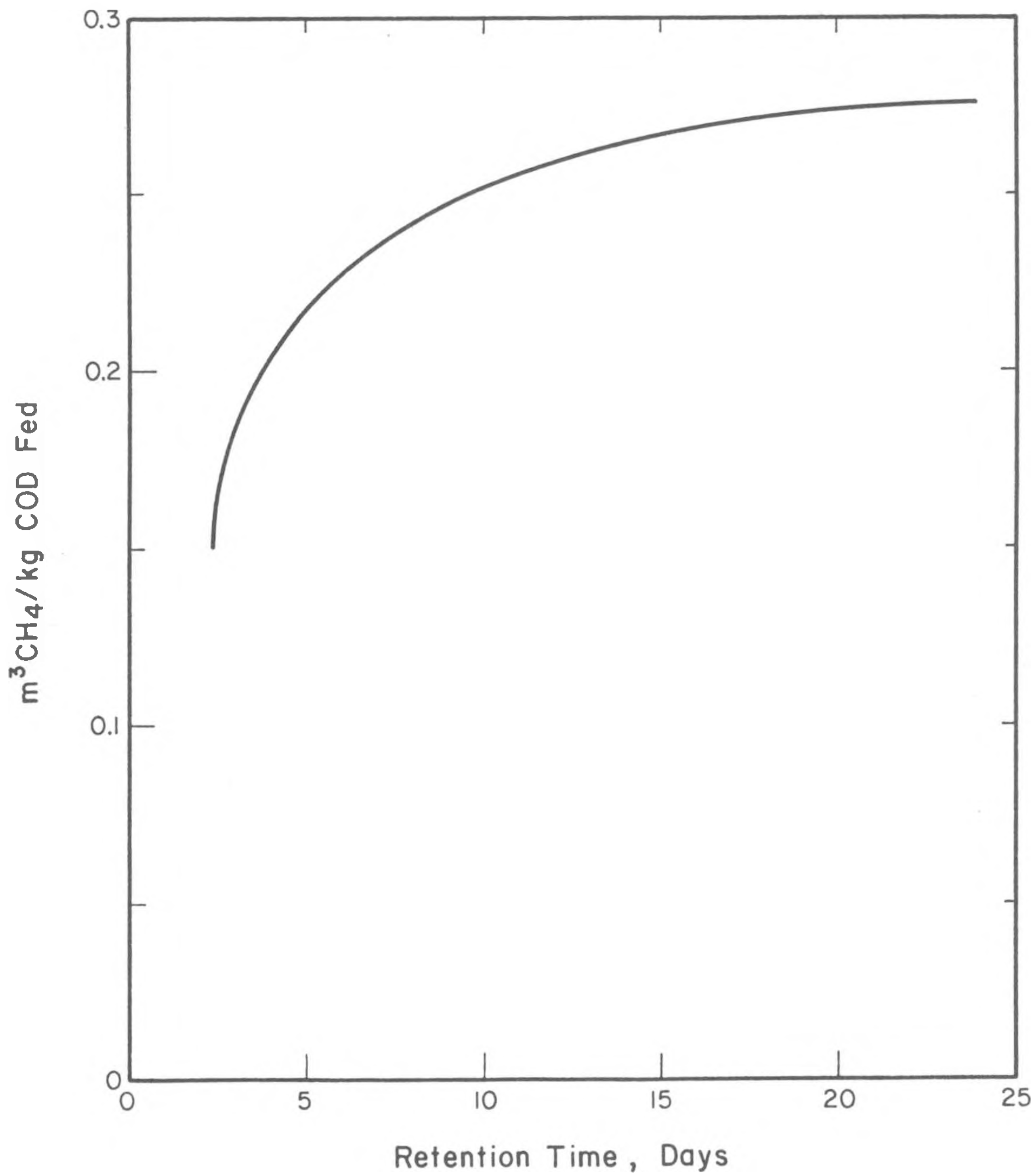

Figure 11. Methane Production as a Function of Retention Time.

7.4 Pretreatment of Wheat Straw

The pretreatment data obtained with wheat straw are presented in Table 16. These results follow the expected trend with the greatest COD solubilization and the lowest pH occurring in the trials experiencing the most severe pretreatment. Equivalent pretreatment results in a similar effect with both wheat straw and corn stover. A comparison of wheat straw center point trials (Trials 5 and 11) and corn stover center point trials (Trials 19, 29, and 30) demonstrates this point (Table 17).

Table 17: Comparison of Wheat Straw and Corn Stover Center Point Runs

	Pretreatment Data		Holding Tank Data	
Parameter	Corn Stover	Wheat Straw	Corn Stover	Wheat Straw
pH	10.4	10.25	6.8	7.25
Alkalinity (mg/l as $CaCO_3$)	2,900	2,950	3,810	4,160
Total COD (mg/l)	64,100	59,700	65,600	58,800
Soluble COD (mg/l)	20,200	18,550	22,300	20,700
COD Solubilization (%)	31.1	31.1	34.0	35.2

Physically, the wheat straw appeared less degraded than comparably treated corn stover. This was most apparent when pumping the slurries. For example, straw Trial 3 (4.33% NaOH, 144°C) could only be pumped from the pretreatment vessel with great difficulty. Trial 2 (4.33% NaOH, 125°C) proved impossible to pump and had to be manually transferred to the holding tanks. No such problems were experienced pumping corn stover pretreated at these NaOH dosages.

Table 16. Summary of Data for the Thermochemical Pretreatment of Wheat Straw

Parameter	Trial 2	Trial 3	Trial 5	Trial 7	Trail 8	Trial 9	Trial 11
pH	8.9	8.7	10.3	11.5	11.3	10.7	10.2
Alkalinity (mg/l as $CaCO_3$)	1,740	2,120	2,980	4,880	4,770	4,580	2,930
Total COD (mg/l)	59,400	62,400	57,900	59,900	59,800	59,200	61,400
Soluble COD (mg/l)	10,100	15,000	18,600	20,500	23,400	23,600	18,500
COD Solubilization (%)	17.0	24.0	32.1	34.2	39.1	39.9	30.1

Table 18. Summary of Holding Data Analysis for Wheat Straw

Parameter	Trial 2	Trial 3	Trial 5	Trial 7	Trial 8	Trial 9	Trial 11
pH	5.6	5.6	7.2	7.6	7.3	7.2	7.3
Alkalinity (mg/l as $CaCO_3$)	2,710	2,240	3,640	4,460	5,190	5,230	4,660
Total COD (mg/l)	57,600	60,500	59,400	56,000	57,600	57,600	58,200
Soluble COD (mg/l)	12,800	16,600	20,500	20,100	24,700	26,200	21,900
COD Solubilization (%)	22.2	27.4	34.5	35.9	42.9	45.5	37.6
Δ Soluble COD (mg/l)	2,700	1,600	1,900	-400	1,300	3,600	3,400

The holding tank data also follows a similar pattern to that observed with corn stover (Table 18). With the exception of Trial 7, all trials show a decreased pH and an increased alkalinity and soluble COD. These factors reflect the effects of microbial action and atmospheric carbonation. Trial 7 is unusual in that it shows a decreased alkalinity and a slight, but insignificant, decrease in soluble COD. The reasons for these effects are not readily apparent.

7.5 Wheat Straw Digestion

A study of the data on the performance of the digesters treating wheat straw demonstrates the difficulty with which this substrate is fermented (Table 19). No pretreatment conditions investigated permitted the steady-state operation of the digesters at retention times in the vicinity of 8 days. Even at longer retention times only one successful pretreatment condition was found. Because of the extreme inhibition at the higher caustic levels, Trials 4, 6, and 10 were not conducted. Also, Trial 1 at low temperature and caustic was not undertaken because it was not possible to pump this slurry.

It is noteworthy that under similar pretreatment conditions there was no difficulty digesting corn stover. As wheat straw has a similar lignin content to corn stover (Ashare et al. 1979, Wilke et al. 1978) it is unlikely that the lignin concentration is the cause of the inhibition. Two possible explanations for the different digestibility of the substrates are:

(1) Wheat straw may have a different lignin structure than corn stover. Upon thermochemical pretreatment this lignin may form soluble products which are more inhibitory to methanogenic bacteria than corresponding products from corn stover.

(2) The higher silica content of the wheat straw may cause the formation of different products upon lignin solubilization. It has been reported that silica is metabolized into structures which provide further protection to the cellulose fibers (Van Soest 1979). This is rather unlikely since the methanogenic bacteria and not the fermentative bacteria were inhibited.

The only successful experiment was Trial 3 which used the lowest hydroxide dosage (4.33% NaOH) and the highest temperature (144°C) in the

Table 19. Summary of Data for Digesters Operating on Wheat Straw

Parameter	Trial 2	Trial 3	Trial 5	Trial 7	Trial 8	Trial 9	Trial 11
Hydraulic Retention Time (d)	15.1	12.7	12.4	11.7	13.3	14.9	9.52
Temperature (°C)	58.09	59.6	58.8	58.5	58.4	58.5	58.9
Volatile Solids Load (kg VS/m^3d)	2.09	2.17	2.49	2.86	2.40	2.12	3.76
COD Load (kg COD/m^3d)	3.64	4.87	4.59	5.02	4.41	3.96	6.76
pH		7.0					
Alkalinity (mg/l as $CaCO_3$)	unable	3,270	unable	unable	unable	unable	unable
Feed Total Solids (mg/l)	to	40,800	to	to	to	to	to
Feed Volatile Solids (mg/l)	attain	35,400	attain	attain	attain	attain	attain
Effluent Total Solids (mg/l)	steady-state	25,700	steady-state	steady-state	steady-state	steady-state	steady-state
Effluent Volatile Solids (mg/l)	operation	18,300	operation	operation	operation	operation	operation
Total Volatile Acids (mg/l as acetate)		2,470					
Methane Content of Gas (%)		57.1					
Volatile Solids Destruction (%)		50.2					
Gas Production (m^3 CH_4/kg VS loading)		.243					
Gas Production (m^3 CH_4/kg COD loaded)		.140					

the experimental design. It appears that such conditions minimize the solubilization of inhibitory products while allowing sufficient reaction and swelling of the fibers to permit digestion. The gas yield of .243 m^3 CH_4/kg VS fed at a retention time of 12.7 days is similar to results obtained when digesting pretreatment corn stover at retention times of about 6 days.

All trial conditions previously tested, except Trial 3, resulted in complete failure of the digesters. Trial 3 pretreatment was at 144°C and 4.33% caustic. Trials 12, 13, and 14 were added to see the effect of higher treatment temperatures at lower caustic levels. The effect of these pretreatment conditions on wheat straw is shown in Table 20. The lower caustic levels resulted in lower pH levels and lower solubilization of COD after pretreatment. Higher caustic dosages have resulted in COD solubilization in excess of 40%. As shown in Table 21, the pH of the slurry dropped significantly in the holding tank. Additional COD solubilization occurred as a result of the bacterial action in this holding tank.

Table 22 shows the digester's response to the pretreated slurries. It was possible to operate Trial 12 at about a 10 day residence time, while the other two trials remained at about 15 days. The shorter retention time resulted in a total volatile acids of 2750 mg/l and a pH of 6.7. Stressed conditions appeared to exist in this digester. Gas production was substantially lower at this shorter retention time.

The typical effect of attempting to operate digesters at shorter retention times is shown in Figure 12. Straw, pretreated with 10.3% caustic at 106°C was the feed for this unit. Seed from a digester having a good methane production rate was added to this unit on Day 0 and Day 4.

Table 20. Summary of Data for the Thermochemical Pretreatment of Wheat Straw for Supplemental Trials

Parameter	Trial 12	Trial 13	Trial 14
ph	8.0	8.2	7.4
Alkalinity (mg/ℓ as $CaCO_3$)	1,950	1,800	1,310
Total COD (mg/ℓ)	64,200	64,500	68,100
Soluble COD (mg/ℓ)	15,400	17,200	14,300
COD Solubilization (%)	24.0	26.7	21.0

Table 21. Summary of Holding Tank Data Analysis for Wheat Straw Supplemental Trials

Parameter	Trial 12	Trial 13	Trial 14
pH	5.59	5.59	5.49
Alkalinity (mg/ℓ as $CaCO_3$)	2,670	2,530	1,970
Total COD (mg/ℓ)	66,600	67,400	66,800
Soluble COD (mg/ℓ)	18,200	19,800	17,400
COD Solubilization (%)	27.3	29.4	26.0
Δ Soluble COD (mg/ℓ)	2,800	2,600	3,100

Δ Soluble COD = Holding Tank Soluble COD - Pretreatment Soluble COD.

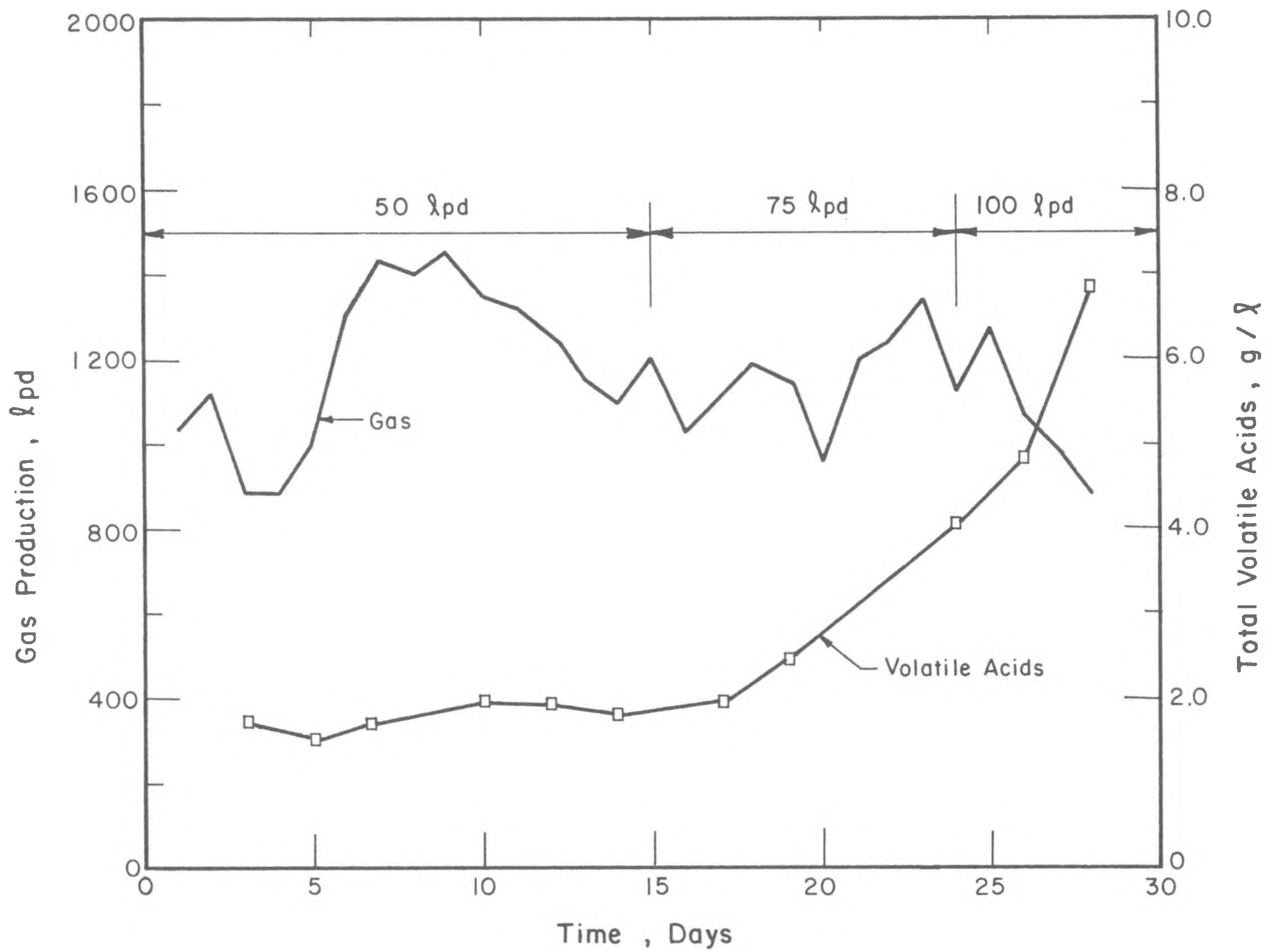

Figure 12. Response of Fermentation to a Feed of Thermochemically Pretreated Wheat Straw.

Table 22. Summary of Data for Digesters Operating on Wheat Straw - Supplemental Trials

Parameter	Trial 12	Trial 13	Trial 14
Hyd. Ret. Time (d)	9.92	15.4	15.2
Temp °C	58.6	59.3	58.7
Vol. Solids Load (kg/m^3-d)	3.15	2.04	1.78
COD Load (kg/m^3-d)	6.39	4.09	4.40
pH	6.7	7.0	6.9
Alkalinity (mg/ℓ as $CaCO_3$)	3,580	3,220	2,820
Feed Tot. Solids (mg/ℓ)	47,400	48,200	40,500
Feed Vol. Solids (mg/ℓ)	40,300	40,700	34,700
Eff. Tot. Solids (mg/ℓ)	33,800	30,900	26,100
Eff. Vol. Solids (mg/ℓ)	24,100	21,700	18,700
Total Vol. Acids (mg/ℓ as HAc)	2,750	1,690	1,850
Methane (%)	54.3	56.0	55.7
Vol. Solids Dest. (%)	40.2	47.7	46.1
m^3 CH_4/kg V.S. Loaded	0.177	0.294	0.211
m^3 CH_4/kg COD Loaded	0.117	0.192	0.111

The pretreated feed was started at the rate of 50 lpd (15 day retention time) on Day 0. By Day 5 gas production began to increase to about 1400 lpd. During this period volatile acids were less than 2000 mg/l. After Day 10, the gas production dropped to between 1100 and 1200 lpd. On Day 15, the feed was increased to 75 lpd. The gas production remained essentially the same even though the volatile solids loading was increased by 50 percent. The volatile acids began to increase. On Day 24, the feed rate was increased to 100 lpd which resulted in the desired retention time of 7.5 days. Failure was almost immediate with a decrease in gas production and pH and an increase in volatile acids.

This pattern was repeated with essentially every trial. When the seed and the new feed was added to the reactor, a surge in gas production would occur. Soon, the gas production rate would drop and the volatile acids would start to increase. Operation at a long retention time, 12 to 15 days, would postpone this effect. Under certain pretreatment conditions, the microorganisms could tolerate the materials in the feed as long as the loading rate remained low. Any attempt to increase this rate and reduce the retention time resulted in a buildup of volatile acids. The methanogenic bacteria were being severely inhibited. Inhibition of other groups such as the acetogenic bacteria may also have been occurring since only the total volatile acids were determined.

In general, the thermochemical pretreatment of straw resulted in a feed material that was inhibitory to the process. Table 23 summarizes the results of the trials attempted. After several attempts, it was apparent that it was not possible to operate a digester on a feed that had been pretreated with caustic at the 7.33 or 10.3% level. Therefore, the added trials were pretreated with a caustic dosage at the 4.33% or less level. Pretreatment at low temperatures and low caustic dosage produced a slurry that was extremely difficult to pump. Consequently, the additional runs concentrated on higher temperatures.

Table 23. Summary of Wheat Straw Data

Trial	Temp	NaOH	CH_4 Production		
			m^3/kg V.S.	m^3/kg COD	Θ
1	106	4.33	-	-	-
2	125	4.33	NSS	NSS	15.1
3	144	4.33	0.243	0.140	12.7
4	106	7.33	-	-	-
5	125	7.33	NSS	NSS	12.4
6	144	7.33	-	-	-
7	106	10.3	NSS	NSS	11.7
8	125	10.3	NSS	NSS	13.3
9	144	10.3	NSS	NSS	14.9
10	125	7.33	-	-	-
11	125	7.33	NSS	NSS	9.52
12	155	4.33	0.177	0.117	9.92
13	175	4.33	0.294	0.192	15.4
14	175	3.00	0.211	0.11	15.2

NSS - Steady State operation could not be achieved

7.6 Biodegradability Factor and Rate Constant for Pretreated Wheat Straw

In the process of trying to establish steady state conditions for Trial 3, the reactor was operated for extended periods at progressively shorter retention times. A reasonably constant gas production rate was obtained at each retention time. These data are given in Table 24.

Table 24. Summary of Data for Digesters Operating on Wheat Straw - Kinetic Studies

Parameter	Trial 3	Trial 3A	Trial 3B
Hydraulic Retention Time (d)	12.7	9.9	8.2
Temperature (°C)	59.6	59.9	58.4
Volatile Solids Load (kg VS/m^3-d)	2.80	3.43	5.33
COD Load (kg COD/m^3-d)	4.01	5.41	7.59
pH	7.0	6.9	6.6
Alkalinity (mg/ℓ as $CaCO_3$)	3,270	2,660	3,830
Feed Total Solids (mg/ℓ)	40,800	39,200	51,200
Feed Volatile Solids (mg/ℓ)	35,400	33,900	43,900
Effluent Total Solids (mg/ℓ)	25,700	24,500	34,100
Effluent Volatile Solids (mg/ℓ)	18,300	17,500	25,100
Total Volatile Acids (mg/ℓ as acetate)	2,470	1,480	3,390*
Methane Content of Gas (%)	57.1	56.8	53.2
Volatile Solids Destruction (%)	50.2	48.4	42.8
Gas Production (m^3 CH_4/kg VS loaded)	.255	.214	.147
Gas Production (m^3 CH_4/kg COD loaded)	.179	.142	.103

*TVA accumulation observed during period of uniform gas production.

At the shorter retention time (8.2 days), the fermentation was stressed, operating with a pH of 6.6 and an average volatile acids content of about 3400 mg/l. It should also be noted that volatile acid levels were increasing during this portion of the trial. Therefore, the gas production may be slightly lower than that which would be obtained under steady state conditions. In general, the volatile acids in an efficient digester averaged about 1500 mg/l. If one assumes that the excess acids in the short retention time unit are equally divided between acetic and propionic, then the loss of these acids in the effluent will be the equivalent of about 120 liters of methane per day at ambient temperatures. For the following calculations, the gas production data for the 8.2 day retention time (Trial 3B) unit was adjusted to 0.17 m^3/kg V.S. fed and 0.119 m^3/kg COD fed as contrasted to the values given in Table 24.

Figure 13 is a semi-log plot of gas production vs. the reciprical of the hydraulic retention time. When the retention time approaches infinity, the gas production that results represents the biodegradability of the organics. Although the retention time span is limited, it is possible to obtain an estimate of the biodegradability of the feed material. The three data points fit the straight line reasonably well. Based on m^3 of CH_4 per kg volatile solids fed, the value of the initial biodegradable substrate level would be 0.52. Since this gas was measured at room temperature, this value is somewhat greater than the methane yield one would expect from fibers that is 100% biodegradable (0.47 m^3/kg V.S. at 25°C).

The parameter, m^3 gas per kg volatile solids fed, has a potential for significant error. This is especially true when the slurry in question contains quantities of volatile material. Volatile acid tests of the slurry

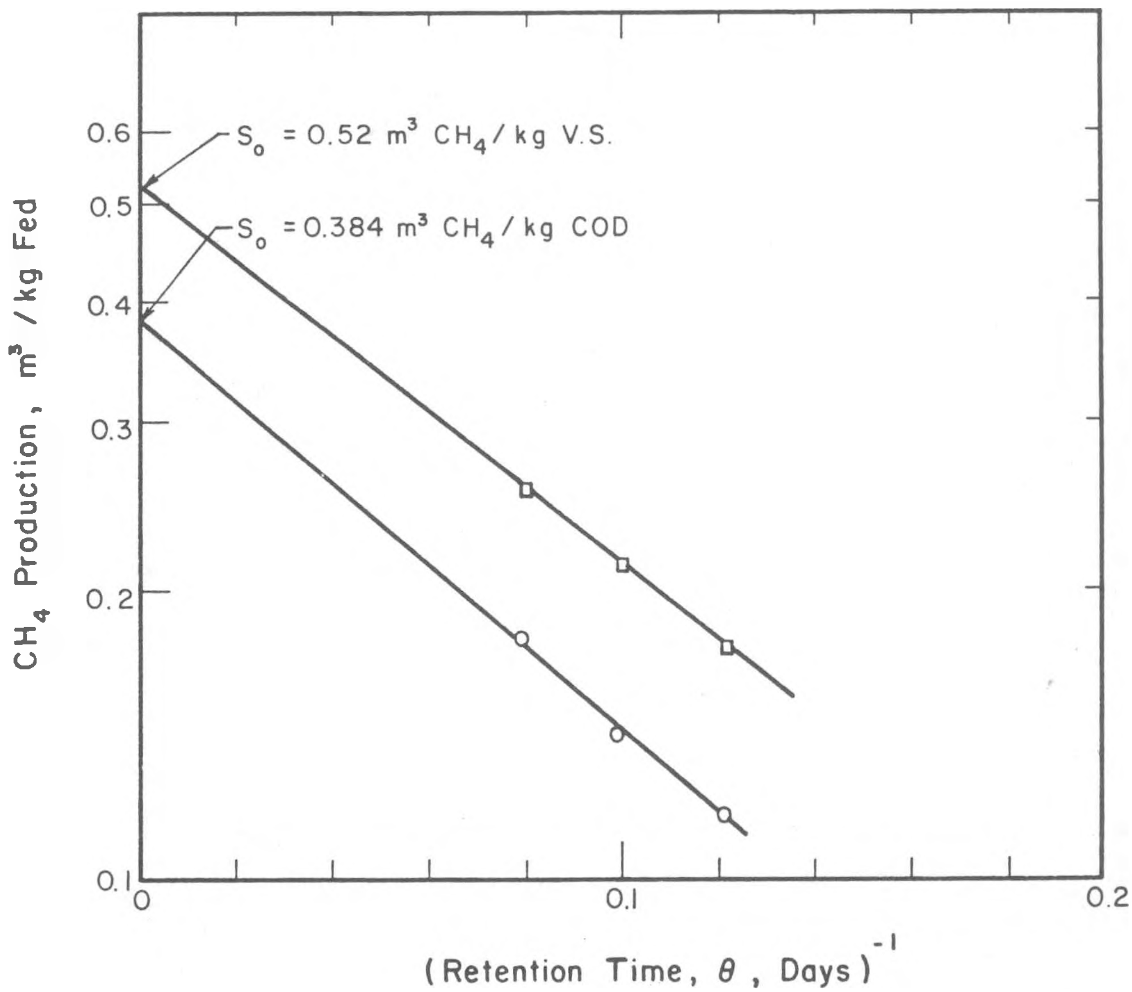

Figure 13. Determination of the Biodegradability of Thermochemically Pretreated Straw.

in the holding tanks showed levels of 3 to 5 g/l. Also, the pretreatment step produced an unknown quantity of volatile organics. When samples of this slurry were dried in an oven at 103°C, it is likely that most of the volatile compounds were lost in this step rather than in the ashing step that measures the volatile solids. Consequently, the kg of volatile solids (organic materials) fed to the reactors could be low by 10% or more.

The COD of the feed slurry would be a more true measure of the organic material added to the reactor. With the proper catalyst, a large percentage of organic material can be oxidized in this test. Figure 13 also shows a plot of m^3 CH_4 per kg COD fed. These data also fit a straight line. The methane production at an infinite retention time is 0.384 m^3/kg COD fed. The theoretical methane production per kg COD fermented is 0.35 m^3 at STP. The gas was measured at about 25°C (ambient temperature), so at this temperature, the methane production would be 0.382 m^3/kg COD fermented. Based on the COD data, the feed slurry prepared by pretreating with 4.33% caustic at 144°C is 100% biodegradable.

This biodegradability factor was then used to determine a first order rate constant. This plot is shown in Figure 14. A least square fit of the three data points is shown in this figure. The slope of the lines determine the K value as shown. These values are very low compared to the previous rate constants of 0.23 day^{-1} for untreated wheat straw (Pfeffer, 1980). This much lower rate constant suggests significant inhibition due to the pretreatment step.

A number of additional observations support this inhibition. As shown in Table 24 reducing the retention time to 8.2 days resulted in a higher volatile acids and a decreased pH. With the pretreated wheat straw, it was

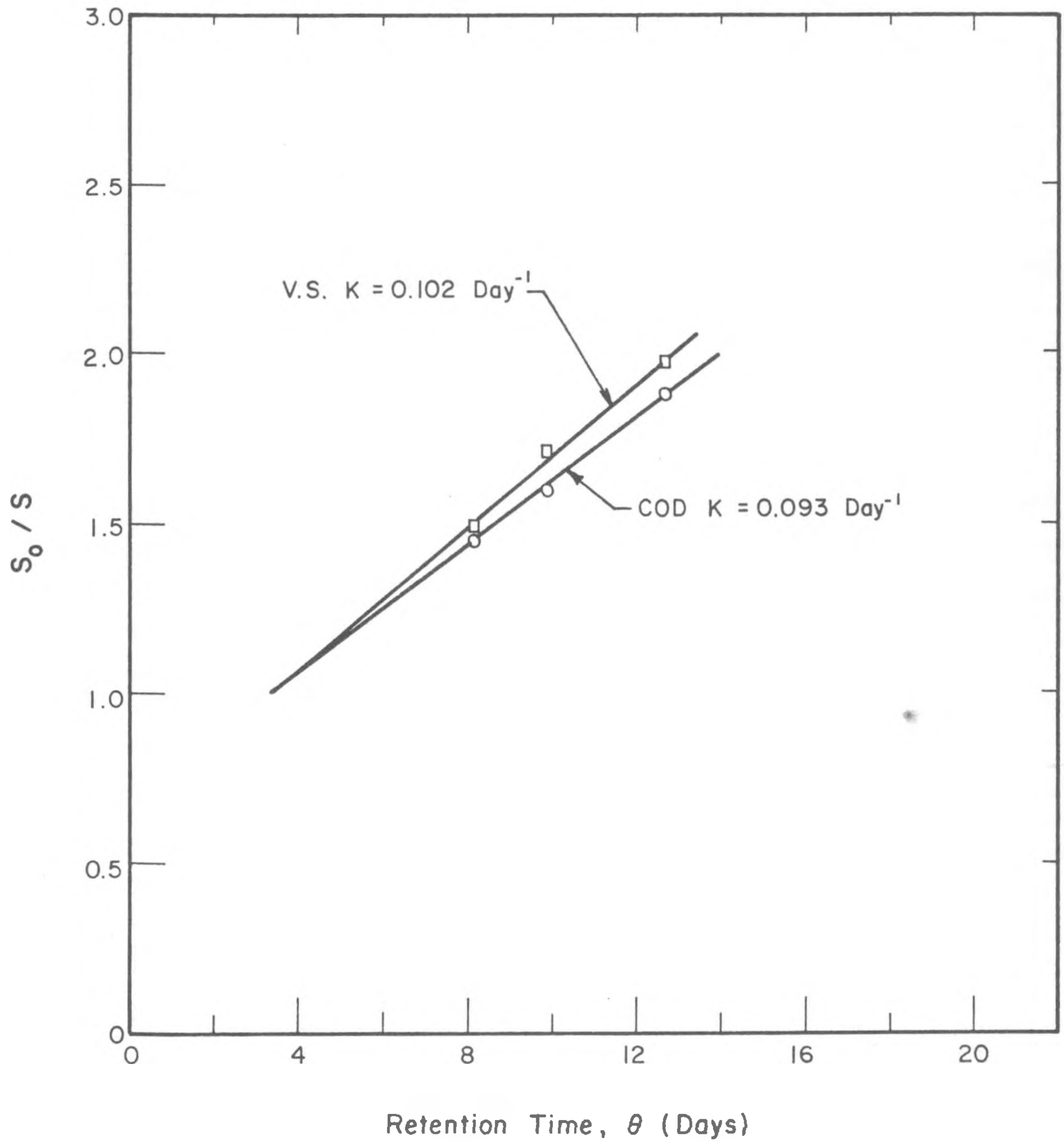

Figure 14. Determination of the First Order Rate Constant for Pretreated Straw.

never possible to reduce the retention time to the 7.75 day or lower range. Retention times of 5 days were common with other substrates. As long as the retention time remained in the 12 to 15 day range, it was possible to sustain a run for several months at the lower caustic levels. However, as soon as the retention time was decreased, the system showed signs of stress. The volatile acids increased and it was difficult to maintain the pH.

When starting a stable digester on a new trial condition, an initial surge in gas was observed. With the same volatile solids loading, gas production may increase by 50% or more the first few days after the new substrate was introduced. The magnitude of the surge and time over which it persisted was primarily a function of level of caustic and the temperature used in the pretreatment. With a high caustic dosage, this gas surge ended in a few days. In 10 to 15 days, the volatile acids generally increased to 6 to 8 g/l and the system failed. This response of the system suggests that the substrate is highly biodegradable, but that as soon as the critical level of the inhibitory material is reached, the fermentation system fails.

7.7 Fiber Composition of Crop Residues Studied.

Because of the time span over which these studies were conducted and the quantity of residue required, it was necessary to aquire the stover and straw in two separate batches. The first lot of stover was harvested in the fall of 1970 and the second lot in the fall of 1980. Also, two separate loads of straw were purchased. The fiber composition of each lot was determined. The results are shown in Table 25.

The composition of these fibers compared favorably with published data (see Tables 1 and 2). The lignin content of the stover was lower and the

Table 25. Fiber Composition of Crop Residues Used in This Study

Crop Residue	Cellulose	Hemi-Cellulose	Lignin	Cell Solubles	Ash	Moisture
Corn Stover #1	40.0	26.8	7.2	15.5	10.5	8.4
Corn Stover #2	38.9	18.8	9.7	20.9	11.7	9.2
Wheat Straw #1	35.4	25.9	14.1	16.4	8.2	8.0
Wheat Straw #2	36.8	22.7	12.9	18.8	8.8	8.9

ash content was higher. This may be due to the experimental technique used to differentiate between lignin and ash. Both lots of wheat straw had essentially the same fiber composition. There was some differences in the hemicellulose and cell solubles fraction of the corn stover. This difference may be a result of the inefficient extraction of cell solubles during the analysis of Corn Stover #1, or hydrolysis of some hemicellulose when the analysis of Corn Stover #2 was conducted. Since both the cell solubles and the hemicellulose are readily fermented, this variation in the composition of the two stover lots should not influence the experimental results.

7.8 Regression Equations for Predicting Gas Yields

An attempt was made to develop regression equations that could be used to predict the methane yield for various pretreatment conditions. Various manipulations were attempted and the following equations resulted.

COD Model

$$\frac{1}{\hat{y}} = 5.64-2.68X_2-0.63X_2^2-1.03X_4^2 \qquad (8)$$

where: $\hat{y}$ = gas yield-m^3CH_4/kg COD

X_2 = NaOH Dosage

X_4 = Pretreatment Time

Data must be submitted to the model in its coded form, e.g. X_2=-1 not mg/l. Since there are no constants for X_1 and X_3, the model assumes these are constant. The curve for gas yield as a function of caustic dosage can be calculated by setting X_4 equal to zero. The results are shown in Table 26. Be comparing the data in this table with the experimental data plotted in Figure 9, one can see that the predicted gas production fits the experimental data well at NaOH dosages not exceeding the center point (7.33%). The model completely fails beyond this point. The data present a response surface that can not be modelled using first order and quadratic terms. A higher order model could be developed that would fit the data. However, there is little value in considering caustic dosages above the center point. Gas production decreases and costs increase because of higher chemical costs.

Volatile Solids Model

$$\hat{y}_1 = -1.256+0.551X_2+0.160X_2^2+0.223X_4^2 \quad (9)$$

The effect of X_1 and X_3, pretreatment temperature and solids concentration, was also found to be constant when predicting the methane production per kg volatile solids added. The predicted gas production at various levels of X_2 are given in Table 26. At treatment levels at or below the center point, the model fit is acceptable. However, it fails completely at levels above the center point.

Similar calculations can be made for the effect of X_4 on gas production. When this is done and the predicted values compared to Figure 8, one can see that the model fails completely. The poor fit of these models can be attributed in part to certain treatments resulting in process failure, or a zero response. This was a particular problem at the higher caustic dosage and longer pretreatment time.

Table 26. Predicted Gas Yields as a Function of Caustic Dosage

X_2		$\hat{y}$	$\hat{y}_1$
Coded Value	% w/w	m^3CH_4/kg COD	m^3CH_4/kg Vol. Solids
-2	1.33	0.118	0.179
-1	4.33	0.130	0.193
0	7.33	0.177	0.285
1	10.3	0.217	0.580
2	13.3	0.658	1.626

In summary, it is evident that there is reasonable fit of the models to the observed data at coded variable values for $X \leq 0$. Above the center point values, the models deviate substantially from the observed data. Also, low levels for X_4 tend to yield higher predicted methane levels. For these reasons and the fact that neither model gives a significant fit of the data at the 95% confidence level, the models are inadequate to describe the data over the full range of values studied.

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9. APPENDIX

9.1 Pretreatment Data

The following tables contain pretreatment tank data for entire period of study. The listings are from a computer program used to analyse the data.

The column headings are defined below:

DAY = Date (Julian); Day 0 = January 1, 1980

ALK = Total Alkalinity (mg/l as $CaCO_3$)

TOTCOD = Total COD (mg/l)

SOLCOD = Soluble COD (mg/l)

SCOD% = Percent COD Solubilization (%)

PH1 = pH x 100

PROGRAM LISTING

```
FILE NAME          COOKAN   ANALYSIS OF COOK VARIABLES
VARIABLE LIST      DAY,PH,ALK,TOTCOD,SOLCOD
INPUT FORMAT       FREEFIELD
N OF CASES       5
INPUT MEDIUM     DISK
VAR LABELS       DAY,PH,ALK,TOTCOD,SOLCOD
MISSING VALUES   DAY(0)/PH(0)/ALK(0)/TOTCOD(0)/SOLCOD(0)
TASK NAME        COOK DATA ANALYSIS
COMPUTE          VARA1=TOTCOD-SOLCOD
COMPUTE            VARA2=VARA1/TOTCOD
COMPUTE          VARA3=1-VARA2
COMPUTE          SCOD%=VARA3*100
COMPUTE          PH1=PH*100
IF                 (SCOD% EQ 100)SCOD%=0
ASSIGN MISSING     SCOD%(0)
LIST CASES       CASES=45VARIABLES=DAY,PH1,ALK,TOTCOD,SOLCOD,
                 SCOD%
CONDESCRIPTIV    PH TO SOLCOD
OPTION           2
STATISTICS       ALL
```

DATA

TRIAL 1

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/02/05.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	373.	1950.	69025.	12753.	18.	890.
2	375.	975.	49806.	9811.	20.	840.
3	381.	1625.	60248.	10376.	17.	840.
4	386.	1487.	74111.	12932.	17.	920.

TRIAL 2

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/02/05.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	364.	1268.	70390.	14660.	21.	730.
2	366.	1219.	74640.	15357.	21.	720.
3	372.	1340.	58125.	14870.	26.	740.
4	378.	1462.	59639.	13748.	23.	720.
5	382.	2145.	59677.	16179.	27.	710.

TRIAL 3

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/02/05.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	339.	4234.	54530.	28020.	51.	1050.
2	340.	4536.	67504.	32495.	48.	1050.
3	343.	4898.	65530.	30680.	47.	1085.
4	350.	5322.	58015.	27340.	47.	1085.
5	353.	3314.	50988.	25490.	50.	1060.

TRIAL 4

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/02/05.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	365.	4268.	58770.	28430.	48.	1020.
2	371.	3705.	57604.	28437.	49.	1010.

TRIAL 5

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/02/05.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	359.	862.	45240.	12103.	27.	810.
2	364.	1462.	69020.	15343.	22.	895.
3	366.	1219.	70360.	14152.	20.	830.

TRIAL 6

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/02/05.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	340.	1260.	58607.	16295.	28.	740.
2	343.	1260.	62404.	14122.	23.	725.
3	347.	1579.	66050.	13130.	20.	705.
4	352.	1544.	65800.	15190.	23.	730.
5	357.	726.	62000.	14320.	23.	725.

TRIAL 7

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 80/09/15.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	180.	4647.	61290.	23760.	39.	1150.
2	183.	5188.	54210.	22810.	42.	1170.
3	189.	4295.	59520.	23730.	40.	1100.

TRIAL 8

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/02/05.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	351.	5141.	58210.	28530.	49.	1020.
2	357.	4860.	60080.	29350.	49.	990.

TRIAL 9

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/02/05.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	365.	1999.	74596.	24650.	33.	950.
2	374.	1683.	65600.	23982.	37.	925.
3	379.	2048.	52892.	22210.	42.	955.
4	385.	2145.	54234.	21774.	40.	950.
5	387.	2925.	61700.	23122.	37.	910.

TRIAL 10

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/02/05.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	380.	2275.	50813.	22155.	44.	950.
2	385.	1950.	57707.	22530.	39.	950.
3	388.	2438.	65217.	22530.	35.	920.
4	390.	2828.	65692.	22174.	34.	950.

TRIAL 11

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/01/22.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	92.	2090.	75500.	18990.	25.	980.
2	101.	2028.	67380.	16500.	24.	990.
3	106.	1508.	46480.	13880.	30.	950.
4	110.	1866.	67000.	14950.	22.	940.
5	114.	1226.	51200.	14550.	28.	0
6	120.	1803.	68450.	15280.	22.	955.

TRIAL 12

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 80/12/17.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	309.	1222.	64776.	14740.	23.	725.
2	312.	1207.	66887.	15728.	24.	730.
3	319.	1109.	68776.	15343.	22.	710.
4	324.	1386.	48979.	15255.	31.	735.
5	329.	1323.	52800.	14700.	28.	725.
6	331.	907.	63529.	14118.	22.	690.

TRIAL 13

COOK DATA ANALYSIS
FILE COOKAN (CREACTION DATE = 80/09/13.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	137.	5013.	0	0	0	1180.
2	141.	4208.	59600.	19700.	33.	1150.
3	144.	4689.	58610.	24370.	42.	1165.
4	145.	4706.	54440.	23610.	43.	1175.
5	150.	4897.	54830.	23790.	43.	1170.
6	153.	4322.	60100.	22430.	37.	1160.
7	158.	6566.	59100.	23900.	40.	0
8	161.	4559.	53110.	25100.	47.	1180.
9	166.	4641.	61440.	21730.	35.	1165.
10	171.	4140.	52800.	24520.	46.	1125.

TRIAL 14

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/02/05.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	337.	3730.	64786.	28112.	43.	1015.
2	343.	4536.	62595.	34732.	55.	1035.

TRIAL 15

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/01/22.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	123.	1767.	63900.	15480.	24.	960.
2	126.	1420.	51950.	13930.	27.	965.
3	130.	1623.	54500.	11750.	22.	940.
4	134.	1932.	64300.	15220.	24.	920.
5	140.	2459.	49200.	14510.	29.	950.
6	143.	2107.	51650.	15210.	29.	930.
7	146.	2096.	53740.	19050.	35.	910.
8	151.	1733.	59700.	14350.	24.	930.
9	157.	2495.	63490.	18080.	28.	0

TRIAL 16

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 80/12/17.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	298.	1493.	62700.	15430.	25.	785.
2	308.	1358.	60256.	15224.	25.	725.
3	312.	1307.	64738.	17964.	28.	690.
4	317.	1310.	65885.	14232.	22.	710.
5	322.	1462.	48996.	17922.	37.	705.
6	325.	1411.	61265.	15069.	25.	775.
7	330.	1411.	55382.	14329.	26.	685.
8	336.	1159.	79572.	17950.	23.	700.

TRIAL 17

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 80/09/15.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	135.	3927.	57800.	21530.	37.	1105.
2	145.	4626.	54440.	20280.	37.	1150.
3	148.	4716.	57390.	25050.	44.	1155.
4	151.	3018.	58000.	25220.	43.	1100.
5	154.	4209.	50200.	23800.	47.	1130.
6	159.	5752.	46900.	24300.	52.	1150.
7	164.	5450.	48800.	26480.	54.	1190.
8	168.	3294.	65770.	22450.	34.	1030.
9	172.	4454.	51200.	23730.	46.	1135.

TRIAL 18

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 80/12/18.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	316.	3303.	60256.	27724.	46.	1020.
2	323.	2835.	56939.	27041.	47.	1000.
3	326.	3427.	58600.	27450.	47.	1010.
4	331.	3226.	63725.	24314.	38.	990.

TRIAL 19

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/01/22.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	91.	1695.	55120.	20180.	37.	1080.
2	100.	2800.	55230.	20410.	37.	1055.
3	103.	3015.	75700.	22090.	29.	1040.
4	108.	2741.	70060.	19120.	27.	1050.
5	113.	2931.	57090.	21650.	38.	1040.
6	116.	2459.	61700.	18380.	30.	1055.
7	121.	2145.	61220.	18600.	30.	990.
8	124.	2749.	61360.	20680.	34.	1000.
9	128.	2705.	57060.	20640.	36.	1025.
10	133.	4019.	72700.	25000.	34.	1045.

TRIAL 20

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/01/22.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	311.	2353.	65513.	19792.	30.	1035.
2	315.	1719.	73717.	19150.	26.	1020.
3	322.	2016.	60241.	20281.	34.	1040.
4	326.	2520.	56324.	20455.	36.	1065.
5	330.	1745.	54171.	21342.	39.	1040.

TRIAL 21

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/01/22.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	40.	3300.	70833.	20010.	28.	1155.
2	43.	3398.	57440.	23870.	42.	1115.
3	49.	2480.	63500.	14690.	23.	1085.
4	53.	2889.	72700.	19020.	26.	1105.
5	58.	3478.	57490.	18800.	33.	1175.
6	63.	2782.	64760.	19590.	30.	0

TRIAL 22

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/02/05.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	338.	2268.	53020.	24250.	46.	940.
2	345.	2494.	65428.	24760.	38.	955.
3	350.	2165.	60820.	25735.	42.	920.
4	352.	2315.	52130.	24370.	47.	960.
5	358.	2453.	67320.	22374.	33.	950.

TRIAL 23

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/01/22.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	77.	759.	32544.	8062.	25.	710.
2	80.	538.	77600.	6800.	9.	720.
3	86.	886.	50260.	8610.	17.	710.

TRIAL 24

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/01/22.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	42.	5580.	62845.	19560.	31.	1245.
2	45.	5243.	52540.	22660.	43.	1210.
3	52.	6020.	0	0	0	1250.
4	56.	5029.	75390.	25500.	34.	1175.
5	60.	5778.	62000.	26500.	43.	1205.
6	65.	6634.	59720.	20430.	34.	1225.

TRIAL 25

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/01/22.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	67.	3103.	57060.	20980.	37.	1010.
2	71.	3137.	62350.	23300.	37.	1045.
3	73.	3688.	58600.	24800.	42.	1075.
4	78.	3226.	58431.	20049.	34.	1040.
5	84.	0	0	0	0	0

TRIAL 26

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/01/22.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	70.	3103.	63900.	15550.	24.	1065.
2	73.	3361.	50000.	21650.	43.	1065.
3	78.	3036.	61470.	24850.	40.	1050.
4	81.	0	59400.	15000.	25.	1060.
5	85.	3890.	58720.	16720.	28.	1070.

TRIAL 27

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/01/22.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	88.	1720.	58350.	23870.	41.	1075.
2	92.	3244.	63300.	15610.	25.	1080.
3	100.	3051.	51900.	19380.	37.	1080.
4	103.	3159.	65640.	23210.	35.	1055.
5	109.	3162.	68810.	20850.	30.	1085.
6	114.	3028.	56600.	20150.	36.	1085.
7	116.	2464.	59900.	19760.	33.	1025.
8	122.	2750.	66270.	17760.	27.	1080.
9	126.	2570.	65250.	18800.	29.	1040.

TRIAL 28

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/01/22.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	91.	0	72600.	25100.	35.	1035.
2	99.	2943.	77050.	23700.	31.	1025.
3	102.	2747.	53440.	22050.	41.	1010.
4	107.	2620.	64380.	21025.	33.	1005.
5	113.	3301.	56120.	23290.	42.	1020.
6	115.	2650.	54200.	23250.	43.	975.
7	120.	2889.	49400.	21230.	43.	1025.
8	124.	2996.	64500.	22400.	35.	980.
9	127.	2586.	62550.	21520.	34.	985.
10	133.	2813.	56100.	22830.	41.	970.

TRIAL 29

COOK DATA AÑALYSIS
FILE COOKAN (CREATION DATE = 81/01/22.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	45.	3156.	66015.	22070.	33.	1045.
2	53.	2674.	65760.	19500.	30.	1035.
3	58.	2675.	52200.	20270.	39.	1030.
4	63.	3050.	76419.	20548.	27.	1020.
5	66.	3317.	68560.	20910.	30.	1015.

TRIAL 30

COOK DATA ANALYSIS
FILE COOKAN (CREATION DATE = 81/01/22.) ANALYSIS OF COOK VARIABLES

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	SCOD%	PH1
1	46.	2820.	54510.	19710.	36.	1062.
2	51.	2860.	66990.	19370.	29.	1065.
3	59.	3050.	66070.	19445.	29.	1070.
4	65.	3264.	67123.	18640.	28.	1045.

9.2 Holding Tank Data

The following tables contain holding tank data for the duration of this study.

The column headings are defined below:

DAY = Date (Julian); Day 0 = January 1, 1980

ALK = Total Alkalinity (mg/l as $CaCO_3$)

TOTCOD = Total COD (mg/l)

SOLCOD = Soluble COD (mg/l)

TCODC = Total COD corrected to 5% TS (mg/l)

SCODC = Soluble COD corrected to 5% TS (mg/l)

SCOD% = Percent COD Solubilization (%)

PH1 = pH x 100

TSLD%1 = Percent Total Solids x 100 ($\frac{W}{W}$ %w)

PROGRAM LISTING

```
FILE NAME           MIXAN  MIX TANK DATA ANALYSIS
VARIABLE LIST       DAY,PH,ALK,TOTCOD,SOLCOD,TOTSLD
INPUT FORMAT        FREEFIELD
N OF CASES          16
INPUT MEDIUM        DISK
VAR LABELS          DAY,PH,ALK,TOTCOD,SOLCOD,TOTSLD
MISSING VALUES      DAY(0)/PH(0)/ALK(0)/TOTCOD(0)/SOLCOD(0)/
                    TOTSLD(0)/
TASK NAME           RAW DATA ANALYSIS
COMPUTE             TSLD%=TOTSLD/1.0E+04
COMPUTE             VARA1=TOTCOD*5
IF                  (TSLD%*TOTCOD*SOLCOD EQ 0)TCODC=0
IF                  (TSLD%*TOTCOD*SOLCOD GT 0)TCODC=VARA1/TSLD%
COMPUTE             VARA2=SOLCOD*5
IF                  (TSLD%*TOTCOD*SOLCOD EQ 0)SCODC=0
IF                  (TSLD%*TOTCOD*SOLCOD GT 0)SCODC=VARA2/TSLD%
IF                  (TCODC EQ 0)VARA3=0
IF                  (TCODC GT 0)VARA3=SCODC/TCODC
COMPUTE             SCOD%=VARA3*100
IF                  (TOTCOD EQ 0)SCOD%=0
COMPUTE             PH1=PH*100
COMPUTE             TSLD%1=TSLD%*100
ASSIGN MISSING      TSLD%,TCODC,SCODC,SCOD%,PH1(0)
LIST CASES          CASES=16/VARIABLES=DAY,PH1,ALK,TOTCOD,
                    SOLCOD,TSLD%1,TCODC,SCODC,SCOD%
CONDESCRIPTIVE      PH TO SOLCOD
OPTION              2
STATISTICS          ALL
```

DATA

TRIAL 1

FILE MIXAN (CREATION DATE = 81/01/29.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	374.	2389.	59612.	14815.	64701.	16080.	25.	610.	461.
2	375.	2145.	44550.	10312.	49555.	11471.	23.	635.	449.
3	378.	2340.	60465.	13178.	79860.	17405.	22.	690.	379.
4	379.	2535.	64271.	13090.	75043.	15284.	20.	640.	428.
5	380.	2194.	60330.	12087.	66268.	13277.	20.	625.	455.
6	381.	2096.	44791.	11828.	51964.	13722.	26.	620.	431.
7	382.	2730.	62195.	13211.	74005.	15720.	21.	590.	420.
8	385.	2247.	51930.	12830.	54503.	13466.	25.	600.	476.
9	386.	1511.	52822.	11895.	60291.	13577.	23.	580.	438.
10	387.	2145.	63636.	13636.	63790.	13669.	21.	570.	499.
11	388.	2242.	63889.	13889.	77095.	16760.	22.	595.	414.
12	389.	2145.	67857.	14534.	66179.	14175.	21.	595.	513.
13	392.	2828.	52079.	12426.	64459.	15380.	24.	600.	404.

TRIAL 2

FILE MIXAN (CREATION DATE = 81/01/29.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	365.	1755.	58430.	17060.	61007.	17812.	29.	570.	479.
2	366.	2340.	65322.	17641.	67113.	18125.	27.	565.	487.
3	371.	2145.	45360.	14642.	63216.	20406.	32.	530.	359.
4	372.	1901.	57600.	16000.	80949.	22486.	28.	545.	356.
5	373.	1804.	51250.	16345.	61147.	19502.	32.	550.	419.
6	374.	1658.	61023.	16225.	69040.	18357.	27.	555.	442.
7	375.	1365.	43725.	11618.	56313.	14963.	27.	555.	388.
8	378.	1560.	47674.	15310.	71247.	22880.	32.	590.	335.
9	379.	1560.	55650.	16581.	65062.	19385.	30.	545.	428.
10	380.	1511.	47520.	15599.	55052.	18072.	33.	555.	432.
11	381.	1560.	45625.	15417.	57429.	19406.	34.	570.	397.
12	382.	1072.	48373.	15040.	66551.	20692.	31.	590.	363.
13	385.	1462.	48884.	14756.	58344.	17612.	30.	570.	419.
14	386.	1950.	52016.	14012.	64809.	17458.	27.	555.	401.
15	387.	1414.	42292.	14032.	56400.	18713.	33.	575.	375.
16	388.	1462.	46428.	14385.	61392.	19021.	31.	590.	378.

TRIAL 3

FILE MIXAN (CREATION DATE = 81/01/07.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	340.	5040.	59800.	32040.	49813.	26689.	54.	995.	600.
2	343.	4334.	62863.	0	0	0	0	620.	533.
3	344.	4284.	62213.	33396.	59728.	32062.	54.	605.	521.
4	345.	4263.	72700.	35290.	69296.	33638.	49.	635.	525.
5	346.	4898.	64015.	34470.	60452.	32551.	54.	615.	529.
6	347.	5351.	69083.	35305.	67109.	34296.	51.	650.	515.
7	350.	5322.	62162.	33783.	62457.	33943.	54.	640.	498.
8	351.	5322.	78600.	37840.	62455.	30068.	48.	755.	629.
9	352.	2751.	76900.	34025.	62039.	27450.	44.	750.	620.
10	353.	4767.	63950.	38565.	53158.	32057.	60.	685.	602.
11	354.	4540.	65525.	31250.	64187.	30612.	48.	665.	510.
12	357.	4994.	57500.	32970.	56528.	32413.	57.	620.	509.
13	358.	5351.	56143.	31920.	57015.	32416.	57.	645.	492.
14	359.	5729.	56300.	28150.	57073.	28536.	50.	660.	493.

TRIAL 4

FILE MIXAN (CREATION DATE = 81/02/04.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	371.	5850.	52860.	32142.	63254.	38462.	61.	820.	418.
2	372.	4241.	64600.	31100.	59747.	28764.	48.	725.	541.
3	373.	4778.	60420.	31250.	55607.	28760.	52.	790.	543.
4	374.	4388.	65255.	31305.	60745.	29142.	48.	790.	537.
5	375.	4388.	60475.	31062.	56631.	29088.	51.	800.	534.

TRIAL 5

FILE MIXAN (CREATION DATE = 81/01/19.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	360.	0	0	0	0	0	0	620.	0
2	361.	0	0	0	0	0	0	595.	0
3	362.	0	0	0	0	0	0	610.	0
4	363.	0	0	0	0	0	0	610.	0
5	364.	2540.	66270.	19841.	64892.	19428.	30.	575.	511.
6	365.	2535.	74510.	15490.	69989.	14550.	21.	575.	532.
7	366.	2730.	64112.	15514.	66521.	16097.	24.	570.	482.
8	367.	0	0	0	0	0	0	575.	0
9	368.	0	0	0	0	0	0	595.	0
10	369.	0	0	0	0	0	0	580.	0
11	370.	0	0	0	0	0	0	590.	0
12	371.	2437.	49642.	13571.	63573.	17380.	27.	560.	390.
13	372.	2194.	51800.	13700.	67847.	17944.	26.	550.	382.
14	373.	2340.	58750.	13020.	78743.	17451.	22.	640.	373.

TRIAL 6

FILE MIXAN (CREATION DATE = 81/01/12.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	343.	2419.	55899.	16296.	61711.	17990.	29.	0	453.
2	344.	2419.	72137.	16412.	75486.	17174.	23.	550.	478.
3	345.	2177.	53460.	18510.	58543.	20270.	35.	575.	457.
4	346.	2404.	68560.	16005.	76398.	17835.	23.	560.	449.
5	347.	2540.	53630.	16173.	64355.	19407.	30.	580.	417.
6	350.	2435.	42471.	16602.	50203.	19625.	39.	570.	423.
7	351.	2526.	52920.	16340.	59339.	18322.	31.	560.	446.
8	352.	6089.	64120.	0	0	0	0	575.	437.
9	353.	2406.	57750.	17250.	60131.	17961.	30.	580.	480.
10	354.	2361.	52620.	16830.	57917.	18524.	32.	570.	454.
11	357.	2724.	55710.	16533.	61453.	18237.	30.	535.	453.
12	358.	2540.	84600.	17144.	85085.	17242.	20.	565.	497.
13	359.	2542.	64200.	16340.	70535.	17952.	25.	560.	455.

TRIAL 7

FILE MIXAN (CREATION DATE = 81/01/14.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	186.	0	0	0	0	0	0	600.	0
2	187.	0	0	0	0	0	0	850.	0
3	188.	0	0	0	0	0	0	685.	0
4	189.	4349.	56620.	24764.	52369.	22905.	44.	670.	541.
5	190.	4926.	57800.	25075.	54592.	23683.	43.	675.	529.
6	191.	5083.	55780.	23900.	56055.	24018.	43.	695.	498.
7	193.	5381.	57760.	26770.	52712.	24431.	46.	1045.	548.
8	194.	0	0	0	0	0	0	975.	0
9	195.	0	0	0	0	0	0	755.	0

TRIAL 8

FILE MIXAN (CREATION DATE = 81/01/16.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	352.	4555.	61450.	31680.	51798.	26704.	52.	945.	593.
2	353.	4449.	65120.	33330.	55956.	28639.	51.	755.	582.
3	354.	3632.	58670.	29440.	58226.	29217.	50.	745.	504.
4	357.	4722.	60520.	29058.	61554.	29555.	48.	730.	492.
5	358.	4898.	60080.	31820.	53370.	28266.	53.	700.	563.
6	359.	4812.	72835.	31300.	66706.	28666.	43.	710.	546.

TRIAL 9

FILE MIXAN (CREATION DATE = 81/02/04.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	371.	3608.	65714.	24107.	68181.	25012.	37.	590.	482.
2	372.	3413.	66600.	25300.	67974.	25822.	38.	590.	490.
3	373.	3461.	76250.	24375.	72300.	23112.	32.	590.	527.
4	374.	3071.	70899.	24686.	71495.	24894.	35.	590.	496.
5	375.	3023.	72325.	19662.	68413.	18599.	27.	610.	529.
6	378.	3218.	67830.	27616.	68936.	28066.	41.	595.	492.
7	379.	3754.	67970.	27207.	66958.	26802.	40.	560.	508.
8	380.	2779.	76033.	25826.	72382.	24586.	34.	570.	525.
9	381.	2925.	59583.	25520.	58410.	25018.	43.	575.	510.
10	382.	3315.	61788.	25406.	64864.	26671.	41.	570.	476.
11	386.	2340.	0	25000.	0	0	0	630.	516.
12	387.	2876.	81818.	24901.	79586.	24222.	30.	630.	514.
13	388.	2632.	55952.	23413.	56503.	23644.	42.	600.	495.
14	389.	2291.	59127.	20833.	62270.	21941.	35.	595.	475.
15	392.	3998.	49703.	23861.	54625.	26224.	48.	580.	455.
16	393.	3510.	54545.	23617.	61465.	26613.	43.	575.	444.

TRIAL 10

FILE MIXAN (CREATION DATE = 81/02/04.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	381.	3022.	77292.	0	0	0	0	680.	560.
2	382.	3217.	65447.	26626.	63807.	25959.	41.	735.	513.
3	385.	3607.	64300.	25050.	68161.	26554.	39.	730.	472.
4	386.	3120.	72984.	26210.	59345.	21312.	36.	655.	615.
5	387.	2827.	56126.	24703.	50380.	22174.	44.	620.	557.
6	388.	2340.	62301.	21032.	72183.	24368.	34.	630.	432.
7	389.	2291.	54762.	24404.	67147.	29923.	45.	620.	408.
8	392.	3998.	57624.	24752.	62104.	26676.	43.	590.	464.
9	393.	3218.	59881.	24407.	64457.	26272.	41.	580.	464.
10	394.	3120.	64426.	24703.	69405.	26612.	38.	590.	464.
11	395.	3608.	59684.	25494.	60119.	25680.	43.	600.	496.
12	396.	2730.	58692.	24806.	57287.	24212.	42.	605.	512.

TRIAL 11

FILE MIXAN (CREATION DATE = 81/01/20.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	93.	2973.	0	18617.	0	0	0	640.	507.
2	94.	2910.	0	18233.	0	0	0	620.	513.
3	95.	2638.	0	0	0	0	0	595.	0
4	96.	0	0	0	0	0	0	580.	0
5	97.	0	0	0	0	0	0	590.	0
6	98.	2827.	70700.	18480.	70400.	18402.	26.	580.	502.
7	99.	2858.	60300.	18285.	58604.	17771.	30.	570.	514.
8	100.	2795.	59565.	21055.	62027.	21925.	35.	565.	480.
9	101.	2640.	64800.	16080.	62366.	15476.	25.	615.	520.
10	102.	2732.	68370.	17015.	67299.	16748.	25.	605.	508.
11	103.	0	0	0	0	0	0	625.	0
12	104.	0	0	0	0	0	0	600.	0
13	105.	2858.	64010.	17900.	64323.	17987.	28.	580.	498.
14	106.	2638.	80230.	17770.	76176.	16872.	22.	600.	527.
15	107.	2732.	65590.	17142.	64123.	16759.	26.	605.	511.
16	108.	2827.	86450.	15500.	85114.	15260.	18.	590.	508.
17	109.	2638.	58100.	16836.	57545.	16675.	29.	570.	505.
18	110.	0	0	0	0	0	0	610.	0
19	111.	0	0	0	0	0	0	590.	0
20	112.	2764.	64765.	17090.	65365.	17248.	26.	570.	495.
21	113.	2669.	47760.	15440.	48157.	15568.	32.	560.	496.
22	114.	2445.	52600.	14640.	53259.	14824.	28.	610.	494.
23	115.	2446.	42800.	14480.	44453.	15039.	34.	600.	481.
24	116.	2536.	52370.	13755.	55081.	14467.	26.	580.	475.
25	119.	2416.	39520.	15140.	44930.	17212.	38.	560.	440.
26	120.	2561.	58730.	16230.	55848.	15434.	28.	670.	526.
27	121.	2597.	56700.	14960.	57847.	15263.	26.	635.	490.
28	122.	2308.	40550.	14880.	41990.	15409.	37.	615.	483.

TRIAL 12

FILE MIXAN (CREATION DATE = 80/12/17.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	308.	2398.	54248.	18137.	68916.	23041.	33.	760.	394.
2	309.	2670.	46154.	16987.	60302.	22194.	37.	775.	383.
3	310.	2127.	0	0	0	0	0	615.	0
4	311.	2353.	48701.	16396.	57745.	19441.	34.	625.	422.
5	312.	2806.	43269.	15785.	51584.	18819.	36.	600.	419.
6	315.	1900.	56291.	15232.	76871.	20801.	27.	575.	366.
7	316.	2172.	49689.	14130.	72626.	20652.	28.	570.	342.
8	317.	2127.	36218.	13702.	51774.	19587.	38.	565.	350.
9	318.	1719.	39055.	13304.	58733.	20007.	34.	550.	332.
10	319.	2167.	40998.	13412.	66198.	21656.	33.	550.	310.
11	322.	2117.	57783.	14286.	77291.	19109.	25.	565.	374.
12	323.	2318.	46185.	14157.	64736.	19843.	31.	560.	357.
13	324.	2167.	49275.	13768.	59726.	16688.	28.	560.	413.
14	325.	3074.	76327.	16735.	75014.	16447.	22.	585.	509.
15	326.	2520.	58776.	15837.	58975.	15891.	27.	575.	498.
16	329.	2570.	60442.	17470.	64080.	18522.	29.	585.	472.
17	330.	2268.	65613.	15415.	73180.	17193.	23.	580.	448.
18	331.	1865.	48400.	14480.	58075.	17375.	30.	545.	417.
19	336.	2016.	53333.	15294.	66820.	19162.	29.	580.	399.
20	337.	1714.	48846.	15346.	66883.	21013.	31.	575.	365.
21	338.	2822.	52140.	14882.	70480.	20117.	29.	550.	370.
22	339.	2117.	43789.	13605.	65168.	20247.	31.	560.	336.
23	340.	1814.	0	12550.	0	0	0	570.	317.

TRIAL 13

FILE MIXAN (CREATION DATE = 81/01/14.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	141.	4580.	50100.	21430.	45330.	19389.	43.	720.	553.
2	142.	4220.	54500.	23700.	47125.	20493.	43.	600.	578.
3	143.	4274.	53980.	25860.	47244.	22633.	48.	785.	571.
4	144.	3881.	55440.	26740.	49898.	24067.	48.	710.	556.
5	148.	4851.	54160.	28920.	52814.	28201.	53.	710.	513.
6	149.	4312.	62200.	27900.	60724.	27238.	45.	870.	512.
7	150.	4348.	54490.	28320.	51367.	26697.	52.	715.	530.
8	151.	5103.	60270.	29300.	57467.	27937.	49.	690.	524.
9	154.	5318.	57600.	28790.	56720.	28350.	50.	705.	508.
10	155.	5174.	64860.	30200.	58075.	27041.	47.	1040.	558.
11	156.	4887.	63300.	27950.	57346.	25321.	44.	900.	552.
12	157.	4779.	65000.	27330.	59823.	25153.	42.	780.	543.
13	158.	4887.	64760.	26830.	54719.	22670.	41.	870.	592.
14	161.	4995.	63650.	26770.	58764.	24715.	42.	680.	542.
15	162.	5462.	60600.	26000.	58006.	24887.	43.	680.	522.
16	163.	5031.	64500.	25300.	59016.	23149.	39.	1010.	546.
17	164.	4779.	0	0	0	0	0	835.	0
18	165.	4635.	0	0	0	0	0	775.	0
19	168.	4635.	61000.	0	0	0	0	655.	520.
20	169.	5135.	51750.	26100.	49715.	25073.	50.	710.	520.
21	170.	5869.	53590.	25145.	52642.	24700.	47.	695.	509.
22	171.	5660.	52120.	24190.	52554.	24391.	46.	1110.	496.
23	172.	4926.	69610.	17970.	69636.	17977.	26.	1000.	500.
24	175.	4559.	46740.	24510.	48199.	25275.	52.	740.	485.
25	176.	3720.	66300.	29820.	56892.	25589.	45.	715.	583.
26	177.	6602.	67230.	30192.	56608.	25422.	45.	705.	594.
27	178.	4837.	64450.	27450.	55170.	23498.	43.	670.	584.
28	179.	5554.	69070.	27510.	61070.	24324.	40.	695.	565.

TRIAL 14

FILE MIXAN (CREATION DATE = 81/01/14.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	338.	4939.	63813.	31712.	57288.	28469.	50.	730.	557.
2	339.	4788.	60835.	31744.	55381.	28898.	52.	730.	549.
3	340.	4536.	68500.	30740.	63035.	28287.	45.	710.	543.
4	343.	5040.	59381.	31625.	57734.	30748.	53.	650.	514.
5	344.	4838.	66030.	32442.	61864.	30395.	49.	695.	534.
6	345.	4716.	71920.	34810.	67742.	32788.	48.	690.	531.
7	346.	5397.	57196.	33240.	55073.	32006.	58.	715.	519.
8	347.	5306.	59160.	33683.	59021.	33604.	57.	690.	501.

TRIAL 15

FILE MIXAN (CREATION DATE = 81/01/14.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	123.	2669.	61300.	15550.	58322.	14795.	25.	615.	526.
2	127.	2730.	59400.	15730.	59765.	15827.	26.	640.	497.
3	128.	2380.	57150.	16440.	56721.	16317.	29.	610.	504.
4	129.	4112.	52200.	15840.	51499.	15627.	30.	590.	507.
5	130.	2489.	0	0	0	0	0	575.	0
6	133.	2885.	41910.	15595.	42367.	15765.	37.	600.	495.
7	134.	2380.	66280.	12410.	77530.	14516.	19.	585.	427.
8	136.	2633.	50290.	13720.	53129.	14495.	27.	615.	473.
9	137.	2669.	41900.	14600.	45210.	15753.	35.	595.	463.
10	141.	2561.	50293.	11270.	52860.	11845.	22.	715.	476.
11	142.	2777.	45100.	14570.	57835.	18684.	32.	880.	390.
12	143.	2550.	48100.	14480.	51597.	15533.	30.	585.	466.
13	144.	2444.	62825.	15110.	59740.	14368.	24.	610.	526.
14	148.	2659.	46400.	14700.	47808.	15146.	32.	560.	485.
15	149.	2443.	61000.	14290.	69156.	16201.	23.	550.	441.
16	150.	2443.	63700.	14060.	70973.	15665.	22.	605.	449.
17	151.	2443.	54850.	13470.	62677.	15392.	25.	585.	438.
18	154.	2192.	64300.	11420.	88898.	15789.	18.	550.	362.
19	155.	2228.	40540.	12160.	53872.	16159.	30.	550.	376.
20	156.	2695.	52100.	0	0	0	0	650.	477.
21	157.	2767.	68180.	14650.	70032.	15048.	21.	635.	487.
22	158.	2767.	66400.	14580.	72842.	15995.	22.	600.	456.
23	161.	2767.	44570.	13650.	51830.	15874.	31.	570.	430.
24	162.	2875.	60000.	15700.	60363.	15795.	26.	615.	497.

TRIAL 16

FILE MIXAN (CREATION DATE = 80/12/17.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	301.	1991.	59375.	16525.	57634.	16041.	28.	620.	515.
2	302.	2263.	51950.	16750.	49686.	16020.	32.	625.	523.
3	303.	1901.	61598.	17076.	56838.	15757.	28.	610.	542.
4	304.	2625.	45247.	16213.	44416.	15915.	36.	600.	509.
5	305.	2353.	62016.	16376.	60913.	16085.	26.	595.	509.
6	308.	2081.	56209.	16993.	59062.	17855.	30.	565.	476.
7	309.	2489.	45513.	15545.	45352.	15490.	34.	610.	502.
8	310.	2489.	0	0	0	0	0	585.	478.
9	311.	2263.	57143.	15422.	61759.	16668.	27.	545.	463.
10	312.	2036.	47115.	14183.	52882.	15919.	30.	570.	445.
11	315.	2715.	52980.	15066.	68428.	19459.	28.	545.	387.
12	316.	1991.	44099.	12267.	57442.	15978.	28.	555.	384.
13	317.	2082.	46474.	13060.	62798.	17647.	28.	535.	370.
14	318.	1991.	48497.	14699.	54830.	16618.	30.	555.	442.
15	319.	2369.	45279.	14861.	52950.	17379.	33.	570.	428.
16	322.	1865.	60981.	13966.	81169.	18590.	23.	545.	376.
17	323.	2268.	69880.	14558.	76139.	15862.	21.	550.	459.
18	324.	2218.	63768.	14182.	79013.	17572.	22.	590.	404.
19	325.	1814.	43673.	12551.	55759.	16024.	29.	595.	392.
20	329.	2470.	63252.	16426.	67403.	17504.	26.	585.	469.
21	330.	2520.	53755.	14704.	59511.	16278.	27.	570.	452.
22	331.	1915.	61200.	16320.	67864.	18097.	27.	515.	451.
23	336.	2318.	44314.	13627.	60861.	18715.	31.	560.	364.
24	337.	1613.	58077.	16615.	65914.	18857.	29.	570.	441.
25	338.	2923.	43580.	15642.	51174.	18368.	36.	540.	426.
26	339.	2520.	53100.	16047.	62515.	18892.	30.	565.	425.

TRIAL 17

FILE MIXAN (CREATION DATE = 80/09/12.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	136.	4905.	57420.	25000.	52713.	22951.	44.	1020.	545.
2	137.	4580.	47200.	25670.	43810.	23826.	54.	955.	539.
3	141.	4328.	54400.	21300.	51538.	20179.	39.	615.	528.
4	142.	4653.	66600.	25950.	61994.	24155.	39.	650.	537.
5	143.	4977.	59400.	24350.	53738.	22029.	41.	860.	553.
6	144.	3665.	62140.	25400.	56763.	23202.	41.	690.	547.
7	149.	5138.	69100.	28380.	62962.	25859.	41.	1020.	549.
8	150.	5138.	72070.	27830.	67383.	26020.	39.	1010.	535.
9	151.	4743.	66080.	27320.	62052.	25655.	41.	930.	532.
10	154.	4204.	67705.	27250.	67609.	27211.	40.	685.	501.
11	155.	4707.	56560.	28280.	52851.	26425.	50.	690.	535.
12	156.	4312.	55900.	27950.	50039.	25020.	50.	870.	559.
13	157.	3486.	65660.	27400.	61704.	25749.	42.	725.	532.
14	158.	4456.	58700.	27940.	56010.	26660.	48.	695.	524.
15	161.	7905.	59405.	27500.	55648.	25761.	46.	670.	534.
16	162.	5390.	55800.	28400.	52764.	26855.	51.	690.	529.
17	163.	5138.	62000.	27700.	59174.	26437.	45.	690.	524.
18	168.	5498.	80440.	0	75661.	0	0	720.	532.
19	169.	4978.	58560.	28700.	50800.	24897.	49.	930.	576.
20	170.	4611.	61550.	28140.	55635.	25436.	46.	773.	553.
21	171.	4821.	62550.	27840.	56146.	24990.	45.	715.	557.
22	172.	4454.	54420.	25240.	49022.	22736.	46.	885.	555.
23	175.	4140.	61025.	25250.	58539.	24222.	41.	720.	521.
24	176.	3563.	69100.	25260.	67073.	24519.	37.	725.	515.
25	177.	4454.	63850.	26310.	54859.	22605.	41.	740.	582.
26	178.	4506.	64700.	26520.	57473.	23558.	41.	710.	563.
27	179.	5240.	58840.	27140.	54016.	24915.	46.	665.	545.

TRIAL 18

FILE MIXAN (CREATION DATE = 80/12/17.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	317.	3756.	68910.	30609.	63893.	28381.	44.	935.	539.
2	318.	3439.	60515.	31545.	55455.	28907.	52.	730.	546.
3	319.	4486.	58369.	30258.	55412.	28725.	52.	790.	527.
4	322.	4334.	68230.	31023.	67679.	30773.	45.	685.	504.
5	323.	4838.	57430.	29719.	57653.	29834.	52.	695.	498.
6	324.	3830.	60041.	29130.	52623.	25531.	49.	715.	570.
7	325.	3881.	63265.	31224.	58325.	28786.	49.	725.	542.
8	326.	2268.	54694.	31592.	50983.	29449.	58.	720.	536.
9	329.	5796.	68876.	36235.	56677.	29817.	53.	720.	608.
10	330.	6098.	72727.	34328.	60310.	28467.	47.	720.	603.
11	331.	4334.	51200.	32040.	50336.	31499.	63.	675.	509.

TRIAL 19

FILE MIXAN (CREATION DATE = 81/01/21.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	92.	3744.	82280.	24800.	78146.	23554.	30.	920.	526.
2	93.	2404.	0	23538.	0	0	0	740.	523.
3	94.	3423.	0	21553.	0	0	0	715.	510.
4	95.	3486.	0	0	0	0	0	670.	0
5	96.	0	0	0	0	0	0	660.	0
6	97.	0	0	0	0	0	0	680.	0
7	98.	2387.	52100.	21580.	53090.	21990.	41.	680.	491.
8	99.	3819.	50500.	22455.	52939.	23540.	44.	680.	477.
9	100.	3486.	52860.	20265.	51504.	19745.	38.	710.	513.
10	101.	3360.	55200.	20900.	67480.	25549.	38.	675.	409.
11	102.	3486.	71710.	21020.	71486.	20954.	29.	670.	502.
12	103.	0	0	0	0	0	0	680.	0
13	104.	0	0	0	0	0	0	655.	0
14	105.	3800.	71200.	24500.	69914.	24057.	34.	635.	509.
15	106.	3926.	53425.	24360.	51628.	23541.	46.	630.	517.
16	107.	4020.	55732.	22333.	55936.	22415.	40.	635.	498.
17	108.	3876.	82070.	22460.	80678.	22079.	27.	670.	509.
18	109.	3800.	58890.	23125.	55069.	21625.	39.	635.	535.
19	110.	0	0	0	0	0	0	640.	0
20	111.	0	0	0	0	0	0	660.	0
21	112.	4303.	61220.	22390.	60297.	22053.	37.	660.	508.
22	113.	3769.	65690.	23050.	60026.	21063.	35.	740.	547.
23	114.	3752.	81400.	22650.	78412.	21819.	28.	655.	519.
24	115.	3886.	49200.	23550.	47015.	22504.	48.	655.	523.
25	116.	4058.	50990.	21937.	48285.	20773.	43.	640.	528.
26	119.	4039.	81800.	22780.	80045.	22291.	28.	665.	511.
27	120.	4039.	53570.	22123.	54202.	22384.	41.	655.	494.
28	121.	3823.	52800.	21900.	48427.	20086.	41.	640.	545.
29	122.	3679.	82900.	21550.	79721.	20724.	26.	640.	520.
30	123.	4003.	54960.	22920.	52445.	21871.	42.	655.	524.
31	126.	4328.	0	0	0	0	0	620.	0
32	127.	4537.	78450.	0	0	0	0	620.	533.
33	128.	3823.	63015.	24500.	60110.	23371.	39.	625.	524.
34	129.	4508.	53300.	22650.	47902.	20356.	42.	640.	556.
35	130.	3895.	0	0	0	0	0	625.	0
36	133.	4575.	61015.	24500.	59199.	23771.	40.	630.	515.
37	134.	4039.	65125.	23930.	57426.	21101.	37.	730.	567.
38	135.	0	0	0	0	0	0	695.	0
39	136.	4436.	66280.	23360.	59850.	21094.	35.	690.	554.
40	137.	4508.	61100.	24400.	55119.	22011.	40.	675.	554.

TRIAL 20

FILE MIXAN (CREATION DATE = 81/02/04.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	315.	3304.	75497.	22350.	69607.	20606.	30.	625.	542.
2	316.	3258.	53416.	20186.	53305.	20144.	38.	615.	501.
3	317.	3575.	56089.	20735.	52035.	19236.	37.	630.	539.
4	318.	3258.	56652.	21352.	52855.	19921.	38.	610.	536.
5	319.	3629.	54077.	20225.	51932.	19423.	37.	600.	521.
6	322.	2974.	60341.	21002.	62309.	21687.	35.	565.	484.
7	323.	2830.	56627.	21928.	58973.	22836.	39.	620.	480.
8	324.	3527.	54244.	22360.	52800.	21765.	41.	625.	514.
9	325.	3326.	50612.	21796.	50257.	21643.	43.	625.	504.
10	326.	3377.	68163.	22408.	67115.	22063.	33.	600.	508.
11	329.	4385.	56024.	24518.	58403.	25559.	44.	630.	480.
12	330.	2167.	59289.	24190.	57233.	23351.	41.	615.	518.
13	331.	3578.	62400.	24480.	59881.	23492.	39.	570.	521.
14	336.	4939.	61569.	24215.	66407.	26118.	39.	575.	464.

TRIAL 21

FILE MIXAN (CREATION DATE = 81/01/20.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	35.	3030.	0	0	0	0	0	720.	507.
2	36.	3399.	0	0	0	0	0	835.	579.
3	37.	3326.	0	23160.	0	0	0	700.	563.
4	38.	3204.	79300.	0	0	0	0	655.	558.
5	39.	2978.	0	0	0	0	0	625.	563.
6	43.	3186.	79051.	0	0	0	0	620.	556.
7	44.	2622.	69860.	0	0	0	0	675.	542.
8	45.	3338.	78500.	0	0	0	0	640.	543.
9	46.	3217.	100000.	22910.	93245.	21363.	23.	635.	536.
10	49.	3520.	83140.	23412.	79909.	22502.	28.	650.	520.
11	50.	3399.	64290.	21131.	63188.	20769.	33.	670.	509.
12	51.	3126.	66870.	21747.	64398.	20943.	33.	645.	519.
13	52.	3247.	63700.	20988.	62554.	20610.	33.	640.	509.
14	53.	3621.	68290.	20688.	68758.	20830.	30.	650.	497.
15	56.	3611.	0	0	0	0	0	650.	504.
16	57.	3578.	0	22470.	0	0	0	675.	500.
17	58.	3946.	52530.	22700.	52053.	22494.	43.	670.	505.
18	59.	3678.	0	21832.	0	0	0	1000.	550.
19	60.	0	62900.	0	0	0	0	755.	545.
20	63.	4481.	0	0	0	0	0	790.	445.
21	64.	3511.	65750.	21969.	56944.	19027.	33.	795.	577.
22	65.	3243.	61107.	23391.	55646.	21301.	38.	710.	549.
23	66.	3678.	76908.	23483.	69283.	21155.	31.	710.	555.

TRIAL 22

FILE MIXAN (CREATION DATE = 81/01/14.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	343.	2730.	77176.	0	0	0	0	600.	532.
2	344.	3679.	73664.	26717.	71137.	25801.	36.	585.	518.
3	345.	3719.	63460.	29230.	67048.	30883.	46.	610.	473.
4	346.	3900.	61930.	28314.	57094.	26103.	46.	650.	542.
5	347.	3719.	73090.	28244.	71278.	27544.	39.	625.	513.
6	351.	3653.	72960.	31130.	61322.	26165.	43.	705.	595.
7	352.	4014.	58015.	27480.	49085.	23250.	47.	720.	591.
8	353.	3312.	56200.	26360.	56956.	26715.	47.	655.	493.
9	354.	3269.	65320.	26110.	70318.	28108.	40.	620.	464.
10	357.	3814.	56900.	26450.	62534.	29069.	46.	580.	455.
11	358.	4127.	50590.	25690.	58656.	29786.	51.	585.	431.
12	359.	2724.	72835.	23288.	75327.	24085.	32.	585.	483.

TRIAL 23

FILE MIXAN (CREATION DATE = 81/01/20.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	72.	1392.	53330.	0	0	0	0	595.	354.
2	73.	1360.	0	7320.	0	0	0	610.	427.
3	74.	0	30390.	6480.	40508.	8637.	21.	615.	375.
4	75.	0	0	0	0	0	0	620.	0
5	76.	0	0	0	0	0	0	620.	0
6	77.	1139.	30528.	5714.	46326.	8671.	19.	570.	329.
7	78.	1455.	67456.	7120.	69433.	7329.	11.	580.	486.
8	79.	1170.	0	0	0	0	0	575.	0
9	80.	1233.	61431.	6958.	69605.	7884.	11.	570.	441.
10	81.	1265.	46800.	7560.	48648.	7858.	16.	555.	481.
11	84.	1992.	46170.	7308.	49454.	7828.	16.	575.	467.
12	85.	1328.	80790.	7861.	78361.	7625.	10.	550.	515.
13	86.	1075.	43650.	7332.	44445.	7465.	17.	550.	491.
14	87.	1170.	0	6990.	0	0	0	570.	477.
15	88.	1297.	36790.	6497.	37927.	6698.	18.	565.	485.
16	91.	1164.	81500.	6630.	91897.	7476.	8.	630.	443.

TRIAL 24

FILE MIXAN (CREATION DATE = 81/01/16.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	35.	5353.	50100.	0	0	0	0	1170.	499.
2	36.	5049.	0	0	0	0	0	1140.	489.
3	37.	5001.	0	24200.	0	0	0	1110.	491.
4	38.	4904.	51980.	0	0	0	0	1095.	495.
5	39.	4709.	0	22500.	0	0	0	1080.	503.
6	42.	5082.	0	23570.	0	0	0	1025.	473.
7	43.	7040.	84585.	0	0	0	0	1220.	619.
8	44.	6463.	72600.	0	0	0	0	1180.	615.
9	45.	7179.	58974.	0	0	0	0	1110.	618.
10	46.	7768.	84770.	32690.	65385.	25214.	39.	1180.	648.
11	47.	0	0	0	0	0	0	1110.	0
12	49.	7617.	53720.	34216.	42108.	26820.	64.	1145.	638.
13	50.	6221.	63100.	27679.	59710.	26192.	44.	0	528.
14	51.	6281.	53420.	28815.	51809.	27946.	54.	1120.	516.
15	52.	5948.	53750.	26383.	51997.	25522.	49.	1100.	517.
16	53.	7223.	66930.	30059.	56508.	25378.	45.	1180.	592.
17	56.	6922.	0	0	0	0	0	1140.	0
18	57.	8627.	0	43300.	0	0	0	1180.	774.
19	58.	6621.	74700.	32390.	63848.	27685.	43.	1170.	585.
20	59.	5183.	0	24366.	0	0	0	1125.	461.
21	60.	5484.	50800.	0	0	0	0	1110.	458.
22	63.	6119.	0	0	0	0	0	1150.	0
23	64.	6186.	56900.	28898.	52395.	26610.	51.	1125.	543.
24	65.	6016.	52378.	27740.	48543.	25709.	53.	1110.	539.
25	66.	7256.	70840.	31920.	58827.	26507.	45.	1225.	602.
26	67.	7323.	55990.	31080.	45746.	25394.	56.	1200.	612.
27	68.	8861.	0	0	0	0	0	1160.	592.

TRIAL 25

FILE MIXAN (CREATION DATE = 81/01/20.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	72.	3542.	52550.	0	0	0	0	865.	576.
2	73.	3447.	0	25440.	0	0	0	725.	535.
3	74.	0	70350.	25230.	65601.	23527.	36.	710.	536.
4	75.	0	0	0	0	0	0	670.	0
5	76.	0	0	0	0	0	0	670.	0
6	77.	3700.	54990.	25949.	52393.	24724.	47.	635.	525.
7	78.	3732.	74951.	25444.	71492.	24270.	34.	670.	524.
8	79.	3099.	0	0	0	0	0	714.	0
9	80.	3226.	100000.	23976.	103361.	24782.	24.	675.	484.
10	81.	3289.	65000.	24240.	69283.	25837.	37.	665.	469.
11	84.	5092.	56190.	24519.	62844.	27422.	44.	710.	447.
12	85.	3321.	65350.	25782.	62017.	24467.	39.	980.	527.
13	86.	3416.	70950.	24901.	67488.	23686.	35.	815.	526.
14	87.	3732.	0	25010.	0	0	0	780.	521.
15	88.	4016.	64970.	25949.	63116.	25208.	40.	790.	515.

TRIAL 26

FILE MIXAN (CREATION DATE = 81/01/20.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	72.	4333.	67450.	0	0	0	0	920.	631.
2	73.	4206.	0	26910.	0	0	0	890.	619.
3	74.	0	60240.	23440.	54125.	21061.	39.	830.	556.
4	75.	0	0	0	0	0	0	715.	0
5	76.	0	0	0	0	0	0	720.	0
6	77.	3416.	65557.	23190.	61873.	21887.	35.	675.	530.
7	78.	3795.	66667.	22959.	63281.	21793.	34.	690.	527.
8	79.	3163.	0	0	0	0	0	765.	0
9	80.	3321.	83300.	22724.	79509.	21690.	27.	740.	524.
10	81.	3416.	65000.	23760.	62448.	22827.	37.	715.	520.
11	84.	5123.	55990.	22456.	55659.	22323.	40.	740.	503.
12	85.	3827.	69820.	24000.	68503.	23547.	34.	695.	510.
13	86.	3163.	62650.	22292.	58876.	20949.	36.	715.	532.
14	87.	3542.	0	22871.	0	0	0	670.	506.
15	88.	3732.	54400.	21663.	53869.	21451.	40.	670.	505.
16	91.	3947.	53600.	21700.	57128.	23128.	40.	725.	469.

TRIAL 27

FILE MIXAN (CREATION DATE = 81/01/21.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	91.	3997.	61100.	24710.	58844.	23798.	40.	680.	519.
2	92.	3997.	74010.	25000.	70411.	23784.	34.	730.	526.
3	93.	3352.	0	23775.	0	0	0	675.	526.
4	94.	3226.	0	23650.	0	0	0	675.	526.
5	95.	3235.	0	0	0	0	0	660.	0
6	96.	0	0	0	0	0	0	675.	0
7	97.	0	0	0	0	0	0	660.	0
8	98.	3423.	71520.	21390.	71156.	21281.	30.	675.	503.
9	99.	3518.	57900.	21108.	56827.	20717.	36.	655.	509.
10	100.	3549.	71005.	22680.	64439.	20583.	32.	670.	551.
11	101.	3580.	53600.	24100.	50889.	22881.	45.	655.	527.
12	102.	3674.	51865.	23183.	48791.	21809.	45.	655.	532.
13	103.	0	0	0	0	0	0	670.	0
14	104.	0	0	0	0	0	0	645.	0
15	105.	3863.	67700.	25670.	63272.	23991.	38.	620.	535.
16	106.	4082.	60270.	23820.	57297.	22645.	40.	630.	526.
17	107.	4128.	62170.	24950.	59605.	23920.	40.	645.	522.
18	108.	4334.	56574.	24740.	54566.	23862.	44.	640.	518.
19	109.	3800.	58300.	24664.	51367.	21731.	42.	665.	567.
20	110.	0	0	0	0	0	0	645.	0
21	111.	0	0	0	0	0	0	665.	0
22	112.	4397.	64765.	25040.	59937.	23173.	39.	655.	540.
23	113.	4560.	67060.	24500.	63926.	23355.	37.	665.	525.
24	114.	3518.	62000.	22860.	57274.	21117.	37.	695.	541.
25	115.	3585.	56600.	22020.	51641.	20091.	39.	690.	548.
26	116.	3990.	42690.	21107.	40938.	20241.	49.	670.	521.
27	119.	3823.	52800.	24490.	49908.	23149.	46.	680.	529.
28	120.	3823.	59127.	21726.	58235.	21398.	37.	670.	508.
29	121.	3967.	68900.	22440.	68029.	22156.	33.	675.	506.
30	122.	3390.	68500.	21850.	65323.	20837.	32.	675.	524.
31	123.	3607.	60700.	21730.	58112.	20803.	36.	670.	522.
32	124.	0	0	0	0	0	0	680.	0
33	125.	0	0	0	0	0	0	680.	0
34	126.	4260.	0	0	0	0	0	715.	0
35	127.	3922.	69100.	23490.	69065.	23478.	34.	640.	500.
36	128.	3138.	52840.	24435.	51904.	24002.	46.	670.	509.
37	129.	4725.	51000.	22950.	47716.	21472.	45.	670.	534.
38	130.	3246.	0	0	0	0	0	695.	0
39	131.	0	0	0	0	0	0	660.	0
40	132.	0	0	0	0	0	0	690.	0
41	133.	3751.	54775.	21050.	53409.	20525.	38.	675.	513.
42	134.	3679.	54720.	19480.	54951.	19562.	36.	685.	498.
43	135.	3679.	0	0	0	0	0	735.	0

TRIAL 28

FILE MIXAN (CREATION DATE = 81/01/16.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	92.	3896.	88980.	31300.	64796.	22793.	35.	880.	687.
2	93.	3858.	0	29051.	0	0	0	745.	613.
3	94.	3522.	0	24058.	0	0	0	835.	566.
4	98.	3989.	56120.	25255.	53517.	24084.	45.	775.	524.
5	99.	3706.	56500.	26228.	49544.	22999.	46.	760.	570.
6	100.	4050.	57200.	25800.	52044.	23474.	45.	735.	550.
7	101.	3805.	66400.	26640.	62053.	24896.	40.	705.	535.
8	102.	3518.	65815.	25990.	61434.	24260.	39.	670.	536.
9	105.	4051.	62600.	27420.	59484.	26055.	44.	665.	526.
10	106.	4146.	61840.	25240.	61130.	24950.	41.	650.	506.
11	107.	3841.	70020.	23240.	66709.	22141.	33.	640.	525.
12	108.	4020.	74104.	24085.	72160.	23453.	33.	625.	513.
13	109.	4020.	62255.	25138.	61058.	24655.	40.	635.	510.
14	112.	4114.	62600.	23505.	63158.	23715.	38.	605.	496.
15	113.	3719.	55170.	22980.	54487.	22695.	42.	765.	506.
16	114.	3920.	0	19600.	0	0	0	700.	506.
17	115.	3658.	56800.	25740.	51846.	23495.	45.	665.	548.
18	116.	1995.	58695.	25613.	55635.	24278.	44.	645.	527.
19	119.	4039.	57500.	27330.	57225.	27199.	48.	650.	502.
20	120.	3715.	60320.	23870.	55902.	22122.	40.	665.	540.
21	121.	3931.	55100.	24450.	54994.	24403.	44.	655.	501.
22	122.	3859.	47600.	25040.	45725.	24054.	53.	685.	520.
23	123.	4076.	69250.	25000.	68970.	24899.	36.	645.	502.
24	127.	4384.	59400.	24850.	61280.	25637.	42.	680.	485.
25	128.	3498.	54010.	23540.	51275.	22348.	44.	630.	527.
26	129.	4436.	52900.	22300.	51558.	21734.	42.	635.	513.
27	133.	4761.	58285.	23685.	59194.	24054.	41.	720.	492.

TRIAL 29

FILE MIXAN (CREATION DATE = 81/01/16.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	37.	3326.	0	23390.	0	0	0	600.	517.
2	38.	3399.	68780.	0	0	0	0	620.	534.
3	39.	3180.	0	23347.	0	0	0	625.	539.
4	42.	3981.	0	24165.	0	0	0	650.	513.
5	43.	3611.	100000.	0	0	0	0	535.	518.
6	44.	3156.	86300.	0	0	0	0	660.	514.
7	45.	3884.	78500.	0	0	0	0	650.	524.
8	46.	3732.	82800.	25490.	70403.	21674.	31.	655.	588.
9	49.	4036.	84710.	27118.	75804.	24267.	32.	670.	559.
10	50.	3490.	69840.	22619.	74458.	24115.	32.	665.	469.
11	51.	3520.	70480.	23313.	77502.	25636.	33.	660.	455.
12	52.	3368.	70360.	21640.	75115.	23102.	31.	640.	468.
13	53.	3595.	69260.	22397.	73863.	23886.	32.	625.	469.
14	56.	4113.	0	0	0	0	0	655.	558.
15	57.	4013.	62460.	25620.	57477.	23576.	41.	660.	543.
16	58.	4180.	67700.	26030.	60923.	23424.	38.	655.	556.
17	59.	3845.	0	24035.	0	0	0	680.	560.
18	60.	4247.	82150.	0	0	0	0	700.	518.
19	63.	4213.	0	0	0	0	0	690.	492.
20	64.	3578.	69500.	24150.	63298.	21995.	35.	725.	549.
21	65.	3544.	55550.	24400.	51252.	22512.	44.	705.	542.
22	66.	3411.	73777.	22250.	69623.	20997.	30.	710.	530.
23	67.	3745.	64830.	24870.	59288.	22744.	38.	710.	547.
24	68.	5818.	0	0	0	0	0	710.	555.
25	69.	0	0	0	0	0	0	680.	0
26	70.	0	0	0	0	0	0	660.	512.
27	71.	0	0	0	0	0	0	690.	413.

TRIAL 30

FILE MIXAN (CREATION DATE = 81/01/20.) MIX TANK DATA ANALYSIS

CASE-NO	DAY	ALK	TOTCOD	SOLCOD	TCODC	SCODC	SCOD%	PH1	TSLD%1
1	35.	3434.	60880.	0	0	0	0	750.	482.
2	36.	3447.	0	0	0	0	0	750.	474.
3	37.	3301.	0	0	0	0	0	750.	485.
4	38.	3338.	78160.	0	0	0	0	740.	471.
5	39.	3399.	0	22860.	0	0	0	835.	538.
6	42.	3787.	0	20475.	0	0	0	660.	511.
7	43.	3702.	93280.	0	0	0	0	745.	604.
8	44.	3216.	72400.	0	0	0	0	695.	612.
9	45.	4066.	63900.	0	0	0	0	665.	578.
10	46.	3763.	77300.	25900.	65920.	22087.	34.	660.	586.
11	49.	3945.	83920.	0	0	0	0	665.	587.
12	50.	3641.	67860.	22679.	66798.	22324.	33.	665.	508.
13	51.	3884.	60240.	23855.	59575.	23592.	40.	675.	506.
14	52.	3429.	58100.	22868.	54459.	21435.	39.	670.	533.
15	53.	3778.	65950.	22868.	63989.	22188.	35.	655.	515.
16	56.	3946.	0	0	0	0	0	655.	0
17	58.	4046.	81910.	26610.	71861.	23345.	32.	665.	570.
18	59.	3912.	0	25965.	0	0	0	660.	555.
19	60.	0	75200.	0	0	0	0	695.	525.
20	63.	4013.	0	0	0	0	0	680.	491.
21	64.	4079.	63400.	21969.	61701.	21380.	35.	670.	514.
22	65.	3879.	50195.	23213.	47932.	22166.	46.	690.	524.
23	66.	3578.	65166.	20900.	61648.	19772.	32.	875.	529.
24	67.	3778.	62500.	20450.	62373.	20408.	33.	735.	501.
25	68.	5751.	0	0	0	0	0	740.	0

9.3 Digester Data

The following tables contain both the raw and calculated data obtained from the digesters for each trial.

The column headings are defined below:

Raw Data:

DAY = Date (Julian): Day 0 = January 1, 1980

LITFED = Liters Fed (e/d)

ALK = Total Alkalinity (mg/l as $CaCO_3$)

FTS = Feed Total Solids Concentration (mg/l)

FVS = Feed Volatile Solids Concentration (mg/l)

ETS = Effluent Total Solids Concentration (mg/l)

EVS = Effluent Volatile Solids Concentration (mg/l)

TVA = Total Volatile Acids (mg/l)

TEMP = Digester Temperature (°C)

PH1 = pH x 100

CH41 = Methane content of Gas ($\frac{v}{v}$%) x 10

Calculated Data:

DAY = Date (Julian): Day 0 = January 1, 1980

GAS = Total Gas Production (l/d)

VSL3 = Volatile Solids Loading (kg VS/m^3·d) x 100

GASL1 = Total Gas Production (m^3 gas/kg VS fed·d) x 1000

VSD1 = Volatile Solids Destruction (kg VS·d) x 1,000

GASD1 = Total Gas Production (m^3 gas/kg VS destroyed·d) x 1,000

VSD%1 = Volatile Solids destruction ($\frac{w}{w}$ %) x 10

CH4D1 = Methane production (m^3 CH_4/kg VS destroyed·d) x 1,000

CH4l1 = Methane production (m^3 CH_4/kg VS fed·d) x 1,000

LPGT1 = Methane production (m^3 CH_4/kg COD fed·d) x 1,000

CODLV1 = COD loading rate (kg total COD/m^3·d) x 100

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FILE NAME         DIG3 STOVER
VARIABLE LIST     DAY,GAS,LITFED,PH,ALK,FTS,FVS,ETS,EVS,TVA,CH4,TEMP,TCOD,SCOD
INPUT FORMAT       FREEFIELD
N OF CASES        13
INPUT MEDIUM      DISK
VAR LABELS        DAY,GAS,LITFED,PH,ALK,FTS,FVS,ETS,EVS,TVA,CH4,TEMP,TCOD,SCOD
MISSING VALUES    DAY(0)/GAS(0)/LITFED(0)/PH(0)/ALK(0)/FTS(0)/
                   FVS(0)/ETS(0)/EVS(0)/TVA(0)/CH4(0)/TEMP(0)/TCOD(0)/SCOD(0)
TASK NAME         RAW DATA MANIPULATION
IF                (FVS EQ 0)VARA=0
IF                (FVS GT 0)VARA=LITFED*FVS
COMPUTE           VSL1=VARA/1.0E+03
COMPUTE           VSL=VSL1/1.0E+03
COMPUTE            VSL2=VSL/.775
COMPUTE            VSL3=VSL2*100
IF                (VSL EQ 0)GASL1=0
IF                (VSL GT 0 )GASL1=GAS/VSL
IF                (VSL1 EQ 0)GASL=0
IF                (VSL1 GT 0)GASL=GAS/VSL1
COMPUTE           VARB=FVS-EVS
IF                (EVS EQ 0)VARB=0
COMPUTE           VARC=VARB*LITFED
COMPUTE            VSD1=VARC/1.0E+03
IF                 (VSD1 LT 0)VSD1=0
COMPUTE            VSD=VSD1/1.0E+03
IF                 (VSD LT 0)VSD=0
IF                 (VSD EQ 0)GASD1=0
IF                 (VSD GT 0)GASD1=GAS/VSD
COMPUTE            GASD=GASD1/1.0E+03
COMPUTE           VARD=VSD1/VSL1
COMPUTE           VSD%=VARD*100
COMPUTE           VSD%1=VSD%*10
COMPUTE            PH1=PH*100
COMPUTE            CH41=CH4*10
COMPUTE            CH42=CH4/100
COMPUTE            CH4L=GASL*CH42
COMPUTE            CH4D=GASD*CH42
COMPUTE            CH4D1=CH4D*1000
COMPUTE            CH4L1=CH4L*1000
COMPUTE            TSLD%=FTS/1.0E+04
COMPUTE            VARA1=TCOD*5
COMPUTE            TCODC=VARA1/TSLD%
COMPUTE            VARA2=SCOD*5
COMPUTE            SCODC=VARA2/TSLD%
COMPUTE            TCODL1=TCODC*LITFED
COMPUTE            TCODL=TCODL1/1000
COMPUTE            CODLV=TCODL/775
COMPUTE            CH4P=GAS*CH42
IF                 (TCODL EQ 0)LPGT=0
IF                 (TCODL GT 0)LPGT=CH4P/TCODL
COMPUTE            SCODL1=SCODC*LITFED
COMPUTE            SCODL=SCODL1/1000
IF                 (SCODL EQ 0)LPGS=0
IF                 (SCODL GT 0)LPGS=CH4P/SCODL
COMPUTE            LPGT1=LPGT*1000
COMPUTE            CODLV1=CODLV*100
ASSIGN MISSING    VSL,GASL,VSD,GASD,VSD%,CH4L,CH4D,LPGT,LPGS,CODLV,SCODC(0)
LIST CASES       CASES=13/VARIABLES=DAY,GAS,GASL1,GASD1,VSL3,VSD1,VSD%1
                   CH4L1,CH4D1,LPGT1,CODLV1
CONDESCRIPTIVE     GAS,GASL,GASD,VSL2,VSD,VSD%,CH4L,CH4D,LPGT,LPGS,CODLV
OPTION             2
STATISTICS         1,5,9,10,11,13,14,15
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TRIAL 1

FILE DIG3 (CREATION DATE = 81/01/30.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LFGT1	CODLV1
1	375.	1729.	484.	461.	1795.	963.	478.	560.	268.	203.	639.
2	376.	1787.	520.	443.	0	0	0	0	255.	158.	841.
3	377.	1729.	462.	483.	0	0	0	0	279.	153.	841.
4	378.	1794.	478.	484.	1760.	1019.	475.	579.	275.	144.	910.
5	379.	1885.	468.	520.	1887.	999.	520.	572.	298.	144.	968.
6	380.	1775.	482.	475.	1598.	1110.	428.	677.	290.	167.	838.
7	381.	1685.	470.	463.	1728.	975.	475.	549.	261.	181.	677.
8	382.	1783.	492.	467.	2074.	860.	544.	487.	265.	135.	964.
9	383.	1734.	488.	459.	0	0	0	0	265.	152.	849.
10	384.	1680.	500.	433.	0	0	0	0	250.	147.	848.
11	385.	1720.	498.	446.	2041.	843.	529.	479.	253.	179.	703.
12	386.	1682.	473.	459.	1816.	926.	496.	533.	265.	161.	778.
13	387.	1746.	544.	414.	2388.	731.	566.	428.	243.	157.	840.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	375.	100.	4924.	44950.	37526.	27425.	19574.	300.	58.	755.	581.
2	376.	100.	0	48342.	40295.	0	0	0	56.	770.	575.
3	377.	100.	0	43393.	35786.	0	0	0	57.	750.	577.
4	378.	100.	5753.	42857.	37061.	28138.	19464.	360.	58.	740.	568.
5	379.	100.	3900.	42823.	36271.	26163.	17398.	0	57.	750.	573.
6	380.	98.	3997.	45514.	38114.	30664.	21804.	420.	58.	740.	610.
7	381.	101.	4290.	43098.	36042.	27542.	18936.	0	57.	740.	563.
8	382.	101.	4193.	42021.	37774.	25197.	17241.	570.	58.	745.	567.
9	383.	101.	0	40818.	37416.	0	0	0	58.	745.	577.
10	384.	101.	0	41573.	38373.	0	0	0	57.	745.	577.
11	385.	100.	3900.	47640.	38606.	26440.	18196.	780.	57.	740.	568.
12	386.	100.	3900.	43806.	36623.	26704.	18461.	0	57.	740.	576.
13	387.	102.	3705.	49879.	41348.	26102.	17933.	480.	58.	740.	586.

TRIAL 2

FILE D1G3 (CREATION DATE = 81/01/29.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	376.	1808.	421.	555.	0	0	0	0	318.	160.	835.
2	377.	1485.	352.	545.	0	0	0	0	313.	141.	778.
3	378.	1627.	359.	584.	1240.	1313.	445.	763.	340.	130.	938.
4	379.	1850.	454.	526.	1994.	928.	567.	540.	306.	167.	831.
5	380.	1777.	456.	502.	1996.	890.	564.	504.	284.	186.	696.
6	381.	1584.	430.	476.	1683.	941.	505.	537.	272.	157.	741.
7	382.	1546.	389.	513.	1559.	992.	517.	578.	299.	135.	859.
8	383.	1466.	393.	481.	0	0	0	0	276.	135.	803.
9	384.	1636.	434.	486.	0	0	0	0	279.	151.	801.
10	385.	1839.	436.	544.	1806.	1018.	534.	585.	312.	187.	730.
11	386.	1867.	430.	561.	1775.	1052.	533.	597.	319.	164.	836.
12	387.	1731.	418.	534.	1475.	1174.	455.	686.	312.	171.	764.
13	388.	1814.	405.	578.	1468.	1236.	467.	693.	324.	164.	800.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	376.	102.	0	38391.	31953.	0	0	0	58.	750.	574.
2	377.	95.	0	35183.	28682.	0	0	0	58.	740.	574.
3	378.	102.	3413.	33457.	27290.	22216.	15138.	780.	58.	725.	581.
4	379.	99.	3413.	42767.	35502.	23172.	15358.	0	57.	740.	582.
5	380.	98.	3412.	43159.	36097.	23538.	15726.	300.	57.	730.	566.
6	381.	100.	3510.	39723.	33299.	24163.	16468.	0	57.	740.	571.
7	382.	100.	3412.	36343.	30130.	21896.	14539.	390.	57.	730.	583.
8	383.	98.	0	37961.	31104.	0	0	0	57.	740.	574.
9	384.	98.	0	38443.	34352.	0	0	0	57.	740.	574.
10	385.	97.	3494.	41893.	34845.	23936.	16227.	360.	57.	735.	574.
11	386.	100.	3315.	40130.	33292.	23788.	15540.	0	57.	730.	568.
12	387.	105.	3315.	37493.	30867.	25031.	16823.	300.	57.	735.	584.
13	388.	101.	3315.	37813.	31096.	24383.	16563.	0	58.	725.	561.

TRIAL 3

FILE DIG3 (CREATION DATE = 81/01/08.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	346.	2253.	570.	510.	2378.	947.	539.	559.	301.	211.	811.
2	347.	2288.	550.	536.	2301.	994.	539.	563.	304.	191.	875.
3	348.	2232.	576.	500.	0	0	0	0	285.	196.	837.
4	349.	2205.	508.	560.	0	0	0	0	319.	209.	775.
5	350.	2166.	503.	555.	1995.	1086.	512.	629.	322.	203.	798.
6	351.	2827.	677.	539.	3251.	870.	619.	482.	298.	243.	830.
7	352.	2725.	649.	542.	3043.	896.	605.	492.	298.	239.	809.
8	353.	2850.	622.	591.	2845.	1002.	590.	572.	337.	306.	686.
9	354.	2488.	561.	573.	2238.	1112.	515.	648.	334.	215.	870.
10	355.	2278.	542.	542.	0	0	0	0	317.	224.	767.
11	356.	2191.	520.	544.	0	0	0	0	318.	0	0
12	357.	2300.	533.	557.	2151.	1069.	521.	627.	327.	234.	744.
13	358.	2180.	512.	549.	2033.	1072.	512.	625.	320.	219.	750.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	346.	104.	5805.	52947.	42453.	29552.	19583.	0	59.	750.	590.
2	347.	101.	5941.	51471.	42238.	28822.	19454.	2640.	59.	760.	566.
3	348.	108.	0	51114.	41315.	0	0	0	59.	745.	570.
4	349.	100.	0	53328.	39393.	0	0	0	59.	755.	570.
5	350.	99.	6314.	49764.	39389.	29401.	19239.	3060.	59.	755.	579.
6	351.	103.	6540.	62925.	50952.	29737.	19388.	0	58.	745.	554.
7	352.	101.	7081.	61977.	49787.	30442.	19663.	2940.	58.	760.	549.
8	353.	100.	6909.	60151.	48220.	30750.	19766.	0	58.	760.	571.
9	354.	105.	7172.	51042.	41388.	30441.	20074.	3120.	57.	760.	583.
10	355.	99.	0	51043.	42416.	0	0	0	54.	750.	584.
11	356.	99.	0	50836.	40700.	0	0	0	56.	760.	584.
12	357.	102.	7673.	50860.	40468.	30173.	19381.	3060.	56.	755.	586.
13	358.	102.	7573.	49235.	38938.	29624.	19006.	0	57.	765.	583.

TRIAL 4

FILE DIG3 (CREATION DATE = 81/02/05.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	368.	2187.	439.	642.	0	0	0	0	0	0	573.
2	369.	1981.	576.	444.	2551.	777.	572.	0	0	0	763.
3	370.	1686.	592.	367.	0	0	0	0	0	0	778.
4	371.	1425.	407.	452.	1176.	1212.	373.	642.	240.	123.	792.
5	372.	1213.	549.	285.	2165.	560.	509.	262.	134.	96.	763.
6	373.	616.	552.	144.	2072.	297.	484.	121.	59.	46.	710.
7	374.	945.	543.	225.	1845.	512.	439.	278.	122.	86.	768.
8	375.	260.	572.	59.	1698.	153.	383.	69.	26.	26.	573.
9	376.	458.	436.	135.	0	0	0	0	0	0	589.
10	377.	84.	368.	29.	0	0	0	0	0	0	496.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	368.	75.	0	55210.	45397.	0	0	0	60.	730.	0
2	369.	100.	0	54738.	44603.	27335.	19094.	0	59.	705.	0
3	370.	102.	0	55563.	44978.	0	0	0	56.	720.	0
4	371.	97.	4778.	41784.	32484.	29722.	20359.	2940.	56.	700.	530.
5	372.	99.	4193.	54061.	42949.	30197.	21084.	0	56.	690.	468.
6	373.	99.	4388.	54328.	43229.	31932.	22295.	2820.	56.	680.	408.
7	374.	98.	3803.	53712.	42920.	33737.	24089.	0	56.	660.	543.
8	375.	102.	3900.	53394.	43487.	36272.	26842.	3840.	56.	630.	450.
9	376.	77.	0	56908.	43918.	0	0	0	56.	630.	0
10	377.	65.	0	55736.	43829.	0	0	0	57.	605.	0

TRIAL 5

FILE DIG3 (CREATION DATE = 81/01/19.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	364.	1969.	537.	473.	2150.	916.	517.	529.	274.	181.	812.
2	365.	1840.	561.	423.	2389.	770.	549.	444.	244.	156.	876.
3	366.	1811.	523.	447.	2050.	883.	506.	496.	251.	153.	858.
4	367.	2109.	594.	458.	0	0	0	0	264.	158.	991.
5	368.	2217.	564.	507.	0	0	0	0	292.	165.	1001.
6	369.	1900.	494.	497.	2422.	785.	633.	452.	286.	155.	912.
7	370.	1927.	499.	498.	0	0	0	0	287.	162.	886.
8	371.	1703.	428.	513.	1860.	915.	561.	498.	279.	141.	845.
9	372.	1670.	413.	521.	926.	1803.	289.	1080.	312.	145.	893.
10	373.	1946.	511.	491.	2483.	784.	627.	466.	292.	179.	833.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	364.	97.	6304.	51062.	42895.	30864.	20732.	2970.	58.	760.	578.
2	365.	97.	6142.	53230.	44821.	30194.	20196.	0	61.	760.	576.
3	366.	100.	6142.	48189.	40517.	29395.	20016.	2400.	57.	760.	562.
4	367.	112.	0	48635.	41128.	0	0	0	58.	745.	576.
5	368.	113.	0	45385.	38668.	0	0	0	56.	760.	576.
6	369.	100.	0	45585.	38247.	21999.	14031.	0	59.	750.	576.
7	370.	100.	0	46082.	38698.	0	0	0	55.	740.	576.
8	371.	103.	5070.	39043.	32223.	22187.	14162.	1980.	56.	740.	544.
9	372.	102.	4956.	38174.	31415.	32066.	22332.	0	57.	750.	599.
10	373.	104.	3803.	47305.	38073.	21030.	14201.	1660.	57.	750.	595.

TRIAL 6

FILE DIG3 (CREATION DATE = 81/01/12.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	350.	1757.	441.	514.	1685.	1043.	493.	606.	299.	203.	648.
2	351.	1846.	506.	471.	1844.	1001.	470.	558.	262.	167.	796.
3	352.	1837.	485.	489.	2054.	894.	546.	507.	277.	138.	974.
4	353.	1894.	520.	470.	2211.	857.	549.	487.	267.	179.	776.
5	354.	1893.	492.	496.	1939.	976.	508.	552.	280.	183.	755.
6	355.	1800.	486.	477.	0	0	0	0	279.	167.	814.
7	356.	1663.	465.	462.	0	0	0	0	270.	152.	823.
8	357.	1872.	471.	513.	1816.	1031.	497.	592.	294.	180.	769.
9	358.	1996.	514.	501.	2167.	921.	544.	532.	290.	137.	1087.
10	359.	1896.	479.	511.	1881.	1008.	507.	579.	293.	159.	883.
11	360.	1740.	489.	459.	0	0	0	0	264.	158.	815.
12	361.	1922.	514.	483.	0	0	0	0	277.	165.	845.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	350.	100.	3022.	42299.	34188.	25445.	17340.	1620.	58.	720.	581.
2	351.	104.	3292.	44591.	37701.	27299.	19967.	0	58.	710.	557.
3	352.	103.	3247.	43748.	36508.	24196.	16566.	1740.	58.	730.	567.
4	353.	100.	3405.	48020.	40299.	26041.	18188.	0	58.	730.	568.
5	354.	101.	3269.	45427.	37767.	26309.	18572.	1890.	56.	720.	565.
6	355.	97.	0	46433.	38865.	0	0	0	58.	710.	584.
7	356.	98.	0	44406.	36760.	0	0	0	57.	720.	584.
8	357.	97.	3496.	45327.	37639.	27188.	18920.	1740.	58.	715.	574.
9	358.	99.	4195.	49715.	40212.	26588.	18319.	0	59.	730.	578.
10	359.	97.	3677.	45509.	38251.	26477.	19858.	1650.	60.	720.	574.
11	360.	97.	0	46097.	39068.	0	0	0	57.	730.	574.
12	361.	103.	0	45363.	38650.	0	0	0	57.	730.	574.

TRIAL 7

FILE DIG3 (CREATION DATE = 81/01/19.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LFGT1	CODLV1
1	183.	607.	317.	247.	1375.	441.	559.	265.	148.	123.	382.
2	184.	1341.	497.	348.	1804.	743.	468.	421.	197.	125.	787.
3	185.	1289.	512.	325.	1731.	745.	436.	397.	173.	130.	679.
4	186.	1200.	485.	319.	0	0	0	0	0	0	0
5	187.	1315.	454.	374.	0	0	0	0	0	0	0
6	188.	1373.	492.	360.	0	0	0	0	0	0	0
7	189.	1320.	527.	323.	1614.	818.	395.	386.	153.	120.	671.
8	190.	1231.	529.	300.	1572.	783.	384.	403.	155.	116.	704.
9	191.	907.	499.	234.	1363.	665.	352.	361.	127.	88.	723.
10	192.	662.	85.	1007.	233.	2846.	354.	1443.	510.	0	0
11	193.	714.	369.	250.	1146.	623.	401.	296.	119.	99.	442.
12	194.	593.	550.	139.	0	0	0	0	0	0	0
13	195.	637.	531.	155.	0	0	0	0	0	0	0
14	196.	661.	458.	186.	1118.	591.	315.	261.	82.	0	0

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	183.	55.	6760.	53690.	44724.	31345.	19720.	0	59.	755.	601.
2	184.	92.	6393.	51532.	41895.	34888.	22283.	3717.	59.	725.	567.
3	185.	94.	5659.	51439.	42190.	35995.	23778.	0	59.	740.	533.
4	186.	90.	0	51347.	41760.	0	0	0	59.	720.	0
5	187.	79.	0	55859.	44556.	0	0	0	59.	700.	0
6	188.	86.	0	55696.	44311.	0	0	0	59.	685.	0
7	189.	100.	4716.	54059.	40842.	37331.	24701.	5418.	59.	675.	472.
8	190.	100.	4873.	52938.	40998.	37581.	25275.	0	59.	645.	515.
9	191.	100.	5292.	49755.	38688.	38052.	25058.	6773.	60.	655.	542.
10	192.	17.	5292.	49755.	38688.	38028.	25005.	0	60.	660.	507.
11	193.	65.	5334.	54788.	43959.	38598.	26326.	7434.	60.	650.	475.
12	194.	99.	0	53752.	43050.	0	0	0	58.	630.	0
13	195.	101.	0	51899.	40775.	0	0	0	57.	620.	0
14	196.	87.	5947.	51899.	40775.	41347.	27929.	8937.	57.	605.	441.

TRIAL 8

FILE DIG3 (CREATION DATE = 81/01/19.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	355.	1536.	528.	375.	0	0	0	0	0	0	737.
2	356.	1600.	496.	416.	0	0	0	0	0	0	737.
3	357.	1634.	508.	415.	2084.	784.	530.	426.	226.	146.	786.
4	358.	1437.	585.	317.	2604.	552.	574.	268.	154.	132.	682.
5	359.	959.	577.	214.	2386.	402.	533.	185.	99.	66.	861.
6	360.	645.	509.	163.	0	0	0	0	0	0	0
7	361.	402.	513.	101.	0	0	0	0	0	0	0
8	362.	388.	473.	106.	0	0	0	0	0	0	0
9	363.	314.	456.	89.	0	0	0	0	0	0	0
10	364.	344.	473.	94.	1164.	296.	318.	121.	38.	0	0

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	355.	98.	0	50319.	41772.	0	0	2370.	58.	710.	0
2	356.	98.	0	48815.	39211.	0	0	0	56.	720.	0
3	357.	99.	4268.	49160.	39733.	27101.	18678.	1890.	56.	715.	544.
4	358.	99.	4444.	56286.	45822.	28454.	19514.	0	58.	710.	485.
5	359.	100.	4177.	54594.	44735.	29649.	20879.	2430.	58.	680.	461.
6	360.	98.	0	49126.	40285.	0	0	0	56.	675.	0
7	361.	101.	0	48191.	39384.	0	0	3030.	56.	650.	0
8	362.	98.	0	46619.	37421.	0	0	0	59.	635.	0
9	363.	97.	0	45284.	36394.	0	0	0	58.	625.	0
10	364.	98.	3628.	47569.	37402.	35398.	25525.	4200.	59.	590.	408.

TRIAL 9

FILE DIG3 (CREATION DATE = 81/02/04.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	380.	2095.	535.	505.	2236.	937.	539.	515.	278.	164.	906.
2	381.	2029.	535.	489.	2148.	944.	518.	528.	273.	194.	754.
3	382.	1736.	498.	450.	1897.	915.	491.	527.	259.	156.	829.
4	383.	2085.	552.	487.	0	0	0	0	277.	175.	872.
5	384.	2070.	520.	514.	0	0	0	0	292.	179.	847.
6	385.	2104.	564.	482.	2287.	920.	524.	530.	277.	183.	857.
7	386.	1995.	570.	451.	2392.	834.	541.	450.	244.	163.	855.
8	387.	2032.	525.	499.	2031.	1000.	499.	537.	268.	138.	1017.
9	388.	2019.	511.	510.	1820.	1109.	460.	620.	285.	202.	722.
10	389.	2114.	499.	547.	1872.	1130.	484.	600.	290.	180.	803.
11	390.	2017.	513.	508.	0	0	0	0	288.	163.	907.
12	391.	2040.	504.	523.	0	0	0	0	297.	173.	865.
13	392.	2094.	490.	552.	1818.	1152.	479.	654.	313.	220.	698.
14	393.	1905.	489.	503.	1552.	1228.	410.	728.	298.	172.	849.
15	394.	1884.	467.	520.	1798.	1048.	497.	590.	293.	161.	848.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	380.	97.	4631.	52522.	42758.	29692.	19710.	1920.	62.	730.	550.
2	381.	100.	4387.	51004.	41483.	29813.	19999.	0	59.	730.	559.
3	382.	99.	41922.	47629.	38979.	29258.	19822.	1950.	54.	720.	576.
4	383.	102.	0	49253.	41942.	0	0	0	55.	730.	568.
5	384.	99.	0	48100.	40694.	0	0	0	58.	740.	568.
6	385.	100.	5167.	51435.	43675.	30659.	20801.	2100.	60.	735.	576.
7	386.	100.	4972.	54607.	44198.	30238.	20278.	0	58.	735.	540.
8	387.	99.	4680.	51402.	41102.	31049.	20585.	1980.	62.	735.	537.
9	388.	99.	4387.	49512.	40003.	31798.	21615.	0	58.	730.	559.
10	389.	100.	3997.	47476.	38644.	29841.	19929.	1760.	59.	720.	531.
11	390.	106.	0	46205.	37478.	0	0	0	58.	730.	568.
12	391.	101.	0	45671.	38639.	0	0	0	58.	740.	568.
13	392.	99.	4778.	45495.	38330.	30134.	19965.	1920.	57.	730.	568.
14	393.	107.	4583.	44371.	35409.	30370.	20905.	0	58.	730.	593.
15	394.	99.	4680.	43869.	36582.	28338.	18418.	1860.	58.	750.	563.

TRIAL 10

FILE DIG3 (CREATION DATE = 81/02/04.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	387.	2131.	599.	459.	2615.	815.	564.	449.	253.	229.	663.
2	388.	2252.	587.	495.	2498.	901.	549.	498.	274.	223.	721.
3	389.	1651.	436.	489.	1416.	1166.	419.	654.	274.	135.	884.
4	390.	1765.	462.	493.	0	0	0	0	278.	160.	806.
5	391.	2031.	505.	519.	0	0	0	0	293.	175.	846.
6	392.	1999.	493.	523.	1790.	1117.	469.	638.	299.	180.	817.
7	393.	1909.	490.	503.	1746.	1093.	460.	664.	305.	178.	840.
8	394.	1897.	500.	490.	1963.	966.	507.	569.	289.	155.	931.
9	395.	1938.	493.	508.	0	0	0	0	285.	176.	799.
10	396.	1857.	552.	434.	2107.	881.	493.	504.	248.	179.	767.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	387.	102.	4095.	55730.	45476.	29533.	19837.	1680.	58.	730.	551.
2	388.	100.	4192.	55730.	45476.	29984.	20492.	0	58.	730.	553.
3	389.	102.	3802.	40778.	33133.	28737.	19255.	1444.	57.	725.	561.
4	390.	99.	0	44430.	36178.	0	0	0	58.	740.	565.
5	391.	104.	0	44223.	37638.	0	0	0	58.	730.	565.
6	392.	102.	4388.	46393.	37448.	29572.	19899.	1410.	59.	720.	571.
7	393.	101.	4095.	46450.	37569.	30135.	20284.	0	59.	730.	607.
8	394.	104.	4095.	46413.	37231.	28355.	18352.	1440.	59.	735.	589.
9	395.	103.	4193.	49638.	37062.	0	0	0	58.	725.	561.
10	396.	102.	3802.	51226.	41938.	31202.	21282.	1680.	59.	735.	572.

TRIAL 11

FILE DIG3 (CREATION DATE = 81/01/12.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	97.	1818.	530.	442.	0	0	0	0	244.	177.	732.
2	98.	1813.	546.	428.	1980.	915.	468.	502.	235.	137.	936.
3	99.	1862.	532.	451.	1983.	939.	481.	503.	242.	174.	741.
4	100.	1899.	512.	479.	1737.	1093.	438.	601.	263.	165.	816.
5	101.	1752.	487.	464.	1765.	993.	468.	542.	254.	172.	716.
6	102.	1875.	550.	440.	1950.	962.	457.	527.	241.	150.	886.
7	103.	1905.	498.	493.	0	0	0	0	272.	174.	779.
8	108.	1992.	543.	473.	1939.	1027.	461.	577.	266.	173.	833.
9	109.	1930.	539.	462.	1944.	993.	466.	546.	254.	184.	743.
10	110.	1964.	622.	407.	0	0	0	0	224.	165.	848.
11	111.	1608.	511.	406.	0	0	0	0	224.	154.	740.
12	112.	1813.	521.	449.	1732.	1047.	429.	579.	248.	153.	843.
13	113.	1827.	553.	426.	1975.	925.	461.	525.	242.	205.	652.
14	114.	1795.	594.	390.	2069.	867.	449.	468.	210.	159.	783.
15	115.	1661.	540.	397.	1830.	908.	437.	488.	213.	188.	614.
16	116.	1794.	497.	465.	1640.	1094.	425.	608.	259.	183.	704.
17	117.	1554.	467.	430.	0	0	0	0	237.	139.	794.
18	118.	1574.	447.	454.	0	0	0	0	250.	148.	755.
19	119.	1826.	471.	501.	1419.	1287.	389.	718.	279.	146.	902.
20	121.	1779.	515.	446.	1905.	934.	477.	513.	245.	169.	746.
21	122.	2090.	600.	450.	2152.	971.	463.	554.	257.	166.	926.

TRIAL 11 (continued)

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH4J
1	97.	95.	0	52690.	43271.	0	0	0	59.	715.	551.
2	98.	103.	3706.	50213.	41117.	33629.	21889.	1568.	58.	720.	548.
3	99.	98.	3518.	51447.	42089.	33665.	21858.	0	58.	710.	536.
4	100.	102.	3455.	48015.	38872.	33314.	21842.	2020.	58.	710.	550.
5	101.	89.	3329.	51951.	42389.	34688.	22563.	0	58.	705.	546.
6	102.	102.	3225.	50796.	41814.	34583.	22701.	1990.	58.	710.	548.
7	103.	101.	0	49755.	38230.	0	0	0	58.	715.	551.
8	108.	100.	2544.	50785.	42088.	33705.	22695.	0	57.	695.	562.
9	109.	100.	2732.	50482.	41746.	33004.	22309.	1510.	58.	685.	550.
10	110.	110.	0	52871.	43842.	0	0	0	59.	695.	551.
11	111.	96.	0	50468.	41268.	0	0	0	58.	700.	551.
12	112.	100.	2732.	49541.	40371.	34123.	23049.	1425.	60.	700.	553.
13	113.	105.	2669.	49588.	40847.	33090.	22035.	0	58.	700.	568.
14	114.	114.	2647.	49381.	40398.	33645.	22245.	1596.	59.	700.	539.
15	115.	107.	2613.	48141.	39145.	32973.	22040.	0	59.	695.	538.
16	116.	99.	2976.	47539.	38935.	32919.	22373.	1653.	59.	700.	556.
17	117.	103.	0	43684.	35122.	0	0	0	59.	700.	551.
18	118.	98.	0	43814.	35358.	0	0	0	58.	690.	551.
19	119.	103.	2741.	43978.	35402.	32396.	21630.	1340.	58.	695.	558.
20	121.	100.	2633.	49009.	39896.	31574.	20848.	1539.	59.	700.	549.
21	122.	118.	2597.	48285.	39394.	31940.	21154.	0	59.	700.	571.

TRIAL 12

FILE DIG3 (CREATION DATE = 81/01/07.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	327.	1417.	544.	336.	0	0	0	0	192.	124.	838.
2	328.	1297.	492.	340.	0	0	0	0	194.	118.	805.
3	329.	1437.	514.	361.	1969.	730.	494.	411.	203.	124.	843.
4	330.	1331.	468.	367.	1716.	775.	474.	460.	218.	112.	906.
5	331.	1347.	445.	391.	1545.	872.	448.	486.	218.	133.	727.
6	332.	1138.	400.	367.	0	0	0	0	205.	101.	814.
7	333.	1228.	438.	362.	0	0	0	0	203.	110.	805.
8	334.	1253.	463.	349.	0	0	0	0	195.	109.	831.
9	335.	1295.	443.	377.	0	0	0	0	211.	108.	863.
10	336.	1356.	416.	420.	1427.	950.	442.	546.	242.	119.	845.
11	337.	1267.	389.	420.	1264.	1002.	419.	595.	250.	118.	820.
12	338.	1321.	385.	443.	1264.	1045.	424.	555.	235.	103.	882.
13	339.	1226.	384.	411.	1336.	918.	448.	559.	251.	118.	816.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	327.	100.	0	49831.	42127.	0	0	0	60.	670.	570.
2	328.	96.	0	47692.	39751.	0	0	0	60.	700.	570.
3	329.	102.	2923.	47161.	39055.	27830.	19752.	2677.	61.	690.	563.
4	330.	96.	2974.	44830.	37761.	28206.	19881.	0	60.	690.	593.
5	331.	97.	2621.	41670.	35525.	27141.	19599.	3119.	61.	675.	557.
6	332.	97.	0	38482.	31984.	0	0	0	60.	705.	560.
7	333.	96.	0	42344.	35329.	0	0	0	60.	685.	560.
8	334.	99.	0	43448.	36283.	0	0	0	60.	690.	560.
9	335.	103.	0	40335.	33309.	0	0	0	60.	690.	560.
10	336.	98.	2923.	39908.	32930.	26397.	18365.	2646.	60.	695.	575.
11	337.	95.	2318.	36516.	31723.	26366.	18417.	0	59.	685.	594.
12	338.	97.	2570.	36989.	30761.	25358.	17733.	2047.	58.	690.	531.
13	339.	97.	2873.	33597.	30715.	24569.	16944.	0	60.	720.	609.

TRIAL 13

FILE DIG3 (CREATION DATE = 81/01/07.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	163.	1873.	562.	430.	2046.	915.	469.	524.	246.	178.	777.
2	164.	1881.	567.	428.	2126.	885.	484.	474.	229.	179.	726.
3	165.	2148.	547.	507.	1839.	1168.	434.	635.	276.	212.	712.
4	166.	2085.	556.	484.	0	0	0	0	259.	199.	726.
5	167.	2125.	591.	464.	0	0	0	0	250.	194.	762.
6	168.	1997.	534.	483.	1834.	1089.	444.	586.	260.	180.	771.
7	169.	1802.	516.	450.	1679.	1073.	420.	590.	248.	195.	655.
8	170.	1735.	496.	452.	1676.	1035.	436.	582.	254.	182.	692.
9	171.	1641.	483.	438.	1548.	1060.	413.	583.	241.	175.	665.
10	172.	1648.	493.	432.	1603.	1028.	420.	559.	235.	133.	872.
11	173.	1680.	475.	457.	0	0	0	0	251.	173.	691.
12	174.	1688.	479.	454.	0	0	0	0	249.	169.	705.
13	175.	1672.	469.	460.	1467.	1140.	404.	619.	250.	193.	606.
14	178.	2000.	579.	445.	2168.	922.	483.	477.	230.	187.	712.
15	179.	2115.	544.	502.	1854.	1141.	440.	587.	258.	188.	749.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	163.	102.	6073.	54656.	42735.	35863.	22675.	3705.	59.	720.	572.
2	164.	102.	6019.	55025.	43089.	35862.	22246.	0	59.	715.	536.
3	165.	100.	6181.	53228.	42390.	35853.	23997.	4504.	59.	720.	544.
4	166.	102.	0	52318.	42270.	0	0	0	59.	730.	536.
5	167.	107.	0	54222.	42822.	0	0	0	59.	730.	538.
6	168.	102.	5821.	52047.	40542.	35599.	22560.	4378.	59.	710.	538.
7	169.	100.	6078.	50990.	40021.	35406.	23230.	0	59.	705.	550.
8	170.	100.	5764.	49934.	38404.	34459.	21647.	5135.	59.	730.	562.
9	171.	98.	6183.	49587.	38231.	35045.	22434.	0	58.	720.	550.
10	172.	97.	5764.	49981.	39361.	34940.	22831.	5292.	58.	715.	544.
11	173.	97.	0	48301.	37924.	0	0	0	59.	710.	550.
12	174.	99.	0	48371.	37526.	0	0	0	59.	720.	548.
13	175.	98.	5607.	48486.	37058.	34417.	22086.	4946.	59.	715.	543.
14	178.	100.	5554.	58410.	44898.	36389.	23217.	0	58.	700.	517.
15	179.	95.	5502.	56550.	44388.	37282.	24870.	6363.	58.	690.	515.

TRIAL 14

FILE D103 (CREATION DATE = 81/01/14.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	341.	1165.	495.	304.	0	0	0	0	0	0	743.
2	342.	1634.	463.	456.	0	0	0	0	0	0	755.
3	343.	1525.	549.	358.	1939.	787.	456.	443.	202.	139.	797.
4	344.	1431.	548.	337.	1997.	717.	470.	426.	200.	136.	806.
5	345.	1253.	555.	292.	1943.	645.	452.	372.	168.	104.	900.
6	346.	696.	541.	166.	1686.	413.	402.	225.	90.	67.	732.
7	347.	413.	534.	100.	1573.	263.	380.	152.	58.	40.	769.
8	348.	279.	493.	73.	0	0	0	0	0	0	0
9	349.	184.	426.	56.	0	0	0	0	0	0	0

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	341.	96.	0	50727.	39937.	0	0	0	59.	690.	0
2	342.	88.	0	51509.	40759.	0	0	0	60.	720.	0
3	343.	107.	1865.	51426.	39758.	32551.	21640.	1560.	60.	720.	563.
4	344.	101.	4889.	53367.	42069.	33076.	22301.	0	59.	690.	595.
5	345.	103.	4444.	53084.	41725.	33838.	22865.	4860.	60.	715.	577.
6	346.	103.	5261.	51927.	40677.	35358.	24308.	0	59.	690.	544.
7	347.	101.	4989.	50118.	40988.	35740.	25417.	4590.	60.	690.	579.
8	348.	100.	0	48724.	38207.	0	0	0	59.	680.	0
9	349.	87.	0	46538.	37921.	0	0	0	59.	655.	0

TRIAL 15

FILE DIG3 (CREATION DATE = 81/01/12.) STOVER

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	129.	99.	2489.	50681.	41558.	33888.	22951.	0	60.	700.	571.
2	130.	102.	2526.	49877.	41048.	34259.	24208.	1340.	60.	695.	553.
3	131.	101.	0	50168.	41780.	0	0	0	60.	680.	553.
4	132.	101.	0	47918.	39477.	0	0	0	59.	690.	553.
5	133.	114.	2741.	49461.	41130.	33481.	21970.	1482.	59.	690.	553.
6	134.	101.	2705.	47328.	40619.	31777.	21479.	0	59.	700.	553.
7	135.	98.	2633.	48162.	40109.	31503.	21201.	1454.	59.	705.	553.
8	136.	96.	2705.	47328.	39395.	30435.	20249.	0	59.	700.	553.
9	137.	98.	3174.	46339.	39970.	30354.	20831.	1397.	60.	700.	553.
10	138.	100.	0	43712.	36401.	0	0	0	60.	705.	553.
11	139.	99.	0	43031.	35681.	0	0	0	58.	700.	553.
12	140.	109.	2669.	43072.	35954.	39440.	19966.	1425.	58.	695.	553.
13	141.	98.	2525.	47572.	39162.	29555.	20302.	0	57.	700.	553.
14	142.	104.	2597.	47091.	38667.	29824.	20217.	1368.	59.	685.	566.
15	143.	101.	2589.	46611.	38173.	28715.	19415.	0	58.	695.	573.
16	144.	105.	2444.	52582.	44569.	29224.	20299.	1368.	59.	700.	552.
17	145.	98.	0	50075.	41618.	0	0	0	59.	690.	553.
18	146.	122.	0	50873.	42630.	0	0	0	58.	690.	553.
19	147.	95.	0	49176.	40854.	0	0	0	58.	740.	553.
20	148.	97.	2659.	48527.	40316.	30158.	20912.	1539.	59.	700.	552.
21	149.	99.	2695.	44013.	39285.	29864.	22182.	1568.	58.	690.	554.

TRIAL 15 (Cont'd)

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	129.	1602.	531.	389.	1842.	870.	448.	497.	222.	179.	658.
2	130.	1436.	540.	343.	1718.	836.	410.	462.	190.	131.	783.
3	131.	1414.	544.	335.	0	0	0	0	185.	130.	776.
4	132.	1528.	514.	383.	0	0	0	0	212.	141.	775.
5	133.	1561.	605.	333.	2184.	715.	466.	395.	184.	179.	623.
6	134.	1457.	529.	355.	1933.	754.	471.	417.	196.	114.	913.
7	135.	1511.	507.	384.	1853.	815.	471.	451.	213.	143.	752.
8	136.	1390.	488.	368.	1838.	756.	486.	418.	203.	151.	658.
9	137.	1125.	505.	287.	1876.	600.	479.	332.	159.	140.	572.
10	138.	1456.	470.	400.	0	0	0	0	221.	135.	768.
11	139.	1234.	456.	349.	0	0	0	0	193.	116.	760.
12	140.	1434.	506.	366.	1743.	823.	445.	455.	202.	0	0
13	141.	1491.	495.	388.	1848.	807.	482.	446.	215.	159.	668.
14	142.	1588.	519.	395.	1919.	828.	477.	468.	224.	180.	643.
15	143.	1618.	497.	420.	1895.	854.	491.	489.	240.	178.	672.
16	144.	1621.	604.	346.	2548.	636.	545.	351.	191.	143.	809.
17	145.	1467.	526.	360.	0	0	0	0	199.	139.	751.
18	146.	1696.	671.	326.	0	0	0	0	180.	129.	935.
19	147.	1124.	501.	290.	0	0	0	0	160.	110.	730.
20	148.	1458.	505.	373.	1882.	775.	481.	428.	206.	174.	598.
21	149.	1395.	502.	359.	1693.	824.	435.	456.	199.	113.	885.

TRIAL 16

FILE DIG3 (CREATION DATE = 81/01/07.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	325.	1268.	420.	390.	1230.	1031.	378.	608.	230.	134.	719.
2	326.	1417.	522.	351.	2119.	669.	524.	396.	208.	142.	764.
3	327.	1575.	490.	415.	0	0	0	0	237.	155.	749.
4	328.	1609.	510.	407.	0	0	0	0	232.	152.	781.
5	329.	1380.	504.	354.	1870.	738.	479.	443.	212.	120.	887.
6	330.	1513.	498.	392.	1928.	785.	499.	458.	229.	146.	783.
7	331.	1618.	475.	440.	1724.	939.	469.	522.	245.	137.	849.
8	332.	1535.	452.	438.	0	0	0	0	235.	139.	766.
9	333.	1575.	464.	438.	0	0	0	0	235.	136.	803.
10	334.	1286.	424.	392.	0	0	0	0	220.	125.	750.
11	335.	1166.	396.	380.	0	0	0	0	220.	118.	741.
12	336.	1383.	393.	454.	768.	1801.	252.	1030.	260.	129.	793.
13	337.	1778.	486.	472.	2105.	844.	559.	461.	258.	143.	876.
14	338.	1591.	455.	431.	1786.	891.	506.	495.	251.	173.	660.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	325.	100.	2873.	39162.	32545.	28972.	20246.	0	58.	695.	590.
2	326.	100.	2520.	54788.	40420.	27680.	19226.	1417.	59.	715.	593.
3	327.	96.	0	47137.	39539.	0	0	0	60.	710.	571.
4	328.	100.	0	47324.	39517.	0	0	0	60.	720.	571.
5	329.	102.	3226.	46921.	38259.	28309.	19923.	1764.	59.	730.	600.
6	330.	102.	3478.	45164.	37852.	27445.	18950.	0	59.	730.	584.
7	331.	97.	2822.	45070.	37913.	28137.	20142.	2048.	59.	705.	556.
8	332.	98.	0	42662.	35738.	0	0	0	59.	735.	536.
9	333.	103.	0	41630.	34919.	0	0	0	59.	715.	536.
10	334.	96.	0	40938.	34210.	0	0	0	59.	715.	563.
11	335.	95.	0	38929.	32322.	0	0	0	59.	710.	580.
12	336.	101.	2923.	36406.	30173.	29820.	22572.	1323.	59.	730.	572.
13	337.	103.	2520.	44055.	36572.	23809.	16131.	0	59.	715.	546.
14	338.	100.	2722.	42580.	35264.	24357.	17403.	1291.	59.	710.	556.

TRIAL 17

FILE DIG3 (CREATION DATE = 81/01/07.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	164.	1837.	582.	407.	2019.	910.	448.	514.	230.	174.	769.
2	165.	1994.	627.	410.	2291.	870.	471.	467.	220.	173.	799.
3	166.	1923.	523.	474.	0	0	0	0	250.	177.	740.
4	167.	1950.	593.	425.	0	0	0	0	221.	161.	814.
5	168.	1726.	553.	403.	1823.	947.	426.	475.	202.	110.	1015.
6	169.	1638.	599.	353.	2255.	726.	486.	358.	174.	156.	669.
7	170.	1730.	570.	391.	1940.	892.	439.	437.	192.	148.	739.
8	171.	1705.	586.	376.	1984.	859.	437.	432.	189.	147.	753.
9	172.	1638.	601.	352.	1957.	837.	420.	431.	181.	164.	664.
10	173.	1655.	562.	380.	0	0	0	0	192.	146.	740.
11	174.	1685.	546.	398.	0	0	0	0	203.	146.	762.
12	175.	1757.	544.	417.	1622.	1083.	385.	563.	217.	152.	778.
13	176.	1686.	518.	420.	1481.	1138.	369.	590.	217.	130.	865.
14	177.	1775.	615.	372.	2169.	818.	455.	420.	191.	158.	743.
15	178.	1825.	556.	424.	1763.	1035.	409.	529.	216.	161.	749.
16	179.	1886.	629.	387.	1940.	972.	398.	500.	199.	157.	795.
17	180.	1895.	567.	432.	0	0	0	0	221.	160.	785.
18	181.	1735.	564.	397.	0	0	0	0	204.	156.	740.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	164.	104.	5677.	56116.	43362.	36623.	23947.	0	60.	705.	565.
2	165.	108.	5677.	56402.	45002.	36081.	23790.	5008.	60.	705.	536.
3	166.	100.	0	51206.	40555.	0	0	0	60.	710.	528.
4	167.	110.	0	53471.	41753.	0	0	0	60.	710.	521.
5	168.	104.	5660.	53158.	41176.	36526.	23643.	5386.	60.	695.	502.
6	169.	102.	6078.	57638.	45501.	35048.	23395.	0	60.	690.	493.
7	170.	103.	5607.	55316.	42908.	36903.	24077.	6395.	60.	695.	490.
8	171.	104.	5554.	55703.	43651.	37292.	24572.	0	60.	685.	503.
9	172.	105.	5450.	55506.	44368.	38006.	25727.	7025.	60.	675.	515.
10	173.	100.	0	54588.	43593.	0	0	0	60.	670.	507.
11	174.	103.	0	52166.	41111.	0	0	0	60.	670.	511.
12	175.	103.	5240.	52123.	40950.	37515.	25198.	7025.	59.	675.	520.
13	176.	100.	4402.	51511.	40157.	38001.	25346.	0	59.	675.	518.
14	177.	105.	5502.	58195.	45383.	37474.	24729.	7434.	59.	680.	513.
15	178.	101.	5397.	56287.	42664.	38505.	25204.	0	60.	675.	511.
16	179.	114.	5135.	54465.	42794.	38335.	25773.	7277.	60.	665.	514.
17	180.	106.	0	52572.	41419.	0	0	0	58.	680.	513.
18	181.	100.	0	55183.	43710.	0	0	0	58.	680.	515.

TRIAL 18

FILE DIG3 (CREATION DATE = 81/01/07.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	317.	995.	295.	435.	1192.	835.	521.	411.	214.	145.	437.
2	318.	1264.	306.	533.	1187.	1065.	500.	495.	248.	196.	386.
3	319.	1197.	302.	512.	1192.	1004.	510.	552.	282.	220.	386.
4	320.	1089.	294.	479.	0	0	0	0	254.	191.	392.
5	321.	1025.	258.	513.	0	0	0	0	272.	190.	369.
6	322.	1031.	259.	513.	921.	1120.	459.	758.	348.	206.	437.
7	323.	971.	370.	339.	1367.	710.	477.	392.	187.	127.	543.
8	324.	1129.	443.	329.	1792.	630.	522.	327.	171.	149.	506.
9	325.	1271.	409.	401.	1534.	829.	484.	444.	215.	160.	549.
10	326.	1074.	407.	340.	1468.	731.	465.	385.	179.	150.	487.
11	327.	1034.	548.	243.	0	0	0	0	129.	116.	613.
12	328.	978.	474.	266.	0	0	0	0	141.	118.	569.
13	329.	795.	492.	208.	1671.	476.	438.	238.	104.	88.	585.
14	330.	654.	598.	141.	1931.	339.	416.	187.	78.	61.	770.
15	331.	608.	542.	145.	1132.	537.	270.	257.	69.	50.	755.
16	332.	538.	617.	112.	0	0	0	0	60.	48.	760.
17	333.	473.	552.	111.	0	0	0	0	59.	45.	723.
18	334.	355.	417.	110.	0	0	0	0	58.	45.	546.
19	335.	190.	450.	54.	0	0	0	0	29.	22.	591.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	317.	53.	2987.	53926.	43175.	30028.	20691.	2016.	59.	695.	492.
2	318.	54.	2896.	54562.	43956.	31748.	21980.	0	60.	685.	465.
3	319.	54.	3175.	52668.	43288.	30450.	21207.	2363.	58.	710.	550.
4	320.	53.	0	52763.	42924.	0	0	0	59.	710.	531.
5	321.	50.	0	50366.	39990.	0	0	0	59.	700.	531.
6	322.	50.	3226.	50407.	40159.	31446.	21746.	2426.	59.	695.	677.
7	323.	73.	3578.	49807.	39280.	30421.	20548.	0	59.	690.	552.
8	324.	75.	3528.	57408.	45743.	31975.	21854.	3213.	58.	675.	519.
9	325.	73.	3226.	54235.	43451.	32697.	22439.	0	58.	670.	536.
10	326.	74.	4334.	53639.	42669.	33321.	22828.	3213.	58.	670.	526.
11	327.	83.	0	63300.	51208.	0	0	0	58.	660.	531.
12	328.	77.	0	60600.	47707.	0	0	0	58.	660.	531.
13	329.	80.	4738.	60762.	47691.	38260.	26805.	5961.	58.	655.	500.
14	330.	99.	5342.	60294.	46846.	39653.	27343.	0	58.	665.	553.
15	331.	104.	4637.	50858.	40353.	41587.	29470.	8757.	58.	635.	478.
16	332.	103.	0	58838.	46453.	0	0	0	58.	660.	531.
17	333.	98.	0	57745.	43626.	0	0	0	58.	640.	531.
18	334.	74.	0	56383.	43626.	0	0	0	58.	625.	531.
19	335.	80.	0	56383.	43626.	0	0	0	58.	630.	531.

TRIAL 19

FILE DIG3 (CREATION DATE = 81/01/08.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	120.	1842.	509.	467.	1822.	1011.	462.	563.	260.	189.	699.
2	121.	1918.	576.	429.	2270.	845.	508.	445.	226.	205.	637.
3	122.	2002.	538.	480.	1924.	1040.	461.	570.	263.	136.	1039.
4	123.	1896.	543.	450.	2072.	915.	492.	497.	244.	196.	677.
5	124.	1780.	540.	425.	0	0	0	0	229.	167.	741.
6	125.	1797.	518.	448.	0	0	0	0	241.	167.	749.
7	126.	1919.	555.	446.	2106.	911.	489.	461.	226.	157.	796.
8	127.	1919.	550.	450.	2076.	925.	487.	512.	249.	144.	950.
9	129.	1958.	595.	424.	2329.	841.	505.	448.	226.	212.	637.
10	130.	1986.	586.	437.	2103.	945.	463.	508.	235.	182.	759.
11	131.	1702.	537.	409.	0	0	0	0	220.	151.	780.
.12	132.	1711.	542.	407.	0	0	0	0	219.	148.	804.
13	134.	2226.	594.	484.	2175.	1024.	473.	551.	260.	209.	741.
14	135.	2088.	583.	462.	2239.	933.	495.	502.	248.	206.	702.
15	136.	1973.	565.	450.	2104.	938.	480.	504.	242.	181.	757.
16	137.	1707.	572.	385.	2075.	823.	468.	443.	207.	170.	697.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	120.	100.	4039.	49417.	39417.	33559.	21194.	0	58.	705.	557.
2	121.	102.	4112.	54515.	43784.	33771.	21526.	2594.	58.	695.	527.
3	122.	101.	3967.	51994.	41291.	34349.	22239.	0	59.	710.	548.
4	123.	100.	4076.	52398.	42112.	33799.	21389.	2879.	60.	705.	543.
5	124.	94.	0	54977.	44552.	0	0	0	60.	715.	538.
6	125.	95.	0	54518.	42221.	0	0	0	60.	720.	538.
7	126.	101.	4193.	53553.	42616.	34261.	21761.	0	59.	710.	506.
8	127.	100.	4653.	53287.	42624.	34469.	21868.	0	59.	720.	554.
9	129.	103.	3895.	55635.	44799.	34577.	22189.	0	59.	710.	533.
10	130.	102.	4003.	54619.	44505.	35672.	23892.	2537.	59.	700.	538.
11	131.	99.	0	52231.	42069.	0	0	0	59.	700.	538.
12	132.	102.	0	51438.	41166.	0	0	0	59.	700.	538.
13	134.	100.	4256.	56703.	46019.	35885.	24272.	0	59.	700.	538.
14	135.	100.	4184.	56050.	45212.	35191.	22825.	3050.	59.	705.	538.
15	136.	98.	4256.	55372.	44701.	35457.	23228.	0	59.	700.	538.
16	137.	98.	4220.	55426.	45222.	35550.	24045.	2508.	59.	690.	538.

TRIAL 20

FILE DIG3 (CREATION DATE = 81/02/05.) STOVER

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	322.	99.	4426.	48421.	40532.	29434.	20390.	1680.	58.	720.	557.
2	323.	101.	4376.	48011.	40072.	29456.	20579.	0	56.	725.	563.
3	324.	100.	4470.	51367.	42307.	29872.	20737.	1417.	59.	730.	551.
4	325.	102.	4683.	50353.	42750.	30058.	21659.	0	59.	730.	543.
5	326.	99.	4537.	50781.	42127.	30135.	21387.	1680.	59.	735.	554.
6	327.	100.	0	49831.	41421.	0	0	0	60.	735.	553.
7	328.	100.	0	48530.	40159.	0	0	0	60.	730.	553.
8	329.	101.	4163.	47963.	39280.	29228.	20019.	1576.	59.	735.	549.
9	330.	100.	4224.	51796.	42496.	28954.	21186.	0	58.	725.	566.
10	331.	97.	4286.	52103.	41310.	29946.	21738.	1739.	58.	730.	553.
11	332.	102.	4398.	49308.	40350.	29051.	20345.	0	59.	730.	545.
12	333.	98.	4552.	48378.	40550.	30357.	20722.	1512.	59.	735.	552.

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	322.	1998.	518.	498.	1994.	1002.	497.	558.	277.	180.	796.
2	323.	2056.	522.	508.	1969.	1044.	486.	588.	286.	194.	769.
3	324.	2098.	546.	496.	2157.	973.	510.	536.	273.	219.	681.
4	325.	2156.	563.	494.	2151.	1002.	493.	544.	268.	228.	661.
5	326.	2135.	538.	512.	2053.	1040.	492.	576.	284.	178.	857.
6	327.	2024.	534.	489.	0	0	0	0	270.	193.	749.
7	328.	1976.	518.	492.	0	0	0	0	272.	188.	749.
8	329.	1993.	512.	502.	1945.	1024.	490.	562.	276.	185.	761.
9	330.	2076.	548.	489.	2131.	974.	501.	551.	277.	205.	739.
10	331.	2053.	517.	512.	1898.	1081.	474.	598.	283.	195.	749.
11	332.	1976.	531.	480.	2041.	968.	496.	528.	262.	182.	765.
12	333.	2027.	513.	510.	1943.	1043.	489.	576.	282.	196.	735.

TRIAL 21

FILE DIG3 (CREATION DATE = 81/01/08.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	51.	2099.	522.	519.	2008.	1045.	497.	609.	303.	194.	814.
2	52.	1726.	498.	448.	1950.	885.	506.	515.	261.	167.	775.
3	53.	2136.	483.	571.	1775.	1203.	474.	695.	330.	189.	843.
4	54.	2095.	543.	498.	0	0	0	0	281.	161.	949.
5	55.	2299.	506.	586.	0	0	0	0	332.	193.	870.
6	56.	2656.	514.	667.	1917.	1385.	481.	809.	389.	232.	863.
7	57.	1618.	498.	419.	1847.	876.	479.	501.	240.	140.	853.
8	58.	1960.	535.	472.	1970.	995.	475.	576.	273.	208.	703.
9	59.	2164.	548.	510.	2252.	961.	530.	540.	286.	186.	844.
10	60.	2191.	575.	491.	2274.	963.	510.	553.	282.	212.	767.
11	61.	2214.	534.	535.	0	0	0	0	302.	187.	862.
12	62.	2083.	512.	525.	0	0	0	0	296.	184.	827.
13	63.	2059.	572.	464.	2545.	809.	574.	453.	260.	212.	703.
14	64.	2172.	591.	474.	2573.	844.	562.	436.	245.	199.	727.
15	65.	2238.	572.	505.	2370.	944.	535.	515.	275.	217.	725.
16	66.	2307.	576.	517.	2392.	965.	536.	531.	284.	183.	894.
17	67.	2315.	539.	554.	2201.	1052.	527.	582.	306.	226.	730.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	51.	98.	4248.	51919.	41256.	32041.	20767.	1508.	58.	730.	583.
2	52.	96.	4309.	50916.	40164.	31062.	19851.	1640.	58.	730.	582.
3	53.	95.	4247.	49660.	39399.	31737.	20712.	1700.	58.	745.	578.
4	54.	110.	0	48769.	38249.	0	0	0	58.	720.	565.
5	55.	101.	0	49605.	38851.	0	0	0	59.	725.	566.
6	56.	101.	0	50442.	39453.	32072.	20470.	1532.	58.	710.	584.
7	57.	99.	4113.	50010.	38984.	32068.	20324.	1592.	58.	740.	572.
8	58.	105.	4514.	50458.	39520.	32321.	20759.	1592.	59.	745.	579.
9	59.	98.	4715.	55032.	43318.	32743.	20340.	0	58.	740.	562.
10	60.	103.	4715.	54479.	43297.	32878.	21219.	1055.	58.	730.	574.
11	61.	100.	0	52262.	41365.	0	0	0	59.	740.	565.
12	62.	96.	0	52262.	41365.	0	0	0	59.	750.	565.
13	63.	100.	4481.	54457.	44353.	31116.	18898.	1116.	58.	740.	560.
14	64.	99.	4380.	57732.	46291.	32693.	20298.	0	59.	740.	517.
15	65.	101.	4347.	54907.	43889.	32684.	20427.	1357.	58.	740.	545.
16	66.	100.	3091.	55503.	44631.	32756.	20713.	0	59.	740.	550.
17	67.	97.	4280.	53590.	43065.	32548.	20376.	1176.	59.	740.	553.

TRIAL 22

FILE DIG3 (CREATION DATE = 81/01/15.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LFGT1	CODLV1
1	346.	1962.	554.	457.	2413.	813.	563.	441.	248.	192.	715.
2	347.	2073.	558.	479.	2372.	874.	548.	504.	276.	165.	938.
3	348.	2029.	533.	491.	0	0	0	0	271.	171.	846.
4	349.	2044.	498.	529.	0	0	0	0	292.	182.	797.
5	350.	1944.	519.	484.	2121.	917.	528.	487.	257.	160.	830.
6	351.	1998.	490.	526.	1833.	1090.	483.	596.	288.	177.	796.
7	352.	2000.	495.	522.	1793.	1116.	468.	597.	279.	183.	755.
8	353.	1847.	509.	468.	1792.	1031.	454.	550.	250.	177.	720.
9	354.	1799.	488.	476.	1651.	1090.	437.	616.	269.	145.	907.
10	355.	1756.	468.	484.	0	0	0	0	267.	155.	805.
11	356.	1539.	470.	423.	0	0	0	0	233.	134.	818.
12	357.	1633.	470.	448.	1433.	1140.	393.	654.	257.	150.	807.
13	358.	1614.	462.	451.	1328.	1215.	371.	647.	240.	141.	787.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	346.	97.	4716.	54235.	44227.	28373.	19346.	0	58.	730.	543.
2	347.	102.	4626.	51271.	42416.	27751.	19166.	3030.	60.	740.	577.
3	348.	103.	0	49342.	40110.	0	0	0	60.	730.	551.
4	349.	97.	0	49313.	39799.	0	0	0	60.	740.	551.
5	350.	101.	4645.	49313.	39799.	28479.	18800.	2190.	60.	740.	531.
6	351.	97.	4736.	49489.	39131.	29947.	20231.	0	59.	725.	547.
7	352.	99.	4645.	49096.	38728.	30528.	20621.	2100.	59.	740.	535.
8	353.	98.	4449.	49336.	40270.	31331.	21985.	0	59.	730.	534.
9	354.	100.	4177.	46446.	37812.	31061.	21305.	2490.	58.	715.	565.
10	355.	98.	0	45550.	37012.	0	0	0	55.	705.	551.
11	356.	100.	0	45480.	36410.	0	0	0	55.	710.	551.
12	357.	100.	4086.	45495.	36415.	31915.	22088.	2430.	56.	705.	574.
13	358.	104.	4444.	43124.	34434.	31696.	21666.	0	57.	720.	532.

TRIAL 23

FILE D163 (CREATION DATE = 81/01/08.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	79.	1199.	515.	300.	2404.	499.	602.	278.	167.	86.	998.
2	80.	1314.	491.	346.	2201.	597.	579.	322.	186.	102.	898.
3	81.	1202.	553.	280.	2706.	444.	631.	237.	149.	130.	634.
4	82.	1385.	578.	309.	0	0	0	0	164.	119.	796.
5	83.	1552.	565.	354.	0	0	0	0	188.	135.	788.
6	84.	1512.	494.	395.	2289.	661.	598.	355.	213.	170.	619.
7	85.	1540.	597.	333.	2774.	555.	600.	294.	176.	99.	1062.
8	86.	1654.	547.	390.	2362.	700.	558.	363.	202.	193.	573.
9	87.	1532.	537.	368.	2200.	696.	528.	368.	194.	129.	811.
10	88.	1538.	577.	344.	2377.	647.	532.	340.	181.	194.	538.
11	89.	1569.	510.	397.	0	0	0	0	211.	136.	788.
12	90.	1633.	558.	377.	0	0	0	0	200.	135.	826.
13	91.	1540.	464.	428.	1787.	862.	497.	444.	220.	87.	1174.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	79.	103.	2277.	44922.	38747.	24090.	15410.	452.	59.	730.	557.
2	80.	100.	2593.	44128.	38019.	24296.	16004.	0	59.	705.	539.
3	81.	101.	1992.	48101.	42438.	23524.	15645.	362.	59.	695.	533.
4	82.	104.	0	50185.	43052.	0	0	0	59.	695.	531.
5	83.	103.	0	49595.	42537.	0	0	0	60.	695.	531.
6	84.	97.	1743.	46680.	39456.	24028.	15861.	302.	59.	695.	538.
7	85.	105.	1486.	51550.	44058.	25444.	17642.	0	59.	685.	530.
8	86.	100.	1328.	49106.	42356.	26502.	18736.	392.	59.	685.	518.
9	87.	106.	1288.	47711.	39293.	26608.	18539.	0	58.	680.	528.
10	88.	110.	1265.	48501.	40651.	27174.	19038.	392.	60.	685.	525.
11	89.	103.	0	46131.	38397.	0	0	0	59.	670.	531.
12	90.	108.	0	47534.	40073.	0	0	0	59.	680.	531.
13	91.	99.	1214.	44343.	36334.	27400.	18284.	362.	59.	670.	515.

TRIAL 24

FILE DIG3 (CREATION DATE = 81/01/08.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	52.	1490.	500.	384.	2115.	704.	545.	398.	217.	165.	658.
2	53.	2070.	623.	429.	2879.	719.	596.	408.	244.	198.	766.
3	54.	2045.	593.	445.	0	0	0	0	252.	203.	733.
4	55.	2290.	667.	443.	0	0	0	0	250.	202.	826.
5	57.	2317.	780.	383.	4011.	578.	663.	303.	201.	190.	824.
6	58.	2336.	605.	499.	2583.	904.	551.	506.	279.	201.	840.
7	61.	1955.	541.	467.	0	0	0	0	245.	190.	699.
8	62.	1782.	543.	424.	0	0	0	0	222.	171.	706.
9	63.	2191.	556.	508.	2272.	964.	527.	500.	263.	203.	722.
10	64.	1620.	549.	381.	2360.	687.	555.	357.	198.	159.	683.
11	65.	1938.	535.	467.	2219.	873.	535.	430.	230.	196.	626.
12	66.	1830.	501.	471.	2093.	875.	538.	0	0	0	660.
13	67.	1896.	601.	407.	2608.	727.	560.	372.	208.	174.	718.
14	68.	2008.	595.	436.	0	0	0	0	218.	176.	734.
15	69.	2198.	543.	522.	0	0	0	0	261.	211.	671.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	52.	98.	6979.	51686.	39570.	30267.	17988.	2412.	59.	745.	565.
2	53.	105.	5885.	59222.	45982.	30685.	18563.	2279.	59.	740.	568.
3	54.	104.	0	57015.	44157.	0	0	0	58.	745.	565.
4	55.	117.	0	57015.	44157.	0	0	0	59.	745.	565.
5	57.	100.	6896.	77403.	60481.	34239.	20372.	2991.	59.	750.	524.
6	58.	102.	7022.	58498.	45931.	34324.	20607.	3618.	56.	740.	560.
7	61.	99.	0	53797.	42319.	0	0	0	58.	740.	525.
8	62.	100.	0	54007.	42063.	0	0	0	58.	750.	525.
9	63.	103.	7055.	54395.	41856.	32872.	19798.	3166.	60.	750.	518.
10	64.	101.	7390.	54299.	42127.	31441.	18763.	4311.	61.	745.	520.
11	65.	100.	6621.	53946.	41483.	32061.	19290.	4131.	54.	740.	492.
12	66.	87.	6922.	60214.	44670.	33665.	20617.	0	68.	755.	0
13	67.	101.	5952.	61196.	46136.	32964.	20318.	4553.	58.	735.	512.
14	68.	104.	0	59215.	44309.	0	0	0	54.	730.	500.
15	69.	95.	0	59215.	44309.	0	0	0	62.	740.	500.

TRIAL 25

FILE DIG3 (CREATION DATE = 81/01/08.) STOVER

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	75.	95.	0	55379.	42740.	0	0	0	59.	735.	540.
2	76.	100.	0	52432.	41113.	0	0	0	59.	735.	540.
3	77.	97.	4459.	52480.	41518.	32295.	19987.	1447.	59.	745.	532.
4	78.	97.	4301.	52419.	41591.	32328.	20219.	0	59.	730.	536.
5	79.	100.	4269.	47974.	38767.	31902.	19459.	1658.	59.	740.	550.
6	80.	100.	4238.	48374.	39101.	31486.	19483.	0	58.	725.	531.
7	81.	102.	4175.	46909.	37905.	31517.	19960.	1749.	58.	720.	552.
8	82.	100.	0	47005.	37888.	0	0	0	59.	720.	540.
9	83.	100.	0	45407.	36381.	0	0	0	59.	725.	540.
10	84.	103.	4554.	44706.	35320.	29731.	18522.	1809.	58.	730.	545.
11	86.	99.	3827.	52565.	42452.	29701.	18819.	1658.	59.	725.	523.
12	87.	108.	3953.	52113.	41869.	30447.	19318.	0	59.	730.	541.
13	88.	97.	4080.	51469.	41179.	30891.	19665.	1930.	59.	715.	549.

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	75.	2215.	524.	546.	0	0	0	0	295.	190.	813.
2	76.	2135.	530.	519.	0	0	0	0	280.	174.	855.
3	77.	2250.	520.	559.	2089.	1077.	519.	573.	297.	236.	656.
4	78.	2130.	521.	528.	2073.	1027.	514.	551.	283.	165.	895.
5	79.	2162.	500.	558.	1931.	1120.	498.	616.	307.	180.	852.
6	80.	2092.	505.	535.	1962.	1066.	502.	566.	284.	162.	884.
7	81.	2290.	499.	592.	1830.	1251.	473.	691.	327.	179.	912.
8	82.	1937.	489.	511.	0	0	0	0	276.	158.	855.
9	83.	1932.	469.	531.	0	0	0	0	287.	157.	855.
10	84.	1960.	469.	539.	1730.	1133.	476.	617.	294.	165.	835.
11	86.	2213.	542.	527.	2340.	946.	557.	495.	275.	173.	862.
12	87.	2289.	583.	506.	2436.	940.	539.	508.	274.	173.	924.
13	88.	2282.	515.	571.	2087.	1094.	522.	600.	314.	205.	790.

TRIAL 26

FILE DIG3 (CREATION DATE = 81/01/08.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	85.	1427.	521.	353.	1824.	782.	452.	384.	173.	103.	875.
2	86.	1483.	558.	343.	2104.	705.	487.	347.	169.	124.	760.
3	87.	1483.	518.	369.	1805.	822.	449.	431.	194.	131.	767.
4	88.	1473.	532.	357.	1803.	817.	437.	432.	189.	142.	709.
5	89.	1475.	513.	371.	0	0	0	0	197.	110.	917.
6	90.	1442.	478.	389.	0	0	0	0	206.	130.	758.
7	91.	1472.	488.	389.	1570.	938.	415.	524.	217.	140.	759.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	85.	99.	4459.	50961.	40795.	33876.	22366.	0	58.	695.	491.
2	86.	100.	4016.	53205.	43222.	33786.	22182.	3075.	58.	695.	493.
3	87.	99.	4238.	50629.	40553.	33962.	22325.	0	59.	690.	525.
4	88.	102.	4238.	50493.	40430.	34591.	22756.	2925.	59.	680.	529.
5	89.	105.	0	47671.	37857.	0	0	0	58.	680.	530.
6	90.	95.	0	49185.	38989.	0	0	0	58.	690.	530.
7	91.	103.	4351.	46912.	36743.	33133.	21499.	2261.	58.	710.	559.

TRIAL 27

FILE DIG3 (CREATION DATE = 81/01/08.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	123.	2425.	552.	567.	2238.	1083.	523.	586.	307.	224.	757.
2	124.	2294.	533.	555.	0	0	0	0	301.	216.	741.
3	125.	2331.	533.	565.	0	0	0	0	306.	209.	782.
4	127.	2662.	557.	616.	2342.	1137.	542.	618.	335.	225.	832.
5	128.	2441.	523.	603.	2038.	1198.	503.	643.	324.	253.	670.
6	129.	2419.	527.	592.	2155.	1123.	528.	612.	323.	291.	585.
7	130.	2336.	548.	550.	2221.	1052.	523.	578.	302.	230.	719.
8	131.	2264.	486.	601.	0	0	0	0	326.	217.	730.
9	132.	2191.	510.	555.	0	0	0	0	301.	206.	745.
10	133.	2470.	551.	578.	2102.	1175.	492.	637.	313.	246.	703.
11	134.	2206.	526.	541.	2035.	1084.	499.	587.	293.	218.	709.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	123.	101.	4184.	52227.	42357.	32326.	20196.	2280.	59.	725.	541.
2	124.	100.	0	51270.	41336.	0	0	0	59.	720.	542.
3	125.	105.	0	50993.	39310.	0	0	0	59.	730.	542.
4	127.	100.	4653.	53564.	43199.	31547.	19778.	0	58.	730.	544.
5	128.	100.	3859.	50902.	40505.	32286.	20123.	1967.	59.	715.	537.
6	129.	95.	3931.	53441.	42998.	32145.	20315.	0	59.	725.	545.
7	130.	98.	4003.	52144.	43334.	31870.	20675.	1596.	59.	715.	549.
8	131.	98.	0	47155.	38452.	0	0	0	59.	700.	542.
9	132.	100.	0	48454.	39507.	0	0	0	59.	720.	542.
10	133.	102.	4076.	51279.	41902.	32817.	21298.	1910.	59.	710.	542.
11	134.	100.	4076.	49790.	40789.	31370.	20435.	0	59.	730.	542.

TRIAL 28

FILE U163 (CREATION DATE = 81/01/16.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LFGT1	CODLV1
1	110.	1501.	502.	386.	0	0	0	0	0	0	0
2	111.	1710.	517.	426.	0	0	0	0	0	0	0
3	112.	1781.	519.	443.	1600.	1113.	398.	600.	239.	148.	839.
4	113.	1804.	536.	435.	1778.	1015.	428.	521.	223.	165.	724.
5	114.	1850.	524.	456.	1692.	1094.	417.	553.	231.	151.	802.
6	115.	1650.	573.	371.	2065.	799.	465.	395.	183.	154.	682.
7	116.	1510.	546.	357.	1788.	845.	423.	447.	189.	142.	725.
8	117.	951.	513.	239.	0	0	0	0	0	0	861.
9	118.	636.	508.	162.	0	0	0	0	0	0	707.
10	119.	301.	496.	78.	1292.	233.	336.	134.	45.	29.	759.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	110.	98.	0	49460.	39689.	0	0	0	57.	695.	0
2	111.	100.	0	50328.	40104.	0	0	0	58.	715.	0
3	112.	103.	4648.	49558.	39044.	36172.	23506.	2081.	57.	705.	539.
4	113.	103.	4554.	50627.	40309.	35897.	23048.	0	57.	700.	513.
5	114.	101.	4288.	50589.	40192.	36276.	23444.	2223.	57.	695.	506.
6	115.	102.	4121.	54778.	43556.	35781.	23306.	0	57.	685.	494.
7	116.	101.	4260.	52749.	41886.	36816.	24187.	3620.	59.	675.	529.
8	117.	99.	0	50700.	40139.	0	0	0	58.	640.	0
9	118.	100.	0	50289.	39376.	0	0	0	57.	630.	0
10	119.	98.	4725.	50240.	39225.	39589.	26045.	6327.	56.	640.	575.

TRIAL 29

FILE DIG3 (CREATION DATE = 81/01/08.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	58.	1932.	550.	453.	2214.	873.	519.	490.	255.	192.	731.
2	59.	1973.	585.	435.	2309.	855.	509.	473.	241.	196.	720.
3	60.	1844.	543.	438.	1966.	938.	467.	521.	243.	154.	857.
4	61.	1796.	545.	426.	0	0	0	0	227.	135.	917.
5	62.	1931.	604.	412.	0	0	0	0	220.	126.	1055.
6	63.	1468.	496.	382.	1693.	867.	441.	427.	188.	0	0
7	64.	1873.	569.	425.	2181.	859.	494.	426.	211.	150.	800.
8	65.	1985.	604.	424.	2190.	906.	468.	480.	225.	194.	701.
9	79.	1854.	590.	406.	1984.	935.	434.	514.	223.	167.	786.
10	80.	1779.	609.	377.	2130.	835.	451.	441.	199.	142.	854.
11	81.	1901.	582.	422.	1954.	973.	434.	527.	229.	133.	1003.
12	82.	1673.	569.	379.	0	0	0	0	202.	117.	982.
13	83.	1698.	534.	411.	0	0	0	0	219.	126.	926.
14	84.	1746.	519.	434.	1571.	1111.	390.	611.	239.	128.	966.
15	85.	1733.	604.	371.	2160.	802.	462.	426.	197.	145.	818.
16	86.	1989.	620.	414.	2223.	895.	463.	458.	212.	128.	1023.
17	87.	1989.	602.	427.	2217.	897.	475.	451.	215.	0	0
18	88.	2060.	555.	479.	1965.	1049.	457.	561.	256.	172.	827.
19	89.	2090.	601.	449.	0	0	0	0	239.	145.	990.
20	90.	2056.	532.	499.	0	0	0	0	266.	157.	900.
21	91.	2012.	515.	504.	1672.	1203.	419.	656.	275.	178.	794.
22	92.	1877.	486.	498.	1636.	1147.	434.	622.	270.	140.	940.

TRIAL 30

FILE DIG3 (CREATION DATE = 81/01/08.) STOVER

CASE-NO	DAY	GAS	VSL3	GASL1	VSD1	GASD1	VSD%1	CH4D1	CH4L1	LPGT1	CODLV1
1	59.	2470.	572.	557.	2405.	1027.	543.	565.	306.	215.	815.
2	60.	2322.	549.	546.	2235.	1039.	525.	598.	314.	187.	923.
3	61.	2181.	532.	529.	0	0	0	0	292.	186.	832.
4	62.	1912.	542.	455.	0	0	0	0	251.	156.	874.
5	63.	2263.	517.	565.	1909.	1186.	477.	665.	317.	188.	873.
6	64.	2080.	520.	516.	2159.	963.	536.	538.	288.	185.	809.
7	65.	1969.	543.	468.	2223.	886.	528.	486.	257.	185.	753.
8	66.	2079.	513.	523.	2025.	1027.	509.	552.	281.	160.	901.
9	67.	2062.	493.	540.	1776.	1161.	465.	607.	282.	176.	789.
10	68.	2045.	499.	529.	0	0	0	0	291.	175.	832.
11	69.	1944.	479.	524.	0	0	0	0	288.	173.	798.

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	59.	98.	4548.	55536.	45233.	32756.	20693.	0	58.	735.	550.
2	60.	100.	4648.	52549.	42565.	31661.	20217.	1658.	57.	725.	576.
3	61.	100.	0	50924.	41201.	0	0	0	59.	730.	551.
4	62.	105.	0	50000.	40000.	0	0	0	58.	740.	551.
5	63.	103.	4514.	49117.	38876.	31971.	20343.	1357.	59.	730.	561.
6	64.	98.	4247.	51377.	41134.	30489.	19103.	1538.	58.	735.	558.
7	65.	100.	4280.	52361.	42068.	31227.	19843.	1447.	58.	730.	549.
8	66.	96.	4213.	52853.	41446.	31586.	20353.	0	59.	725.	538.
9	67.	98.	4180.	50102.	38984.	32569.	20859.	1779.	59.	730.	523.
10	68.	100.	0	49836.	38676.	0	0	0	59.	720.	551.
11	69.	96.	0	49836.	38676.	0	0	0	59.	720.	551.

TRIAL 29 (continued)

CASE-NO	DAY	LITFED	ALK	FTS	FVS	ETS	EVS	TVA	TEMP	PH1	CH41
1	58.	93.	3946.	55562.	45836.	33146.	22027.	3377.	59.	710.	562.
2	59.	100.	4013.	55988.	45358.	33609.	22272.	0	59.	715.	553.
3	60.	100.	4046.	51757.	42109.	33603.	22452.	2653.	59.	720.	555.
4	61.	100.	0	51804.	42207.	0	0	0	59.	720.	533.
5	62.	115.	0	50490.	40712.	0	0	0	62.	730.	533.
6	63.	98.	4414.	49177.	39217.	33366.	21938.	3317.	60.	705.	492.
7	64.	98.	3912.	54899.	45012.	34035.	22756.	2985.	58.	700.	496.
8	65.	106.	3611.	54193.	44154.	34606.	23493.	3648.	59.	695.	530.
9	79.	109.	4111.	52771.	41921.	35868.	23722.	2291.	61.	710.	550.
10	80.	107.	4175.	54609.	44129.	36072.	24227.	0	58.	690.	528.
11	81.	105.	4143.	53074.	42927.	36016.	24313.	2894.	56.	685.	542.
12	82.	107.	0	52398.	41244.	0	0	0	56.	685.	533.
13	83.	101.	7.	50854.	40948.	0	0	0	56.	0	533.
14	84.	103.	4934.	49348.	39065.	35409.	23814.	3256.	56.	700.	550.
15	85.	103.	4269.	56705.	45409.	35966.	24436.	0	56.	695.	531.
16	86.	107.	4143.	55572.	44874.	35555.	24097.	2502.	57.	700.	512.
17	87.	108.	4238.	54053.	43179.	35367.	22652.	0	59.	705.	503.
18	88.	97.	4269.	56286.	44348.	35987.	24094.	2804.	58.	700.	535.
19	89.	108.	0	54824.	43132.	0	0	0	58.	690.	533.
20	90.	98.	0	53869.	42051.	0	0	0	58.	700.	533.
21	91.	103.	0	50299.	38752.	35264.	22516.	2502.	58.	700.	545.
22	92.	97.	4099.	50344.	38869.	34386.	22000.	0	58.	700.	542.

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17. Document Analysis

a. Descriptors Biomass; methane; anaerobic digestion; lignin; hemicellulose; biodegradation; agricultural wastes; cellulose; sodium hydroxides; heat; gas yields; yields

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