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MONFORT WASTE CONVERSION DEMONSTRATION

QUARTERLY PROGRESS REPORT

FOR THE PERIOD APRIL 1, 1977 - JUNE 30, 1977

HAMILTON STANDARD DIVISION
UNITED TECHNOLOGIES CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

JULY, 1977

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WASHINGTON, D. C. 20545
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1.0 INTRODUCTION

This progress report describes the activities of the Hamilton Standard mobile fermentation system at the Monfort feedlots during the April-June, 1977 period. In addition, it provides a short description of the overall objectives of the program and summary of activities since inception.

1.1 Background

Previous work with fresh beef residue in the laboratory and field tests with residues from an environmental beef cattle feedlot, had demonstrated that yields of over 4 $ft.^3$ of methane from each pound of volatile matter fed, and 2 $ft.^3$ of methane per day from each cubic foot of fermentor volume, could be achieved. In addition, the solids cake harvested from the effluent contained about one half the crude protein of cottonseed meal and demonstrated a dietary usefulness as a source of protein for cattle equivalent to that contained in cottonseed meal.

1.2 Program Objectives

The purpose of this program is to evaluate the operation of an anaerobic fermentor under field conditions, utilizing residues from a dirt feedlot in their normally collected condition. The data is intended to be site specific and to include the effects of the day-to-day variation in climate, diet, animal care, as well as the existing residue collection and management techniques.

It was expected that the primary factors which would influence the fermentation process during this field test evaluation would be the loss of readily biodegradable material prior to residue collection and the inclusion of foreign refractory material in the dirt lot residue. Another important factor would be the variability of these characteristics. Decreased yields of methane, lowered dietary usefulness of the effluent solids, and increased difficulty in maintaining process control were the expected effects of these factors. The objective of the field experiment was to document and evaluate these effects and develop corrective actions where possible.

1.3 Program Summary, 2nd Half, 1976

Testing with mobile 1500 gallon experimental facility at the Monfort of Colorado Feedlot at Kuner, Colorado was initiated in mid 1976. The testing conducted in the last half of 1976 established the following:

- Pen residues were much lower in volatile matter content and much more variable than expected. On a dry matter basis the volatile matter averaged ~ 25%. The major fraction of inert material consisted of particles less than 1 μ diameter and of a composition similar to that of Colorado road dust. This material was not removable from the residue slurry by settling without significant losses in volatile matter. These inert constituents are partially due to air borne contamination of both the cattle feed and their deposited residue; but, is primarily the result of the pen subsurface being mixed, by hoof action, into the residue during periods of wet weather.

- Biological start-up operation of the fermentor utilizing fresh residue from the feedlot cattle as both the organic substrate and the source of biological population was erratic with methane yields of slightly over 2 $ft.^3$ per pound of volatile matter fed. This represents a much lower value than expected for fresh residues. Dietary ingredients in the cattle diet, such as pharmaceuticals, were indicated as potential causes of this low performance.

- Operation with fresh dairy residue, free from pharmaceuticals, demonstrated extremely stable performance with significant capacity to utilize additions of readily available organic material. The methane yields were 2.75 $ft.^3$ per pound of dairy residue volatile matter which were approximately 20% less than that expected for fresh dairy residue.

- Operation with pen residue collected in a normal manner yielded insignificant methane production (0.5 $ft.^3$/#v.s.). This poor yield may result from the lack of biologically accessible organic material and/or the existence of inhibitory concentrations of ingredients such as pharmaceuticals or minerals.

1.4 Program Summary, 1st Quarter, 1977

During the first quarter of 1977 the objectives established for the field experimental program were:

- Start-up and operation with a Total Volatile Acid (TVA) concentration of no greater than 1000 mg/L. This value is based upon traditional experience with waste treatment processes and was recommended at the December Quarterly Review Meeting.

- Operation at a temperature further into the thermophilic range (135°F/57.2°C vs. 125°F/51.7°C). Increasing the temperature would eliminate the possibility of an ambivalent microbial colony.

A review of the operating conditions mid-way through the last reporting quarter indicated that the sluggish start-up response experienced might be due to the low concentration of volatile solids (0.3%) in the fermentor. A one time loading of 127# volatile solids from fresh dairy waste was added to the fermentor resulting in a typical start-up involving a rapid increase in TVA, followed by a rapid decline in conjunction with a spurt in gas production. At the end of the last quarter, the TVA had levelled off at 1000 mg/L while gas production averaged 1 ft.^{3}/hr. Nominal daily loadings of 0.03 #vs./ft.^{3} at a residence time of 10 days were initiated on March 26 and continued into the first week of the current reporting period.

2.0 ACTIVITIES DURING THE LAST QUARTER

2.1 Objectives

During the second quarter of 1977, the objectives established for the field experimental program were:

- Continue evaluation of fermentor start-up at operating conditions of 135°F/57.2°C, and maintenance of low TVA concentrations.
- Begin fermentor loading with beef steer residue from cattle fed a typical finishing ration.
- Establish baseline performance at a loading rate of 0.25# volatile solids/ft.^{3} and a ten day residence time.

2.2 Test Results

2.2.1 Fermentation

Beginning on April 7, 1977 residue from the twenty steers set aside for our use became available. These steers were on a ration schedule that brought them to a typical finishing ration by the first week in May. The animals are not receiving any pharmaceuticals nor were they inplanted with any growth additives. Use of this material is meant to assure a supply of raw material free of any potentially inhibitory substances. A comparison of the various residue sources is shown below.

Source	Dry Matter (%)	Volatility (%)
Dairy (fresh)	15-20	70-75
Steer (fresh)	20-30	70-75
Pen 140 (aged)	50-75	25

It may be seen that the steer residue and that collected from the dairy farm compare very favorably.

Loadings of the steer residue were begun at a rate of 0.10# volatile solids/ft.^{3}/day. Beginning at this same time a planned steady withdrawal of fermentor contents was begun. A final operating volume of 100 ft. was chosen so that, based upon material availability from the twenty steers, a loading rate of 0.25# volatile solids/ft.^{3}/day would be achievable.

Beginning on April 14, 1977, a residence time of 10 days was imposed upon the system to help reduce the Total Volatile Acid concentration which had steadily risen to over 2000 mg/L. In fact, on April 18, 1977 instead of an organic load, 625 pounds of water were added to the fermentor in an attempt to reduce the TVA concentration. This dilution did provide some temporary relief by reducing the TVA level to 1000-1100 mg/L for the ensuing two days. An organic loading rate of 0.03# volatile solids/ft.^{3} was incorporated in a further attempt at maintaining a low TVA level.

With the TVA at 1170 mg/L on April 21, 1977, it was decided to increase the loading rate to 0.075# volatile solids/ ft.^{3}/day. This rate was to remain in effect until April 27, 1977 by which time the TVA had increased to 2130 mg/L. During this period of increasing concentration the residence time had been increased to 18 days (4/24) in an attempt to provide additional time for the methanogenic colony to establish itself.

It was obvious by this time that increases in loading could not be accomplished without a concomitant increase in TVA. Samples of contents were analyzed for soluble concentrations of heavy metals (copper, zinc, iron, aluminum) as well as sulfur and phosphorus; any of which could potentially be inhibitory to the bacterial process. Soluble sulfide concentrations greater than 200 mg/L (1) and concentration of phosphate greater than 50 mg/L (2) have been reported to inhibit the methanogenic population in anaerobic fermentation. The technique employed by the testing laboratory reports phosphorus not phosphate. As such, the 50 mg/L level phosphate level reported by Dr. Pfeffer becomes 16 mg/L phosphorus. Similarly the laboratory tested for total soluble sulfur not just soluble sulfide. It was felt that if the total soluble sulfur concentration (including sulfate, sulfite & hydrogen sulfide) were within the stated limit then, by inference, the sulfide concentration would be acceptable.

(1) Lawrence, A. W., McCarty, P. L. & Guerin, F.J.A. The Effects of Sulfides on Anaerobic Treatment

(2) Pfeffer, J. T. & White, J. E., The Role of Iron in Anaerobic Digestion

Previous analyses of fermentor contents for soluble sulfide concentrations had indicated values less than 100 ppm. They were not, therefore, considered a problem. In fact, some level of soluble sulfide is needed to provide a precipitating mechanism for soluble heavy metal ions.

The results of samples taken during the latter part of April and the first part of May are indicated below (values in ppm):

Specie	4/25	5/3	5/4	5/5
Soluble Sulfur	<30	660	660	<50
Soluble Phosphorus	76	87	69	81.
Soluble Zinc	2.2	1.4	1.5	0.6
Soluble Copper	0.7	0.6	0.3	0.1
Soluble Iron	1.5	11.0	7.8	3.9
Soluble Aluminum	-	4.8	4.2	2.1

Reviewing this data indicated the following:

a) The high variability of the soluble sulfur concentration lead to an evaluation of the laboratory technique utilized for its determination. Because of the characteristics of the sample, the laboratory had not been able to strictly follow the filtering procedure outlined in Standard Methods. This departure lead to the inclusion of some of the non-soluble fraction being reported as soluble.

b) The concentration of soluble phosphorus exceed the level reported to be inhibitory.

Many ionic forms are effective in their precipitation of phosphorus from solution. Most notable among these, due to their relatively low cost and general availability, are aluminum, calcium and iron. Under favorable pH conditions the quantity of aluminum ion required for phosphate precipitation can be estimated from the stoichiometry of the following equation:

$$Al^{3+} + HnPO_4{}^{-(3-n)} = ALPO_4\downarrow + nH^+$$

From this relationship it can be seen that the removal of phosphorus closely approximates a 1:1 ratio.

Based upon these calculations sufficient aluminum chloride was added to the fermentor on May 6 to precipitate the soluble phosphorus. No observable changes in fermentor performance were noted during the next several days.

Although the levels of soluble heavy metals reported did not seem reasonable in light of the concentration of soluble sulfur measured, the difficulties with the sulfide test convinced us to assume the existence of a potential heavy metal toxicity problem. As such, an addition of sodium sulfide ($Na_2 S.9H_2O$) was made on May 10 based upon the levels of soluble zinc, copper and iron reported by the laboratory.

During this period some mechanical difficulty with the hot water heater had caused large temperature variations. However, even in light of this additional perturbation, gas production remained fairly reasonable. On the other hand, the TVA remained high indicating that the stress condition had not been relieved.

At this point it was still not certain whether the soluble sulfur or soluble phosphorus was causing the inhibition. Not knowing which level of soluble sulfur was more realistic (30 ppm vs. 660 ppm) a dosage of iron chloride calculated to reduce the 660 ppm soluble sulfur level as well as the soluble phosphorus level was introduced into the fermentor on May 11.

The effects upon the measured parameters were apparent the following day. TVA, which had been 1602 mg/L prior to the addition decreased to 1176 on May 12 and 888 on May 13. In a similar manner, daily gas production increased during the succeeding days. While awaiting a shipment of iron chloride, additional daily samples of fermentor contents were analyzed and are shown on the following table (results in ppm). Figure 1 displays these results along with selected fermentor parameters. It should be noted that there is a delay of approximately two weeks between sample taking and receipt of analysis.

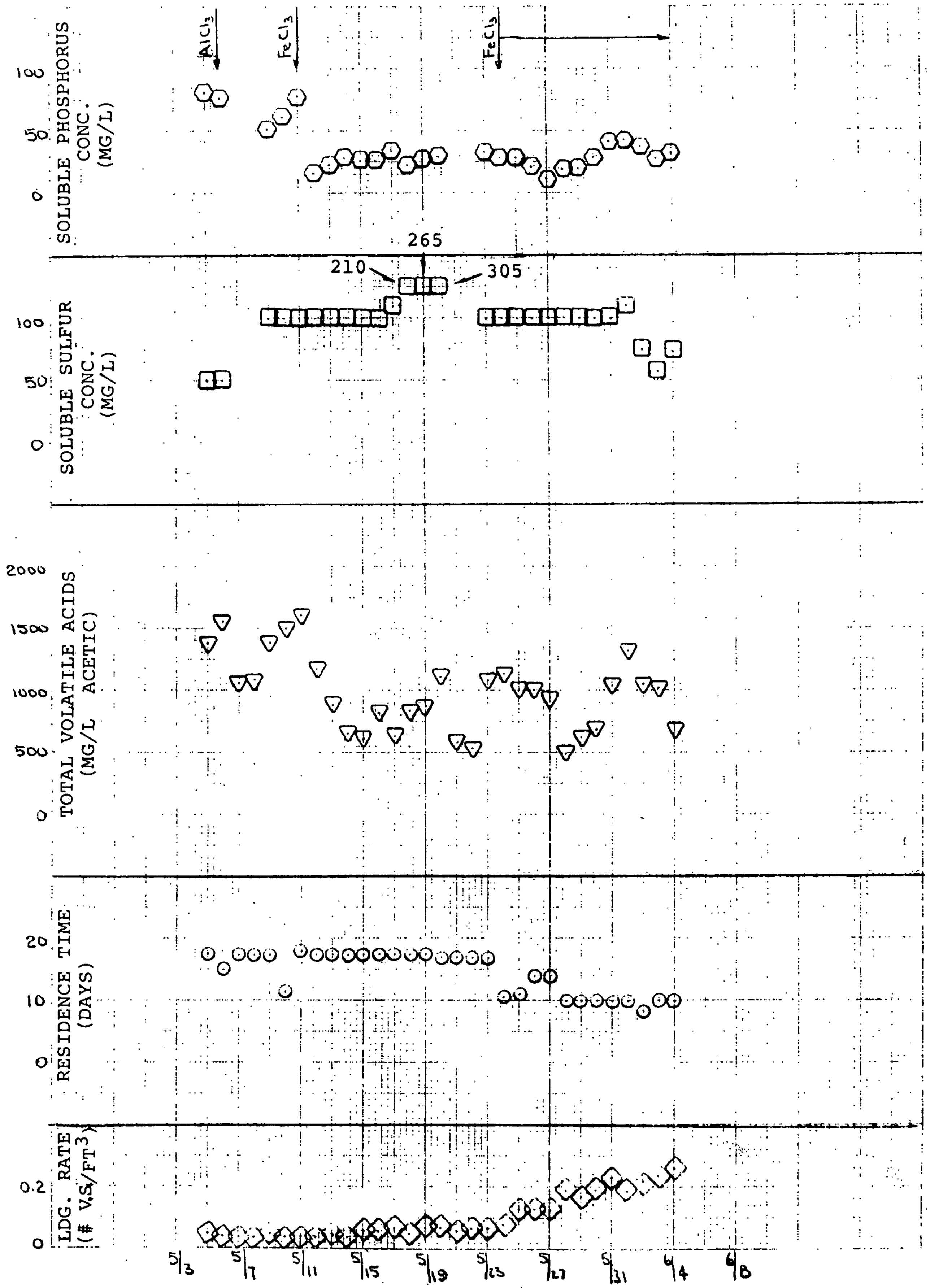
Soluble Specie	5/6	5/9	5/10	5/11	5/12	5/13
Sulfur	<50	<100	<100	<100	<100	<100
Phosphorus	76	51	61	78	16	22
Zinc	0.4	1.6	1.8	1.5	1.0	0.9
Copper	0.1	0.6	0.6	0.4	0.3	0.3
Iron	0.19	10.0	11.0	10.0	36.0	42.0
Aluminum	0.2	8.0	9.0	10.0	1.8	2.8

Soluble Specie	5/14	5/15	5/16	5/17	5/18	5/19	5/20
Sulfur	<100	100	100	110	210	265	305
Phosphorus	28.4	26.4	25.4	34.5	23.0	27.0	29.0
Zinc	0.4	0.5	0.6	0.6	0.8	0.8	1.2
Copper	0.3	0.2	0.3	0.1	0.2	0.3	0.3
Iron	45.0	46.0	50.0	38.5	23.0	11.0	22.0
Aluminum	2.5	2.6	3.0	2.4	2.6	2.6	3.5

Soluble Specie	5/23	5/24	5/25	5/26	5/27	5/28	5/29
Sulfur	<100	100	<100	<100	<100	<100	<100
Phosphorus	33.4	28.8	28.4	21.0	12.0	19.0	20.0
Zinc	< 0.1	< 0.1	0.1	2.5	1.5	1.3	1.5
Copper	< 0.1	< 0.1	0.2	0.3	0.2	0.4	0.2
Iron	0.3	0.5	2.6	240.0	4.6	120.0	100.0
Aluminum	< 0.1	< 0.1	2.1	1.6	1.2	1.0	1.1

Soluble Specie	5/30	5/31	6/1	6/2	6/3	6/4
Sulfur	<100	<100	110	75	57	73
Phosphorus	28.0	41.0	43.0	37.0	28.0	32.0
Zinc	1.7	2.5	2.3	2.1	1.6	1.2
Copper	0.1	0.1	0.3	0.1	0.4	0.2
Iron	90.0	125.0	680.0	170.0	185.0	140.0
Aluminum	1.0	1.2	1.4	1.0	1.3	.0.6

Figure 1



SOLUBLE PHOSPHORUS CONC. (MG/L)
100
50
0
AlCl3
FeCl3
FeCl3
265
210
305
SOLUBLE SULFUR CONC. (MG/L)
100
50
0
TOTAL VOLATILE ACIDS (MG/L ACETIC)
2000
1500
1000
500
0
RESIDENCE TIME (DAYS)
20
10
0
LDG. RATE (# V.S/FT3)
0.2
0
5/3
5/7
5/11
5/15
5/19
5/23
5/27
5/31
6/4
6/8

The effects of the singular $AlCl_3$ addition on May 6 is seen in the analyses of May 9, 10 and 11 by the approximate 40% reduction in phosphorus followed by its gradual rise back to its previous value of 80 ppm. Similarly, the effect of the $FeCl_3$ addition on May 11 was to radically reduce both the phosphorus concentration and volatile acid concentration while loading rate was increasing and appears to be circumstantially responsible for the unblocking of the methanogenic pathway. The phosphorus levels continued to remain low but with some tendency to rise as the backlog of soluble iron dissapeared.

A large supply of $FeCl_3$ was secured in place by May 24 and regular daily additions started. Assuming that the total soluble phosphorus and sulfur concentration were at "worst case" condition, an amount of $FeCl_3$ calculated to reduce sulfur concentration by 100 mg/L and phosphorus concentration by 25 mg/L was introduced on May 24, 1977. Concomitant with the $FeCl_3$ addition the residence time was reduced and loading rate gradually increased with a goal of achieving 10 day residence time and a loading rate of 0.20 # volatile solids/ft.^{3}/day by the end of May while controlling Total Volatile Acid as well as phosphorus concentration. Daily additions of $FeCl_3$ continued through the end-date of the presented data (6/4/77). A review of Figures 2, 3 & 4 indicate that a loading rate of 0.25 #/ft.^{3}, residence time of 10 days and maintenance of TVA concentration at approximately 1000 mg/L were achieved while hourly gas rate increased greatly. While daily gas production increased, the increase in loading rate was more rapid resulting in a specific gas rate of approximately 6.5 SCF/# volatile solids. It should be noted that these values have not yet stabilized at baseline conditions.

The current fermentor conditions indicate a healthy microbial colony capable of accepting large and rapid increases in organic loading while maintaining reasonably stable TVA concentrations at 1000 mg/L. While the exact corrective mechanism of the iron chloride (reduction of soluble sulfur, soluble phosphorus or increased soluble iron concentration) is not completely understood its effect has been to convert what had been a sluggish unit into a healthy fermentor capable of yielding expected quantities and qualities of end products.

Daily addition of $FeCl_3$ continued in an attempt to offset the total soluble sulfur and phosphorus entering the

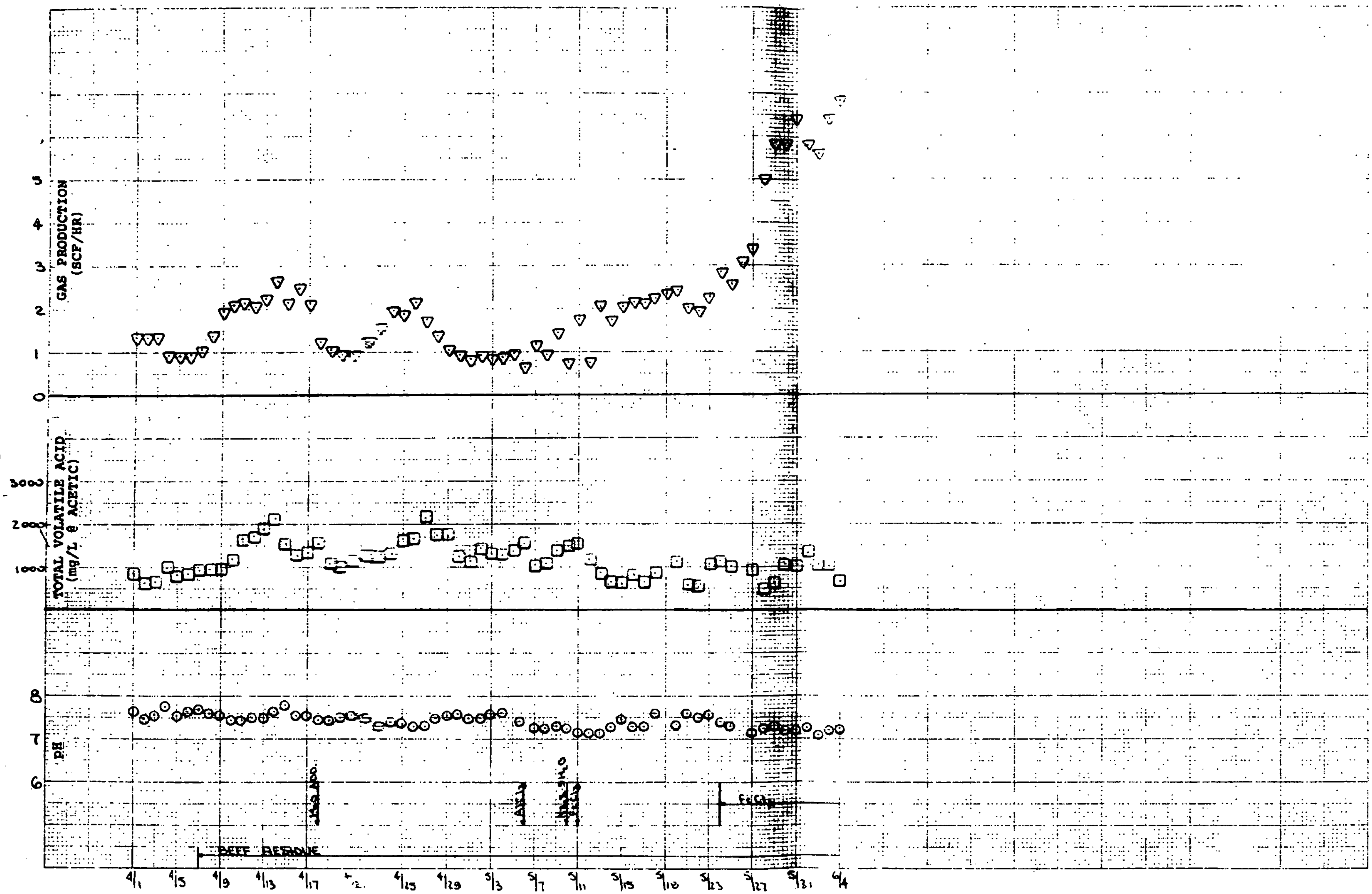

GAS PRODUCTION (SCF/HR)
0
1
2
3
4
5
TOTAL VOLATILE ACID (mg/L @ ACETIC)
1000
2000
3000
pH
6
7
8
BEEF RESIDUE
FeCl3
4/1
4/5
4/9
4/13
4/17
4/25
4/29
5/3
5/7
5/11
5/15
5/23
5/27
5/31
6/4

Figure 2

Figure 3

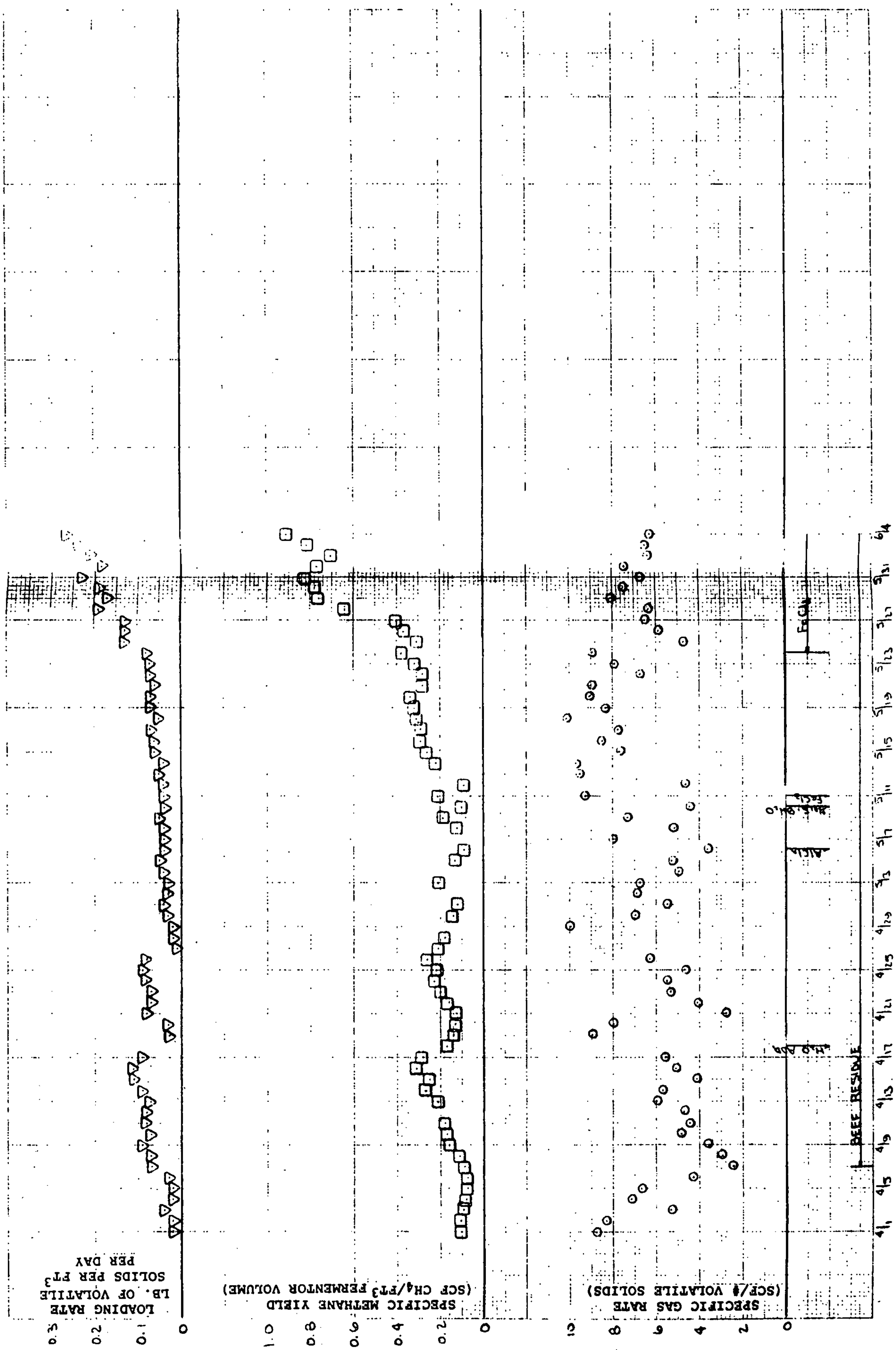
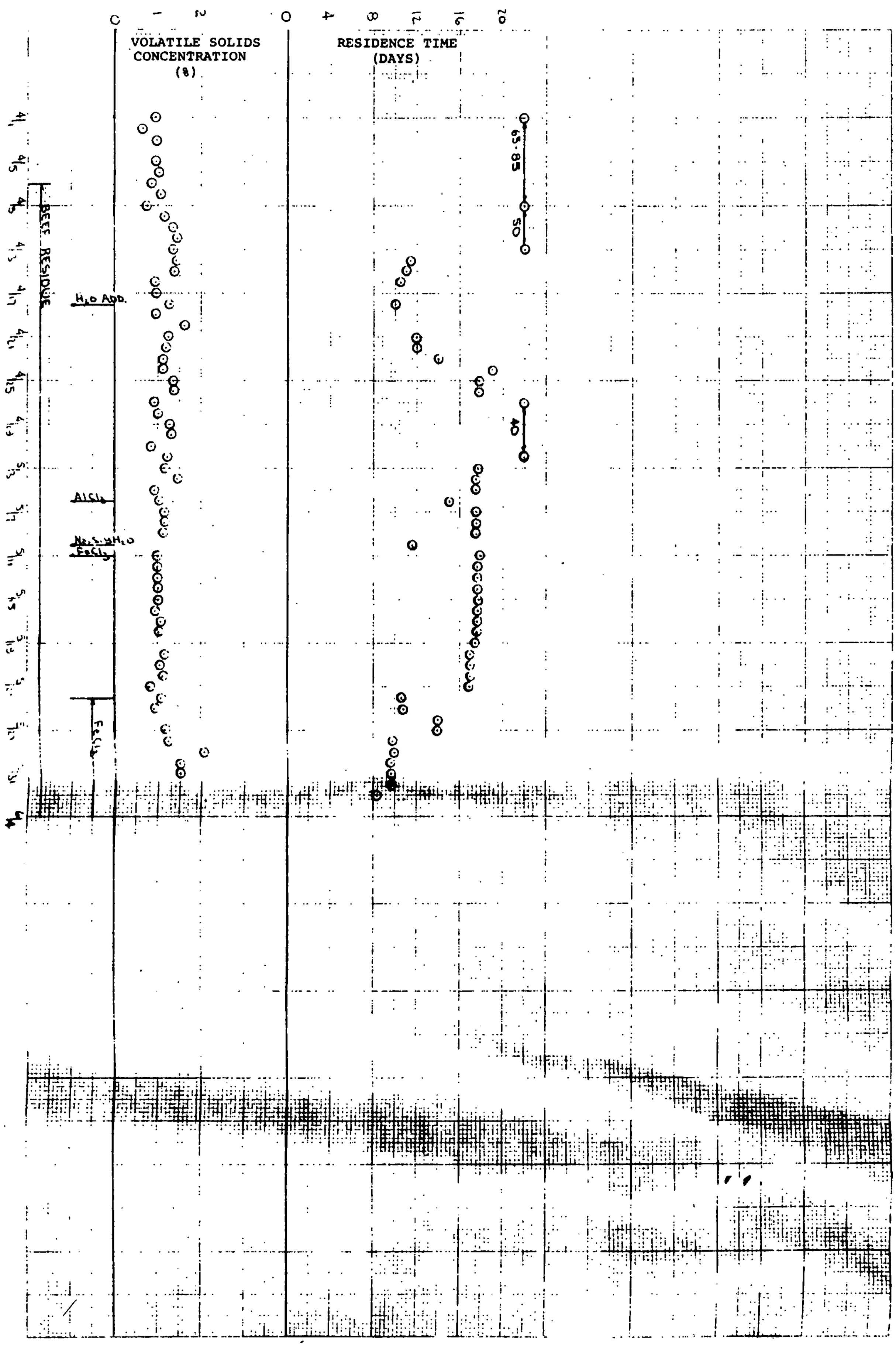

LOADING RATE
LB. OF VOLATILE
SOLIDS PER FT3
PER DAY
SPECIFIC METHANE YIELD
(SCF CH4/FT3 FERMENTOR VOLUME)
SPECIFIC GAS RATE
(SCF/# VOLATILE SOLIDS)
BEEF RESIDUE
AlCl3
FeCl3
4/1
4/5
4/9
4/13
4/17
4/21
4/25
4/29
5/3
5/7
5/11
5/15
5/19
5/23
5/27
5/31
6/4

Figure 4


VOLATILE SOLIDS CONCENTRATION (%)
RESIDENCE TIME (DAYS)
0
1
2
0
4
8
12
16
20
65-85
50
40
BEEF RESIDUE
H_2O ADD.
$AlCl_3$
$FeCl_3$

fermentor from the steer residue (measured at 630 ppm and 615 ppm respectively) and from the well water used at the Kuner feedlot (measured at 800 mg/L as SO_4=).

2.2.2 Pen Waste Characterization Study

Analyses conducted early in this experiemntal program on the pen waste available at the Monfort Feedlot indicated a higher than expected non volatile content which also proved to be highly variable. In order to better define the wastes which would be available to a full scale production system, a program was initiated to periodically sample and analyse the waste from cattle pens at different locations within the Kuner Feedlot. These samples are being analyzed for dry matter and volatile matter and tabulated along with information pertinent to the sample location. A partial listing of these results is shown in Table I. This sampling will continue so that a good cross-section of the feedlot will be developed.

3.0 PROBLEMS

None

4.0 PLANNED EFFORT

During the next quarterly period it is planned to complete the following activities:

- Use of beef steer residue will continue during the establishment of baseline performance at 0.25# volatile solids/$ft.^3$ with a ten day residence time.
- After establishment of the baseline, the pharmaceuticals in question will be gradually included into the diet fed to the steers. The residue from the animals will then be introduced to the fermentor to evaluate its effect upon performance.
- Performance characteristics of typical dirt feedlot residues will be evaluated.

Table I

Pen Waste Characterization Study

Date	Pen	Location	Dry Matter	Ash	#Volatile Solids / #Residue
4/21/77	388	East	31.44	25.89	.233
4/21/77	82	East	36.60	33.72	.243
4/21/77	363	East	36.48	36.58	.231
4/21/77	201	East	46.60	59.29	.190
4/21/77	241	East	49.49	46.34	.315
4/26/77	155	West: Feed Bunk	58.49	44.37	.326
4/26/77	155	Water	59.24	50.45	.294
4/26/77	174	Back Fence	78.52	85.17	.116
4/26/77	174	Feed Bunk	74.65	71.90	.210
4/26/77	140		55.54	34.82	.362
4/26/77	119		67.14	57.32	.287
5/16/77	100	Bunk	75.15	40.27	.449
5/17/77	100	Back Fence	55.86	70.27	.166
5/18/77	291	Bunk	56.29	39.65	.340
5/18/77	292		62.27	43.35	.353
5/18/77	290		54.52	46.05	.294
5/18/77	289		59.60	40.52	.355
5/19/77	245		65.78	37.37	.412
5/19/77	247		54.53	27.85	.393
5/19/77	246		65.85	50.30	.327
5/19/77	248		66.20	44.10	.370
5/20/77	224		63.43	64.31	.226
5/20/77	225		51.28	40.56	.305
5/20/77	226		48.91	37.66	.305
5/20/77	227		45.29	34.41	.297
5/23/77	334		63.90	30.72	.442
5/23/77	335		64.41	32.13	.437
5/23/77	338		56.44	26.93	.412
5/23/77	339		59.59	27.87	.430
5/24/77	313	Water	62.51	47.43	.329
5/24/77	314	Bunk	58.75	35.56	.378
5/24/77	316		65.44	37.66	.408
5/24/77	317		59.98	31.58	.410
5/26/77	42	Back Fence	66.48	66.21	.225
5/26/77	44		84.31	61.03	.329
5/26/77	117		74.85	57.94	.315
5/26/77	118		62.65	57.76	.265
5/26/77	21		81.05	77.43	.183
5/27/77	306	Bunk	51.37	30.36	.358
5/27/77	307		57.76	34.09	.377
5/27/77	308		58.20	36.11	.372
5/27/77	309		54.41	32.05	.370
5/27/77	310		52.08	39.64	.314
5/31/77	131	Tank	61.75	55.63	.274
5/31/77	132	Bunk	77.59	57.12	.333
5/31/77	133	Tank	54.40	34.80	.355
5/31/77	134	Bunk	58.43	51.29	.285
6/2/77	114	Stock Pile	66.70	59.02	.273
6/2/77	114	Stkpl-1' Down	51.92	52.79	.245

Table 1 (Continued)

Pen Waste Characterization Study

Date	Pen	Location	Dry Matter	Ash	#Volatile Solids / #Residue
6/2/77	116	Stock Pile	75.55	76.63	.177
6/2/77	116	Stkpl-1' Down	76.63	78.04	.168
6/3/77	119	Stkpl	73.10	73.69	.192
6/3/77	119	Stkpl-1'	74.65	79.53	.153
6/3/77	121	Stkpl	81.19	75.39	.200
6/3/77	121	Stkpl-1'	80.47	71.20	.232
6/6/77	145	Bunk	57.79	55.34	.258
6/6/77	146		62.33	49.69	.314
6/6/77	147		64.71	55.93	.285
6/6/77	148		60.68	48.11	.315
6/7/77	156		59.42	50.96	.291
6/7/77	157		61.30	44.97	.337
6/7/77	158		60.74	46.39	.326
6/7/77	159		58.12	49.05	.296
6/8/77	174		72.65	68.11	.232
6/8/77	175		60.26	49.09	.307
6/8/77	176		59.57	53.97	.274
6/8/77	177		70.34	74.37	.180
6/9/77	161		61.19	37.21	.384
6/9/77	162		62.08	46.00	.335
6/9/77	163	Tank	63.55	47.74	.332
6/9/77	164	Bunk	61.46	44.12	.343
6/10/77	149		63.33	49.50	.320
6/10/77	150		49.88	-	-
6/10/77	151		56.20	36.54	.357
6/10/77	152		59.66	51.40	.290
6/14/77	161		61.65	47.36	.325
6/14/77	162		58.14	45.30	.260
6/14/77	163		68.82	46.98	.365
6/14/77	164		62.77	76.72	.146
6/15/77	37		61.40	56.42	.268
6/15/77	35		50.11	32.28	.339
6/15/77	39	Bunk	55.28	55.93	.244
6/15/77	40	Tank	70.86	77.80	.157
6/16/77	33	Bunk	50.95	33.98	.336
6/16/77	34		65.36	69.14	.202
6/16/77	35		61.21	49.44	.309
6/16/77	36		58.65	54.62	.266
6/17/77	37		63.19	62.39	.238
6/16/77	38		53.91	55.06	.242
6/17/77	39		54.31	47.79	.284
6/17/77	40		53.57	58.13	.224
6/21/77	281	Back Fence	58.52	40.59	.348
6/21/77	283		62.88	55.12	.282
6/21/77	285		69.61	67.65	.225
6/21/77	286		64.02	47.22	.338

Appendix A

Graphical Data

PROCESS GAS YIELD TOTAL GAS

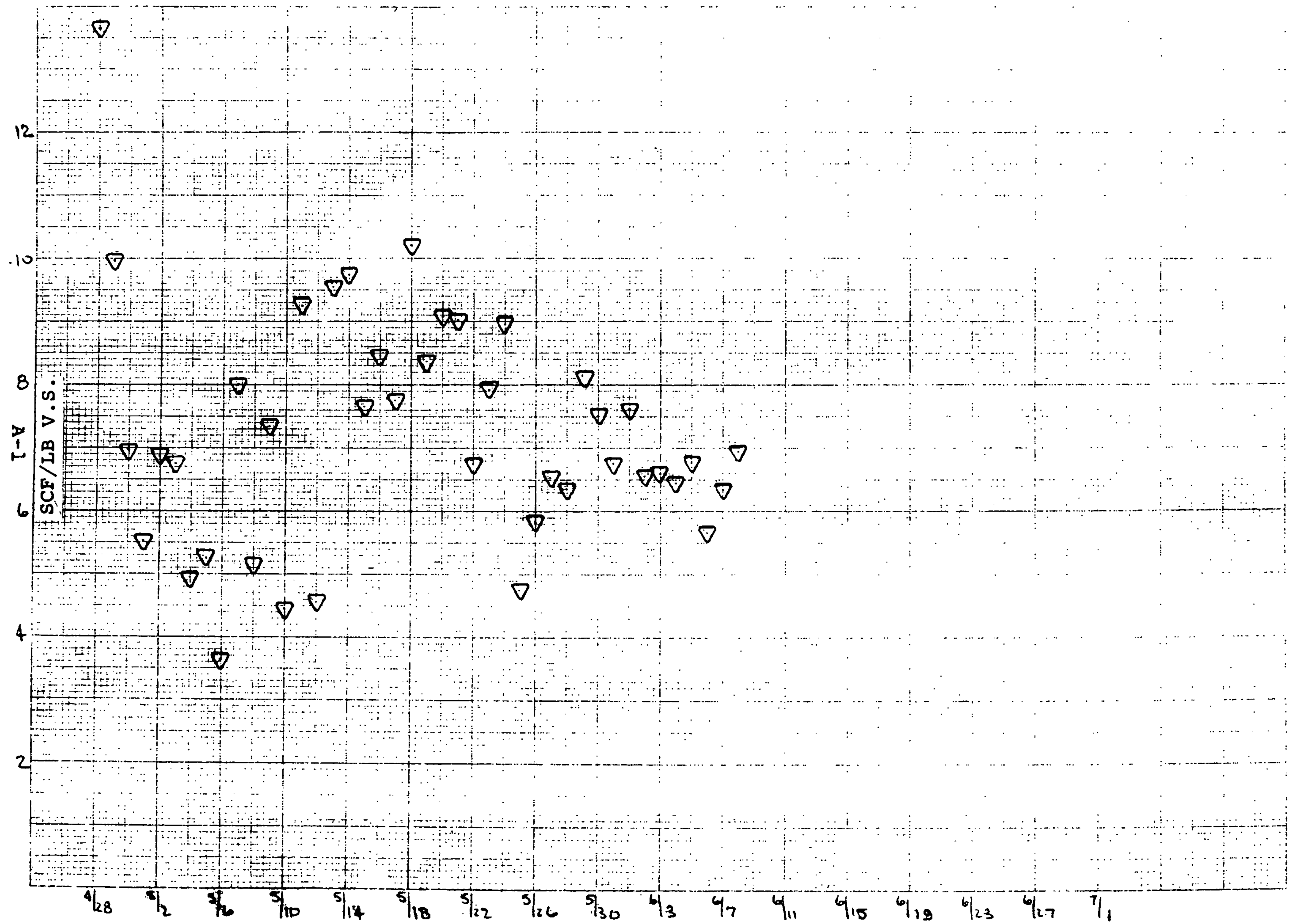
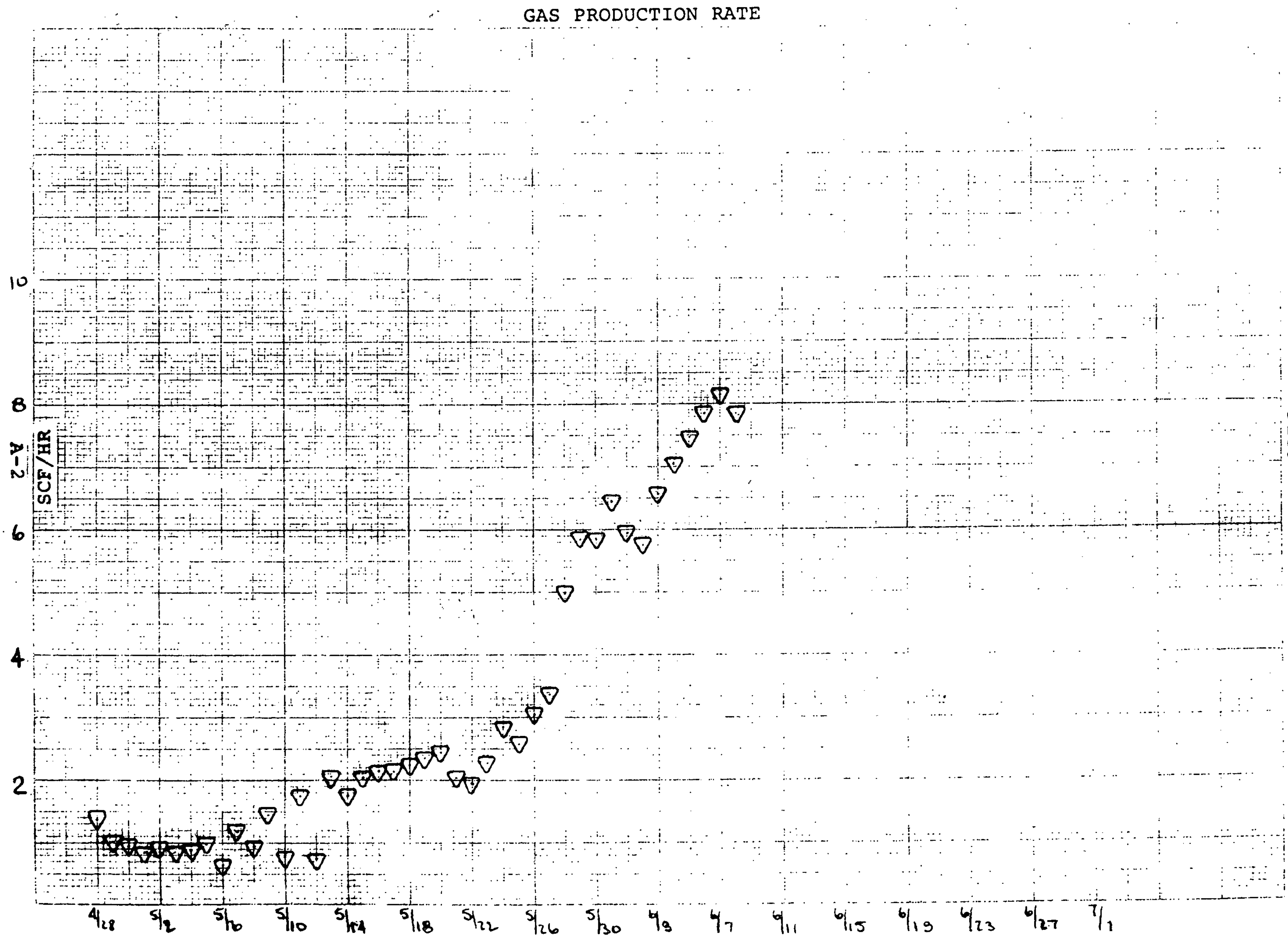


FIGURE 1


GAS PRODUCTION RATE
A-2
SCF/HR
10
8
6
4
2
4/28
5/2
5/6
5/10
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6/23
6/27
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FIGURE 2

PROCESS GAS QUALITY METHANE GAS

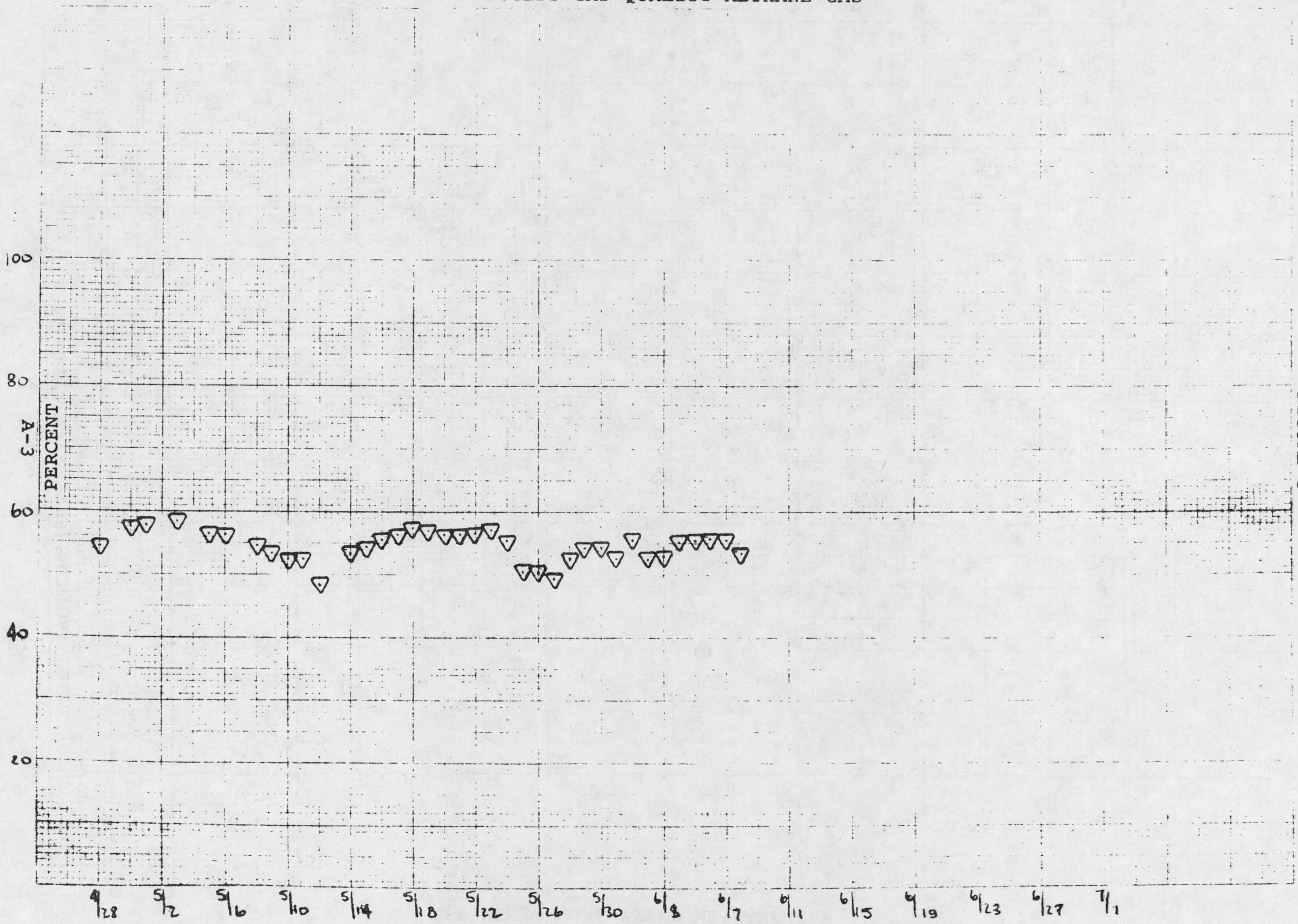


FIGURE 3

FERMENTOR GAS YIELD METHANE GAS

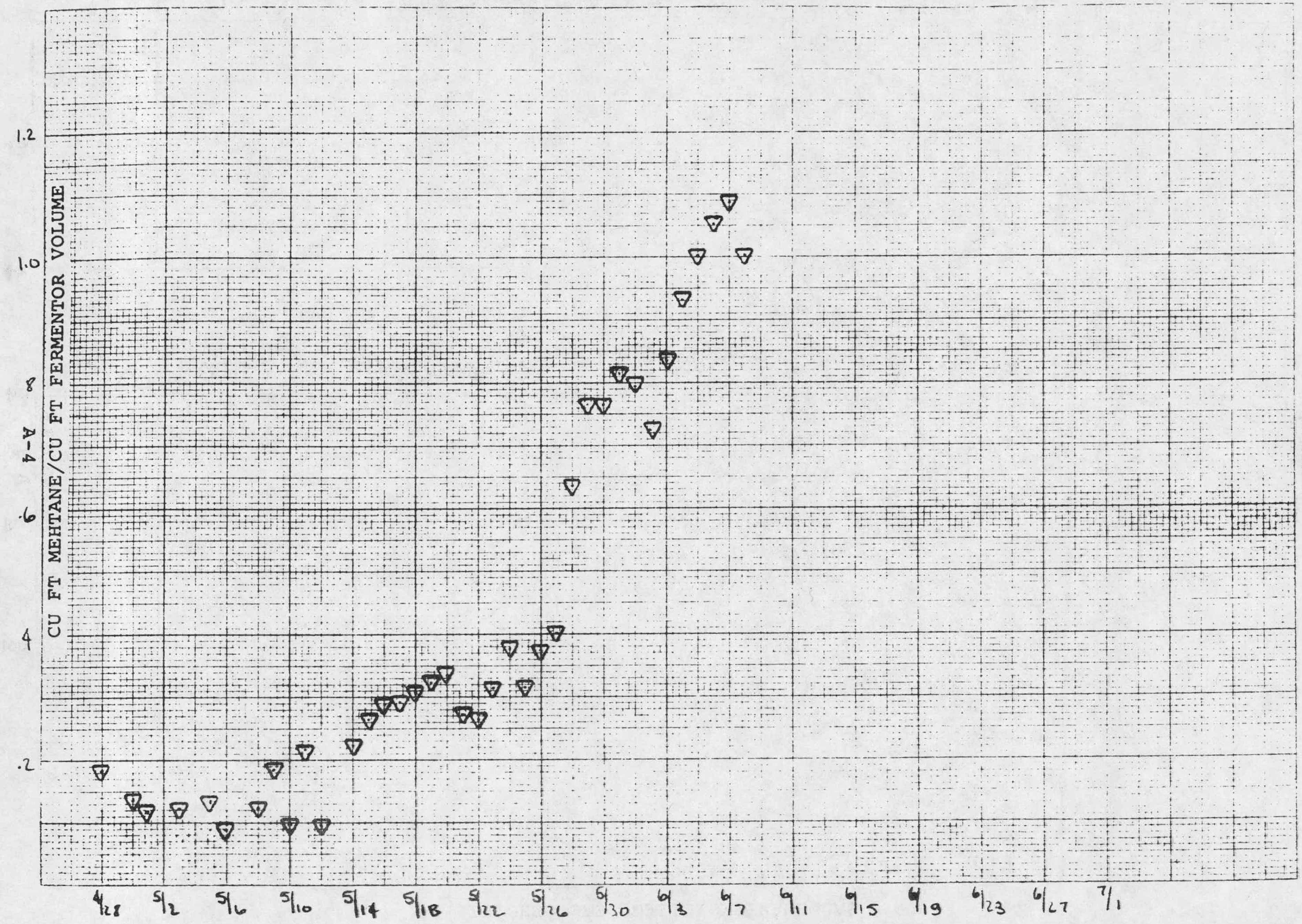


FIGURE 4

PROTEIN FERMENTATION PRODUCTS TOTAL WEIGHT

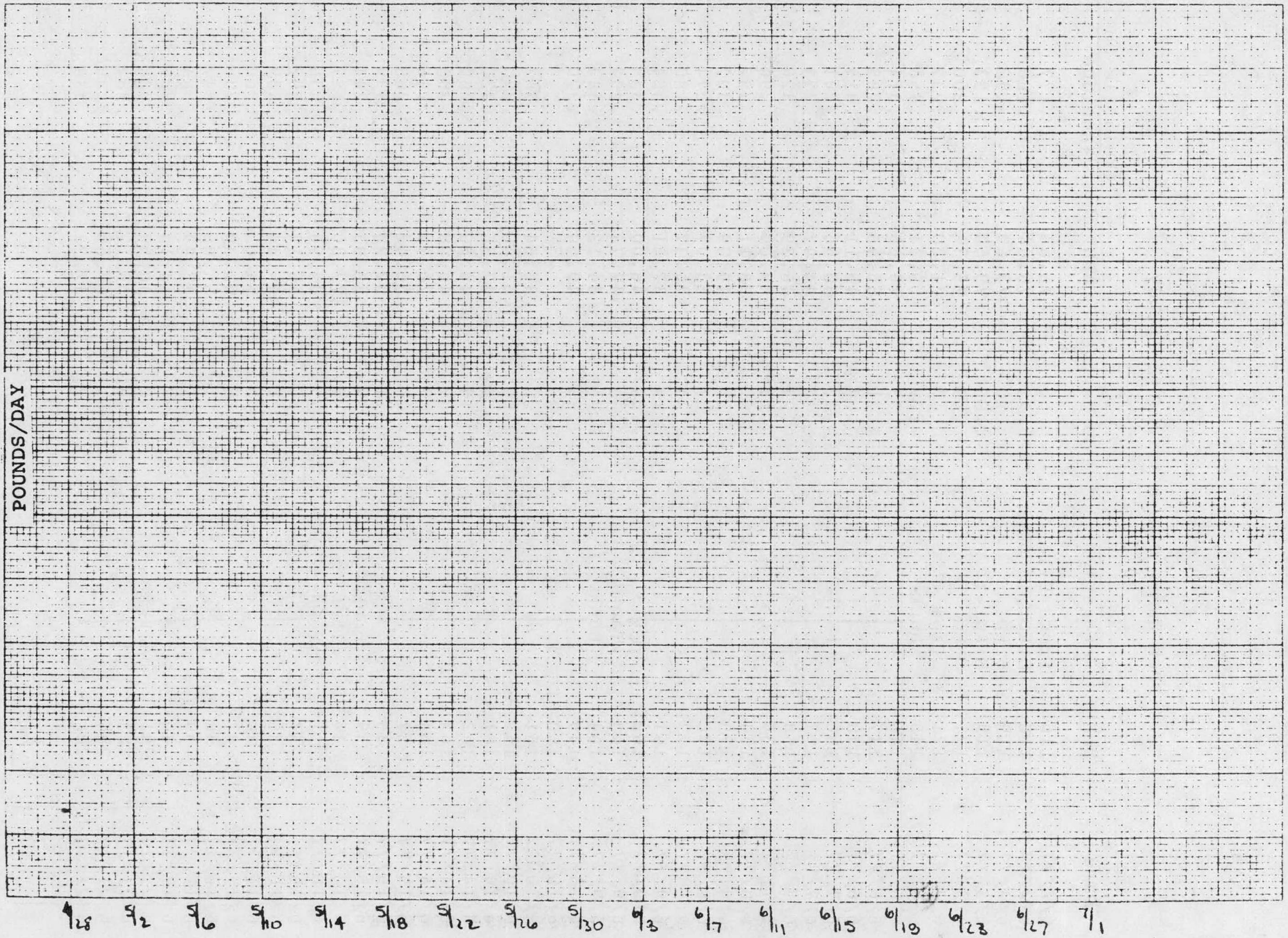


FIGURE 5

PROTEIN FERMENTATION PRODUCT DRY MATTER

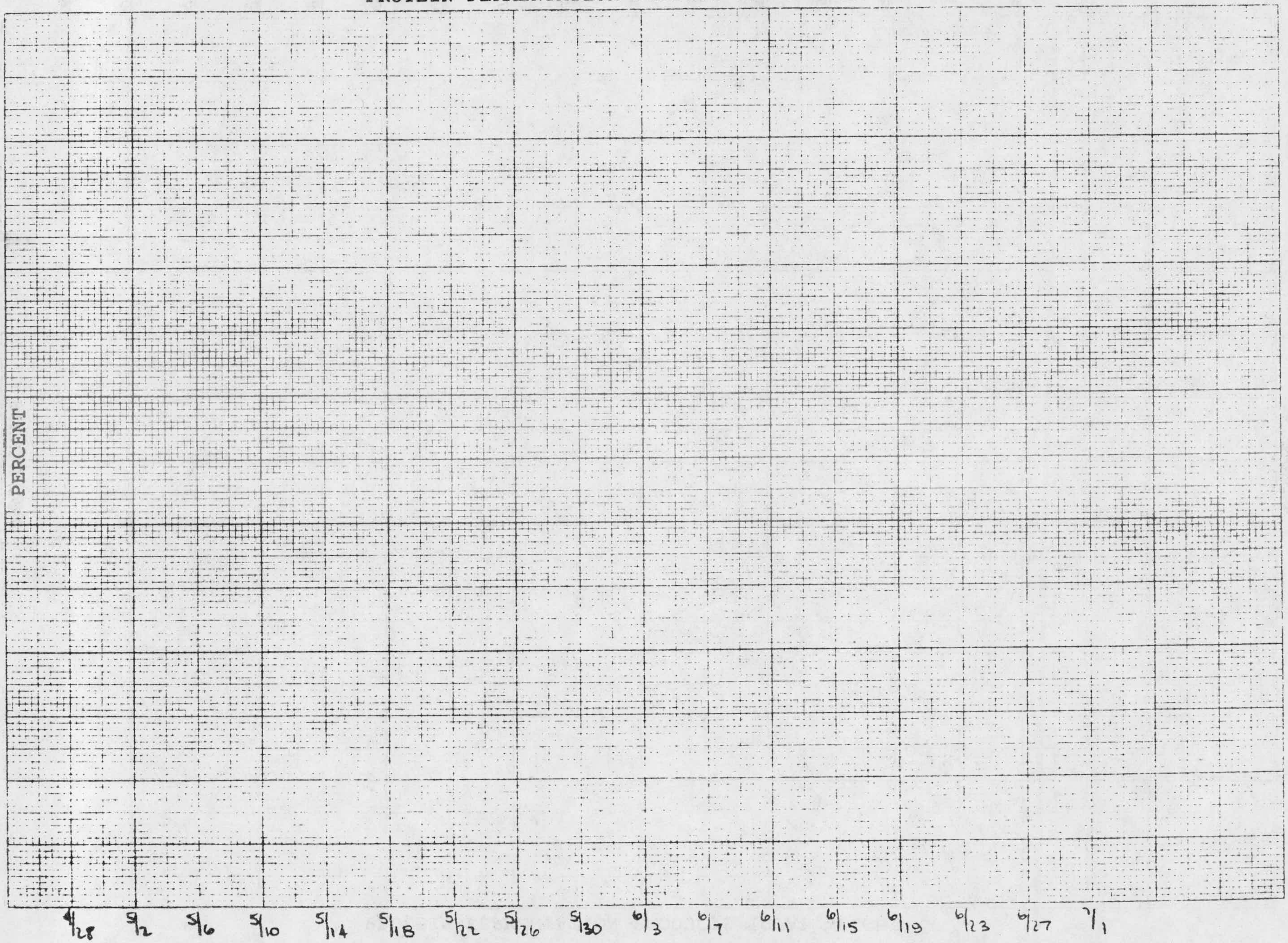


FIGURE 6

PROTEIN FERMENTATION PRODUCT CRUDE PROTEIN

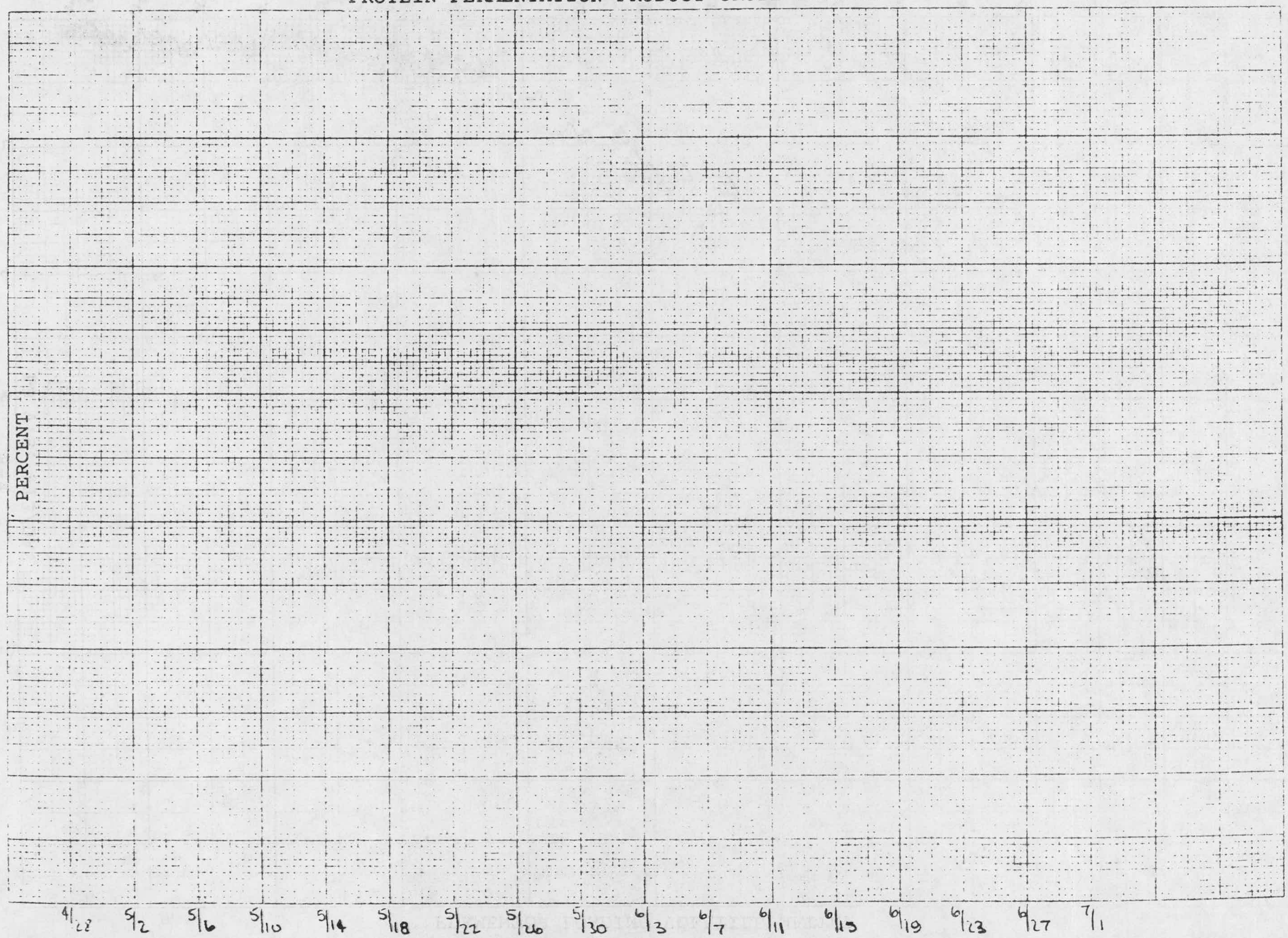


FIGURE 7

FERMENTOR LOADING VOLATILE MATTER

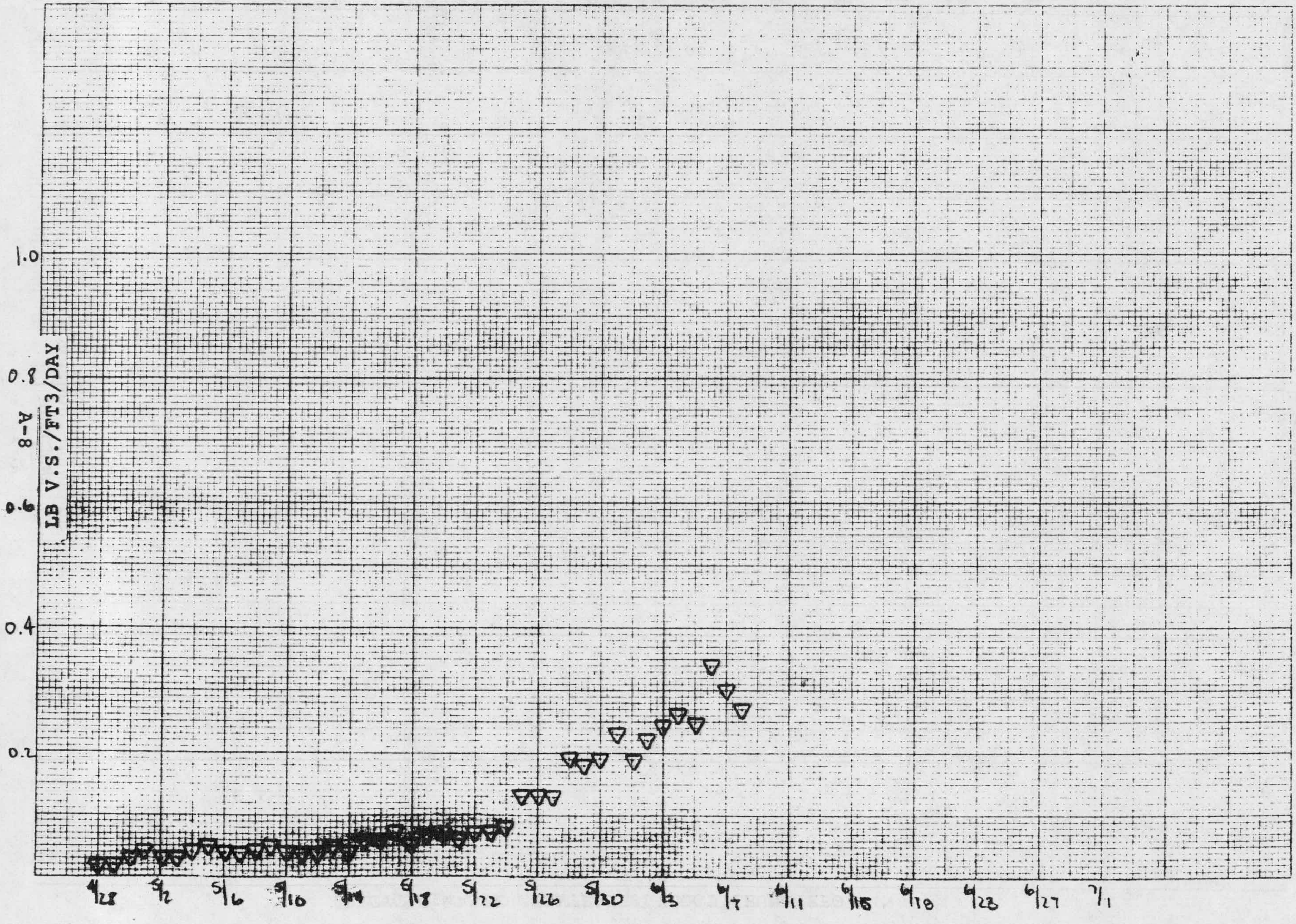


FIGURE 8

FERMENTOR RESIDENCE TIME

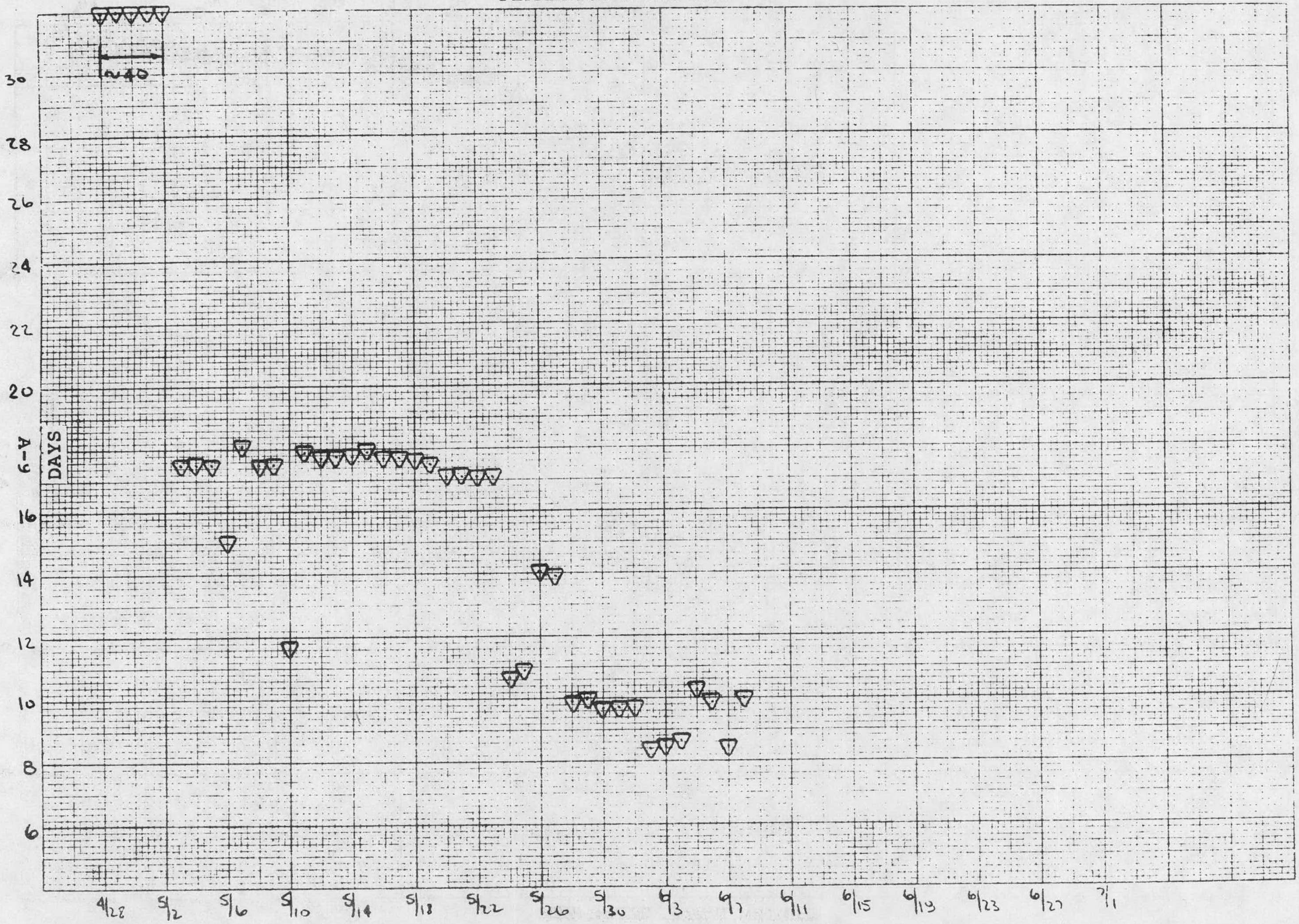


FIGURE 9

RAW WASTE TOTAL WEIGHT

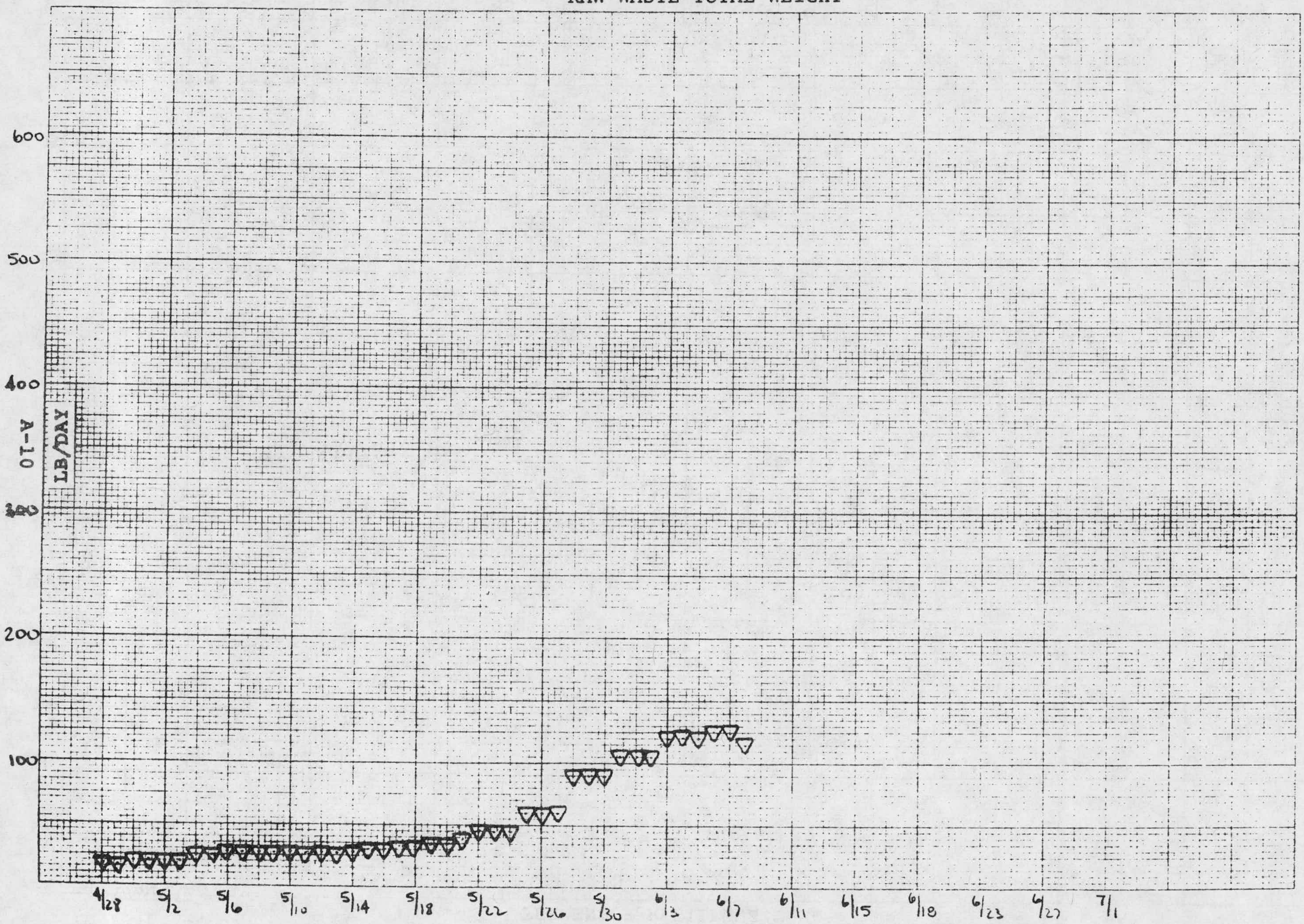


FIGURE 10

RAW WASTE DRY MATTER

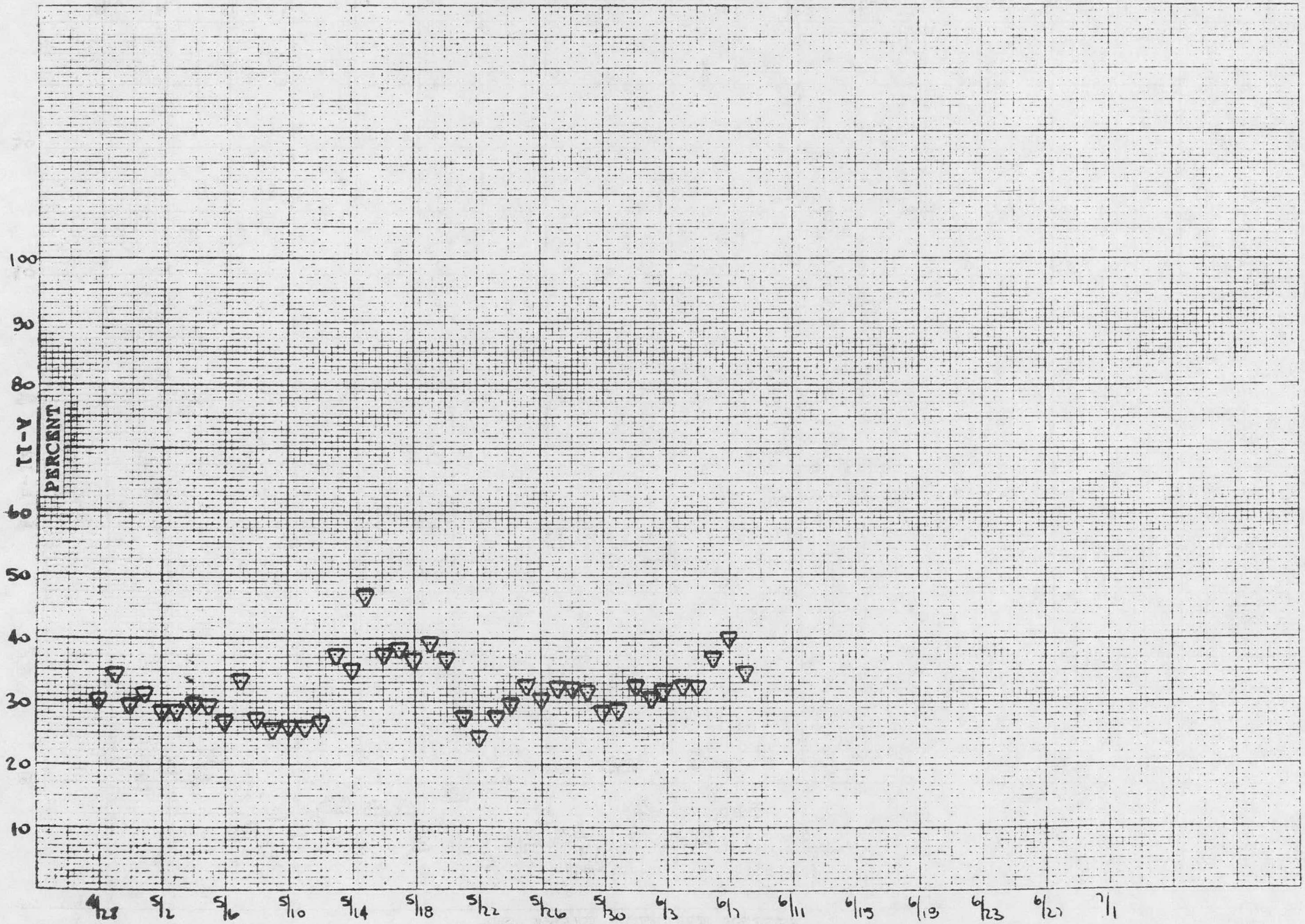


FIGURE 11

RAW WASTE VOLATILE MATTER

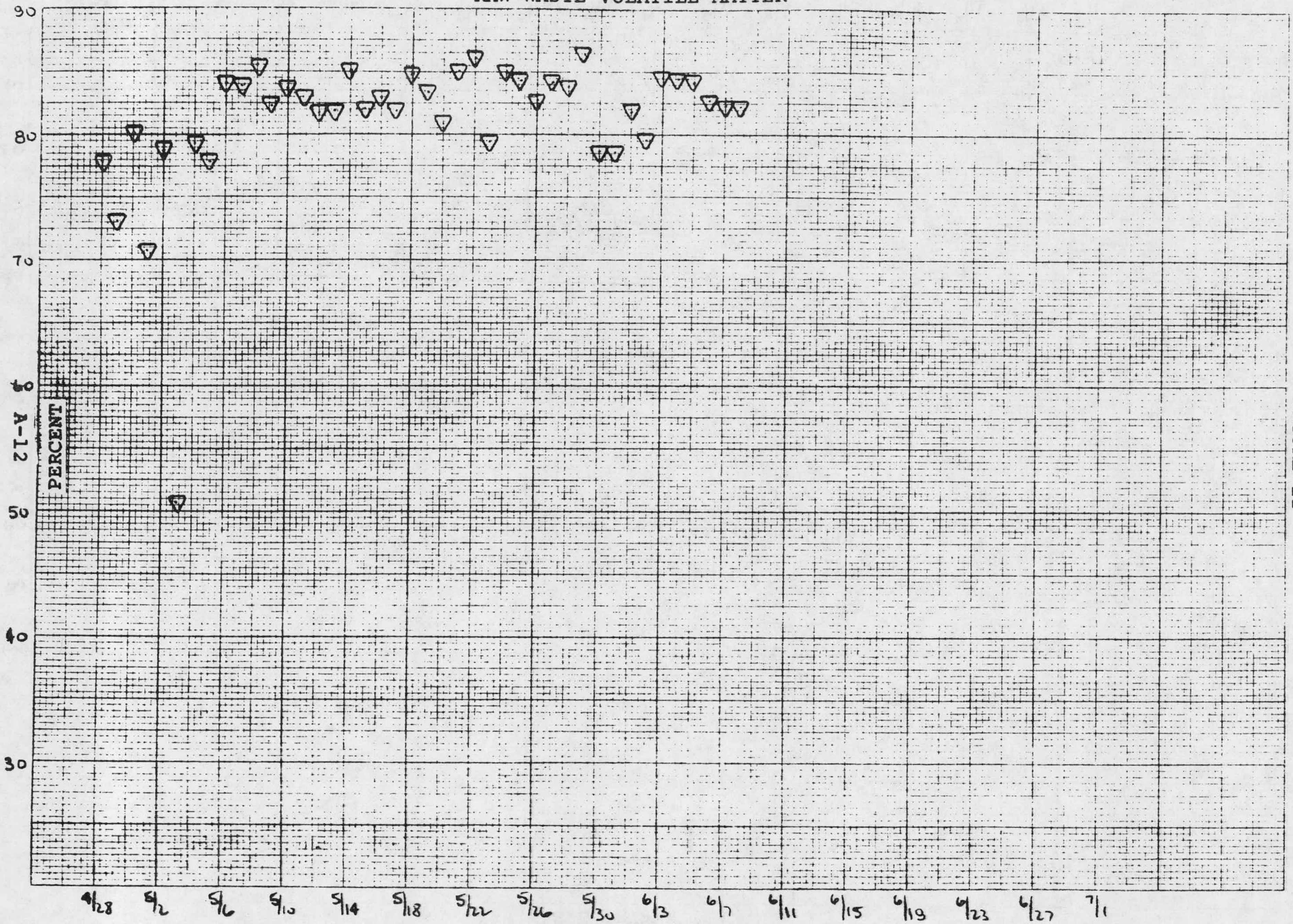


FIGURE 12

RECYCLE WASTE (CENTRATE) TOTAL WEIGHT

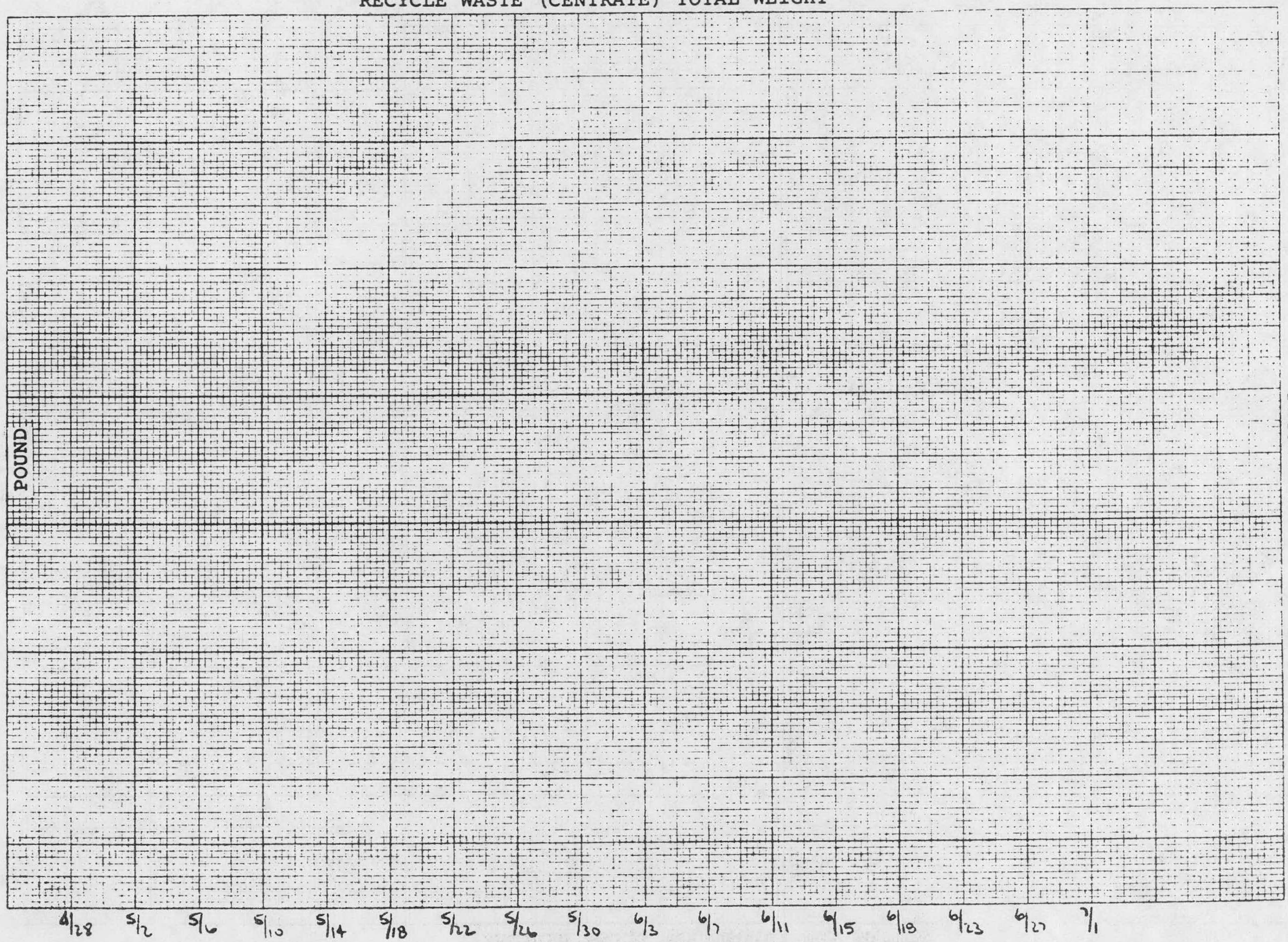


FIGURE 13

RECYCLE WASTE (CENTRATE) DRY MATTER

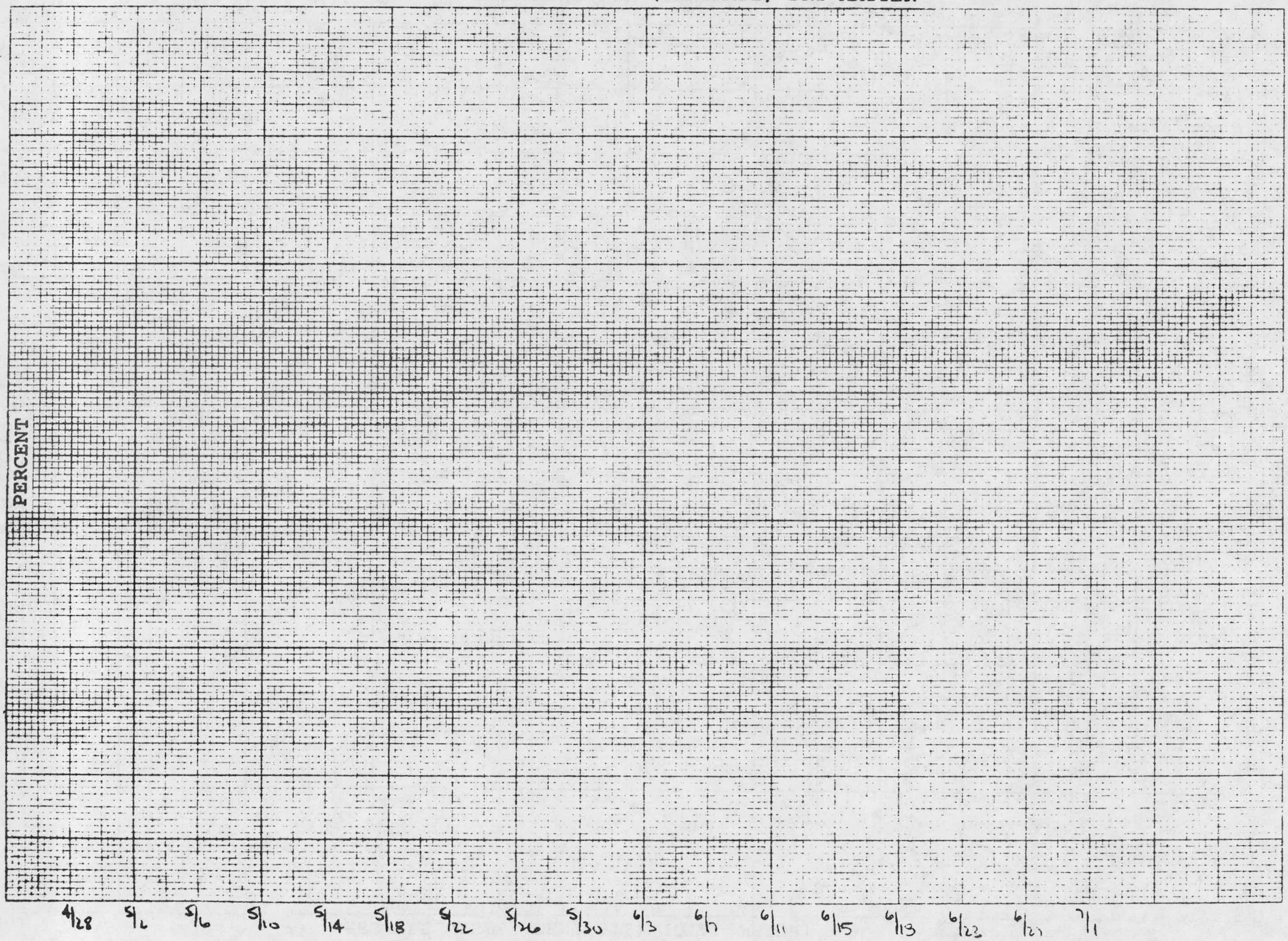


FIGURE 14

RECYCLE WASTE (CENTRATE) VOLATILE MATTER

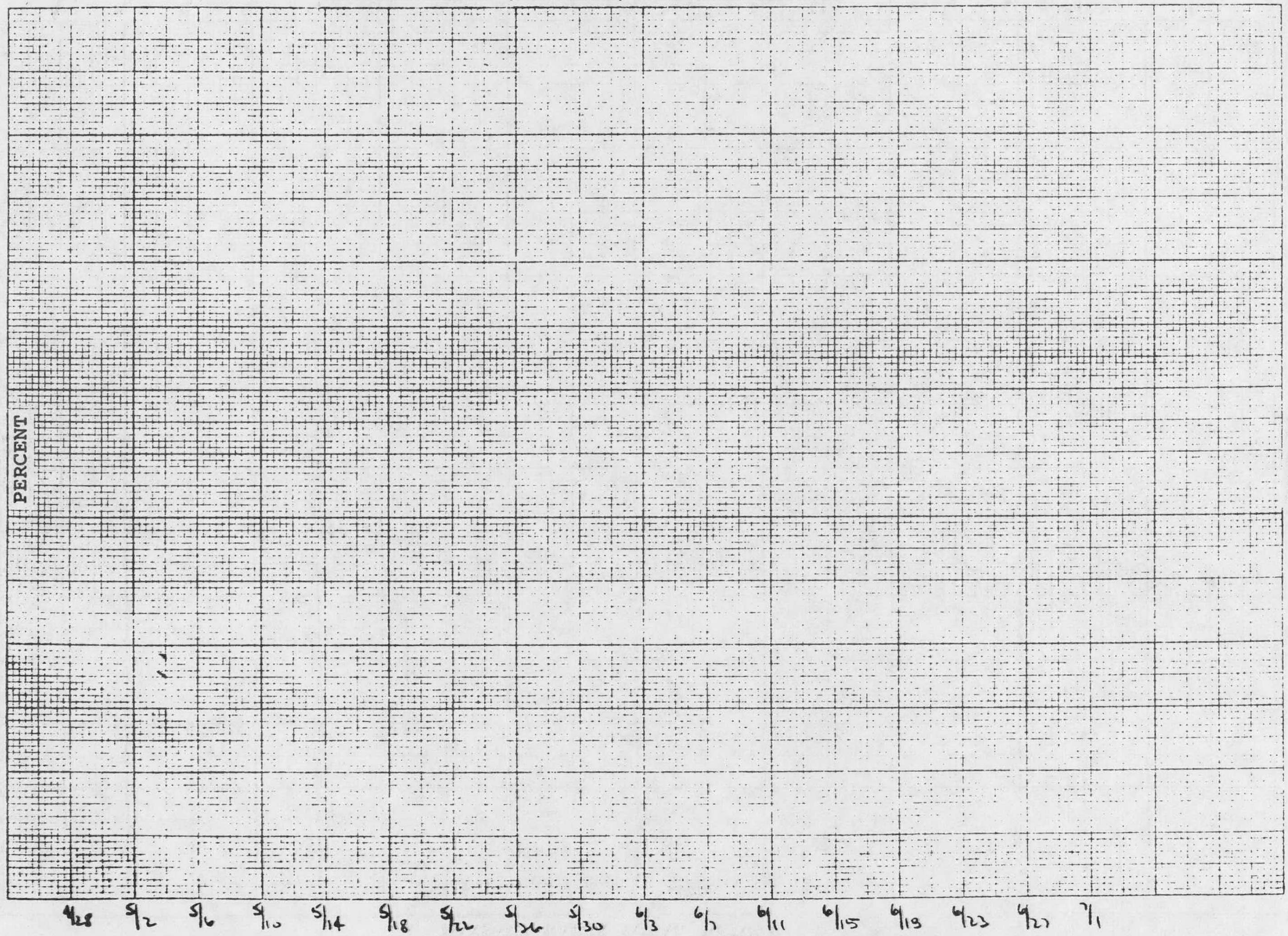


FIGURE 15

MAKE-UP WATER TOTAL WEIGHT

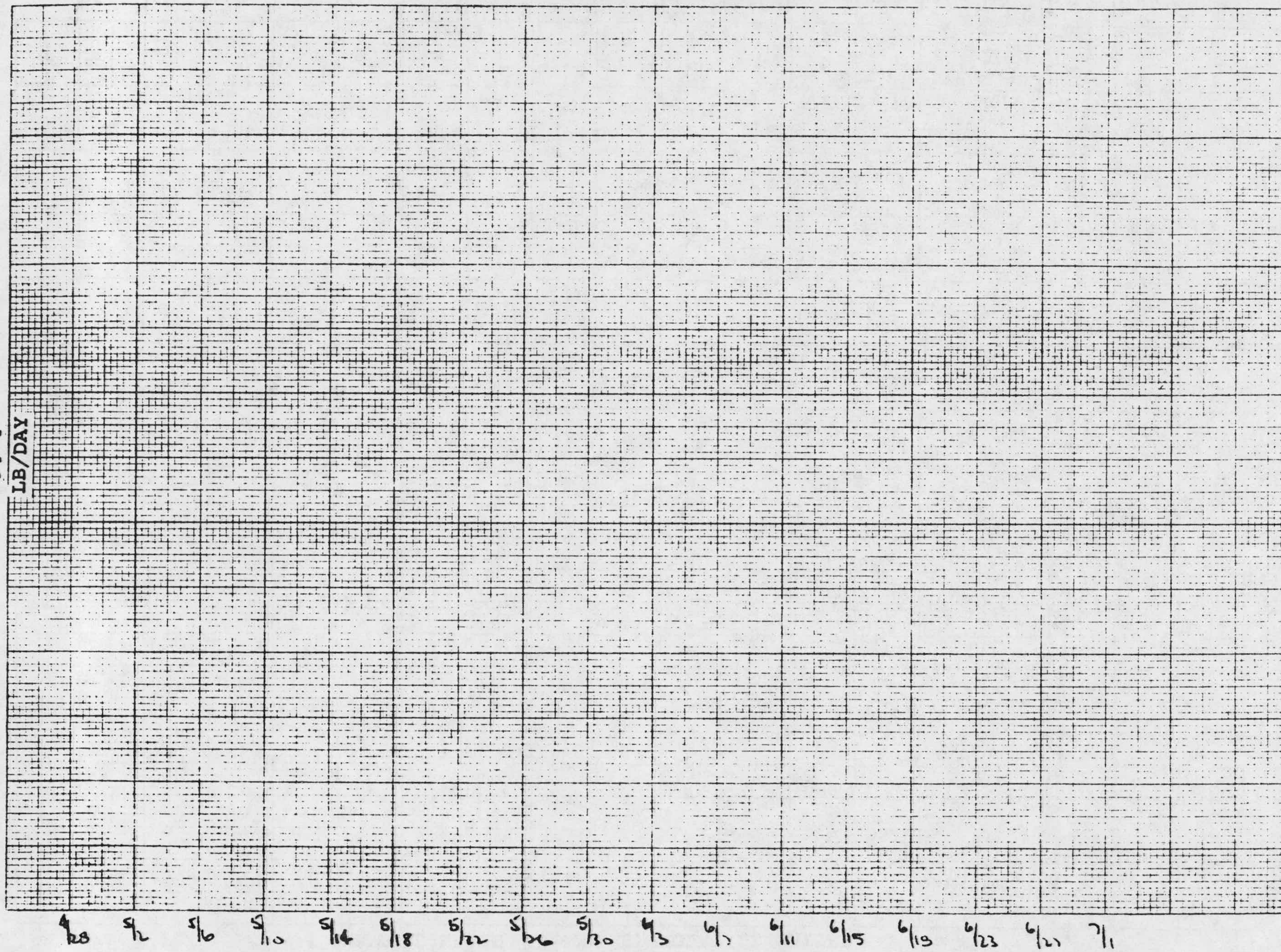


FIGURE 16

RESIDUAL GRIT VOLATILE MATTER

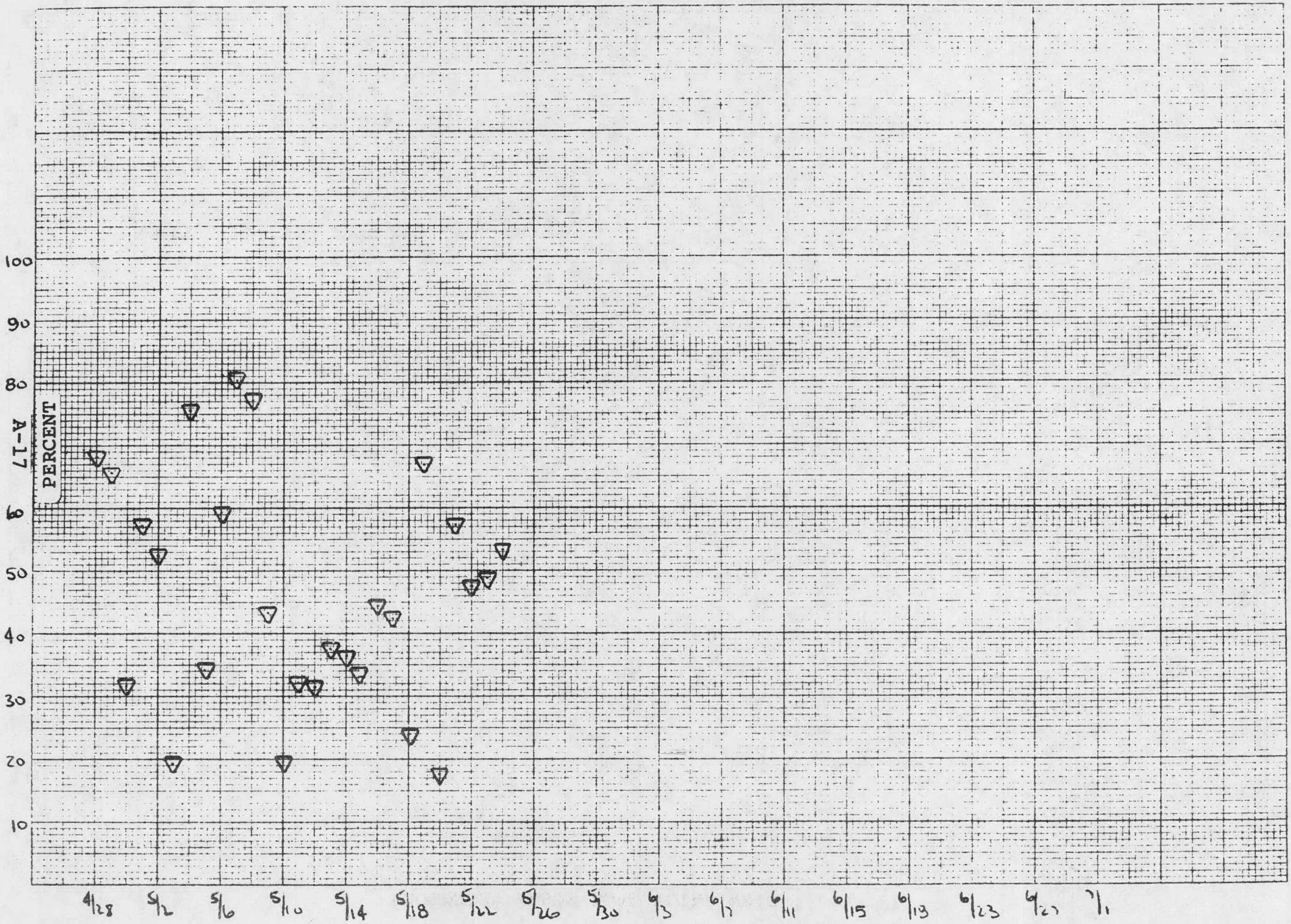


FIGURE 17

PROCESSED WASTE LOAD TOTAL WEIGHT

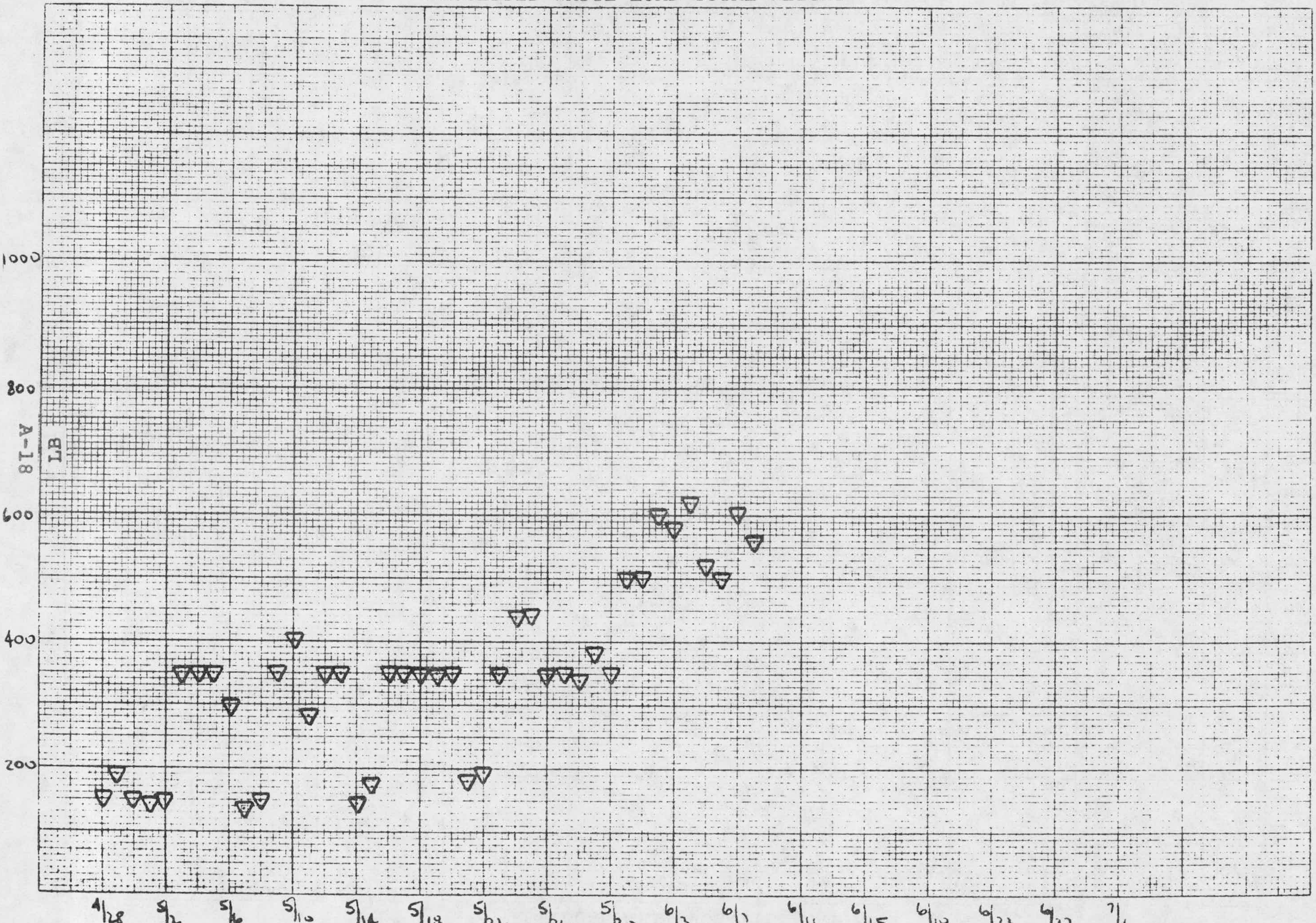


FIGURE 18

PROCESSED WASTE LOAD DRY MATTER

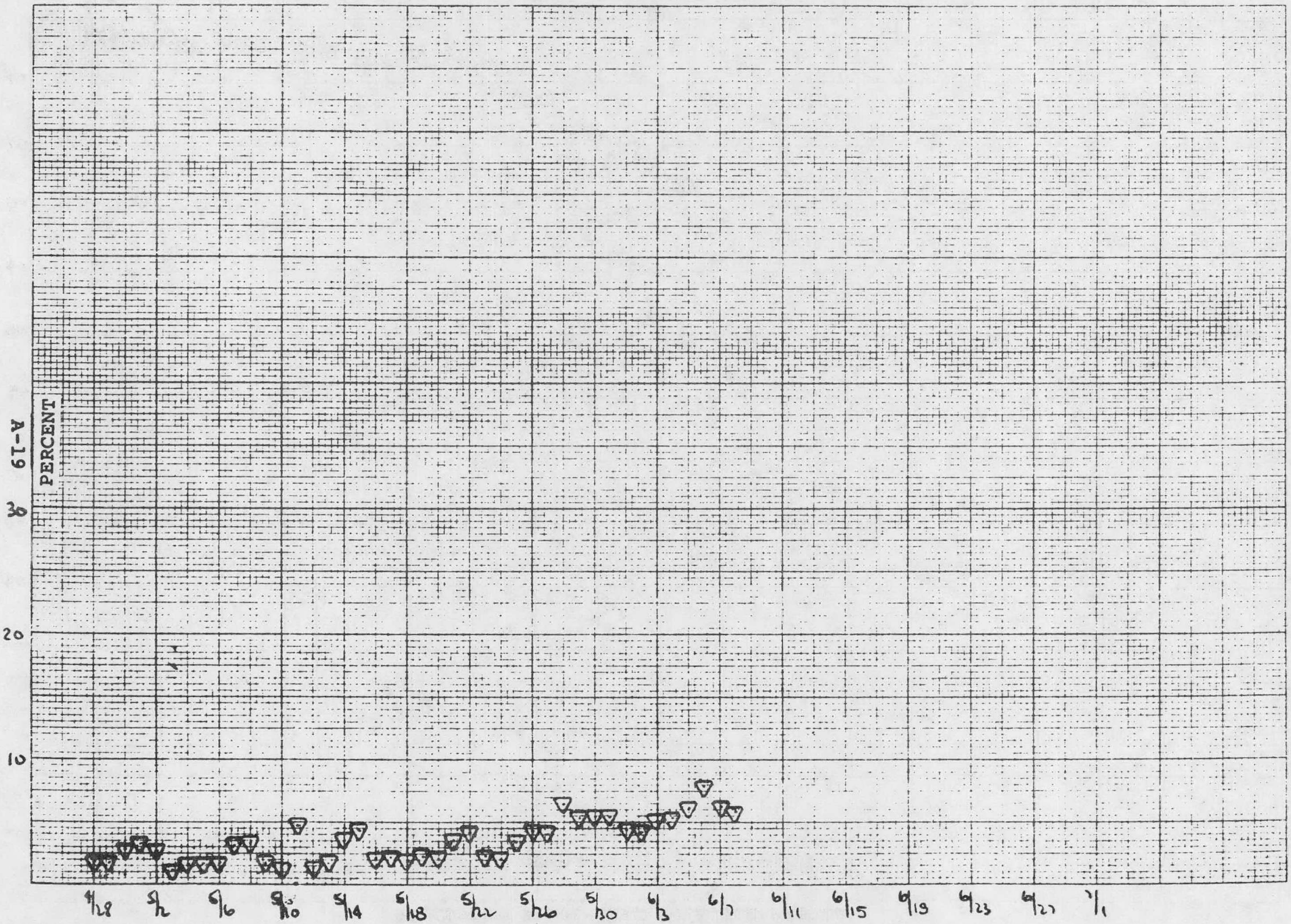
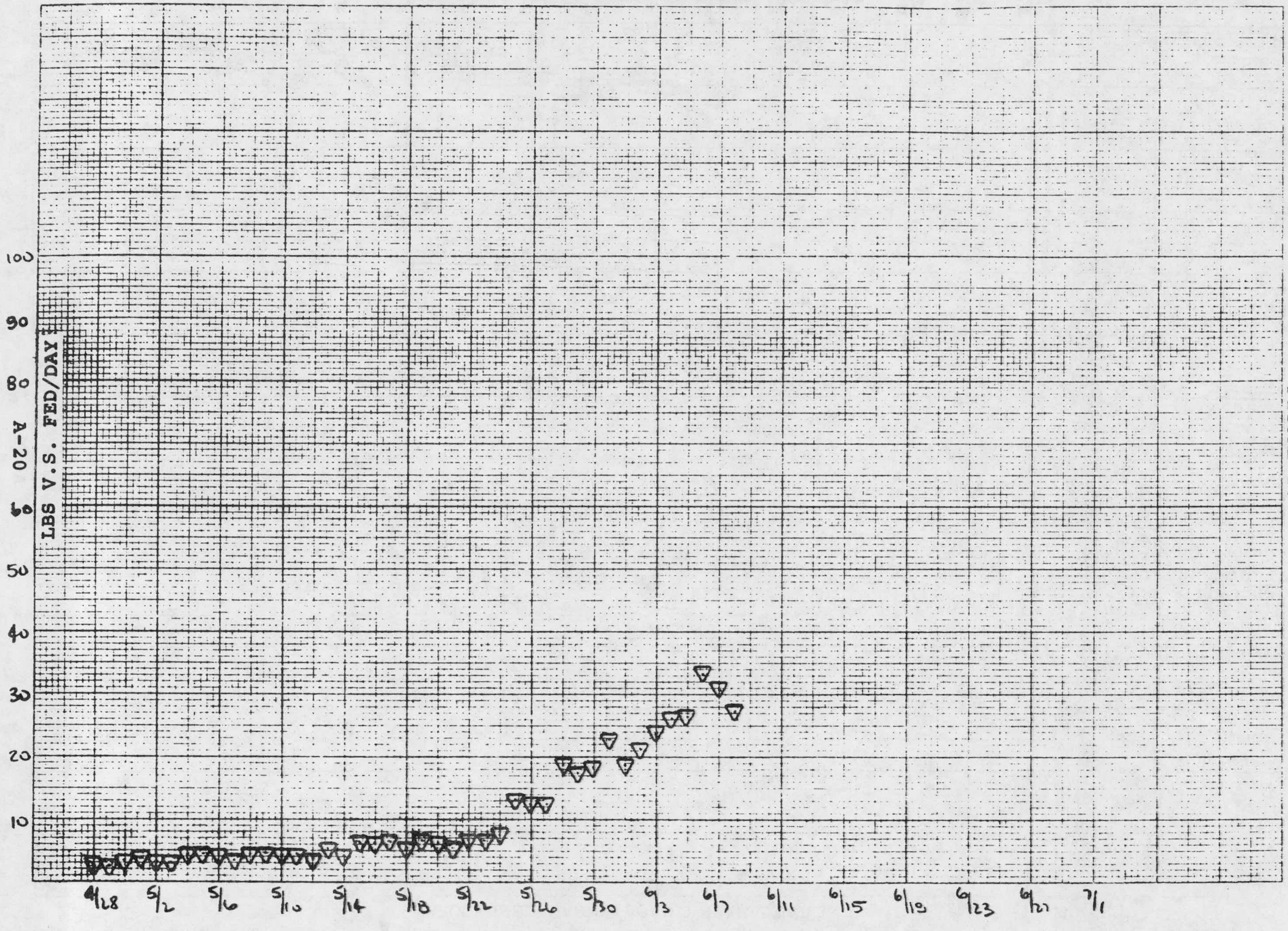


FIGURE 19

PROCESSED WASTE LOAD VOLATILE MATTER



A-20

FIGURE 20

PROCESSED WASTE LOAD pH

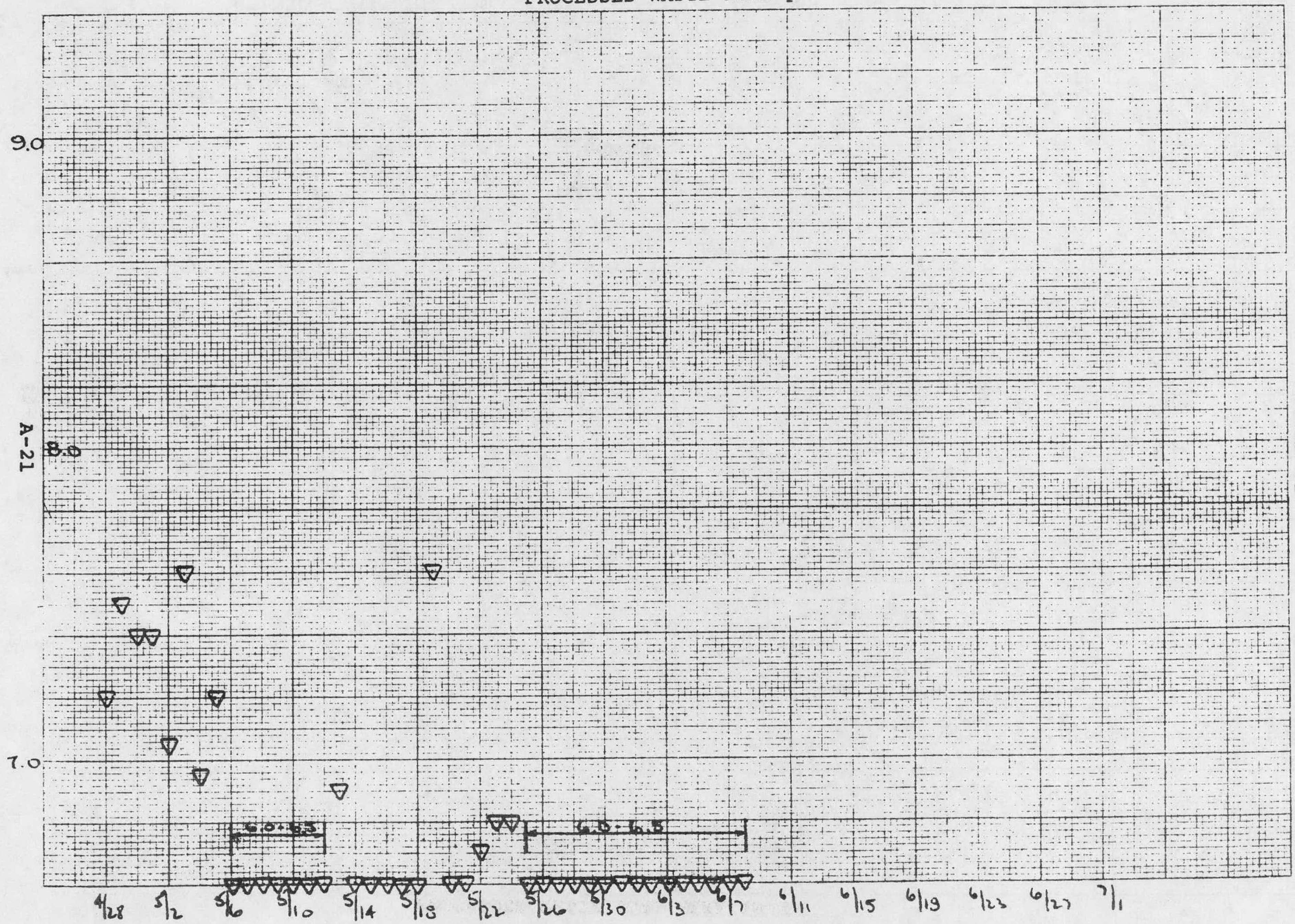


FIGURE 21

PROCESSED WASTE LOAD ALKALINITY

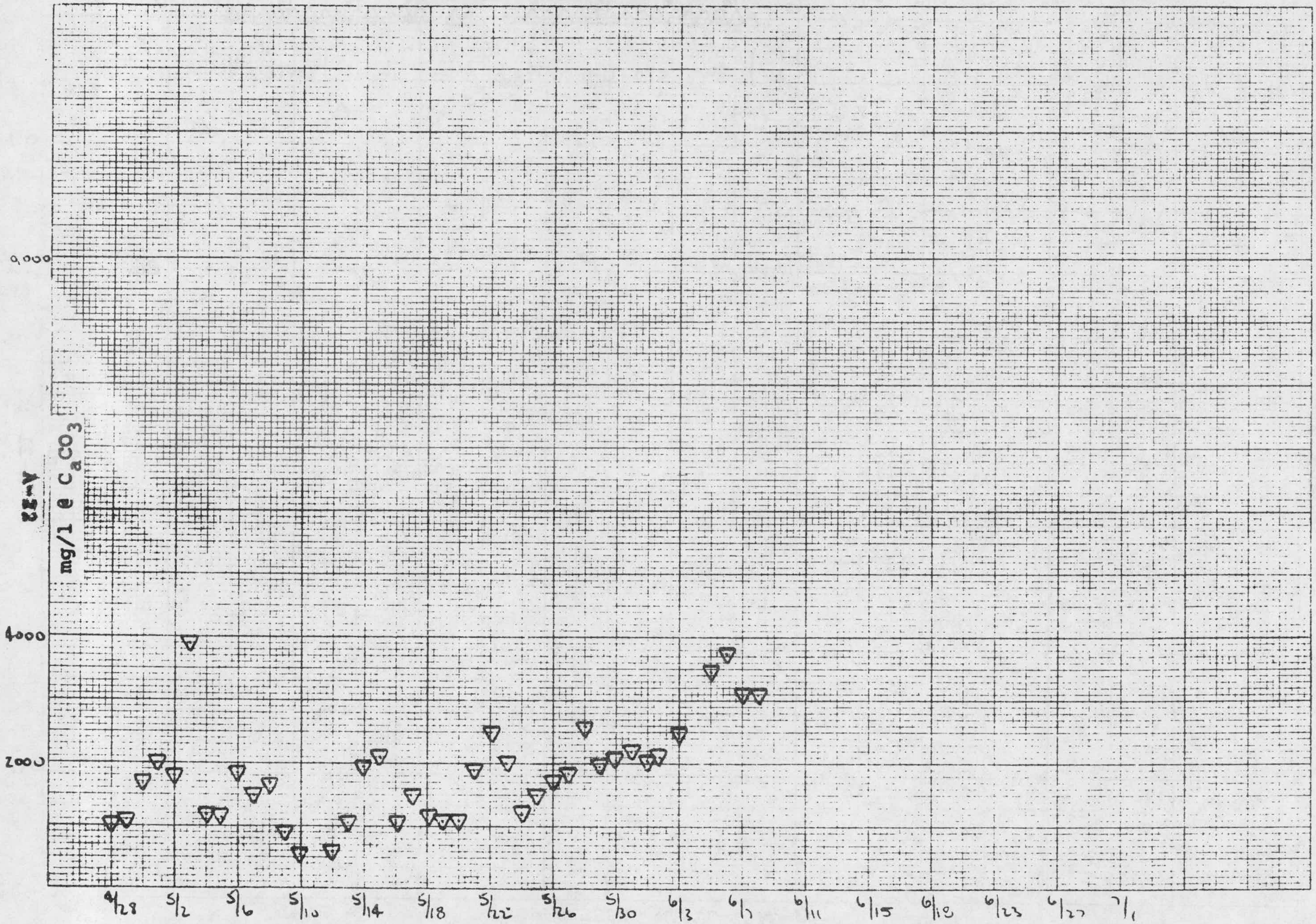


FIGURE 22

PROCESSED WASTE LOAD TOTAL VOLATILE ACIDS

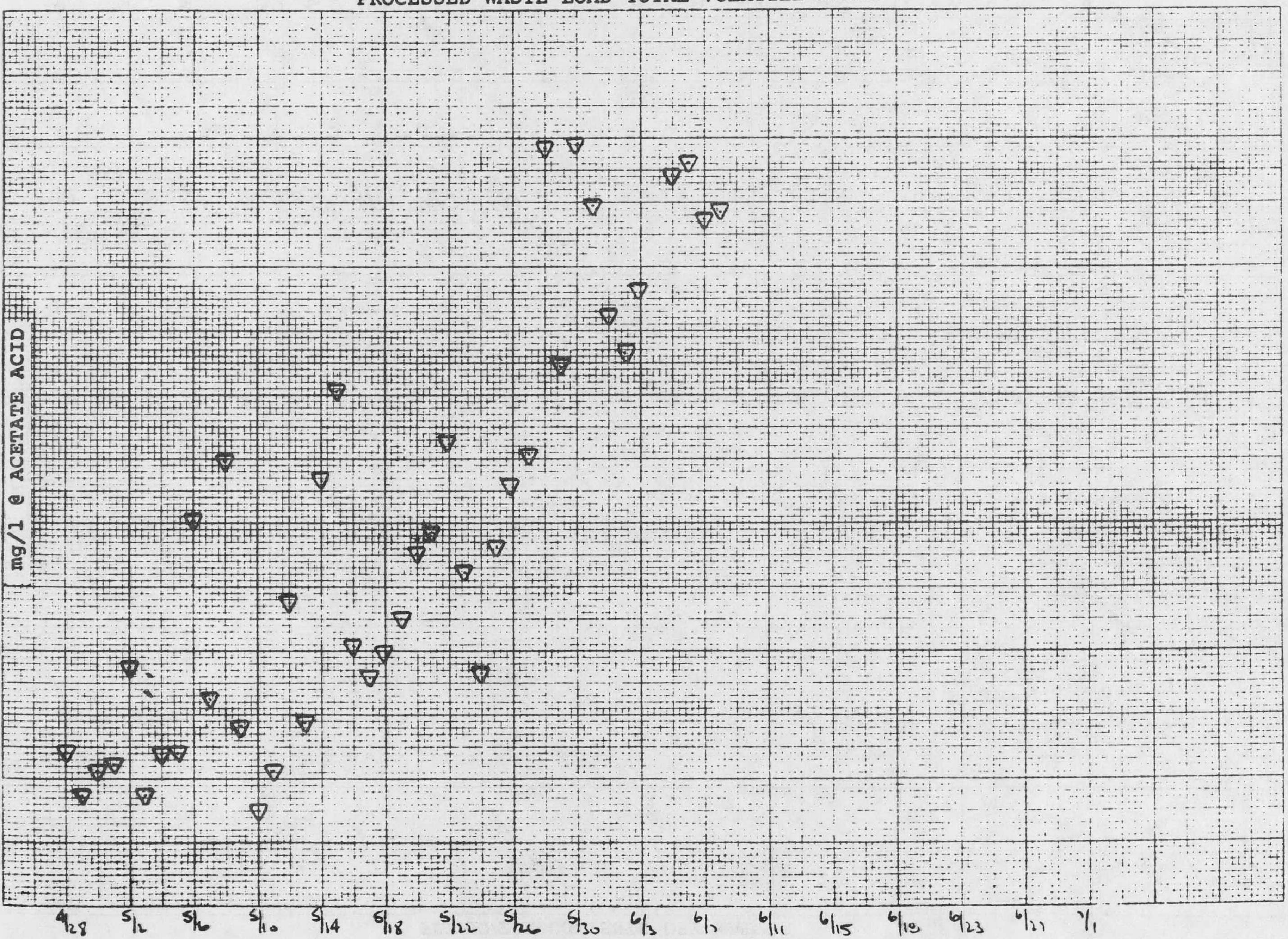


FIGURE 23

FERMENTOR CONTENTS DRY MATTER

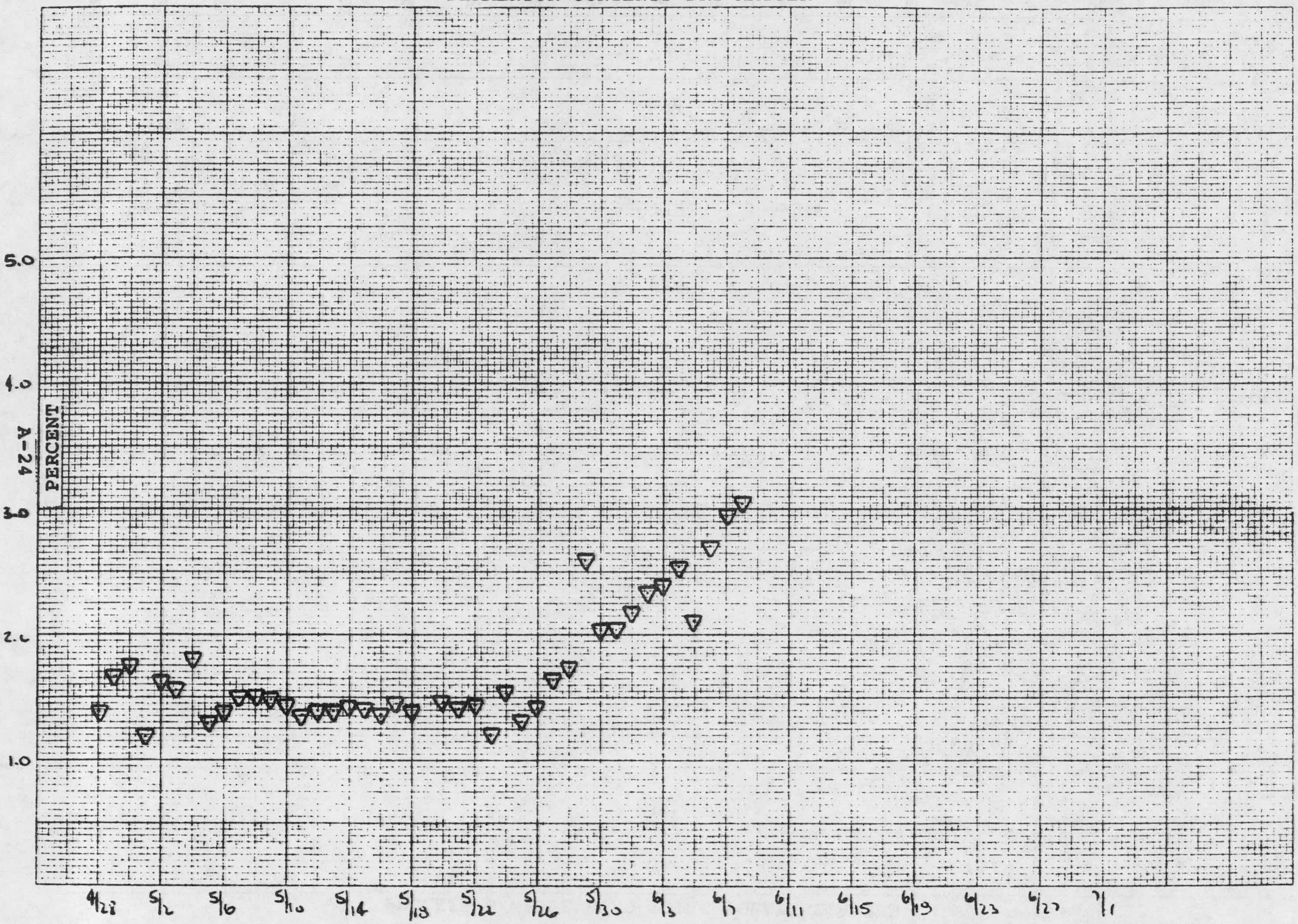


FIGURE 24

FERMENTOR CONTENTS VOLATILE MATTER

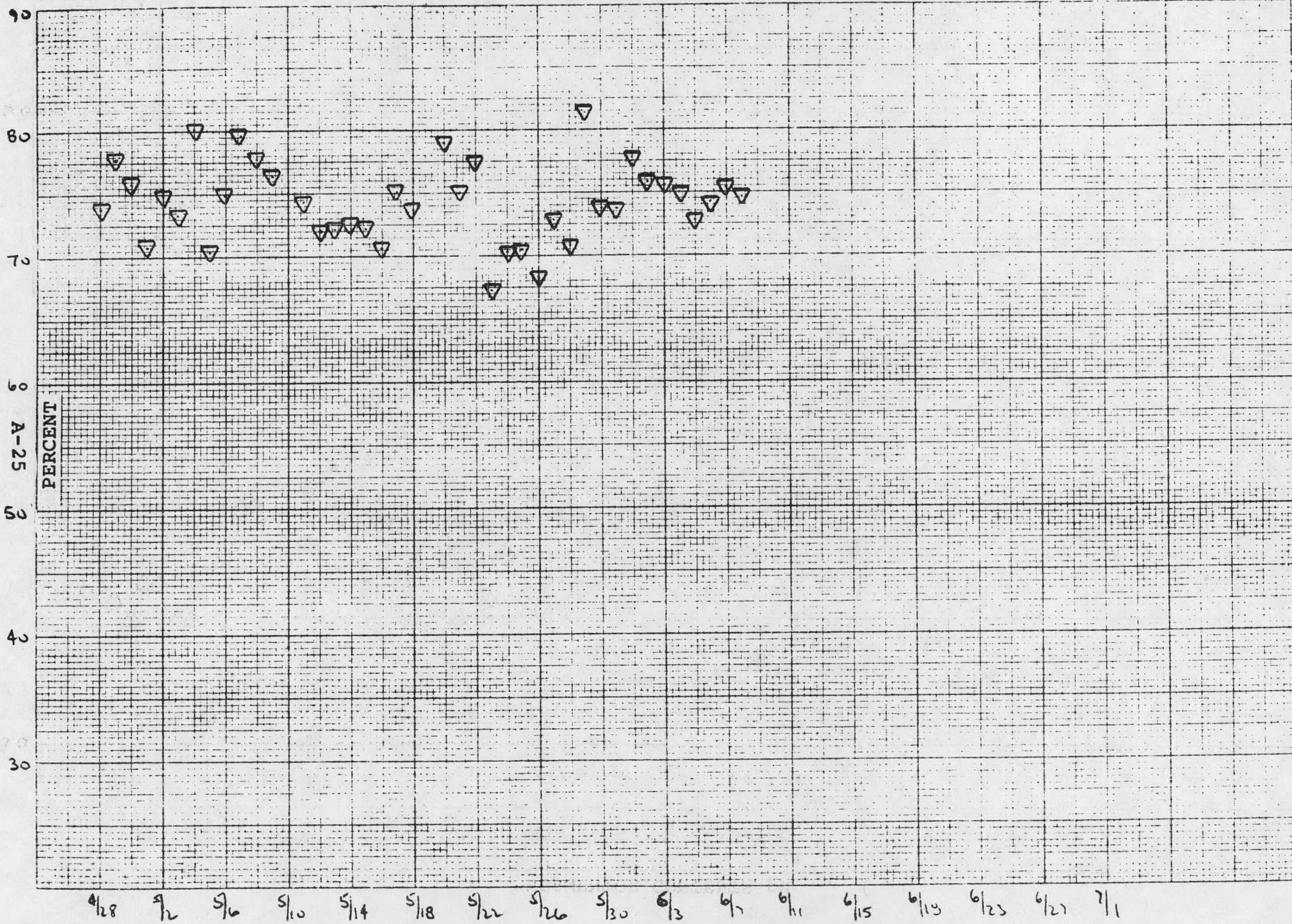


FIGURE 25

FERMENTOR CONTENTS pH

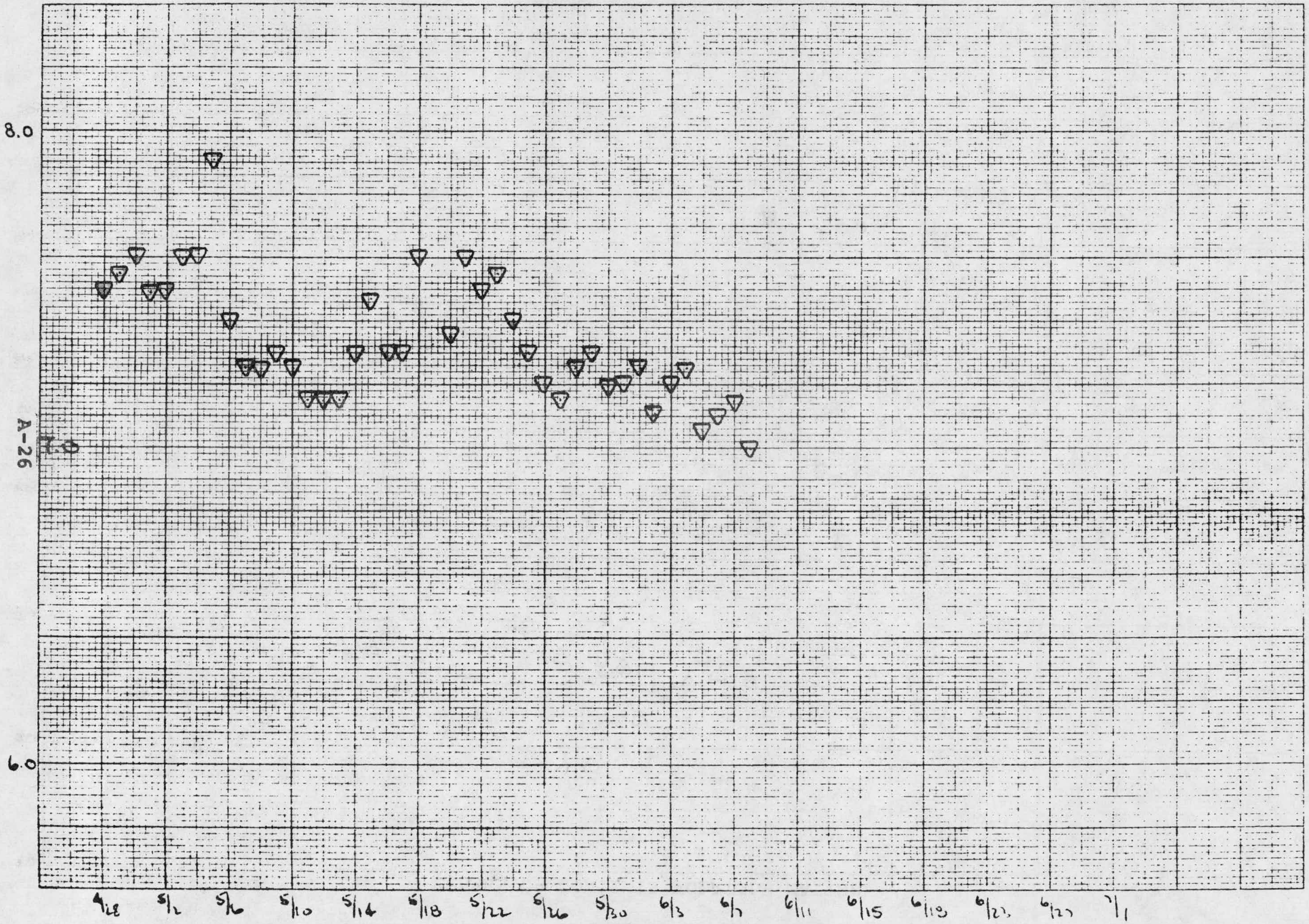


FIGURE 26

FERMENTOR CONTENTS ALKALINITY

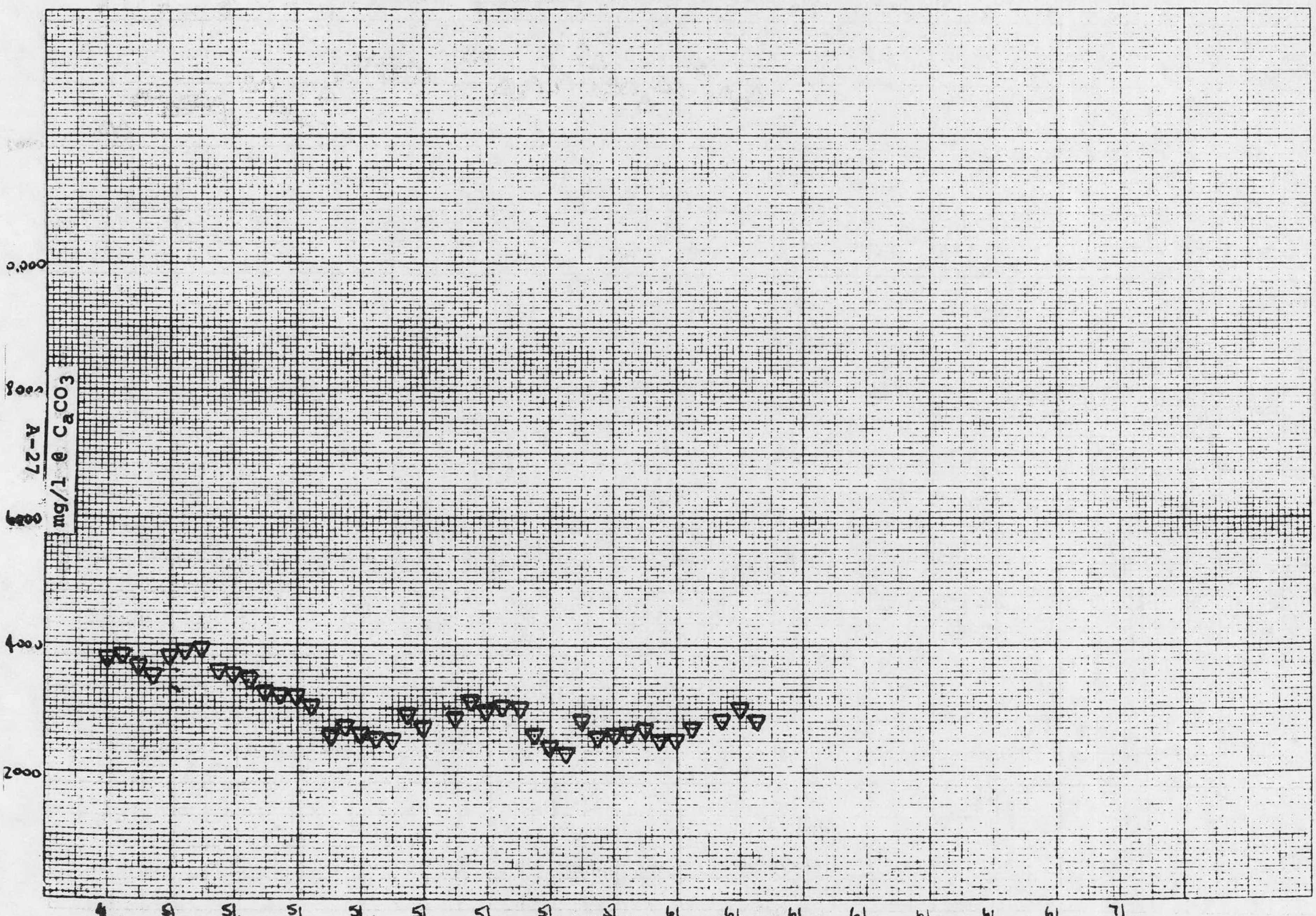


FIGURE 27

FERMENTOR CONTENTS TVA

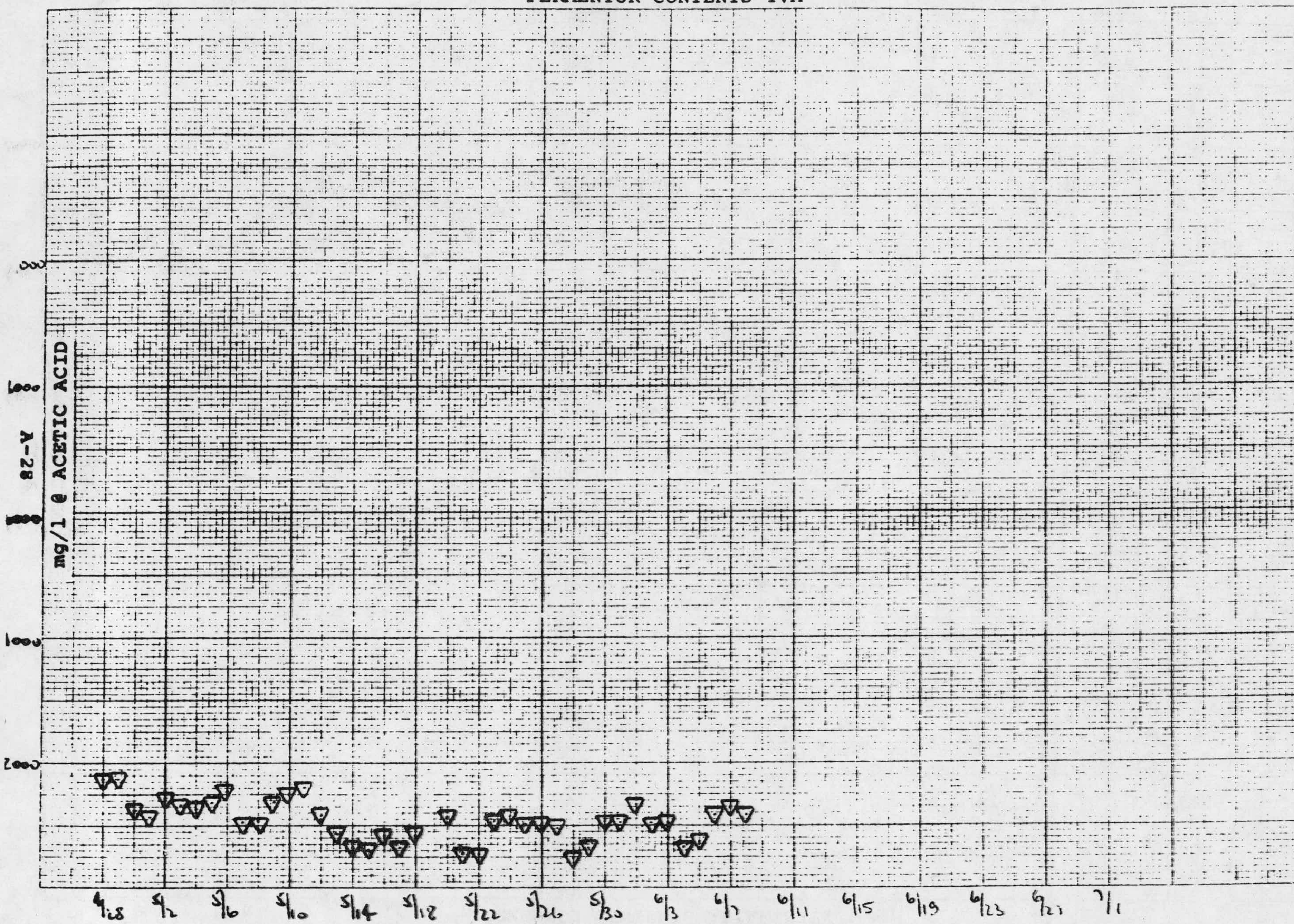


FIGURE 28

FERMENTOR TEMP

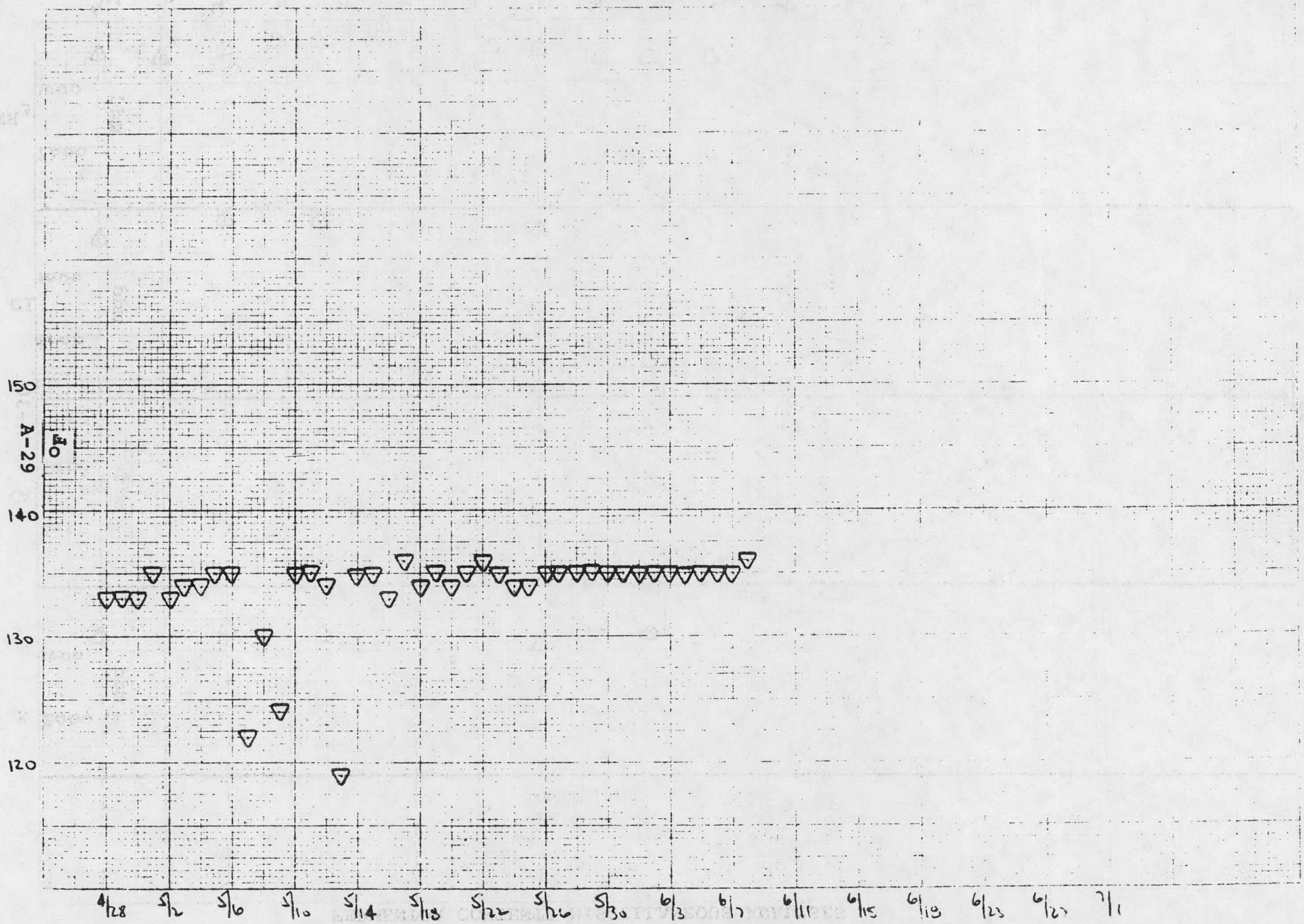


FIGURE 29

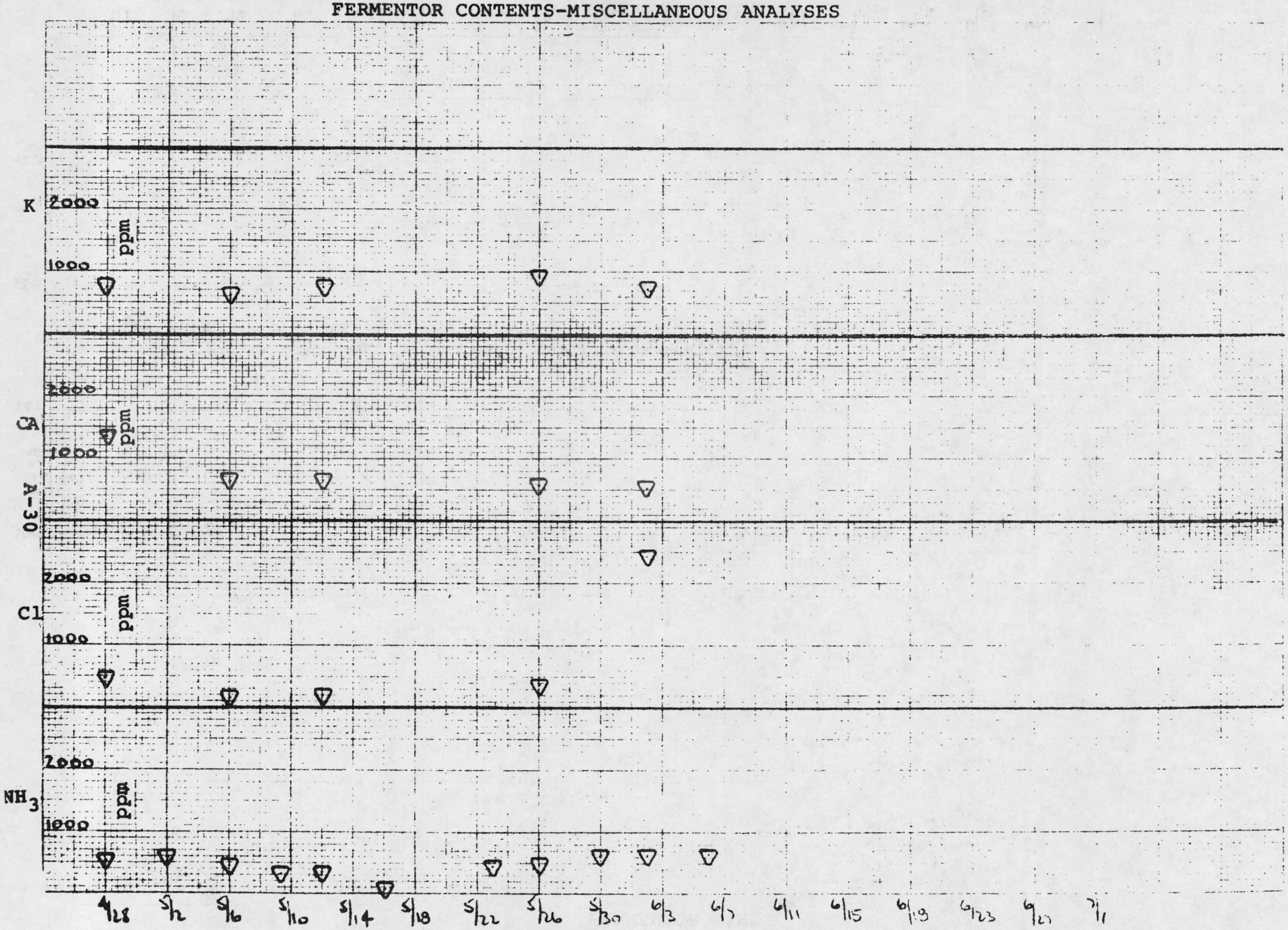

FERMENTOR CONTENTS-MISCELLANEOUS ANALYSES
K
CA
A-30
Cl
NH3
ppm
2000
1000
4/28
5/2
5/6
5/10
5/14
5/18
5/22
5/26
5/30
6/3
6/7
6/11
6/15
6/19
6/23
6/27
7/1

FIGURE 30

FERMENTOR CONTENTS-MISCELLANEOUS ANALYSES

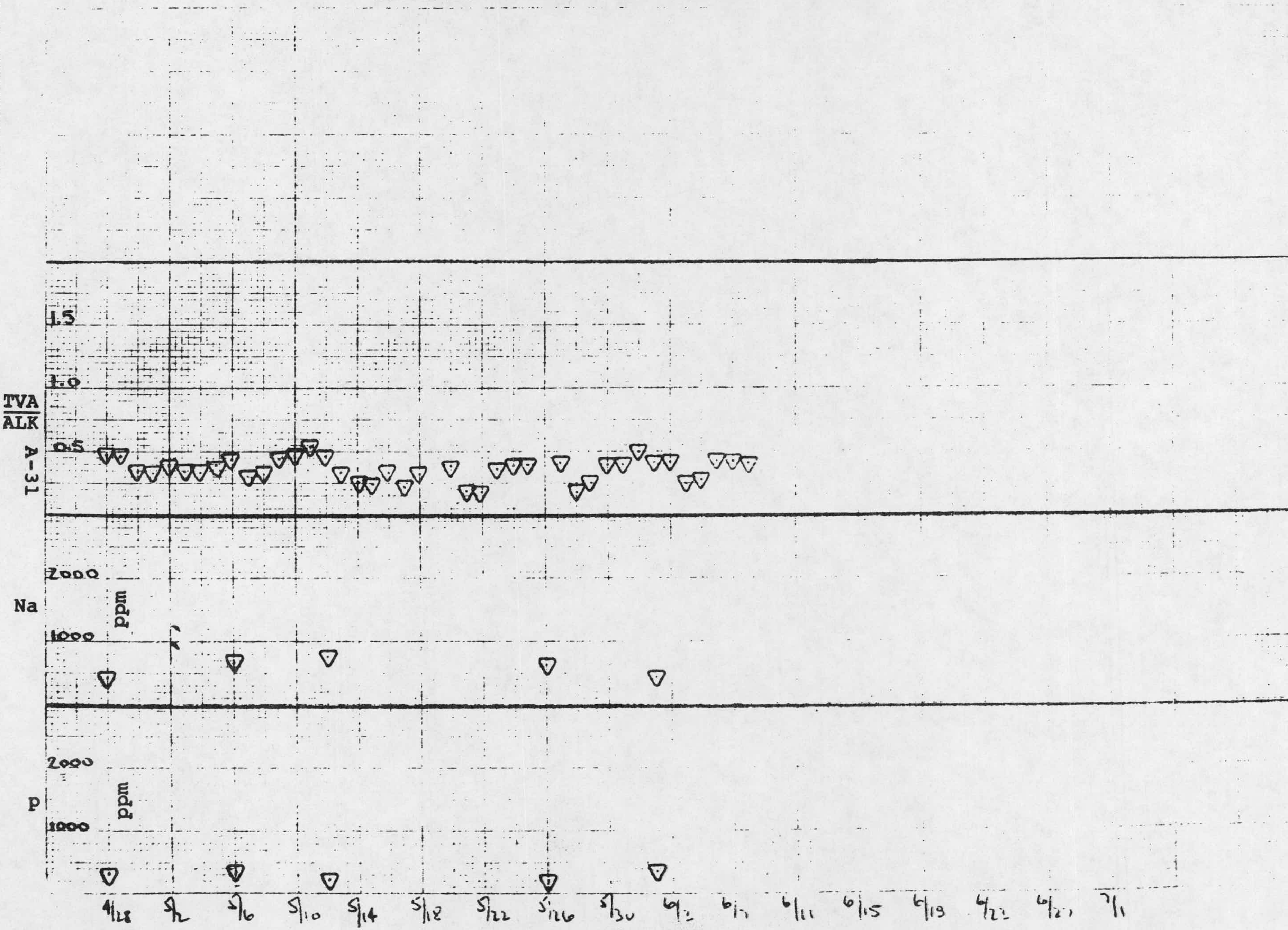


FIGURE 31

*U.S. GOVERNMENT PRINTING OFFICE: 1978-740-306/9451. Region 4.