

PHASE II INTERIM PROGRESS REPORT ON:

"PHOSPHORUS REMOVAL WITHIN INDIVIDUAL SEPTIC  
TANK SYSTEMS"

Submitted by:

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Submitted to: The New York State Science & Technology Foundation

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Project Supervisor

## GENERAL OVERVIEW

With reference to "Phosphorus Removal Within Individual Septic Tank Systems: Phase II," the objectives are numerous. This interim report will direct its attention to those data which demonstrate significant progress in achieving some of these objectives.

Accordingly, the development of the project for construction of prototype septic tank-leach field system for both residential and summer recreational use has proceeded to the installation stage. In addition, Figures 1, 2, and 3 on the following pages show various aspects of the system including water table, contour, and tile field layout. The system will be installed in the Bolton Landing, New York area as soon as northern spring weather permits. Several meetings were necessary with the District Sanitary Engineer, New York State Department of Health (Glens Falls), and verbal acceptance of the chemical-feed system for the septic tank has been given.

The engineer has indicated one concern, however, the possibility of increased accumulation of sludge solids in the tank due to accelerated precipitation of phosphates by the chemical additive. As this is a demonstration project, this parameter will receive close scrutiny as it is an operational concern. Some discussion regarding this topic is found in a later portion of this report. It is important to note that preliminary laboratory studies (NYSSTF Proposal Register No. J-32-73) indicated that increased phosphate-sludge accumulation will not necessarily increase the sludge volume in the tank, but could decrease the volume due to the production of greater sludge solids concentration than is normally attained with the conventional system.

## THE PROTOTYPE SYSTEM/FIELD STUDIES

The dwellings utilizing this system consist of one full-time family residence served by one 750 gallon septic tank and a 6'

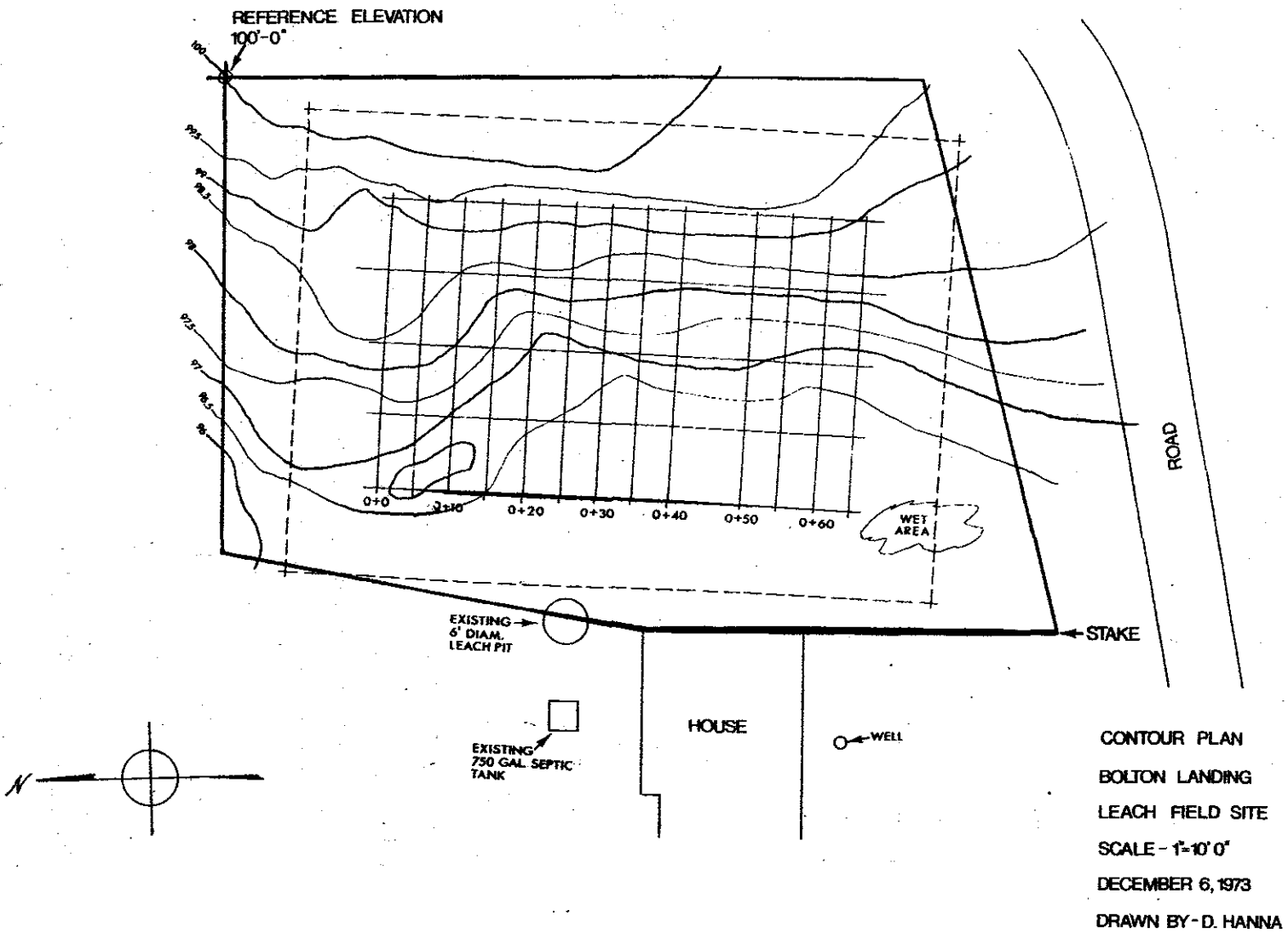


FIGURE 1

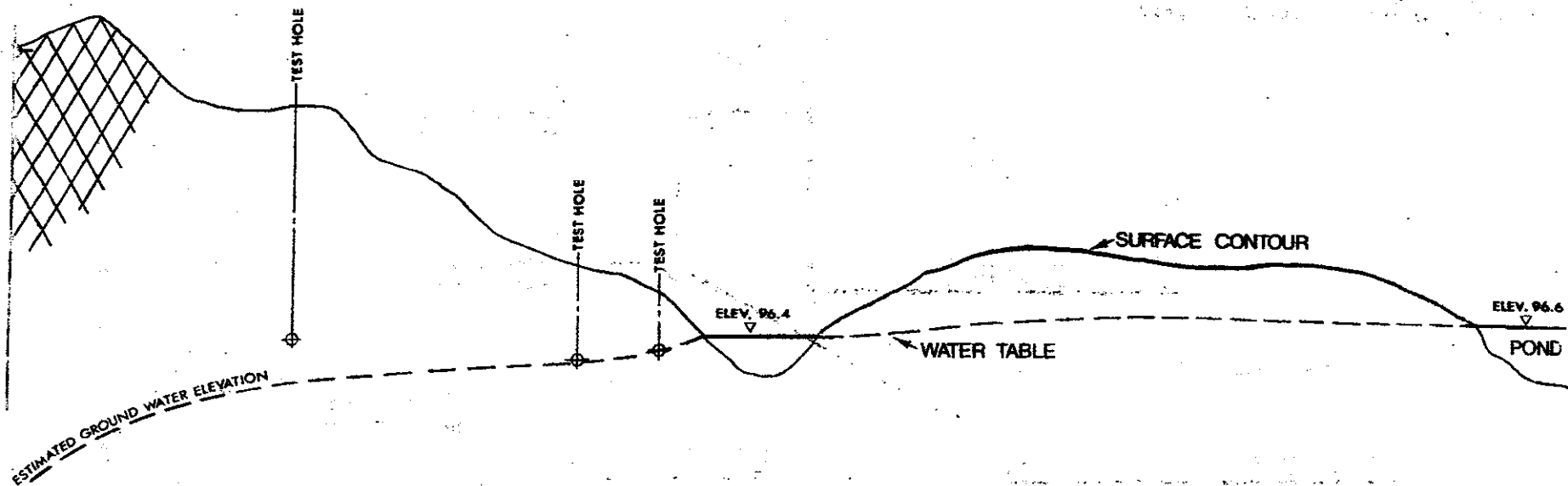
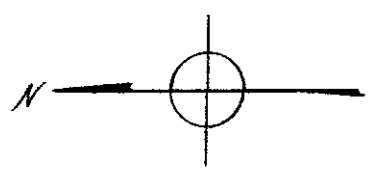
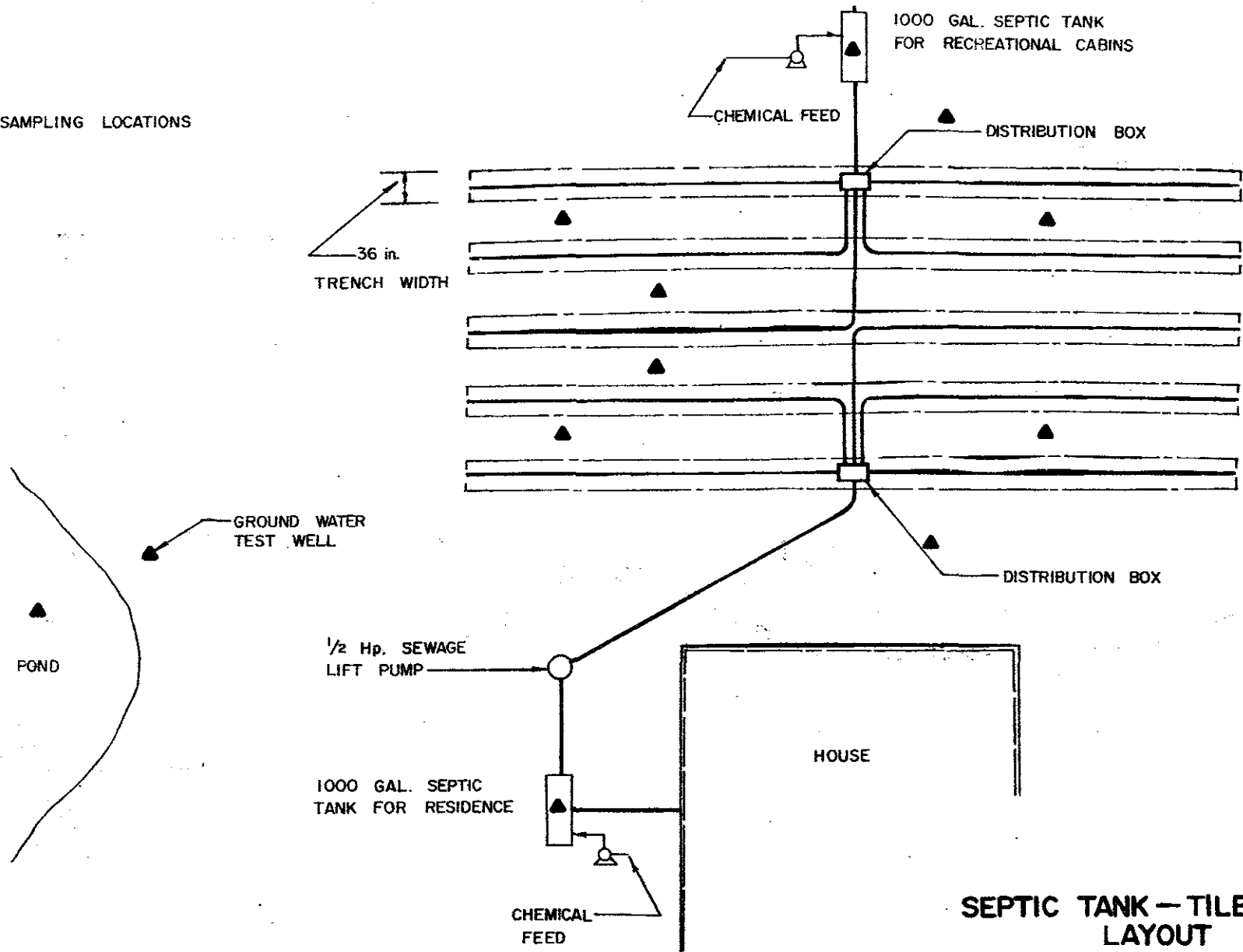


FIGURE 2



SOIL & WATER TABLE PROFILE  
 BOLTON LANDING  
 LEACH FIELD SITE  
 SCALE - vertical-1"=10' 0"  
           horizontal-1"=10' 0"  
 DECEMBER 11, 1973  
 DRAWN BY- D. HANNA

▲ SAMPLING LOCATIONS



SEPTIC TANK - TILE FIELD LAYOUT

BOLTON LANDING, N.Y.  
Scale Dwn. by F.W. HARDT

diameter by 6' deep leach pit; and 7/8 summer cabins using three cesspools, dimensions unknown.

This system will be replaced by a 1,000 gallon tank for the residence and a similar one for the cabins. Both tanks will discharge to a common leach field which will have a total surface area of 2,600 square feet and contain 325 lineal feet of 6" tile. Due to the properly stringent design criteria required for the Lake George basin, as required by the New York State Health Department, the leach trenches will be underlain by four feet of fill material having approximately a twenty minute percolation test time. This will provide an average wastewater application rate of 1.0 gal./sq.ft./day.

It is estimated that the maximum wastewater discharge from the residence and cabins combined will be in the order of 1,200 gal./day during the summer months (June-September). In the fall, winter and spring the cabins receive limited or no use and the wastewater discharge would be in the order of 750 gal./day.

The chemical-feed system will be incorporated into both the residence septic tank and that for the cabins. This will be accomplished by using positive displacement pumps with appropriate monitoring equipment in order to maintain accurate control of the chemical addition. The particular choice of chemicals to be utilized will be ascertained from current laboratory studies.

Efficiency of the chemical additive(s) process will be evaluated in terms of anticipated improvement in nutrient removal and in terms of the bio-degradation accomplished within the septic tank. The process will be monitored through withdrawal of samples from various points throughout the system. These will include sampling points located at the septic tanks, at the distribution box, and at various locations in the leach field. Since the new system will be in an area in which the natural groundwater flow is in the direction of a pond which eventually drains into Lake George, groundwater in the proximity

of the pond and the pond water itself will be chemically analyzed for nutrient content.

#### INSTALLATION/MONITORING SCHEDULE

1. 5/1/74 - Submission of final design specifications to the New York State Health Department.
2. 5/15/74 - Site excavation for tanks and leach field.
3. 5/20/74 - Begin construction of leach field and tank installation.
4. 6/1/74 - Completion of construction, installation of chemical-feed equipment, and necessary sampling ports.
5. 6/15/74 - Full operation of system and initiation of monitoring.

It is anticipated that some preliminary conclusions can be made by the fall of 1974.

Previous research demonstrated the feasibility of using ferric chloride as a chemical precipitant for phosphorus removal from septic tank systems (Clesceri, 1973). In addition to the data found within those reports previously submitted to the New York State Science and Technology Foundation, however, a series of recommendations for additional research were suggested. Some of these involved the examination and evaluation of using aluminum sulfate as a chemical precipitant for phosphorus, a determination of sludge accumulation and additional research was suggested regarding the fate of precipitated phosphorus in order to establish the insolubility of the precipitant-phosphorus complex under various conditions.

#### ALUMINUM SULFATE (Alum): ITS USE IN PHOSPHORUS REMOVAL

Figures 4 and 5 illustrate the effects of alum ( $Al_2(SO_4)_3$ ) addition on gas production and final pH within the Warburg flask at temperatures of 26 and 20°C, respectively. These curves show many of the same trends as those found in earlier studies with ferric



FIGURE 4

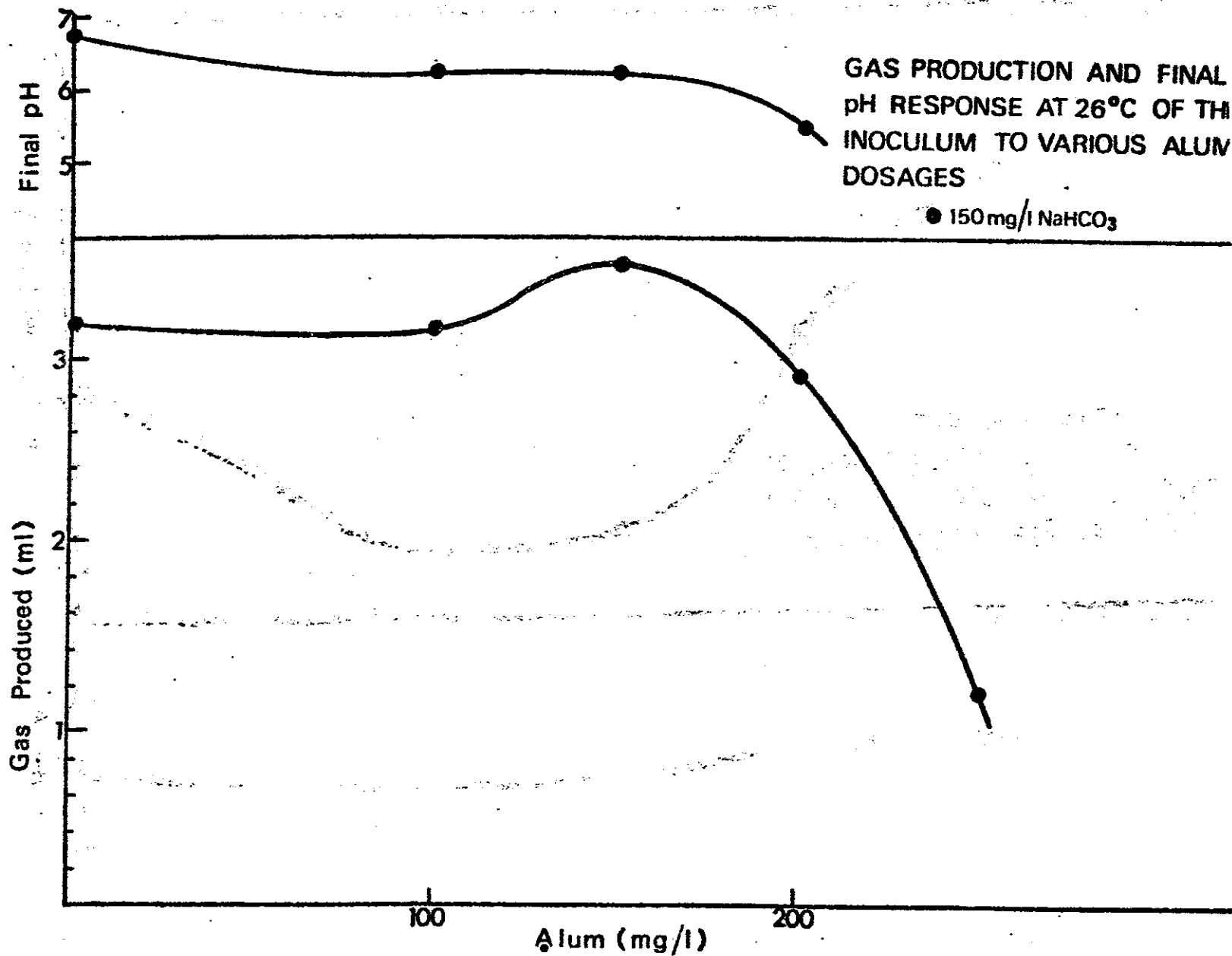
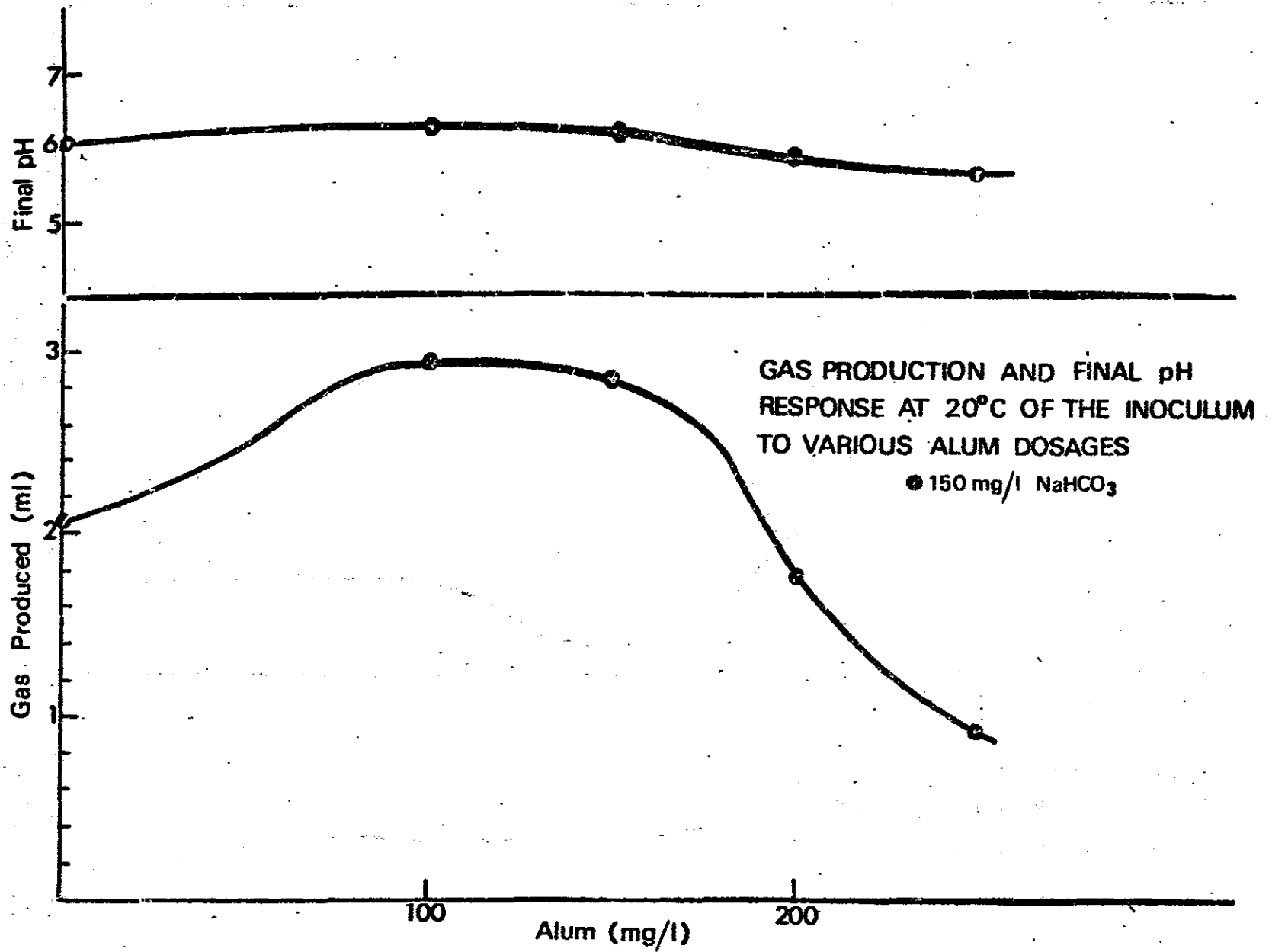


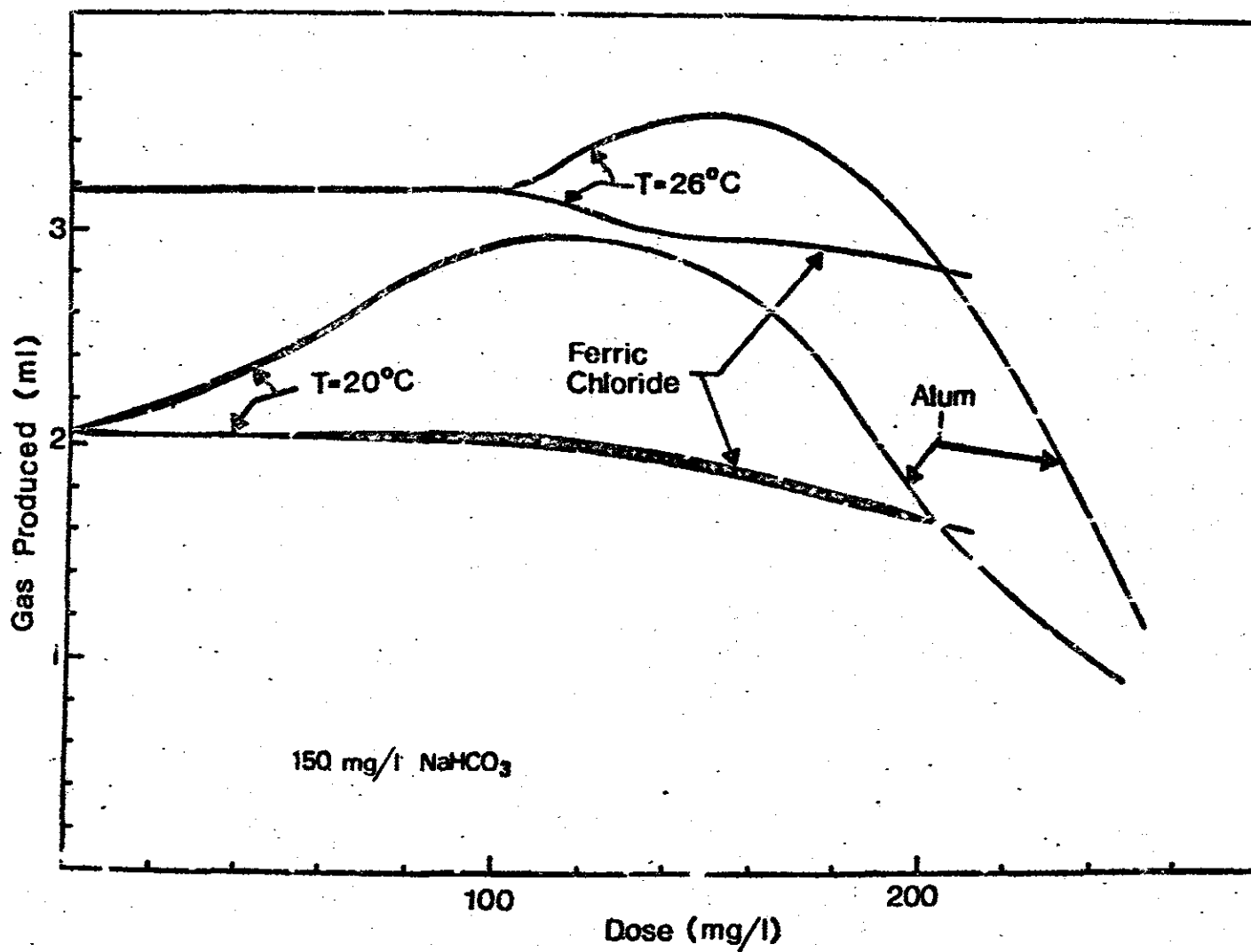
FIGURE 5



chloride, i. e., decrease in final pH with decrease in gas production, inhibition of gas production in the dose range of 150-200 mg/l, and general decrease in gas production with decreasing temperature. However, there are some interesting differences between the observed effects of the two chemicals. For example, at 26°C and 150 mg/l sodium bicarbonate, gas production was found to be enhanced by a dose of 150 mg/l alum, whereas no such enhancement was observed with ferric chloride addition under the same conditions. Similarly, at 20°C and 150 mg/l sodium bicarbonate, enhancement of gas production was observed for doses of 100 to 150 mg/l alum, yet any such enhancement was again absent under the same conditions with ferric chloride addition. At the same time, the final pH observed with alum addition was always higher than with ferric chloride at those points where gas production was also higher. For example, at doses of 100 and 150 mg/l alum, at 20°C with 150 mg/l sodium bicarbonate, the final pH was 6.25 and 6.15, respectively, while for similar ferric chloride doses it was 5.65 and 5.8 respectively. Finally, it can be seen from Figure 6 that for temperatures of 26°C and 20°C with 150 mg/l sodium bicarbonate, alum addition resulted in gas production that was either equal to or higher than that observed for ferric chloride addition up to dose levels of 200 mg/l. Beyond this point the increased addition of either chemical caused severe inhibition of gas production.

In general, these data indicate that gas production will be significantly inhibited by the addition of ferric chloride or alum in excess of 150-200 mg/l. The extent to which this effect occurs will depend on the temperature and alkalinity of the systems. However, it is not evident exactly why this effect occurs. It could possibly be due to the presence of either Fe(III), Fe(II), Al(III), or chloride ions in toxic concentrations. Alternatively, it may simply be due to the lowering of the pH and the reduction of alkalinity (hence buffering capacity) in the

FIGURE 6



COMPARISON OF INOCULUM RESPONSE TO FERRIC CHLORIDE AND ALUM DOSES

Warburg flask caused by the addition of either ferric chloride or alum. The pH drop resulting from either ferric chloride or alum addition is illustrated in Figures 7 and 8. The reduction of alkalinity has been observed by Minton and Carlson (5); for a waste stream with an initial alkalinity of 255 mg/l as  $\text{CaCO}_3$ , the addition of 20 mg/l Al (127 mg/l alum) resulted in a final alkalinity of 160 mg/l. Figure 9 shows the results of a Warburg experiment in which the initial pH in the flask was adjusted by the addition of varying amounts of 0.02N  $\text{H}_2\text{SO}_4$ . The initial pH of 6.6 represents a flask with no  $\text{H}_2\text{SO}_4$  added. It can be seen that if the initial pH is decreased by  $\text{H}_2\text{SO}_4$  addition to pH 6.2 or below, gas production is severely inhibited, dropping from 2.55 ml at initial pH 6.6 to approximately 0.6 ml at initial pH of 6.2 or less. These results indicate that a reduction of pH is indeed one possible cause for the inhibition of gas production. In the case of pH and alkalinity reduction, it would be possible to postulate the following sequence of events. The process of anaerobic digestion requires a dynamic equilibrium between the acid-formers and the methane-formers. The methane bacteria require a pH of 6.6 to 7.6 in order to function optimally; if the pH drops below 6.6, this will decrease their rate of substrate (volatile acid) utilization. The acid-formers, however, can endure pH's lower than 6.6 without any significant effect on their metabolic activity. Hence, if the initial pH of the system were to drop much below 6.6, the acid-formers would be producing volatile acids at a rate greater than the rate of utilization of the acids by the methane bacteria. Thus, as the acids accumulated, the pH would drop even lower as the buffering capacity of the system became exhausted. In a fairly short time, then, the methane bacteria would cease to function and gas production would virtually stop. As was previously discussed, the rate of decrease of the final pH observed in other Warburg runs was small up until gas production began to decrease, at which point the final pH began to drop off more rapidly. This observation seems

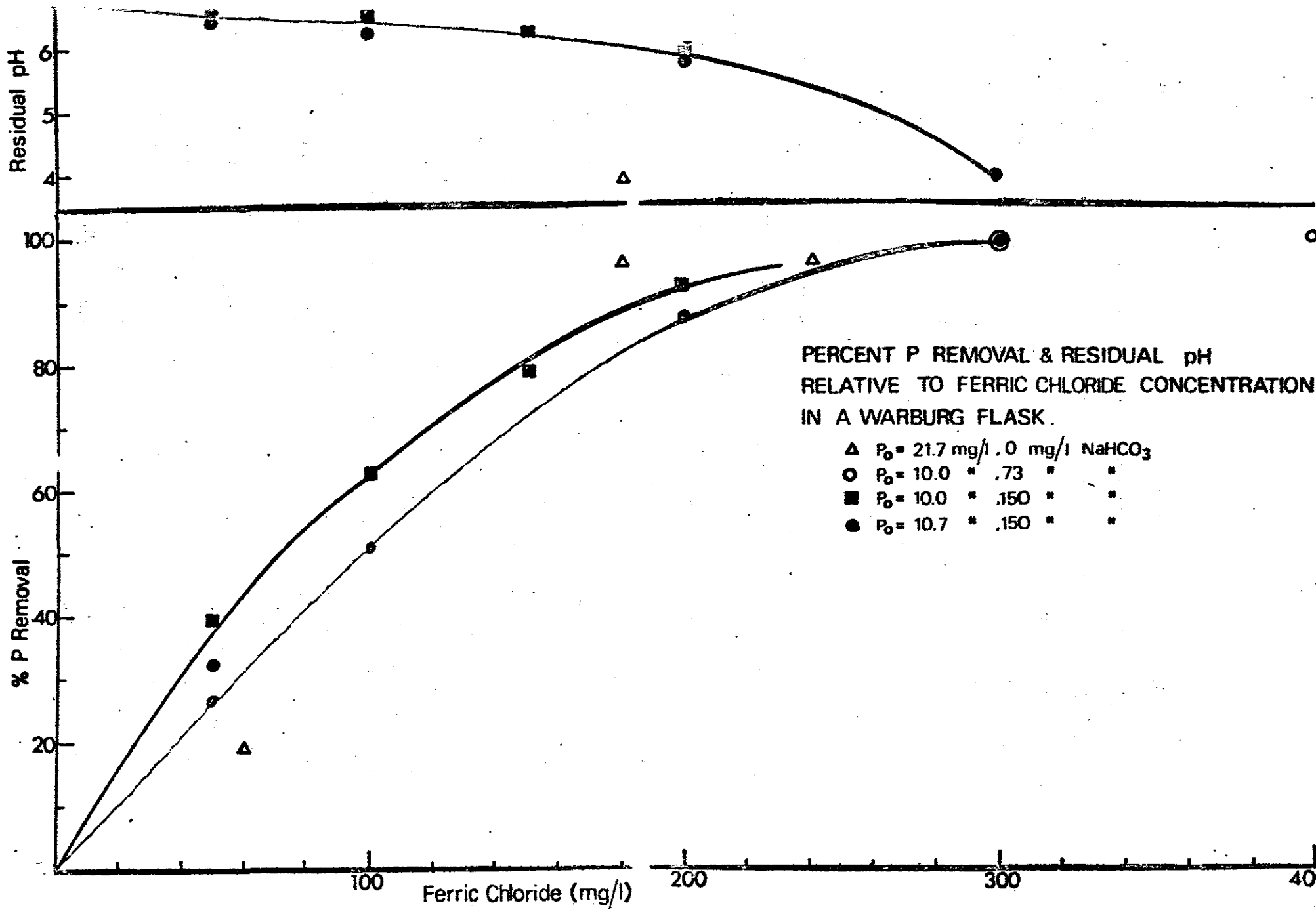


FIGURE 8

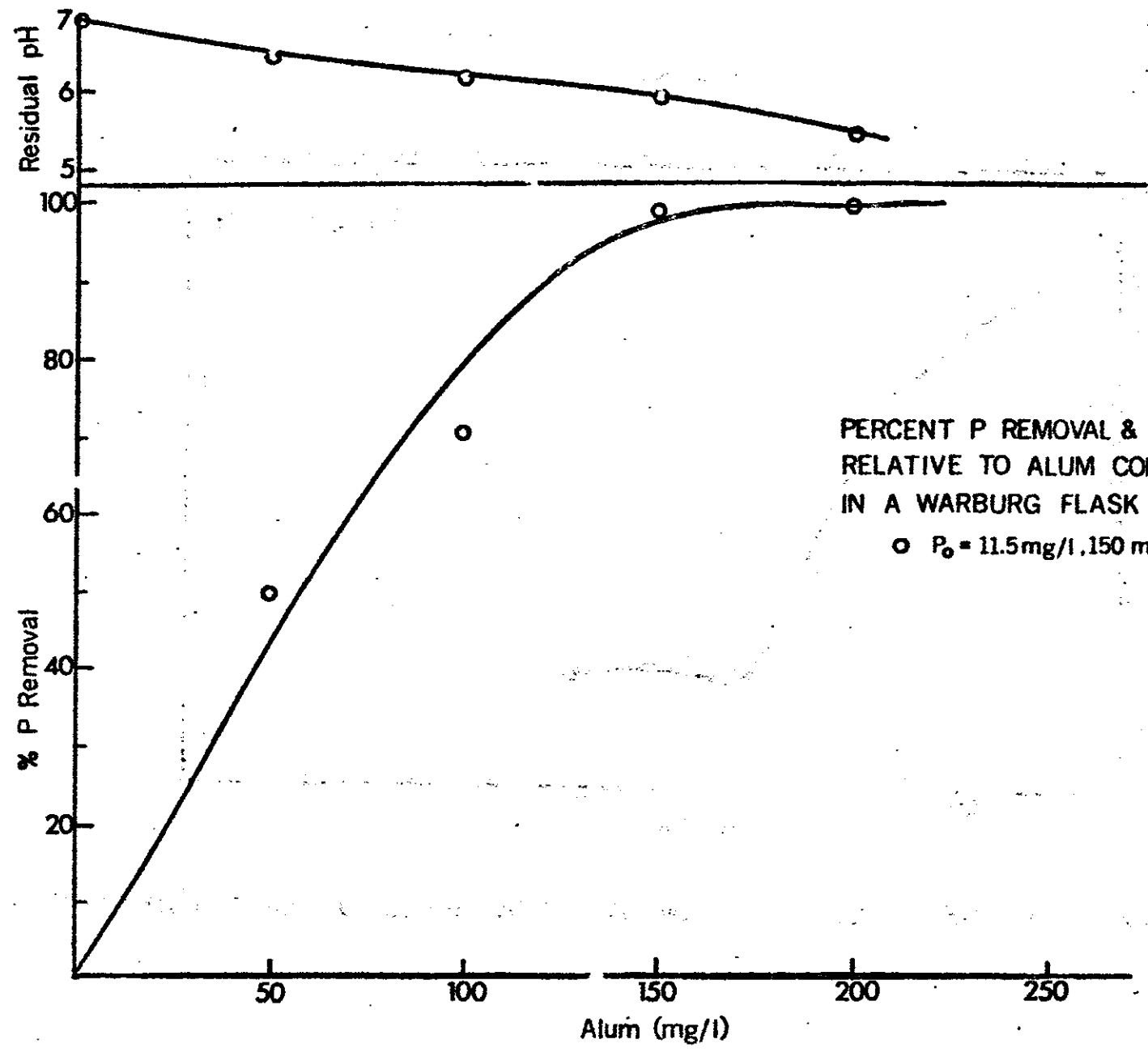
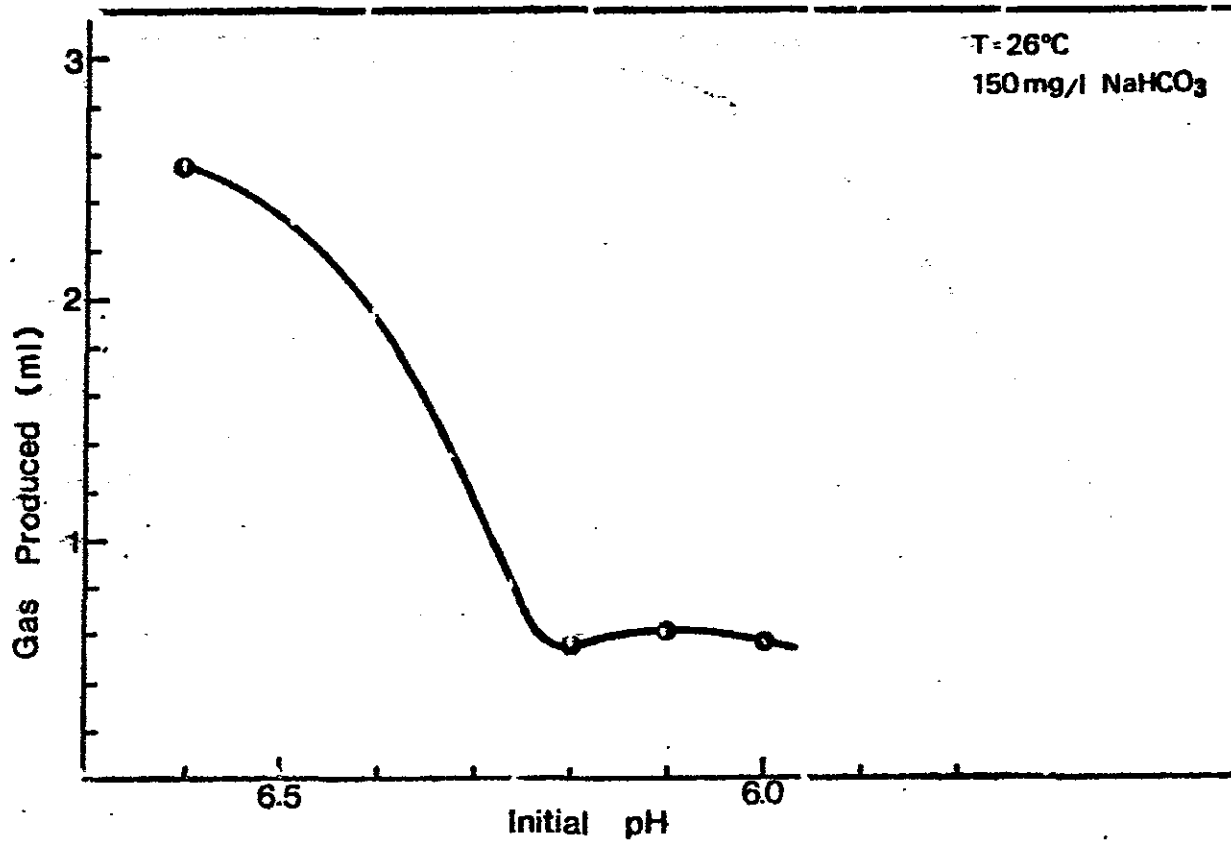


FIGURE 9



GAS PRODUCTION RESPONSE OF THE INOCULUM TO INITIAL pH ADJUSTMENT WITH H<sub>2</sub>SO<sub>4</sub>



to provide evidence to support the above sequence of events.

### FATE OF PRECIPITATED PHOSPHORUS

The data from the Warburg experiments are listed in Table 1, in which the removal efficiencies are based on total phosphorus data. From this table, it appears that the fate of the initially precipitated phosphorus is dependent on several factors including temperature, microbial activity, and type of chemical dose employed. The effect of temperature may be seen by comparing the removal efficiencies at 20°C and 26°C, with 150 mg/l sodium bicarbonate. At 26°C, doses of 100 mg/l and 150 mg/l ferric chloride resulted in final % P removals of approximately 1% for both doses, whereas at 20°C final % P removals were 15% for the same doses.

At 26°C and 50 mg/l sodium bicarbonate, doses of 120 and 180 mg/l ferric chloride resulted in final % P removals of 65 and 47% respectively. At this same temperature but with 150 mg/l sodium bicarbonate, doses of 100 and 170 mg/l ferric chloride resulted in final % P removals of only 1 and 5% respectively. The increased alkalinity added to the Warburg flask thus seems to in some way affect phosphorus precipitation and the stability of the iron-phosphorus complex during anaerobic digestion. In view of the pH dependence of  $\text{FePO}_4$  precipitation, it seems probable that the increase in the added alkalinity serves to raise the pH further above the optimum range for phosphorus precipitation with ferric chloride, thereby decreasing the initial phosphorus precipitated. Additionally, the increased pH and buffering capacity that result from the added alkalinity may, via increasing the level of microbial activity, increase the release of iron-bound phosphorus, assuming the bacteria play a role in this phenomenon. This factor of microbial activity could also serve as an explanation for the increase in phosphorus when the temperature was increased from 20 to 26°C. Jaber (3) found that when insoluble phosphate

TABLE 1.

## PHOSPHORUS PRECIPITATION IN WARBURG FLASKS

Temp. (°C)	Dose Level (mg/l)	NaHCO <sub>3</sub> (mg/l) <sup>3</sup>	% P Removal			
			Initial		Final	
			FeCl <sub>3</sub>	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	FeCl <sub>3</sub>	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>
20	100	150	40	81	15	85
	150	"	75	98	15	97
	200	"	90	99	7	99
	250	"	-	99	-	99
26	120	50	54	-	65	-
	180	"	54	-	47	-
	300	"	92	-	92	-
	400	"	92	-	92	-
	50	150	52	-	22	-
	100	"	59	80	1	91
	150	"	79	98	1	99
	170	"	91	-	5	-
	200	"	91	99	5	98
	250	"	-	99	-	99
30	50	150	30	-	13	-
	100	"	67	-	24	-
	200	"	88	-	18	-

reaction products (e.g., iron-phosphate complexes) were added to normal raw sludge and subjected to anaerobic digestion, the anaerobes could extract the needed phosphorus from the added insoluble phosphate reaction products, thereby releasing additional soluble phosphate species to the supernatant. It does seem possible, therefore, that microbial activity could be a contributing factor to the observed release of iron-bound phosphate in this investigation.

Figure 10 gives a rough comparison between the performance of ferric chloride and alum when the respective phosphate complexes underwent anaerobic digestion. From the diagram it can be seen that although high initial % P removals could be obtained using ferric chloride, these removal efficiencies could not be maintained when the system underwent anaerobic digestion. On the other hand, removal efficiencies with alum were initially at least 80% for doses of 100 mg/l or greater and were maintained during anaerobic digestion. It should be noted that the point at which a ferric chloride dosage resulted in a final removal efficiency of 92% was for a dose of 300 mg/l, which severely inhibited gas production. Insofar as the use of a chemical to remove phosphorus in an anaerobic system is concerned, these results indicate that the use of alum will result in greater final removal efficiencies than the use of ferric chloride.

#### SLUDGE ACCUMULATION

The results of the experiments dealing with sludge settling and accumulation are shown in Figures 11 and 12. The curve in Figure 11 illustrates the volume of sludge accumulated when 500 ml of clarified digester effluent was dosed with 120 and 180 mg/l alum. The "sludge" in this case was a spongy, pale white precipitate. After 2-4 hours of settling and compaction, clumps of precipitate began to rise to the surface of the cylinder. Tiny gas bubbles could be seen throughout the clumps, indicating that bacteria which had been precipitated by

FIGURE 10

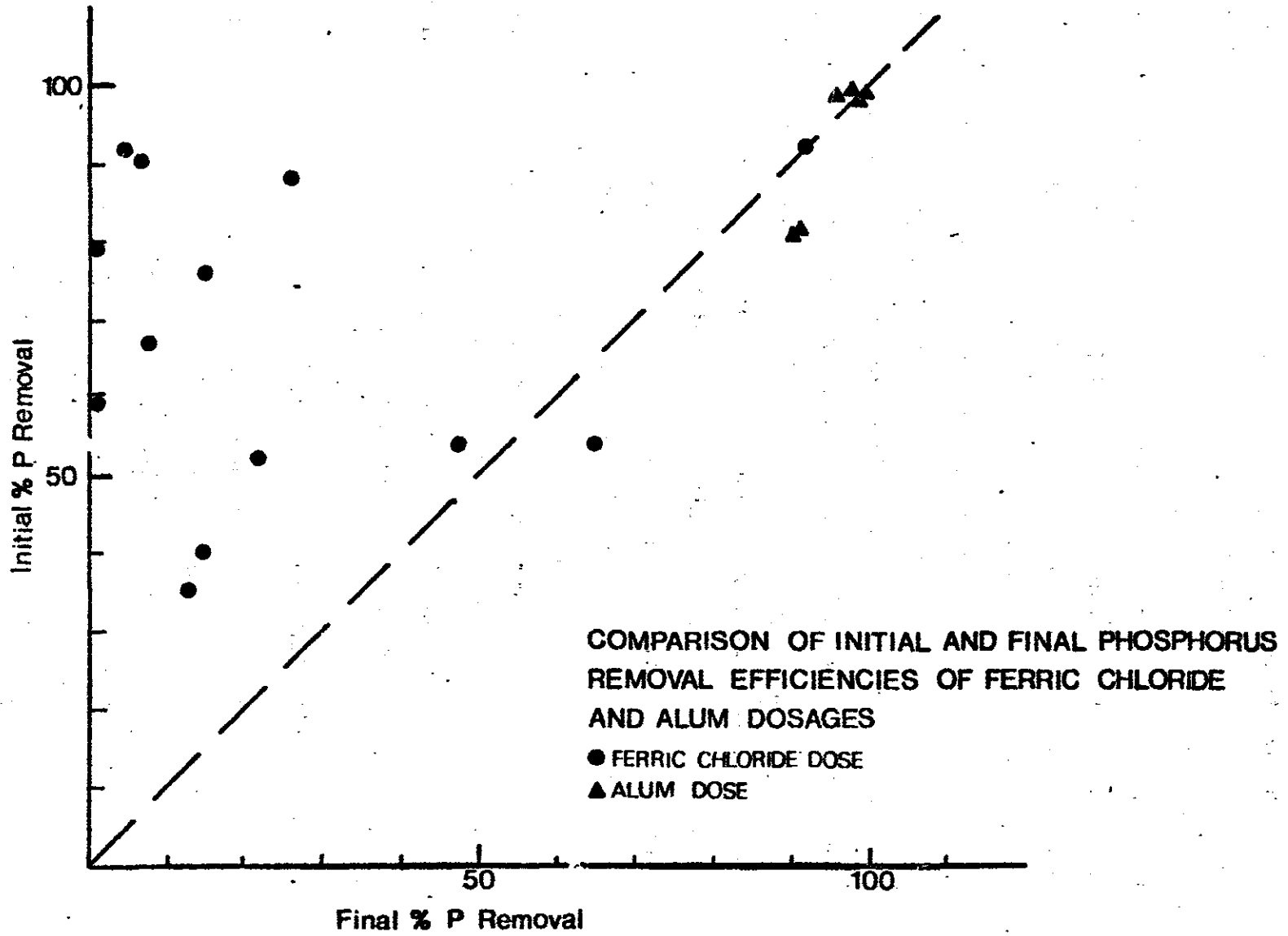
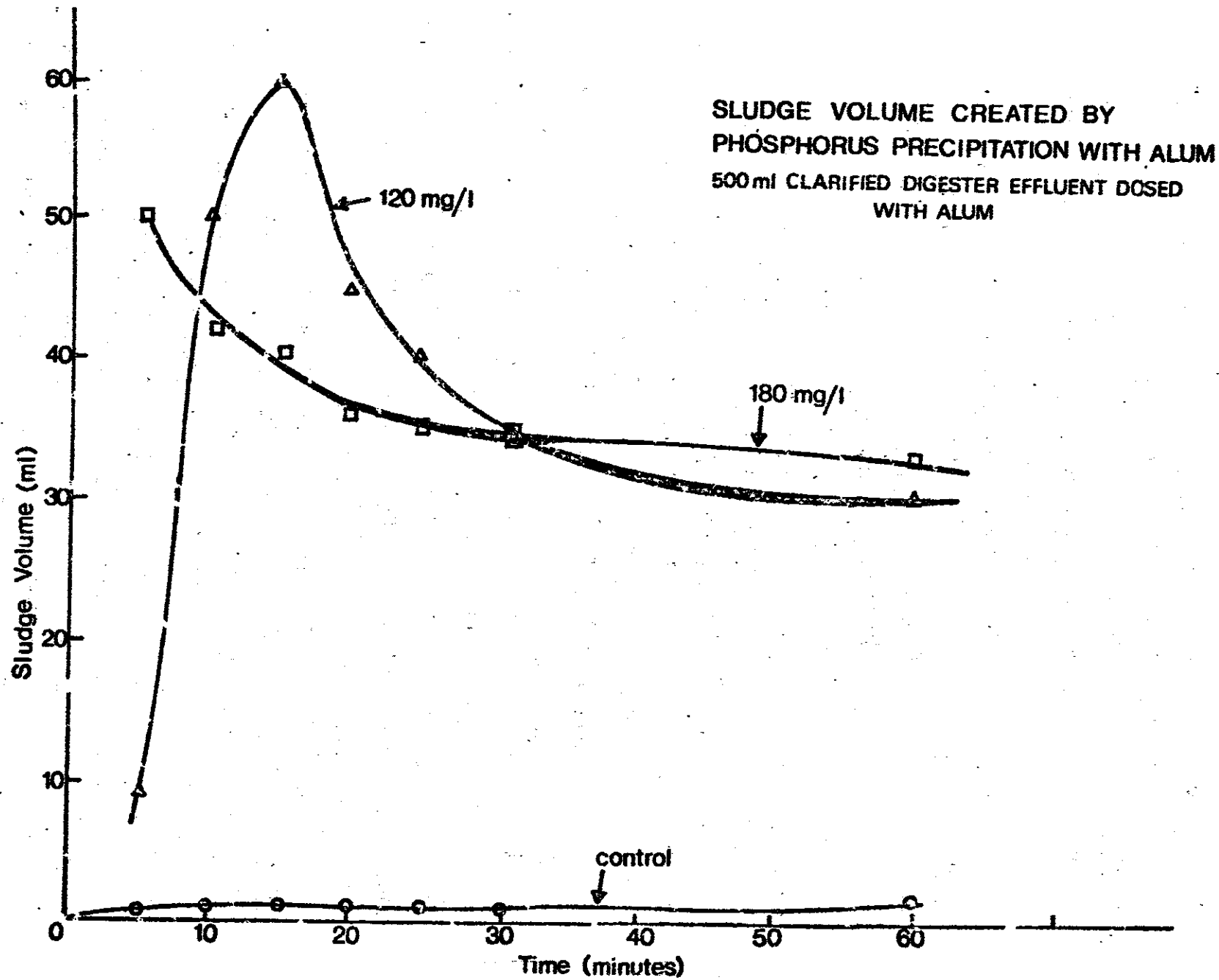


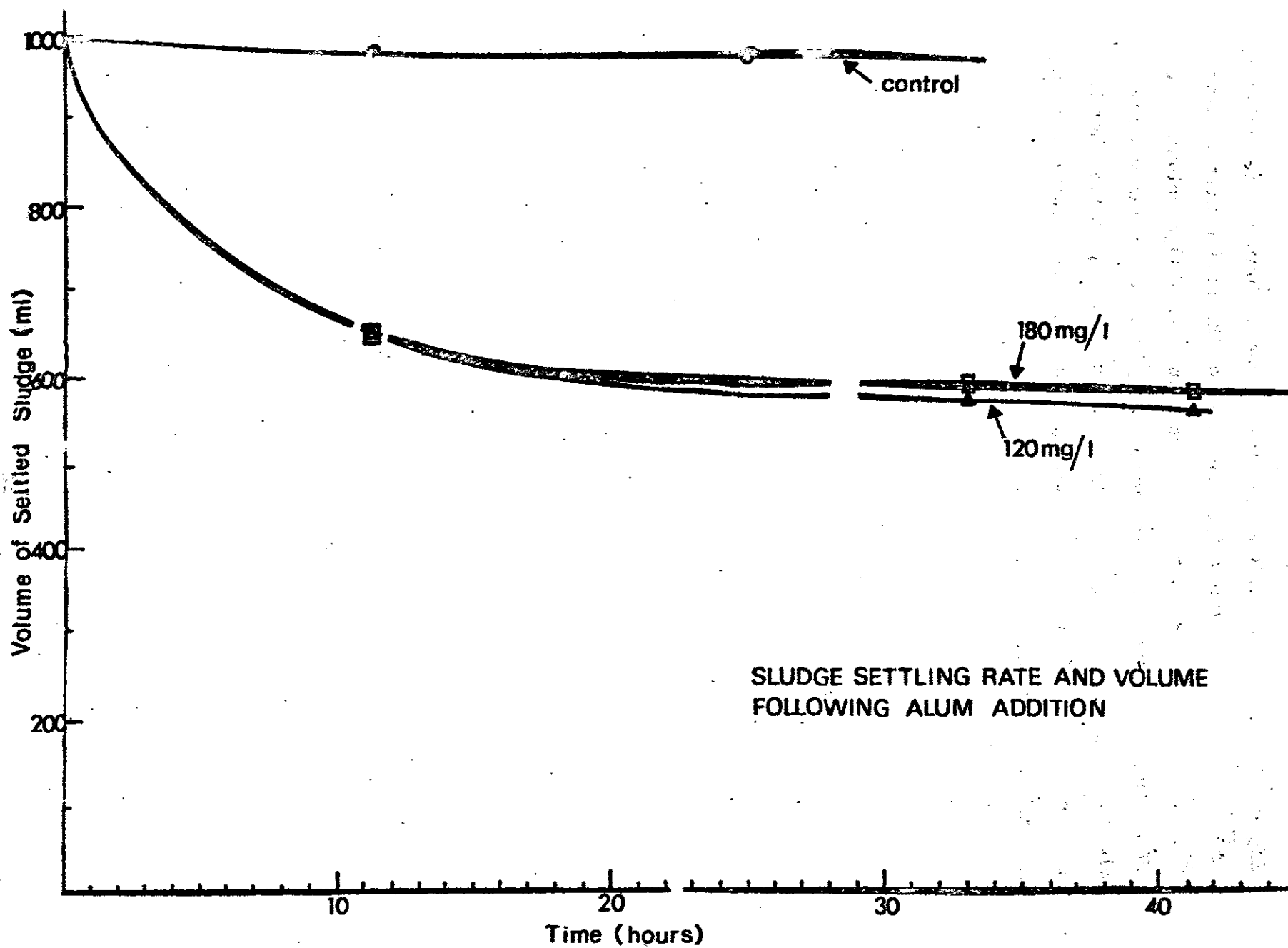
FIGURE 11



the alum were still active and producing gas which became trapped in the spongy precipitate. Thus when a sufficient number of gas bubbles were present in the "sludge" to decrease its effective density below that of the supernatant, the sludge would begin rising to the surface to form a scum layer. A slight disturbance of this scum layer would release some of the gas bubbles and thereby cause some of the scum to settle back to the bottom. After allowing the cylinders containing this treated digester effluent to stand for 48 hours, the cylinders were shook to resuspend the floc and they were then set aside to allow the floc to settle. Final volumes after 30 minutes of settling were 20 ml for a dose of 120 mg/l and 22 ml for a dose of 180 mg/l. These volumes remained constant over the next 24 hours.

Figure 12 shows the results of an experiment in which 2 liters of sludge (6 months old) from the laboratory digester was mixed with 1 liter of tap water and placed in three 1-liter cylinders, two of which were dosed with 120 and 180 mg/l alum, respectively. As can be seen from these curves, the addition of alum to the two columns greatly increased the settling rate and appears to have even increased the compaction of the sludge, i. e., resulted in a smaller final volume of sludge. An analysis of the initial (well-mixed) sludge-tap water slurry showed that the total suspended matter in the slurry was 77.6 g/lm, i. e., the slurry was 7.76% solids.

The results of the first sludge experiment indicate that dosing clarified digester effluent with 120 to 180 mg/l alum will result in a sludge volume equal to roughly 4% of the volume of wastewater treated. However, it is difficult to equate these findings with what might be expected to occur in the septic tank because of the many differences between the two systems (e. g., batch vs. continuous flow, suspended solids concentration, etc.). The results of the second experiment indicate that the addition of alum will increase sludge compaction, presumably by improving the dewatering characteristics of the sludge. Minton and Carlson (5) reported that the use of aluminum dosages



ranging from 10 to 30 mg/l Al (63 to 190 mg/l alum) in the activated sludge process has resulted in a doubling of the sludge mass. However, the effect of the aluminum in reducing the sludge volume index (SVI) resulted in sludge accumulations of roughly the same volume ( $\pm 25\%$ ). Thus the increase in the dewatering ability of the chemical-biological sludge offset the increase in mass and the volume of sludge accumulated remained the same.



## REFERENCES

1. Clesceri, N. L. 1973. Phosphorus Removal Within Individual Septic Tank Systems. Phase I - Final Technical Report to the New York State Science and Technology Foundation, Proposal Register No. J-32-73. 29 pp.
2. Daniels, S. L., and D. G. Parker. 1973. Removing Phosphorus from Wastewater. Journ. Env. Sci. & Technol. 7(8): 690.
3. Jabero, A. A. 1971. Cation-Phosphate Reaction Products as a Nutrient Source for Anaerobes and Phytoplankton. Chem. Abs. 75, 10, 6725F.
4. Malhotra, S. K., T. P. Parilla, and A. G. Hartenstein. 1971. Anaerobic Digestion of Sludges Containing Iron Phosphates. Journ. ASCE, San. Eng. Div. 97: 629.
5. Minton, G. R., and D. A. Carlson. 1972. Combined Biological-Chemical Phosphorus Removal. Journ. WPCF 44(9): 1736.
6. Singer, P. C. 1972. Anaerobic Control of Phosphate by Ferrous Ion. Journ. WPCF. 44(4): 663.