THE EFFECT OF A COMMERCIAL ENZYME PRODUCT ON THE OPERATION OF GREASE TRAPS

by

Jeremiah Robert Lynch

Bachelor of Civil Engineering
Rensselaer Polytechnic Institute
1953

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in Sanitary Engineering

at the
Massachusetts Institute of Technology

1954

Signature of Author...
Department of Civil and Sanitary Engineering
September, 1954

Signature of Professor
in Charge of Research..

Signature of Chairman of Department
Committee on Graduate Students....

ABSTRACT

THE EFFECT OF A COMMERCIAL ENZYME PRODUCT ON THE OPERATION OF GREASE TRAPS

by

Jeremiah Robert Lynch

Submitted in partial fulfillment for the degree of Master of Science

The object of this thesis was to evaluate the effect of the commercial enzyme product Sea Chem (Saxon Enterprises Inc.) on the operation of grease traps. It is claimed that this product is capable of removing the scum layers in the traps, thus cleaning the traps.

A preliminary investigation was made to determine the best method of attack of the problem. From this investigation it was found that Sea Chem, in large concentrations, is capable of decreasing certain types of scum layers with a corresponding increase in sediments.

This early work led to a pilot plant study, using model grease traps and a model sink. These traps were operated in a manner analogous to actual restaurant operation, using several types so that almost all common fats would be represented. Three of six traps were treated with Sea Chem while the other three served as controls. Among the measurements made were pH and acidity of the trap effluents, scum thickness in the traps and weight of scum and sediment remaining at the end of the runs.

The conclusions drawn from this work are as follows:

1. Sea Chem is capable of hydrolysing some of the fats present in a grease trap.

2. It is not possible for much breakdown of the fat, other than hydrolysis, to occur under the conditions present in a grease trap.

3. Hydrolysis of fats causes relatively little change in their characteristics. The hydrolysed fats are still capable of clogging sewer pipes.

4. The fatty acids are removed from the trap only slightly more rapidly than the original fats.

5. In sufficient concentrations Sea-Chem is capable of weighting the scum in a grease trap so that it will sink and be carried out of the trap. This action, however, defeats the purpose of the trap.

6. The use of Sea-Chem does not appear to be an effective method of cleaning grease traps.

Thesis Supervisor..............................Rolf Eliassen

Title...................Professor of Sanitary Engineering

Cambridge, Massachusetts
September, 1954

Leicester F. Hamilton
To the Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dear Sir:

In partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering from the Massachusetts Institute of Technology, I submit this thesis entitled "The Effect of a Commercial Enzyme Product on the Operation of Grease Traps."

Respectfully submitted,

Jeremiah R. Lynch

TABLE OF CONTENTS

TABLE OF CONTENTS

PAGE

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

One of the difficult maintenance problems in restaurants is that of keeping grease traps clean and free from odors. Kitchen personnel are frequently loath to clean the traps. Still the traps must be cleaned to protect the sewers following the traps.

Sea chem has been developed by Saxon Enterprises as a substance to be added to grease traps for the reported purpose of breaking down the scum layers in traps. The problem of this thesis is to determine the effect of Sea Chem on this scum.

The method of attack has been to duplicate as nearly as possible the situation existing in a grease trap by using model grease traps and a model sink. Scum layers were produced in these traps in the same manner as they would be in prototype traps. Several different types of fats were used in the production of the scum layers so that all common classes of fats would be represented. These scum layers were treated with Sea Chem and the effects measured in a variety of ways.

This investigation concerned itself primarily with the effect of Sea Chem on the scum layers in the traps.

However, certain effects which would occur in the sewer pipes following the traps were also discussed.

The conclusions drawn from this thesis are largely negative. Sea Chem did appear capable of causing the hydrolysis of some of the fats present in the traps. However, since hydrolysis causes little change in the properties of the fats, no significant decrease in the quantity of scum occurred. Some scum was removed by the Sea Chem due to a weighting effect, however, this action defeats the purpose of the trap. In general, it was concluded that the use of Sea Chem does not appear to be an effective method of cleaning grease traps.

CHAPTER II

THEORY

A grease or oil interceptor is a form of catch basin placed in the drain line of a plumbing fixture for the purpose of collecting and retaining greases and oils so that they may be periodically removed and thus prevented from entering the sewer system. The operation of an interceptor depends on the fact that at low velocities of flow grease and oil tend to separate from the water because of their lower specific gravities. The designers takeinto account the horizontal velocity of liquid and the vertical velocity of fats in accordance with well established sedimentation theories. The fats rise to the surface and are retained in the interceptor, while the water is drawn off from a lower elevation. Since it is claimed that the product under investigation is able to remove this grease by enzyme activity, a discussion of the chemistry and biochemistry of fats is relevant.

A. CLASSES OF FATS

The fats are members of the larger group of compounds called lipids. This group has been defined by Bloor (18).

"The lipids are a group of naturally occurring substances consisting of the higher fatty acids, their naturally occurring compounds and substances found naturally in chemical association with them."

The lipids are characterized in general by insolubility in water and solubility in "fats solvents" such as ether, chloroform or benzene. They are divided into the following classes of compounds:

I. Simple lipids - esters of the fatty acids with various alcohols.

  A. Fats - esters of the fatty acids with glycerol.

  B. Waxes - esters of the fatty acids with alcohols other than glycerol. (Oils are fats which are liquid at room temperature.)

II. Compound lipids - compounds of the fatty acids with alcohols, but containing groups in addition to the alcohols.

III. Derived lipids - substances derived from the preceding groups which have the general properties of the lipids.

B. FORMATION OF FATS

Esters are formed from the reaction of monocarboxylic acids and alcohols. This reaction may be represented as follows:

$$\mathrm{RCOO\ {-H}\quad + HO\quad - R_1 \qquad H_2O + RCOOR_1}$$

Acid   Alcohol   Water   Ester

In the case of the fats the alcohol is the trihydroxy alcohol glycerol. The fatty acids involved are relatively long-chain organic acids and may be either saturated or unsaturated. The smallest member of this group is the saturated four-carbon butyric:

$$\mathrm{CH_3CH_2CH_2COOH}$$

An example of a longer chain unsaturated acid is gadoleic acid:

$$\mathrm{C_8H_{17}CH\ :\ CH\ C_9H_{18}COOH}$$

The reaction of glycerol and a fatty acid such as butyric will give the following ester:

$$\begin{array}{l} \mathrm{H_2\ C - O - \overset{\displaystyle O}{\overset{\|}{C}} - C_3H_7} \\ \mathrm{H - C - O - \overset{\displaystyle O}{\overset{\|}{C}} - C_3H_7} \\ \mathrm{H_2C - O - \overset{\displaystyle O}{\overset{\|}{C}} - C_3H_7} \end{array}$$

The compound formed is the fat glyceryl tributyrate or simply butyrin. In many cases however the acid groups are not identical. Thus a large number of combinations are possible from a few fatty acids.

C. PHYSICAL PROPERTIES OF FATS, FATTY ACIDS AND SALTS OF FATTY ACIDS

1. Solubility

The fats of the longer chain saturated fatty acids are totally insoluble in water while those of the shorter chain saturated fatty acids are very slightly soluble. Unsaturated bonds in the fatty acid groups increases the solubilities slightly. Due to their very low solubilities fats can in general be classed as insoluble in water.

All fats are soluble in fat solvents such as ether, chloroform, benzene, methyl and ethyl alcohol, and acetone, especially when the solvent is hot.

The solubility of the fatty acids in water is given in Table I. As can be seen the solubility decreases with increasing chain length and increases with the number of double bonds for constant chain length acids. In general the acids above lauric are considered almost insoluble. Like the tri-glycerides, the fatty acids are soluble in all fat solvents.

Table 1

PHYSICAL CONSTANTS OF FATS, FATTY ACIDS AND FATTY ACID SALTS

	Fatty Acid	Carbon Atoms	Double Bonds	Formula	M.P. (8)	S.P.	Sol. at 60°C (9)	Corresponding Simple Fat			Fatty Acid Salts Solubility at 50°C	
								M.P. (10)	S.P.	Sol.	Na Salt	Ca Salt
1.	Butyric	4	0	$CH_3CH_2CH_2COOH$	-7.9	-19	5.62	-75		Ins.		22.0
2.	Caproic	6	0	$CH_3(CH_2)_4COOH$	-3.4	- 3.2	1.171	-25		"		2.3
3.	Caprylic	8	0	$CH_3(CH_2)_6COOH$	16.7	16.3	0.113	9.8	-10.1	"		0.26
4.	Capric	10	0	$CH_3(CH_2)_8COOH$	31.5	31.2	0.027	31.5		"		
5.	Lauric	12	0	$CH_3(CH_2)_{10}COOH$	44.2	43.9	0.0087	46.4		"	2.0	0.026
6.	Myristic	14	0	$CH_3(CH_2)_{12}COOH$	53.9		0.0034	56.5		"		0.014
7.	Palmitic	16	0	$CH_3(CH_2)_{14}COOH$	63.1	62.8	0.0012	65.1		"	0.1	0.009
8.	Palmitoleic	16	1	$CH_3(CH_2)_7HC{:}CH(CH_2)_5COOH$	0.5							
9.	Stearic	18	0	$CH_3(CH_2)_{16}COOH$	69.6	69.3	0.00050	70.8		"	Soluble	0.008
10.	Oleic	18	1	$C_8H_{17}CH{:}CH(CH_2)_7COOH$	14.0			4.9 - 6		"	10.0	0.04
11.	Linoleic	18	2	$C_{18}H_{32}O_2$	-11			-12.9		"	0.6	0.03
12.	Linolenic	18	3	$C_{17}H_{29}COOH$				-23.0		"		
13.	Arachipic	20	0	$CH_3(CH_2)_{18}COOH$	75.3	74.9				"		

M.P. - Melting Point (°C)
S.P. - Solidification Point (°C)
Sol. - Solubility (Gms/100 Gms H_2O)
Ins. - Insoluble (very low solubility)

The true solubilities of the calcium and sodium salts of some of the fatty acids are entered in Table 1. However, the sodium salts, and to a much lesser extent the calcium salts are emulsifying agents. They will disperse in water to a state very near to solution. In addition, they will emulsify any fats and free fatty acids present, provided the pH is in the basic range and the mixture is agitated.

2. Melting and Freezing Points

The melting points of the fats vary as the chain length of their fatty acids. Unsaturation in the fatty acids lowers the melting point. The fats are one of the few classes of compounds which often exhibit solidification points markedly lower than their melting points. In most cases the melting point of the fat is not far from that of the fatty acid of which it is made. For example, stearic acid melts at 69.6°C while glycerol tri-stearnin melts at 70.8°C. In only two cases, butyrin and caproin, do the melting points of the tri-fats differ greatly from those of the fatty acids.

Each fat listed in Table 1 is composed of only one type offatty acid. The melting point of a mixed fat can be estimated, since it will probably lie between the melting points of the tri-fats of the fatty acids of which the mixed fat is composed.

As mentioned above, the melting points of the fatty acids are very close to those of the corresponding fats. Although the melting points of the saturated fatty acids follow a regular progression, the unsaturated fatty acids may vary considerably. Not only the number of double bonds present, but also their position of the bond affects the melting point. For example, an 18-carbon acid with a double bond between the 2nd and 3rd carbon atoms (from the carboxyl group) will melt at 59°C, whereas the same chain with a double bond between the 12th and 13th carbons will melt at about 10°C.

3. Color, Odor and Taste

The pure triglycerides are colorless, odorless and tasteless. The presence of these properties is due entirely to foreign substances mixed with or dissolved in the glycerides. The colors of fats are variously due to carotenes and xanthophyls. Odor when present may be due to short-chain, free fatty acids such as butyric, or rancidity products such as ketones or peroxides.

D. CHEMICAL PROPERTIES

1. Hydrolysis. The most vulnerable spot for a chemical change in the triglyceride molecule is the ester

linkage. Until this linkage is broken no major change can occur in a saturated fat. In hydrolysis, water is added at the ester linkage to separate the fat into its component fatty acids and glycerol. This reaction can be accomplished either chemically, at high temperatures and in the presence of acids added as catalyists, or biochemically thru the action of enzymes known as lipases and esterases. As this study is concerned primarily with the second mechanism, it will be discussed more fully later.

2. Rancidity. Rancid fats are noted for their disagreeable taste and smell. The most common form of this reaction is an oxidation phenomenon occurring in the presence of atmospheric oxygen, moisture, light and heat. Metal salts appear to hasten the process (7). Unsaturated fats, particularly olein, become rancid much more rapidly than saturated fats.

The reactions involved in oxidative rancidity are not clear, but the process probably proceeds in the following sequence:

a. Hydrolysis.

b. Addition of oxygen at an unsaturated bond to produce a peroxide, thus:

$$2\ CH_3(CH_2)_7\ CH : CH(CH_2)_7\ COOH + 3\ O_2$$

(OLEIC ACID)

$$2\ CH_3\ (CH_2)_7\ \overset{H}{C} - O - \overset{H}{C}\ (CH_2)_7\ COOH$$

$$O \quad - \quad O$$

(OLEIC ACID OXONIDE)

c. Further breakdown of the oxygen-carrying peroxide to form aldehydes, semialdehyde acids and fatty acids.

A second type of rancidity, known as hydrolytic rancidity, is common to butter. In this reaction hydrolysis releases certain short-chain fatty acids such as butyric and caproic, thus causing considerable stench. This phenomenon cannot account for rancidity in most other fats, however, since only long chain fatty acids which are odorless would be released.

A third type, known as ketonic rancidity, is little understood and seems to be distinguished only by the necessity for large numbers of bacteria and nitrogen and by the production of various ketones.

It is seldom that any one of these sets of reactions acts alone, but rather rancidity is a combination of all three.

3. <u>Hydrogenation</u>. In the hydrogenation of a fat, hydrogen is added to the double bond in the unsaturated fatty

acid chains by substituting nascent hydrogen into the acid in the presence of nickel as a catalyst. The hardness and melting point of the fat are increased by this process, and the tendency of the fat to become rancid is lessened. Consequently, hydrogenation is used to convert such oils as cotton seed to fats of the consistency of lard for use in shortenings. In the case of shortenings, however, the hydrogenation is not carried to completion.

E. BIOCHEMISTRY OF FATS AND FATTY ACIDS

1. Lipid-Splitting Enzymes

Certain enzymes are capable of splitting fat molecules at the ester linkage, thus hydrolyzing the fat and yielding the component fatty acids and glycerol. These enzymes seem to be of two types.

a. Lipases - Enzymes which rapidly split the true fats, that is, the neutral triglycerides of the higher fatty acids, but act slowly on the triglycerides of the short-chain fatty acids and the fatty acid esters of primary and secondary alcohols.

b. Esterases - Enzymes which split the glycerol esters of the lower fatty acids and the esters of simple alcohols rapidly but which act on the true fats slowly.

Lipases can be found in the pancreas of mammals and fish and in certain seeds, notably the castor bean (Ricinus). The characteristics of these enzymes are essentially the same regardless of their source. They are soluble in water and in glycerol, although they are unstable in water. Maximum activity seems to occur at a temperature of about 37°C and decreases to nearly zero at 0°C. When heated for 10 minutes at 45°C the activity is greatly lessened, and when heated to 55°C it is destroyed.

Calcium chloride is generally necessary to activate lipase and this activation occurs at a pH of from 5.0 to 6.0. After activation is complete, hydrolysis may proceed within wider pH ranges.

Esterase is most commonly found in the liver of mammals and is quite abundant in the liver of such fish as carp. Its properties are very similar to those of lipase with the exception that some types are not soluble in water.

2. Factors in Fat Splitting

The amount of hydrolysis which takes place when a fat is brought into contact with a fat-splitting enzyme depends on a number of factors.

a. Acidity and pH. High acidity destroys and low acidity inhibits the action of lipase. the optimum pH seems to be between 5.0 and 6.0 and buffering material such as protein should be present if much fat is to be split.

b. State of division of the fat. Since lipase and fat have no commom solvent, the enzyme can only act at the surface of the fat particles. Consequently, unless the particles are small and the surface area is great, as in an emulsion, not much splitting is likely.

c. Length of time. Since enzyme reactions are characteristically slow, the enzyme must remain active and in contact with the fat for a relatively long period, in order for a significant amount of hydrolysis to occur.

d. Temperature. The optimum temperature for lipase is about 37°C and much variation from this point will considerably lessen the activity or even cause irriversible inactivation.

3. <u>Oxidation</u>

Another set of enzyme reactions involving fats is the oxidation of the fatty acids yielded by hydrolysis. Although enzymes are known to accomplish this, little is known as to their types, sources and properties.

The mechanisms of oxidation of the fatty acids into smaller end products is known as Knoop's oxidation. In this process the long-chain fatty acids are shortened by two carbon atoms at a time and with the aid of organic peroxides yielding acetic acid. The reaction is stopped when only four carbons are left, thus leaving acetoacetic acid (not butyric since oxidation was begun on the last four carbons). Thus one mole of stearic acid, C_{18}, would yield seven moles of acetic acid and one mole of acetoacetic acid at completion.

Further oxidative reactions will convert the short-chain fats to CO_2 and water in the presence of oxygen, either atmospheric or dissolved, or as nitrates, nitrites or sulfates. If no form of oxygen is available the fatty acids release by hydrolysis can only be reduced to ultimately form methane.

F. Composition of Grease Trap Scum

The composition of the fats found in a grease trap will reflect the type of establishment using the trap. If, as is usually the case, the trap is located in a hotel or restaurant kitchen, or on the drain of a food-preparing plant, the fats will be those released in the cooking of common meats, as beef, mutton, pork, and chicken, plus certain hydrogenated vegetable oils used as shortenings. The fatty acid concentrations released by hydrolysis of these fats are given in the following table:

TABLE 2

FATTY ACID CONCENTRATIONS OF COMMON FATS

Fatty Acid	Mutton Tallow	Beef Tallow	Pig (Back Fat)	Chicken Fat	Soy-Bean	Cotton Seed
	(1)	(2)	(3)	(11)	(4)	(5)
Myristic	4.6	3.3	1.7	0.1	0	3.3
Palmitic	24.6	24.9	25.5	25.6	6.8	19.9
Palmitoleic	0	2.4	0	7.0	0	0
Stearic	30.5	24.1	13.7	7.0	4.4	1.3
Oleic	36.0	41.8	50.2	38.4	33.7	29.6
Linoleic	4.3	1.8	8.9	21.4	52.0	45.3
Total	100%	98.3%	100%	99.4%	96.9%	99.4%

From the above table it can be seen that these common fats are essentially the esters of only six fatty acids. The number of theoretical combinations possible from n fatty acids, considering that each glycerol molecule takes three acid molecules, and that the two end positions on the glycerol molecule are equivalent, is given by the formula $N = \frac{1}{2}(n^3-n^2)$. Thus the total number of chemically distinguishable tri-glycerides from six fatty acids is 126. However, the number of fatty acids, rather than the number of pure fats, is more indicative of the range of properties exhibited by the crude fats.

Shortenings, such as Spry, Crisco, Covo, etc., are generally composed of 50% soybean oil and 50% cottonseed oil, the exact proportions depending on relative market prices. These fats are hydrogenated to increase their hardness and to prevent rancidity. Consequently, the linoleic and oleic acids have been largely converted to stearic acid. Thus, although the stearic acid reported for the raw oil is less than 5%, the stearic acid in the finished product will be in the order of 70%.

The animal fats are largely accounted for by 16 and 18 carbon saturated acids and by oleic acid. Chicken fat, however, contains considerable linoleic acid. Excepting butter, which due to its high price is not likely to be allowed to reach the grease trap, no common fat contains a significant concentration of any acids below mynistic, C_{14}.

In addition to the fats, some solid matters, such as food particles, are apt to be caught by the trap. These particles are carried to the surface by grease adhering to them. The amount caught will be greater if the trap is cold since fats collect on surfaces much more rapidly at low temperatures.

CHAPTER III

PRELIMINARY INVESTIGATIONS

In order to determine which methods of attack would give the most significant data, a preliminary study was made. The selection of the methods and procedures used in this first phase was largely a matter of trial and error, with each unsuccessful attempt giving a clue which led to the next attempt. In general, several samples of scum as collected from actual operating traps were collected and treated by varying methods, using readily available laboratory equipment. A short theoretical investigation was also made. The results of these rather rudimentary tests were used to plan a larger scale study to be made with especially constructed equipment.

A. SOURCE OF GREASE

The initial sample of the scum used in these experiments was obtained from the main kitchen of the Waldorf Cafeteria System, located at 60 Purchase Street, Boston. This scum was removed from a grease trap measuring 8 feet deep, 6 feet wide and 10 feet long, located in the basement. The wastes from the sink drains and dishwashers throughout the building emptied at the top of the head end of this tank and passed down and under the three baffles which separated the tank into compartments. As the sewage passed through, the grease and other floating matter rose and was trapped. This tank required cleaning every 3 to 6 months. However, since the labor to perform this job was difficult to obtain, the tank had not been cleaned for over 6 months. Sea-Chem had been used in this tank about two weeks prior to the beginning of this investigation. Violent foaming occurred, causing the scum to push out of the tank, and the dosage was not repeated.

Later in the investigation it was considered desirable to have a sample of scum from a trap that had never been treated. To meet this need several pounds of grease were removed from the trap on the dishwasher in the basement of the M.I.T. Graduate House. No difficulty had been experienced with this trap.

B. EFFECT ON RENDERED GREASE

Since the manufacturer claims that this product is capable of "liquefying" grease, the first tests were made on the supernatant fat removed from the scum after rendering on a steam bath. During the rendering process a very strong odor of butyric acid was produced.

Three runs were set up using this fat, each differing by the method of mixing the Sea-Chem with the fat. In the first, 50 ml of the rendered grease was placed in the bottom of a 100-ml graduate and allowed to harden. After hardening, 50 ml of water containing the Sea-Chem dosage was added. In the second the Sea-Chem-water mixture was added first and the rendered grease poured on top. Some mixing occurred since the grease was added hot. In the third run the hot grease and the water-Sea-Chem mixture were mixed with a stirring rod in the graduate. Five concentrations of Sea-Chem were used in each run: 1/2, 1, 3, 5 and 10% by weight.

In a few cases at the higher concentrations some gas production was observed, but no liquefaction or reduction in fat was apparent. However, since enzyme activity is a surface phenomenon, and since the surface area of the grease might have been reduced by rendering, these results are probably not significant.

C. EFFECT ON SEPARATION AS DETERMINED BY CENTRIFUGING

It was evident from the rendering process that the grease trap scum was less than half grease, the remainder being solid material that was entrapped by the grease and buoyed to the surface. Since these solids might sink if they could be separated from the grease, it was decided to investigate the separation and classification of the scum after Sea-Chem treatment.

The scum as it came from the trap was mixed with dry Sea-Chem in concentrations of 1/2, 1, 3, 5, 10 and 15 gms per 100 ml of scum. This mixture was allowed to stand for up to 12 hours and then centrifuged in duplicate for 5 minutes. The depth of the scum layer was measured with a ruler and recorded. The data for this run appeared in Table 3.

The results of this method were very erratic and would not give a smooth plot. However, some decrease in the thickness of the scum layer was noted in almost every case. The change appeared to be as great in the 5-minute contact time samples as in the 12-hour samples. In general, the reduction in the scum layer was between 10 - 30 percent in the higher concentrations (10-15 gm/100 ml) with almost no effect in the lower concentrations. In the higher concentrations the gas production was so great as to push the mixture out of the 4-ounce bottle in which it was contained.

The results of this test were considered inconclusive due to the enormous difference in the magnitude of the forces exerted by centrifuging as compared with classification by gravity alone, as in actual conditions.

Table 3

EFFECT ON SEPARATION AS DETERMINED BY CENTRIFUGING

Sea-Chem gms	Contact Time Hrs.	Contact Time Min.	Cent. Tubes + Grease gms *	Cent. Tube gms 1**	Cent. Tube gms 2	Grease gms 1	Grease gms 2	Scum mm 1	Scum mm 2	Scum/gm of Grease 1	Scum/gm of Grease 2	Scum/gm of Grease Ave.
0	12	5	70.0	26.8	22.3	43.2	47.7	73	69	1.69	1.45	1.57
1/2	12	5	70.0	23.4	22.7	46.6	47.3	73	69	1.57	1.46	1.56
1	12	20	65.0	23.8	22.2	41.7	42.8	66	62	1.58	1.45	1.51
3	12	20	65.0	22.9	22.0	42.1	43.0	48	62	1.14	1.44	1.29
5	12	40	66.7	26.8	22.3	39.9	44.4	49	-	1.23	-	1.23
10	12	40	66.7	23.4	22.7	43.3	44.0	-	52	-	1.28	1.28
15	12	55	69.4	23.0	22.2	46.4	47.2	51	-	1.10	-	1.10
0	7	55	63.7	26.8	22.3	36.9	41.4	64	63	1.78	1.52	1.60
1/2	7	55	63.7	23.4	22.7	40.3	41.0	72	65	1.78	1.58	1.68
1	8	10	60.3	23.8	22.2	36.1	38.1	55	49	1.52	1.28	1.40
3	8	10	60.3	22.9	22.0	37.4	38.3	62	52	1.65	1.39	1.52
5	8	35	65.9	26.8	22.3	39.1	43.6	67	56	1.71	1.28	1.49
10	8	35	65.9	23.4	22.7	42.5	43.2	53	46	1.25	1.06	1.15
15	7	50	69.5	22.9	22.0	46.6	47.5	-	47	-	.99	.99
0	4	30	66.5	25.1	22.9	41.4	43.6	60	60	1.45	1.38	1.41
1/2	4	30	66.5	26.8	22.3	39.7	43.2	57	63	1.44	1.46	1.45
1	5	0	66.0	25.1	22.9	40.9	43.1	BK	63	-	1.46	1.46
3	5	0	66.0	26.8	22.3	39.2	43.7	63	65	1.61	1.49	1.55
5	5	15	64.8	23.4	22.7	41.4	42.1	55	55	1.33	1.31	1.32
10	5	15	64.8	23.0	23.4	41.8	41.4	57	BK	1.36	-	1.36
15	5	40	68.7	26.8	22.3	41.9	46.4	-	50	-	1.08	1.08

* Weight given is for each of a pair of centrifuge tubes plus grease. (Weights identical since centrifuge must be balanced.)

** Separation run in duplicate.

It is possible that solid matter with a density greater than one was pulled down by centrifuging where it would have remained entrapped by the grease under normal conditions.

D. EFFECT ON SEPARATION AS DETERMINED BY SETTLING

In order to approximate field conditions as nearly as possible with the equipment at hand, it was decided to dilute the treated mixture and allow it to classify by gravity. This was accomplished by first diluting the scum with water in the ratio of 1:1, then mixing for a brief period to obtain a uniform dispersion, and finally dosing with Sea-Chem in concentrations of 0, 1, 3, 5, 10 and 15 gms/100 ml of diluted scum in a 250-ml Erlenmeyer flask. These flasks were allowed to stand for various contact times, ranging from 15 min. to 18 hrs. The mixture was then dumped into 500-ml graduates and diluted with cold water to make 500 ml. After settling for from 15 to 20 min. the volume of scum and the volume of sediment were read and recorded (see Table 4). In the earlier runs an attempt was made to obtain a settling curve. However, the separation was much too rapid to obtain significant data.

For the runs made on the Waldorf grease the results are shown in the following tables:

TABLE 4

Scum Volume in ml (15 to 20 min. settling)

Sea-Chem Dosage Grams	Contact Time - Hours				
	.25	1.5	4	6	18
0	140	115	125	120	125
3	90	80	85	85	80
5	75	70	75	75	70
10	60	55	60	60	55
15	60	50	45	50	45

TABLE 5

Sediment Volume in ml (15 to 20 min. settling)

Sea-Chem Dosage Grams	Contact Time - Hours				
	.25	1.5	4	6	18
0	60	55	50	60	50
3	95	75	85	90	75
5	105	85	90	100	85
10	110	110	115	115	110
15	115	115	115	125	120

TABLE 6

Per Cent Reduction in Scum
(15 to 20 min. settling)

Sea-Chem Dosage	Contact Time - Hours				
Grams	.25	1.5	4	6	18
0	0	0	0	0	0
3	35.7	30.4	32.0	29.1	36.0
5	46.4	39.1	40.0	37.5	44.0
10	57.2	52.2	52.0	50.0	56.0
15	57.2	56.5	64.0	58.3	64.0

Since the total volume of scum plus sediment for each run is approximately a constant, it is more illustrative of the effect to report the scum and sediment as a percentage of this total. In view of the fact that contact time had no effect, the percentages for all contact times were averaged.

TABLE 7

Per Cent Scum (15 to 20 min settling)

Sea-Chem Dosage Grams	.25	1.5	4	6	18	Avg.
0	78	68	72	68	71	71
3	49	52	50	49	52	50
5	42	45	45	43	45	44
10	35	33	34	34	33	34
15	34	30	28	29	27	30

TABLE 8

Per Cent Sediment (15 to 20 min contact time)

Sea-Chem Dosage Gram	Contact Time - Hours .25	1.5	4	6	18	Avg.
0	30	32	28	33	29	30
3	52	48	50	49	48	49
5	58	55	55	57	55	56
10	66	70	72	71	73	66
15	66	70	72	71	73	73

These results have been plotted in Fig. 1.

During the runs made on this grease several observations were made as follows:

a. The viscosity of the grease and the size of the particles seemed to be reduced when treated with 10 or 15 gms of Sea-Chem since the grease poured easily and flowed smoothly with fine lumps.

b. As the concentration of Sea-Chem rose the color of the scum became darker and the scum became less flocculent and more uniform.

c. An analysis of the Waldorf grease yielded the following results:

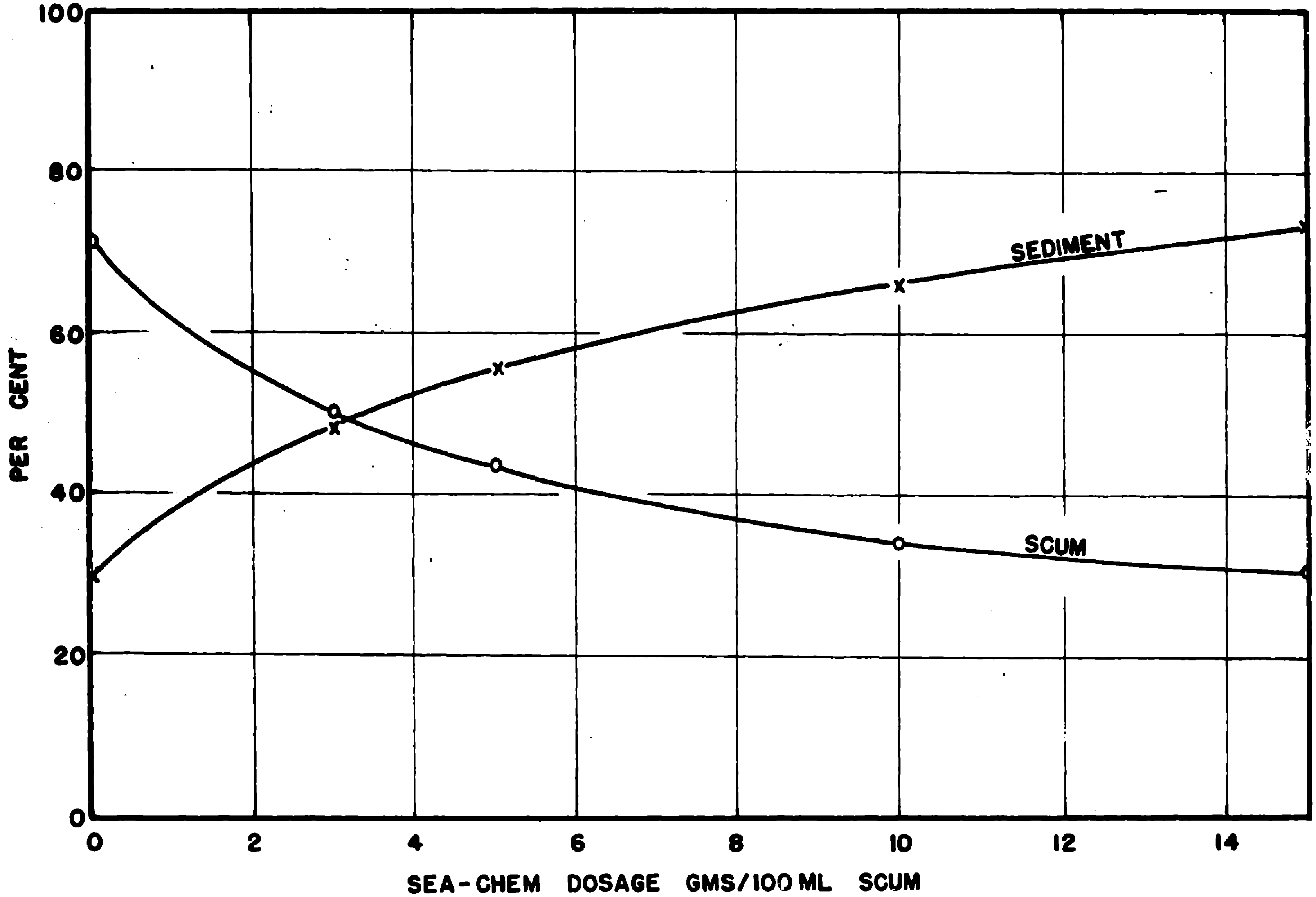


FIG I - EFFECT OF SEA-CHEM AS DETERMINED BY SETTLING

Moisture - 35.5%

Volatile Matter = 98.1% (of solids)

Grease (Soxhlet Extraction) = 34.1%

A second set of tests was made using the grease from the cafeteria at the M.I.T. Graduate House. The procedure in these runs was the same as that used with the Waldorf grease.

The results of these runs are shown in Table 9. The contact time is 15 min. and the settling time 15 to 20 min. in both cases. The values represent the amount of scum and sediment in ml in the 500-ml graduate.

TABLE 9

Scum, Sediment and pH

Sea-Chem	Scum		Sediment		pH	
Grams	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2
0	75	70	25	10	6.2	5.7
3	55	70	30	15	6.0	5.7
5	60	60	35	30	6.0	5.8
10	50	45	40	35	5.9	5.9
15	70	55	50	50	5.8	5.9

Some observations are as follows:

a. Little change in viscosity occurred with increased dosage. Lumps of grease did not appear to be broken down.

b. When the graduates were heated, considerable gas was evolved causing the scum to foam and making accurate volume readings impossible.

c. The grease did not disperse easily and showed little affinity for water.

d. An analysis of the Graduate House grease gave the following results:

Moisture - 57.0%

Volatile Matter = 96.6% (of solids)

Grease (Soxhlet Extraction) = 37.6%

E. <u>BALLS MATLACK TEST</u>

A theoretical test has been devised (12) for measuring the hydrolytic activity of a crude lipase preparation. The procedure for this test is as follows:

Method for Lipase: 0.00565 mole of substrate is weighed into a glass stoppered bottle of about 125 cc capacity. To this are added 5 cc of a solution of dried ox bile in glycerol (10 cc of glycerol to 1 gm of bile) kept at 60-70° for convenience in measuring. A quantity of glass beads is introduced and the bottle is placed in boiling water and shaken until the substrate is completely dissolved. The bottle is then shaken under the cold water tap until the contents are cooled down to room temperature.

To the emulsion of glycerol and fat are then added 10 cc of 0.05M ammonium chloride-buffer at pH 8.0, 100 mg of calcium chloride (in water solution), and 0.25 cc of 3 per cent phenolphthalein solution. Enough water is next added so that the total volume of the system will be 30.0 cc after the enzyme has been introduced. The enzyme is put in last of all and the contents of the bottle are well mixed, but not shaken to a froth. A 5-cc sample of the emulsion is pipetted into 75 cc of a mixture of 9 volumes of alcohol and 1 volume of ether and titrated with alcoholic KOH, with phenolphthalein as an indicator.

The "Food, Chemical and Research Laboratories, Inc." have applied this test to Sea-Chem. The substrate used was the simple ester, benzyl n-butyrate, and the reaction took place at a temperature of 40°C. It has been reported that 100 per cent hydrolysis of 0.25 gms of the substrate occurred in 90 min.

To corroborate these findings, the same test was conducted by the author. However, 0.00565 moles (1.00 gms) of benzyl n-butyrate were used as substrate instead of 0.25 gms. The results of this test are shown in Table 10.

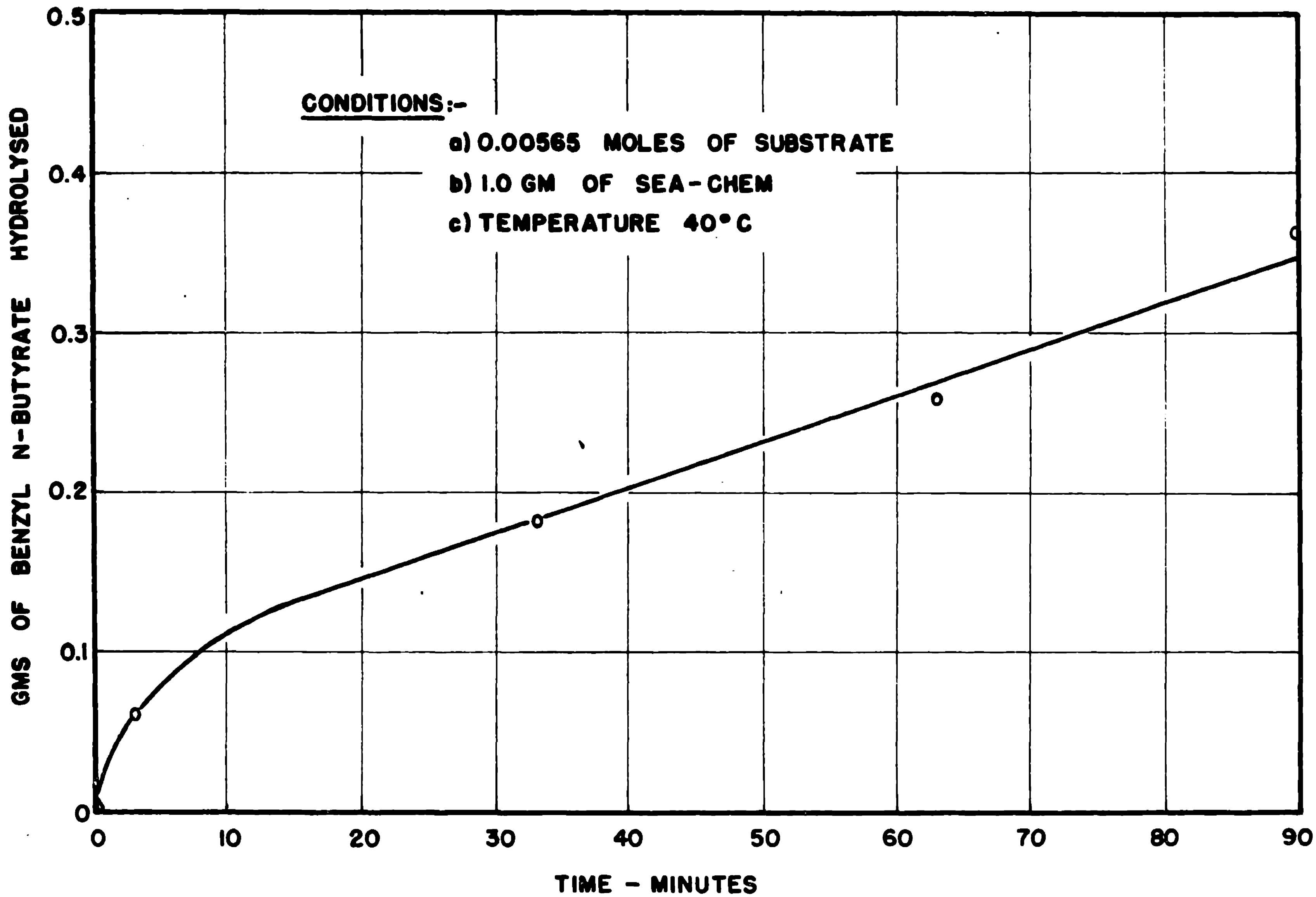


FIG 2 - BALLS - MATLACK TEST

TABLE 10

Hydrolysis of Benzyl- N-Bityrate

Elapsed Time Min	0.1 N KOH ml	Titration Corrected* ml	Hydrolysis gms
3	2.3	0.6	.064
33	3.4	1.7	.181
63	4.1	2.4	.257
90	5.1	3.4	.364
750	11.0	9.3	1.00

* 1.7 ml substracted from titration for acidity of the system without hydrolysis.

Since it has been found (13) that the total amount of substrate present does not affect the amount of hydrolysis these results are comparable to those obtained by Food, Chemical and Research Laboratories Inc. In general, the agreement is fair; 0.25 gms being hydrolysed in 60 min in these tests instead of 90 minutes. The error could be due to variation in the product or to certain variables in the test itself.

This test however is not of value in determining the effect of Sea-Chem on a grease trap, since the results are at best relative due to the very unnatural conditions under which the test is conducted. Further, the substrate used, benzyl n-butyrate, was selected (13) because it is hydrolysed very rapidly in a zero order (linear) reaction, not because it is typical of any fat. As discussed in Chapter II simple esters, such as benzyl n-butyrate, are hydrolysed rapidly by esterase but slowly by lipase while true fats act the reverse. Thus all that has been determined is the relative esterase content of Sea-Chem and not the concentration of lipase, which is of importance in this study.

F. DISCUSSION OF RESULTS

The reduction in scum which was seen to occur may have been attributable to the separation of solids heavier than water from the grease, thus allowing these solids to settle. This is based on the following observations:

a. The percentage of grease in the scum is not great enough to account for the reduction in the quantity of scum since the reduction was in the order of 50% while the grease content of the untreated material only amounted to 34.1% of the original scum solids. Therefore, some of the nongreasy substances must have dropped out of the scum.

b. A change in the viscosity of the Waldorf grease was noted. Large lumps appeared to have been broken down so that the remaining scum flowed more readily.

A single treatment does not seem to accomplish much effect. The grease from the Waldorf had been treated once, before it was brought to the laboratory while the grease from the Graduate House had never been treated. This possibly accounts for the fact that almost no effect was noted in the laboratory treatment of the Graduate House grease.

It is likely that more occurs than mere hydrolysis since considerable gas is produced by the mixing of Sea-Chem and grease. The results of the Balls-Matlack test are not a valid measurement of the ability of Sea-Chem to hydrolyse common fats.

These studies tend to indicate that several physical conditions are of considerable importance in evaluating the action of Sea Chem. Surface area, degree of agitation, concentration and compaction of the scum layer are all variables which must be taken into account if this product is to be treated in a realistic manner.

CHAPTER IV

PILOT PLANT STUDIES

A. OBJECTIVES

It became evident during the preliminary studies that the effects of the several important factors upon which the action of Sea-Chem on the fat in a grease trap depends would make it imperative that the conditions in a grease trap be very closely reproduced, and further that the results of all tests be correlated with adequate controls. The surface area of the grease for example is more important than the actual quantity of grease since an enzyme which is not soluble in both fat and water must act at the fat-water interface only. This area is dependent upon how the fat and water are mixed, and upon their respective temperatures; consequently in any test the two-phase system of fat and water must closely resemble the situation found in a typical trap. Other factors, such as temperature and degree of agitation must also be considered and be made to simulate their counterparts in grease-trap operation.

For these reasons, it was decided to set up a number of model grease traps on the drain of a model sink. To further simulate prototypes, the water used was a synthetic sewage containing the salts and bacterial populations that might be expected in a restaurant sink drainage. Each test setup was in duplicate so that one unit could be treated and compared to an identical but untreated unit.

B. DESCRIPTION OF APPARATUS

The apparatus designed to meet the conditions mentioned consisted of an elevated storage tank (model sink) containing hot water with salts and bacteria, an arrangement for mixing melted grease with this water as it flowed to the traps and a set of six model traps and containers for the trap effluents.

Model Sink. Mounted above the level of the traps was a stainless steel water storage tank 35.1 cm in diameter and 56.5 cm deep having a total volume of 52 liters. The cover of this tank held a motor stirrer, two immersion heaters regulated by a thermostat, a float mechanism for measuring the level in the tank, a thermometer, and an inlet hose connected to the cold water tap.

Drainage Feed System. A pipe, connected to the bottom of the storage tank so that the tank would drain dry, led through a valve to a rubber hose to the traps below. Above the top of the tank was a one-liter leveling bulb connected by a glass tube to a tee on the pipe between the tank and valve. This bulb was used to hold the melted grease so that it would feed into the flow from the tank when a clamp on the grease line was opened. A leveling bulb was used for this purpose since it is constructed with an outlet on the bottom and will not retain any grease.

The rubber hose leading from the storage tank pipe to the traps terminated in a 4-in. glass tube held in the proper position at the trap by a ring stand and clamp. The hose can thus be moved from trap to trap without changing the orientation of the outlet tube.

Model Grease Traps. McLeod (14) investigated the factors affecting the operation of a grease trap. It was found that a trap utilizing a louvered inlet dam with simple underflow inlet and outlet baffles operated at the highest efficiency. The effect of this dam was to produce an upward current and thus prevent the grease from short-circuiting across the bottom of the trap. However, this louver also prevents settled solids from being removed until they reach the level of the first opening in the louver.

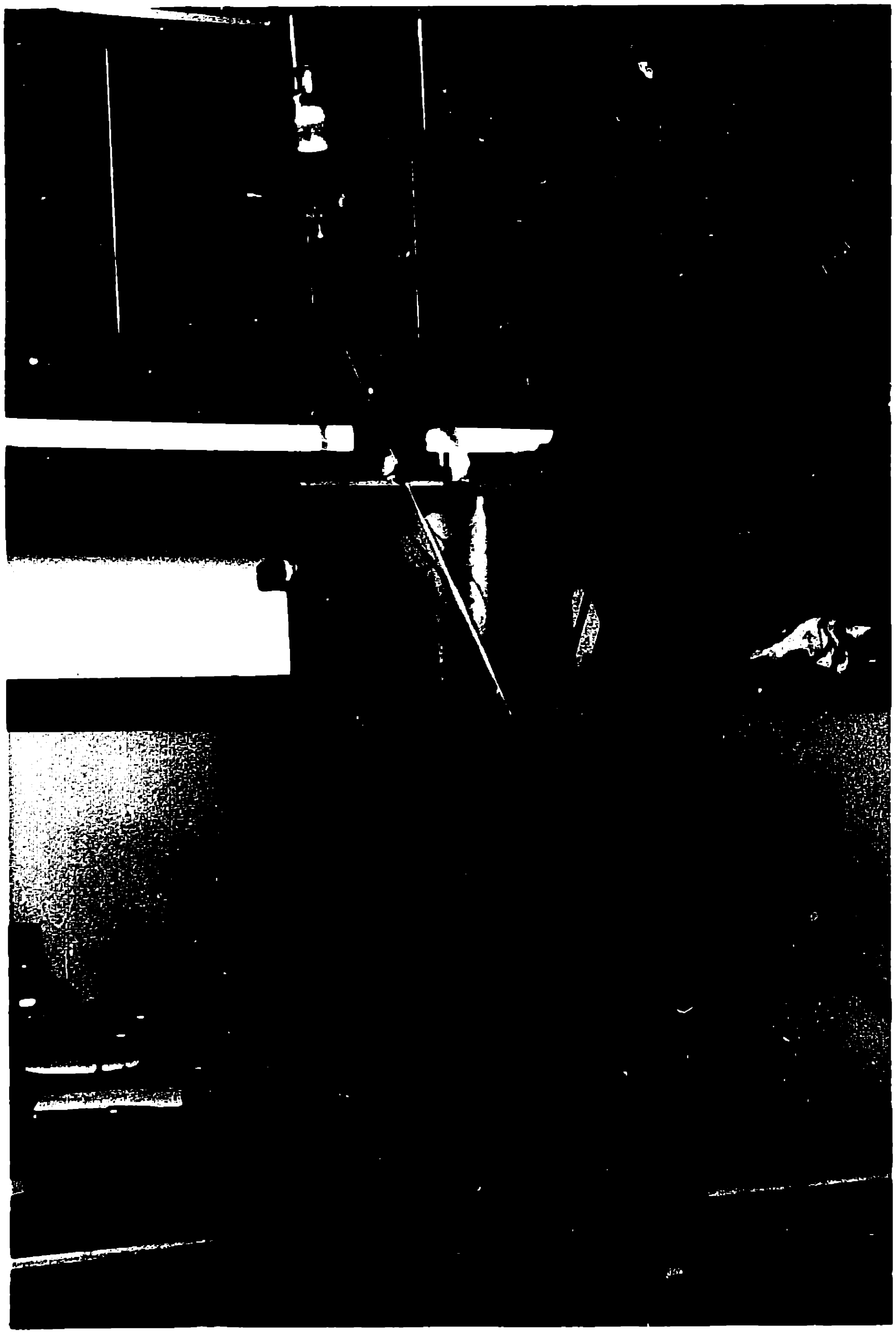


FIGURE 3

MODEL SINK AND GREASE FEED SYSTEM

A grease trap may be considered an inverted settling tank and certain of the same design criteria apply. Babbitt (15) has stated that in practice the magnitude of V_R, the minimum rising velocity of grease in water, is in order of 10 in./min. Further it has been recommended that the horizontal velocity through the trap should be approximately 1 ft./min. and that the detention time should be either 1 min. or the drainage period of the sink if longer than 1 minute. Since the water storage tank contained 52 liters and it was desired to operate six traps, the maximum flow per flushing was set at 8.5 liters. Assuming a drainage period of 1 minute, a typical value for a well designed restaurant sink, the flow rate would be 8.5 liters/min. or 2.24 gal./min. Thus the surface area of the tank for an overflow rate of 10 in./min. would be:

$$A = \frac{2.24 \times 12}{10 \times 60 \times 0.125} = .358 \text{ ft}^2 = 51.6 \text{ in}^2$$

With a detention period of one minute the volume of the trap would be:

$$V = 2.24 \times 1 = 2.24 \text{ gal} = 517 \text{ in}^3$$

From the surface area and the volume the depth may be calculated:

$$D = \frac{517}{51.6} = 10 \text{ in}$$

The horizontal velocity will then determine the width:

$$W = \frac{12 \times 2.24 \times .00223 \times 60}{10 \times 1} = .36 \text{ ft} = 4.32 \text{ in}$$

From the volume, width and depth the length may be calculated:

$$L = \frac{517}{4.32 \times 10} = 12 \text{ in}$$

The dimensions of the trap thus designed were 12 in. long by 10 in. deep by 4.32 in. wide. It was found however, that a number of Plexiglas tanks measuring 15 in. long by 7 in. deep by 5.75 in. wide were available and since they were near to the designed dimensions, it was decided to modify these tanks to make use of them. By placing the inlet and outlet baffles 1 1/2 in. from each end the length was reduced to 12 in. Plastic strips 1 1/2 in. high were at the top on the sides and the influent end to prevent splashing so that the full 7 in. depth could be utilized. Using the same method as with the preceding design the following were determined for these modified tanks:

Surface Area = 0.480 ft^2

Cross-Sectional Area = 0.284 ft^2

Volume	= 0.280 ft^3
Flow	= 7.9 liters/min
O/F	= 4.36 $gal/ft^2/min$
	= 7 in/min
Horizontal Velocity	= 1.0 ft/min
Detention Time	= 1 min.

This design therefore meets the criteria exactly in all respects except that the overflow rate is 7 in/min instead of the recommended 10 in/min. The lower overflow rate will increase the efficiency slightly; however, it in no way detracts from the operation of the trap.

A photograph of a trap as designed is shown in Fig. 4. A chute was added to carry off the effluent. The flow would pass over the weir through the chute, into a funnel and down a 1 1/2-in. glass tube to a five-gallon glass jug on the floor. This jug was marked at 8 liters and a jug was provided for each trap.

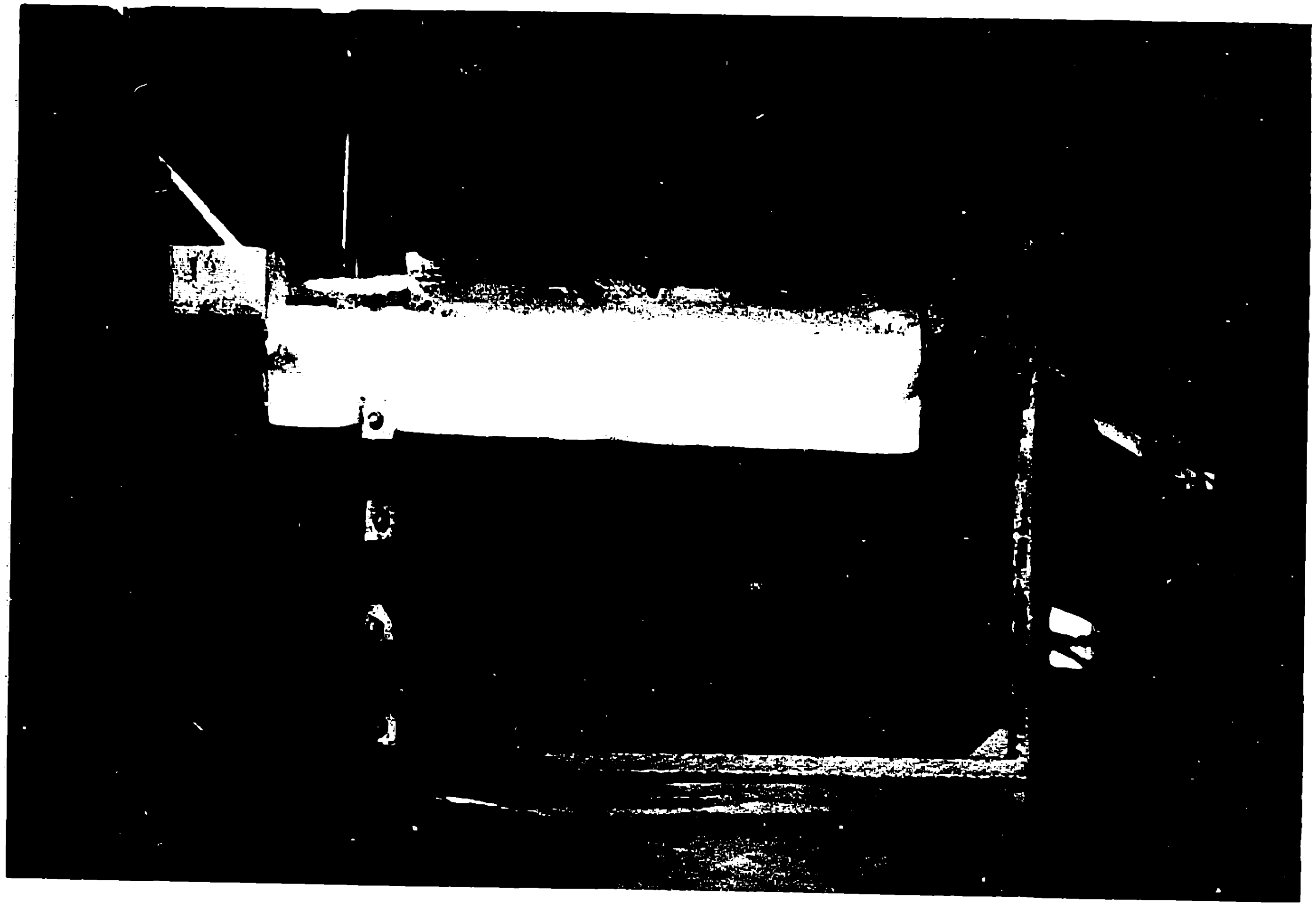


FIGURE 4
MODEL GREASE TRAP

C. EXPERIMENTAL PROCEDURE

1. Arrangement

The six traps were divided into three groups of two each. In general the procedure consisted of loading each group of traps with a different type of scum and treating one of the two traps in each group with Sea-Chem. The other trap was held as a constrol. The analyses made were grease, acidity and pH of the daily effluent, depth of scum in the traps and weight of grease, acidity and solidification point of the scum remaining at the end of the run.

2. Loading and Flushing

In the traps which were loaded with a homogeneous fat the procedure was as follows:

a. The water storage tank was filled with cold tap water and heated overnight by two immersion heaters to 60°C. The temperature was held at this point by a thermostat. Sixty degrees centigrade was selected because it is approximately the normal temperature of typical restaurant sink drainage.

b. Immediately before flushing, the grease to be added, if any, was heated to 100°C and poured into the leveling bulb above the water storage tank.

c. Next the tube on the end of the hose from the water storage tank effluent pipe was placed in position at the head end of the trap to be flushed by moving the ring stand and clamp. The effluent funnel, tube and container were then placed in position under the effluent chute.

d. The valve had been previously calibrated so that the system would deliver 8 liters/min. when the valve was opened to a marked point. After the flow had begun the clamp on the hose connection from the leveling bulb was opened. The grease was then pulled into the flowing water by venturi action and mixed by the turbulence in the pipe. If no grease was to be added this clamp would remain closed, thus preventing air from entering the trap.

e. When the 8-liter mark was reached in the effluent jug the valve was closed. The ring stand, hose effluent tube and funnel were then moved to the next trap and the procedure repeated.

f. After all traps had been flushed and loaded, the remainder of the water in the storage tank was emptied and the tank flushed and refilled. Last the motor stirrer immersion heaters were turned on.

The quantity of grease added in each group of traps was designed to load the traps to capacity in a time typical of restaurant trap operation. This rate of addition however is not critical since in most cases the Sea-Chem treatments would start when the trap was fully loaded.

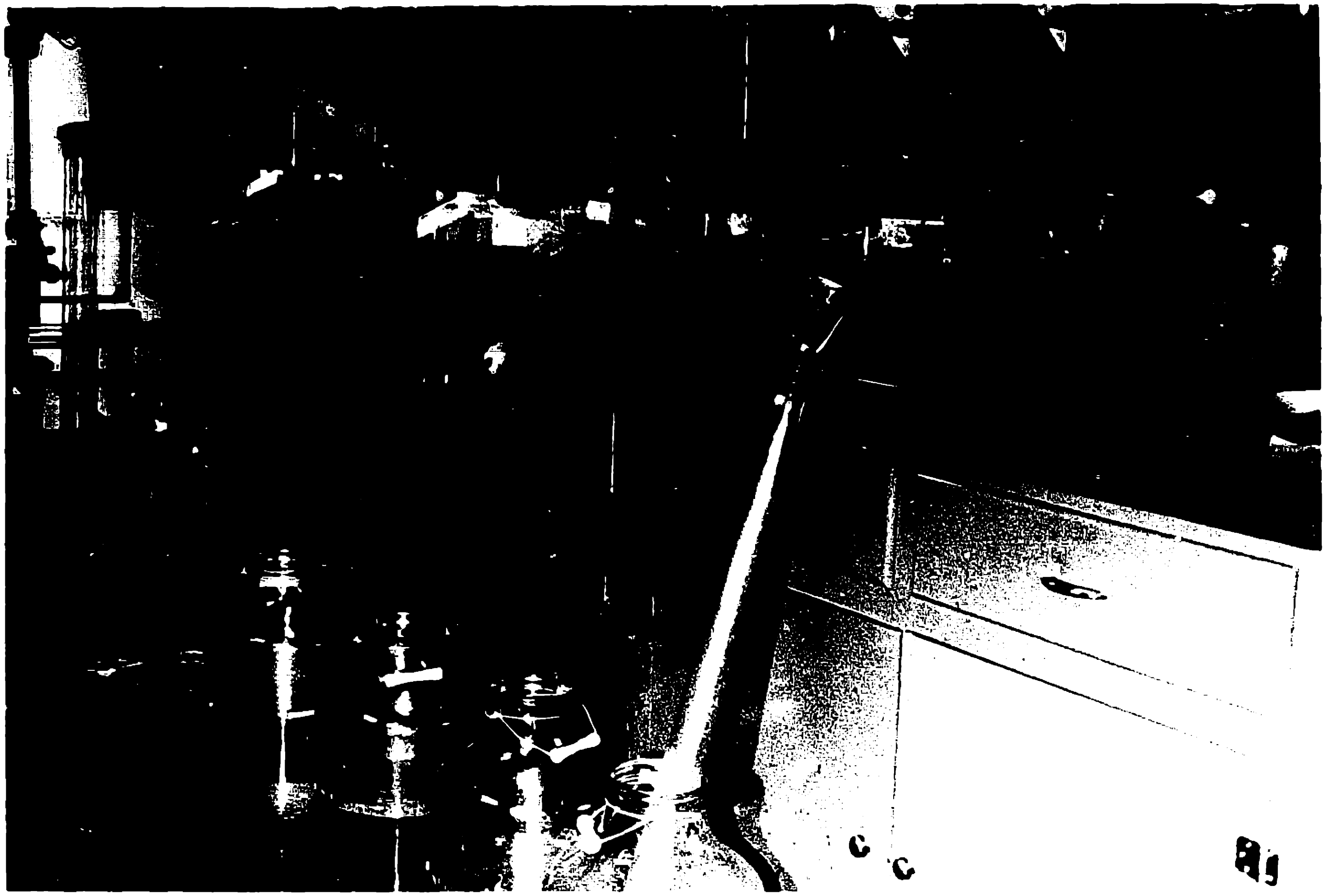


FIGURE 5

TRAPS AND EFFLUENT JUGS IN POSITION

It was found that the pH in the treated traps dropped to a very low value after a number of days. Since a sink waste will contain proteins and other buffering materials, this situation might be unnatural. Further it was possible that some biological activity might occur in grease traps even if Sea-Chem were not added if nutrients and seed material were present. Therefore it was decided to add nutrients, buffer salts and sewage seed to the feed water.

Weinberger (16) developed a synthetic sewage whose strength and composition are similar to those of a domestic sewage. This sewage contained organic matter such as proteins, sugars and fats, nutrient salts and buffers and some colloidal material. In these experiments the organic matter was supplied by the fat, any additional organic matter would probably only increase the load. Consequently, only the two principal inorganic nutrient salts from the Weinberger sewage, dipotassium hydrogen phosphate for phosphorus, and ammonium sulfate for nitrogen, were added, together with sodium bicarbonate to provide alkalinity for buffering capacity. The concentrations of the added salts in the flushing water were as follows:

Dipotassium Hydrogen Phosphate	27.5 ppm
Sodium Bicarbonate	168.0 ppm
Ammonium Sulfate	90.0 ppm

These salts were made up in a single solution such that 2 ml/liter gave the above concentrations.

Since the waste from a sink has been quite hot it would not be likely to contain many viable organisms, thus only 2 ml of Boston sewage were added as seed to each liter.

One hundred ml each of both nutrient-buffer solution and the sewage seed were added to the water storage tank immediately after the tank was filled.

3. Dosing Procedure

Two methods were used to add the Sea-Chem to the treated traps. At the beginning of each run and at each change in dosage the quantity to be added was spread on the surface of the trap and both the treated and untreated traps mixed thoroughly. The daily doses between changes in concentration were added at the head end of the trap where the influent enters, and this area stirred thoroughly without disturbing the scum. These methods follow from the manufacturer's recommendation. It is stated in the instructions for the use of the product that the first dose should be mixed with the scum and that succeeding doses should be dumped down the drain with a small quantity of cold water. With respect to the latter it is likely that the procedure used in these experiments caused the Sea-Chem to be more thoroughly distributed through the traps.

In all cases the traps were treated with Sea-Chem from 4 to 8 hours after flushing. This delay was necessary so that the trap could cool; otherwise the enzymes might be deactivated immediately upon entering the trap by the heat. When diatomaceous earth was added it was done at the same time and in the same manner as with the Sea-Chem.

The size of the Sea-Chem dose at the beginning of the run was based on the manufacturer's recommendations. These recommendations state that for a 200-gallon grease trap the following procedure should be used:

First Treatment	1 lb (mixed)
First Week	4 oz/day
Second Week	2 oz/day
Third Week	1 oz/day

Thus for the size traps used in these experiments the dose should be 4 gms in the initial treatment and proportionally decreasing doses in succeeding treatments.

The first traps to be loaded, numbers 1 and 2, contained relatively pure bleachable tallow. In actual traps the fat concentration is usually equal to about one half the total concentration of solid matter. Consequently the Sea-Chem dosage was raised to 10 gms for the first day and 2.5 gms for the next 19 days.

After the magnitude of the effect of the Sea-Chem became evident, the dosage was increased far above the recommended dosage. Thus traps 1 and 2 were continued at 2.5 gms/day after the first week and traps 3 and 4 and 5 and 6 were started at much higher dosages. As each run progressed the dosage was increased further in an attempt to stimulate the effect. However the ratio of the initial dose to the daily dose in each period remained 4 to 1.

4. <u>Types of Scum Layers</u>

The greases to be added to the traps were selected so that any common type of fat or mixture of fats and solids would be represented. The fats which would be expected in a grease trap are those released by the cooking of common meats; beef, mutton and pork, plus certain hydrogenated vegetable oils and as shortenings. Consequently traps 1 and 2 were loaded with the typical shortening Spry (Lever Bros.). Traps 5 and 6 were loaded with bleachable tallow, a mixture of common meat fats obtained by rendering. The bleachable tallow was procured from the Hinkle Rendering Company, Somerville. Both these fats were homogeneous and were therefore added by the procedure described under loading and flushing.

Since the scum in an operating grease trap contains non-fat solid matter in addition to the fats, it was decided to load one set of traps with an actual grease trap scum. Traps 3 and 4 were therefore loaded with a scum obtained from the Waldorf Cafeteria System grease trap (See Chapter III). This trap had been thoroughly cleaned since the previous sample of scum was taken, and no further Sea-Chem treatments had been made. As this scum was not homogeneous and contained large lumps of solid matter it was impossible to load the traps in the usual manner. Therefore the scum was deposited in the trap at the beginning of the run and no further additions made after flushing had begun. Thus, at the start of the run, the traps represented fully loaded restaurant traps which had not been treated. The procedure for flushing was the same as outlined above, except that no grease was added.

D. ANALYSES

1. Effluent Grease

The determination of grease in the effluent was made in a rather unique manner. Since the volume of the effluent was so great and since, due to the scum on the surface of the effluent, a homogeneous sample could not be obtained, the usual methods of grease analysis, such as Soxhlet extraction, could not be made. Further, since even the shortest of these analyses requires 7 hours elapsed time and 2 hours working time it would not be possible to make daily determinations on as many as six effluents. A less accurate, but still satisfactory method was devised.

The only solid matter in the effluent other than the grease and its decomposition products were the solids in the tap water, plus a certain amount of Sea-Chem in the cases of the treated traps. It was therefore possible to determine the total solids of a quantity of an emulsion formed by mixing the effluent with 10 gms of a detergent (Lakeseal glass cleaner). To correct this value, the solids concentrations caused by the tap water, Sea-Chem and detergent were substracted.

As the run progressed it was seen that relatively little grease was leaving the trap. Consequently the grease determination was discontinued and reliance was placed on the acidity of the effluent, the thickness of the scum layer and ultimately upon the amount and condition of the scum and sediment remaining in the trap at the end of the run.

2. Acidity and pH

From the theory it can be seen that any form of decomposition of a fat is going to result in the production of acids. Therefore the acidity of the effluent could be used as an index of enzyme activity.

Early in the experiment, before the nutrient solution was added, the acidity was determined by titrating 50 ml of the effluent with N/50 sodium hydroxide to the phenolphthalein end point. The use of sodium hydroxide would cause the free fatty acids to be converted into sodium soaps. Thus, the acids would be brought into solution and their complete neutralization would be assured. However, the pH was not raised high enough to cause the fat to saponify. Measurements were made of the pH of the liquid in the traps and not of the effluent at this time.

Later, after nutrients were added, titration curves were made of the effluent with nutrients and of the nutrient alone. From these curves it was evident that all the acidity of the effluent was neutralized when the pH of the nutrient solution in tap water was reached. Consequently, the acidity determinations from this time on were made with a pH meter, by titrating to the pH of a sample of the feed water taken during flushing. The pH of the effluent was taken before the titration was begun.

3. Scum Thickness

The thickness of the scum in each trap was measured with a scale after the trap had time to cool. In some cases the scum layer was irregular and several measurements had to be made and arranged.

4. Quantity of Grease in the Traps

At the end of each run the scum and sediment were removed from each trap and placed in battery jars. The jars containing the scum were then placed on a steam table and heated for several days. Periodically the grease on the surface was decanted and collected in a tared battery jar. When all the grease had been removed, it was weighted and stored for further determinations.

Since the sediment contained a great deal of matter other than grease, mere heating would not cause the grease to separate. An ether extraction was therefore necessary.

First as much water as possible was removed by evaporation. The residue was then mixed with petroleum ether (B.P. 35-60°C) and filtered. After repeated extraction the filtrate was placed on a steam table to drive off the ether, and the volume of the extracted fat was measured. It is unlikely that all the grease was removed by this rather crude process, consequently the volume of grease is only approximate. However, this grease was needed for other determinations.

5. Solidification Point of the Scum

The temperature at which the grease congealed was determined on all samples of scums, sediment extracts and original fats. About 125 ml of each grease was melted and placed in a 500-ml graduate. A melting point thermometer was lowered into the grease to the immersion line (75 mm from the bulb). At intervals the temperature was recorded and when evidence of hardening, together with a leveling off of the temperature decrease was noted, the solidification point had been reached.

6. Acidity of the Scum

The acidity of the grease was determined by the method described in the Balls-Matlack test for titrating the acidity of the hydrolysis reaction mixture. Since this titration is carried out in an ether-alcohol dilution, it is not necessary to rely on the solution of the fatty acids in water.

E. METHODS OF COMPUTATION

1. Cumulative Acidity Curve

The acidity data as taken are in the form of parts per million as $CaCO_3$. This method of expression had little significance in these experiments. The object of these determinations was to find the quantity of hydrolyzed fat being carried over into the effluent. From the analysis of fats presented in Chapter II it can be seen that the fatty acids released by hydrolysis of the fat would be predominantly 18-carbon acids. Consequently, it was decided to convert the acidity into terms of the saturated 18-carbon stearic acid. Further, since the volume of the effluent on which the acidity was determined was known, it was possible to determine the number of grams of stearic acid leaving the trap per day.

Since the acidity values varied somewhat erratically it was decided to present the cumulative weight of stearic acid rather than the daily weight. This method of expression is of particular value since it indicates the total amount of hydrolyzed fat which has left the trap up to any given day.

2. Per Cent Hydrolysis

At the end of each run the scum was titrated to determine its acidity. The acidity of a fat is usually expressed as its acid value.

Acid value = number of MG of KOH required to neutralize the free fatty acids in one gm of fat.

It was desired, however, to convert this value into per cent hydrolysis of the fat. This was possible since the acid values of the insoluble fatty acids released by 100 per cent hydrolysis of the common fats were essentially constant. These values are presented below:

Fat	Acid Value of Insoluble Fatty Acids at 100% Hydrolysis (17)
Beef Tallow	197.2
Mutton Tallow	198.0
Cotton Seed Oil	198.4

The acid value of the fats calculated from the assumption that the fatty acids released were predominantly stearic acid is given below:

$$\text{Acid value} = \frac{56.10}{284.47} \times 1000 = 197.1$$

Since the agreement was so close it was assumed that at complete hydrolysis the acid value would be about 200. Consequently, the per cent hydrolysis can be calculated from the following formula:

$$\% \text{ Hydrolysis} = \frac{\text{Acid Value of Fat} \times 100}{200}$$

$$= \frac{\text{Acid Value of Fat}}{2}$$

This method was used to obtain the data presented in Table 15.

F. SOURCES OF ERRORS

1. General Accuracy

Since the objective of these experiments involved qualitative observations, each determination was carried to the reasonable limit of its accuracy, and when possible, erratic results were checked. The nature of the material on which determinations were made was such as to cause considerable interference in some analyses.

Some mention of the accuracy of the tests is given under analyses; however, more complete discussion will be added here. Those tests not mentioned in this section were as accurate as would be expected for the type of test.

2. Effluent Grease

No great accuracy can be claimed for this procedure due to variations in tap water solids and Sea-Chem concentrations. For example, it was necessary to estimate the amount of Sea-Chem carried over into the effluent.

However, it is evident that if any significant quantity of grease was carried out with the effluent, the grease would greatly exceed the other solid matter and any inaccuracy in the correction would be unimportant.

3. Acidity and pH

It was noted early in the run that the pH meter electrodes became clogged with fat, and therefore were not always reliable. The effect of this clogging was to make the meter read low; consequently, if the acidity values were in error, they were too high.

Since the pH of the feed water was always read before the electrodes came into contact with the effluent, this pH may be relied upon. In most cases this pH was very close to 8.2. As this is the end point of phenolphthalein, this indicator was used as a check on the pH meter. When the meter and the indicator disagreed, the indicator was relied upon.

The pH of the effluent was usually determined before the electrodes had an opportunity to clog. These values, therefore, are very nearly correct.

CHAPTER V

RESULTS

On the sixteenth day titration curves were determined for the effluent of trap 1 and the feed water with nutrients and buffer added. The data for these curves are shown in Table 11. The curves are plotted in Figure 6.

The data for the runs made with the three groups of traps are presented in Tables 12 through 14. Significant curves from these data are shown in Figures 6, 8, 10, 11 and 12. The results of the determinations made on the scums and sediments at the end of the runs are recorded in Table 15. In addition to the quantitative data, a number of photographs and observations are also presented.

Table 11

TITRATION OF FEED WATER AND EFFLUENT
(500-ML. SAMPLES)

Feed Water

ML 1/N NaOH	pH	ML 1/N NaOH	pH
0.00	8.25	1.45	10.30
0.10	8.50	1.55	10.40
0.20	8.75	1.70	10.50
0.30	8.95	1.80	10.60
0.40	9.15	1.90	10.65
0.50	9.30	2.00	10.75
0.60	9.40	2.30	10.90
0.70	9.55	2.45	11.00
0.80	9.70	2.70	11.05
0.90	9.80	3.00	11.20
1.05	9.90	4.00	11.40
1.10	10.00	5.60	11.60
1.20	10.10	8.50	11.80
1.30	10.20		

Effluent

ML 1/N NaOH	pH	ML 1/N NaOH	pH
0.0	6.50	1.9	10.20
0.1	7.05	2.0	10.30
0.2	7.10	2.1	10.45
0.3	7.20	2.2	10.50
0.4	7.55	2.3	10.60
0.5	7.95	2.4	10.65
0.6	8.50	2.5	10.75
0.7	8.70	2.6	10.80
0.8	8.90	2.7	10.85
0.9	9.05	2.8	10.90
1.0	9.25	2.9	10.95
1.1	9.35	3.1	11.05
1.2	9.50	3.3	11.15
1.3	9.65	3.5	11.20
1.4	9.75	3.7	11.25
1.5	9.85	3.9	11.30
1.6	9.95	4.5	11.40
1.7	10.05	5.1	11.45
1.8	10.15	7.7	11.70

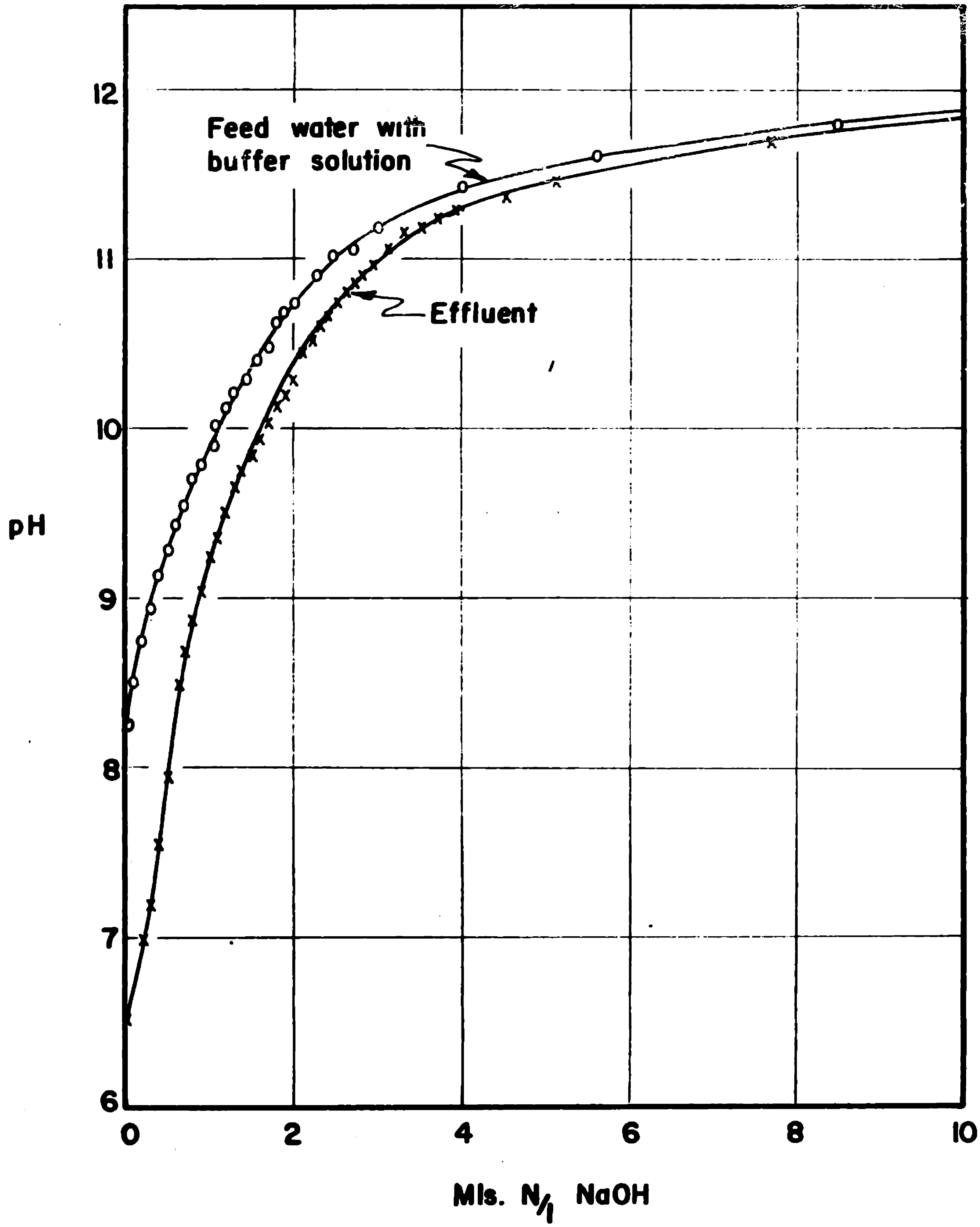


FIG 16 - TITRATION OF FEED WATER AND EFFLUENT

Table 12

DATA FOR TRAPS NO. 1 AND 2
(Trap 1 Treated)

Day	Spry Added Gms. (Both Traps)	Grease Out Gms. 1	Grease Out Gms. 2	Scum In. 1	Scum In. 2	pH (In Traps) 1	pH (In Traps) 2	Feed Water pH	Acidity ppm as $CaCO_3$ 1	Acidity ppm as $CaCO_3$ 2	Sea-Chem Gms. 1	Hydrolyzed Fat Out (Cumulative) Gms. as Stearic Acid 1	Hydrolyzed Fat Out (Cumulative) Gms. as Stearic Acid 2
1	500	6.0	6.0	1/2	1/2	6.7	7.3		(3.0)	(1.0)	10	.136	.045
2	500	7.7	8.6	3/4-1	7/8-1	6.15	6.90		(20.0)	(2.0)	2.5	1.04	.136
3	500	3.6	10.1	1 1/2	1 1/2	6.05	6.90		44.4	4.6	2.5	3.06	.346
4	200	1.3	3.1	1 3/4	1 3/4	5.75	6.90		(40.0)	(3.0)	2.5	4.88	.482
5	200	1.0	6.0	2	2	5.40	6.85		35.4	1.4	2.5	6.49	.546
6	200	3.4	6.4	2 1/8	2 1/8	5.50	7.10		30.8	3.2	2.5	7.89	.691
7	200	2.8	7.7	2 3/8	2 3/8	5.50	6.90		35.8	3.0	2.5	9.53	.828
8	200	0.0	5.9	2 1/2	2 1/2	5.50	6.90		39.0	3.0	2.5	11.30	.965
9	200	2.0	8.6	2 3/4	2 3/4	5.50	7.10		42.2	3.2	2.5	13.22	1.11
10	200			2 7/8	2 7/8	5.35	6.70		43.8	4.6	2.5	15.21	1.32
11	200			3 1/8	3 1/8	5.70	6.80		46.8	3.6	2.5	17.34	1.48
12	0			3 1/8	3 1/8				(50)	(10)	-0	19.62	1.53
13	0			3 1/8	3 1/8	(In effluent)			(50)	(10)	2.5	21.89	1.57
14	0			3 1/8	3 1/8	6.35	7.30		(50)	(10)	2.5	24.16	1.62
15	0			3 1/8	3 1/8	6.40	7.40		51.0	17.4	2.5	26.49	2.41
16	0			3 1/8	3 1/8			8.25	54.0	9.8	2.5	28.94	2.86
17	0			3 1/8	2 7/8	6.6	7.8	8.10	49.2	8.8	2.5	31.18	3.26
18	0			3 1/8	2 3/4	6.65	7.9	7.95	53.6	2.4	2.5	33.62	3.36
19	0			3 1/8	2 3/4	6.90	7.85	8.10	50.8	8.6	2.5	35.93	3.75
20	0			3 1/8	2 3/4	6.50	7.65	8.00	44.2	9.8	2.5	37.94	4.20
21	0			3 3/8	2 7/8	7.25	8.10	8.15	80.4	10.0	20	41.60	4.66
22	0			3 1/2	3	6.70	8.00	8.20	83.4	10.6	5	45.40	5.11
23	0			3 1/2	2 7/8	6.70	7.40	8.20	(80.0)	26.0	0	49.04	6.30
24	0			3 1/2	2 7/8	6.40	7.50	8.35	84.0	48.0	5	52.86	8.48
25	0			3 1/2	2 7/8	6.60	7.95	8.35	69.4	13.0	5	56.02	9.07
26	0			3 1/2	2 7/8	6.75	7.60	8.30	59.0	19.0	5	58.70	9.94

Table 12 (Continued)

Day	Spry Added Gms. (Both Traps)	Grease Out Gms.		Scum In.		pH (In Traps)		Feed Water pH	Acidity ppm as $CaCO_3$		Sea-Chem Gms.	Hydrolyzed Fat Out (Cumulative) Gms. as Stearic Acid	
		1	2	1	2	1	2		1	2	1	1	2
27	0			3 1/2	2 7/8	6.60	7.65	8.55	37.6	17.0	5	60.41	10.71
28	0			3 3/8	2 7/8	6.75	7.65	7.65	92.2	28.0	5	64.61	11.98
29	0			3 1/4	2 5/8	6.75	7.60	8.30	97.6	40.8	5	69.05	13.84
30	0			3 1/8	2 1/2	6.90	7.35	7.75	54.6	20.0	5	71.53	14.75
31	0			3 1/2	2 3/4	6.05	7.25	7.95	70.0	15.0	40*	74.72	15.43
32	0			3 5/8	3 1/4	6.00	7.15	8.40	94.2	24.0	10	79.00	16.52
33	0			3 5/8	3 1/4	4.75	7.25	8.30	500.0	36.8	10	101.8	18.20
34	0			3 5/8	3 1/4	5.45	7.65	8.20	195.2	16.8	10	110.6	18.96
35	0			3 5/8	3 1/4	5.75	7.70	8.35	154.8	13.8	10	117.7	19.59
36	0			3 1/2	3 1/8	5.65	7.15	8.35	146.0	28.0	10	124.3	20.87
37	0			3 3/8	3	5.90	6.70	8.10	74.6	24.0	0	127.7	21.96
38	0			3 1/4	3	4.65	6.75	7.75	548.6	22.8	10	152.7	22.99
39	0			3 1/8	3	5.20	6.70	7.50	186.6	25.2	10	161.2	24.14
40	0			3 1/8	3	5.50	6.65	8.25	111.0	28.0	10	166.2	25.42
41	0			3 1/8	3 3/4	5.45	7.20	8.15	157.6	24.0	80*	173.4	26.50
42	0			3 3/8	3 1/2	5.40	7.15	7.95	162.2	23.0	20	180.8	27.55
43	0			3 1/2	3 3/8	5.35	7.00	8.25	237.8	33.0	20	191.6	29.05
44	0			3 1/2	3 1/2	5.80	7.15	8.10	200.0	26.8	20	200.7	30.27
45	0			3 1/2	3 5/8	5.80	7.05	8.20	198.8	32.2	20	209.7	31.74
46	0			3 1/2	3 5/8	5.55	6.95	8.30	244.8	33.4	20	220.9	33.26
47	0			3 1/2	3 5/8	5.70	6.80	8.20	156.0	33.0	-	228.0	34.76

* On these days an equal weight of diatomaceous earth was added to Trap 2 (untreated trap).

( ) Values in parentheses are of doubtful accuracy.

Table 13

DATA FOR TRAPS NO. 3 AND 4
(Trap 3 Treated - Both Traps Loaded with Grease Trap Scum)

Day	Scum In.		pH (In Effluent)		Feed Water pH	Acidity ppm as $CaCO_3$		Sea-Chem Gms.	Grease Trap Scum Hydrolyzed Fat Out (Cumulative) Gms. as Stearic Acid	
	3	4	3	4		3	4	3	3	4
1	3	3				(350)	(350)	20	15.92	15.92
2	2 1/8	1 7/8				(300)	(300)	5	29.57	29.57
3	2	1 7/8	5.15	5.15	8.25	320	270	5	39.67	41.86
4	2	1 5/8	6.05	6.25	8.10	120	110	5	45.14	46.86
5	2	1 5/8	6.40	6.60	7.95	130	90	5	51.05	50.96
6	1 7/8	1 5/8	6.70	7.00	8.10	86.0	47.0	5	54.96	53.10
7			7.10	7.40	8.00	123.8	66.8	5	60.59	56.14
8	2	1 7/8	6.50	6.65	8.15	103.6	64.4	5	65.31	59.07
9	1 7/8	1 7/8	6.60	7.00	8.20	69.0	49.6	0	68.45	61.32
10	1 7/8	1 7/8	6.25	6.95	8.20	173.6	72.0	5	76.35	64.60
11	1 7/8	1 7/8	5.95	6.95	8.35	136.0	78.8	5	82.54	68.19
12	1 3/4	1 3/4	5.85	6.70	8.30	117.0	46.0	5	87.86	70.28
13	1 3/4	1 3/4	5.75	6.65	8.55	135.2	60.8	5	94.01	73.04
14	1 3/4	1 3/4	6.00	7.00	8.00	150	67.4	5	100.8	76.11
15	1 5/8	1 5/8	6.55	7.10	8.30	149.0	72.0	5	107.6	79.39
16	1 5/8	1 5/8	7.10	6.70	8.00	105.0	44.0	5	112.4	81.39
17	1 5/8	1 3/4	5.60	6.25	7.95	136.8	84.4	5	118.6	85.23
18	1 5/8	1 3/4	6.00	6.55	8.40	114.6	68.2	5	123.8	88.33
19	1 1/2	1 7/8	5.80	5.80	8.30	381.2	93.2	5	141.2	92.57
20	1 3/8	1 3/4	5.75	6.00	8.20	120.0	60.2	5	146.6	95.31
21			5.90	5.95	8.35	122.0	64.2	40*	152.2	98.23
22			5.45	5.10	8.35	323.6	148.4	10	166.9	104.9

Table 13 (Continued)

Day	Scum In.		pH (In Effluent)		Feed Water pH	Acidity ppm as $CaCO_3$		Sea-Chem Gms.	Grease Trap Scum Hydrolyzed Fat Out (Cumulative) Gms. as Stearic Acid	
	3	4	3	4		3	4	3	3	4
23			5.85	5.90	8.10	99.6	42.8	0	171.4	106.9
24	1 3/8	2	5.75	5.80	8.00	108.6	54.0	10	176.4	109.4
25	1 1/2	2	5.90	6.10	8.00	86.0	33.6	10	180.3	110.9
26	1 1/2	1 3/4	5.70	5.90	8.25	81.4	44.0	10	184.0	112.9
27	1 1/2	1 3/4	5.75	5.90	8.15	125.8	84.0	10	189.7	116.7
28	1 1/2	1 3/4	5.80	5.70	8.10	111.2	88.8	10	194.8	120.8
29	1 1/2	1 3/4	5.90	5.85	8.20	118.6	85.4	10	200.2	124.7
30			6.20	6.00	8.30	104.0	96.0	80*	204.9	129.0
31	3/4	1 1/2	5.60	6.20	8.20	346.4	75.2	20	220.7	132.5
32	3/4	1 1/2	5.80	5.50	8.00	199.4	102.4	20	229.7	137.1
33	3/4	1 3/8	5.85	5.50	8.20	159.0	97.4	20	237.0	141.5
34	3/4	1 3/8	6.00	6.60	-	145.4	76.2	-	243.6	145.0

* On these days an equal weight of diatomaceous earth was added to Trap 4 (untreated trap).

( ) Values in parentheses are of doubtful accuracy.

Table 14

DATA FOR TRAPS NO. 5 AND 6

(Trap 5 Treated - Both Traps Loaded With Bleachable Tallow)

Day	Tallow Added Gms. (Both Traps)	Scum In.		pH (In Effluent)		Feed Water pH	Acidity of Effluent		Sea-Chem Gms.	Hydrolyzed Fat Out (Cumulative Gms. as Stearic Acid	
		5	6	5	6		5	6	5	5	6
1	300	5/16	5/16	7.80	7.80	8.10	3.2	2.0	40	.146	.091
2	300	9/16	5/8	7.15	7.90	8.00	89.0	12.2	10	4.19	.646
3	300	7/8	1	7.20	8.25	8.15	102.0	0.0	10	8.83	.649
4	300	1 1/8	1 1/4	6.80	7.40	8.20	79.2	46.2	10	12.44	2.75
5	300	1 1/2	1 5/8	6.55	8.10	8.20	93.8	18.6	10	16.70	3.59
6	300	1 3/4	1 7/8	6.90	7.75	8.35	85.2	23.4	10	20.58	4.66
7	300	2 1/8	2 1/4	6.40	7.60	8.35	75.6	17.0	10	24.02	5.43
8	300	2 3/8	2 5/8	6.40	7.55	8.30	94.4	31.0	10	28.32	6.84
9	300	2 3/4	3	6.30	7.80	8.55	83.0	20.6	10	32.09	7.78
10	300	3 1/8	3 3/8	6.20	7.70	8.00	119.6	25.2	80*	37.53	8.92
11	300	3 1/8	3 1/8	5.90	7.25	8.30	310.4	17.6	20	51.66	9.73
12	300	3 3/8	3 5/8	5.30	7.05	8.00	274.0	16.8	20	64.13	10.49
13	300	3 5/8	3 3/4	5.35	6.90	7.95	252.6	21.8	20	75.62	11.48
14	300	3 7/8	4 1/8	5.55	7.35	8.40	259.2	37.8	20	87.41	13.20
15	0	4	4 1/8	5.60	7.15	8.30	249.8	56.8	20	98.78	15.79
16	0	4	4 3/4	5.60	7.05	8.20	206.8	29.6	20	108.2	17.13
17	0	4	4 3/4	5.60	6.55	8.35	182.0	40.8	20	116.5	18.99
18	0	4	4 3/4	6.10	6.50	8.35	91.8	25.4	0	120.6	20.15
19	0	4	4 3/4	5.75	6.30	8.10	93.2	34.6	20	124.9	21.72
20	0	3 7/8	4 3/4	5.90	6.50	8.00	102.0	33.4	20	129.5	23.24
21	0	3 7/8	4 3/4	5.80	6.30	8.00	112.0	37.8	160*	134.6	24.96
22	0	4 3/8	4 1/2	5.80	6.50	8.25	114.6	38.8	40	139.8	26.73
23	0	4 3/8	4 3/8	5.50	6.85	8.15	364.0	38.2	40	156.4	28.46
24	0	4 3/8	4 3/8	5.45	6.45	7.95	326.0	49.6	40	171.2	30.72
25	0	4 3/8	4 3/8	5.70	6.55	8.25	288.2	50.0	40	184.3	33.00
26	0	4 1/4	4 1/4	5.65	6.45	8.10	274.4	51.2	40	196.8	35.33
27	0	4 1/4	4 1/4	5.55	6.30	8.20	293.0	52.8	40	210.2	37.73
28	0	4 1/4	4 1/4	5.60	6.50	8.30	286.2	54.8	40	223.2	40.22
29	0	4 1/4	4 1/4	5.60	6.25	8.20	221.6	58.6	-	233.3	42.89

* On these days an equal weight of diatomaceous earth was added to Trap 6 (untreated trap).

Table 15

ANALYSES OF SCUMS AND SEDIMENTS

	Weight Gms.	Acid No.	Per Cent Hydrolyzed	Solidification Point °C
Scum Trap 1	2525	74.8	37.4	31.1
Scum Trap 2	2895	7.1	3.55	33.1
Sediment Trap 1	123	28.2	14.1	28.0
Sediment Trap 2	None			
Spry		0.645	0.32	33.1
Scum Trap 3 (Fat only)	252	152	76.0	33.7
Scum Trap 4 (Fat only)	416	138	69.1	32.8
Sediment Trap 3	(1150 ml)			
Sediment Trap 4	(150 ml)			
Grease Trap Fat (Waldorf)		152	76.0	
Scum Trap 5	3400	43.9	22.0	26.1
Scum Trap 6	3824	11.6	5.8	33.7
Sediment Trap 5 (Fat only)	300	144	72	36.6
Sediment Trap 6 (Fat only)	200			
Bleachable Tallow	4200	5.67	2.84	31.0

Table 16

MATERIAL BALANCE

Traps Loaded with Spry

	Trap 1 Gms.	Trap 2 Gms.
Fat in Scum	2525	2895
Fat in Sediment	123	0
Fat in Effluent	228	35
Total	2876	2930
Fat Added	3100	3100
Unaccounted for	224	170

Traps Loaded with Bleachable Tallow

	Trap 5 Gms.	Trap 6 Gms.
Fat in Scum	3400	3824
Fat in Sediment	300	200
Fat in Effluent	233	43
Total	3933	4067
Fat Added	4200	4200
Unaccounted for	267	133

OBSERVATIONS

Traps 1 and 2 (Spry)

Day	Observation
4	Considerable odor from trap 1. None from trap 2.
14	Black sediment in bottom of trap 1.
19	Distinct odor of H_2S from trap 1.
22	Scum in trap 1 appears to be much less dense and to contain some gas.
32	Bottom surface of scum in trap 2 appears irregular from diatomaceous earth added on day 31.
33	Quite offensive stench and increased foaming in trap 1.
36	Surface of scum in trap humped due to gas formation.

Traps 3 and 4 (Waldorf scum)

Day	Observation
1	Light brown scum in both traps. Considerable stench.
2	Gray granular sediment in both traps, about 7/16 inch thick. Scum layers compacted when traps were flushed with hot water. Less stench.

Traps 3 and 4 (Waldorf scum) (Cont'd)

Day	Observation
14	Scum lagers in both traps divided into three distinct zones. Bottom layer very dark, next layer light brown, top layer melted fat.
20	Grease leaking through outlet baffle in trap 3.
22	Large quantity of solid matter carried over in effluent from trap 3. Some carried out of trap 4.
24	Fat forming separate layer on surface of trap 4 but not of trap 3.
31	Large quantity of solid matter carried over in effluent of both traps. Considerable sediment (one in) in trap 3. Fat leaking through effluent of trap 4.

Traps 5 and 6 (Bleachable Tallow)

Day	Observation
4	Scum in trap 5 is a brownish red color while scum in trap 6 is a cream color.
8	Strong smell of H_2S from trap 5.
9	Bottom of scum in trap 5 very irregular and lumpy.

Traps 5 and 6 (Bleachable Tallow) (Cont'd)

Day	Observation
10	Large lumps of grease seen being carried to the bottom by the Sea-Chem in trap 5 and the diatomaceous earth in trap 6.
11	Increase in odor of H_2S. Effluent from trap 5 changed from brown to dark green when titrated from 5.90 to 8.20. Bottom of scum in trap 6 very irregular.
22	Considerable increase in sediment in traps 5 and 6. Sediment now about 1 in.
24	Some of the sediment in both traps seen being carried over weir during flushing.
29	Surface of scum in trap 6 disturbed by gas evolution.

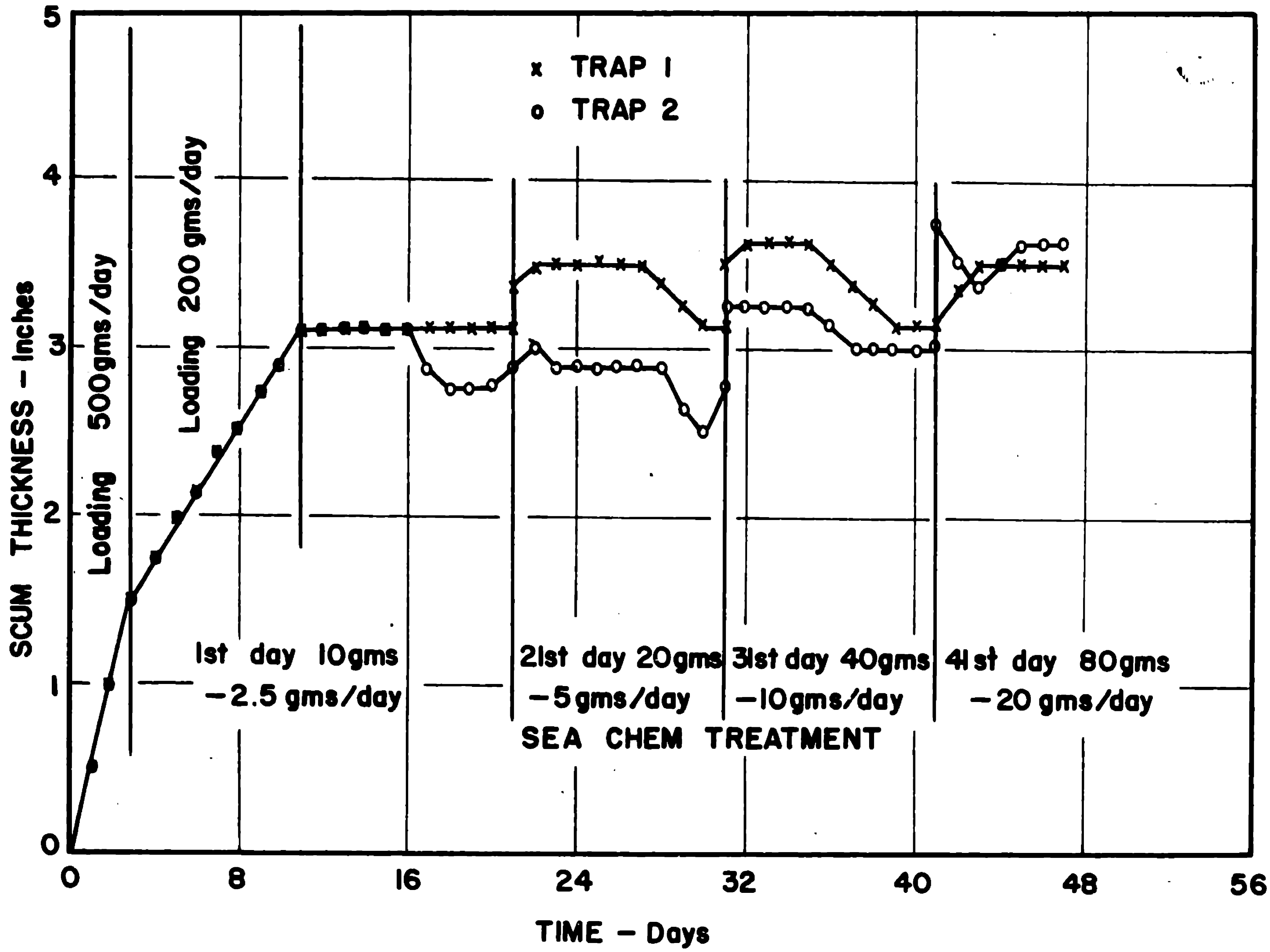
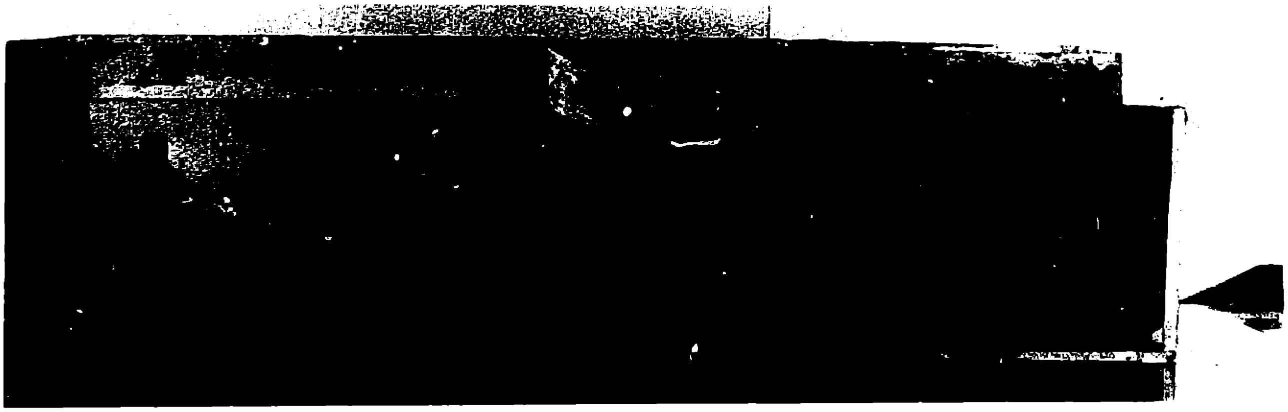
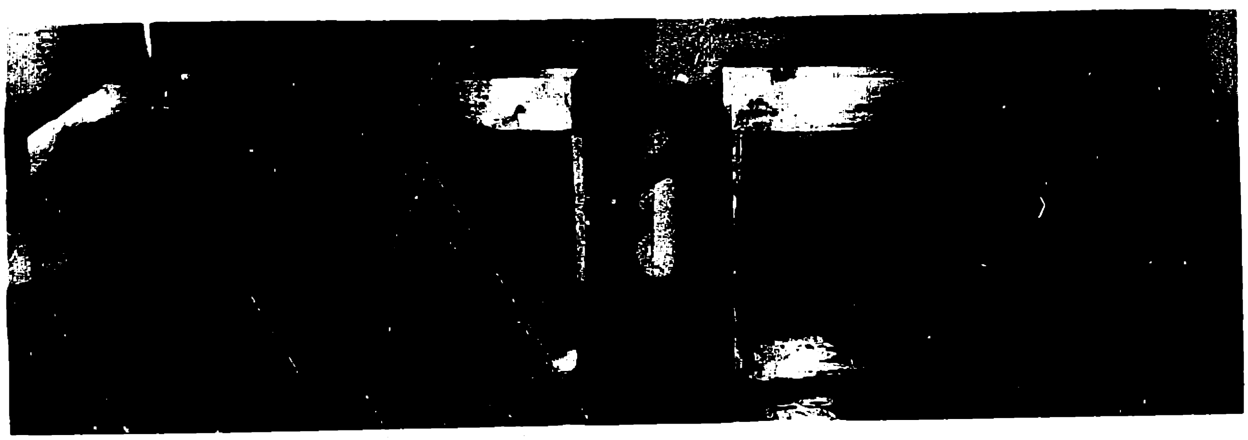


FIG 7—SCUM THICKNESS IN TRAPS 1 AND 2



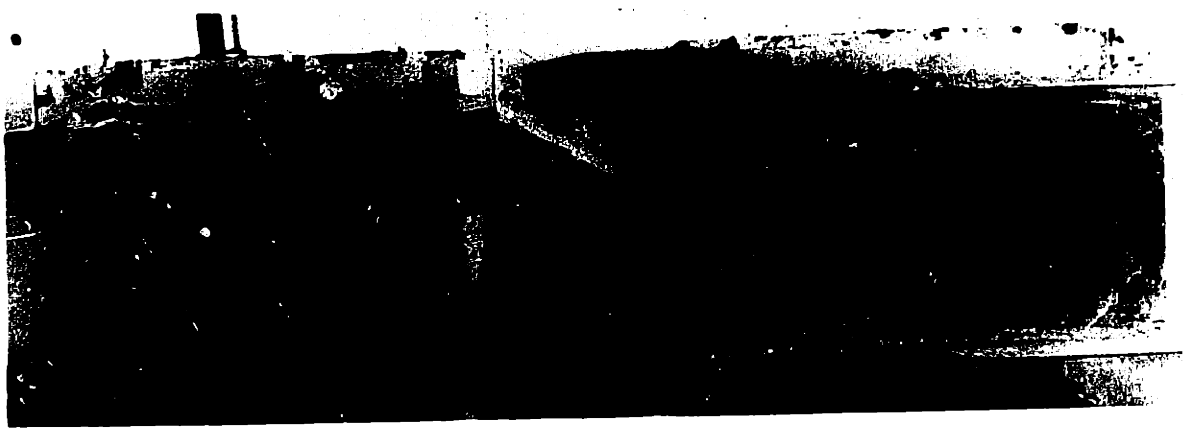
UNTREATED TREATED

TRAPS 1 AND 2 ON 44th DAY



UNTREATED TREATED

TRAPS 3 AND 4 ON 11th DAY



UNTREATED TREATED

TRAPS 3 AND 4 ON 30th DAY

FIGURE 8

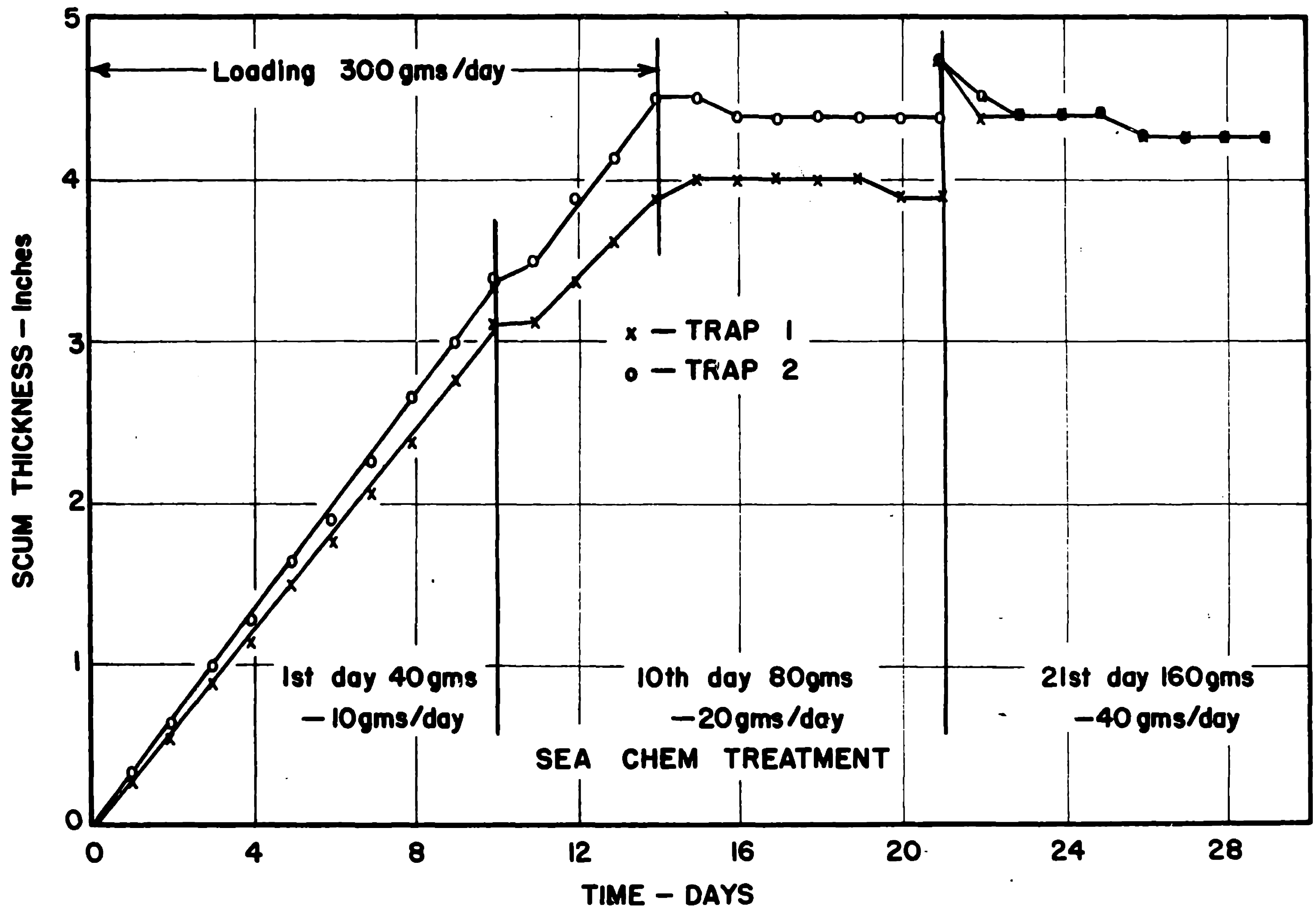
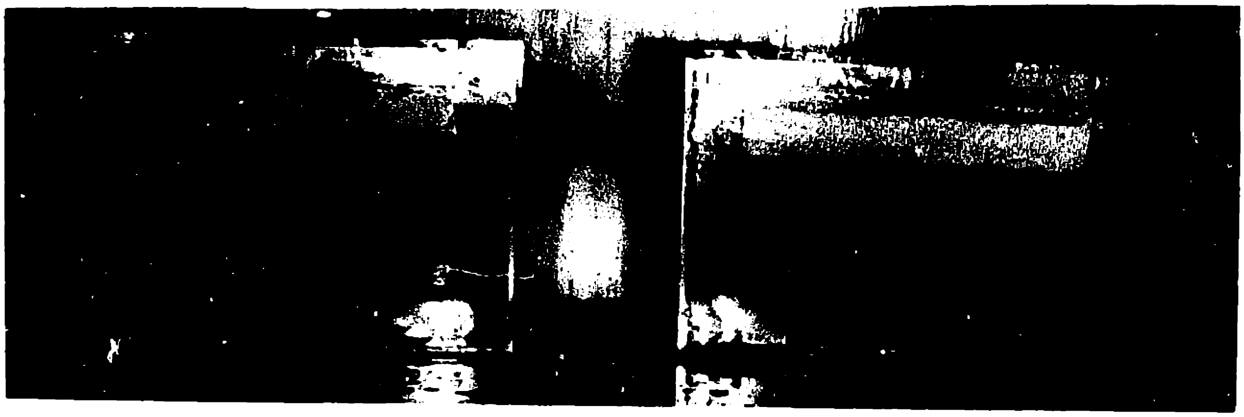
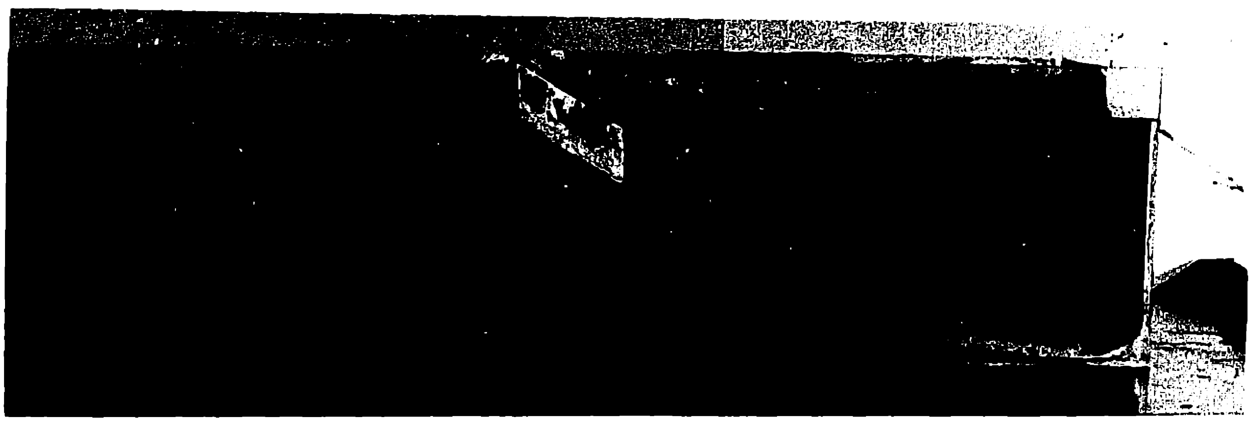


FIG 9 - SCUM THICKNESS IN TRAPS 5 AND 6



UNTREATED TREATED
TRAPS 5 AND 6 ON 6th DAY
BEFORE ADDING GREASE

UNTREATED TREATED
TRAPS 5 AND 6 ON 6th DAY
AFTER ADDING GREASE



UNTREATED TREATED
TRAPS 5 AND 6 ON 25th DAY

FIGURE 10

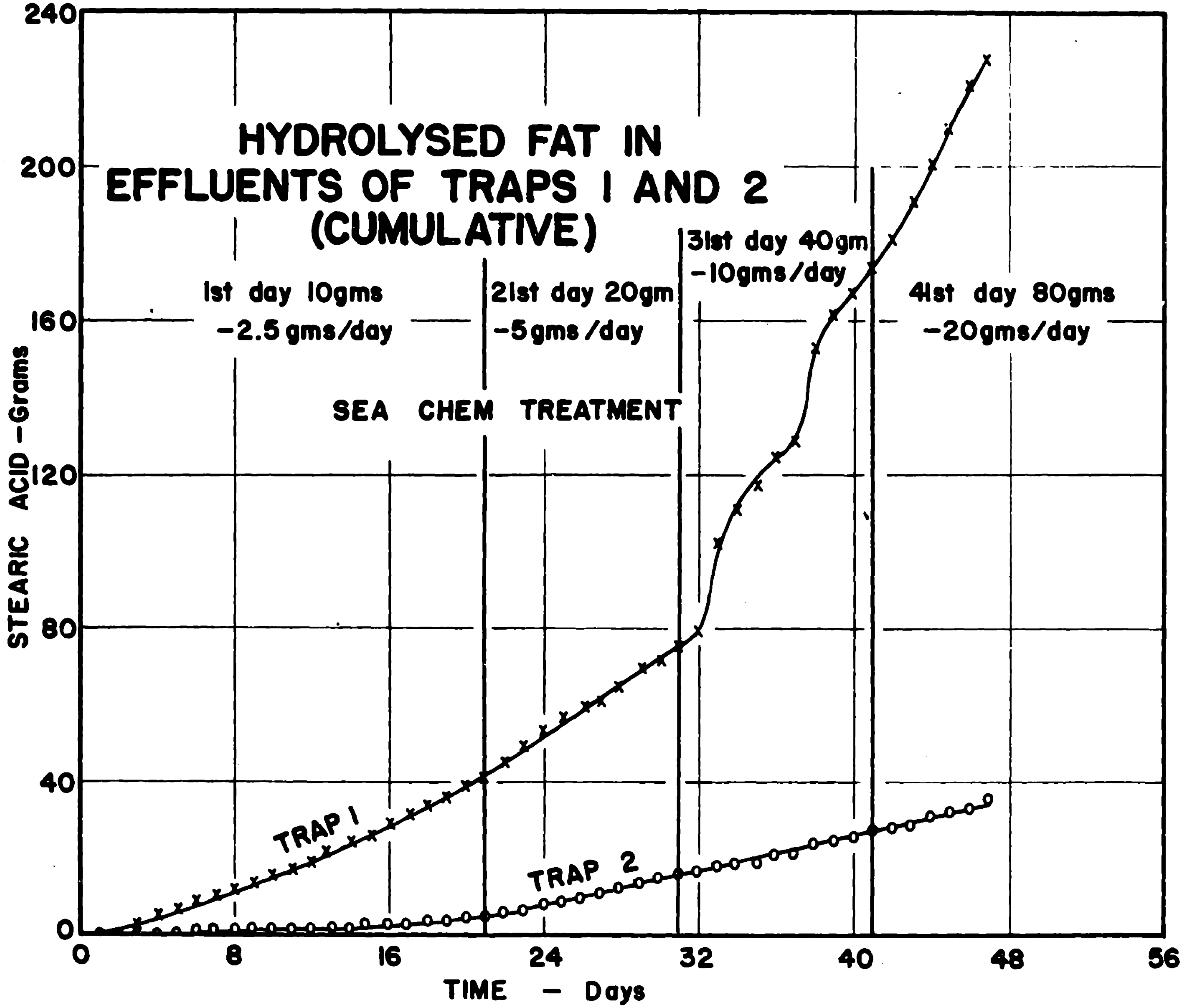

HYDROLYSED FAT IN
EFFLUENTS OF TRAPS I AND 2
(CUMULATIVE)
1st day 10gms
-2.5 gms/day
21st day 20gm
-5gms/day
31st day 40gm
-10gms/day
41st day 80gms
-20gms/day
SEA CHEM TREATMENT
TRAP 1
TRAP 2
STEARIC ACID -Grams
TIME - Days
0
8
16
24
32
40
48
56
40
80
120
160
200
240

FIGURE 11

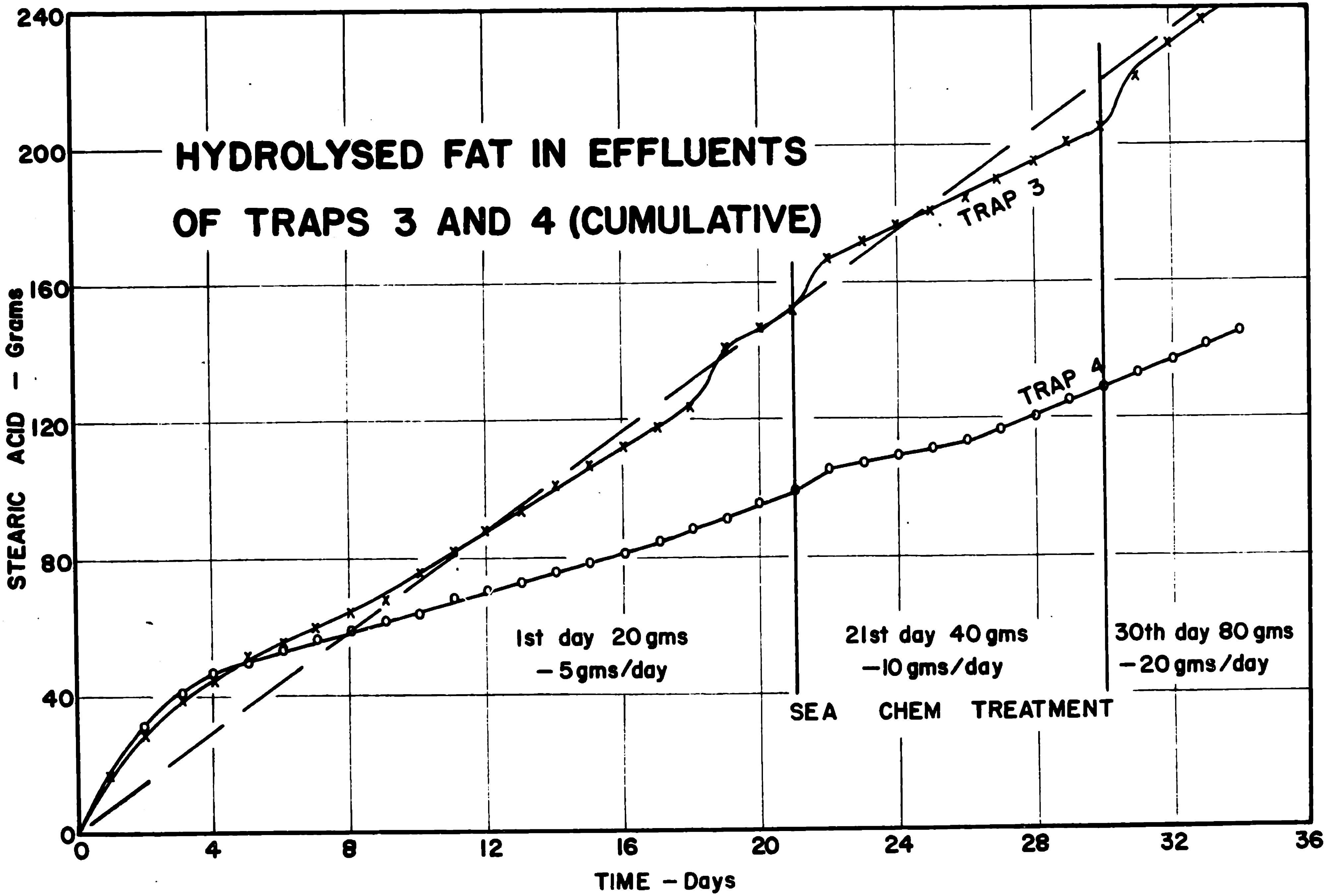

HYDROLYSED FAT IN EFFLUENTS
OF TRAPS 3 AND 4 (CUMULATIVE)
TRAP 3
TRAP 4
1st day 20 gms
— 5 gms/day
21st day 40 gms
—10 gms/day
30th day 80 gms
— 20 gms/day
SEA CHEM TREATMENT
STEARIC ACID — Grams
0
40
80
120
160
200
240
0
4
8
12
16
20
24
28
32
36
TIME — Days

FIGURE 12

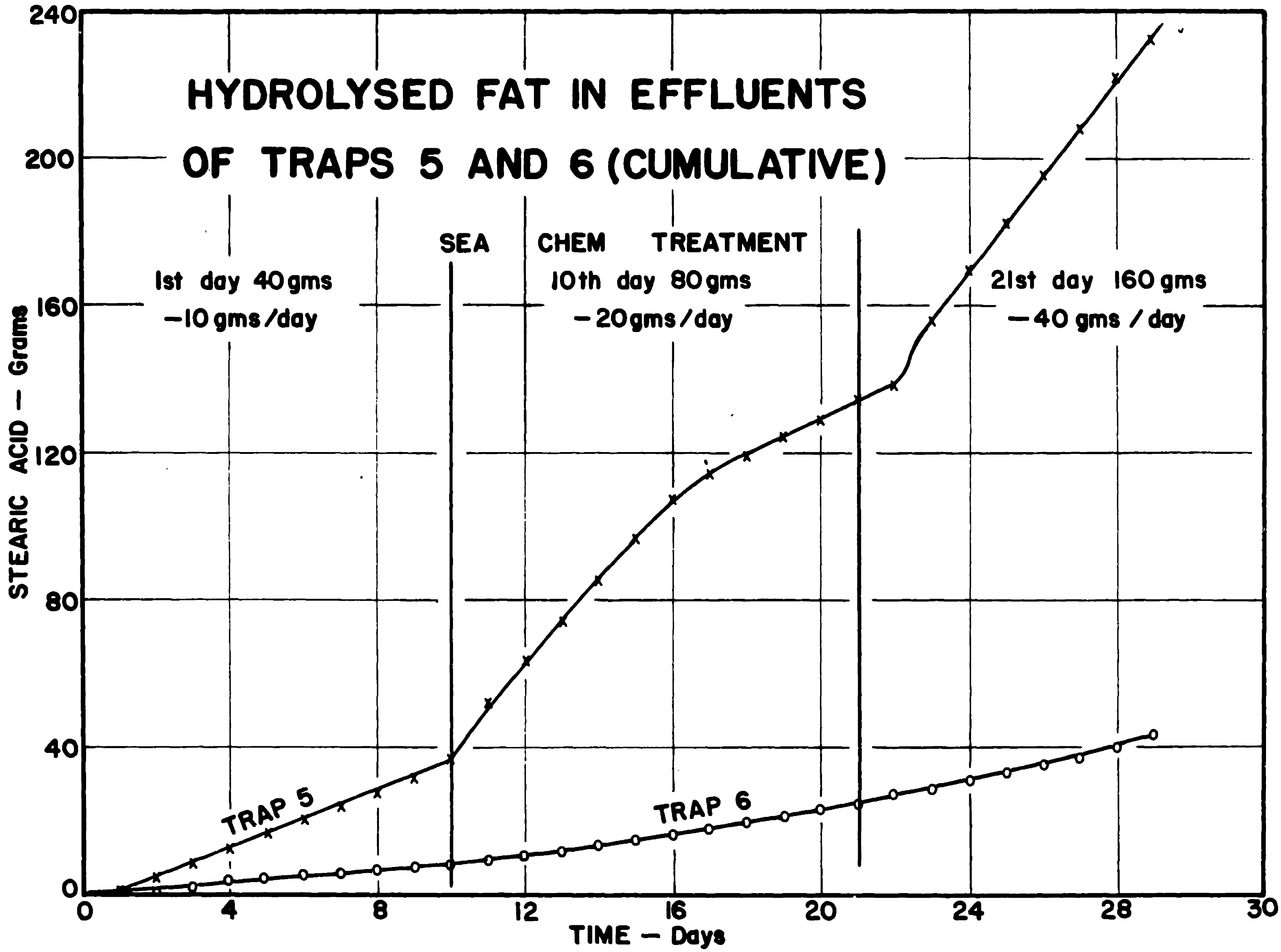

HYDROLYSED FAT IN EFFLUENTS
OF TRAPS 5 AND 6 (CUMULATIVE)
SEA CHEM TREATMENT
1st day 40gms
-10 gms/day
10th day 80gms
-20gms/day
21st day 160 gms
-40 gms / day
TRAP 5
TRAP 6
STEARIC ACID — Grams
TIME — Days
0
40
80
120
160
200
240
0
4
8
12
16
20
24
28
30

FIGURE 13

CHAPTER VI

DISCUSSION OF RESULTS

A. BIOCHEMICAL ACTION

1. Hydrolysis

It was evident that Sea-Chem caused considerable hydrolysis of the fat. As shown in Table 15 the scums in the treated traps 1 and 5 were 37.4% and 22.0% hydrolysed at the end of the runs. However, the untreated traps showed only slight hydrolysis. It should be noted that in both runs the Sea-Chem dosage was much higher than that recommended by the manufacturer. In one case it was 16 times higher. It is impossible to determine from the data what fraction of the scum would have been hydrolysed if the Sea-Chem dosage had been held to the recommended size. From the preliminary test, however, it is certain that less would have been hydrolysed.

In the case of the traps loaded with scum from an operating grease trap a somewhat different situation was evident. As before, the hydrolysis of the fat in the treated trap was higher than that in the untreated trap. However, the scum from the untreated trap was almost as thoroughly hydrolysed as the treated scum. Further, a sample of the original scum allowed to stand for the length of the run was hydrolysed to exactly the same degree as the fat from the treated trap. In both these traps the hydrolysis was greater than in either of the traps loaded with bleachable tallow or the traps loaded with Spry. It is evident that although Sea-Chem will cause hydrolysis, it would have occurred without Sea-Chem if enough time were allowed.

2. Oxidation

Any further breakdown of the fat would have involved oxidation. That this did not occur to any significant degree is established by the following:

a. Some source of oxygen would be necessary. Oxygen was available only in the dissolved oxygen in the feed water and in the nutrient and buffer salts. Although these sources were thoroughly utilized, as evidenced by the strong odor of H_2S in the effluents, they would not be enough to allow a large quantity of the fat to be oxidized.

b. If oxidation had occurred by any of the several possible mechanisms, the end products would have been evident. In oxidative rancidity, considerable butyric acid would be produced and its presence known from the overpowering stench. There was, however, only a slight odor of butyric acid. If either oxidative rancidity or oxidation had occurred, the soluble acid end products would have caused the acidity of the effluents to reach a very high value. However, the maximum acidity obtained could not account for any significant quantity of these acids.

c. The solidification points of the fats would have been lowered considerably by the presence of any oxidative end products. This did not occur as can be seen from Table 15.

3. Effect of Hydrolysis

Since free fatty acids were known to be present in large concentrations, the possibility of their conversion to soluble soaps appears. Several conditions are necessary for this conversion. First, sodium and potassium must be present in large quantities. Second, the pH must be above 8.60. Third, a certain amount of agitation must occur. In all the treated traps the pH was continually below 7.00 and in some cases as low as 4.75. This fact, together with an insufficiency of sodium and potassium ions and a lack of agitation, precludes the possibility of soap formation.

In figures 11 through 13 the cumulative quantity of hydrolysed fat expressed as stearic acid contained in the effluent is plotted vs. time. The quantity of hydrolysed fat leaving the treated traps is greater than that leaving the untreated traps. This is in agreement with the result that a larger percentage of the fat in the treated traps was hydrolysed. However, the total quantity of fat which left the traps in the form of dissolved fatty acids in no case exceeded 250 gms by the end of the run.

Since the traps contained several thousand gms of fat, this removal is not significant.

The scum thickness curves for traps 1, 2, 5 and 6 are shown in figures 7 and 9. Photographs of the traps are shown in figures 8 and 10. Neither the photographs nor the curves showed any marked reduction in volume of the scum in the treated traps. In the case of figure 7, the scum in the treated trap was consistently thicker than the scum in the untreated trap. This does not mean that the Sea-Chem caused an increase in the grease. Rather, the gas evolved in the treated traps made the scum much less dense. The significance of the scum thickness curves for traps 5 and 6 will be discussed under physical action.

From the material balance made at the end of the runs it can be seen that the grease was accounted for within an error of 8%. The fraction of grease unaccounted for is largely due to the neutral fats carried over into the effluents due to the inefficiency of the traps. It was not possible to obtain a material balance for traps 3 and 4 since the quantity of scum added was not known exactly and the traps both developed leaks. The scum thickness curves were not plotted for these traps for the same reasons.

It is evident from these balances that the grease remaining in the treated traps at the end of the runs was slightly less than that in the untreated traps. This can be accounted for in part by the fact that the fatty acids are slightly more soluble than the original fats. The amount of grease removed in this manner is shown by curves 11 through 13. The remainder of the difference is caused by grease in the sediment due to weighting action.

The net effect of hydrolysis, therefore, has been to cause a slight removal of fat as dissolved fatty acids. Since soaps were not produced, no further effect should be expected since free fatty acids differ slightly from their original fats. The fatty acids have very nearly the same melting points as the fats and an only slightly greater solubility. Consequently, if they were released from the traps in any quantity they would adhere to surfaces and cause the clogging of pipes to almost the same degree as fats.

B. PHYSICAL ACTION

From the scum thickness curves for traps 5 and 6 it can be seen that the scum layer in the treated trap was slightly less thick up to the 21st day. This difference can be accounted for by the soluble fatty acids in the effluents and by the weighting action of the Sea-Chem. On the 10th day the Sea-Chem solution was made by pouring it on the surface and mixing. The same procedure was applied to the untreated traps, using diatomaceous earth instead of Sea-Chem, since Sea-Chem contains diatomaceous earth as an inert filler. As is recorded in theobservations, large lumps of grease were seen being carried to the bottoms of the traps. When this procedure was repeated on the 21st day, additional grease was seen to fall and the thickness of sediments in each trap reached one inch. As shown in figure 9, the scum thicknesses were equal from this point on. At the end of the run it was found that the sediments in traps 5 and 6 contained 300 and 200 gms of grease respectively. Thus it can be seen that Sea-Chem is capable of removing scum by weighting the fat and carrying it to the bottom. Eventually this sediment would be removed. However, it has only slightly different properties from the scum above it. It is exactly the material the trap was designed to remove from the sewage. Consequently its release from the trap is defeating the purpose of the trap, namely to prevent any grease substances from reaching the sewage system.

CHAPTER VII

CONCLUSIONS

1. Sea-Chem is capable of hydrolysing some of the fats present in a grease trap.
2. It is not possible for much breakdown of the fat, other than hydrolysis, to occur under the conditions present in a grease trap.
3. Hydrolysis of fats causes relatively little change in their characteristics. The hydrolysed fats are still capable of clogging sewer pipes.
4. The fatty acids are removed from the trap only slightly more rapidly than the original fats.
5. In sufficient concentrations Sea-Chem is capable of weighting the scum in a grease trap so that it will sink and be carried out of the trap. This action, however, defeats the purpose of the trap.
6. The use of Sea-Chem does not appear to be an effective method of cleaning grease traps.

BIBLIOGRAPHY

1. G. Collin, T. P. Hilditch and C. H. Lea, J. Soc. Chem. Ind., 48, 46-50 (1929).

2. T. P. Hilditch and H. E. Longenecker, "A Further Study of the Components Acids of Ox Depot Fat", Biochem. J., 31, 1805-1819 (1937).

3. N. R. Ellis, C. S. Rothwell and W. O. Pool, "The Effect of Injected Cottonseed Oil on the Composition of Body Fat", J. Biol. Chem., 92, 385-398, (1931).

4. Baughman, W. F., G. S. Jamieson, "The Chemical Composition Soya Bean Oil", J. Am. Chem. Soc., 44, 2947-2952, (1922).

5. T. P. Hilditch and C. E. Jones, J. Chem. Soc., 1932, 805-820.

6. V. Leukowitsch, "Chemical Technology and Analysis of Oils, Fats and Waxes", 6th Ed., Vol. 1, p. 28, 237, 239, Macmillan, London, 1921.

7. G. R. Greenbank and C. E. Holm, "Some Factors Concerned in the Antoxidation of Fats", Ind. Eng. Chem., 16, 598 (1924).

8. K. S. Markley, "Fatty Acids", Interacience , New York, 1947, p. 114.

9. A. W. Ralston and C. W. Hoerr, "The Solubilities of the Normal Saturated Fatty Acids", J. Org. Chem. 7, 546-555 (1942).

10. E. S. Sutton, "The Polymorphism of Tristearin and Some of its Homologs", J. Am. Chem. Soc., 67, 524-527 (1945).

11. T. P. Hilditch, E. C. Jones and A. V. Rhead, "The Body Fats of the Hen", Biochem. J., 28, 786-795 (1934).

12. A. K. Balls, M. B. Matlack and I. W. Tucker, "The Hydrolysis of Glycerides by Crude Pancrease Lipases", J. Bio. Chem., 122, 125-137 (1937).

13. A. K. Balls and M. B. Matlack, "The Enzymic Hydrolysis of Benzyl Stearate and Benzyl Butyrate", J. Bio. Chem., 125, 539-543, (1938).

14. A. M. McLeod, "The Grease Interceptor", Univ. Of Wis., Eng. Exp. Sta. Bull. No. 85 (1938).

15. H. E. Babbit, "Sewerage and Sewage Treatment", Wiley, New York, 1950, p. 384.

16. L. W. Weinberger, "Nitrogen Metabolism in the Activated Sludge Process", Sc. D. Thesis, M.I.T., 1949.

17. C. D. Hodgman and H. N. Holmes, "Handbook of Chemistry and Physics", 25th Ed., Chemical Rubber Co., p. 1174.

18. W. R. Bloor, "Biochemistry of the Fatty Acids", Reinhold, New York, 1943, p. 1.