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OF THE

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IN CONJUNCTION WITH

THE PENNSYLVANIA SEWAGE WORKS ASSOCIATION

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SEWAGE WORKS JOURNAL

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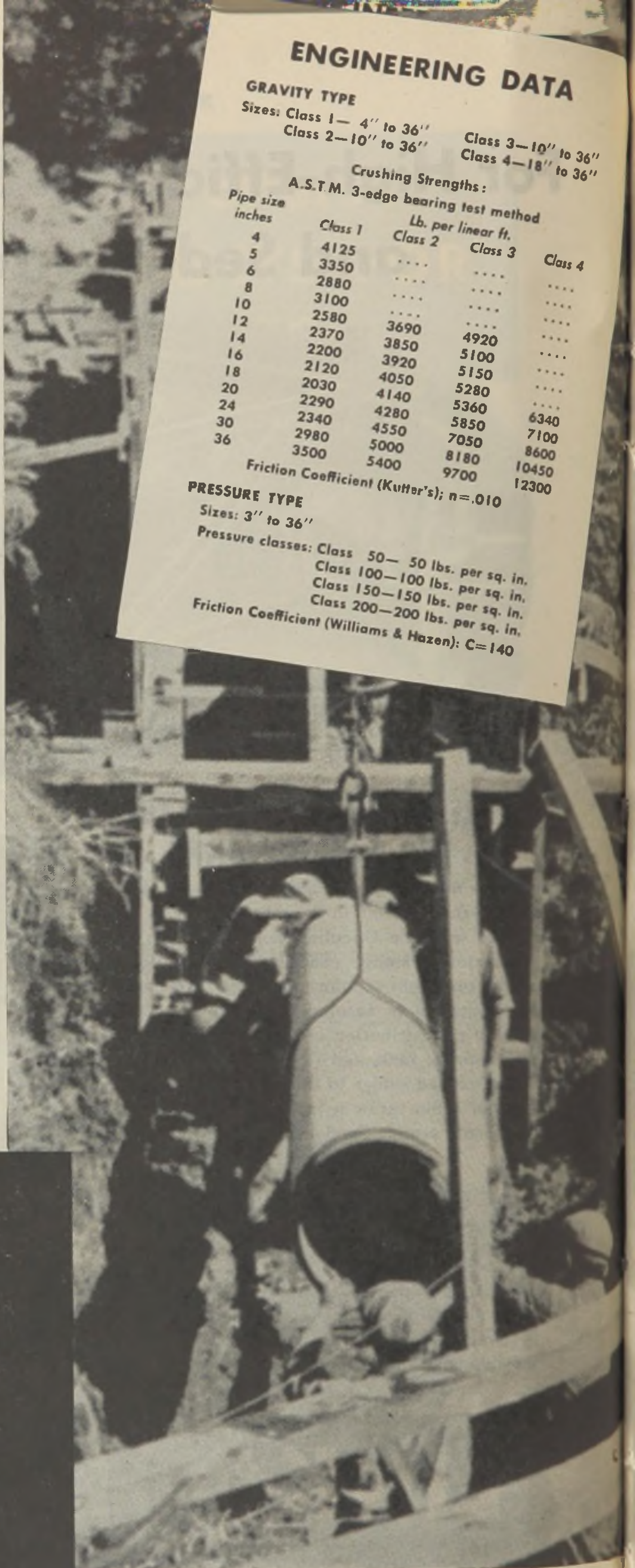

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5	3350	....	....	....
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8	3100	....	....	....
10	2580	3690	4920	....
12	2370	3850	5100	....
14	2200	3920	5150	....
16	2120	4050	5280	....
18	2030	4140	5360	6340
20	2290	4280	5850	7100
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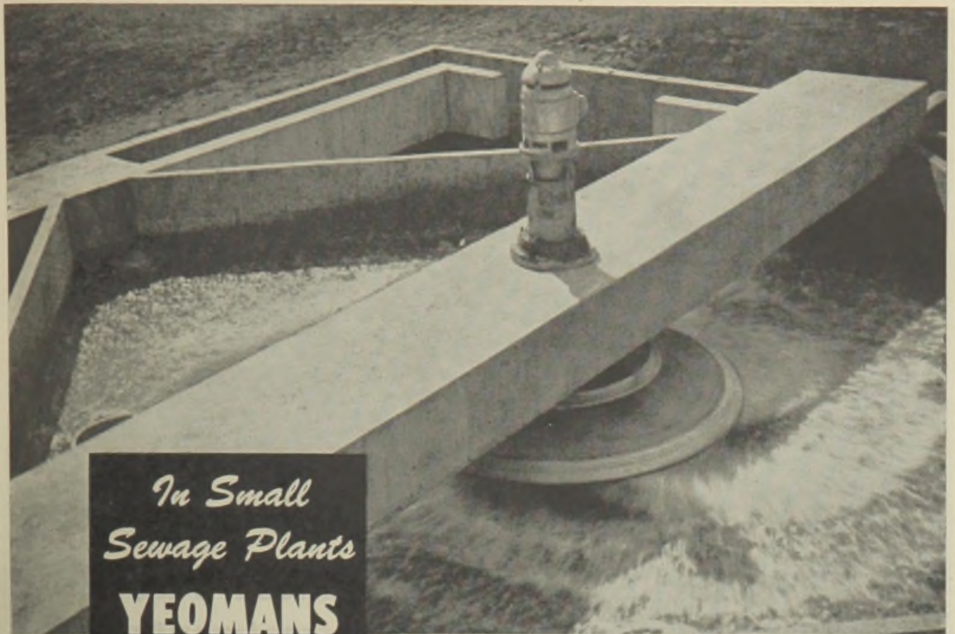

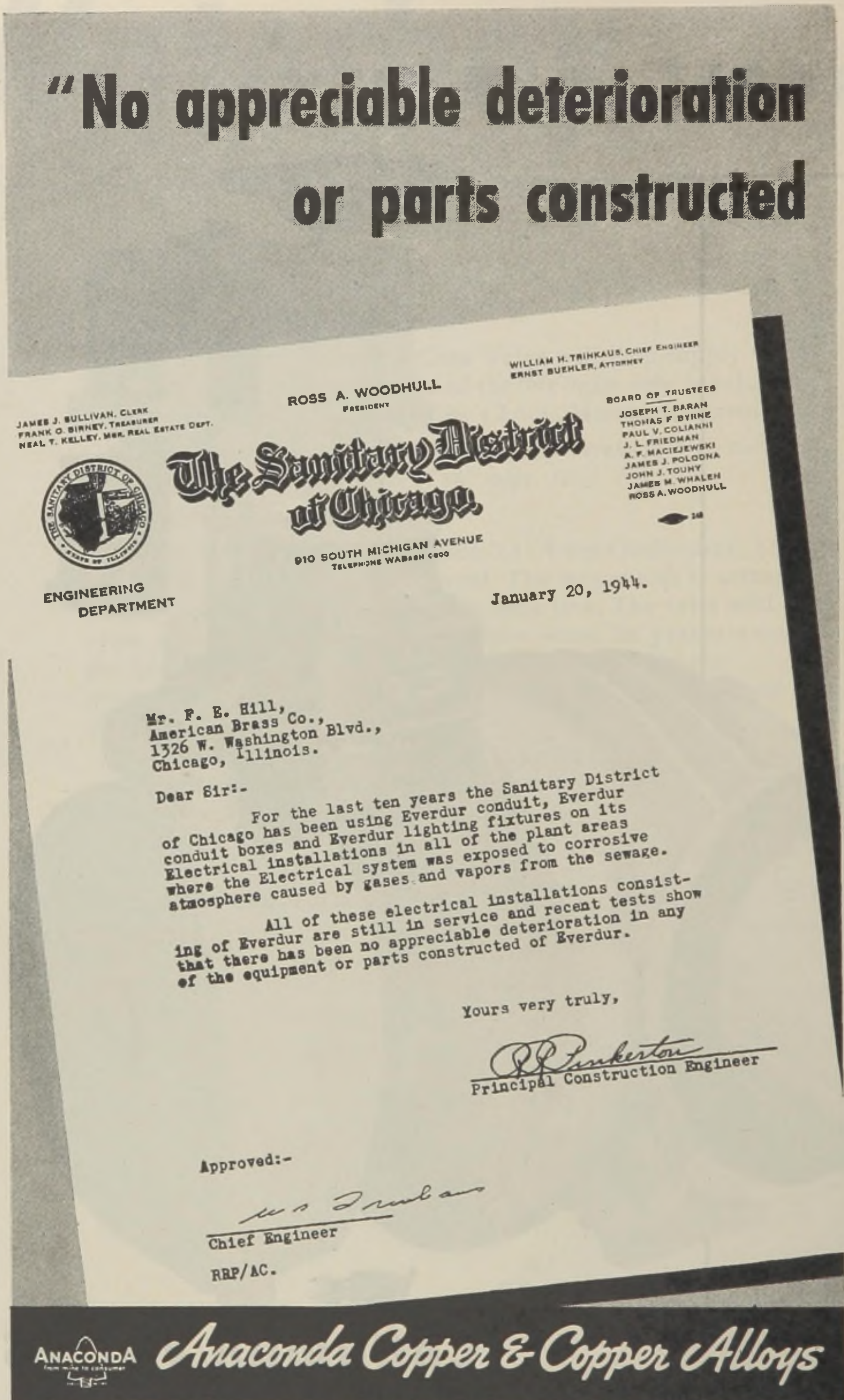
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Sewage Works Journal

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Plant Operation:

Sewage Research:

Industrial Wastes:

Stream Pollution:

Operator's Corner:

Plant Operation

SEWAGE WORKS CHECK LIST FOR POSTWAR PLANNING

Presented herewith is a check list suggested by the Committee on Water and Sewage Works Development, for the guidance of public works department officials, city engineers and sewage works superintendents engaged in preliminary postwar planning. It is recommended that several copies of the list be made and distributed to the various municipal officials who may be responsible entirely or in part for the sewage collection and treatment works serving the community. A master list of needed improvements can be readily compiled from the individual lists thus obtained.

While the suggested list is very detailed and complete, there may be local situations which are not covered and there should be no hesitancy in making revisions to meet such local conditions. It is hoped that the check list will be put to immediate use in those municipalities in which postwar planning is as yet in a preliminary stage and where there is a possibility that certain needs may have been overlooked.

Item	Yes	No
A. Sewer System—General:		
1. Are the sanitary sewers separate from the storm sewers?	....	....
2. Is the capacity ample to prevent overflows during storm periods?	....	....
3. Are industrial wastes admitted to system without preliminary treatment by industry?	....	....
4. Are periodic charges for service rendered made to each contributor of sewage?	....	....
5. Is infiltration reducing system capacity?	....	....
6. Has there been any "failure" due to chemical reaction in sewers?	....	....
7. Do you collect all the outfalls into one intercepter?	....	....
B. Separate Sanitary Sewers:		
1. Has roof drainage been excluded from the sewers?	....	....
2. Are there "unsewered" areas in your city?	....	....
3. Are the manholes adequately spaced for proper cleaning operations?	....	....
4. Do manholes need:		
(*a*) replacement of war substitute covers?	....	....
(*b*) new manhole steps?	....	....
(*c*) reconstruction of failed mortar joints?	....	....
5. Are "sewage gas" odors noticeable near manholes?	....	....
6. Is there a need for chlorination or other chemical treatment in the system?	....	....
C. Combined Sewerage System:		
1. Will cleaning increase carrying capacity?	....	....
2. Are additional catch basins needed?	....	....

3. Have the sewers been checked for erosion—both physical and chemical? ....
4. Are "sewer gas" odors obnoxious in dry periods? ....
5. Are the sewers utilized for:
   (*a*) snow removal? ....
   (*b*) ground garbage disposal? ....

D. Sewage Pumping (Lift) Stations:
1. Are stations fully automatic as to operation? ....
2. Are the pumps properly protected? ....
3. Are the pumps of proper capacity for efficient, economical operation? ....
4. Are the operators protected against gas hazard by positive ventilation? ....
5. Is explosion-proof equipment used? ....
6. In the event of power failure, is there a by-pass available? ....
7. Can the station be by-passed for rehabilitation? ....
8. Are you using sewage gas engines as a power unit? ....

E. Sewage Treatment Works:
1. Have you devices for measuring:
   (*a*) plant influent? ....
   (*b*) plant effluent? ....
2. Have you a by-pass of proper size so that the entire plant may be shut off? ....
3. Grit Removal and Disposal:
   (*a*) Are increased channels needed? ....
   (*b*) Are repairs necessary to mechanical removal devices? ....
   (*c*) Do you wash the grit before disposal? ....
4. Screenings:
   (*a*) Are the coarse bar screens in need of repair? ....
   (*b*) Are the mechanical cleaning devices satisfactory? ....
   (*c*) Are the screenings ground through adequate grinders? ....
   (*d*) Is disposal troublesome from a manpower standpoint? ....
5. Pre-sedimentation Processes:
   (*a*) Are flocculation devices utilized? ....
   (*b*) Is chemical precipitation used? ....
   (*c*) Is grease collection and disposal satisfactory? ....
6. Sedimentation:
   (*a*) Is the detention period sufficient at all times? ....
   (*b*) Will improved baffling give better results? ....
   (*c*) If so, do mechanical collecting devices need repair? ....
   (*d*) Are there ample interconnections and valves for proper operation? ....
   (*e*) Is there need for betterment in scum disposal? ....
7. Sludge Pumping:
   (*a*) Are pumps in need of repairs or replacement? ....
   (*b*) Are pump pits properly ventilated? ....
   (*c*) Are sludge pump discharge lines clean? ....
   (*d*) Are there ample interconnections and valves for proper operation? ....
8. Secondary Treatment:
   (*a*) Is additional capacity needed? ....
   (*b*) Would recirculation improve efficiency in filters? ....
   (*c*) Do filters need cleaning? ....
   (*d*) Are filter flies a serious problem? ....
   (*e*) Are mechanical blowers, distributors, etc., in proper operating condition? ....

(*f*) Do air distributors need cleaning? ....
(*g*) Would sludge concentration be of value in operating the plant? ....

9. Chlorination:
   (*a*) Has your equipment an adequate operating range or capacity? ....
   (*b*) Have you proper protection devices against accidental breaks in chlorine containers or pipe lines? ....
   (*c*) Have you a control system for chlorine dosage? ....
   (*d*) Have you any need of additional chlorinators for:
      (1) standby service? ....
      (2) treatment of ponded trickling filters? ....
      (3) treatment of clogged porous plates, etc.? ....
      (4) treatment of returned activated sludge? ....
      (5) prevention of digester foaming? ....
      (6) odor control? ....
10. Solids Disposal:
   (*a*) Have you sufficient:
      (1) digester capacity? ....
      (2) vacuum filters? ....
      (3) elutriation? ....
      (4) sludge drying beds? ....
      (5) sludge incinerators? ....
      (6) glass covered drying beds? ....
      (7) fertilizer manufacturing equipment? ....
   (*b*) Are you recovering and using sludge gas for:
      (1) boilers (digester temperature control)? ....
      (2) heating of structures? ....
      (3) power in gas engines? ....
      (4) grease and skimmings incineration? ....
   (*c*) Have you any method of measuring sludge going to and from digesters? ....
   (*d*) Are you using lagoons for disposal? ....
   (*e*) Are you disposing of dried sludge by:
      (1) grinding? ....
      (2) sale to public? ....
      (3) stock piling? ....
   (*f*) Can you recirculate the sludge and supernatant in your digesters? ....
   (*g*) Have you satisfactorily solved the supernatant problem? ....
   (*h*) Is scum handling a problem? ....
11. General Plant and Operation:
   (*a*) Are full precautions as to safety of operators taken by protective fences, walks, explosion-proof equipment, etc? ....
   (*b*) Are you utilizing adequate laboratory control over the plant processes? ....
   (*c*) Have you a cost account system for the plant? ....
   (*d*) Does the plant need a new climb-proof fence? ....
   (*e*) Have the grounds been properly graded and planted to grass, flowers, shrubbery, etc.? ....
   (*f*) Are flood lights available for night operation? ....
   (*g*) Is the plant accessible by a good road? ....

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SYMPOSIUM ON GREASE REMOVAL *

DESIGN AND OPERATION OF GREASE INTERCEPTORS

By F. M. Dawson and A. A. Kalinske

Iowa Institute of Hydraulic Research

Grease interceptors (or "grease traps" as they are sometimes called) have been used in plumbing drainage systems for many years. They are frequently required by plumbing regulations, especially for restaurants. In general, such interceptors have been used for one or for all of the following reasons: (1) To prevent clogging of waste lines with grease, (2) to prevent large quantities of grease from reaching the sewage disposal works, (3) to facilitate the reclaiming of grease because of its economic value. The latter reason is, of course, at present a very important one for intercepting all waste grease and fats. The separation of gasoline and oils from waste water is also accomplished by use of a similar type fixture installed in the plumbing system; however, this paper will be concerned primarily with grease interceptors.

The grease interceptors used at present are for the most part commercial products of various patented designs constructed of cast-iron (ceramic models have been used during the war). If properly installed and serviced, they do a fair job of preventing fats and grease from getting into the sewerage system. However, proper installation and servicing is usually the exception. To perform its job properly an interceptor should be installed as close to the fixture discharging greasy wastes as possible, and should be so designed and installed as to be easily cleaned. The less mixing and emulsifying there is, the easier the grease will separate from the waste water. Also the possibility of clogging the drain lines between the fixtures and the interceptor will be prevented if the interceptor is installed near the fixture.

Up until a few years ago the use of grease interceptors, especially in domestic installations, has in general not been overly successful. The interceptors were too small to handle adequately the rate of flow, and the owners did not properly remove the grease which had been collected in the interceptor. If, however, it is desired to separate the grease from the waste water in as complete a manner as possible and also to have the grease in good condition, an interceptor of the proper size installed right at the fixture which discharges greasy waste water is the best solution to the whole problem of grease removal.

Design Principles

A great many types of commercial grease interceptors are and have been on the market and with them many "home made" designs. However, the basic principle of grease interception in all such designs is that

* This symposium of four papers was presented at the Sixteenth Annual Meeting of the New York State Sewage Works Association, New York City, January 21, 1944.

of gravity-differential separation. That is, the liquid greases and fats separate from the waste water in the interceptor, when the velocity of flow is reduced, owing to the difference in specific gravity.

Gravity-differential separators for liquids are used in many commercial processes, such as, for instance, in the petroleum industry. Of course, so far as grease interceptors are concerned, the problem is complicated by the fact that rarely is it a case of separating pure grease from water. The presence of soaps and food particles increases the difficulty of separation. Of interest, in connection with grease-interceptor design, is the congealing temperatures and approximate specific gravity of various common fats; these are listed in Table A.

TABLE A

Type of Fat	Congealing Temp. °F.	Specific Gravity
Butter Fat	76–67	0.91
Beef Tallow	88–85	0.90
Mutton Tallow	106–97	0.94
Pork Lard	86–81	0.91

If the interceptor is installed in a kitchen, the temperature will usually be between 80° F. and 90° F. In any case, the discharge of hot water through the interceptor will heat it up, and the time required for passage of greasy wastes through an interceptor will usually not permit congealing to occur. In other words, separation must occur with the grease in a liquid state. Because of the short time it takes for liquids to pass through, cooling interceptors by the use of water jackets is of no consequence, and such interceptors should not be installed because of the danger of having made a direct connection from the pure-water lines to the interceptor, thus producing a potentially dangerous cross-connection.

Since grease separation is due to gravity-differential, a quantitative analysis of what occurs as waste water flows through an interceptor may lead to the establishment of some basic design data. For simplicity let us assume that pure grease and water enter near the bottom of a rectangular-shaped interceptor L feet long, B feet wide, and with a water depth of D feet. The interceptor will do a good job of separation if, as the flow goes through the interceptor, the mean velocity of flow is such as to permit a grease globule to rise a vertical distance D in a length of L feet. If we neglect, for a moment, the presence of turbulence we see that the controlling item in the sizing of the interceptor for any particular rate of flow is the rate of rise of the grease globules. If the size of the globules is known, the maximum velocity of rise can be calculated readily from known principles of fluid mechanics, by equating the buoyant force on a globule to the force of fluid resistance. An expression for the terminal velocity of a spherical grease globule is as follows:

$$v = \sqrt{\frac{4d(w - w')g}{3Cw}} \tag{1}$$

where d is the diameter of the globule, w and w' the unit weights of water and grease respectively, and C a fluid-resistance coefficient, which in texts on fluid mechanics is given as a function of the Reynolds number, which for the globule is vd/ν, where ν is the kinematic viscosity of the water, and v the velocity of rise of the globule.

Obviously, the size of the grease globules is an important item. Observations and certain analyses indicate that the design of interceptors should be based on separating out globules of about 0.05 cm. The rate of rise of globules much less than this size is so small that gravitational separation is impracticable, and globules much larger than this will be easily separated. Taking a grease having a specific gravity of 0.90 and the water temperature as 150° F., the rate of rise (v in Eq. 1) of a 0.05 cm. globule is about 0.05 ft. per sec. For a globule of this size the time to rise a vertical distance D is $D/0.05$, and this should be equal to the time of flow for a distance L, which can be expressed as L/V, where V is the mean velocity of flow through the interceptor. We thus have:

$$V = \frac{0.05L}{D} \tag{2}$$

In most commercial interceptors of rectangular shape, the length is from 1.5 to 2 times the water depth. In that case, according to Eq. (2), the mean water velocity through the interceptor can thus be about 0.08 to 0.10 ft. per sec. However, because it is impossible to secure uniform velocity distribution and owing to the presence of some turbulence, the design value of V should not be over one-half of that given by Eq. (2). Modern commercial interceptors having good efficiency check this value of V fairly well.

In all interceptors, the separated grease accumulates in the top of the device and must be removed manually. Naturally, as the grease accumulates, the water-flow cross section decreases and the efficiency of the interceptor soon begins to drop. Some type of baffling is usually necessary and helpful, especially near the inlet. Such an inlet baffle ordinarily has louvers which distribute the flow and give it a gentle upward motion. Many baffles in the interceptor body, however, are undesirable since they induce turbulence. The outlet opening should, of course, be near the bottom at a point farthest from the inlet. Provision should be made for relieving air from the top of the interceptor which is brought down by the incoming flow. In general, to have settleable solids accumulate in a grease interceptor is undesirable. Our plumbing drainage and sewerage systems are designed to carry solids and there is no need of collecting them in a grease interceptor if it can be prevented.

Probably one of the most important design features of a grease interceptor is provision for easy cleaning and removing of accumulated grease. If this is not done, the chances of the interceptor's being properly serviced become remote. The interceptor cover should be light and easily removable, and the grease-accumulation chamber should be free of baffles and partitions which would get in the way during cleaning.

Sizes and Installation

The determining item so far as grease interceptor size is concerned is the rate of flow from the fixture or fixtures to which the interceptor is connected. This, of course, requires a knowledge of the rate of flow from various types of plumbing fixtures discharging greasy wastes. If several fixtures are connected to the same interceptor, then some estimate must be made of the probable simultaneous discharge.

Considerable data have been collected on the discharge rate from various fixtures. In Table B is given the recommended minimum rate of flow capacity of any interceptor connected to the fixtures shown:

Table B

Type of Fixtures	Rate of Flow in G.P.M.
Small Residence or Apartment Sink	5.0
Large Residence Sink or Dishwasher	10.0
Restaurant Kitchen Sink	15.0
Single Compartment Scullery Sink	20.0
Double Compartment Scullery Sink	25.0
2 Single Compartment Sinks	25.0
2 Double Compartment Sinks	35.0
Dishwashers for Restaurants:	
Up to 30 gal. water capacity	15.0
30 to 50 gal. water capacity	25.0
50 to 100 gal. water capacity	40.0

In addition to its rate-of-flow capacity, a grease interceptor should be rated as to its accumulated-grease capacity. This is the amount of grease in pounds that the interceptor can hold before its average efficiency drops below, say, 90 per cent.

The grease interceptor should be installed, as mentioned before, as near the fixtures as is practical, and its top should be easily accessible for cleaning. The discharge pipe from the interceptor should *always* be vented so as to prevent siphonage of the interceptor contents. This is quite important.

Testing and Rating

In order that interceptors may be properly rated as to capacity, some sort of a standard laboratory test is necessary. After years of experience in testing various types of interceptors, investigators have found that various results can be obtained by slight variation of the test procedure. Though field conditions cannot be duplicated in the laboratory, nevertheless, the test procedure should have some relation to what the interceptor will experience in the field. A great many test methods have been tried in order to isolate the important items which affect interceptor efficiency. Thus, it has been found that the type and degree of mixing of the liquid grease and the hot water before discharging into the interceptor is an important item. The temperature of the grease and water and grease concentration did not have much effect on the results.

About two years ago, the U. S. Army Engineers, Construction Branch, asked the Iowa Institute of Hydraulic Research to test and rate each type of interceptor that was to be installed in the Army Cantonments. At that time, a standard test was developed which has been used extensively and which seems to give reliable and consistent results. The apparatus used in the tests is shown in Fig. 1.

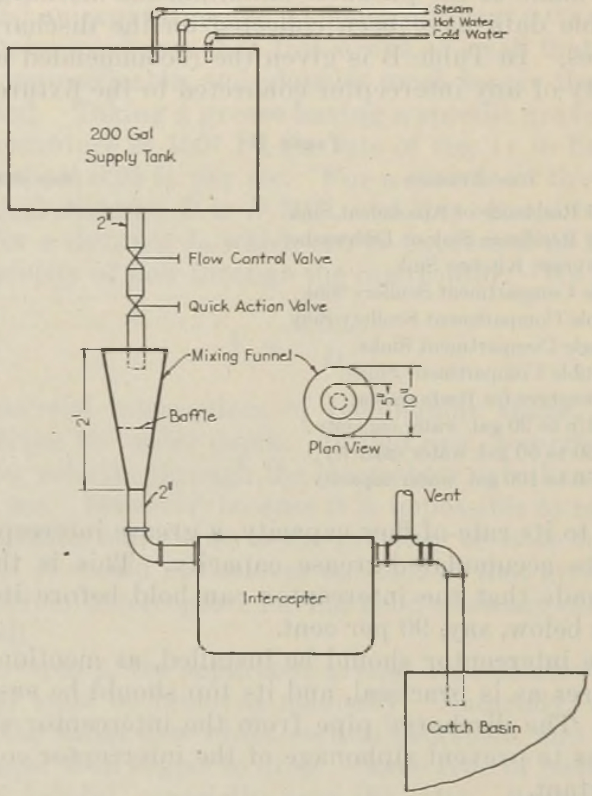

FIG. 1.—Arrangement of apparatus for testing grease interceptors in the laboratory.

The hot water for the tests is supplied from a 200-gallon gravity-feed tank which has water and steam connections for controlling water temperature. Below this tank is a calibrated "flow-control" valve, the setting of which determines the rate of flow. Below this valve is a quick-action valve, which permits quick starting or stopping of the flow. The hot water from the tank discharges into a mixing funnel into which hot grease is poured at a uniform rate during the flow of hot water. The mixing obtained is thus not subject to any manual control. The mixture then discharges into the interceptor. Beyond the interceptor is a large tank from which the grease escaping the interceptor can be caught and skimmed off.

During the discharge of hot water, pure pork lard is added at a concentration of one pound for five gallons of water. This gives a grease concentration of about 2.4 per cent by weight. The water and lard are at a temperature of 150° F. Before starting a run the interceptor is filled with water at 150° F.

A run consists of discharging, at a selected rate of flow, the hot water and grease mixture at a number of two-minute periods. After each two-minute period the grease leaving the interceptor is collected, de-

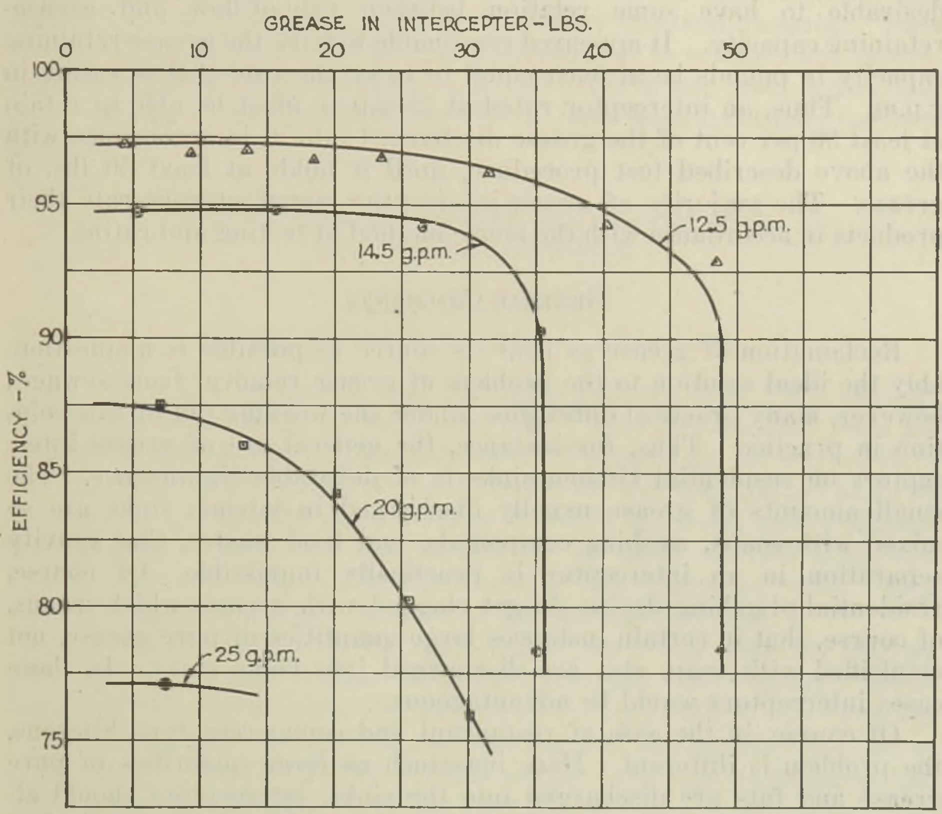

FIG. 2.—Typical laboratory test data for a commercial grease interceptor.

watered, and weighed. For certain large interceptors this collection of escaping grease is made only after two or three discharge periods. The discharging of the mixture of water and grease in two-minute periods is continued until the grease-retaining efficiency of the interceptor drops very appreciably. The average efficiency is calculated as follows:

$$\text{Efficiency} = \frac{(G_i)\ 100}{G_t} \tag{3}$$

G_t = Total grease in pounds added to interceptor since start of run.

G_i = The pounds of grease actually intercepted; this also equals G_t minus the total grease in pounds that left the interceptor since the start of run.

The foregoing value of efficiency is plotted against total grease in the interceptor, G_i. Thus it is possible to obtain the average grease-retaining efficiency of any interceptor from the time it is clean to when a certain amount of grease is accumulated. A typical plotting of test data is shown in Fig. 2.

Authorities have agreed that the average efficiency for the rate of flow at which an interceptor is rated and for its specified grease-retaining capacity should not drop below 90 per cent. Also, it appeared desirable to have some relation between rate-of-flow and grease-retaining capacity. It appeared reasonable to have the grease-retaining capacity in pounds be at least equal to twice the rate-of-flow rating in g.p.m. Thus, an interceptor rated at 25 g.p.m. must be able to retain at least 90 per cent of the grease discharged into it, in accordance with the above described test procedure, until it holds at least 50 lbs. of grease. The majority of grease-interceptor manufacturers rate their products in accordance with the above method of testing and rating.

General Comments

Reclamation of grease as near its source as possible is unquestionably the ideal solution to the problem of grease removal from sewage; however, many practical difficulties hinder the working out of this solution in practice. Thus, for instance, the general use of grease interceptors on residential kitchen sinks is of debatable significance. The small amounts of grease usually discharged in kitchen sinks are so mixed with soaps, washing compounds, and food wastes, that gravity separation in an interceptor is practically impossible. Of course, residential-plumbing drains do get clogged with grease, which means, of course, that in certain instances large quantities of pure grease, not emulsified with soap, etc., are discharged into home sinks. In these cases interceptors would be advantageous.

Of course, in the case of restaurant and commercial-type kitchens, the problem is different. Here inasmuch as large quantities of pure grease and fats are discharged into the sinks, interceptors should always be installed on such fixtures. If, however, the important problem is that of reclaiming grease of high economic value, then it appears that a somewhat different arrangement might be desirable for establishments which have significant amounts of waste grease. In such cases, the better procedure would seem to be to have a special fixture available which would be used only for discharging greasy wastes. In other words, all water containing grease and fats would be discharged into a special "separator" which would intercept the relatively pure grease and discharge the water to the sewer. No wash water or soap solutions would be discharged into this fixture. By following this plan, much more and much better grease could be salvaged. On a small scale such a method might be used even in homes. However, the success of such grease-salvaging procedures would depend entirely on the public cooperation, and we question whether the American people are sufficiently imbued at present with the need for grease salvaging to carry out any such procedures very extensively.

From certain information which we have been able to obtain, it appears that large quantities of grease are being collected from the interceptors installed in army camp kitchens. Since very few data on actual field operation of grease interceptors is available, it is hoped further definite information about the operation of these interceptors will be obtained as time goes on. These interceptors are of supposedly proper size, and if orders are obeyed they will receive frequent cleaning. Data on their functioning should give an indication as to whether our laboratory testing and rating method is sound. There are good indications that it is, but, as always, the final proof is "how does it actually perform in practice."

EXCLUSION OF WASTE OIL FROM THE BALTIMORE SEWAGE

By C. E. Keefer

Associate Engineer, Bureau of Sewers, Baltimore, Md.

In 1927 a fire broke out near the outlet end of Jones Falls conduit, the largest storm drain in Baltimore city. This fire resulted from the escape of gasoline and oil into the drain. Fortunately, no serious damage was done. One beneficial result, however, was the passage of a city ordinance requiring the daily storage of waste oil, crank case drainings and greases in approved steel drums by all users of such materials. This ordinance is enforced by the Board of Fire Commissioners. Anyone violating it is subject to a fine of $50 for each offense.

In order to provide for the collection of these materials the city entered into a two-year contract with the Provident Oil Company. Since September 30, 1929, when the first contract terminated, the work has been done by three companies, each having had the contract for two or more years. The cost to the city has varied from $500 to $3,240 a year and under the present contract amounts to $1,575 annually. The amount paid for the service during the past 16¼ years from October 1, 1927 to December 31, 1943, has totalled $32,013.75 and has averaged $1,970.08 a year. During this period 4,287,714 gal. of material has been collected, or 263,860 gal. yearly, at an average cost of 7.5 mills per gal.

The contract requires the contractor to furnish steel drums for the storage and the transportation of oil and greases where the amount collected is more than 20 gal. weekly. Where the quantity is less than this amount, the containers are furnished by those who have oils and greases to dispose of. The contractor is required to collect the containers within 24 hrs. after they are full.

The present contractor has three 1,000-gal. tank trucks for the transportation of the materials. Each truck is equipped with a suction and a discharge pump for handling the oils.

Oil Purification Plant.—At the purification plant the oil is discharged from the tank truck into an underground storage tank. From here the oil is pumped into a 2,600-gal. dehydrating tank, which contains a number of steam coils. Steam at 90 lb. pressure is passed through the coils for a period of 5 to 8 hrs. until all of the moisture has evaporated.

From the dehydrating tank the oil is transferred to a 1,500-gal. acid treating tank, where sulfuric acid is added. Sludge, which is precipitated from the oil, is disposed of in a lagoon.

The partially purified oil, to which clay is added, is then cooked with steam in a still at about 600° F. for 8 to 10 hrs. and the higher volatile hydrocarbons such as kerosene, naphthalene and the alcohols are distilled off. These are used as fuel in the steam generating plant. After leaving the still, the oil is cooled to about 200° F. and filtered through a Shriver plate press. The filtered material, which is said to be equal in quality to new oil, is ready for sale. The entire purification process takes about 12 hrs.

The oil recovery company also collects waste oil from railroads and from neighboring towns as far distant as Annapolis, Md. The collecting and the purifying of oil is not unique in Baltimore. Similar plants are in operation in New York City, Philadelphia and other cities. The unique feature about the situation in Baltimore is that the city has adopted an ordinance that requires the daily collection and disposal of greases and oils and has made the necessary provisions for having this work done.

Since this ordinance has been in effect, the sewers and the drains in the city have been remarkably free of inflammable materials and, most important of all, no fires have been reported.

Acknowledgments are due G. H. Elliott, Jr., formerly associate engineer, Bureau of Street Cleaning of Baltimore, and J. A. Inciardi of the City Waste Oil Co., for their assistance in preparing this paper.

Cost of Collecting Grease and Oil in Baltimore From 1927 to 1943

Year	Contractor	Amount Paid Contractor	Grease and Oil Collected, Gal.
1927		$ 810.00	71,701
1928		3,240.00	265,000
1929		3,037.50	318,000
1930	Provident Oil Service Co.	2,430.00	286,850
1931		2,430.00	280,100
1932		2,422.50	229,299
1933		2,400.00	139,804
1934	Thomas Leonard	2,400.00	143,280
1935		2,300.00	155,690
1936		2,000.00	169,515
1937		2,000.00	156,150
1938		1,625.00	120,940
1939		500.00	327,440
1940		500.00	437,420
1941	City Waste Oil Co.	768.75	473,420
1942		1,575.00	416,099
1943		1,575.00	297,006
	Total	32,013.75	4,287,714

GREASE REMOVAL ORDINANCES AND GREASE PROBLEMS IN SEWER MAINTENANCE

By Morris M. Cohn

Sanitary Engineer, City of Schenectady, N. Y.
Editor, Sewage Works Engineering

It appears to be my function to read into this symposium on grease removal the portion of the problem which lies between the grease interceptors, if any are used, and the sewage treatment plant. That portion of the problem involves the vast expanse of the public sewer system and the ills to which it is subject as a result of the discharge of greasy materials with the spent water of the community.

My subject is a double-barreled one; it seems to say that there are grease removal ordinances in effect but, despite that fact, there are grease problems in sewer maintenance. It, therefore, becomes my function to describe the restrictions whereby municipalities have attempted to overcome potential grease problems in sewers; and to touch briefly on what happens to a sewer system when grease is discharged through ineffective interception devices, through ineffectively maintained devices, or directly into the sewer without the use of any interception facilities.

Amid all of the practical discussions of the three other gentlemen associated with me on this symposium, I should like to inject some brief comments on the philosophy of sewerage practice. A sewer system is a publicly-owned device designed for the purpose of removing dangerous wastes from the home, commercial establishment and industry. It replaces a back-yard device which stored material on the home site for periodic removal. It changed the standards of live, personal comfort and cleanliness, simply because it *did* remove from man's habitat his own physiological wastes.

At the time when some "radical" engineer dreamed up the idea of using a sewer system instead of a "honey wagon," officials were filled with grave doubts about the ability of sewers to carry certain wastes and they actually began limiting the use of drains for storm water only, and the discharge of sewage was frowned upon. It is little wonder, then, that when sewers began to be used for the transportation of solids-bearing waste water that municipalities wrote into their laws certain restrictions and prohibitions aimed at preventing promiscuous discharge of materials which would clog sewers or damage their physical structures. The materials mentioned in such municipal ordinances give an interesting insight into the habits of the time and the way sewers might have been used. Included with grease were such items as: butchers' offal, sawdust, garbage, paunch wastes, tallow, acids, steam and other logically objectionable materials.

I have a definite philosophy on the purpose of sewerage service; with it some people staunchly agree and others vehemently disagree. It is my contention that a municipality has certain inalienable responsibilities to its constituents and that one of these responsibilities is to remove through a public sewer system all waste material which can be removed without endangering the ability of that sewer to serve all the other persons in the community. If the Golden Rule can be applied to anything as lowly as a sewer, the principle could well be established that while a sewer should be used by each individual to its maximum ability, the individual should do unto the sewer only as all others are able to do. The point I am trying to make is that the city has the legal right to restrict the discharge of materials into the sewer system but that any attempt to restrict the use of the sewer for materials which can be successfully carried by the waste water of the community may be fair legally but unfair morally.

In the light of this principle, we can now consider the waste matter which is the subject of this symposium—grease. Grease is a material which, unfortunately, has two forms. If grease could be retained in liquid state, it would flow from the point of production to the treatment plant without any more serious effect on the sewer system than the "sleeking over" of the barrel of the sewer. The great advances being made in grease removal processes at treatment plants would make it possible, perhaps even desirable, to permit property owners to discharge greasy materials into the sewer system and overcome forever the necessity of rehandling objectionable materials at the point of production. In short, it is my belief that this would be making full use of the water-carriage system.

I have merely been arguing for the sake of arguing, because grease does not have the happy ability to remain in a liquid state. Portions of it tend to solidify and to coat any chill surfaces which convert it from a liquid to a solid, thus producing a material which can have a deleterious effect on the sewer system as a carrying device. It is because of this fact that many municipalities have enacted regulations limiting the discharge of grease into the sewer system.

Grease Interception Ordinances

Despite many efforts to obtain an intelligent analysis of existing grease regulating ordinances in municipalities, I am unable to supply information which has any real dependability and merit. However, it appears from the opinions of such agencies as master plumber groups and a survey conducted by the writer, that most American towns under 50,000 population have no grease interception regulations and that from 50 to 60 per cent of communities over 50,000 population size has some form of regulation. It is interesting to note that some 25 per cent of the small towns, in which residents utilize private septic tanks for individual sewage disposal, require the use of grease traps ahead of septic tanks and others do not. It is further interesting that Report BMS 66, Plumbing Manual, of the U. S. Dept. of Commerce, National Bureau of Standards, states that "grease interceptors should normally be omitted on small septic tank installations."

In establishing regulations limiting the discharge of grease into public sewer systems, municipalities have been swayed by standards of *quantity* rather than *quality*. In the main, the grease from a restaurant or public eating place is the same type of grease discharged from a home, only it is in much larger quantity. Recognizing this fact, those municipalities which have established grease regulation ordinances have required interception of grease in the former establishments but not in domestic installations. Of course, garbage and industrial greases are of different nature, but I am limiting my discussion to food greases.

Grease Problems in Sewers

The foregoing comments bear on the first portion of my assigned title—Grease Removal Ordinances. There is little to say about grease problems in sewers, which is not already known to all sewer system officials and sewage treatment plant operators. Grease solidifies in sewers, forming upon the barrel of the sewer at and above fluctuating flow lines and even clogging the complete barrel of the sewer. This material, mixed with entrained sewage solids or with scouring powders, becomes a tenacious material which is extremely difficult to remove from sewer lines and which has frequently caused complete stoppage of sewer systems. However, in all of my experience in sewer maintenance work, I have seen or experienced little serious stoppages in sections of sewers serving truly domestic areas. Primarily, major stoppages due to grease formations have been experienced in sections of line tributary to large eating establishments, due to the use of ineffective interception equipment or, more likely, to the failure of restaurant personnel to keep grease traps clean. After all, an uncleaned grease trap is no better than no grease trap at all.

Those of you who associate the speaker with the idea of grinding food wastes in the home and discharging this material through the home plumbing system into the sewer system, may recognize why I have academically discussed the philosophy of sewerage service and the responsibility of the community to permit the discharge of any material which does not tend to clog the sewer or damage its physical structure. The first natural reaction of sewer system officials, when the idea of food waste grinding in the home was proposed by the writer, was that this material would clog the sewer and that increased grease content would cause greater grease stoppages. This has not been so. The finely divided water-borne wastes have been easily transported through sewer lines and greases have been chilled, solidified and homogenized by household grinders into a form which is non-clogging and which can cause no congealed depositions on the lining of sewers. In other words, the grease in ground foods assumes a solid or non-clogging form before it enters the public sewer system, because of cold water grinding, centrifugal aeration and flushing and it is, therefore entitled to sewer transportation, as I have contended above.

Impact of War

My portion of this symposium would not be complete without taking cognizance of the impact of war living on the problem of grease in sewers. I have been in a peculiarly effective position to know something about this subject, as a sewage works official who is serving as the Chairman of a County Salvage Committee of the War Council.

Sewage is a waste material of life; its composition and quantity is, therefore, affected by anything which affects life itself. It is natural, therefore, that the composition of sewage should be changed by the impact of war upon our home and eating habits. If I may coin a phrase, *ordnance* has done for sewage grease what *ordinance* could not do.

When Japan marched roughshod over the South Pacific, it succeeded in cutting off the American supply of imported crude oils and fats. Aside from the effect upon miscellaneous commodities of civilian life, this cessation of grease importation hindered the production of glycerine and of explosives needed for the purpose of driving the Jap from his ill-gotten gains. More than a year ago, the War Production Board completely prohibited the use of glycerine in the manufacture of anti-freeze solutions and subsequently restricted its use in tobacco, beverages, dentrifices, flavors, cosmetic and toilet preparations. Every ounce of glycerine has gone to war. Despite these conservation efforts, America cannot maintain its ordnance schedules unless we begin "living on our own fat."

It is estimated that housewives and eating establishments pour two billion pounds of waste fats down the drain yearly—the grease which we have been discussing. The War Production Board grasped at this waste fat as a means of "living on our own fat." As a result, an intensive campaign was and is being conducted by radio, newspaper, posters and public speakers, urging housewives to save waste fats for explosives. Such slogans as "Out of the Frying Pan into the Firing Line" appealed to housewives as a patriotic act to save waste fats rather than throw them away.

As a result, millions of housewives are pouring this material into tin cans rather than down the sewer, thus making less work for plumbers and more for soldiers who fire a Bazooka, a weapon that looks as though it needed a plumber to handle it. A tablespoonful a day, the War Production Board's quota for every household, multiplied by the population of your community will give you some notion of the quantity of material which can be eliminated from your sewers in the interest of our war effort. It is estimated that the quantity of materials previously poured down the drain was equal to the total of fats and oils we formerly imported from the Far East. Is it any wonder then that we have worried about grease troubles in sewers?

All public officials recognize that the public is disdainful of certain municipal regulations and that enforcement is frequently impractical or impossible. In the case of regulation of grease discharges into the public sewer system, ordnance may be doing what ordinances were unable to do. Since very few regulations prohibit discharge of domestic greases into sewer lines, and since the usual practice has been to discharge these wastes into the drain despite the fact that sluggish sink drains resulted, it is evident that the war will result in the elimination of millions of pounds of waste which previously caused sewer maintenance problems.

Someday the war will be over. Will we return to the practice of wasting two billion pounds of kitchen grease into the public sewer systems of the United States, or will we have learned that these wastes contain a valuable commodity when poured into a tin can? If we can continue in peace the salvaging practices of the war period, we will have gained something tangible in sewer maintenance practice as a result of the war.

UTILIZATION OF SEWAGE GREASE

By Wellington Donaldson

Chief, Bureau of Sewage Disposal Design, Department of Public Works, New York City

Last year, before this Association, the writer stated that plans were under way for sale of grease collected from sewage treatment works of New York City, but as yet no sales had been made. Subsequently, these plans were brought to fruition with the result that since June of last year, the grease skimmings from several of the larger plants in the City have been sold to a local concern specializing in the rendering of inedible fats. Negotiations necessary to consummate these sales, and the results therefrom, were very clearly and fully set forth by Mr. Nathan I. Kass, Chief of the Bureau of Sewage Disposal Operation, in a paper published in the *American City,* issue of November 1943 (Vol. 18, pp. 11 and 56). That paper reported on the grease collected from Wards Island, Bowery Bay and Coney Island plants. The new Jamaica activated sludge plant went into service September 28, 1943, and subsequently the collection of grease from this plant was added to the list. The purpose of this paper is to bring the figures up to date and discuss some of the aspects of grease utilization as they may apply generally.

Briefly, during the last seven months of 1943, some 650,000 pounds of sewage scum were collected and sold to a fat vendor at 0.8¢ per pound, wet basis, f.o.b. sewage plants. The returns from these sales thus amounted to $5,206, equivalent to about $8,900 per annum for otherwise waste material contributed to the war effort. The returns are regarded as net income since no more plant labor was required to place the skimmings in cans than by former methods of handling.

It should be borne in mind that what we are talking about here is not purified and concentrated grease but the ordinary skimmings from settling tanks which contain considerable water and various floating impurities. On the basis of analysis, 100 pounds of the skimmings removed from the scum manholes by the operators and placed into cans by means of hand dippers will contain about 53 pounds of water, 37 pounds of ether soluble fat, and 10 pounds of impurities. On the basis of the fat content, it follows then that the scum sold represented some 242,000 pounds of fat which is equivalent to 2.15¢ per pound dry fat basis. The present ceiling price to householders for rendered kitchen fats is 4¢ per pound plus two brown ration stamps, while the present ceiling price of inedible fats is 8⅝¢ per pound. The difference may be taken to represent the expense and profit to the renderer for processing a difficult material.

TABLE I.—*Scum Sold in 1943*

Wet Pounds

Plant	Wards	Bowery	Tallmans	Coney	Jamaica	Total
Ave. Flow M.G.D.	200	35	14	48	40	337
June	24,480	17,820	20,410	14,580		77,290
July	13,140	20,880	17,820	31,860		83,700
Aug.	17,640	25,740	17,100	28,980		89,460
Sept.	21,600	23,040	13,140	44,640		102,420
Oct.	12,060	39,060	13,920	23,220		88,260
Nov.	6,840	27,540	13,140	38,520	30,060	116,100
Dec.	6,660	30,420	15,660	19,350	21,520	93,610
Total	102,420	184,500	111,190	201,150	51,580	650,840
Ave. Month	14,631	26,357	15,884	28,736	25,790	22,280
Ave. Day	479	862	520	940	845	729
Lbs./Mg./Day	2.4	24.6	37.1	19.6	21.2	21.0

The quantities of scum collected from the New York City sewage treatment plants up to the end of 1943 are summarized in Table I and the composite analyses of the scum as delivered into the vendor's cans are shown in Table II.

TABLE II.—*Scum Analyses*

From Daily Composites

Plant	Wards		Bowery		Tallmans		Coney		Jamaica		Averages	
	% Solids	% Fats	% Solids	% Fats	% Solids	% Fats	% Solids	% Fats	% Solids	% Fats	% Solids	% Fats
June												
July			33.2	77.8	37.9	76.9	44.2	68.3			38.4	74.3
Aug.	45.0	78.4	44.3	78.9	31.6	81.6	40.8	80.9			40.4	80.0
Sept.			59.4	74.6	41.1	81.4	53.1	73.2			51.2	76.4
Oct.	57.1	86.0	75.2	72.2	34.8	85.4	54.4	72.9			55.4	79.1
Nov.	54.0	84.2	36.6	84.6	42.1	87.9	51.7	84.8	48.6	79.2	46.6	84.1
Dec.			40.1	89.0	51.7	88.2	50.6	85.6	46.9	80.2	47.3	85.8
Ave.	52.0	82.9	48.1	79.5	39.9	83.6	49.1	77.6	47.8	79.7	46.6	80.0

100 pounds wet scum contains approximately 37 pounds ether soluble grease.

It is very noticeable that the quantities of grease collected bear little relation to the size of the plants and the volume of sewage treated. The discrepancies are due to the individuality of the plant layouts and to the practical operating conditions at the plants. No effort has been made by modifications of operating procedures nor by installation of special grease separation processes to increase the amount of grease recovery. The quantities recovered therefore represent a "run of mine" operation.

Wards Island is an activated sludge plant with preliminary tanks having about 50 min. detention period. The tanks are square, Dorr type, equipped with skimming mechanisms. The concentrated scum is,

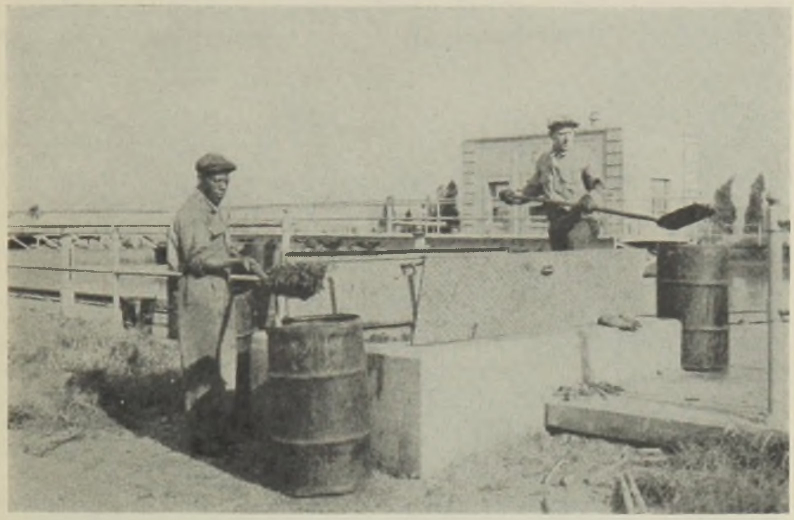

Fig. 1.—Wards Island Grease Skimming.

however, hand removed into cans by wire mesh dippers, as shown in Fig. 1. All the scum at Wards Island is collected from the preliminary tanks.

Bowery Bay is an activated sludge plant with rectangular preliminary basins of about one hour retention equipped with Jeffrey mechanical skimming flights, also auxiliary mechanisms for delivering the concentrated scum to the grease trough from which it is flushed to a central grease separation manhole. An experimental spiral grease remover, furnished by the American Well Works, has been installed on one of the units to move the scum from tank to grease trough. In addition to the scum from the primary tanks, scum is also collected from the two unaerated influent channels feeding the final settling tanks. Scum separating in these channels after aeration is squeegeed by hand over a weir into a manhole thence flushed into the central grease separation manhole from which the scum is ladled into cans.

Tallmans Island is an activated sludge plant having rectangular preliminary tanks of about one hour retention equipped with Link-Belt skimming flights. Originally, the concentrated scum was lifted into the grease trough by an auxiliary mechanism but this has been removed and replaced by hand operation. The scum is flushed from the grease trough into a central grease separation manhole from which it is ladled into cans.

Coney Island is a plain sedimentation plant during 8 months a year. Chemical precipitation with ferric salts and chlorination is employed during the four summer months. The original four tanks are circular, Dorr type, equipped with mechanical skimmers which require manual operation to deliver the scum to the central manhole. The new settling tanks are rectangular, equipped with Dorr monorake which has a me-

FIG. 2.—Coney Island Grease Skimming.

chanical skimmer to concentrate the scum at the weir end of the tanks where it is removed by hand to the scum trough and then flushed to the central grease separation manhole from which it is ladled into cans. The latter operation is shown in Fig. 2.

Jamaica is an activated sludge plant without preliminary sedimentation. The scum is collected from final settling tanks which are circular, Dorr type, equipped with mechanical skimmers which deliver the scum to a central manhole from which it is ladled into cans.

Evidently, the purchaser of the scum regarded the 1943 contract as being profitable to him since he entered into a contract for the calendar year 1944 at the same price of 0.8¢ per wet pound, with the following stipulations:

1. Work of removal shall be done between 9 A.M. and 3 P.M.
2. Empty containers will be filled by the employees of the Department of Public Works.
3. Purchaser shall carry on operations at the Sewage Disposal Plants in a manner satisfactory to the Bureau of Sewage Disposal Operation of the Department of Public Works.

4. The purchaser shall furnish a sufficient number of approved cans, drums, or barrels that can be sealed water-tight. These containers shall be used only for handling this material.

5. Changes of plant or methods of operation relating to the handling of skimmings must first be approved by the Department of Health.

6. Payment shall be on a wet pound basis of material as collected at the plant, and the purchaser accepts the assumption that quantities will be measured on a cubic foot basis and that one cubic foot weighs sixty pounds.

7. The purchaser or his representative shall sign, in triplicate, at the time of each removal, a Department of Purchase delivery ticket for the quantity removed.

8. The purchaser will be billed for the quantity removed monthly, and payment shall be made within five days after date of invoice, by cash or certified check made payable to the City Treasurer, City of New York, and submitted to the Commissioner of Purchase, Room 2210, Municipal Building, Manhattan.

9. This order is subject to termination upon one week's notice by the Department of Purchase if the contractor fails to conform to all conditions of this contract.

Grease analysis of sewage or sewage materials at the New York City treatment plants is not carried out on a routine basis but only as some special studies have dictated the need of such data.

In Table III are given some determinations relating to this matter.

TABLE III.—*Grease Content of New York Sewage and Sludges*

Plant	Period	Number Samples	P.P.M.	Solvent
Raw Sewage				
Bronx Grit Chamber	Oct. 29–Dec. 8, 1940	27	67	Chloroform
Manhattan Grit Chamber	Oct. 29–Dec. 8, 1940	27	104	Chloroform
Wards Island	(From above)		86	
Tallmans Island	January 2, 1941	1	40	Pet. Ether
Primary Effluent				
Wards Is.	Oct. 29–Dec. 8, 1940	27	85	Chloroform
Tallmans Is.	Jan. 2, 1941	1	40	Pet. Ether
Final Effluent				
Wards Is.	April 1, 1940	1	8.0	Chloroform
	April 7, 1940	1	5.0	Chloroform
	May 2, 1940	1	4.0	Chloroform
Excess Activated Sludge				
Ward Is.	Apr. 27, 1939	1	9% dry basis Ethyl Ether	
Tallmans Island	Dec. 21, 1941	1	11.9% dry basis Pet. Ether	

It is obvious that the amount of grease recovered is a very small part of that contained in raw sewage. Using the recovery quantities shown in Table I and calculating on the basis of actual sewage flows during the same period, we find that they correspond as follows:

	P.P.M.
Wards Island	0.1
Bowery Bay	1.1
Tallmans Island	1.5
Coney Island	0.7
Jamaica	1.0

The question may be asked why, in view of the relatively low price obtained for wet scum, the grease is not rendered at the individual sewage plants or at a central plant in order to enhance the sale value? The two rendering methods available are referred to as "dry" and "wet." The dry process is one used by commercial firms specializing in the sale of fats. The fatty material is cooked in a closed steam-jacketed vessel for some two or more hours at a temperature of 250–260° F. which melts the fats and distills off the moisture. The hot fats are then passed through a filter press into cans where they are cooled and ready for the market. The filter cake has some commercial values. The dry process involves considerable investment in plant and equipment.

The wet process, which is much simpler, involves heating the fatty material in a tank of water above the melting points of fats, which is 77–80° C. (170–176° F.) for several hours. The separated fats collected on the surface are then strained through cloth. The resulting material, after cooling, is a brown paste similar to that obtained by the dry process but having a darker color and some water content. From 100 pounds of sewage scum so rendered, one would expect a yield of 34 pounds of grease and 32 pounds of ether soluble. Table IV gives actual analysis of these "home" rendered samples.

TABLE IV.—*Analyses of Rendered Fat*

(By Central Testing Lab.—Dept. of Purchase)

	Sample A	Sample B	Sample C
Appearance	Brown paste	Dark	Light
Moisture		0.5%	0.7%
Ash by Weight	0.1%	0.6%	0.6%
Nature of Ash	Essentially iron compounds	—	—
Melting Point	33–35° C.	30–32° C.	36–38° C.
Glycerol (Chemically liberated)	4.0%	7.8%	5.8%
Saponification Value	192	183	180
Neutralization Value	108	—	—
Acidity, as Oleic Acid	—	62%	75%
Unsaponificable	4.6	0.7	1.4
Constants of the mixed fatty acid prepared from paste			
Iodine Value	54	55	33
Titer	38° C.	36.5° C.	39.5° C.

Sample A—Wards Is.—Apr. 1942—Evaporated to dryness, extracted with ethyl ether.

Sample B—Tallmans Is.—Nov. 1943—Strained hot through cloth and filter paper, dried at 105° C.

Sample C—Jamaica—Nov. 1943—Strained hot through cloth and filter paper, dried at 105° C.

A sample of Jamaica scum similarly prepared was submitted to one of the well known soap makers of the City who reported that it was close in analysis to commercial No. 2 tallow and was quite suitable for soap-making. It was suggested as being attractive to soap makers at the present ceiling price of 8⅝¢.

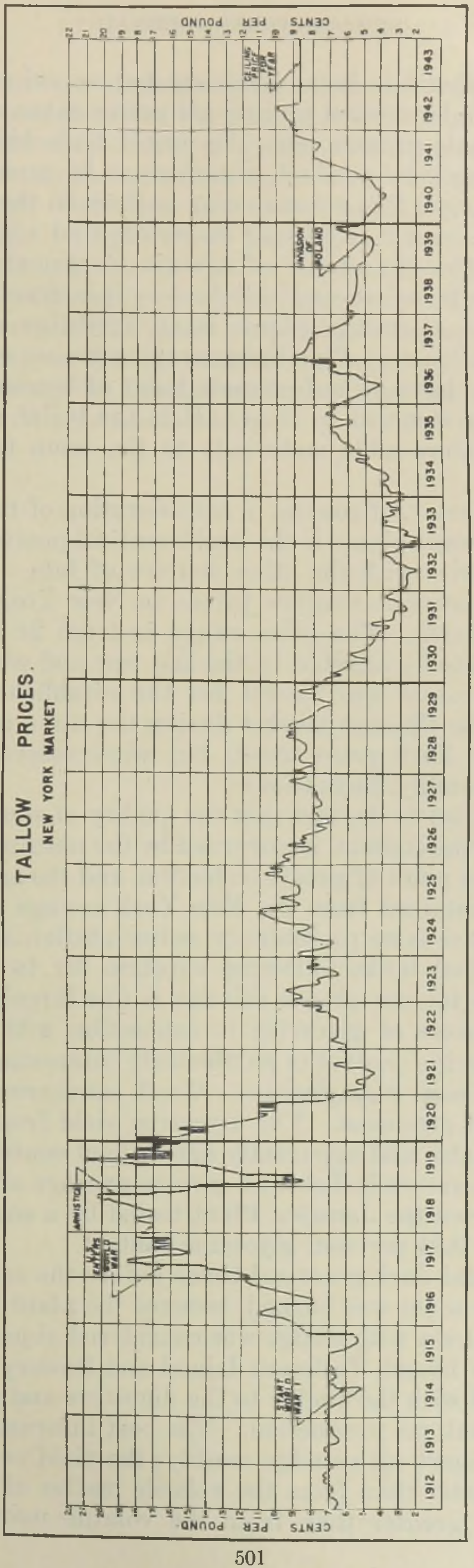
TALLOW PRICES.
NEW YORK MARKET
CENTS PER POUND
1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943
START WORLD WAR I
U.S. ENTERS WORLD WAR
ARMISTICE
INVASION OF POLAND
CEILING PRICE FOR 1 YEAR

Fig. 3.

Although our chemists have demonstrated experimentally that the sewage greases can be worked up into attractive cakes of shaving soap, fine cutting oils, axle greases, etc., the writer finds himself allergic to undertaking any such by-product manufacture by municipalities, even though it can be shown that revenue may be derived therefrom. Under local conditions at least it is difficult enough to find adequate personnel for carrying out the operations of sewage treatment without undertaking auxiliary enterprises and side lines. It is true that the normal handling of grease at sewage plants is an operation never free from trouble and unsightliness. Pipe lines carrying grease either by gravity or pump discharge have an unfortunate habit of becoming clogged and must be rodded or steamed to clear. It is the belief also that grease pumped into digesters adds materially to the scum troubles in those units.

A controlling factor, of course, in consideration of the sale of grease from municipal sewage plants is the problematical postwar market when competition will arise with the other sources of fats. Figure 3 shows the monthly fluctuations of tallow prices in New York for the period 1912 to 1943 inclusive. The price range is from 2¢ to 21¢ a pound. The price was markedly affected by the last war and would be similarly affected by the present war except for the established ceiling price. Tallow prices in the Chicago market during the same period in general followed the New York price trends but were somewhat higher and showed greater monthly fluctuations.

Attention is called to the fact that the quality of sewage grease, particularly its glycerine content, is governed by the nature of sewage treatment processes, the point of grease collection, and the age of the sewage. The best grease obtained from the New York sewage plants is that at Jamaica where there is no preliminary sedimentation and grease is collected from the final tanks following aeration for two to four hours. Since the impetus for our grease salvage is due largely to the appeals for additional sources of glycerine in connection with the war effort, the potential glycerine content is particularly interesting. Glycerine is a by-product of soap manufacture. Good commercial tallow yields 9 to 10 per cent of glycerine. The glycerine yield from sewage grease is much more variable and apparently not without controversial aspects. The three samples shown in Table IV give an average of 5.9 per cent, yet another sample from the Jamaica Plant tested by a soap manufacturer was credited with 9.94 per cent glycerine content.

At Wards Island during normal times before the sale of grease was consummated, the scum was burned, because the plant has no digesters and the disposal at sea with sludge was considered objectionable. However, at the Coney Island, Tallmans Island and Bowery Bay Plants, the scum was pumped with the sludge to the digesters and presumably contributed to the total gas production. The best information available is that grease will digest with sludge readily; the yield per pound of volatile matter is greater than from the volatile matter of primary sludge and considerably greater than from the volatile matter of activated sludge. The digestion of grease is also believed to yield a gas richer in methane. The magnitude of the gain in power to be obtained by digestion of grease instead of sale of grease is not easy to determine, but could hardly amount to more than 2 per cent, with the present ''run-of-mine'' methods of separation and collection. If the gains were shown to be substantial, it might be of interest to us to seek more efficient means of separating grease in view of the trend locally of installing gas engines to supply the energy for plant operation. It should be recalled, however, that most of the grease captured is contained in the sludges that now go to digesters. Any additional recovery would have to come about by decreasing the grease content of the final effluent, a difficult and not very profitable undertaking.

CONTROLLED DIGESTION *

By Harry E. Schlenz

Vice-Pres., Pacific Flush-Tank Co.

Digestion in separate tanks is a development of comparatively recent origin to provide a means of control found lacking in the digestion section of an Imhoff tank. Such control has in the main been related to the maintenance of optimum temperatures. Since the first heated digesters went into successful operation in about 1926 there has been installed in the United States over 70 million cu. ft. of separate sludge digestion capacity serving a population of approximately 30 million.

Great progress has been made in the utilization of the gas from the digestion process for power in addition to its use as a source of heat to accelerate the digestion action. At the present time almost 40,000 b.h.p. is being generated in the United States from these gases which previously were only related to odor nuisances. In some cases excess gas is utilized in the municipal or commercial gas supply systems.

Despite the progress in only about 17 years, as briefly related above, it is the writer's opinion that the digestion process has not reached the degree of perfection of other sewage treatment units.

Digestion tanks have been called upon to serve as the ''take-up'' in the sewage treatment system, operated mainly to accommodate the optimum schedules of other portions of the system, such as pumpage of solids and grease from clarifiers, withdrawal of sludge in amounts and at intervals to best suit a drying bed or incinerator schedule, without regard to the maintenance of proper balance between raw and digesting sludges in the digester.

Digestion tanks have, in a majority of cases, been started under unfavorable conditions, many times with ice actually present despite the fact that the organisms responsible for the action require a warm environment. As a result, the operator experiences trouble for months due to an increasing layover of non-digesting raw sludge, foaming, poor supernatant, etc.

The operator has been faced with the difficulties of improper operation due to inadequate pipe connections limiting him only to the addition and removal of sludge, with supernatant liquor generally overflowing from a fixed elevation in the tank without regard to its quality or rate of withdrawal. We might also mention undersized gas lines which prevent the proper removal of that end product of digestion.

True, there have been some developments in devices to attempt to aid in the digestion process; supernatant drawoffs to allow withdrawal of a satisfactory liquor; division of the process into two or more stages mainly to overcome the supernatant problem by reducing activity in the

* Presented at the Sixteenth Annual Meeting of the New York State Sewage Works Association, New York City, January 21, 1944.

additional stages, but not always resulting in the best use of the digestion capacity. However, it will be agreed that this recognized important step in the treatment process has a long way to go to achieve its fullest effectiveness.

To make up for the lack of proper digester control, designers and state agencies have added to the capacity allowances or requirements . . . but this prophylactic falls short of the proper diagnosis. Perhaps the additional capacity allowances combined with projection of design population into the future has aided in successful starting of digester operation.

During the past few years we have been confronted with the problems of digester operation in concentrated form, due largely to the number of sewage plants at military installations which were called upon to go into full design loading on the first day sewage was turned into the plant. With the experience gained in correcting conditions found at such installations we have devoted our energies to determining the weak points in digester design from the standpoint of the lack of provision of necessary connections, devices and procedures to permit the operator to exercise the utmost in digester control.

Without reviewing the much discussed elements of digester operation in regard to optimum temperatures, solids balance, reaction, etc., we will approach digester operation in a slightly different manner, including, but going beyond, the normally accepted standards.

Controlled Digestion

Description

"Controlled Digestion" embodies a system of tanks, piping, circulating and transfer pumps, supernatant withdrawal and supernatant treatment means and procedures for the speeding up and control of the digestion process. The best understanding of the "Controlled Digestion System" may be obtained by discussing individual sections, some of which may be readily accepted, while others may provoke discussion. The order of presentation, nor the length of each "tirade" does not bear any relationship to the importance of each section.

System of Piping

The system of piping required to practice "Controlled Digestion" may appear elaborate, but in the final analysis it is no more extensive nor does it contain any more valves than would be desired in a digester system by a "live wire" operator. I have yet to encounter an operator who kicked about having more piping connections or valves about a digester than he has use for. The criticism is generally in the other direction.

Figure 1 shows all of the piping in a "Controlled Digestion" system, with that portion shaded which is normally used for basic digester operation to practice either series or parallel operation, involving the addition of raw solids, withdrawal of digested solids, and transfer of solids or liquor from the primary digester to the secondary digester.

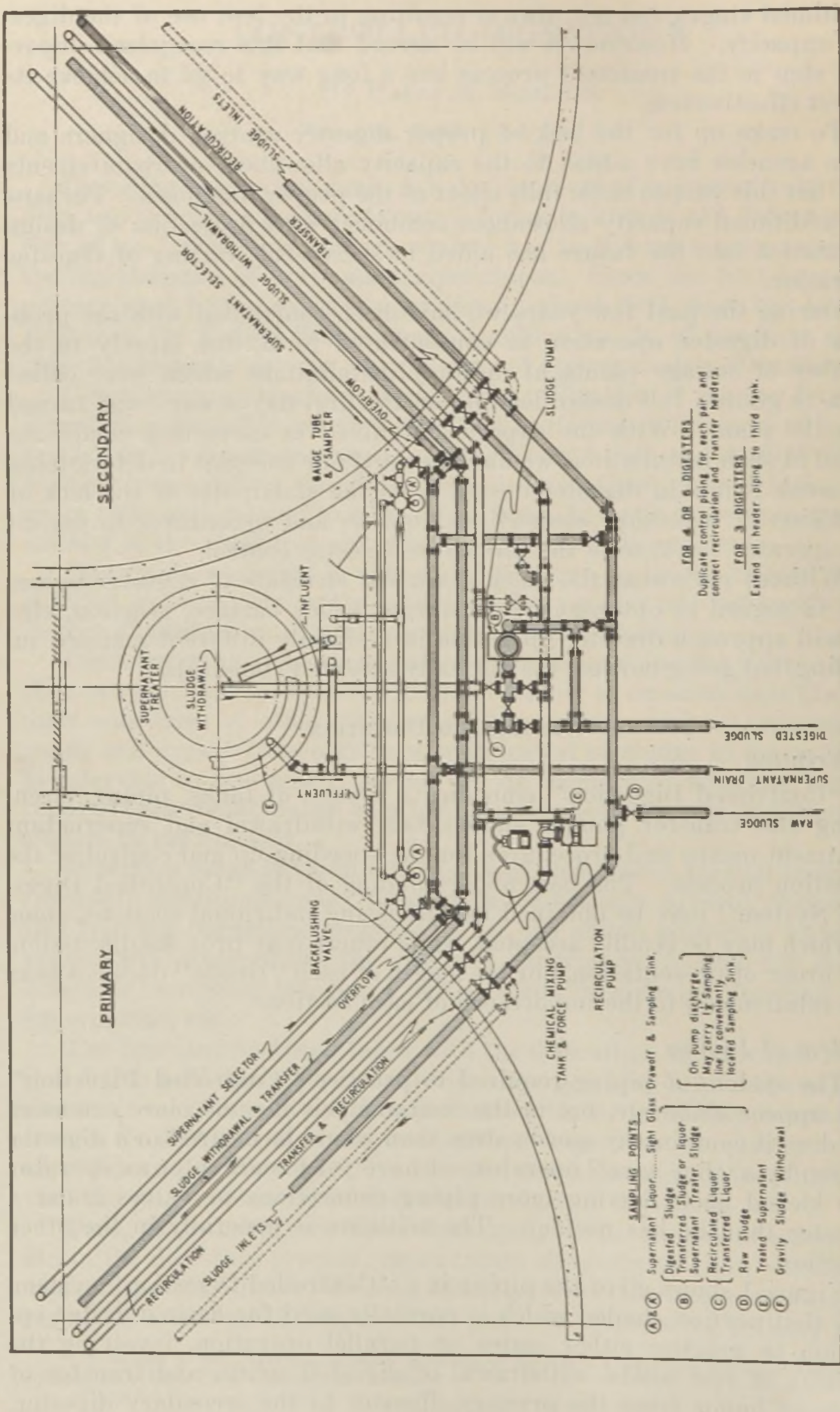

FIG. 1.—Piping normally used in digester operation. (Shown shaded in "Controlled Dgestion" system.)

The manner in which the relatively small amount of additional piping will be utilized effectively in the "Controlled Digestion" system will be revealed as the other features of the system are related.

Supernatant Liquor

There is no need to relate the difficulties experienced with supernatant liquor, which when discharged from a digester in large volume or high in suspended solids and B.O.D., is so damaging to the balance of the treatment process. Supernatant liquor can be utilized in the digestion process to great advantage . . . and the excess easily "selected" and treated before being returned to the treatment plant proper.

Supernatant Circulation

Experiments conducted by the writer in 1928–29 at the Engineering Experiment Station of the University of Illinois (1) demonstrated the seeding value of supernatant liquor containing active organisms in greater numbers than in the digested sludge. Provision should be made for the continuous or frequent circulation of supernatant liquor from the mid-section of each digester to the top of the tank for the purpose of bringing this "seed" material in contact with "layover" sludge forming the top of the digesting mass.

By circulating the supernatant liquor only, the digested sludge at the bottom of the tank is not disturbed and is allowed to concentrate to become available as the best material for removal and final disposal, or for transfer to a second stage tank.

A trend is indicated in the procedure of making use of the circulated supernatant liquor for heating and maintaining optimum temperatures in the digestion system by the use of simple heat exchanger units of standard size with supernatant passing through coils surrounded by heated water. Such coils are so arranged to facilitate cleaning by sections without necessitating removal of all units from service.

Supernatant Selection

It is desirable to select the supernatant lowest in suspended solids for removal from the digestion system and it should be withdrawn at a continuous and slow rate. Until recently there has not been any reliable means of accomplishing this, except the skill of the operator in selecting the proper drawoff level, and even if successful in doing so, the rate of drawoff generally was excessive.

Figure 2 shows a method of positive selection of the best supernatant by means of a vertical slotted pipe "selector." Slots of about 0.125″ wide prove to be small enough and numerous enough in extending through a 10 ft. depth of tank to allow withdrawal of only the best available supernatant liquor. A back-flushing provision should be included for the occasional cleaning of the slots if necessary. The unit is designed for removal from the tank without the necessity of dewatering, if ever necessary for inspection or yearly maintenance. About 20 installations are in successful operation to date. Close observation of a

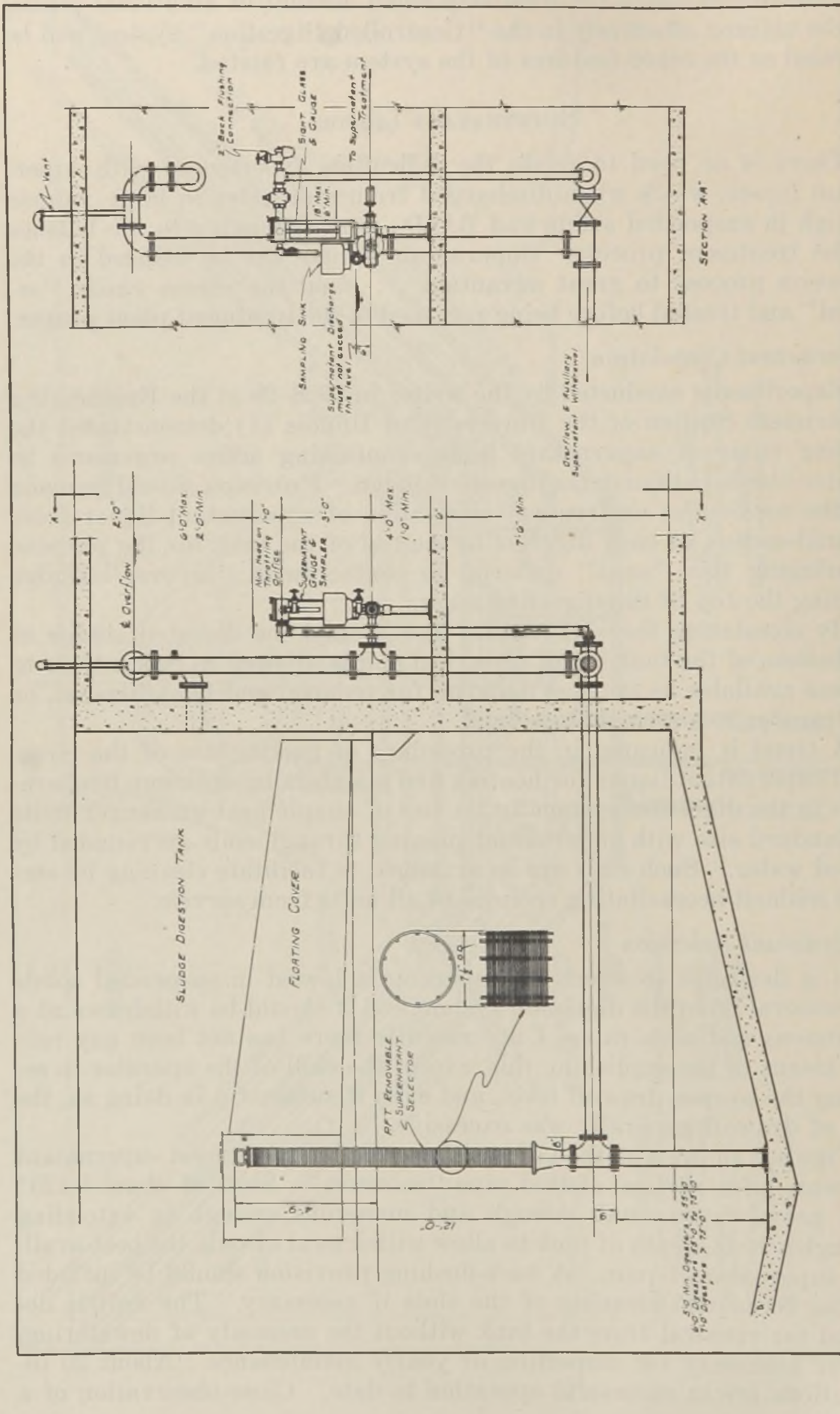

FIG. 2.—Arrangement of selector, gauge, sight glass and sampler for withdrawal of supernatant liquor.

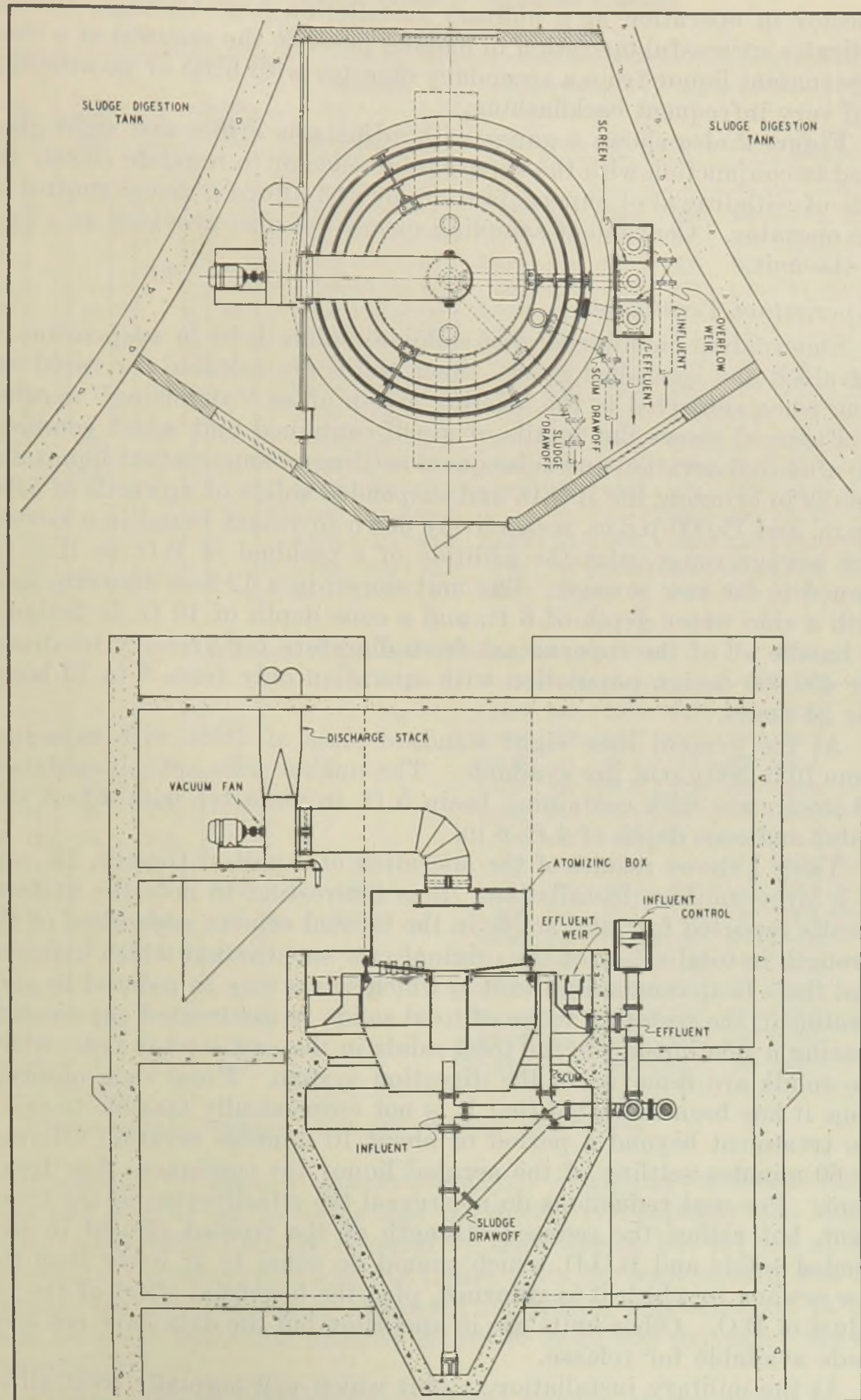

Fig. 3.—Details of supernatant treater.

selector in operation at a military installation near Chicago, Illinois, indicates successful operation in making possible the removal of a clear supernatant liquor from a secondary digester with little or no attention and very infrequent backflushing.

Figure 2 also shows a gauge with adjustable orifice and sight glass used in conjunction with the supernatant selector to regulate closely the rate of withdrawal of supernatant liquor and afford a visual control by the operator. Convenient sampling means are also provided as a part of the unit.

Supernatant Treatment

Supernatant liquor contains colloidal solids held in suspension by entrained and enmeshed gases. Such solids are released for rapid settling when subjected to the blasting action of an ''atomizing'' aerator.

Figure 3 shows the details of a self-contained unit which combines the atomized aeration and subsequent settling of supernatant liquor and results in bringing the B.O.D. and suspended solids of upwards of 5,000 p.p.m. and 15,000 p.p.m. respectively down to values found in a normal raw sewage range, plus the addition of a residual of D.O. as it is returned to the raw sewage. The unit shown in a 12-foot diameter tank with a side water depth of 6 ft. and a cone depth of 10 ft. is designed to handle all of the supernatant from digesters for primary treatment for 450,000 design population with operation only from 8 to 12 hours per 24 hours.

At the present time eight standard sizes of units with capacities from 10 to 300 g.p.m. are available. The smaller sizes are self-contained all-steel units with containing basin 5 ft. in diameter with 3-foot side water and cone depth of 4 ft. 6 in.

Table I shows results of the operation of a unit at Geneva, Ill., and at a large military installation. It is interesting to note the uniform results reported for total solids in the treated effluent regardless of the strength in total solids of the original raw supernatant which indicates that there is an economical limit to which solids may be reduced by such treatment, the resulting value of total solids in the treated supernatant bearing a relationship to the total solids in the raw sewage from which the solids are removed to the digestion system. From such observations it has been indicated that it is not economically feasible to carry the treatment beyond a period of about 10 minutes aeration followed by 60 minutes settling of the aerated liquor for continuous flow treatment. Per cent reductions do not reveal the effectiveness of the treatment, but rather the reduced strength of the treated effluent in suspended solids and B.O.D. which should be equal to or lower than the raw sewage to which it is returned, plus the beneficial effect of the residual of D.O. Other units are in operation but the data have not been made available for release.

At the military installation, a unit which will normally treat all of the supernatant liquor wasted from tanks digesting activated sludge solids with only 6 to 8 hours operation per day, was operated on a 24

TABLE I.—*Table of Results of Supernatant Treatment*

Large Military Installation—1942

Date of Run	Aeration Period, min.	No. of Turn-overs	Settling Period, min.	Total Solids			Suspended Solids			5-Day B.O.D.			Effluent D. O., p.p.m.
				Infl., p.p.m.	Effl., p.p.m.	% Re-duct.	Infl., p.p.m.	Effl., p.p.m.	% Re-duct.	Infl., p.p.m.	Effl., p.p.m.	% Re-duct.	
4–30				1,332	1,120	17.5	404	324	20.0	268	205	23.5	2.8
5–1				1,840	1,140	38.0	912	412	55.0	205	115	44.0	1.0
5–2		3.7		3,064	1,240	60.0	2,216	148	93.5	373	115	69.2	—
5–4				1,328	1,180	11.2	480	353	26.5	202	110	45.6	1.6
5–5	10		45	2,932	1,182	59.7	1,968	425	78.4	400	170	57.5	1.6
5–6				3,282	1,260	61.6	2,208	445	79.9	318	120	62.3	1.6
5–7				1,410	1,132	19.7	440	336	23.7	173	140	19.1	1.9
5–8		2.8		2,436	1,144	53.0	1,656	384	76.8	345	95	72.5	2.0
5–9				1,320	1,132	14.3	472	400	15.3	198	178	10.1	1.3
*4–28	20	2		1,592	1,140	28.9	504	236	53.0	263	167	36.5	0.8
*4–24	40	4		1,688	1,062	37.0	664	256	61.0	238	200	16.0	1.0
*4–25				4,500	1,068	75.3	4,032	234	94.2	418	140	66.5	0.6
*4–18	60	6	60	14,460	1,236	91.5	—	—	—	1,825	425	76.7	—
*4–20				3,310	1,012	69.7	2,432	34	98.7	500	135	73.0	—
*4–22	80	8		1,380	932	25.2	492	40	92.0	275	200	27.3	0.5
*4–23				3,818	1,036	72.8	2,884	238	91.7	368	185	49.7	—
Municipal Installation—(Geneva, Illinois)—1940													
*10–4		4	120				1,640	162	90.0	542	158	70.8	
*10–4	15						3,088	172	94.3	1,042	173	83.3	
*10–15		3.6	90				10,068	155	98.5	2,512	249	90.1	
10–12	18	5.8					6,192	200	96.8	1,539	204	86.5	
10–24	20		66				4,212	204	95.0	1,185	183	84.5	
10–11	24	7.5					1,804	182	89.8	672	169	74.7	
*10–4		8	60		Not		1,640	218	86.7	542	173	68.0	Not
*10–4			120		Deter-		1,640	178	89.0	542	150	72.3	Deter-
*10–1		6.4	90		mined		1,228	188	84.6	550	174	68.4	mined
*10–4	30	8	120				3,088	180	94.1	1,042	167	84.0	
*10–5							3,056	196	93.5	1,152	194	83.2	
*10–15		7.8	90				9,088	180	98.0	2,432	237	90.3	
*10–2		7.1	120				15,484	158	99.0	2,446	179	92.7	
10–10	36	11.2	66				2,816	201	92.7	873	187	79.5	
*10–18	45	12.7	90				13,840	174	98.5	2,852	235	91.7	

* Designates batch operation—other runs on continuous flow basis.

hour schedule for about 7 consecutive days. Sludge in the second stage tank had been so low in solids that the drying bed capacity was inadequate, necessitating sludge removal by tank wagon, but the use of the supernatant treater in extracting liquid from the supernatant and returning the removed solids increased the sludge concentration in the tank by about twice and allowed return to sand bed drying of the digested sludge.

Figure 4 shows diagrammatically the portion of the piping in the "Controlled Digestion" system shown in Fig. 1, which is used in the control of the supernatant liquor, comprising selection and gauging for removal from the digester system, and supernatant treatment.

Volatile Acids Control

Plant operators generally rely upon pH determinations as an indication of the condition of a digester, with liming resorted to for correction of a low pH, but it has been found that this criterion may be quite unreliable.

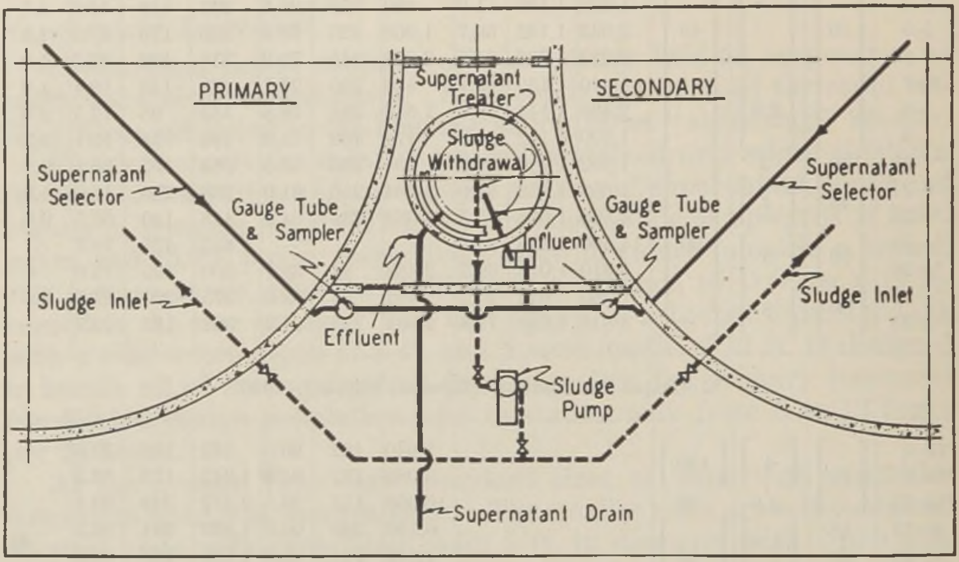

Fig. 4.—Diagram of piping used in control of supernatant liquor comprising selection and gauging for removal and treatment.

At Durham, N. C., W. M. Piatt provided a B.T.U. recorder which is in continuous operation on the gas from each digester. He claims by this means to be able to foretell, by a decrease in B.T.U. of the gas, which indicates an increase in the percentage of CO_2, the approach of poor digestion conditions at least a week before they show up in the form of a reduced rate of gas production and corresponding reduced digestion rate.

Volatile acids control has been employed successfully to foretell the approach of retarding digestion conditions at a number of trade waste installations with digesters operating at higher loadings than those normally encountered in domestic sewage treatment practice. In fact, to digest successfully most trade wastes it has been found to be absolutely necessary to practice volatile acids control. This involves a simple determination, as outlined below, which may be easily made daily to provide the "warning" long before a change of pH, alkalinity, drop in rate of gas production, or "foaming" conditions would indicate that trouble is at hand.

Volatile Acids Determination

Two hundred ml. of a sample is measured into a distilling flask; 5 ml. of concentrated H_2SO_4 is added and 150 ml. is distilled into a receiver. The distillate is titrated with 1/10 normal NaOH and results calculated as acetic acid and reported in parts per million.

In practice, if the volatile acids determination indicates a concentration of a value of, say, 2,000 or perhaps 3,000 p.p.m. in a digester sample or if succeeding determinations indicate a continued rise in the concentration of volatile acids, either of the following steps must be taken:

1. Reduce the loading of raw solids in the digester showing the increase by diverting some of the raw solids to another digester in the system, or
2. Circulate lower volatile acid content material from a second stage digester to the overloaded primary digester. As a result of such circulation a more rapid gasification takes place and the volatile acids are reduced much more than can be accounted for by mere dilution.

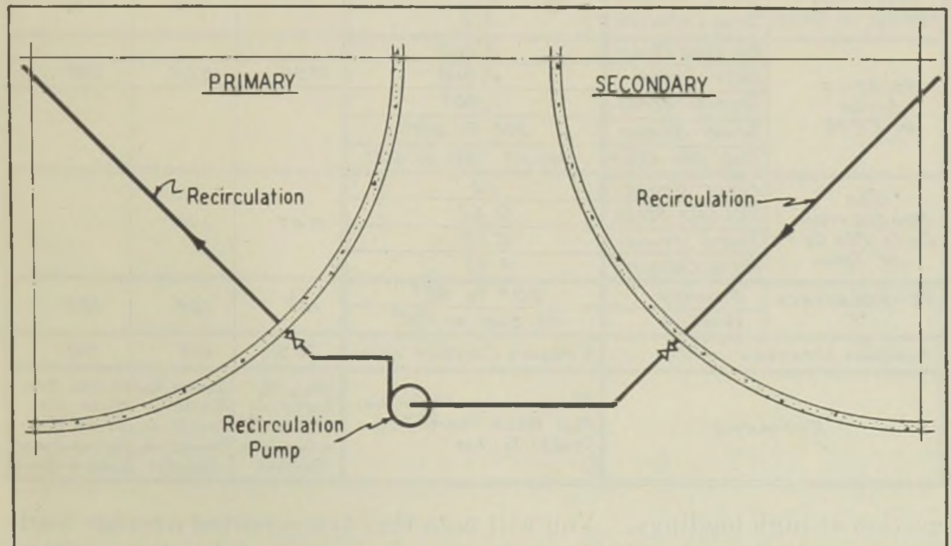

FIG. 5.—Diagram of piping used in control of volatile acids.

Figure 5 shows diagrammatically the portion of the piping in the "Controlled Digestion" system shown in Fig. 1 which is used for volatile acids control. The employment of this procedure of circulating from a second stage digester to a primary digester indicates a greater justification and usefulness for a second stage digester, than that normally assigned to it in the production of a better supernatant and in concentrating digested sludge solids.

Table II is a tabulation of summarized data for two trade waste installations which practice volatile acids control to accomplish rapid di-

Table II—*Summary of Data*
Trade Wastes Treatment
Volatile Acids Control in Digestion

		Pekin Illinois Standard Brands Co. Wastes		Peoria Illinois Commercial Solvents Co. Wastes		
G.P.D. of Waste Treated		250,000		173,600	112,100	108,700
Waste from Fermentation of		Molasses & Malt		70% Molasses 30% Hydrol	Molasses & Corn Slop	Corn Slop
B.O.D. in P.P.M.	Raw Waste	5,000 To 10,000		5400	7540	18,600
	Digested Waste	500 To 1,000		2420	2280	
	% Reduction	Average 90%		55.4%	70.0%	75.0% (Est.)
Total Solids in P.P.M.		Total	Volatile			
	Raw Waste	12,000	8,100	17,200	22,200	27,800
	Digested Waste	7,500	4,000	9,400	8,200	
	% Reduction	37%	50%	45.3%	60.3%	65.0% (Est.)
Capacity of Digesters in Cu. Ft.	First Stage	80,000		334,000	167,000	167,000
	Second Stage	80,000				
	Third Stage	80,000				
	Total	240,000		334,000	167,000	167,000
Solids Loading Lbs./cu. ft. 24 hrs.	First Stage	0.312		0.075	0.125	0.151
	Total Capacity	0.104				
Digestion Period in Days	First Stage	2.4		14.4	11.2	11.5
	Total Capacity	7.2				
Volatile Acids in P.P.M.	Breaking Point	3,000				
	First Stage	2,000		1090	820	210
	Second Stage	1,000				
	Third Stage	500 To 600				
	One Day Rest	Drops 500 To 600				
Gas Production Cu. Ft. per Cu. Ft. of Tank	First Stage	1.0		0.47	1.10	
	Second Stage	0.67				
	Third Stage	0.33				
	Total Capacity	0.67				
Temperatures °F	Summer	90° To 92°		133	124	125
	Winter	As Low As 70°				
Ammonia Nitrogen P.P.M.		Nitrogen Content High		265	615	710
Remarks		Recirculate 30,000 Gal. Per Week From 3rd. Stage To 1st.		$(NH_4)_2SO_4$ Added As Nutrient in Commercial Process	Sulphur Free Nutrient Added in Commercial Process	Diluted With Water and Seeded With Digested Sewage Sludge as Needed

gestion at high loadings. You will note that the reported average loadings are 0.15 lb. and 0.312 lb. per cu. ft. per day of solids of about 70 to 80 per cent volatile matter with reductions in B.O.D. of from 75 to 90 per cent by digestion in only 7 to 12 days. The first of three stages of digestion at the Standard Brands plant at Pekin, Illinois, has a detention of only 2.4 days. The loading of this plant on the primary tank is about 3 times that normally used in domestic sewage practice, and the gas production per cu. ft. of tank capacity is in like proportion. The tanks have at times indicated their capability of handling double the reported average loadings.

Volatile acids determinations and remarks in connection with two domestic sewage installations will be discussed in connection with the following section of the paper.

Ammonia Nitrogen Control

In the cases studied recently, it was found that in the digestion of trade waste solids where high loadings are successfully handled, the raw solids were higher than normal in ammonia nitrogen content. It appeared, therefore, that the presence of ammonia nitrogen might aid in the digestion.

In the case of the Standard Brands waste, the digestion of which was previously discussed, it was found that an ammonium salt is actually added in connection with the yeast fermentation process of the plant as a food accessory in supporting the bacterial activity. Since the treatment of the wastes by digestion is largely a continuation of the fermentation process on waste products not utilized in the main industrial process, it is logical to assume that the ammonium salt present would be equally beneficial in the digestion of the waste.

Table III.—*Effect of Ammonia Nitrogen Control, Cellulose Digestion Experiments*

			Maximum	Minimum	Average
Low NH_4-N Content	NH_4-N (p.p.m.)		28.0	4.2	15.1
	Volatile Acids as Acetic, p.p.m.		494	275	377
	Gas	Cu. Ft. per Day	8.9	3.5	6.8
		Cu. Ft. per Cu. Ft., Tank Vol.	0.064	0.025	0.048
High NH_4-N Content	NH_4-N (p.p.m.)		123.9	23.8	59.0
	Volatile Acids as Acetic, p.p.m.		364	95	228
	Gas	Cu. Ft. per Day	68	24	34.2
		Cu. Ft. per Cu. Ft., Tank Vol.	0.48	0.17	0.25

The question will be raised, "Why add ammonia nitrogen to a digesting sludge mixture which is already high in nitrogen?" The only answer one can give is, "It seems to be quite effective from the evidence which will be presented."

Dr. A. M. Buswell (2) of the Illinois State Water Survey reports the results of experiments indicating that the regulation of the ammonia content of the liquor in a digester is important and that when the ammonia concentration is too low, the rate of gasification decreases, and the amount of volatile acids increases. Table III shows results reported in a patent (3) in his and Dr. C. S. Boruff's name on the addition of ammonium salts to a digestion process involving mainly cellulose. Attention is directed to the average gas yield of about 5 times with a regulated ammonia nitrogen content as compared with non-regulated ammonia content.

Buswell (2) states that: "the minimum ammonia nitrogen concentration found suitable for the anaerobic fermentation of cellulose is 100 p.p.m. The bacteria seemingly utilize the ammonia nitrogen to build up their own structure. Lysis (disintegration) of these bacteria following death, releases the nitrogen which under anaerobic conditions is reduced to ammonia nitrogen, thus completing the cycle.'' It was indicated that approximately 7 milligrams of ammonia nitrogen are required for each gram of carbohydrates and related compounds decomposed.

N. M. Fuller (4) at Olean, N. Y., reported recently on the successful results of his efforts in controlling scum (''top sludge'') fermentation in digestion tanks by the addition of an ammonium salt, plus other changes in the digester design and operation. These included, (*a*) starting anew with clean tanks, (*b*) supernatant seeding, (*c*) control of the balance of digested sludge and raw solids added, and (*d*) insulation of the floating covers. The overall result of the above measures was freedom from the stiff, 6-foot scum layer which previously persisted, and the operation for a reported 18 months with only an average 2-foot layer of soft spongy material at the top of the digesters. Although he recognizes the fact that the improvement may not all be credited to the addition of the ammonia salt, he reports that:

(1) Following periodic additions of ammonia salt to the equivalent of 40 p.p.m. in the scum zone, there is a greater bacterial activity resulting in increased gas production.
(2) Supernatant recirculation pumps could be kept in operation following treatment with ammonium salts while previously it was impossible.
(3) The scum layer was reduced following application of the ammonium salt as indicated by monthly reports over a period of 13 months.

Fuller recently advised that continued use of the ammonia nitrogen control has resulted in a more uniform gas production rate. He also advises the use of caution in adding ammonium salts when tank conditions are bad, suggesting starting its use before critical conditions exist.

The possibilities of ammonia nitrogen control of digestion may be best indicated by briefly relating the successful results obtained in starting activity in a previously dormant digestion system and in controlling the formation of scum at a large Naval installation; and by a progress report of observations not yet completed on the control of an overloaded digestion system at the Buffalo Sewer Authority Treatment Plant at Buffalo, N. Y.

Large Naval Installation

The digesters at the activated sludge sewage treatment plant of this Naval installation were placed in operation during September 1942. They received the full sludge and grease load from the entire plant from October on. By November 1st the temperature in the primary digester had been raised to 88° using bottled gas. Figure 6 shows the various stages through which the primary digester passed in coming into full operation. It will be noted that during the initial period of operation of about nine months, attempts were made to bring this digester into operation by the addition of about nine tons of lime and the maintenance of optimum temperatures, which for 60 days were held at about 90° F. and then raised and held at about 100° F. for 45 days without any activity being evident.

After the digesters failed to respond to the usual practices of adjustment, engineers from the Pacific Flush-Tank Company were asked to aid in the problem. It was found that both digesters contained heavy layers of grease and scum, there being about 9 ft. of yellow sickly-looking material in the primary tank, so heavy that it was impossible to penetrate it with a 2 x 4. There was a small layer of dilute "sludge" in the bottom of the primary digester, the pH of which was about 7.0.

It was decided that an attempt be made to bring these tanks into operation by the addition of ammonium sulfate. The first addition was made on July 15th and within the next fifteen days, 500 lbs. of ammonium sulfate were added. This is equivalent to about 35 p.p.m. of available ammonia nitrogen on the basis of the total primary tank volume. There was no satisfactory means for mixing this material into the top scum. The only pump available was a 40 g.p.m. sludge pump which could only be used periodically when raw sludge was not being pumped. Provision was made to secure another pump, which was installed on top of the primary digester and put into service ten days later.

By recirculating at 250 g.p.m. rate from the zone below the scum at the gas dome of the cover, the ammonium sulfate which was previously added was intermixed with the top greasy scum. This new pump would only operate intermittently for three days because of difficulty with grease in the suction but a considerable turn-over was affected in the tank contents. Slight foaming was noted within 48 hours of the time of the first recirculation. On the fourth day after placing this pump in operation an extension was placed on the suction pipe and it was possible to operate the pump continuously. The foaming increased and within 48 hours of the time of continuous operation the foaming was so violent that it went over the tank walls into the surrounding territory. Because of mechanical difficulties with this pump and the increased activity, this pump was cut out of service after having been used for only about five days. Two weeks later a new recirculation pump with a capacity of about 300 g.p.m. was installed and this pump operated continuously. Within two weeks after the time this new recirculation pump was installed, the foaming had subsided completely. Raw solids were then added, building up to the full plant load of raw solids by October 15th. Since this time all raw solids have been added to this tank. Since December 2nd all grease solids have also been added to the tank. No foaming has resulted.

The recirculation pump operation was discontinued on November 2nd. By December 20th a stiff layer of grease over 3 ft. thick had reaccumulated at the top of the digester. The recirculation pump was started on December 20th and run for ten days without affecting the thickness of the scum layer. On December 30th and 31st, 50 lbs. of ammonium sulfate each day were added and on January 1st the digestion tank started to foam. The gas production increased from 0.75 cu. ft. per cu. ft. of tank capacity to 1.10 cu. ft. per cu. ft. of tank capacity. On January 5, 1944, samples from the tank indicated that the scum was completely dispersed throughout the tank.

Table IV shows the tabulation of analyses of grab samples taken at the start of activity of the digester and also after the digester had reached the stage of normal operation. It is interesting to note the change in volatile acids and ammonia nitrogen content, although more knowledge of relative values for volatile acids and ammonia nitrogen is needed to establish optimum values definitely.

TABLE IV.—*Tabulation of Digester Analyses*
(*Large Naval Installation*)

Tank	Date of Sample 1943	Condition of Tank	Sampling Point	Per Cent Solids	Per Cent Volatile	Volatile Acids (As Acetic) p.p.m.	Ammonia Nitrogen, p.p.m.	Approx. Gas Prod. Rate, Cu. Ft./Cu. Ft. Tank	Remarks
Primary	Aug. 21	Activity started following ammon. sulfate addition. Foaming and sensitive	Top	8.53	73.93	6,000	1,422	Very high (No means for measurement)	Tank started from dormant to reported condition in 10 days following ammon. sulfate addition and circulation
			Bottom	5.61	70.61	6,000	1,428		
			Supernatant	—	—	—	—		
	Dec. 18	Stabilized digestion. Full load	Top	5.63	82.58	1,688	663	0.75 cu. ft. per cu. ft. of tank vol.	Tank handling full load of solids and grease
			Bottom	1.39	74.88	527	583		
			Supernatant	2.10	72.35	538	623		
Secondary	Aug. 21	Dormant. No gassification	Top	9.06	71.25	8,750	1,148	0	Heated to 85° F.
			Bottom	3.96	72.04	5,000	1,149		
	Dec. 18	Transfer from primary starting Aug. 22	Top	2.08	70.96	600	703	Not measured	Tank pumped Nov. 7 except 4′ ± scum and grease. Filled with overflow from primary digester
			Bottom	1.60	66.30	500	677		

The high ammonia nitrogen content reported in the analyses may not mean that it is available to bacteria in proper composition or location, as indicated by the beneficial results shown when ammonium sulfate is added. The promotion of digestion at a higher than normal volatile acid range is also of interest.

The second digester, which was full of material similar to that found in the primary digester, had been heated to and maintained at an optimum temperature before and during the manipulations on the primary digester. Since the second tank was not dosed with ammonium sulfate it served as a control in that it remained dormant until the period when material was transferred to it from the active primary tank. It is true that liquor in this digester was not circulated, which procedure would have been desirable to provide a complete control, but it must be realized that the manipulations on the digester system at this location were not undertaken as an experiment as a demonstration of ammonia nitrogen control, but as a means of overcoming a serious condition which existed. However, the observations on the first digester as reported above and shown in Fig. 6, which was circulated from Dec. 20th to 30th

Period 1942-44		Nov. 1 To Dec. 31	Jan. 1 To Feb. 28	Mar. 1 To Mar. 31	Apr. 1 To May 31	June 1 To July 15	July 16 To Aug. 5	Aug. 6 To Aug. 15	Aug. 16 To Aug. 31	Sept. 1 To Sept. 20	Sept. 21 To Oct. 31	Nov. 1 To Dec. 20	Dec. 21 To Dec. 30	Dec. 31 To Jan. 5
Total Days		61	59	31	61	45	21	10	16	20	41	50	10	6
Temperature °F	Average	85°	75°	65°	90°	100°	95°	93°	97°			92	89	
	Range	80°-90°	70°-80°	61°-70	85°-95°	95°-105°	86°-102°	93°-97°	95°-99°	95°-100°	95°-100°	89°-99°	88°-90°	88°-89°
pH	Top	5.0	5.0	5.2-5.4	5.0			6.9	6.8	6.6	Up To 7.6 Then Back To 7.2	7.2	7.2	6.8
	Bottom				7.0									
Solids Added	Raw Sludge	All Sludge Solids Added				No Raw Solids Added					Full Load Reached Oct. 15 To Date			
	Grease	All Grease Added				None Added						All Grease Added Since Dec. 2		
Lime Added Lbs.	Per Period	5350	5400	None	7000	300	None							
	Total To Date		10,750	10,750	17,750	18,050								
Supernatant Circulation	Interval	None					Intermittent	Continuous 5 Days	None	Continuous		None	Continuous	
	Approx. Rate						40 G.P.M.	250 G.P.M.		300 G.P.M.			300 G.P.M.	
Ammonium Sulphate Added	Lbs. Per Period	None					500	150	25	25	None			100
	Lbs To Date							650	675	700				800
	Equiv. NH_4N P.P.M.						35	45.5	47.4	49.1				56.1
Scum	Nature	Building Up				Heavy Yellow	Slight Softening	Dispersed				Building Up	Stiff	Dispersed
	Depth					9 Ft. +	9 Ft.					3 Ft. ±	3 Ft. ±	
Digester Activity		Dormant					Slight	Violent With Foaming	Slight Foaming	Normal				Slight Foaming
Gas Production	Visual	None					Slight	High	Good			High		Very High
	Cu. Ft. Per Cu. Ft. of Tank						No Provision For Metering				0.50	0.75	Increased To 0.80	Increased To 1.10
Characteristics of Period		Control of Optimum Temperature and Reaction (pH.)--Dormant & Scum Building-Up					NH_4N Control & Supernation Circulation--Activity & Scum Dispersal				No Addition $(NH_4)_2SO_4$ -- Reduced Circulation -- Scum Reappearing			$(NH_4)_2SO_4$ Addition Liquor Circulation Activity Increased Scum Dispersed

FIG. 6.—Summary of digester operation—activated sludge solids—large naval installation.

without ammonium sulfate being added, indicated that circulation alone did not result in accelerating the digestion sufficiently to overcome the excessive lay-over scum. It is concluded that to achieve the full beneficial effect, it is necessary to provide both supernatant circulation and add ammonium sulfate.

The determination used for ammonia nitrogen, for purposes of the record, is as follows:

> Ammonia nitrogen is determined by adding 25 ml. of the sample to 225 ml. of ammonia free water containing 5 ml. of sodium carbonate solution (1 g./100 ml.) and distilling 200 ml. into N/20 H_2SO_4. Back titration done with N/20 NaOH using sodium alizarine sulfonate as the indicator. Ammonia nitrogen reported in parts per million. Another indicator used in the absence of the above is a mixture of 1 part methylene blue (0.4 g./100 ml.) plus 3 parts methyl red (2 gms./100 ml. 70 per cent alcohol) which has a color of lavender to green at a pH about 4.0 to 5.0.

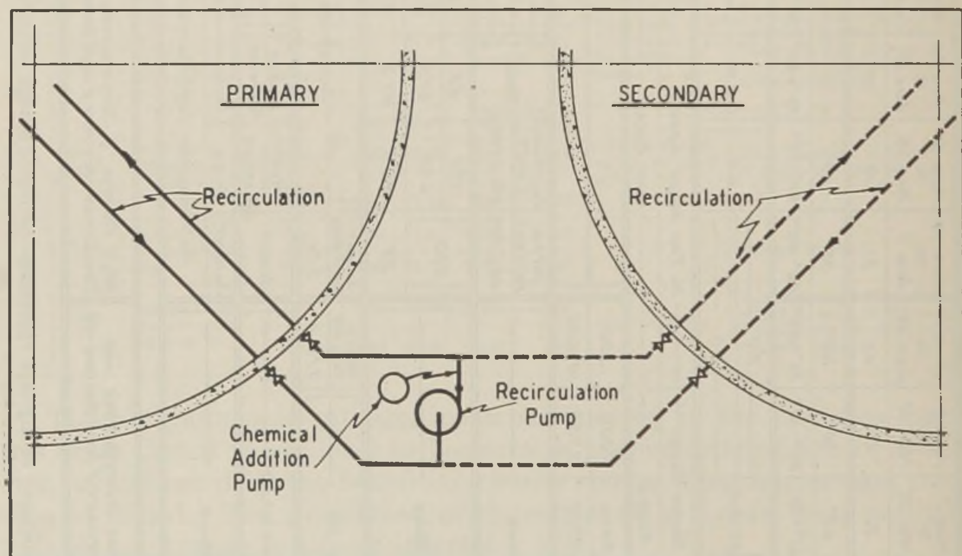

FIG. 7.—Diagram of piping used in supernatant circulation and ammonia nitrogen control.

Figure 7 shows diagrammatically the portion of the piping in the "Controlled Digestion" system shown in Fig. 1, which is employed for the addition of chemicals to the digester system along with supernatant circulation. Lime may also be added by this system.

Buffalo Sewer Authority Installation

At Buffalo, N. Y., four 90-foot diameter digestion tanks with a total maximum capacity of 758,000 cu. ft. were originally designed to operate as storage tanks prior to sludge filtration and incineration and hence must be operated as the "take-up" in the system. However, from the reduction of solids by digestion and based upon gas produced, which for the months of August and September 1943 averaged 0.78 cu. ft. per cu. ft. of tank capacity per day, they are truly digesters operating at a high solids loading.

Loadings of raw solids on a dry weight basis for an entire year averaged 0.156 lbs. per cu. ft. per day with a maximum month of 0.321 lbs. per cu. ft. per day and maximum successive months of 0.23 lbs. per cu. ft. per day.

Since the digesters are operated on a schedule mainly to satisfy the demands of the incinerators it is difficult to maintain balanced digestion conditions, with the result that heavy layers of thick scum have always been present and but little suitable supernatant is available for withdrawal.

In July of 1943, recommendations made by the writer resulted in putting into effect certain features of "Controlled Digestion."

Tanks No. 3 and No. 4 were set to operate on a schedule of more or less continuous supernatant liquor circulation and ammonium sulfate was added only to tank No. 4. Since tank No. 1 had just been cleaned out and changes made in gas, sludge and supernatant piping, tank No. 2 was relied upon as the control. Sludge solids were to be added to each tank as equally as possible.

At about the time the first dose of ammonium sulfate was to be added, the violent reaction experienced following the addition of ammonium sulfate at the Naval installation previously discussed caused the writer to advise going slow on the amount added at Buffalo, since the landscaping and elaborate installation there might not be as well accepted when covered with froth and sludge. For the period of the data as reported herein ammonium sulfate doses to tank No. 4, and later to tank No. 1 have been made in amounts as reported in Fig. 8*A*. The amount of ammonium sulfate and equivalent in ammonia nitrogen is rather small as compared with the amounts added at the Naval installation so it was not expected that any startling results would be obtained.

It must be realized that at Buffalo we are not dealing with an experimental installation, since the solids from a population of approximately 640,000 must still be handled and the incinerators must be supplied with sludge at a rate dependent upon the number of units maintained in operation. Therefore we were limited in the amount of control which could be instituted. For instance, sludge and scum must be withdrawn from the tanks as it is available and in amounts which may be most easily removed without as close a balancing of raw solids additions with sludge withdrawals as would be desired. For the above reasons, the data which will be presented and the trends indicated by this data must be viewed in the light of conducting an experiment on a large scale which must take second place to the more important problem of operating an existing plant.

Figures 8*A* and 8*B* show in graphic form and by recorded determinations, the results of monthly inventories of the contents of each of the four digesters. An attempt will be made to point out trends shown

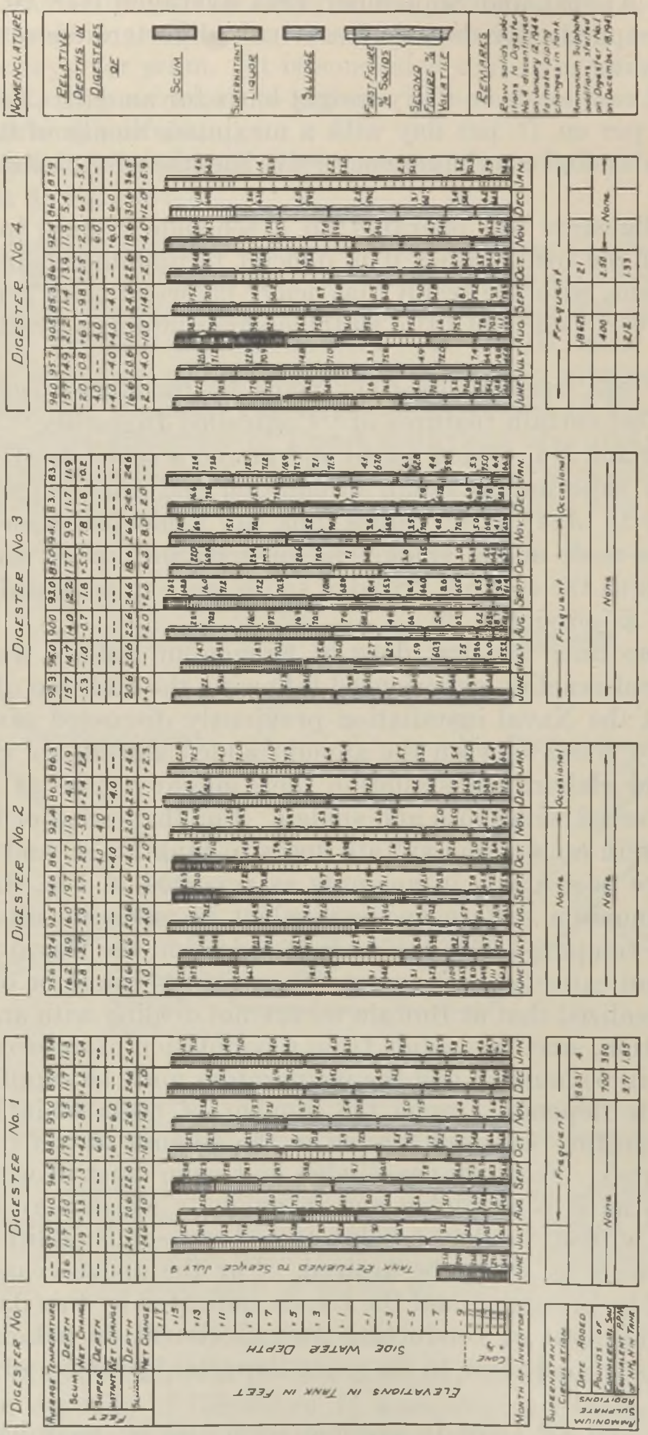

FIG. 8.—Charts of monthly inventories of digesters at Buffalo, New York, 1943 and 1944.

FIG. 8A.—Relative depth of scum, supernatant and sludge with analyses of samples from increments of depth.

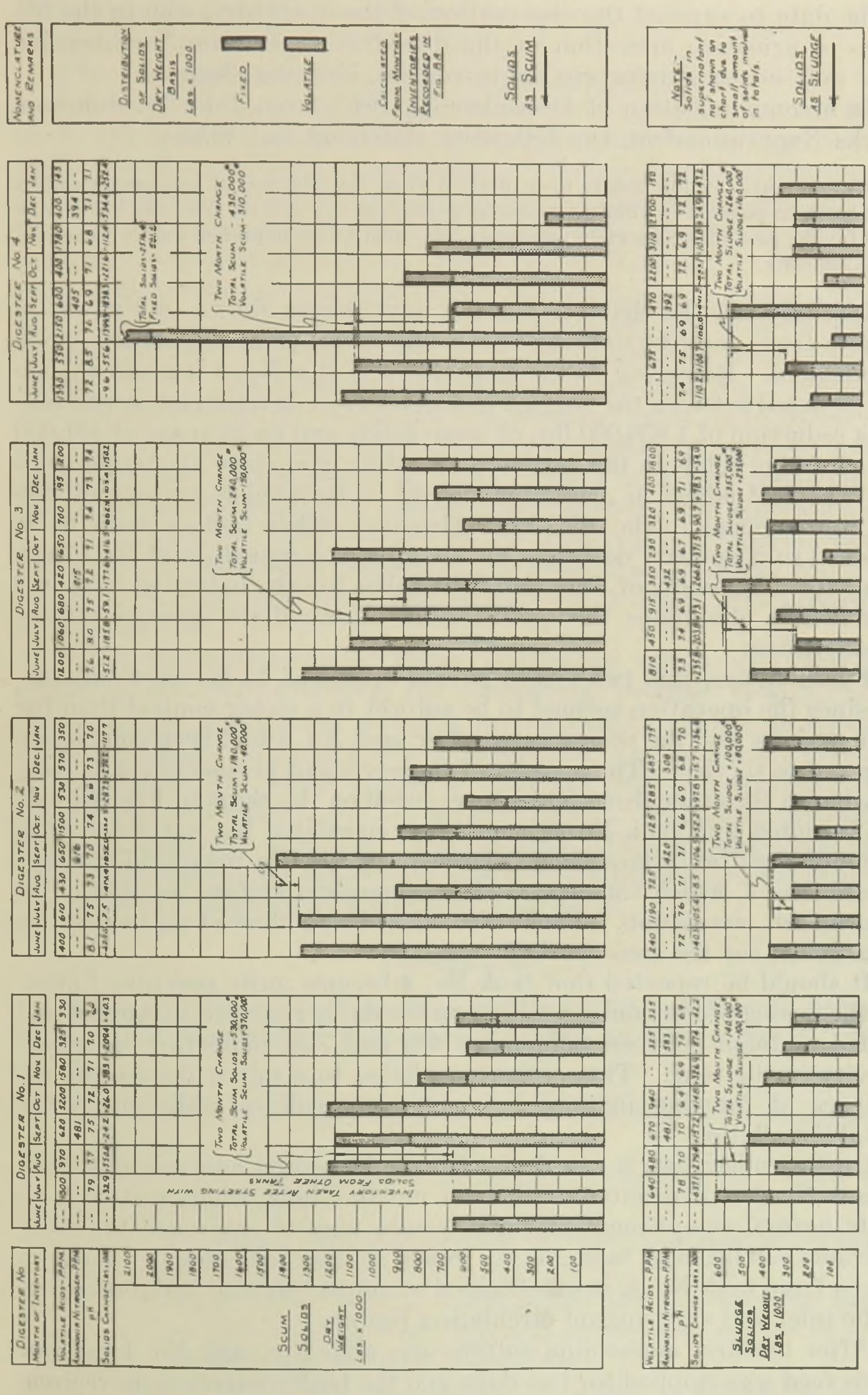

FIG. 8B.—Distribution of solids in digesters on dry weight basis and tabulation of analytical data Buffalo, N. Y., 1943 and 1944.

by the data to support the observation of the operators, who in the 5½ years of sensitive operation of the digesters at Buffalo have become quite deft in recognizing any improvement, however slight.

In a communication of December 30, 1943, from John W. Johnson, Works Superintendent, the following statement was made,

> We are optimistic on the results to be derived from the addition of ammonium sulfate for it has been possible to withdraw scum, by gravity, in any amount from the top of tank No. 4 for the past six weeks while previously this could be accomplished only with considerable difficulty.

In analyzing the chart of monthly inventories shown in Fig. 8*B*, a definite trend in reduction in scum solids and increase in sludge solids is indicated. Referring to the chart for digester No. 4 a great change will be noted between the August and September inventories, representing a reduction of 1,838,000 lbs. of scum solids and an increase of 491,000 lbs. of sludge solids in the bottom of the tank, and since ammonium sulfate was first added in August we might be tempted to give credit for the improvement to the addition. However, other factors seem to be involved so it appears desirable to rely upon a comparison of the inventories for the months of July and September for the indicated improvement which eliminates the questionable intermediate inventory from consideration.

Furthermore, this two-month period appeared to be most satisfactry since the operation seemed to be subject to a closer control than for later periods, and the period came after tank No. 1 had been completely returned to service. The amount of improvement in tank No. 4 as compared with the other three tanks is recorded on the chart in Fig. 8*B*. It will be noted that tank No. 3, which was circulated but not dosed with ammonium sulfate, showed an improvement next in magnitude to that of tank No. 4, which was dosed with ammonium sulfate in addition to supernatant circulation. Tanks No. 1 and No. 2 showed an increase in scum solids for the same period.

It should be reported that tank No. 4 became quite sensitive following the dosing of ammonium sulfate on the dates reported in August and tended to foam between September 4th and 7th, indicating increased activity in the tank. This action paralleled to a minor degree the experience of foaming induced by ammonium sulfate additions at the Naval installation.

On December 18th it was decided to begin adding ammonium sulfate to tank No. 1 to determine whether or not this tank, which had built up to its normal complement of scum, would tend to approach the more desirable condition of tank No. 4. Since solids could now be easily removed from tank No. 4, it was decided to empty same to make revisions in the inlet and supernatant circulation piping.

After the first ammonium sulfate was added to tank No. 1 the raw solids feed was stopped for two days and the tank contents were recirculated. The gas production dropped from about 4,500 cubic feet per hour to 1,900 cubic feet, but upon the resumption of raw solids feeding in the regular cycle the gas production increased to a range of 4,500 to 7,000 cubic feet per hour.

After the addition of the 350 lbs. of ammonium sulfate to tank No. 1 on January 4th, the gas production in that tank reached a rate of 10,000 cu. ft. per hour for about 5 days as compared with the average for December of about 6,000 cu. ft. per hour. It then dropped but the average for the month of January was approximately 7,600 cubic feet per hour for tank No. 1 as compared with an average of 6,540 cubic feet per hour for tank No. 2 and 6,310 cubic feet per hour for tank No. 3. Tank No. 4 was not receiving any raw solids so its gas production was consequently low. For the month of February the gas production of tank No. 1 averaged 21 per cent more than tank No. 2 and 10 per cent more than that of tank No. 3. Daily gas production figures for tank No. 1 seemed to indicate a maximum period of gas production at rates up to 20 per cent over the monthly average continuing for a number of successive days. This maximum period seems to occur about 6 to 9 days following the addition of ammonium sulfate as observed following five separate doses.

G. F. Fynn, the Chief Chemist at the Buffalo plant, reported that in February the uppermost portion of the scum mass in tanks No. 2 and No. 3 was slightly stiff while that in tank No. 1 dosed with ammonium sulfate was soft.

In the operations related above, ammonium sulfate was used as a source of ammonia nitrogen, the commercial product yielding about 25.6 per cent of ammonia nitrogen and is readily soluble in an equal weight of water. Although this ammonia salt is more readily available at the present time, other sources of ammonia such as ammonium chloride, ammonium nitrate, ammonium hydroxide or ammonium phosphate might be even more desirable. For instance, although ammonium phosphate is expensive, the phosphate would be completely recovered in the sludge and be valuable as a fertilizer component.

Conclusions

By the provision of means for practicing the various features of "Controlled Digestion" it appears possible to obtain the following advantages:

I. *Reduce digester capacity allowances materially in the original design by:*
   (*a*) Successful handling of greater solids loadings per cubic foot of capacity by:
      1. Increased rate of digestion of solids through supernatant recirculation.
      2. Bringing of layover scum solids into digestion by use of ammonia nitrogen control and consequent release of additional space for active digestion.
      3. Use of volatile acids control to be able to handle the higher loadings by anticipating any retarding conditions and providing a means for rapidly overcoming same.

(*b*) Elimination of capacity allowances for effecting a separation of supernatant liquor by:
1. Providing selector means to make it unnecessary to depend upon a separation layer.
2. Treatment of liquor before returning to treatment process, which reduces need for quiescent second stage tank, and reduces recycling of supernatant solids through treatment plant and back to digester.

II. *Increase the effectiveness of existing digester capacity for digestion by greater reductions of solids and more uniform rate of gas production for reasons outlined in I above.*

III. *Allows greater use of all tanks of a stage digestion system by:*
(*a*) Using second stage for volatile acids control.
(*b*) By handling of supernatant liquor by selector and treater, does not require retarding of activity in secondary tanks as now practised to obtain supernatant liquor separation.
(*c*) By provision of a system of piping to allow flexible control of the digestion process. Takes digestion out of the "Capacity displacement holding tank" design.

IV. *Provides means of overcoming difficulties normally encountered in starting digestion action in a newly installed digestion system.*

Acknowledgments

The writer wishes to express appreciation to the Assistant to Public Works Officer at the Naval installation, name and location not given for obvious reasons, and to J. W. Johnson, Works Superintendent, and G. F. Fynn, Chief Chemist, at Buffalo, N. Y., for their interest in trying features of "Controlled Digestion" and collecting data on same; and to J. R. Longley, Superintendent, and L. S. Kraus, Chemist of the Greater Peoria Sanitary and Sewage Disposal District, in making available some of the data used in this discussion.

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A WATER SUPERINTENDENT'S INTEREST IN SEWAGE TREATMENT*

By Richard E. Bonyun

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The strength of a nation depends primarily upon the health of its people, and in this respect the preservation of the purity of water for domestic use is of great importance. Progressive development in the fields of sanitation and water supply has played a large part in attaining the excellent health record which our nation enjoys today. These two fields of endeavor are closely related, since the one has a direct bearing upon the other.

We have come a long way since the days of serious epidemics of typhoid, cholera, dysentery and all water borne diseases attributable to improper methods of sewage disposal, and consequent contamination of the water supply. History records, for example, the typhoid epidemic which occurred in Plymouth, Pa. in 1885, when one-fifth of the total population of the town was afflicted. The water supply had become polluted, due to the improper waste disposal of one typhoid patient on the stream from which the supply was taken. That was in the days before water supplies were chlorinated or filtered, and before the general public had come to realize the importance of proper sewage disposal methods, in relation to safe water supplies.

In spite of the very great improvement in water supplied to our towns and cities, with consequent reductions in typhoid death rates, water supply problems are increasing in the country as a whole. Increase in population and the ever increasing migration from rural to urban areas complicate and intensify the problem of water supply and sewage disposal. Prevention, restriction and reduction of pollution of inland waters, from which our municipal supplies must be obtained, are the constant concern of sanitary and water supply engineers.

Many public potable water supplies are taken from rivers and streams with hundreds of square miles of drainage area. Most of the drainage area is usually not the property of the owner of the water supply. The control of pollution on such large watersheds is a problem requiring the permanent employment of experienced watershed personnel.

Since these problems are seldom, if ever, in one municipal jurisdiction, the comprehensive treatment of such problems to protect the public welfare, imposes a responsibility upon the State Department of Health. In New Jersey the necessary protection was provided by laws enacted in 1899.

The statute referred to is Title 58, Chapter 10, which reads in part as follows: "Pollution of potable waters prohibited. . . . No excre-

* Presented at the 29th Annual Meeting of the New Jersey Sewage Works Association, Trenton, March 23–24, 1944.

mental matter, domestic, factory, workshop waste or other polluting matter shall be placed on or discharged into the waters of . . . any river, brook, stream or tributary thereof . . . above the point from which any municipality shall or may obtain its supply of water for domestic use.'' The law provides for Department of Health general supervision, penalties for violations and Chancery Court injunction to prohibit further violations. Authority to move in court for the assessment of penalties and to secure injunctions is lodged in the State Department of Health, the local health authority and the owner of the public water supply which may be affected.

Thus it is clear that a heavy responsibility is placed on the water superintendent and on the sewage plant operator. As the Superintendent of the Passaic Valley Water Commission, it will be better for me to describe our water supply system and operations as they pertain to this subject, with the hope that it may be of interest to you and may indicate how any superintendent of a similar supply is interested in the subject of sewage treatment and waste disposal on his watershed.

The Passaic Valley Water Commission owns and operates the water supply and distribution system for the Cities of Paterson, Passaic and Clifton. It also sells water at wholesale to many other municipalities and water companies adjacent to its system, which is extensive. The total population served is approximately 350,000 people. The water works system was previously owned and operated by the Passaic Consolidated Water Company, whose holdings were purchased outright by the three cities through the Commission in 1930.

Two sources of water supply are owned, namely 37.75 million gallons per day in the Wanaque Project and water rights in the Passaic River up to 75 million gallons per day. The Wanaque Reservoir headworks and aqueduct are operated by the North Jersey District Water Supply Commission acting as agent for the eight municipalities who own the project. The Passaic River source of water supply is owned outright by the Cities of Paterson, Passaic and Clifton and is operated by the Passaic Valley Water Commission with intake, purification plant, and pumping station located in Totowa Borough and known as the Little Falls Plant. Water is drawn from both sources, depending upon the demand, which is at present averaging approximately 56 million gallons per day, of which twenty-nine are being taken from Wanaque and twenty-seven from the Passaic.

The Passaic River has been used as a source of public potable water supply for Paterson and vicinity since 1857, the original intake of the Passaic Water Company, at that time, being at the Great Falls in Paterson. In 1899 headworks were constructed and intake transferred upstream to Little Falls, about five miles above Paterson. In 1902 the filtration plant was constructed and at that time it constituted the largest and most modern rapid sand filter installation in the country, and it is the same plant which is now operated by the Commission in the purification of its Passaic Supply.

The watershed of the Passaic River above our intake at Little Falls is approximately 770 square miles in area, of which approximately 275 square miles have been appropriated on tributaries for other water supply developments, namely the Pequannoc, Rockaway and Wanaque. Thus the Commission is interested in approximately 500 square miles of drainage area tributary to the Passaic River above its water supply intake. This is a large area, fairly heavily populated and located thereon are such towns as Butler, Essex Falls, Caldwell, Morristown, Chatham, Madison and others.

In order to protect its water supply and control pollution, the Commission maintains a Watershed Patrol consisting of two inspectors deputized by the State Department of Health, who work under the direction of our Chemist and Superintendent of Filtration. The work done includes inspections, into which enter the collection and analyzing of effluent samples of all sewage disposal plants and industrial waste treatment plants. Careful watch is also maintained on the establishment of new factories, garbage dumps, cesspools and other operations, wherever they may be, which might have an effect upon the quality of the water in the river.

Stream samples are taken and analyzed periodically from points along the tributaries of the river, and, of course, raw water samples are taken three times daily at the plant intake. In this manner a close check is maintained on the water in the streams, and when changes in analysis warrant it, investigations as to cause are conducted.

We have encountered problems in regard to industrial waste disposal, such as the effluents from paper mills, dairies, rubber reclamation plants, etc. The improper or ineffective treatment of such wastes create water supply problems in respect to taste and odor, suspended solids, bacteria and changes in pH value and chemical character of the raw water.

As a practical measure to facilitate this work, and to provide a "yard stick," the Passaic Valley Water Commission adopted certain minimum standards for waste effluents discharged into the streams of the watershed above its potable water supply intake at Little Falls, New Jersey. These minimum standards were set up after careful thought and upon the recommendation of consulting engineers, and are intended to apply to all types of effluents including industrial waste disposal, and are as follows:

1. The effluent shall contain no free titratable acidity or free caustic alkalinity. The pH of the effluent shall be between 4.0 and 8.3.

2. The effluent shall be free of toxic substances.

3. The effluent shall be free of noticeable floating solids, scum, oil, grease, or sleek.

4. The effluent shall be sufficiently free of color or turbidity, or both, so that after dispersion in the receiving waters, or not more than 1,000 feet below the point of effluent discharge, it will not noticeably discolor or add to the turbidity of the receiving waters.

5. The effluent shall be free of offensive odors.

6. The effluent shall be of such quality that organisms of the Coli-aerogenes group shall be present in not more than 20 per cent of the 1 cubic centimeter portions examined from any 1 sample or any series of samples of effluent tested. For the purpose of the test for organisms of the Coli-aerogenes group a sample shall consist of 5 one cubic centimeter portions.

7. The effluent shall have a biochemical oxygen demand not exceeding in the average over any 4-hour period of a day 60 parts per million, and not exceeding at any time 80 parts per million.

I hope that these standards may evoke some discussion at the termination of this paper.

As regards sewage disposal plants, it can be said that we have experienced very little difficulty on account of their operations and existence on the watershed. As you know, such plants are supervised by operators licensed by the State Department of Health under the provisions of Article 5, R. S. 58:11. All the municipal sewage treatment plants on our watershed conform to the policy of the State Department of Health requiring sedimentation, oxidation, and chlorination as the minimum degree of treatment. We have frequently found some effluents so good as to comply with bacterial drinking water standards. From a water supply standpoint, we are particularly interested in the chlorination of the effluent. There have been occasions when an increase in the bacteria count on river water samples, taken at the intake, has been attributable to the failure of the chlorinating equipment on a sewage disposal plant effluent. This results in the "seeding" of the river, and endangers the water supply. Thus it is important to us that the sewage disposal plants on the watersheds be maintained and operated efficiently at all times.

In closing I would like to emphasize the importance of our responsibility—the responsibility of water superintendents and sewage plant operators—and the necessity of working together. Millions of dollars have been spent in New Jersey to construct our plants to protect potable water supplies, and we have been entrusted with the operation of the plants. It is our duty and obligation—legally and morally—to maintain effective operation. We must protect our potable water streams from all encroachments within our power, and our continued co-operation will go far toward the preservation of invaluable assets to public health, and to a better State.

Discussion

W. C. Mallalieu

Sanitary Engineer, Bureau of Water, Jersey City, N. J.

The excellent paper which Mr. Bonyun has presented is especially pertinent today as it covers in a general way the subject of water supply sanitation, never more important than now because of the role a safe water supply plays in national defense, and never more difficult to achieve to a proper degree because of the increased demand due to population concentration in the cities, the increase in volume and types of trade wastes in the catchment areas, scarcity of chemicals and other material, and all of these often combatted with an inadequate or reduced personnel.

As the author of the paper has stated, "We have come a long way," since the days of that historic typhoid epidemic in Plymouth, Pa.; but it cannot be too strongly emphasized that the present relative freedom from water borne epidemics is an armistice rather than a victory, and that we still have a long way to go, because increasing knowledge brings an ever mounting number of problems, equal to, or slightly ahead, of those under control. It is my opinion that more public health problems will confront this country after the close of the present war, than ever before in its history, and a fairly large proportion of these will either directly or indirectly, affect water supply sanitation. Constant vigilance is still the price of safety in a water supply.

The paper we are discussing states that the author has experienced little difficulty on account of the existence and operation of sewage disposal plants in the watershed; I believe that the constantly increasing number of such plants has played no small part in the improvement noted in water supply quality, but I believe wherever possible small plants should be combined to assure better supervision.

A responsibility above and beyond the solution of a waste disposal problem rests on the designers and operators of all treatment plants, when the effluent from the same reaches a potable water supply. A water man must strive to secure an adequate plant for all polluting material, yet no detrimental trade waste should be discharged into the sewerage system serving an existing plant not designed to receive the same.

In the Rockaway Valley plant for which I am responsible, the effluent actually improves the lower Rockaway River, into which it discharges; it is clear with no measurable amount of suspended matter, and has had coliform bacteria in 50 ml. of effluent only once in approximately sixteen years of operation. The annual average agar count and pollution index of the lower river, above and below the outfall, were as follows for 1943:

	Agar Count	Index Per 100 Ml.
Above	1,702	4,225
Below	635	520

This sewage treatment plant is wholly a function of water supply being designed to remove domestic polluting material from the towns in the Jersey City watershed, and to so treat the same that it will not cause any increase in the pollution of the lower river. It is mentioned here, as an example of what can be accomplished by a sewage plant in the line of water protection.

I believe it also brings out the relation between water plant operators and sewage plant operators. I think that we all agree that the use of water for potable purposes is paramount to any other recreational or commercial use.

As to the matter of standards I am entirely in accord with these in principle, providing the same are sufficiently flexible to apply to the varying conditions met with in watershed sanitation, in fact, about seven years ago we were able, at a hearing before the State Department of Health to establish a set for the correction of a particular case of pollution, and these might well have some value as a base for those with larger application, they were as follows:

1. That there will be no increase in the B. Coli content of the river below the plant over that above.
2. That the D.O. of the river below the plant shall not drop below 5.5 p.p.m. or 60 per cent saturation.
3. That the increase in the B.O.D. of the river due to the wastes shall not cause a reduction in the D.O. content of the river below 5.5 p.p.m. at any point downstream.
4. That the hydrogen-ion concentration of the waters of the river shall remain in the brom thymol blue range (pH 6.0–7.6) in passing the plant.
5. That the discharge of the wastes shall not discolor or add to the turbidity of the waters of the Rockaway River, result in the production of oil or grease on the surface of the said river, render the river objectionable to the sight, or produce sludge banks of a putrescible nature in the bed of the river.
6. That the point of application of chlorine shall be such that one half hour detention period shall be provided after the introduction of chlorine before discharge of wastes to the river, even under maximum flow conditions; that a residual of 1 p.p.m. shall be maintained in the effluent when discharged to the river, and that the chlorinator be properly housed.
7. That the disposal and/or treatment of the wastes shall be under satisfactory laboratory control, including the daily performance of the necessary tests to furnish information on conditions established under 1–6 inclusive, and that a monthly report of such tests shall be submitted to the State Department of Health.
8. That the downstream sampling station be 500 feet downstream.
9. That the necessary tests shall be performed in conformity with Standard Methods for the Examination of Water and Sewage.

In comparing these standards with those of Mr. Bonyun you will note that his are directed at the character of the effluents discharged into the potable supply, while those which we built up were worked out on the existing character of the river water, and the standards were intended to prevent any lowering of its quality as a result of trade waste discharged therein; these in both cases I believe, were to govern existing established plants, the general prohibition in Title 58, Chap. 10, as quoted in the paper under discussion should, in my opinion, apply to all new industries.

In my opinion, a combination of watershed zoning with standards, will achieve considerable improvement in the quality of the yield from any catchment area; in my own experience it has produced a reduction in an annual average pollution index from around 3,000 to between 600 and 700, then the sewage treatment plant was placed in operation and the combination brought a further reduction to a figure generally below 200 per yearly average, with, in some instances, a figure below 100. Nothing that we have here discussed, however, will control recreational pollution, which in my opinion, is rapidly assuming an important role as a major source of water supply pollution.

In conclusion, it would seem that we might with profit, combine stream and effluent standards, and I also join in hoping that we may have some discussion on this general question.

DIGESTER HEATING AND MIXING EQUIPMENT *

By Vinton W. Bacon

Assistant Engineer, Los Angeles County Sanitation Districts

Effective digester heating yields a greater total quantity of gas which is produced at higher rates, places the digestion process under uniform control, and decreases the required detention time, thus increasing digestion tank capacity. These advantages have become so well established that even the very small plants are designed to include heating equipment.

Hot Water Coils in Digester

In the United States, practically all plants utilize hot water coils placed in the digester, the water being supplied from hot water plants, or where the coils are known to be clean, trouble is nearly always the result of insufficient heating unit or circulating pump capacity, or from

Table I.—*Heating Trouble Table for Coil System*

Case	Heating Water Temperatures, °F.		Average Digester Sludge Temp., °F.	Condition of Operating and Corrective Possibilities
	Inlet to Coils	Return from Coils		
1	130	110	85	*Assumed optimum* operating temperatures. They are representative of an average plant.
2	120	100	75	Increase coil temperatures. If possible, more heating unit capacity should be installed.
3	130	90	75	Temperature drop indicates sufficient coil area Utilizing larger capacity circulating pump will maintain higher average coil temperatures with resulting greater heat transmission to sludge.
4	130	125	75	High temperatures indicate that heat is available, but it is not being transmitted to sludge. Increase coil area. Little gained by increasing rate of circulation.

inadequate coil area. The accompanying table is intended to assist you in locating and correcting these difficulties. The optimum temperatures assumed may not represent those for all plants, but the method of trouble location may be found useful.

In older plants, exterior pipe incrustation will be a source of trouble (Table I) where too high coil temperatures have been maintained. The

* Paper presented at Sixteenth Annual Meeting, California Sewage Works Associations, Fresno, June 10–13, 1943. Reprinted from *California Sewage Works Journal*, Vol. 15, No. 2 (1943).

building up of this insulating cover on the coils manifests itself by the need for maintaining higher and higher water temperatures to transfer the heat to the sludge. Most plant operators report incrustation if the water exceeds 130° F., although Walraven (1) reports that 150° F. was used two years at Springfield, Illinois, without serious incrustation. If rapid coil caking occurs at your plant, it may be necessary to operate the system at lower temperatures. This will require the installation of more coils to compensate for the reduced temperatures.

Interior pipe scaling in closed systems is rarely of consequence. Walraven reports that a hard scale may form if a considerable amount of hard water make-up is necessary and if temperatures exceed 150° F.

The coil cleaning methods to be used will be determined largely by local conditions. To expedite this operation for vertical coils, the design should permit removal from the digester of individual sections of the pipe. Thus those near the inlet end, where greatest incrustation occurs, could be more easily and frequently removed without involving a major construction job or digester shutdown. A spare section of coil can be provided to replace that being cleaned.

Poor heating, and also some exterior incrustation, will also result from improper coil location. The coils should be placed in the actively digesting sludge, and, to promote establishment of convection currents, at least 3 feet from the tank walls. In most digesters the region of active digestion will extend from 3 or 4 feet above bottom to slightly over mid-depth, and good heat distribution should result if the coils are located between these levels. Scum is an excellent insulator. If it is assumed that it must be heated to reduce its formation, then this can probably be accomplished by mixing heated sludge from below rather than by coils. The convection currents which will exist in a well heated tank provide a sweeping action around the pipes, which reduces incrustation.

Due to the low temperatures used in hot water heaters or boilers, considerable condensate often forms in the tubes and burners, which causes corrosion. To prevent this, Brown and Preston (2) recommend minimum water temperatures of 180° F. in the heater and 130° F. for the return, or make-up. Very few plants can maintain a return water temperature as high as 130° F. and still avoid coil incrustation; but the boiler can be maintained at 180° F., and still deliver water to the coils at about 130° F., by means of a thermostatically controlled by-pass around the heater. Most heating systems have this by-pass arrangement, but if it has not been furnished, either corrosion of the heater or coil incrustation may be expected.

Some operators have reported coil breakage either from scum loads or vibration set up by gas ebullition. In either case, better support and use of extra heavy pipe is indicated. Vertical coils have the least tendency to break under scum loads.

Steam Injection into Sludge

I have enumerated some of the difficulties experienced and corrective measures to be used in the operation of a hot water coil heating system. At the Los Angeles County Sanitation Districts' Joint Disposal Plant, we believe that by heating with steam we have eliminated some of these difficulties, achieved greater operating flexibility, saved much critical material, and decreased costs.

Figure 1 is a diagrammatic drawing of our system. The sludge is merely preheated by steam injection as it is being pumped from open concentration tanks to the digesters. Piping arrangement is such that preheating and recirculation to the concentration tanks is possible. As the digesters show a temperature drop of only 2 or 3° F., no further heating of the sludge is necessary. The make-up water conditioning system and the controls are also shown.

Preheating was more adaptable to our existing conditions than direct steam injection into the digesters, but it is probable that the latter method could be used at other plants with equally satisfactory results and with the following advantages: First, it would be easier to compensate for tank heat losses, as no sludge would have to be recirculated to the heating point. Second, smaller capacity heating units could be used, as the heating could be made more continuous; whereas, large intermittent loads placed on preheat systems demand larger units. Third, convection current mixing can be established by steam injection at low levels.

Steam injection into sludge transfer pipes feeding the digester is another possible heating variation.

Some question has arisen as to the quantity of steam condensate which will be added to the sludge. Neglecting losses, this amounts to slightly less than 1 per cent for every 10° F. temperature rise given the sludge, or 1 gallon per 10° F. temperature rise for every 110 gallons of sludge heated. Thus, for all practical purposes, the amount of condensate added is negligible.

The steam pressures required are usually very low. For injection into open preheat tanks or digesters, a pressure equal to the friction loss in the transmission line plus 1 pound per square inch for every 2.3 feet of depth into which the steam injects is all that is required. This sum should rarely exceed 15 pounds. A higher pressure might be required for injection into a transfer pipe, as here the head can be considerable. In any event, it is desirable to keep the boiler in the heating class, 15 pounds or lower, as controls and accessories will be less costly. Also, as I (3) mentioned at the Bakersfield meeting, there is only 4 per cent more heat in saturated steam at 125 pounds than at 0 pounds.

Most operators ask how much of their hot water heating equipment could be used in the steam system. Many of the existing hot water boilers are of such design that they can be used as steam generators, but the controls should be revised to include water level regulation with high-low protection, pressure regulators, and automatic firing control.

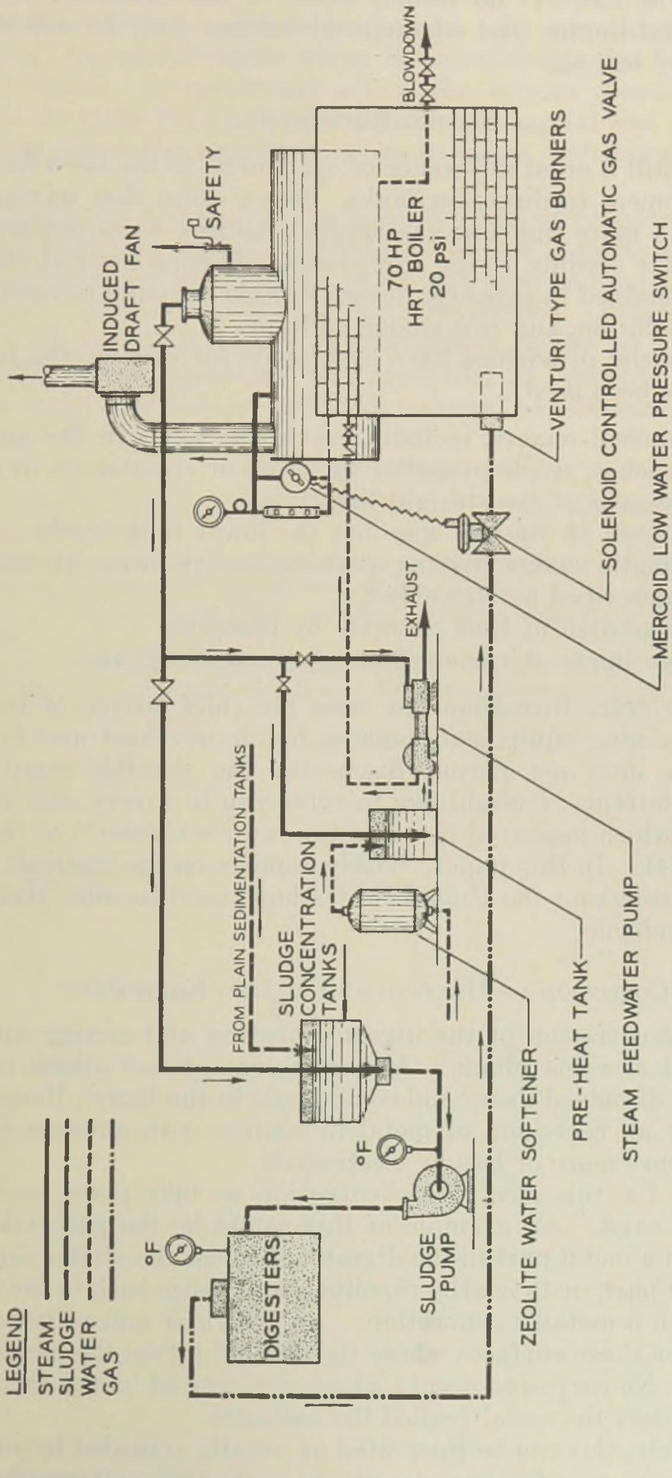

FIG. 1.—Diagrammatic drawing of sludge steam heating system and controls, Los Angeles County Sanitation Districts' Joint Disposal Plant.

Note.—by-passes, incidental valves, fittings, etc., are not shown.

In addition, as there is no return water in the steam system, boiler feedwater conditioning and adequate blowdown must be considered to prevent boiler scaling.

Mixing Equipment

There is still a great difference of opinion as to the need for special mixing equipment in digestion tanks. Some claim that mixing yields a greater and more uniform gas supply, reduces scum problems, and provides better seeding of the raw sludge. Others contend that these results are obtained in properly designed tanks through convection currents, gas ebullition, and raw sludge addition.

Where special provisions have been made for mixing, the following methods have been used:

(1) Mechanical mixers, including revolving arms in the upper and lower tank reaches, single propeller agitators or circulators, or continuous moving sweeps of the straight line type.

(2) Discharge of digester gas into the lower tank levels.

(3) Automatic sludge stirring mechanisms operating on the air lift principle as described by Rawn (4).

(4) Recirculation of tank contents by pumping.

(5) Sludge inlets at various locations and elevations.

Excessive scum formation has been the chief source of trouble to mechanical mixing equipment, causing motor overload and failure of parts. Time does not permit discussing the possible scum control measures; therefore, I would like to refer you to a very able paper on this subject which appeared in "The Operator's Corner" of *this Journal,* July, 1941. In this paper, Wisely reports on the methods various operators throughout the United States have used to solve their excessive scum problems.

Corrosion of Heating and Mixing Equipment

Extensive corrosion of the digester heating and mixing equipment has occurred at some plants. Although some direct attack might be the result of dissolved gases and compounds in the liquid, Pomeroy (5) believes that all corrosion of metal in contact with aqueous solutions probably occurs more or less by electrolysis.

In order for this electrolytic corrosion to take place, a complete circuit must exist. An example of this would be the path taken by a current from a metal part in the digester through the sludge liquor to a second metal part, or to nearby pipelines, and hence back to the starting point through a metallic connection. An irregular and pitty corrosion takes place on those surfaces where the current leaves the metal (called the anode). No corrosion occurs where the current leaves the solution and again enters the metal (called the cathode).

Fortunately, this can be prevented or greatly retarded by supplying direct current to sacrificial anodes placed in the tank and completing the external metallic circuits so that all digester parts act as cathodes. The method is called cathodic protection. Its recent successful use recommends its consideration where the corrosion is due to electrolysis or direct attack. It apparently solved the serious corrosion problem at the Los Angeles Terminal Island plant at a capital cost of only $200. The anodes, which are usually of scrap iron, are replaced as they waste away.

Other methods which might be considered in solving the problem include the use of less corrodible metals or the use of parts heavy enough to withstand considerable attack. Cast iron coils and parts in digesters have shown considerable resistance to attack, but probably their use increases the corrosion of the steel members in the tank. Protective coatings have been suggested, but, according to Pomeroy, metal parts placed in unaerated sewage and sludge should be left bare.

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Sewage Research

OXIDATION-REDUCTION POTENTIAL MEASUREMENTS IN ACTIVATED SLUDGE AND ACTIVATED SLUDGE-SEWAGE MIXTURES *

By Gerard A. Rohlich

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This paper reports a study of the oxidation-reduction potentials of sewage, activated sludges, and activated sludge-sewage mixtures. It includes comparative studies of changes in oxidation-reduction potentials and the rate of oxygen utilization of activated sludge-sewage mixtures. It also presents the results of a study of the redox potentials of sewage-sludge mixtures in the activated sludge sewage treatment plant at Madison, Wisconsin, under ordinary operating conditions. A portion of the data presented in this paper appeared in "A Symposium on Hydrobiology," University of Wisconsin Press, 1941.

The fundamental theoretical considerations involved in the measurement of oxidation-reduction potentials, and their application to biological problems, have been presented in monograph form by Michaelis (1) and Hewitt (2), and in the well known works of W. Mansfield Clark (3). The important findings in bacteriology and biochemistry made possible by redox potential measurements have made it desirable to use this means in an attempt to discover the more exact nature of the oxidation of sewage by activated sludges, and if possible to make practical application of these measurements in the control of the process.

The use of dyes as indicators of changes in oxidation-reduction potential, although of proven value in many cases, is a less accurate and less direct means of measurement than electrometric methods. Thornton and Hastings (4) in studies on oxidation-reduction in milk obtained good results with the use of methylene blue as an indicator dye. The use of methylene blue in testing sewage, (5) familiar to sewage plant operators as the relative stability test, has oxidation-reduction as a basis. Dickinson (6) in a colorimetric study of the system activated sludge-oxygenated water used methylene blue. Because of interference due to adsorption he was unable to obtain a relationship between E_h and the condition of the sludge. His studies showed that methylene blue will not catalyze sewage purification processes because of its ready reduction to the leuco compound and reoxidation. He does make the observation, however, that a well-aerated sludge adsorbed the dye more

* Presented before the Division of Water, Sewage and Sanitation Chemistry of the American Chemical Society, in Detroit, April 16, 1943.

strongly than an underaerated sludge and does not reduce the dye as rapidly, and points out that activated sludge decolorizes methylene blue by reduction which proceeds concurrently with the adsorption of oxygen from solution. Dickinson (7) further shows that dyestuffs with an electro-positive colored ion are invariably adsorbed giving this as evidence that sludge particles carry a negative charge.

Electrometric methods provide a means for more accurate determinations of the redox potential changes in a dynamic system, and although the interpretation of such measurements is still in the beginning stages, such data as have been presented in the fields of bacteriology and biochemistry indicate that in the interpretation of sewage oxidation processes redox potential measurements are of value.

Description of Apparatus

A vacuum tube potentiometer was used as the measuring instrument. Bright platinum electrodes were used throughout the experimental work. Considerable difficulty was encountered in the early experimental work in finding a satisfactory means of cleaning electrodes, and in getting identical readings with different electrodes in the same medium. Cleaning in hot nitric acid and washing in distilled water was found to produce fairly satisfactory results, but on several occasions after being in the activated sludge or sewage it was discovered that upon using the electrodes again, after cleaning, checks on readings by several electrodes in the same sewage-sludge mix could not be obtained, thus leading to question as to the value of the results obtained. This discrepancy was believed due to the formation of a film on the electrode.

The most successful means found to clean the electrodes was to first polish them vigorously with a paste made from levigated alumina, allow them to remain in aqua regia or hot nitric acid, and then wash thoroughly with distilled water. After washing, the electrodes are placed in distilled water for several hours before reuse. The electrodes may be checked occasionally by inserting them into a mixture of known redox potential. However, the author has found that when the electrodes are placed in a well poised inorganic system of known redox potential, they will rapidly come to the equilibrium reading of the system, but the same electrodes in a medium such as beef broth may not come to equilibrium for some time or even give poor results. It is essential, therefore, to reclean the electrodes and to check them in a medium similar to that to be used. In this way "sluggish" electrodes can be discovered that ordinarily would come to equilibrium rapidly in an inorganic system. In nearly every case electrodes were used in triplicate, and readings were taken at each electrode during the course of the run. When electrodes had been properly cleaned and prepared, the readings at each electrode at any given time checked within 10 millivolts, and often gave even closer, sometimes exact checks. Occasionally one of the three electrodes gave results that were inconsistent with the other two, and even inconsistent with itself throughout the run. In some cases the values obtained from this electrode were discarded, and the average value of readings of the two checking electrodes was used. In most of these cases the electrode giving inconsistent results was replaced by an electrode known to be in good condition, to be used as a further check on the electrodes giving good results. In those cases where all three electrodes gave divergent results, the run was discontinued and the electrodes removed and examined to determine possible reasons for the divergencies. They were then subjected to recleaning as mentioned above and the run repeated.

Occasionally during a test run electrodes that were checking well would vary by twenty to forty millivolts when the potential was undergoing a rapid change, such as at the onset of rapid reducing conditions, but these electrodes would give good check results again when the reduced condition had been attained. This is a normal situation, due to stratification and formation of zones in the medium, and for this reason average readings were used.

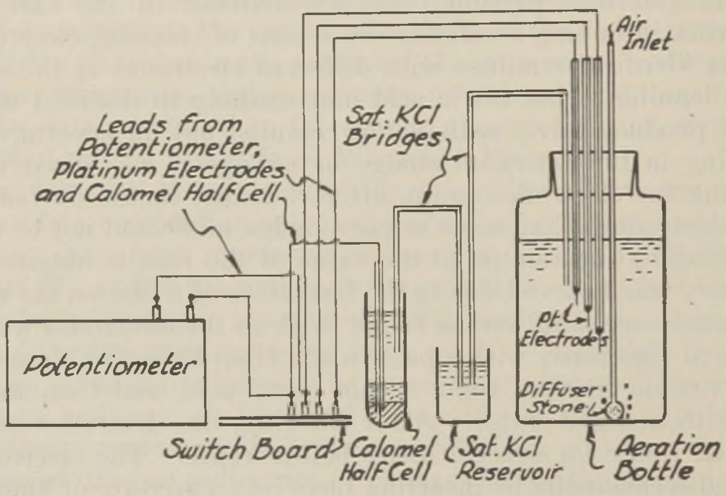

FIG. 1.—Experimental apparatus.

A calomel half cell was used as the reference electrode. The readings obtained were then corrected to the hydrogen electrode. The bridge from the unknown half cell to the calomel half cell consisted of saturated potassium chloride agar bridges through a reservoir of saturated potassium chloride. Shielded leads from the platinum electrodes and the calomel half cell were connected to the potentiometer through a multiple switch arrangement so that readings on all electrodes could be taken in a minimum of time.

The work was conducted under controlled temperature. Determinations of pH of the sewage and sludge before and after and during the course of the run were made with the use of a glass electrode. Determinations of suspended solids, B.O.D. and dissolved oxygen were made in accordance with Standard Methods of Water Analysis (8).

Figure 1 shows a typical setup of the apparatus used in some of the experimental work. It shows the bottle which contains the sludge, sewage or sewage-sludge mixture; the vacuum tube potentiometer, and the connections between the potentiometer, the calomel half-cell, and the platinum electrodes in the bottle.

Results of Experiments

The first studies involved a comparison of the changes in the oxidation-reduction potential with changes in the amounts of dissolved oxygen in sewage-sludge mixtures and reaerated activated sludge.

Figure 2 shows the results of a study made on an activated sludge-sewage mixture containing 2,155 p.p.m. of suspended solids. For this study a twenty-gallon spiral-flow type of tank equipped with diffuser

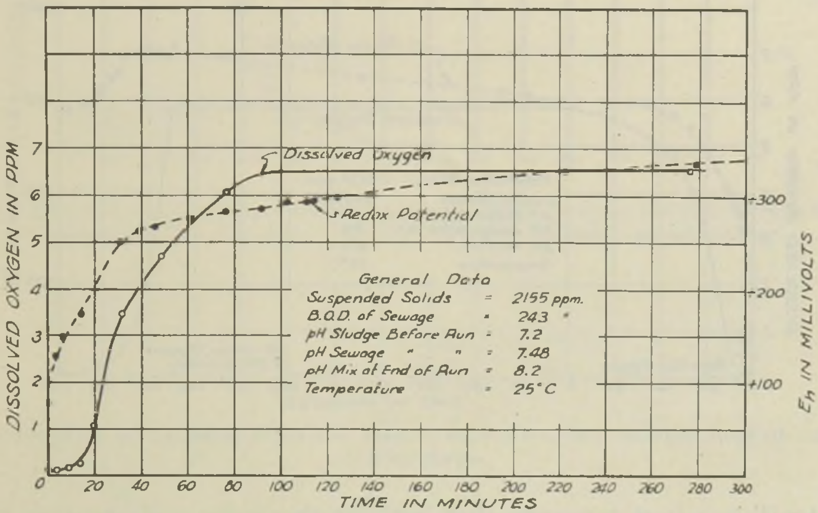

FIG. 2.—Relation between dissolved oxygen content and redox potential for activated sludge-sewage mixture.

plates was used. Sewage and sludge were mixed in this tank and aeration begun. The E_h readings were obtained by inserting a platinum electrode in the tank and an agar salt bridge from the tank to a KCl reservoir. A calomel half cell was bridged to the KCl reservoir to complete the circuit, and the E_h measured across the completed chain. The initial dissolved oxygen content of the mix was 0.1 p.p.m., and the initial E_h + 78 millivolts.

The dissolved oxygen content was determined at different time intervals by taking a two-liter sample from the tank in a wide-mouthed bottle to which 10 ml. of a 10 per cent solution of copper sulfate had been added. After shaking without entrainment of air and allowing the sludge to settle, the supernatant liquid was syphoned into 250-ml. bottles and the dissolved oxygen content was determined.

The curve (Fig. 2) shows that the increase in dissolved oxygen content is accompanied by a corresponding increase in E_h, but that when the mixture had reached its saturation point with regard to dissolved oxygen, the rise in E_h continues, indicating that the system is becoming more oxidized.

A similar run was repeated the next day using the same activated sludge which had been aerated continuously in the twenty gallon tank. Sewage with a B.O.D. of 240 p.p.m. was added to the sludge; the mix then contained 1,370 p.p.m. of suspended solids. The initial dissolved oxygen content of the mix was 1.1 p.p.m., and the initial E_h + 126 millivolts. Inspection of the curve (Fig. 3) shows that the results are similar to those obtained on the previous day and plotted in Fig. 2.

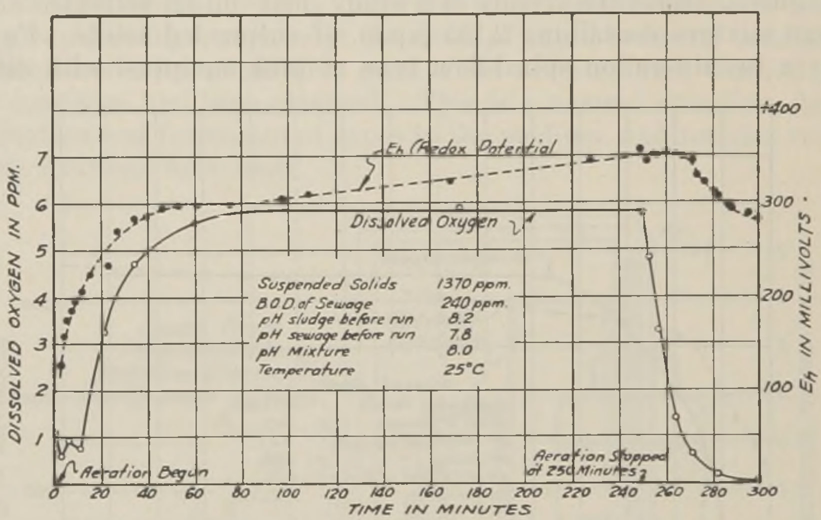

FIG. 3.—Relation between dissolved oxygen content and redox potential for activated sludge-sewage mixture.

It will be noted, however, that initially there was a slight drop in the dissolved oxygen content with no apparent effect on the redox potential. It is possible that this drop may have been caused by imperfection in sampling or in titrating, but is more likely due to the fact that the sludge in this initial stage of oxidation of the sewage was using dissolved oxygen at a rate much greater than the rate at which it was being supplied. The existence of high initial rates of oxygen utilization in sewage-sludge mixtures has been pointed out by Kessler and Nichols (9) and by Sawyer (10).

In this experiment, aeration was stopped after 250 minutes to determine the effect on the oxidation-reduction potential of depletion in dissolved oxygen content. After aeration was stopped, the mixture was stirred continuously by mechanical means.

Figure 4 is an enlargement of the portion of Fig. 3 representing that portion of the aeration period between 220 to 370 minutes. While the dissolved oxygen content rapidly decreased to less than one p.p.m., the E_h value remained almost constant. The E_h did not start to drop until the dissolved oxygen had decreased to less than one p.p.m., and the drop was gradual, even after the dissolved oxygen had practically disappeared. An E_h value of zero was reached about 17 hours after aeration had been stopped.

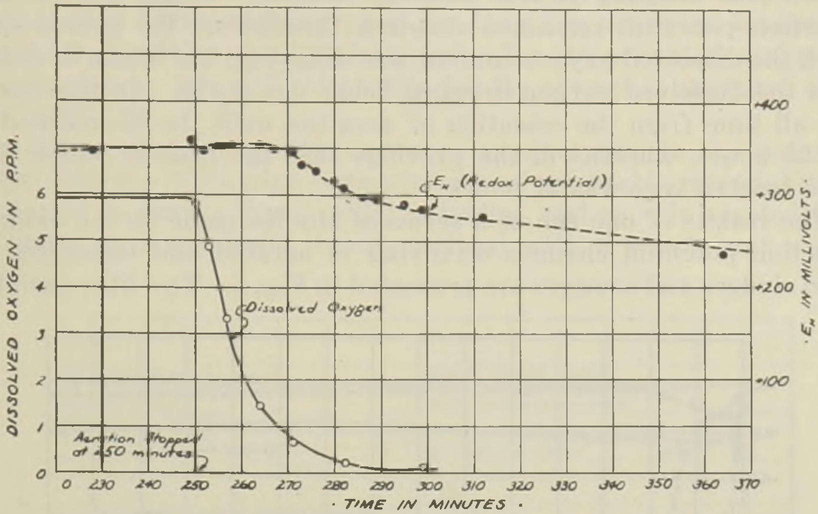

FIG. 4.—Enlarged section of Fig. 8 showing relation between depletion in dissolved oxygen after stopping aeration and redox potential for activated-sludge sewage mixture.

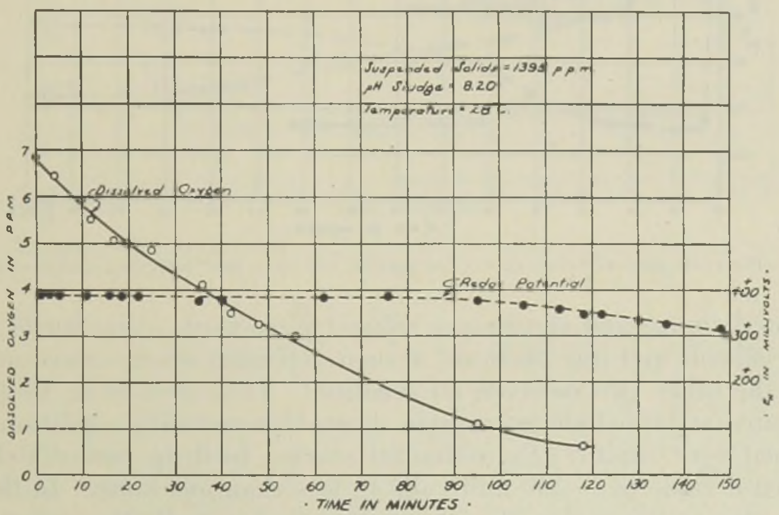

FIG. 5.—Relation between dissolved oxygen content and redox potential of reaerated activated sludge after stopping aeration.

Figure 5 is a plotting of data obtained on a run similar to the one described above except that the liquid was reaerated activated sludge and not a sludge-sewage mixture. The sample was from the reaerated sludge employed in the foregoing experiment. In this case again, the depletion of dissolved oxygen and the E_h values were determined with respect to time after aeration had been stopped. The depletion in dissolved oxygen content was much slower than in the previous run; the dissolved oxygen content did not fall below one p.p.m. until 100 minutes after aeration was stopped, whereas in the previous run a similar depletion was attained in less than 20 minutes. Again the oxidation-reduction potential remained constant throughout the period during which the dissolved oxygen content was dropping, but began to decrease when the dissolved oxygen dropped below one p.p.m. In this case the over-all time from the cessation of aeration until the E_h reached zero was 25 hours, whereas in the previous case the time at which the E_h value reached zero was 17 hours.

The results of one run of a series of studies made on the oxidation-reduction potential changes occurring in aerated and unaerated activated sludges and sewages are presented in Fig. 6. Two liter samples of

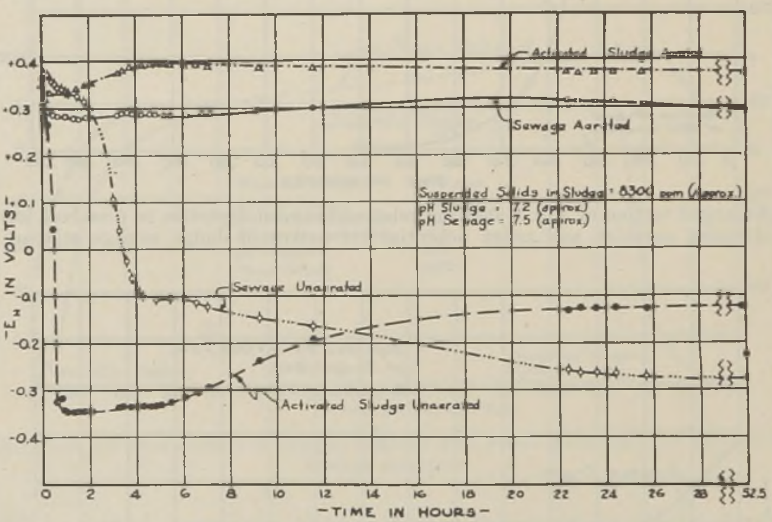

FIG. 6.—Electrode potential-time curves for aerated and unaerated activated sludge and sewage.

activated sludge and of primary effluent were used. One bottle of primary effluent and one bottle of return activated sludge were aerated, while the other two received no aeration. The curve (Fig. 6) for the unaerated activated sludge sample shows that reducing conditions were obtained very rapidly; the potential started to drop immediately and reached a value of — 350 millivolts in less than one hour. In the case of the unaerated sewage, it will be noted that initially the potential decrease was rather slow corresponding somewhat to the lag phase observed in bacterial cultures. After two hours, however, the drop in potential was very rapid until a value of — 100 millivolts was reached. Beyond this point, which was after approximately five hours, reduction as measured by the drop in potential continued, but at a much slower rate. At 26 hours the lowest value of E_h (— 280 millivolts) was reached and this did not change appreciably between the twenty-sixth and the fifty-third hour. In comparing this curve with that for the unaerated activated sludge it is to be noted that there was no rise in the E_h once the maximum reduced state was reached.

For the sludge and sewage samples that were aerated very slight reducing conditions were manifest during the first hour but the potential remained at a high oxidizing level for both the activated sludge and sewage, but it will be noted that the value for the activated sludge was approximately + 380 millivolts while for the sewage it averaged about + 300 millivolts.

In the aerated sewage there was a gradual rise in the potential. Sewage, because of its high concentration of oxidizable material would be expected to have a lower initial potential, and as it is aerated these substances were gradually being oxidized with a consequent rise in potential.

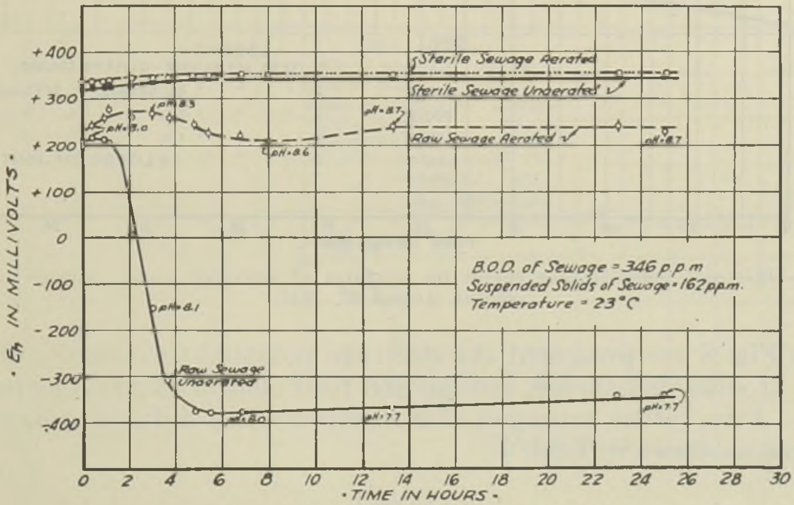

FIG. 7.—Electrode potential-time curves for aerated and unaerated, natural sewage, and sterile sewage.

In Fig. 7 are presented electrode potential time curves of sterile and natural sewages. Sterilization was accomplished by autoclaving for 40 minutes at 15 lbs. pressure. Electrodes were sterilized at the same time as the sewage. This was done by suspending the electrodes in a two liter-flask. The electrodes were held in place by a cotton stopper in the neck of the flask. Also in the flask was one end of a glass U tube to be used as the bridge. This tube rested in a test-tube of KCl agar in the flask. After sterilization, the saturated KCl agar was drawn through the tube and allowed to solidify. The entire assembly consisting of the three electrodes and bridge were then removed, and transferred aseptically to the sterile sewage. The free end of the bridge was placed in the KCl reservoir, and the chain completed with a calomel half cell in the manner described previously (Fig. 1). Values of pH were recorded frequently through the course of the run and are shown on the curve (Fig. 7). As in the curve (Fig. 6) reducing conditions occurred in the septic unaerated sewage. In the aerated non-sterile sewage, the generous supply of air prevented reducing conditions. In both the aerated and unaerated sterile sewages there was very little change in the redox potential during the twenty-six hour run and the value for both samples remained fairly constant at approximately 350 millivolts.

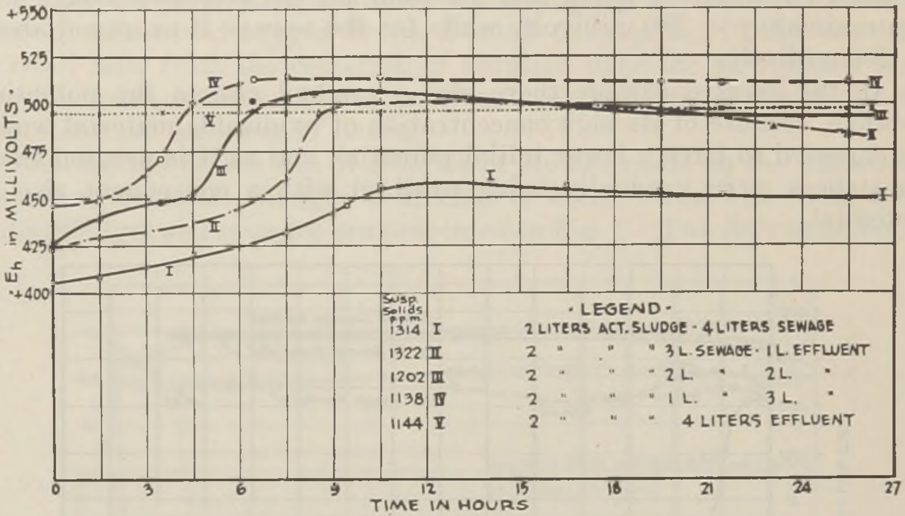

FIG. 8.—Electrode potential-time curves for mixtures of activated sludge, sewage and final effluent, August 27, 1942.

In Fig. 8 are presented the electrode potential-time curves of mixtures of activated sludge, sewage and final effluent in varying proportions. Five bottles arranged with electrodes and diffuser stones were charged as shown in Table I.

TABLE I

Bottle No.	Ml. Activated Sludge	Ml. Sewage	Ml. Final Effluent	Susp. Solids, p.p.m.
I	2,000	4,000	—	1,314
II	2,000	3,000	1,000	1,322
III	2,000	2,000	2,000	1,202
IV	2,000	1,000	3,000	1,138
V	2,000	—	4,000	1,144

5 Day B.O.D. – Sewage = 192 p.p.m.
Effluent = 14 p.p.m.

The bottles contained different amounts of oxidizable organic material. The curve (Fig. 8) shows that the bottle containing the greatest concentration of sewage had a lower initial potential than the other samples and the value of the potential during the first hour of the run was dependent upon the concentration of oxidizable material present. The rate of increase in potential was also dependent on the concentration of sewage, the greater the concentration of sewage, the less rapid was the rise in potential. This shows clearly that with a lesser amount of organic material present the more rapid was the increase in the ratio of oxidant to reductant, therefore, the potential rose more rapidly.

In the sample containing activated sludge and final effluent, very little oxidizable material was present and the potential remained at a fairly constant value throughout the course of the run.

If activated sludges contain actively oxidizing systems, then when return activated sludge is first added to sewage in the presence of air, and the sewage is becoming oxidized, the mixture becomes more oxidizing and the potential should rise. Figures 9 and 10 show results of studies made on mixtures of activated sludge and sewage undergoing aeration. Comparative studies on oxygen utilization were made at the same time on the same mixtures, using the oxyutilometer (11).

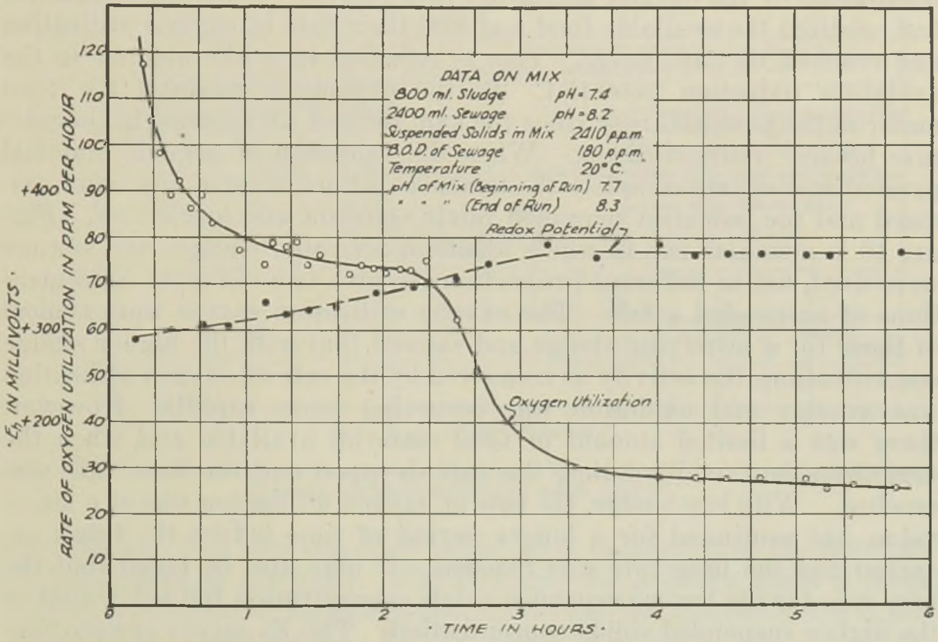

FIG. 9.—Electrode potential-time curve and oxygen utilization curve for activated sludge-sewage mixture.

For the data presented in Fig. 9 return activated sludge was obtained from the Madison, Wisconsin, Nine Springs Plant and sewage from the Brittingham Park Pumping Station, Madison, Wisconsin. A mixture of 800 ml. of sludge and 2,400 ml. of sewage was used. The mixture contained 2,410 p.p.m. of suspended solids. Other pertinent data are shown on the curve sheet. The curve for the rate of oxygen utilization is typical of that obtained with nitrifying Madison sewage-sludge mixtures; an initially high rate leveling off rather quickly, and then a sharp break, and after approximately three and one-half hours aeration the rate of oxygen utilization is at a value near its base rate. The oxidation-reduction curve in this case is of particular interest in itself. When compared with the oxygen utilization curve it will be seen that the E_h curve begins near a value of + 285 millivolts at 10 minutes' aeration time after the sludge and sewage were added to the aeration bottle. The potential then climbed steadily and reached its maximum value of about + 385 millivolts at very nearly the same time that the oxygen utilization curve had reached its base rate of oxygen utilization. At this point the oxidation-reduction potential leveled off as did the oxygen utilization curve. Analysis of the E_h curve indicates that when the activated sludge and sewage were first brought into contact with each other the mixture was at a definite potential; upon aeration, however, the mixture became more oxidizing and the potential rose. As the mixture became more oxidizing or, in other words, as the ratio of oxidant to reductant increased, oxygen was used by the organisms. This is manifested by the oxygen utilization rate curves. When the organisms had oxidized the available food material their rate of oxygen utilization had reached its base value. This is reflected in a like manner in the oxidation reduction potential. As the organisms oxidized the food material the potential rose since the sum total of all systems in the mixture became more oxidizing. When the oxidation of organic material present was nearly complete the mixture did not become any more oxidized and the potential remained fairly constant and leveled off. Figure 10 is a similar run in which identical activated sludges and sewage were used, but in different proportions to give two different concentrations of suspended solids. The oxygen utilization curves were typical of those for a nitrifying sludge and showed that with the higher sludge concentrations the activity as measured by the rate of oxygen utilization was greater and oxidation was occurring more rapidly. However, there was a limited amount of food material available and when the organisms had oxidized this, the rate dropped and the base rate was reached. With less sludge, the rate of oxygen utilization was of a lesser value, but continued for a longer period of time before the break occurred and the base rate was reached. It may also be noted that the base rate for the lower suspended solids concentration fell below that of the higher suspended solids concentration. The E_h curves are particularly interesting in this study. For Mix A with 2145 p.p.m. suspended solids the E_h curve began at a lower value than for Mix B which had 3,220 p.p.m. of suspended solids. This is in order if we consider that Mix A, having a greater amount of sewage than Mix B, had more oxidizable material present and so was more reducing. It will be observed also from Fig. 10 that Mix B arrived at a maximum potential value in less time than Mix A, and that for both mixes the time when the potential no longer rose corresponded quite closely to the time when the oxygen utilization rate curve had reached its base rate.

With the laboratory studies previously reported as a background, it was decided that studies should be made at an activated sludge-sewage treatment plant to see if the results would be similar to those obtained in the bottle experiments in the laboratory.

Permission to make studies at the Madison, Wisconsin, Nine Springs Sewage Treatment Plant was very kindly granted to the author by Mr.

Herbert O. Lord, Chief Engineer of the Madison Metropolitan Sewerage District, and by Mr. John C. Mackin, Superintendent of the Nine Springs Plant, who lent every aid to facilitate the work.

The sewage flow to the Madison Nine Springs Plant is divided into two portions after passing through mechanically cleaned coarse screens and a grit chamber. One portion is treated in Imhoff tanks followed by trickling filters, and the other portion is an activated-sludge plant.

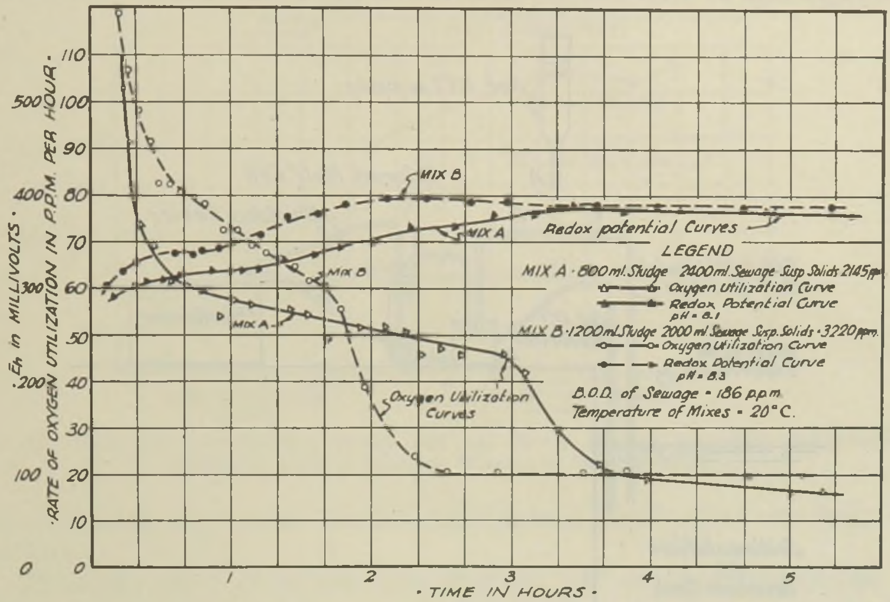

FIG. 10.—Electrode potential-time curves and oxygen utilization curves for activated sludge-sewage mixtures of varying solids content.

The studies made and reported herein were conducted in the activated sludge portion of the plant. The flow into the primary tanks is measured by an automatic recording flow meter and the return sludge is also measured by recording flow meters, there being a separate flow meter for the sludge returned from each final tank.

In making the E_h and pH survey through the plant the rate of flow through the tanks was determined, and based on this flow rate, sampling stations were selected. E_h measurements were made in two ways at each station. First, a sample was dipped from the tank in a beaker and a platinum electrode suspended in the beaker. Also in the beaker was one end of a saturated KCl agar bridge. The other end of the KCl bridge dipped into a KCl reservoir. From this reservoir there was a KCl bridge to a calomel half cell. The potential across the chain from the platinum electrode in the unknown to the platinum in the calomel half cell was measured with the potentiometer. Shielded leads were used from both electrodes to the potentiometer. This apparatus was so arranged that the reading was taken almost immediately after the sample was taken from the tank. After the reading was taken the platinum electrode was washed thoroughly with distilled water and suspended in a flask of distilled water until the next reading was to be taken. As a check on this procedure readings at each station were also taken directly in the tank. To do this a three foot platinum electrode was used. A ring stand equipped with a long-arm clamp was used to hold the electrode so that it could be suspended in the aeration tank. A special saturated KCl liquid salt bridge was also constructed. This is shown in Fig. 11 and was operated as described below. One end of this

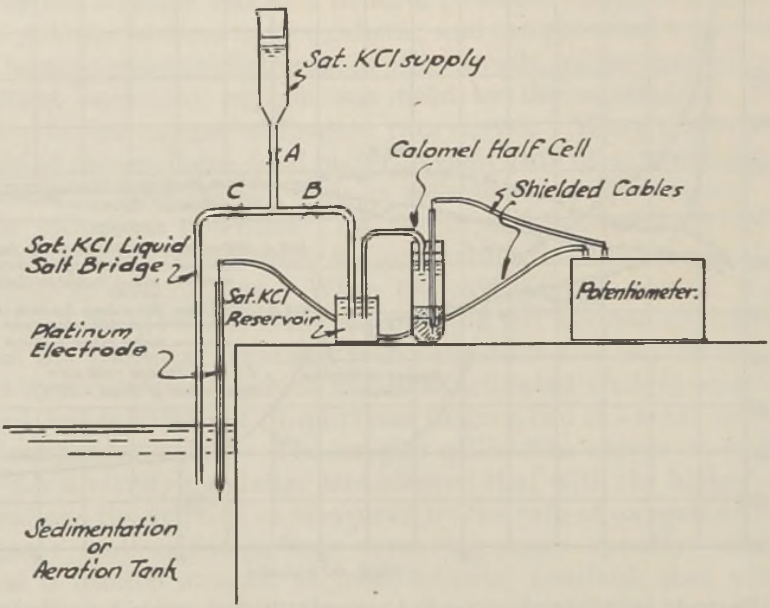

FIG. 11.—Diagrammatic sketch of apparatus as arranged for plant studies.

bridge was immersed in the tank and the other in a KCl reservoir. The cell was completed by a bridge from the KCl reservoir to a calomel half-cell and readings taken with the potentiometer which was connected across the chain by shielded cables. When a reading was to be taken the electrode was immersed in the aeration tank, as was one end of the special KCl bridge. The bridge was filled with KCl by opening pinch clamps A and B, then A and C. A fresh junction at the interface between the bridge and the mix could be made at any time by opening clamps A and C.

Samples of the aeration mix at several points in the plant were analyzed for suspended solids and 5 day B.O.D. pH was determined in a sample taken from the tank at each station by use of a glass electrode and the electrometer.

The results of one run are shown in Fig. 12. The diagrammatic sketch of the tanks is to a fixed scale and the time scale for the primary sedimentation tank and aeration tank data is arranged to show the corresponding position in the tank where the data were obtained. Table II is a tabulation of the data obtained giving B.O.D., temperature and suspended solids data in addition to the pH and oxidation-reduction values obtained. Values for oxidation-reduction in both the tank and sample from the tank are shown. The values of E_h plotted are the average of the two values obtained. B.O.D. values at the various stations in the

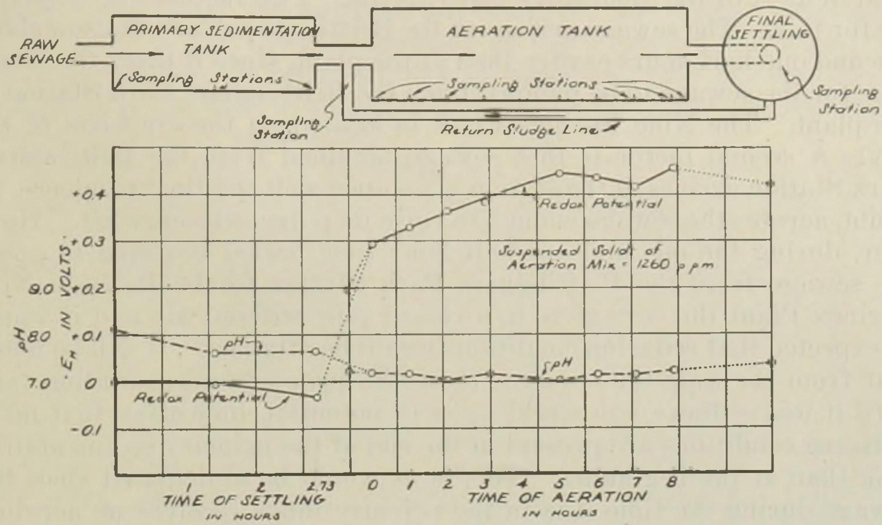

FIG. 12.—Electrode potential-time survey and pH survey through activated sludge-sewage treatment plant at Madison, Wisconsin, June 19, 1940.

aeration tank were made on the supernatant liquid after one hour of settling.

From the curve it will be seen that the pH value of the sewage is slightly higher than for the return sludge, but at the first station in the aeration tank the pH value is more nearly that of the return sludge than

TABLE II.—*Madison, Wis. Nine Springs Sewage Disposal Plant*

Station No.	Location	Time	O-R Potentials			O-R Potential Corrected to H Electrode	pH	Temp. °C.	Susp. Solids, p.p.m.	5 Day B.O.D.
			Sample	Tank	Avg.					
1	Raw	10:25 A.M.		−302	−302	−57	7.64	21	297	115
2	Mid-primary	12:00 N.		−270	−270	−25	7.62	24		67
3	End-primary	1:00 P.M.	−311	−327	−319	−82	7.58	21.8	84	105
4	Return sludge	1:00 P.M.	+20		+20	+265	7.10	21.8	4,710	
5	Influent to Aeration tank	1:10 P.M.	+20	+12	+16	+261	7.28	21.8	1,330	6.5
6	Aeration tank	3:00 P.M.	+38	+42	+40	+305	7.0	21.8	1,370	
7		4:00 P.M.	+92		+92	+337	7.02	21.7		
8		5:00 P.M.	+112	+109	+110	+355	7.02	21.6		12
9		6:00 P.M.	+139	+122	+130	+375	7.02	21.8		3.9
10		7:00 P.M.	+150	+138	+144	+389	7.1	21.8		12
11		8:00 P.M.	+185	+162	+173	+418	7.12	21.6		7.8
12		9:00 P.M.	+178	+150	+164	+409	7.1	21.5		2.5
13	Aeration tank	10:00 P.M.	+142	+140	+141	+386	7.0	21.5	1,300	8.0
14	Final tank	11:30 P.M.	+150	+150	+150	+395	7.1	21.5		5.0

of the sewage. This would indicate that the sludge was sufficiently buffered to overcome the effect of the more alkaline sewage.

The redox potential of the sewage in the primary tank was lower than for sewage that was obtained at the Brittingham Park Station and used in most of the laboratory experiments. Two factors are responsible for this. The sewage arrives at the Brittingham Park Station about one and one-half hours earlier than at the plant, since it takes this much time for the sewage to be pumped from the Brittingham Park Station to the plant. The Nine Springs Plant is located on the outskirts of the city. A second factor is that sewage obtained from the Brittingham Park Station arrives at the station in an open well and the turbulence, no doubt, aerates the sewage enough to raise its potential somewhat. However, during the one and one-half hour time period required to pump the sewage from the Brittingham Park Station to the Madison Nine Springs Plant the sewage is in a closed pipe without air and it would be expected that reducing conditions would be attained. It will be noted that from the time the sewage enters the primary sedimentation tank until it leaves there is a slight drop in potential, indicating that more reducing conditions are present at the end of the primary sedimentation tank than at the beginning. This is as would be anticipated since the sewage during the time it is in the primary tanks receives no aeration other than that occurring by diffusion at the air-sewage interface.

As soon as the sewage contacts the more oxidizing return sludge the potential rises and then continues to rise throughout the aeration tank as oxidation progresses.

Figure 12 shows that after six hours aeration the potential levels off, indicating that at this time the most oxidizing conditions are obtained in the sewage sludge mixture. Comparison of this curve with the studies conducted in the laboratory (Figs. 9 and 10) shows the same general trend and the values of potential for the sewage-sludge mixtures in the plant and in the laboratory are in good agreement. Figure 12 also shows that the oxidation-reduction potential in the final tank is much higher than that in the return sludge entering the aeration tank. This is further proof that reduction occurs while the sludge is in the final settling tank and in the return sludge channels. Reaeration of this sludge would increase its potential value and provide a sludge of higher oxidizing intensity for mixture with settled sewage to be admitted to the aeration tank.

Discussion

The practical use of the activated sludge process for the treatment of sewage has made great strides since the fundamental information on the purification of sewage in the presence of aeration and activated sludge was first provided by Ardern and Lockett (12) in 1914. As mentioned previously, the actual mechanism of the process is as yet but incompletely understood, but the evidence presented points to a complex mechanism involving physical, chemical, and biological factors, the interdependence of which will undoubtedly be made evident by further research.

The complexity of the oxidation process and the heterogeneous character of activated sludge and sewage in which many oxidizing and reducing systems are present does not allow for any simple explanation of the process, but the measurement of redox potential changes may prove of value in the interpretation of conditions that will lead the investigator in the field to a clearer understanding of the process, and to a better method of plant control.

If oxidation-reduction potentials are to have any value they must be reproducible and particularly so if they expect to find an application as a control device in activated sludge plants. A considerable amount of time was taken in the early part of this work in getting consistently reproducible data. Dependable results were obtained only when the electrodes were cleaned in the manner described in the experimental portion of this paper. A point of value to be noted is the manner of checking electrodes. Many times the same electrodes were found to give good checks in a well poised inorganic system, but poor checks in a poorly poised medium. The best test to employ is to have the electrodes check in a poorly poised medium, or in the medium to be studied. Generalizing, it can be said, electrodes that will rapidly come to equilibrium and give good checks (within 5 to 10 millivolts of each other) in the system being studied can be used, and should give consistent results.

Comparative studies on the variation of E_h with dissolved oxygen content are of interest when the results are compared with the early statement of Nordell as reported by Kessler and Nichols (9) that "the sludge absorbs oxygen from the water just as rapidly when there are only a few parts per million in solution as it does when the water is almost saturated." Figures 3, 4 and 5 show that the oxidation-reduction potential remains at a highly oxidizing level while the dissolved oxygen content decreases. This indicates that the oxidizing intensity of the sludge is not affected within the range of dissolved oxygen usually encountered. It is only when the dissolved oxygen drops to a very low level (less than 1.0 p.p.m.) that the potential begins to decrease. With a well stabilized activated sludge, reducing conditions occur quite slowly after aeration ceases. This indicates the value of reaeration of return sludge in those plants where, because of poor aeration facilities or the necessity for oxidizing strong sewages, sludges need reconditioning. Electrode potential measurements would be of value in this respect as a means of determining the condition of the sludge in that they may be used to note the rapidity with which reducing conditions will occur.

The bacterial systems for carrying on oxidation and reduction are present naturally in activated sludges and sewage, and the changes which occur can be noted by the measurement of the electrode potential changes. Activated sludges have stronger reducing tendencies than the sewages from which they are developed due probably to the greater numbers of microorganisms present.

A question may be raised concerning the gas-electrode potential occurring in aerated mixtures. The activated sludge process by its very nature embodies aeration and any study leading to an explanation of the process must be concerned with the natural conditions under which the process operates. Hewitt (2) has shown that reduction can occur in an aerated culture of *C. diphtheriae.* Frazier and Whittier (13) in studies on the influence of oxidation-reduction potential in milk found that bubbling air through cultures of *A. aerogenes* had a comparatively slight effect on the potential level. Boyd and Reid (14), however, report that bubbling air through sterile broth causes a rise in potential at a platinum electrode. The author has found very little difference in the electrode potential in sterile sewage whether aerated or unaerated. It is natural to expect that aeration affects the potential value and the interpretation made herein is one that embodies the sewage-sludge system as a whole.

The electrode potentials of activated sludge-sewage mixtures, undergoing aeration, increases as the sewage is being oxidized and the rapidity of this increase is dependent upon the concentration of oxidizable material present. With mixtures containing the same amount of activated sludge and varying proportions of sewage, the mix having the larger amount of sewage, and hence the highest concentration of oxidizable organic material will have a lower initial potential and the rise in the oxidation-reduction potential will be slower.

Correlation between the stage of oxidation of sewage, as measured by the rate of oxygen utilization, and the oxidation-reduction potential is demonstrated in both plant and laboratory studies.

As the organic matter in the sewage is being oxidized the redox potential increases indicating that the ratio of oxidant to reductant increases. When the base rate of oxygen utilization is reached the highest oxidizing intensity of the mixture is attained.

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MODIFICATIONS OF THE RELATIVE STABILITY TEST FOR SEWAGE

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Various tests have been devised to determine the relative putrescibility of sewage. Requiring that the technician have considerable skill, these time-consuming tests employ many reagents. The relative stability test is one of the simplest to perform, and although its usefulness is limited because the results must await a long incubation period (Mohlman (1)), the test still has a general applicability (Theriault (2)).

The purpose of this research was to investigate the possibility of using dyes other than methylene blue in an attempt to obtain an indication of relative stability in less time than that required by the standard methylene blue procedure.

The excellent review of the literature by Theriault summarizes the work done to 1927. Dickerson and Wein (3) reported that a mixture of methylene green and methyl orange, along with potassium dihydrogen phosphate, gives a rapid test for sewage effluents. In attempts to shorten the time of decolorization (4) other modified stability tests have been reported using the Thunberg technique, hydrogen donators, and incubation at higher temperatures.

Materials and Method

The method followed in the present investigation was similar to that outlined in *Standard Methods for the Examination of Water and Sewage,* eighth edition (5), with modifications as noted below. Obtained from Eastman Kodak Company, the dyes tested were: resazurin, neutral red, gallocyanine, thionin, methylene blue, sodium indigodisulfonate, phenosafranin, safranine T indigotine, and brilliant cresyl blue. The dyes chosen were all of different E_h ‡ levels and covered a wide range of oxidation reduction potential. They were so chosen that some would be above and others below the level of E_h of methylene blue. Aqueous solutions of the dyes (0.05 per cent) were prepared by dissolving 0.5 gram of dye in one liter of distilled water. These were then stored in

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‡ Where E_h is the electrical potential of the dye, and is equal to a constant for any given system plus the 0.03 log of the ratio of oxidized to reduced forms of the substance studied, or

$$E_h = E_0 + 0.03 \log \frac{\text{ox.}}{\text{red.}}$$

For more complete information on this subject, see Reference 6.

stoppered, brown-glass bottles and kept in a refrigerator maintained at below 10° C.

The sewage was obtained from both the R. M. Clayton and the South River sewage disposal plants of Atlanta, Georgia. Both influent and effluent samples were used in a series of 426 tests. The pH of each sample was determined electrometrically as the pH value of the solution. Duplicate samples were incubated in thermostatically controlled water baths at temperatures of 20° C. and of 37° C. The temperature of each bath was kept within one degree of the desired temperature at all times. Each sample was observed at 15 minute intervals until decolorization.

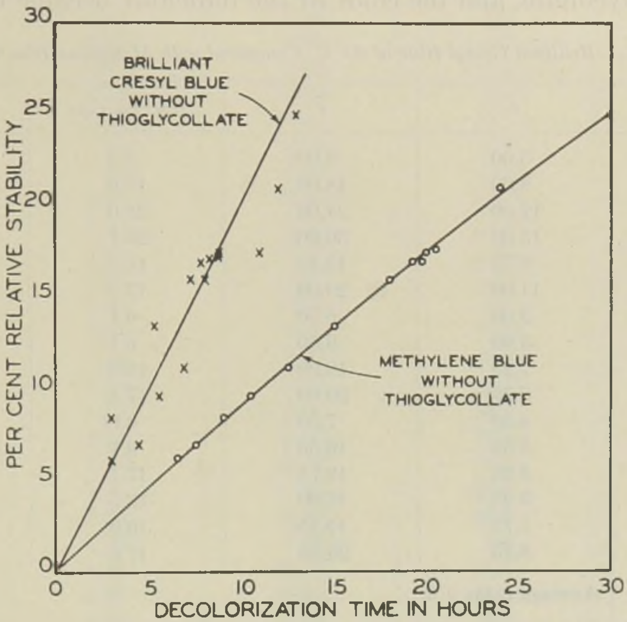

FIG. 1.

As the work progressed, the standard procedure was modified by the addition of sodium thioglycollate medium * to the sample. It was hypothesized that since the thioglycollate medium would allow for a better growth of both facultative and strict anaerobes, its addition to a sewage sample might speed up the test, since more of all the organisms present would have improved conditions for growth.

* The sodium thioglycollate medium was obtained from the Baltimore Biological Laboratory, 500 N. Calvert St., Baltimore, Md., and has the following composition (when dissolved):

Polypeptid, B.B.L.	2.0	per cent
Sodium Chloride	0.5	per cent
Dextrose	1.0	per cent
Agar	2.0	per cent
Sodium Thioglycollate	0.2	per cent
Sodium Formaldehyde Sulfoxylate	0.1	per cent
Methylene Blue	0.0002	per cent

This medium is used for growth of anaerobes, the oxygen in the special type of Petri dish being absorbed by the thioglycollate. The dry medium is dissolved in the proportion of 58 grams to 1,000 cc. of distilled water.

For our work, the medium (Lot No. 4–886) was made up without the dextrose and methylene blue.

For each set of samples to be tested, a stock solution of the sodium thioglycollate medium was prepared by dissolving 2.85 grams in 100 ml. of distilled water. This was heated to boiling for one minute to remove dissolved air, allowed to cool, and measured into the sample bottles. To find the concentration of thioglycollate which would give the best results, a series of concentrations were tried, varying from 2 per cent to 50 per cent by volume of the thioglycollate solution in the sewage samples. In general, as the concentration of thioglycollate was increased the time of decolorization of the indicator was decreased. With concentrations greater than 25 per cent, the sample took on the yellow color of the thioglycollate, and the color of the indicator became masked.

TABLE I.—*Brilliant Cresyl Blue at 20° C. Compared with Methylene Blue at 20° C.*

Exp. No.	t	t'	R.S.' Per Cent	t'/t
1	3.00	9.00	8.4	3.0
2	8.00	18.00	15.9	2.3
3	12.00	24.00	21.0	2.0
4	13.00	30.00	25.1	2.3
5	6.75	12.50	11.3	1.9
6	11.00	20.00	17.4	1.8
7	3.00	6.50	6.1	2.2
8	3.00	6.50	6.1	2.2
9	7.25	18.00	15.9	2.5
10	8.75	20.00	17.4	2.3
11	4.50	7.50	6.9	1.7
12	5.50	10.50	9.7	1.9
13	8.25	19.75	17.1	2.4
14	5.25	15.00	13.5	2.8
15	7.75	19.25	16.9	2.7
16	8.75	20.50	17.6	2.4
	Average ratio (t'/t)			2.0

Where:

t = time of decolorization of brilliant cresyl blue at 20° C.

t' = time of decolorization of methylene blue at 20° C.

R.S.' = relative stability calculated from t'.

t'/t = the ratio of the times of decolorization for methylene blue compared with brilliant cresyl blue.

Note that the relative stabilities for t are not calculated. The purpose of the test is to shorten the time of decolorization of the dye for a given relative stability, obtained by the standard technique. Thus, in Exp. No. 1, a relative stability of 8.4 per cent at time t' (9 hours) is obtained in time t (3 hours) using the new technique.

After repeated trials, it was found that a concentration of 2.7 per cent thioglycollate solution gave adequate speed of decolorization. Consequently, the remainder of the tests were carried out with 4 ml. (2.7 per cent by volume) of thioglycollate stock solution and 0.4 ml. of dye solution in a 150 ml. sample of sewage.

All samples of sewage were quickly brought to the temperature of incubation before the dye was added, and all tests were made in duplicate.

Results and Discussion

Of the nine dyes listed above, in a series of sixteen tests, only thionin, brilliant cresyl blue, and gallocyanine decolorized faster than methylene blue. It was found that gallocyanine decomposes readily, and therefore its use was discontinued. The remaining five dyes were discarded, as

Table IA.—*Brilliant Cresyl Blue with 2.7 Per Cent Thioglycollate at 20° C. Compared with Methylene Blue at 20° C. without Thioglycollate*

Exp. No.	t	t'	R.S.′ Per Cent	t'/t
1	1.75	5.50	5.2	7.3
2	1.00	6.00	5.6	6.0
3	1.00	6.00	5.6	6.0
4	1.25	6.50	6.1	5.1
5	2.75	13.50	12.1	5.1
6	1.75	9.50	8.8	5.5
7	1.75	9.50	8.8	5.5
8	2.00	15.00	13.5	7.5
9	1.75	9.50	8.8	5.5
10	3.25	13.50	12.1	4.2
11	3.00	14.00	12.5	4.7
12	3.25	13.00	11.7	4.2
13	2.25	12.50	11.3	5.6
14	1.25	9.00	8.4	7.3
15	2.75	15.50	13.9	5.6
16	4.75	22.00	19.1	4.6
17	2.75	12.00	10.9	4.4
18	4.50	22.00	19.1	4.4
19	2.50	11.00	10.1	4.4
20	7.25	45.00	35.2	6.2
21	1.50	7.50	6.9	5.0
22	3.25	18.50	16.3	5.7
23	3.25	18.50	16.3	5.7
24	1.50	6.50	6.1	4.3
25	1.50	8.50	7.8	5.7
26	2.25	9.50	8.8	4.0
	Average ratio			5.0

Where:

t = time of decolorization of brilliant cresyl blue with 2.7 per cent thioglycollate.

t' = time of decolorization of methylene blue.

R.S.′ = relative stability calculated from t'.

t'/t = ratio of time of decolorization of methylene blue, used as directed in *Standard Methods*, to brilliant cresyl blue to which 2.7 per cent thioglycollate has been added.

they either did not decolorize or took a very long time. Consequently, the remainder of the work was done with thionin, brilliant cresyl blue, and methylene blue.

Table I summarizes typical results. The ratio of the time of decolorization for methylene blue to the corresponding time for brilliant cresyl blue averaged about 2.0. Thus the time for decolorization with methylene blue is about twice as long as that for brilliant cresyl blue at 20° C.

The graph comparing the results of the use of brilliant cresyl blue with methylene blue at 20° C., Fig. 1, shows quite clearly that brilliant cresyl blue decolorizes in half the time of methylene blue for relative stabilities varying from approximately 5 per cent to 25 per cent. The relative stabilities were calculated by means of Phelps' formula: $S = 100\ (1 - 0.794^t)$, in which S is the stability in per cent and t is the time in days required for decolorization at 20° C. (7).

TABLE II.—*Thionin at 20° C. Compared with Methylene Blue at 20° C. Used as Directed in "Standard Methods"*

Exp. No.	t	t'	R.S.' Per Cent	t'/t
1	3.00	9.00	8.4	3.0
2	8.00	18.00	15.9	2.3
3	12.50	24.00	21.0	2.0
4	13.00	30.00	25.1	2.3
5	7.25	12.50	11.3	1.7
6	12.50	20.00	17.4	1.6
7	4.25	6.50	6.1	1.5
8	4.25	6.50	6.1	1.5
9	7.25	18.00	15.9	2.5
10	8.75	20.00	17.4	2.3
11	4.50	7.50	6.9	1.7
12	5.50	10.50	9.7	1.9
13	5.25	15.00	13.5	2.8
14	8.75	19.75	17.1	2.3
15	8.75	20.50	17.6	2.3
	Average ratio t'/t			2.0

Where:

t = time of decolorization of thionin at 20° C.
t' = time of decolorization of methylene blue at 20° C.
R.S.' = relative stability calculated from t'.
t'/t = ratio of time for decolorization of methylene blue compared with thionin.

Table II and Fig. 3 show similar results when thionin is compared with methylene blue. Here the average ratio for time of decolorization of methylene blue compared with thionin was also 2.0.

The addition of thioglycollate to the sewage samples caused a marked reduction in time of decolorization for all of the dyes tested, both at 20° C. and at 37° C. Table II and Fig. 5 summarize the results of 46 tests done in duplicate on the effect of the addition of 2.7 per cent thioglycollate to methylene blue at 20° C. on decolorization time. The average ratio of the time for decolorization without thioglycollate to that with it was 2.0. Thus it appears that the same relative stability results may be obtained in one-half the time if 2.7 per cent thioglycollate is added to methylene blue.

Table IIA and Fig. 2 show the effect of 2.7 per cent thioglycollate on the speed of reduction or decolorization of brilliant cresyl blue at 20° C., compared with methylene blue used as directed in *Standard Methods* (without thioglycollate and at 20° C.). Thus with methylene

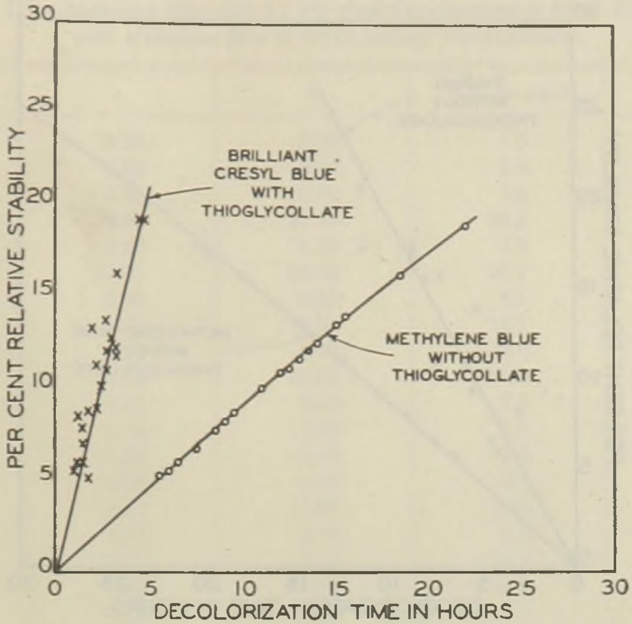

FIG. 2.

TABLE IIA.—*Thionin with 2.7 Per Cent Thioglycollate at 20° C. Compared with Methylene Blue at 20° C. without Thioglycollate*

Exp. No.	t	t'	R.S.' Per Cent	t'/t
1	1.00	5.50	5.2	5.5
2	1.25	6.00	5.6	4.8
3	1.25	6.50	6.1	5.2
4	2.75	13.50	12.1	4.9
5	1.75	9.50	8.8	5.4
6	1.75	9.50	8.8	5.4
7	2.00	9.50	8.8	4.8
8	3.00	14.00	12.5	4.7
9	5.00	22.00	19.1	4.4
10	3.00	12.00	10.9	4.0
11	4.50	22.00	19.1	4.9
12	2.50	11.00	10.1	4.4
13	1.50	7.50	6.9	5.0
14	2.25	9.50	8.8	4.2
15	4.00	18.50	16.3	4.6
16	4.00	18.50	16.3	4.6
17	1.50	6.50	6.1	4.3
18	2.00	7.50	6.9	3.8
	Average ratio			5.0

Where:

t = time of decolorization of thionin with 2.7 per cent thioglycollate.
t' = time of decolorization of methylene blue.
R.S.' = relative stability calculated from t'.
t'/t = ratio of time of decolorization of methylene blue, used as directed in *Standard Methods*, to thionin to which 2.7 per cent thioglycollate has been added.

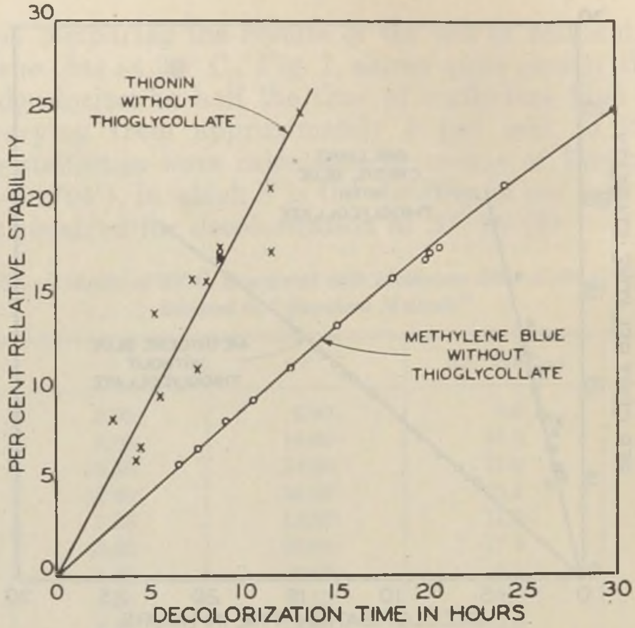

FIG. 3.

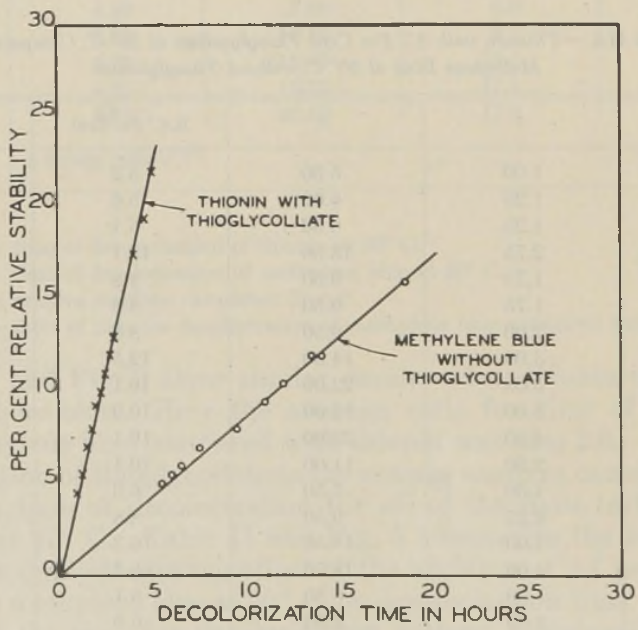

FIG. 4.

blue, a sample possessing a relative stability of 15 per cent would require about 17 hours to decolorize; whereas, a sample treated with brilliant cresyl blue with added thioglycollate requires only 3½ hours to decolorize. This is approximately one-fifth the time.

Table IIA and Fig. 4 summarize the results with thionin to which 2.5 per cent thioglycollate has been added. Comparison of Fig. 4 with

TABLE III.—*Methylene Blue with 2.7 Per Cent Thioglycollate at 20° C. Compared with Methylene Blue at 20° C. without Thioglycollate*

Exp. No.	t	t'	R.S.′ Per Cent	t'/t
1	3.25	5.50	5.2	1.7
2	3.50	6.00	5.6	1.7
3	3.50	6.00	5.6	1.7
4	19.00	37.00	29.9	1.9
5	2.00	4.50	4.3	2.3
6	17.00	34.00	27.7	2.0
7	3.25	6.50	6.1	2.0
8	8.00	13.50	12.1	1.7
9	2.50	6.00	5.6	2.4
10	12.50	25.00	21.3	2.0
11	4.25	8.00	7.4	1.9
12	4.50	8.00	7.4	1.8
13	5.00	9.50	8.8	1.9
14	5.00	9.50	8.8	1.9
15	5.75	15.00	13.5	2.6
16	4.75	9.50	8.8	2.0
17	7.75	15.50	13.9	2.0
18	7.25	11.50	10.5	1.6
19	7.00	13.50	12.1	1.9
20	7.25	14.00	12.5	1.9
21	5.50	13.00	11.7	2.4
22	6.50	22.00	19.1	3.4
23	5.25	7.50	6.9	1.4
24	5.75	12.50	11.3	2.2
25	5.75	9.00	8.4	1.6
26	8.75	15.50	13.9	1.8
27	5.00	8.00	7.4	1.6
28	10.00	22.00	19.1	2.2
29	7.75	12.00	10.9	1.6
30	14.75	22.00	19.1	1.5
31	7.75	11.00	10.1	1.4
32	14.50	22.50	19.5	1.5
33	4.00	7.50	6.9	1.9
34	5.00	9.50	8.8	1.9
35	8.50	18.50	16.3	2.2
36	8.50	18.50	16.3	2.2
37	4.50	6.50	6.1	1.5
38	3.75	9.50	8.8	2.5
39	3.75	7.00	6.5	1.9
40	1.75	3.50	3.4	2.0
41	3.25	6.50	6.1	2.0
42	2.00	6.50	6.1	3.3
43	4.00	7.00	6.5	1.8
44	5.50	11.00	10.1	2.0
45	8.00	12.00	10.9	1.5
46	7.50	13.00	11.7	1.8
	Average ratio			2.0

Where:

t = time of decolorization of methylene blue at 20° C. with 2.7 per cent thioglycollate.
t' = time of decolorization of methylene blue at 20° C.
R.S.′ = relative stability calculated from t'.
t'/t = ratio of time of decolorization of methylene blue without thioglycollate to methylene blue with 2.7 per cent thioglycollate added.

Fig. 2 clearly indicates the similarity of the thionin results with those obtained using brilliant cresyl blue. Here again the test samples decolorized in about one-fifth the time for decolorization of methylene blue.

At 37° C. the addition of 2.7 per cent thioglycollate to either brilliant cresyl blue or to thionin (Tables IV, V) gave such short periods of decolorization that it was felt that the results introduced a large subjective error. These results are tabulated in Tables IV and V. When 2.7 per cent thioglycollate was added to methylene blue (Table VI) the time for

TABLE IV.—*Brilliant Cresyl Blue with 2.7 Per Cent Thioglycollate at 37° C. Compared with Methylene Blue Used as Directed in "Standard Methods" at 20° C. and without Thioglycollate*

Exp. No.	t_{37}	t_{20}	R.S.′ Per Cent	t_{20}/t_{37}
1	0.25	5.50	5.2	22.0
2	0.50	6.00	5.6	12.0
3	0.50	6.00	5.6	12.0
4	0.25	6.50	6.1	13.0
5	1.00	13.50	12.1	13.5
6	0.50	6.00	5.6	12.0
7	0.50	8.00	7.4	16.0
8	0.75	9.50	8.8	12.7
9	0.75	9.50	8.8	12.7
10	1.00	15.00	13.5	15.0
11	0.75	9.50	8.8	12.7
12	2.00	15.50	13.9	7.7
13	1.25	11.50	10.5	9.3
14	1.50	13.50	12.1	9.0
15	1.50	14.00	12.5	9.4
16	1.75	13.00	11.7	7.4
17	1.00	22.00	19.1	22.0
18	0.50	7.50	6.9	14.9
19	0.50	9.00	8.4	18.0
20	2.00	22.00	19.1	11.0
21	1.00	12.00	10.9	12.0
22	2.00	22.50	19.5	11.2
23	3.25	22.50	19.5	6.7
24	0.50	7.50	6.9	14.9
25	1.25	9.50	8.8	7.6
26	1.25	18.50	16.3	14.8
27	1.25	18.50	16.3	14.8
28	0.25	5.00	4.7	20.0
29	0.50	6.50	6.1	13.0
30	1.00	13.00	11.7	13.0
	Average ratio			13.0

Where:

t_{37} = time of decolorization of brilliant cresyl blue at 37° C., with 2.7 per cent thioglycollate.

t_{20} = time of decolorization of methylene blue, used as directed in *Standard Methods*.

R.S.′ = relative stability calculated from t_{20}.

t_{20}/t_{37} = ratio of time of decolorization of methylene blue, used as directed in *Standard Methods*, to brilliant cresyl blue to which 2.7 per cent thioglycollate has been added.

decolorization at 37° C. was approximately one-fourth to one-fifth the time required when methylene blue was used at 20° C. without the thioglycollate.

Comparing the results of the modified technique, *i.e.*, one using 2.7 per cent thioglycollate with either brilliant cresyl blue or thionin, with the results of the standard technique, one can see from Figs. 2 and 4 that for relative stabilities up to 20 per cent cent the determination can be made in less than 8 hours. The standard technique requires 20 to 25 hours to accomplish the same result. In general, the color change of brilliant cresyl blue seemed clearer than that of thionin, and the end-point appeared to be easier to distinguish.

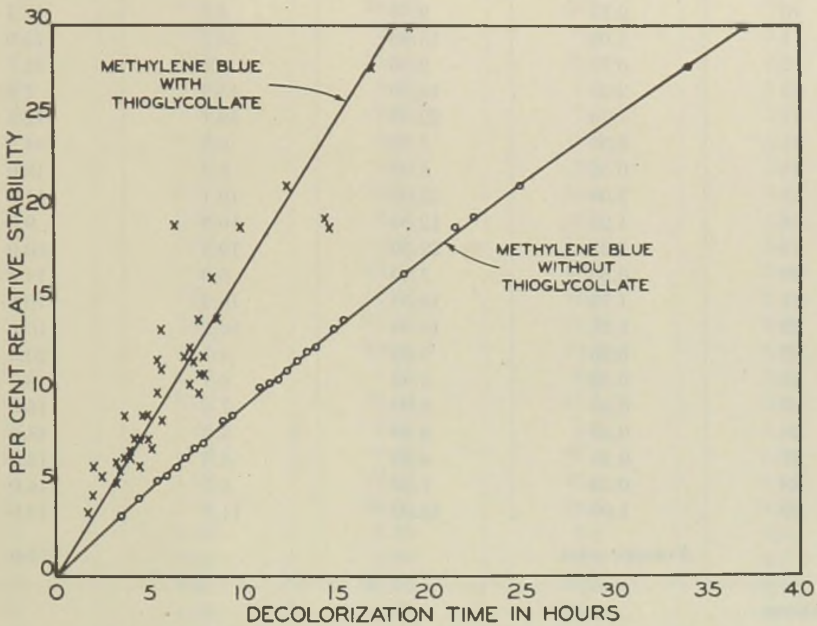

Fig. 5.

The speed of decolorization of any dye is the result of the interrelation of many complex oxidation-reduction reactions occurring simultaneously. Thus no attempt has been made to offer any detailed explanation for the observed phenomena. However, it does appear that the addition of thioglycollate quite probably improves conditions for the growth of both facultative and strict anaerobes, and this is reflected in the increased speed of decolorization. Whether there is any correlation between results obtained with these dyes, either with or without thioglycollate, and the biochemical oxygen demand of the sewage is an interesting speculation. If there were any such correlation, one could prophesy the 5-day B.O.D. within a few hours. Certainly there is the prospect that the speed of the relative stability test may be increased by changing the conditions standard to the procedure and by changing from methylene blue to other dyes. Where it is necessary to determine

Table V.—*Thionin with 2.7 Per Cent Thioglycollate at 37° C. Compared with Methylene Blue Used as Directed in "Standard Methods" at 20° C. and without Thioglycollate*

Exp. No.	t_{37}	t_{20}	R.S.′ Per Cent	t_{20}/t_{37}
1	0.25	5.50	5.2	22.0
2	0.50	6.00	5.6	12.0
3	0.50	6.00	5.6	12.0
4	0.25	5.50	5.2	22.0
5	0.50	6.50	6.1	13.0
6	1.00	13.50	12.1	13.5
7	0.50	6.00	5.6	12.0
8	0.50	8.00	7.4	16.0
9	0.75	9.50	8.8	12.7
10	0.75	9.50	8.8	12.7
11	1.00	15.00	13.5	15.0
12	0.75	9.50	8.8	12.7
13	2.25	15.50	13.9	7.6
14	1.75	22.00	19.1	12.6
15	0.50	7.50	6.9	14.9
16	0.50	9.00	8.4	18.0
17	2.00	22.00	19.1	11.0
18	1.25	12.00	10.9	9.6
19	2.25	22.50	19.5	10.0
20	0.50	7.50	6.9	14.9
21	1.75	18.50	16.3	10.6
22	1.75	18.50	16.3	10.6
23	0.25	5.00	4.7	20.0
24	0.50	6.50	6.1	13.0
25	0.50	8.00	7.4	16.0
26	0.50	9.50	8.8	18.0
27	0.25	4.50	4.3	18.0
28	0.50	7.00	6.5	14.0
29	1.00	13.00	11.7	13.0
	Average ratio			13.0

Where:

t_{37} = time of decolorization of thionin at 37° C. with 2.7 per cent thioglycollate.

t_{20} = time of decolorization of methylene blue, used as directed in *Standard Methods.*

R.S.′ = relative stability calculated from t_{20}.

t_{20}/t_{37} = ratio of time of decolorization of methylene blue, used as directed in *Standard Methods,* to thionin to which 2.7 per cent thioglycollate has been added.

relative stability in a shorter time than that required by methylene blue, the thioglycollate medium and brilliant cresyl blue are suggested.

Summary and Conclusion

Using the technique of the relative stability test, a total of 426 tests with sewage influents and effluents were made. The dyes brilliant cresyl blue and thionin decolorized more quickly than methylene blue at 20° C. For relative stabilities varying from 5 per cent to 25 per cent, brilliant cresyl blue and thionin decolorized in half the time of methylene blue.

The addition of thioglycollate to the sewage samples markedly decreased the time for decolorization with all of the dyes used. Thus methylene blue at 20° C. decolorized in half the time when 2.7 per cent thioglycollate was added. At 37° C. it decolorized in approximately one-fifth time.

TABLE VI.—*Methylene Blue with 2.7 Per Cent Thioglycollate at 37° C. Compared with Methylene Blue Used as Directed in "Standard Methods" at 20° C. and without Thioglycollate*

Exp. No.	t_{37}	t_{20}	R.S.$_{20}$	t_{20}/t_{37}
1	1.00	5.50	5.2	5.5
2	1.50	6.00	5.6	4.0
3	1.50	6.00	5.6	4.0
4	9.25	37.00	29.9	4.0
5	8.75	34.00	27.7	3.9
6	1.50	6.50	6.1	4.3
7	6.25	25.00	21.3	3.9
8	1.50	8.00	7.4	5.3
9	1.75	8.00	7.4	4.6
10	2.50	9.50	8.8	3.8
11	2.50	9.50	8.8	3.8
12	3.00	15.00	13.5	5.0
13	2.00	9.50	8.8	4.7
14	5.00	15.50	13.9	3.1
15	2.50	13.50	12.1	5.4
16	2.75	14.00	12.5	5.1
17	4.00	13.00	11.7	3.3
18	5.75	22.00	19.1	3.8
19	1.50	7.50	6.9	5.0
20	2.50	12.50	11.3	5.0
21	1.75	9.00	8.4	5.1
22	1.50	8.00	7.4	5.3
23	4.50	22.00	19.1	4.9
24	5.25	22.50	19.5	4.3
25	1.50	7.50	6.9	5.0
26	2.00	9.50	8.8	4.7
27	4.50	18.50	16.3	4.1
28	4.50	18.50	16.3	4.1
29	1.00	5.00	4.7	5.0
30	1.50	6.50	6.1	4.3
31	2.00	9.50	8.8	4.7
32	1.00	4.50	4.3	4.5
33	1.50	6.50	6.1	4.3
34	1.75	6.50	6.1	3.7
35	2.00	7.00	6.5	3.5
36	1.25	6.00	5.6	5.2
37	1.50	6.50	6.1	4.3
38	1.75	7.50	6.9	4.3
39	2.50	13.00	11.7	5.2
	Average ratio			4.5

Where:

t_{37} = time of decolorization of methylene blue at 37° C.
t_{20} = time of decolorization of methylene blue at 20° C.
R.S.$_{20}$ = relative stability calculated from t_{20}.
t_{20}/t_{37} = ratio of time of decolorization of methylene blue at 20° C. to time of decolorization of methylene blue at 37° C. with thioglycollate.

Brilliant cresyl blue with thioglycollate at 20° C. decolorized in about one-fifth the time required for the standard methylene blue test. Thionin acted similarly. Since the end point with thionin is difficult to distinguish, its use is not recommended. However, a dependable estimate of relative stability of a sewage sample may be obtained in approximately one-fifth the time required by the standard methylene blue procedure by using brilliant cresyl blue along with 2.7 per cent sodium thioglycollate stock solution.

Thus, if the time of decolorization of a sample treated with brilliant cresyl blue and thioglycollate is multiplied by five, this result may be substituted in Phelps' formula which is based on the standard methylene blue procedure.

Results from additional tests on a larger number of sewage samples tested with brilliant cresyl blue and thioglycollate might warrant the calculation of a different value for the constant k (0.794) in Phelps' formula $S = 100\ (1–0.794^t)$.

The writers wish to acknowledge the technical assistance of Mr. Fred V. Rowland * in carrying out many of the tests.

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Industrial Wastes

VOLUME CHARACTERISTICS AND DISPOSAL OF LAUNDRY WASTES *

By Harry W. Gehm

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One of the most common liquid wastes present in sewage is laundry waste. It is one which every municipal sewage treatment plant is required to handle during at least one day of the week. Plants serving institutions and those to which commercial laundries are connected often receive considerable laundry waste throughout the entire week, because the most common method of disposal of such waste is by treatment with the sewage.

Domestic laundry waste normally makes up only 5 to 10 per cent of the average daily flow of sewage. The fact that it is generally received in quantity at a sewage plant during a part of the day can result in periodic concentrations in the sewage exceeding this percentage to a considerable degree. On account of fluctuations in flow, strength and characteristics, chemical and biological processes can be seriously affected. This is true of small plants, particularly those serving communities of low water consumption. While most plants treating in excess of five m.g.d. find that it has relatively little effect on volume and strength of sewage, hundreds of small plants find a major treatment problem arising on days when the wash water content of the sewage is high. In considering the effect of laundry wastes on sewage flows and character, we have limited our observations to relatively small sewerage systems, since, as pointed out, this is mainly a small plant problem.

Discharge of commercial laundry waste into sanitary sewers frequently causes complaints from the small sewage plant operator concerning difficulties and interference with the treatment processes. Major objections generally come from plants receiving relatively large volumes of the waste due to washing of clothes collected from a wide area or other communities and from those serving cantonments. Supporting data, however, seldom accompany such statements. One comprehensive follow-up and evaluation of the effect of laundry waste on a trickling filter plant is reported by Riker (18). The plant investigated received 25 per cent of the total daily flow in laundry waste from a commercial laundry, which raised the plant loading, in terms of oxygen consumed and suspended solids, more than 100 per cent over that of the domestic sewage alone. The oxygen consumed value of the effluent rose

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100 per cent, suspended solids 600 per cent, and nitrification was greatly reduced when the waste was treated with the sewage.

Difficulties at plants treating the sewage from army establishments are reported by Kessler and Norgaard (10), although data supporting the statement are not presented. Ridenour (17), in a survey of institutional treatment in New Jersey, which was supported by many test data, makes no mention of laundry waste as a problem, despite the fact that considerable quantities of such waste were handled.

Hood (8) experienced difficulty with alum coagulation of sewage when laundry waste concentrations were high. The high alum dosages required under these conditions affected sludge digestion as the sludge became acid.

The purpose of this paper is (1) to evaluate the effect of laundry waste on the flow and character of municipal and institutional sewage, (2) to determine at what percentage of waste, in relation to sewage flow, necessary pretreatment is indicated, (3) what methods of pretreatment are practical, and (4) by what method the waste should be handled under different conditions. It is hoped that the information presented will serve to clarify our viewpoint regarding this waste as it affects sewage treatment and point out the most practical solution to the problem.

Effect of Laundry Waste on Sewage Flows

Domestic

As previously stated, the quantity of laundry waste received at a municipal plant is estimated at between 5 and 10 per cent of the average daily flow. Flow data collected from four small municipal plants, treating practically nothing but domestic flow (Fig. 1), substantiate these assumptions.

The percentages of variation from the mean week-day flow for each day are shown for annual averages exclusive of wet-weather flows. These four communities each represented a distinct type. One, consisting primarily of day labor families of which a high percentage of the female population is employed outside the home, is designated as City A. Increases in flow higher than the five-day average are experienced on both Monday and Tuesday but amount to only about 2 per cent each day. Much of the laundering evidently is carried on at off hours throughout the entire week. Municipality B represents a community of more or less average middle class. Sewage flows were found to exceed the average by 6.3 per cent on Monday and 2.4 per cent on Tuesday. Evidently practically all of the washing is done on these two days on account of regular schedules of the non-working housewives. The third town C, represents largely a high middle income population. Here the sewage flow on Mondays exceeded by 7.9 per cent the five-day average. Tuesday flow decreased to the five-day average. It is evident from this that practically all the laundry is done on Monday, undoubtedly by household help held to strict routine. The fourth community D, a wealthy one, showed increases over the average of but 4.4 per cent on

Mondays and 1.7 per cent on Tuesdays over the five-day average. Most of the laundry of this community is evidently done out and the remaining by resident help on Mondays.

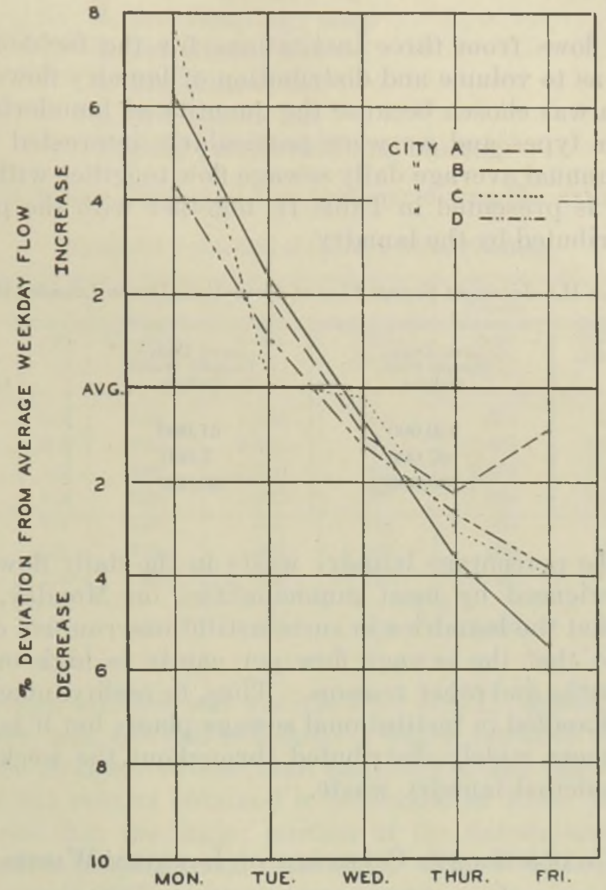

Fig. 1.—Effect of laundering on municipal sewage flows.

The significance of the above observations is that in most towns the laundry waste is distributed over two or more days with the one exception. The range of from 5 to 10 per cent of the average daily dry weather flow is a fair estimate, as judged from the calculations made from the flow data of these four communities (Table I).

Table I.—*Increased Sewage Flow Due to Laundry Waste*

Municipality	Per Cent of Average Daily Flow
A	5.4
B	7.6
C	6.8
D	6.2
Average	6.5

Though all these percentages are lower than 10 per cent, incidental irregular washing, which cannot be estimated, would probably raise the actual percentage to a higher figure.

Institutional

Laundry flows from three institutions for the feeble-minded were investigated as to volume and distribution of laundry flows. This type of institution was chosen because the quantity of laundering is greater than in other types and we were particularly interested in maximum flows. The annual average daily sewage flow together with the average laundry flow is presented in Table II, together with the percentage of the flow contributed by the laundry.

TABLE II.—*Increased Sewage Flow at Institutions Due to Laundry Waste*

Institution	Ave. Daily Sewage Flow, Gallons	Ave. Daily Laundry Waste, Gallons	Per Cent of Daily Flow Laundry Waste
A	950,000	61,000	6.4
B	97,000	7,000	7.2
C	1,708,000	80,000	7.2

Though the percentage laundry waste in the daily flow is the same as that experienced by most municipalities on Monday, it must be pointed out that the laundries in such institutions run five or more days per week and that the sewage flow per capita is high on account of therapeutic baths and other reasons. Thus, in reality, much more laundry waste is handled in institutional sewage plants but it is more highly diluted and more widely distributed throughout the week than is the case with municipal laundry waste.

Character and Strength of Laundry Wastes

Analyses of commercial laundry waste are common in the literature. The most extensive are those presented by Rudolfs and Setter (19), Kline (11), and Eldridge (4). The value of the data published, however, is limited, for it covers commercial waste only and represents either catch or equalized samples. No analysis of the waste from each distinct laundry operation was found, nor were any figures on domestic laundry waste available. Some institutional laundry waste data were found, but as such laundries operate in much the same manner as commercial laundries, analyses were very similar to those recorded for the waste of such establishments.

From the treatment angle it is often well to know the character of each separate waste discharged from an industry, because a considerable portion may not require treatment and separate discharge may facilitate the treatment of the remainder. With this thought in mind, samples of each cycle of an average wash for a large commercial laundry were collected. These cycles with the chemicals employed were as follows:

1. Break; washing soda
2. 1st Soaping; soap
3. 2nd Soaping; soap
4. 1st Rinse; hot
5. 2nd Rinse; hot
6. 3rd Rinse; hot
7. Sour; citric acid and blueing

The volume of water employed for each cycle was the same.

TABLE III.—*Analysis of Laundry Waste Fractions*

Sample	pH	Total Alkalinity, p.p.m.	Total Solids, p.p.m.	Ash of Total Solids, p.p.m.	Volatile Matter of Total Solids, p.p.m.	B.O.D. (5-day), p.p.m.	Grease, p.p.m.
Break	9.3	748	1,306	632	674	355	25
1st Soaping	9.2	900	3,444	976	2,468	3,950	1,698
2nd Soaping	9.2	940	3,426	856	2,570	4,500	1,779
1st Rinse	9.2	360	1,292	268	1,024	1,500	705
2nd Rinse	8.9	180	532	184	348	515	231
3rd Rinse	8.5	124	294	106	188	176	109
Sour and Blue	7.4	60	258	178	80	32	43
Combined	9.0	473	1,507	457	1,050	1,575	656

Each of these samples was analyzed for B.O.D., grease, total solids, volatile matter, ash, pH and alkalinity. Equal portions of each of the fractions were composited and then analyzed in the same manner. A tabulation of the results obtained is presented in Table III, inspection of which shows that the major portion of the decomposable matter is found in the two soapings and first rinse. The B.O.D. of these three fractions averaged 3317 p.p.m. as compared to a 270 p.p.m. average for the remaining four fractions (Table IV). The B.O.D. of the latter is

TABLE IV.—*Analysis of Combination of Commercial Laundry Waste Fractions*

Sample	pH	Total Alkalinity, p.p.m.	Total Solids, p.p.m.	Volatile Matter, p.p.m.	Ash, p.p.m.	Grease, p.p.m.	B.O.D. (5-day), p.p.m.
Ave. two soapings and 1st rinse	9.2	733	2,721	2,021	700	1,394	3,317
Ave. remaining fractions	8.5	278	598	275	323	102	270
Ave. combined waste	9.0	440	1,507	1,062	457	656	1,430

in the range of domestic sewage, whereas the former is about 13 times as high. It is appreciated that laundry practice varies considerably and not only depends upon the character of the material washed, but the discretion of the laundryman. However, the data in Table III will serve to illustrate the observation that more than 50 per cent of such waste is not high in strength.

Commercial and domestic laundry wastes are inclined to differ considerably for the following reasons: (1) softening of all except very soft waters is almost universally practiced in commercial laundries, but not frequently in households; (2) soaping is well controlled in commercial laundries, but generally excessive in domestic washing; (3) bleaches, sizes, acids, silicates, fluorides, alkalies and other chemicals are more widely used by commercial laundries, and (4) commercial washing generally employs much more rinse water than domestic washing.

Difference in strength and character of the two types is evident from the analyses of three typical commercial and domestic wastes presented in Table V. B.O.D. values of the domestic waste, where water contained 250 p.p.m. of hardness, ran from two to three times that of commercial waste, whereas the pH and alkalinity of domestic waste were much lower, never exceeding 8.4, and therefore contained no carbonate or caustic alkalinity.

TABLE V.—*Analyses of Commercial and Domestic Laundry Wastes*

Analysis in p.p.m.	Commercial				Domestic			
	A	B	C	Ave.	A	B	C	Ave.
pH	10.8	9.0	11.0	10.3	7.6	7.9	8.7	8.1
Total Alkalinity	492	440	600	511	585	530	920	678
Total Solids	2,636	1,507	2,200	2,114	2,990	3,875	3,076	3.314
Volatile Solids	1,962	1,062	1,590	1,538	2,280	2,908	2,356	2,515
Ash	672	457	610	579	710	963	720	731
B.O.D. (5-day)	2,280	1,430	1,870	1,860	3,600	4,160	3,680	3,813
Oxygen Consumed	995	699	911	868	945	1,210	980	1,045
Grease	556	656	450	554	1,254	1,688	1,277	1,406

Both household and commercial laundry practice varies and both stronger and weaker samples of such waste as those presented here are frequently observed. This fact is brought out clearly by analytical data published by Rudolfs and Setter (19) showing maximum, minimum and average figures for a large number of samples. Domestic samples were collected by combining in proportion to volume one soaping and two rinses of a wash of average size and character where a water of 250 p.p.m. hardness was employed. Commercial waste samples contained proportional parts of each washing cycle from so-called white washes of household textiles where softened water was employed. Combined commercial waste might be expected to be somewhat lower in strength than the figures presented because spillage, condensate and other discharges of relatively clean waters would be included. The general composition and proportions of the constituents, however, would be similar to the collected samples. That the strength is not far from the average for this region is borne out by an average total solids of composite samples taken from forty laundries in New Jersey (19) which ran 2,678 p.p.m. as compared to the 2,114 p.p.m. average for the three samples presented in Table V.

Of considerable interest in reference to these analyses is the fact that ratios of the various analyses in commercial waste are rather uniform for all samples as shown in Table VI. This is as might be expected, as the main constituent of laundry waste is soap of fairly uniform composition. Knowledge of such ratios is important in that from one or two of the more rapid determinations we can estimate, within rough limits, the quantities of other constituent analyses, thus facilitating surveys of laundry waste problems. As the main difference in commercial practice is most likely to be the quantity of rinse water employed, the ratios given in Table VI will probably hold for any combined commercial laundry waste within practical limits. As examples of the use of this table the B.O.D. can be estimated by multiplying determined oxygen consumed values by 2.2 or the determined total solids by 1.1.

TABLE VI.—*Ratios of Analyses of Commercial Laundry Waste*

Multiply first analysis by number to obtained second analysis	A	B	C	Average
O.C. to B.O.D.	2.3	2.1	2.1	2.2
O.C. to Grease	0.6	0.9	0.5	0.6
O.C. to Total Solids	2.6	2.2	2.4	2.5
O.C. to Volatile Solids	2.0	1.5	1.7	1.8
B.O.D. to O.C.	0.4	0.5	0.5	0.5
B.O.D. to Grease	0.2	0.5	0.2	0.3
B.O.D. to Total Solids	1.2	1.1	1.2	1.1
B.O.D. to Volatile Solids	0.9	0.7	0.9	0.8
Total Solids to O.C.	0.4	0.5	0.4	0.4
Total Solids to Grease	0.2	0.4	0.2	0.3
Total Solids to B.O.D.	0.9	1.0	1.2	1.1
Total Solids to Volatile Solids	0.7	0.7	0.7	0.7
Volatile Solids to O.C.	0.5	0.7	0.6	0.6
Volatile Solids to Grease	0.3	0.6	0.3	0.4
Volatile Solids to B.O.D.	1.2	1.3	1.2	1.2
Volatile Solids to Total Solids	1.3	1.4	1.4	1.4
Grease to O.C.	1.8	1.1	2.0	1.6
Grease to B.O.D.	4.1	2.2	4.2	3.4
Grease to Total Solids	4.7	2.3	4.9	3.8
Grease to Volatile Solids	3.5	1.7	3.5	2.8

The linear relationship between the volatile matter of the total solids and the B.O.D. is evident from Fig. 2, where the B.O.D. in p.p.m. is plotted against the p.p.m. volatile matter in the total solids, from all data available on commercial laundry waste.

McCarthy (12) and others have directed attention to the rapidity with which laundry waste can be oxidized by aerobic devices. No information in the form of B.O.D. rate curves for laundry waste, however, were found in the literature. Knowledge of such rates would give us an idea of the behavior of such waste in regard to self-purification in a stream, and the relative rate of oxidation in treatment devices.

For this work typical samples of combined commercial and domestic laundry waste were collected and B.O.D. determinations made with seeded and supplemented dilution water. Tests were run after 1, 2, 3, 5,

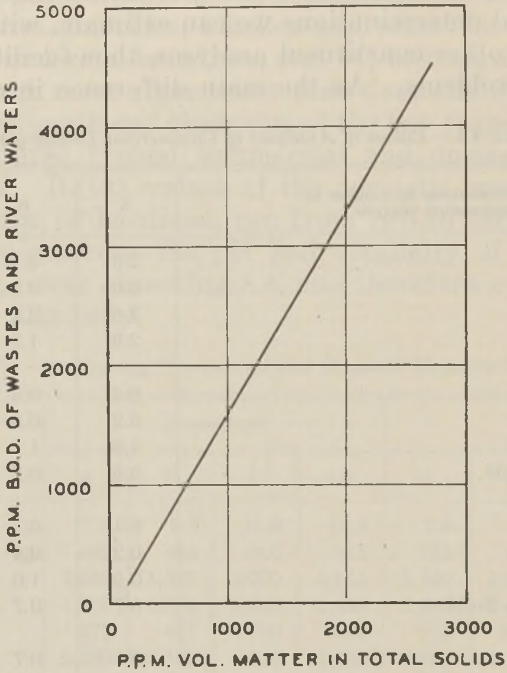

FIG. 2.—Relationship between volatile matter and B.O.D. in laundry waste.

7, 10, 15, and 20 days. The data thus obtained were calculated in terms of percentage of the 20-day B.O.D. and plotted along with the Theriault (23) curve for sewage as shown in Fig. 3.

Comparison of the curves reveals that domestic waste was oxidized at practically the same rate as sewage. Commercial waste showed a first day lag, only 9 per cent of the 20-day B.O.D. having been satisfied as compared to 21 per cent for the sewage. By the second day, however, it had caught up to the sewage and domestic laundry waste level. Tests made to determine the cause of the slag were not fruitful. It is believed that some chemical employed in the process was responsible, because conditions of seeding, minerals addition, and pH were all satisfied to the extent of our knowledge.

In the course of this work several titration curves were made on laundry waste samples. These were of interest in regard to coagulation by acids or acid salts. One hundred ml. samples were titrated with N/10 HCl and pH values measured with a glass electrode.

Typical of all the curves obtained is the one presented in Fig. 4. The buffering effect of the soaps present is clearly shown by the shape of the curve above pH 4.5. Below this value, coagulation is rapid and reaches a maximum around pH 2.5. Addition of more acid, lowering the pH below 2.5, results in marked redispersion.

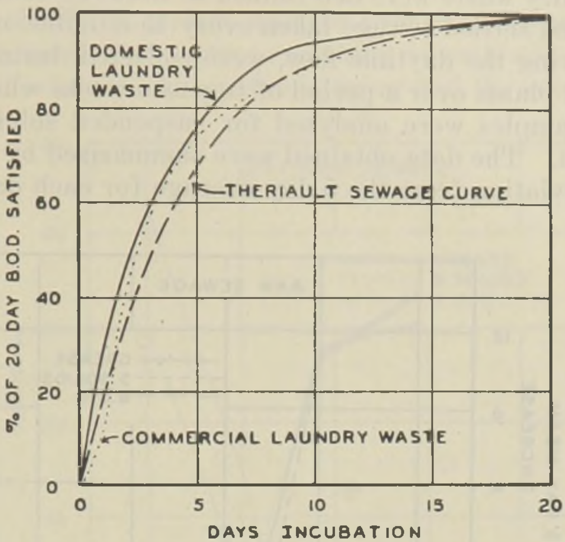

FIG. 3.—B.O.D. rate curves of commercial and domestic laundry waste.

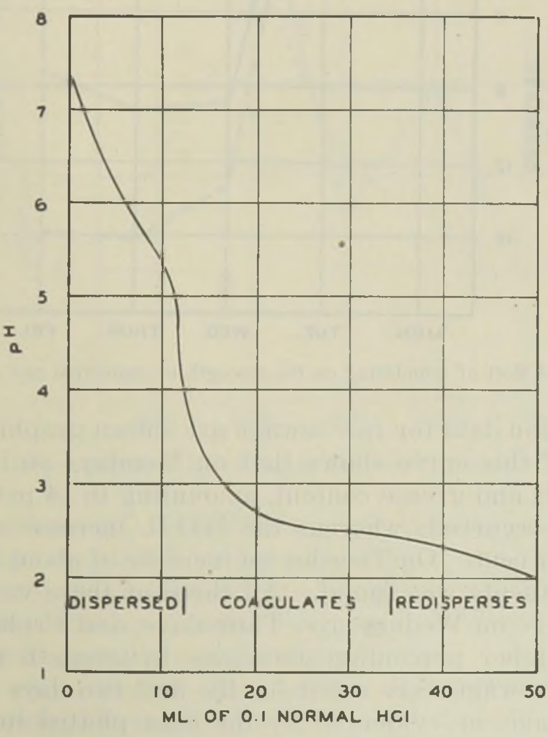

FIG. 4.—Titration curve of laundry waste.

Domestic Laundry Waste as a Constituent of Domestic Sewage

Increases in B.O.D., suspended solids, and grease in domestic sewages received at small plants and containing a normal complement of domestic laundry waste were determined as follows: Composite samples of both raw and settled sewage taken every 15 minutes over a period of 8 hours, covering the daytime flow, were collected during weekdays at two treatment plants over a period of fourteen weeks when dry weather prevailed. Samples were analyzed for suspended solids, B.O.D., and grease content. The data obtained were summarized by calculating the percentage deviation from the 5-day average for each day over the period of test.

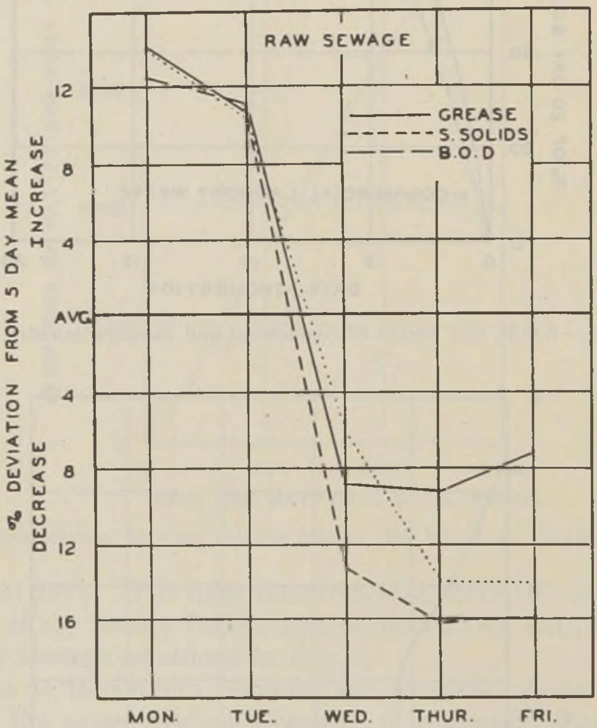

FIG. 5.—Effect of laundering on the strength of municipal raw sewage.

The calculation data for raw sewage are shown graphically in Fig. 5. Examination of this curve shows that on Mondays an increase in the suspended solids and grease content, amounting to 14 per cent over the 5-day average, occurred; whereas the B.O.D. increase amounted to a little over 12 per cent. On Tuesday an increase of about 11 per cent for all three constituents was found. All three of these values fell below the 5-day average on Wednesdays, Thursdays, and Fridays.

Decidedly higher percentage increases in strength than those observed for raw sewage were noted for the first two days of the week in the settled sewage, as evidenced by the data plotted in Fig. 6. Suspended solids and grease increased about 41 per cent and B.O.D. 30 per cent over the 5-day average. Similar to the raw sewage, all analyses show a percentage decrease from the 5-day average for the last three days of the week. The increased values are undoubtedly due to the nature of the laundry waste received on the first two days of the week. The solids are finely dispersed, and the grease and soaps are highly emulsified. Because of this the percentage of settleable solids in the total suspended solids in the sewage is lower and the efficiency of sedi-

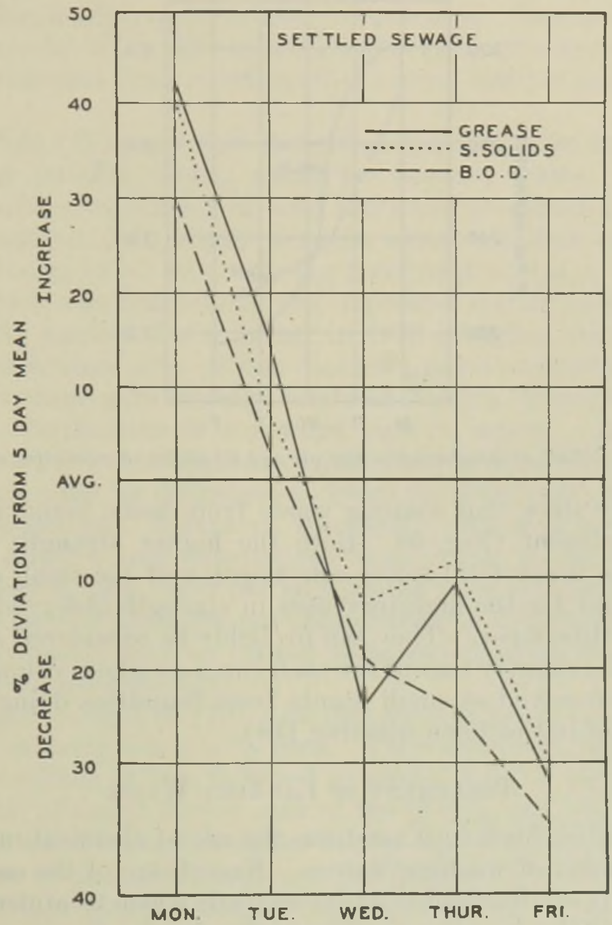

FIG. 6.—Effect of laundering on the strength of municipal settled sewage.

mentation is decreased. Alkalinities and pH values of Monday and Tuesday sewage are raised by domestic laundry waste; this is evident in Fig. 7, showing daily alkalinities and pH values of 8-hour composite samples obtained during 5 days from a plant treating only domestic flow. No caustic and little carbonate alkalinity is evident, as the pH value did not rise over 8.5. Ten catch samples taken at this plant on a Monday morning during dry weather had pH values below 8.4 with the exception of one sample of pH 8.6. This serves to demonstrate that domestic laundry waste does not turn the sewage caustic. Extensive data published by Hood (8) and others verify these findings.

Household laundries account for a substantial rise in strength of small flows of domestic sewage. Some of the increase in strength noted for Monday flows may be the result of flushing out of material settled in sewers during low weekend flow velocities. Both the appearance and chemical character of the Monday discharge received at small

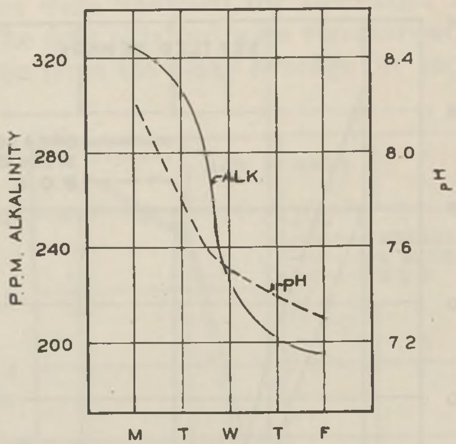

FIG. 7.—Effect of laundering on the pH and alkalinity of municipal sewage.

plants readily show that soaping waste from home laundries is an important constituent (Fig. 5). Both the higher strength of domestic waste and the lower total water consumption of the small communities studied account for the high increases in strength observed in the data presented in this paper. They can probably be considered as maximum figures for this country except for such cases as where commercial laundry waste is received at small plants from laundries doing a considerable amount of out-of-town washing (18).

Treatment of Laundry Waste

Early English literature mentions the use of chemicals and filtration for the treatment of washing waters. Knowledge of the early methods of treatment is summarized in a text on trade waste treatment by Wilson and Calvert (24) who write that lime, alumino-ferric and calcium chloride have been found to be satisfactory coagulants. To obtain further purification than that obtainable with chemicals, filtration is recommended. One process not mentioned by the authors is that of Mead-King (13) advising the use of iron salts or alum and salt water.

The only advance in the chemical treatment of laundry waste over the early English work is the use of acids to replace part of the coagulant when alum or a ferric salt is employed.

Treatment of laundry waste with a combination of alum and sulfuric acid was found by Daniels (2) to be less costly than ferric sulfate-lime or acid-lime treatment. Sakers and Zimmerman (20), however, were able to produce results comparable to acid-alum treatment with ferric sulfate and lime at about equal cost.

Riker (18) suggests the use of sulfuric acid and alum but does not present details of treatment. Boyer (1) presented data on treatment with copperas, ferric sulfate, and alum in conjunction with sulfuric acid. He came to the conclusion that adjustment of the pH to 6.4 to 6.6 with acid prior to addition of the coagulant produced optimum purification at lowest coagulant dosage. Wolman (26) successfully treated this waste with chlorinated copperas and sulfuric acid. Tests of five typical laundry wastes by Wise (25) with 15 different chemicals indicated that calcium chloride and alum constituted the most feasible and economical treatment.

In 1937 Pohl (15) gave data indicating calcium oxide as the poorest and alum the best clarifying agent for laundry waste. The simultaneous use of a combination of acid and alum produced better results with less chemical than either reagent alone. British patents were granted to Jones, et al. (9) covering treatment of soapy wastes with acid-alum which was claimed to give improved results over acid alone. Singleton (21) applied for a patent in 1935 covering the conditioning of wastes and sewage with carbon dioxide prior to coagulation, following tests on sewage with laundry waste at Atlanta, Georgia.

Excellent clarification of a sewage high in laundry waste was obtained by Hood (8) who applied carbon dioxide from burned digester gas on a plant scale by diffusion, to lower the alkalinity and pH prior to alum coagulation. Extensive laboratory coagulation experiments from which relative cost calculations were made, as included in McCarthy's research, also favor pH adjustment with acid and coagulation with alum or ferric sulfate for partial purification of laundry waste. A number of chemicals such as copper salts and hypochlorites were also tried but proved uneconomical.

Kessler and Norgaard (10) experimented at army posts with pretreatment of laundry waste with lime. They assert that application of 428 parts per million of lime followed by aeration and settling will result in the removal of about 35 per cent of the B.O.D. and grease.

A description of a plant designed for the use of acid-alum treatment, including data on such treatment, was published by Snell and Fain (22) in 1942. Another process suitable for the treatment of laundry waste is the Miles acid process (14) which employs flue gas or SO_2 for lowering the pH to induce coagulation. Hommon (7) describes treatment with alum alone, employing 1580 p.p.m.

That oxidation of laundry waste and waste-sewage mixtures can be successfully accomplished on trickling filters has been demonstrated repeatedly. Wilson and Calvert (24) recommend this process for purification, and the data presented by Riker (18) show that considerable oxidizable matter was removed from sewage containing 25 per cent laundry waste by a trickling filter. Eldridge (3 and 4) recommends trickling filter treatment at 1.0 m.g.a.d. McCarthy (12) made a detailed study of treatment of the waste alone on a trickling filter and found that rates of application of 1.5 m.g.a.d. could be handled for periods of several months despite grease loadings up to 490 pounds per acre foot per day, and pH values of 11.0 and alkalinities of 1000 p.p.m. in the raw waste. Grease removal reached 87 per cent, and relative stability of the effluent, 68 per cent. Grease did not accumulate on the filter at this rate, and ripening was rapid. Incomplete experiments at rates as high as 10 m.g.a.d. showed promise of the filter's ability to handle much higher loadings than 1.5 m.g.a.d.

Activated sludge oxidation of laundry waste-sewage mixtures can be accomplished at normal aeration periods if the B.O.D. and grease loading limits are not exceeded by too great a percentage of waste in the mixture. Ridenour (16) presented operational data on an institutional plant which received in excess of 10 per cent laundry waste, from which no difficulty apparently was experienced. By means of laboratory experiments Heukelekian (6) demonstrated the ability of activated sludge to purify sewage to which 25 per cent of laundry waste was added.

Wise (25) experimented with the activated sludge process for the treatment of the waste alone. He found that purification could be accomplished by longer periods of aeration than commonly used for sewage. An interesting innovation consisting of the use of inorganic catalysts was tried. Such additions, however, did not appear to accelerate the oxidation. One difficulty seldom mentioned, but frequently encountered in treating laundry waste with chemicals, is settling. The release of carbon dioxide on treatment causes partial flotation of the sludge. Eliassen and Schulhoff (5) experimented with flotation by vacuation, whereby they obtained better results than by settling.

Our knowledge of laundry waste treatment to date can be summarized by the following statements:

(1) To remove about 75 per cent of oxygen consumed, solids, and grease, laundry waste can be treated most economically by acidification with sulfuric acid, carbon dioxide, or sulfur dioxide, followed by coagulation with alum or ferric sulfate. It also can be coagulated partly and completely by many salts and acids and by lime, but in most cases such treatment is too costly.

(2) Laundry waste can be purified to a high degree by means of a conventional and probably the high-rate trickling filter, or by the activated sludge process if long aeration periods are used.

(3) The sludge obtained can be dried on sand beds directly or very probably digested anaerobically, or filter pressed. Final disposition of undigested sludge can be accomplished by a soap-recovery process or by incineration.

(4) Waste treated by chemical coagulation can be further purified by passage through a biological filter or by the activated sludge process.

(5) Sewage containing any percentage of laundry waste can be treated on a biological filter of adequate capacity and correctly designed for this purpose.

(6) The activated sludge process employing normal aeration periods can handle sewage containing laundry waste in concentrations approaching 20 per cent.

It appears from the above statements that the alkaline character and the presence of chemicals in laundry waste have little effect on the organisms responsible for biological treatment. The concentration of toxic chemicals is low and probably their character is rapidly changed during the laundering process, dissipating their toxicity. The alkaline character of the waste affects coagulation; it is responsible for dispersion of the soaps. This property is valuable in the process but disadvantageous from the standpoint of chemical treatment because a considerable portion of the alkalinity must be destroyed before coagulation can take place.

Study of the published information indicates that to date the most practical and economical method of chemical treatment of laundry waste and sewage containing a high percentage of laundry waste and sewage containing a high percentage of laundry waste is acidification with sulfuric or carbonic acid to a pH value between 4.5 and 6.0, followed by coagulation with alum or ferric sulfate. The use of sulfurous acid does not seem practical, as sulfites formed by such treatment demand oxygen. Other mineral acids such as hydrochloric, nitric, or phosphoric are also suitable but are higher in cost than sulfuric acid. The use of such acids, in diluted form wasted from chemical plants, offers a possibility for laundry waste treatment.

The most attractive of the two commonly used acids is carbonic, particularly in treating sewage high in laundry waste, for the following reasons, pointed out by Hood (8) and Singleton (21):

(1) An abundant supply is available at most sewage plants in the form of burned digester gas.

(2) It can be handled more readily than sulfuric acid and without danger.

(3) When diffused into sewage as CO_2 it is more or less self-controlling, as no matter how much is absorbed the pH never drops below 4.2.

(4) Mineral acidity, which affects sludge digestion adversely, will not appear in the sludge when carbonic acid is applied to destroy the alkalinity. It can occur, however, when mineral acids or large alum dosages are used.

Little information is on record, however, regarding the relative effectiveness of carbonic and sulfuric acids in reducing alum dosages in laundry waste treatment. It is quite possible that sulfuric, the stronger acid, is considerably more effective. In order to determine if this were the case, the following experiment was made.

The waste used in this work consisted of a mixture of three washings, in which soap and sodium orthosilicate were used, and a fourth washing, to which bleach plus three rinsings were added. The chemical analysis of the waste was as follows:

pH	10.8
Total alkalinity	492 p.p.m.
Oxygen consumed	556 p.p.m.
Total solids	2,636 p.p.m.

Liter aliquots of this waste were treated with ferric chloride alone, ferric chloride—carbon dioxide, and ferric chloride with sulfuric acid. Sufficient acid was applied to lower the pH value to 6.0 which is considered an optimum value for coagulation.

The ferric chloride was added with flash mixing in all cases. Carbon dioxide was diffused through the waste prior to ferric chloride treatment, and where sulfuric acid was applied it followed the ferric chloride dosage, a procedure which was found to give the best results. All samples treated were flocculated thirty minutes and settled for one hour. Oxygen consumed and turbidity were determined on all supernatants after treatment. The results obtained are graphically shown in Figs. 8 and 9.

The results showed that although carbon dioxide was not quite so effective as sulfuric acid in reducing the quantity of ferric chloride required to clarify and purify laundry waste when the pH was adjusted to the same value, the difference was small and would not justify the choice of sulfuric over carbonic acid.

The experiments were repeated with alum replacing the ferric chloride, all other conditions being the same. The curves obtained for alum

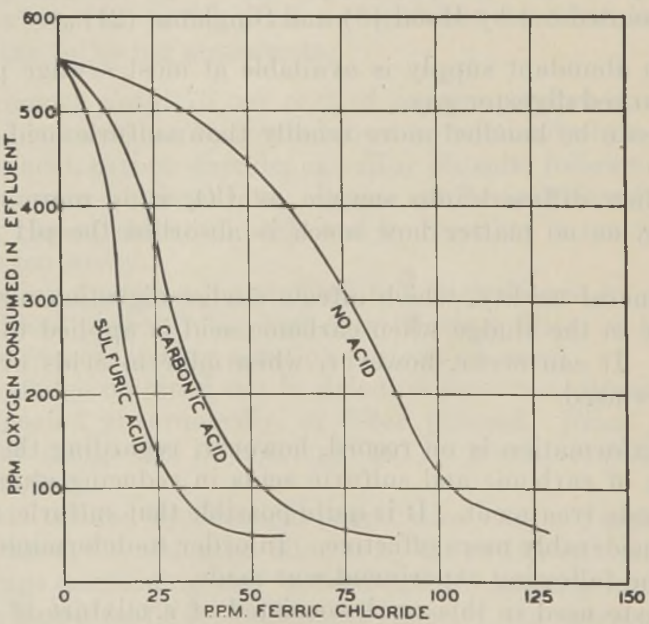

FIG. 8.—Reduction of oxygen consumed value of laundry waste by ferric chloride-acid treatment.

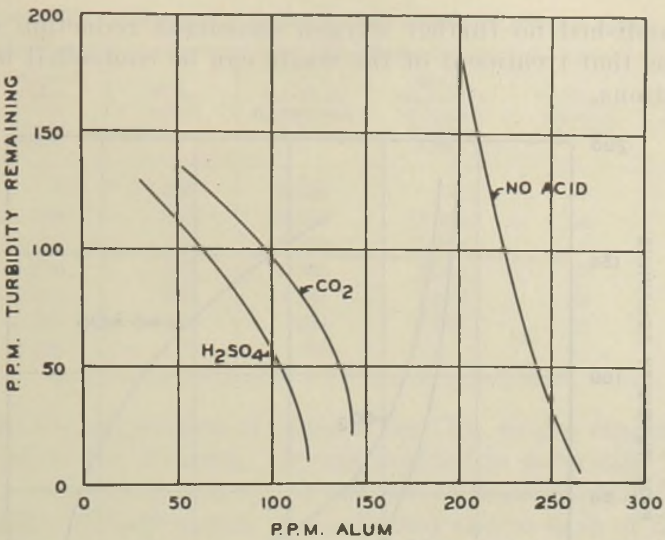

FIG. 9.—Reduction of turbidity of laundry waste by ferric chloride-acid treatment.

(Figs. 10 and 11) show that in respect to acid treatment, results were identical with those obtained with ferric chloride as the coagulant.

Of interest is the progressive removal of both turbidity and oxygen consumed from the waste at increasing coagulant dosages. Comparison of Fig. 8 with Fig. 9 and Fig. 10 with Fig. 11 reveals that a unit removal of turbidity results in a definite increment of oxygen consumed reduction until clarification is complete. After complete clarification

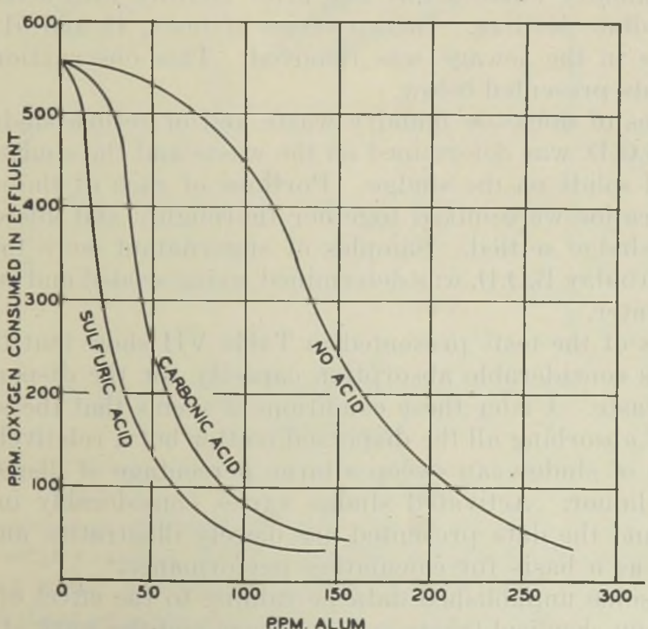

FIG. 10.—Reduction of oxygen consumed value of laundry waste by acid-alum treatment.

was accomplished no further oxygen consumed reduction was found. This means that treatment of the waste can be controlled by turbidity determinations.

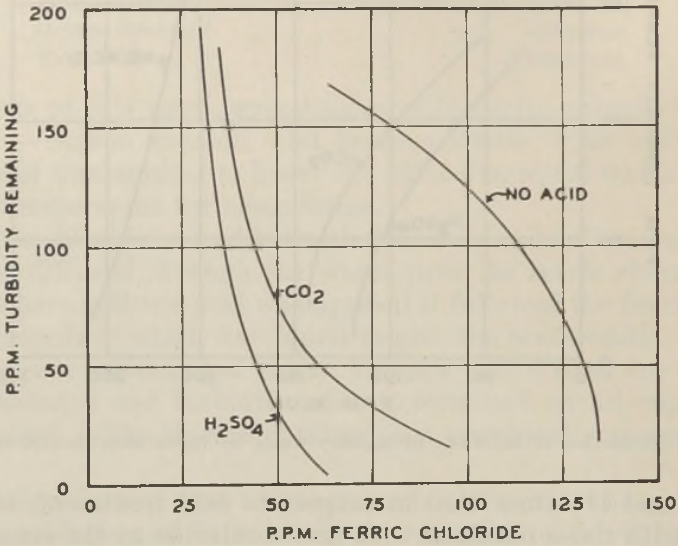

FIG. 11.—Reduction of turbidity of laundry waste by acid-alum treatment.

Rapid absorption of an appreciable quantity of soap dispersion from laundry waste by activated sludge is indicated in data presented by Heukelekian (6). He shows grease analyses on sewage containing 25 per cent laundry waste before and after mixture with activated sludge and immediate settling. In two series of tests, 41 and 51 per cent of the grease in the sewage was removed. This observation led to the experiments presented below.

Samples of domestic laundry waste and of return sludge were collected. B.O.D. was determined on the waste and the sludge liquor, and suspended solids on the sludge. Portions of each of these samples in different ratios were mixed together thoroughly and allowed to stand until the sludge settled. Samples of supernatant were then siphoned off and the 5-day B.O.D. was determined, using seeded and supplemented dilution water.

Results of the tests presented in Table VII show that the activated sludge has considerable absorption capacity for the dispersed soap in laundry waste. Under these conditions it seems that the sludge is not capable of absorbing all the dispersed matter but a relatively small concentration of sludge can sweep a large percentage of dispersed matter from the liquor. Activated sludge varies considerably in absorption capacity and the data presented are merely illustrative and cannot be employed as a basis for calculating performance.

From some unpublished data pertaining to the effect of infiltrating sea water on chemical treatment of sewage and the work of Mead-King (6), it was noted that sea water aided coagulation. This observation,

TABLE VII.—*Absorption of Laundry Waste B.O.D. by Activated Sludge*

Activated Sludge Added, ml.	Activated Sludge Solids Present, mgm.	Waste Added, m.	B.O.D. of Supernatant, p.p.m.	B.O.D. Absorbed by Activated Sludge, p.p.m.	B.O.D. Absorbed, per cent	B.O.D. Absorbed per Mgm. Sludge Solids, mgm.
0	0	1,000	5,328	—	—	—
150	723	850	2,180	2,351	52	3.3
250	1,207	750	2,100	1,900	47	1.6
333	1,610	667	1,500	2,053	57	2.1
500	2,414	500	1,290	1,172	44	0.5
750	3,621	250	330	1,014	75	0.3
1,000	4,828	0	16	—	—	—

together with the suggestion of Mead-King (13) to use coagulants and salt water, led to the decision. It was decided to determine the effect of sea water on laundry waste. A sample of domestic laundry waste having a B.O.D. of 4,160 p.p.m. was collected and to each of five 1-liter portions, sea water sufficient to give final concentrations of 2, 4, 10, 15, and 20 per cent of sea water were added. The mixtures were stirred for five minutes and allowed to settle for thirty minutes, after which, separation was complete. B.O.D. was determined on the supernatants, using seeded and supplemented water, and the result was corrected on the basis of the volume of waste employed.

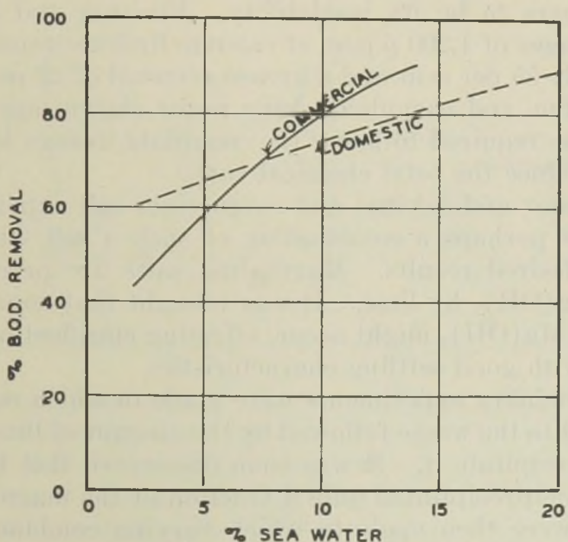

FIG. 12.—Removal of B.O.D. of laundry wastes with sea water.

A similar series of experiments was run on combined waste from a commercial laundry with a B.O.D. of 1,460 in which 2.5, 5, 7.5, 10, and 15 per cent sea water concentrations were used.

Results of these experiments, plotted in Fig. 12, show the effectiveness of sea water in coagulating laundry wastes. When the sea water exceeded 10 per cent the B.O.D. removal approached 90 per cent for both samples. It is also interesting to note that quantities of sea water as low as 2 per cent produced B.O.D. removals in excess of 40 per cent.

The sludge produced by this treatment was very voluminous and did not separate well from the liquor. In most cases some sludge settled and some floated, leaving an ill-defined internatant liquor.

To determine whether the effectiveness of sea water was due to the calcium and magnesium salts present or to a physical "salting out" effect, aliquots of a sample of waste were treated with varying dosages of calcium chloride, magnesium sulfate, and sodium chloride. Both the magnesium and calcium salts demonstrated an ability to coagulate the waste when the concentration of salt in the waste was between 500 and 1,000 p.p.m. Dosages of sodium chloride producing concentrations as high as 20,000 p.p.m. were required to produce coagulation.

The above test showed clearly that the calcium and magnesium salts in the sea water were responsible for coagulation of the laundry waste. It is also apparent from the shape of the B.O.D. removal curves that "salting out" is not the cause of coagulation. Curves illustrative of this phenomenon exhibit less slope at lower concentrations of salt and more slope when the critical concentration producing coagulation is exceeded than do those shown in Fig. 12.

Partial treatment of laundry waste with lime can be obtained, and considerable interest in such treatment exists. The limitation of this chemical appears to be its insolubility. Eliassen and Schulhoff (5) show that dosages of 1,200 p.p.m. of calcium hydrate produced a B.O.D. removal of only 55 per cent and a grease removal of 22 per cent. Combinations of lime and coagulants have never shown much promise, as dosages of lime required to lower the coagulant dosage tended to raise rather than reduce the total chemical cost.

The sea water and calcium and magnesium salt experiments led us to believe that perhaps a combination of such a salt with lime might produce the desired results. Magnesium salts are precipitated from solution as $Mg(OH)_2$ by lime. It was thought that coprecipitation of the soaps and $Mg(OH)_2$ might occur, effecting clarification and producing a sludge with good settling characteristics.

Some preliminary experiments were made in which magnesium sulfate was added to the waste followed by the amount of lime theoretically required to precipitate it. It was soon discovered that the theoretical quantity of lime precipitated only a fraction of the magnesium sulfate. Experiments were then made in which varying combinations of both chemicals were employed. These were conducted as follows: Four series of eight 500 ml. portions of a combined commercial waste having a B.O.D. of 2,460 p.p.m. were set up; to each series 0, 100, 200, and 300 p.p.m. dosages of $MgSO_4$ were added. To consecutive portions of each series lime slurry sufficient to give concentrations of 200, 400, 600, 800, 1,000, 1,200, 1,400, and 1,600 p.p.m. was added. All portions were then stirred at flocculator speed for 15 minutes and allowed to settle for 30 minutes. Supernatant samples were then withdrawn and B.O.D. was determined, using seeded and supplemented water.

The percentages B.O.D. removal observed for all chemical concentrations involved are presented in Fig. 13. Inspection of these curves reveals that the presence of as little as 100 p.p.m. of magnesium sulfate added with 1,000 p.p.m. of lime produced a B.O.D. removal of 90 per cent as compared to the 53 per cent removal produced by 1,600 p.p.m. of lime alone. Removals fell off rapidly, however, when the lime dosage

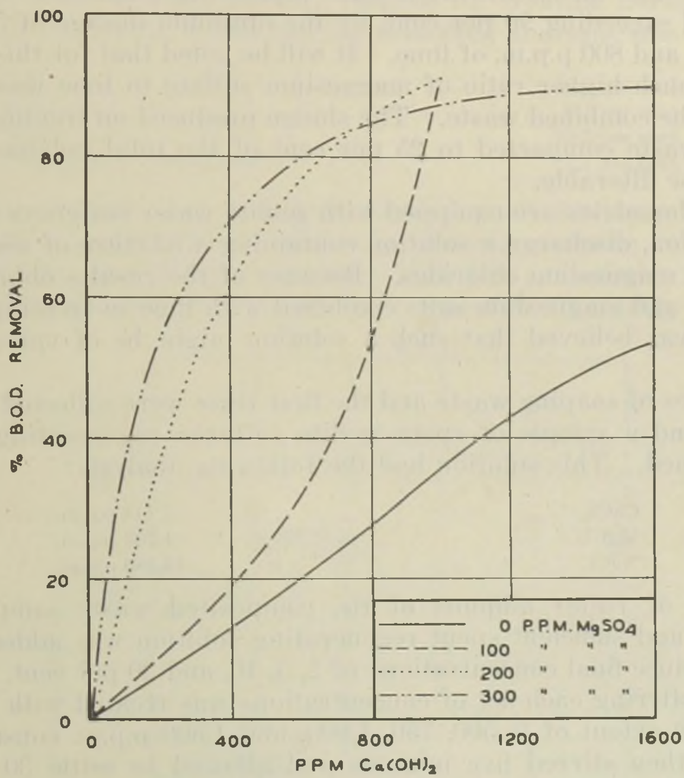

FIG. 13.—Reduction of B.O.D. of laundry waste by treatment with magnesium sulfate and lime.

decreased below 1,000 p.p.m. In the series employing 200 p.p.m. of magnesium sulfate the same amount of lime was required to produce 90 per cent B.O.D. removal as in the 100 p.p.m. magnesium sulfate series; the 300 p.p.m. magnesium sulfate series produced B.O.D. removals in excess of 60 per cent at lime dosages below 400 p.p.m. As distinct from the 100 p.p.m. series, the 200 p.p.m. series produced B.O.D. removals in excess of 60 per cent at lime dosages below 400 p.p.m. The 300 p.p.m. magnesium sulfate series produced results about comparable to the 200 p.p.m. series; the larger dosage appeared to be excessive.

The sludge produced by this process settled rapidly and compacted well. It was found to be filterable, producing a cake of about 70 per cent moisture. The dried cake would burn when ignited, producing ash consisting mainly of magnesia. The magnesia was converted to magnesium sulfate by treatment with sulfuric acid. Experiments showed that magnesium sulfate solution also was produced by treatment of the wet cake with acid. The insoluble fatty acids produced by this treatment floated to the surface of the solution, from which they were recoverable.

An experiment similar to that reported above was made on soaping waste from the same laundry run from which the combined waste was obtained. The initial B.O.D. of 4,220 p.p.m. was reduced to 405 p.p.m., a removal exceeding 90 per cent, by the optimum dosage of 500 p.p.m. of $MgSO_4$ and 800 p.p.m. of lime. It will be noted that for this stronger waste a much higher ratio of magnesium sulfate to lime was required than for the combined waste. The sludge produced on treatment of the soaping waste compacted to 25 per cent of the total volume and was found to be filterable.

Many laundries are equipped with zeolite water softeners which, on regeneration, discharge a solution containing a mixture of sodium, calcium, and magnesium chlorides. Because of the results obtained with sea water and magnesium salts combined with lime in treating laundry waste it was believed that such a solution might be of value for this purpose.

Samples of soaping waste and the first rinse were collected and composited, and a sample of spent zeolite softener regenerating solution was obtained. This solution had the following analysis:

$CaCl_2$	7,144 p.p.m.
$MgCl_2$	1,703 p.p.m.
NaCl	13,489 p.p.m.

Five sets of 1-liter aliquots of the composited waste samples were made up, and sufficient spent regenerating solution was added to each set to produce final concentrations of 2, 5, 10, and 20 per cent. After a minute's stirring each set of concentrations was treated with hydrated lime to the extent of 0, 500, 750, 1,000, and 1,500 p.p.m. consecutively. All were then stirred five minutes and allowed to settle 30 minutes. Samples of supernatant were withdrawn, on which the 5-day B.O.D. was determined.

TABLE VIII.—*Treatment of Soaping Waste and First Rinse with Spent Zeolite Regenerating Solution and Lime* *

$Ca(OH)_2$, p.p.m.	Per Cent by Volume Spent Softener Regenerant				
	0	2	5	10	20
0	2,190	1,860	1,770	690	300
500	2,080	1,530	1,440	280	—
750	1,990	1,020	360	—	—
1,000	1,800	770	260	—	—
1,500	1,500	355	—	—	—

* P.p.m. 5-day B.O.D. remaining after treatment.

Removal of B.O.D. resulting from the coagulation and sedimentation of the dispersed matter in the waste by this treatment is shown in Table VIII. It will be noted that as little as 2 per cent of regenerant added to the waste increased tremendously the effectiveness of lime treatment.

In all cases where lime was employed a rapid settling and compacting sludge was produced. Large percentages of spent regenerant could effect high removals, but the sludge so produced settled poorly.

Waste pickling liquor consisting mainly of ferrous sulfate and sulfuric acid should be a satisfactory reagent for treating laundry waste. A sample of the liquor, which had the following analysis, was obtained:

$FeSO_4$	10.5 per cent
H_2SO_4	8.1 per cent
Water	79.3 per cent
Ferric Iron and Insolubles	2.1 per cent

Five 1-liter aliquots of a combined laundry waste having a B.O.D. of 1,430 p.p.m. were aerated in cylinders. During aeration 0.5, 1.0, 1.5, 2.0, and 2.5 ml. of pickling liquor were added to consecutive cylinders. Aeration was allowed to continue for 5 minutes. Aeration was then

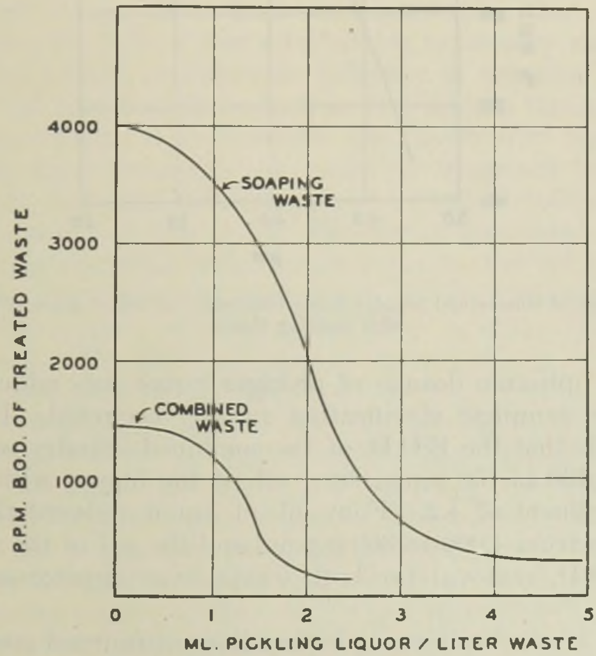

FIG. 14.—Reduction of B.O.D. of laundry wastes by treatment with waste pickling liquor.

stopped and samples of the liquor were immediately withdrawn and pH and B.O.D. determined on them using seeded and supplemented water.

This experiment was repeated with a sample of soaping waste having a B.O.D. of 4,000 p.p.m. In this case 1.0, 2.0, 3.0, 4.0, and 5.0 ml. of pickling liquor were employed and the same analyses made on the effluents obtained.

On addition of pickling liquor to aerating samples of laundry wastes the dispersed material rapidly coagulated and was driven to the surface by the air in the form of a foam. The foam broke down rapidly to form a relatively dry scum of fatty acids and iron soaps which adhered to the walls of the vessel. The volume of this material was very small compared to the amount of sludge formed by other chemical treatment processes and was at least as dry as filter cake produced by vacuum-filtering such sludges.

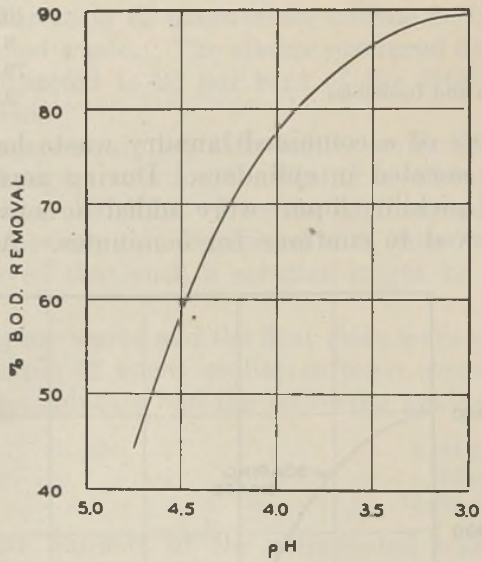

Fig. 15.—pH values of commercial laundry waste treated to various degrees of B.O.D. reduction with pickling liquor.

When the optimum dosage of pickling liquor was added to a given waste sample, complete clarification rapidly occurred. Inspection of Fig. 14 reveals that the B.O.D. of the combined laundry waste was reduced from 1,430 to 150 p.p.m. by 1 ml. of the liquor, with a pH value of the clear effluent of 4.2. Four ml. of liquor reduced the B.O.D. of soaping waste from 4,000 to 360 p.p.m., and the pH of the clear effluent was 3.0. B.O.D. removal for both wastes was approximately 90 per cent.

Somewhat lower dosages of pickling liquor produced good removals; however, in treating soaping waste to more than 70 per cent B.O.D. removal, pH values below 4.2 were observed, which indicates the presence of mineral acidity. The relation between B.O.D. removal and pH values is shown in Fig. 15.

In contrast to the strong soaping waste, complete treatment of the weaker combined laundry waste did not produce mineral acidity in the effluent.

Discussion

Study of the quantities of laundry wastes produced shows that from 5 to 10 per cent of the average weekday municipal sewage flow consists of domestic laundry waste. The B.O.D. of domestic laundry waste samples where a water contained 250 p.p.m. of total hardness, consisting of one soaping and two rinses, ran in the neighborhood of 4,000 p.p.m. Laundry waste produced in communities using softer water would be expected to run somewhat lower, and those with harder water, higher. This appears to be a high figure but the common household tendency toward excessive application of soap flakes or powder undoubtedly accounts for these results. The harder the water, the greater is the quantity of soap required for washing, and the more soap present in the waste, the higher will be the B.O.D. In terms of B.O.D. loading, laundry waste having a B.O.D. of 4,000 p.p.m. added in a quantity of 10 per cent to an average domestic sewage of 200 p.p.m. B.O.D. raises the strength of the sewage in terms of B.O.D. to 545 p.p.m., or almost three times normal. This periodic rise in B.O.D. may be still greater if all the waste is discharged during only a portion of the day as is generally the case. In but few communities, however, is the laundry waste load received in one day. It is also interesting that a municipality which receives the bulk of flow attributable to laundry waste on a single day has experienced considerable difficulty in treating the sewage on that day. The fact that there is some distribution throughout the week in most communities is undoubtedly the reason why domestic laundry waste is not more frequently the cause of treatment troubles. There is little doubt, however, that though not actually troublesome, the laundry waters cause a decline in the efficiency of treatment during the day or days during which the bulk of such water is received at sewage treatment plants. On account of their lower B.O.D., equivalent percentages of commercial laundry waste are less likely to cause difficulties in sewage treatment. The effect of various concentrations of laundry waste of different strengths on the B.O.D. of a normal domestic sewage is indicated by the findings (Fig. 16) that per 100 p.p.m. rise in the sewage B.O.D., inclusion of 30 per cent of a 500 p.p.m. B.O.D. waste, 12.5 per cent of a 1,000 p.p.m. waste, 7.5 per cent of a 1,500 p.p.m. waste, and 2.5 per cent of a 2,000 p.p.m. waste, is necessary.

It has been repeatedly demonstrated that a secondary treatment process with adequate capacity can readily handle 10 per cent of commercial laundry waste per day. Institutional plants are good examples of such conditions. When the percentage is raised to 25 per cent, however, performance falls off seriously and troubles develop.

The unit process of sewage treatment which is probably most seriously affected is primary sedimentation. This is due to the fact that sedimentation is not operative on laundry waste under most conditions, because large percentages of oxidizable solids present are non-settleable in nature. Figures presented show that the efficiency of sedimentation of sewage is reduced 30 to 50 per cent in terms of B.O.D. removal because of laundry waste. Failure of this unit to remove an appreciable percentage of B.O.D. means that the load placed on secondary treatment units is greater. Hence, overloading of secondary units can readily occur. Acid wastes and salts of calcium and magnesium present in sewage may help to improve the efficiency of primary settling by coagulating a portion of the dispersed laundry waste solids. Acid wastes tend to coagulate laundry waste, and a community using hard water may realize better removal of laundry waste solids by plain settling than one using soft water relatively free of coagulating salts.

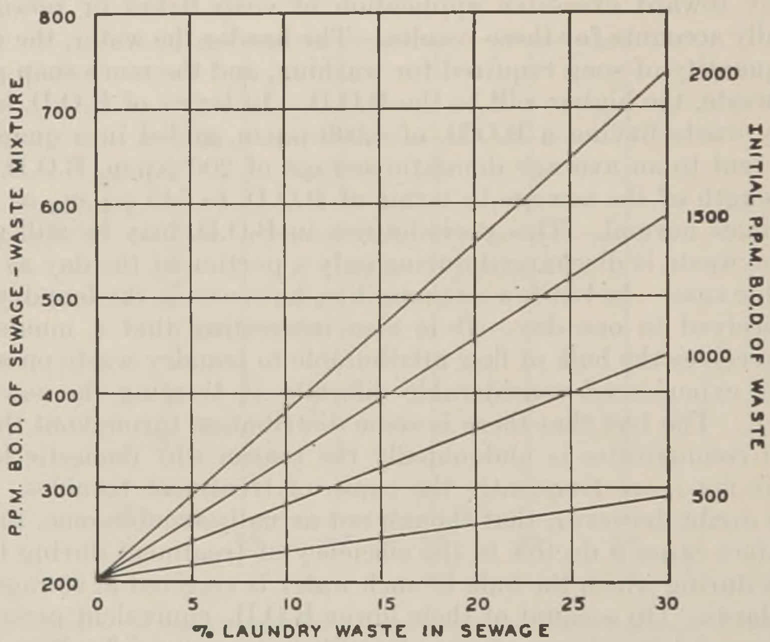

FIG. 16.—Effect of laundry wastes of various B.O.D. values on the B.O.D. of sewage.

Fewer chemicals, less rinsing water, and relatively more soap account for the fact that domestic laundry waste shows at least twice the strength of its commercial counterpart. Because of this difference, a relatively small percentage of domestic laundry waste discharged into the sewage produces the same effect as a larger volume of the commercial waste. A relatively small load of commercial waste discharged during the same period as the domestic waste may produce excessive B.O.D. loading on a particular plant. Such overloading may in some cases be prevented by a change in washing schedule at commercial laundries to avoid waste discharge at periods when much domestic laundry waste is received. Holding of a portion of the waste for a controlled discharge during the night warrants study, because the night load on most sewage plants is low. Since only the soaping wastes and first rinse would generally require a treatment, a tank of sufficient capacity to hold these portions of the waste would be decidedly lower in cost of construction and operation than any pretreatment method applied to the whole discharge.

Ratios of the various analyses of laundry waste showed that for general survey work a rapid and easy analysis can provide a fair estimate of other constituents in the waste. This does not mean that such calculations should be represented as actual analyses, but they can be used as a tool for obtaining more data than usually would be possible.

The B.O.D. rate curves presented illustrate the rapidity with which wastes, consisting essentially of soap, respond to aerobic oxidation. The oxidation rate corresponds closely to that of sewage, indicating that on the B.O.D. basis oxidation of this waste can be considered to proceed in much the same manner as domestic sewage.

Titration curves for laundry waste shed some light on the mechanisms of acid treatment processes. The fatty acids from which soaps are made are insoluble in water, and when the soaps present in laundry waste are converted to fatty acids, by acidification, the fatty acids precipitate. Such treatment is generally more costly than acid-coagulant treatment. Inasmuch as clarification with acid requires acidification to about pH 3.0, the acidity of the effluent can be objectionable. In economical acid-coagulant treatment the pH is lowered to between 4.2 and 6.5 in order to destroy alkalinity interfering with the activity of the coagulating agent. The coagulant reacts with the soaps, forming metallic soaps, which are insoluble. If coagulant alone is employed, sufficient must be added to react with both the alkalinity and the soaps. The economy of the acid-coagulant combination lies in the fact that less of the acid is required to react with the alkalinity than of the more expensive coagulant which produces acid by hydrolysis.

In activated sludge plants good practice dictates wasting activated sludge to the head of the plant. One of the claims made in support of this practice is that added clarification is obtained by absorption of dispersed solids on the sludge flocs. Data presented in this paper demonstrate clearly that considerable absorption of laundry waste on activated sludge takes place. Trickling filter sludge return probably acts in a similar fashion. The data presented are not sufficient to form a basis for extended calculations. Variability of results obtained in experiments is wide, and no attempt was made to obtain more complete information for this paper, but will be considered in a separate study of this phenomenon. It appears that the waste activated sludge can exert a considerable effect in improving results of primary settling units when laundry waste is present, and this may account for the absence of overload due to laundry waste in a number of activated sludge plants.

Laundry waste and sewages containing this waste can be treated by means of pre-acidification with sulfuric acid or carbonic acid and a coagulant. Of the two acids, sulfuric produces somewhat the better results in terms of lower coagulant dosage at the optimum pH value. Inasmuch as considerable acid is required and carbonic acid is available at most plants as burned digester gas, together with other advantages, carbonic acid is far more acceptable of the two for this purpose.

The coagulation of laundry waste by the addition of sea water, well waters high in calcium and magnesium salts, and spent zeolite regenerant is of interest from a number of standpoints. Their use for the coagulation of combined laundry waste is limited, as the sludge produced is voluminous and does not settle well. Possibly vacuation-flotation such as suggested by Eliassen and Schulhoff would eliminate both difficulties, because the sludge could be made to float and might possibly compact under vacuator treatment.

Treatment of soaping waste alone where the total volume of waste is small enough so that the entire volume could be passed through a plate and frame filter to remove the sludge presents a possible application of the salt water process. Another is the improvement of primary sedimentation by mixing a small volume of sea or well water high in calcium and/or magnesium salts with the sewage prior to settling. Results presented showed that a little over 2 per cent sea water could reduce the B.O.D. of laundry waste over 40 per cent.

Small percentages of sea water would not raise the specific gravity of the sewage sufficiently to upset settling, and the sewage solids would aid in carrying down the partly coagulated soaps, thereby improving the B.O.D. removal of the mass.

Relatively small dosages of magnesium sulfate added in conjunction with lime greatly improve the treatment of combined commercial laundry waste. Complete clarification accompanied by 90 per cent B.O.D. removal was obtained by the use of 100 p.p.m. of $MgSO_4$ and 1,000 p.p.m. of lime. Soaping waste alone responded to such treatment, but required a much higher ratio of $MgSO_4$ to lime than did the combined waste. Calculations showed that the cost of treating the combined waste by this method was lower than that for treating the soaping waste alone. The chemical cost of treating laundry waste by this method would run in the neighborhood of 5 cents per 1,000 gallons, a cost which compares favorably with that of the acid-alum processes. An added advantage over the acid-alum process is that the sludge produced settles cleanly, compacts well, and dewaters more easily. Sea water, well water high in magnesium salts, or wastes containing soluble salts of magnesium could be substituted for the $MgSO_4$, depending on availability and cost. Small percentages of spent zeolite regenerating solution were found to be an effective means of producing high B.O.D. removals from soaping wastes with relatively low lime dosages. The quantity of such solution available at a laundry, softening in this manner and using 100,000 gallons of water daily is in the neighborhood of 5,000 gallons daily. The soaping waste and first rinse from such a laundry would amount to a maximum of 56,000 gallons daily. Thus, almost 10 per cent by volume of spent solution is available, and under these conditions the soaping waste and first rinse could be treated to produce an effluent with a B.O.D. of less than 300 p.p.m. with this solution and a lime dosage of 500 p.p.m. This amounts to but 230 pounds of lime per day. Chemical cost would run to about one cent per thousand gallons on the basis of 100,000 gallons discharged. The lime dosage required will depend to some degree on the calcium and magnesium salt content of the spent regenerant. Plants using salt savers which produce a spent regenerant richer in these salts should require less lime.

Pickling liquor and aeration were found to be capable of producing excellent results in laundry waste treatment. Ninety per cent B.O.D. removal and the production of a rather dry scum rather than a wet sludge, in 5 minutes' aeration time, resulted from application of the optimum quantity of the liquor. In treating combined waste, optimum results were obtained before mineral acidity appeared in the liquor. In treating soaping waste alone, best results were produced at a pH of 3.0, which indicates that little mineral acidity was present. On discharge of waste so treated into any reasonable volume of sewage, the mineral acidity would be completely neutralized.

Treatment of a thousand gallons of combined waste, having a B.O.D. of 1,430 p.p.m., to 90 per cent B.O.D. removal would require but 2 gallons of pickling liquor. Thus a laundry producing 100,000 gallons of waste a day would require 200 gallons of liquor. Transportation of this quantity from a steel mill within reasonable distance presents no great problem or expense, as the pickling liquor is generally readily available at little or no cost. With fair-sized storage facilities, a month's supply could be brought in readily by tank truck or car. The absence of wet sludge also facilitates such treatment. The only equipment required to handle the scum would be an adequate skimming mechanism and a scum storage tank. It is quite possible that a market could be found for the skimmings (consisting mainly of fatty acids and iron soaps) which might pay part of the cost of treatment.

Summary and Conclusions

Information available pertaining to quantities and chemical composition of laundry wastes, methods of collecting, handling, and treatment, supplemented by experimental work and calculations has been correlated. To choose the most economical and workable method of handling the waste and to determine the treatment at sewage plants, information must be collected pertaining to (1) sewage flows (hourly totals and rates for wet and dry weather), (2) capacity of sewage plant in relation to flow, and B.O.D. loadings and removals obtained by existing units, (3) laundry waste flows (quantity, rates, hourly and daily fluctuations), (4) B.O.D. of laundry waste (waste alone, combined, and fractions of wastes), (5) chemicals locally available for treatment (lime, pickling liquor, acid, magnesium salts, sea water, zeolite softener regenerant, high mineral content water, etc.), (6) equipment and personnel available at laundry and sewage plant.

From the data collected the plant loadings in respect to flow and B.O.D. can be calculated for any one or more of the following procedures:

1. Equalization of flow of all or certain fractions of the laundry waste.

2. Provision for holding capacity for all or certain fractions of the laundry waste to be discharged during periods of low loading at the sewage plant.

3. Chemical treatment of all the laundry waste at the laundry. A number of methods of treatment can be expected to reduce the B.O.D. of such waste to 50–250 p.p.m.

4. Chemical treatment of the strong fractions of the waste which reduce the B.O.D. of the total to 200–300 p.p.m.

5. Treatment of the combined sewage and laundry waste at the sewage plant by chemical addition prior to the primary settling tanks. (Equalization of the waste at the laundry should be included if this method is employed so that chemical demand of the sewage does not fluctuate too widely.)

6. Pre-aeration or flocculation of sewage-laundry waste combinations with waste activated sludge prior to primary settling can be expected to improve removals appreciably. Where activated sludge plants are not greatly affected by laundry waste the additional removal so obtained might relieve periodic high loadings. The degree of relief to be expected of this procedure must be determined by experimentation. Conditions at different activated sludge plants vary too much to allow generalization. The tests should cover a considerable period of time, because the absorption ability of activated sludge varies considerably.

In general, if pre-treatment is necessary, best results usually can be obtained at the sewage plant where personnel familiar with, and equipment suitable for such treatment are to be found. Since functioning of the sewage plant is dependent upon efficient operation of the pre-treatment process, an incentive is present for the sewage plant personnel to insure good operation of pre-treatment devices. Laundry waste alone or combined with sewage can be readily and economically treated to any degree desired by existing physical, chemical, or biological methods or by combinations and improvement of such methods.

Acknowledgment

The valuable aid of R. P. Logan and L. L. Falk, assistants in the Department of Water and Sewage Research, in the preliminary experimentation involved in the laundry waste project is hereby acknowledged.

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Stream Pollution

SEWERAGE DEVELOPMENTS AND PROSPECTS IN CANADA *

By Dr. A. E. Berry

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Sewerage practice in Canada has progressed through a number of stages since the early systems were built. Today there is the gratifying prospect of a major development which will lead to the widespread provision of these facilities in most urban centers. Abatement of stream pollution is on the essentiality list, and the construction of a substantial number of treatment plants is anticipated immediately following the war.

Canadian practice has responded to both external and internal influences. In earlier days English methods were reflected in our municipalities, but in recent years there has been a more pronounced concatenation with American procedure, and especially since mechanization has been applied. In addition to these influences from abroad our conditions have called for measures of local significance.

Population Concentration in Canada

It may not be easy to visualize the extent of Canada, and the anomalous factors which have a bearing on sewerage practice. The population of twelve millions is dispersed over a wide territory, and much of this is listed as rural. This rural percentage, however, is steadily decreasing, as greater concentration takes place in the cities. Industrial developments associated with the war have suddenly augmented urban populations, and it is anticipated that much of this will continue in the postwar era, in which industry is expected to operate at a considerably expanded rate over that of pre-war days. Canada is planning now, and is indoctrinated with the concept that an industrial expansion will be needed to supply the demands of a higher standard of living for citizens in the future.

Urban assemblage is marked in the province of Ontario, and particularly in the south. Certain parts of the Province of Quebec have experienced a similar growth. These are the sections of the Dominion in which major sewerage works have been built in the past, and where most activity may be expected in the near future. Several of the larger centers in other provinces are on waters which have not called for sewage treatment.

* Paper presented at Sixteenth Annual Meeting of New York State Sewage Works Association, New York City, Jan. 21, 1944.

Systems of Government

In the administration of Canada it is sometimes heard that the country is over-governed, but that is a criticism which probably arises in most places. In an extensive investigation a few years ago of all governments of the Dominion, an attempt was made to determine the proper place and responsibility of each legislative body. While these changes have not yet been put into effect on a large scale they have caused a good deal of discussion, and are likely to be revived after the war.

At present, the federal government, the governments of the nine provinces and those of the 4,400 municipalities have their respective fields of activity. Public Health, and concomitantly, sewerage, is an obligation of the provinces rather than of the Dominion government. Legislation pertaining to the sanitary field, is variable in the different provinces, although of a generally similar nature. Each province has a well organized Department of Health, and these jointly with the municipal administrators must ever be the protagonists in sewerage activities. This arrangement, it is understood, would be similar to that in the various states of this country.

The authority given to municipalities to carry out public works comes entirely from provincial governments, and all peacetime controls are of the same origin. This does not preclude financial assistance from the Dominion government. It has been given in the past and may be forthcoming in the future.

Local Administration

While supervision of requirements and standards for sewage systems is a provincial obligation, the construction and management of these is a function of the local municipalities. There naturally follows the question of the type of administration, and what local agency will do this work. In Canadian communities this is performed in several ways. The predominating procedure is to place this activity under a committee of the municipal council. The local engineer, where there is one, is the executive or administrative officer. Only in a small number of instances is a special commission assigned this duty. An outstanding paradigm of this kind of administration is found at Winnipeg, Manitoba where the sanitary district embraces a group of municipalities, and where the united system is operated and financed by one commission. While there is an increasing interest in sanitary districts, very little progress has actually been made as yet. The future may bring advances in this at the larger cities.

Public Utility Commissions

In the Province of Ontario considerable success has attended the administration of utility services by public utilities commissions. These are operated by commissioners, usually three or more in number, and elected by public vote in much the same manner as local councillors. This development, which is confined almost entirely to Ontario, was initiated with the formation of commissions to handle the hydroelectric power enterprises of the province. The Public Utilities Act of the province permits all utilities, that is generally those for which rates are charged, to be administered under the one commission. These include electricity, water, gas, heat and others. As yet, no appreciable trend has been in evidence to place sewerage systems under these commissions, but there is now an increasing interest in this, and a change in legislation is being considered in Ontario to facilitate this procedure. This would seem to carry letificant potentialities for those centers where there are no well organized engineering departments, and this is the case in many Canadian municipalities. The use of sewer rentals for financing is stimulating this procedure.

Methods of Financing

Financing of capital expenditures, as well as operating costs for sewerage systems is generally done in one or more of three methods. The sewers may be paid for under the Local Improvement Act, through which a frontage tax is levied for a specified period. The sewage treatment plant, pumping stations and miscellaneous works are financed by general taxation, funds for which are raised chiefly on the assessment of real property. These two have been the most accepted methods, but now in several of the provinces the sewer rental plan is in effect. Legislation permitting this has just recently been passed in Ontario, and it is expected that increasing use will be made of this measure.

Close supervision is maintained over municipal finances by the provinces. In Ontario, no capital expenditures on works of this nature can be undertaken without approval of the province. Every effort is made to ensure that municipal obligations are discharged in a stated period. This time limit is being shortened for most works to something less than 20 years. Every little use is made now of sinking funds in Ontario, but the generally recommended plan is that of retirement of the debt by equal annual payments, which include both principal and interest.

Provincial Health Department

The Provincial Department of Health has control over all sewerage installations in much the same manner as is found in your different states. The authority of the Department in Ontario is considerable, in that mandatory orders may be issued through which municipalities may be compelled to proceed with sewerage systems or any parts thereof. This has two advantages; the first to get necessary work completed, particularly in the abatement of stream pollution, and secondly to avoid, in many instances, the necessity of a vote by the ratepayers. When such an order is issued no further authority is required by the municipal council to undertake the work. This procedure has been used to advantage in a goodly number of cases.

Governmental Aid and Control

Capital charges for sewerage systems have, in most instances, been met entirely by the municipal taxpayers. Only for a limited period during the early depression years did the federal and provincial governments assist in meeting the costs of these works. That procedure was discontinued after a short experiment, when other efforts were made to relieve unemployment.

In general, this same policy has been followed during the war, but where treatment plants or other works have required enlargement or extensive changes to supply government war industries the Dominion has paid its share towards this expenditure. A number of sewage treatment plants have been built at government expense to serve new industrial enterprises.

The Dominion Government has embarked on comprehensive housing schemes in those localities where war industries have created new and unbalanced living conditions. Where possible the sewers serving these houses are connected to municipal lines. Payment for sewage treatment and other municipal services has resulted in differences between the two parties concerned. The general procedure has been for the government to pay in lieu of taxes about one month's rent of the premises. This is for all services supplied by the municipality. In addition, grants have been given by the Dominion for extension of treatment plants and like facilities.

Sewer Systems

In the design and construction of sewers the procedure in Canada is similar to that in the United States. Our rainfall rates are quite variable across the Dominion, with the high annual precipitation at the coasts, and the low figures inland. Intensity records are available for representative stations, and some use, although probably not as much as might be expected, is made of these. Some solution has been sought to standardize on the minimum size of sewers. This is 8, 9 or 10-inch, according to the preference of the designer.

There is no unanimous opinion in Canadian municipalities in respect to the use of separate or combined sewers. In general, where convenient storm water outlets are available separate sewers are used. The requirement for treatment plants has not induced widespread use of separate pipes, although there appears to be an increasing interest in separate rather than combined systems. A difficulty with this has been the problem of preventing heavy infiltration to the sewers in time of rain. This has been sufficiently great in some instances to nullify to a considerable extent the advantages of the separate system. It is likely that in the future, Canadian practice will tend more and more to the separate system, unless the cost is too much in favor of the other.

Frost Control

Frost control is a problem indigenous to Canadian conditions. Wide variations in temperature occur in some parts of the Dominion, and special precautions must be observed during the winter. Sewers and house connections are laid deep enough to prevent freezing, a depth which varies widely. Freezing of catch basins is common in extreme weather, but this is met either by thawing through the use of steam boilers, or by adding salt or other antifreeze compound to the basins. The former practice is more general. Condensation of moisture at manholes, with resulting unevenness of the road surface, is difficult to avoid. The use of closed manholes overcomes this to some extent.

Watermain and Sewer in Same Trench

The use of single or dual purpose trenches for watermains and sewers is an open question. The usual method is to lay these pipes in separate trenches, but where extensive rock formation is found there has been a propensity to lay both pipes in the one trench. The watermain at the top is offset to some extent. The objection to this procedure has centered about the difficulty of making repairs to either pipe. While some danger must be associated with this method it has not been prohibited on public health grounds.

Sewage Treatment Practice

In sewage treatment, Canadian practice is not unlike that generally followed in northern United States. The composition of our sewage is much like that in this country, with large per capita water consumption. Mechanization of plants is increasing markedly, and since this equipment is made either in the United States or in Canada, its design is influenced chiefly by that in this country.

In any place the size of Canada there must be a wide variation in the volume and use made of the waters which receive sewage discharges. In Ontario, at least, there fortunately is available many lakes and large rivers which provide substantial dilution for sewage. This would be most useful except that drinking water supplies usually must be taken from the same sources. The Great Lakes system of fresh water has provided a convenient receptacle for sewage and other wastes, but there is a growing recognition of the necessity for conserving the purity of these waters both to safeguard drinking supplies, and to retain them for the general benefit of the public. Consequently, it is essential that adequate treatment of the sewage be provided to meet these conditions. It is anticipated that the postwar era will present a major opportunity for progress in this direction.

Trade Wastes

Trade wastes in Canadian municipalities, generally have not created the same problems as are found in many American cities. In recent years, however, a change in this is noted. Our practice of not requiring primary treatment at the industry may have to be modified to protect sewers and to assist the treatment plant. There is generally a reluctance on the part of municipalities to impose undue restrictions on industries, and the taxpayers are asked to shoulder the extra expense for treatment.

The practice now developing is to require a degree of treatment for some objectionable wastes, particularly tanneries, canning factories, and others which discharge concentrated or offensive material. Screening or sedimentation is the usual treatment called for in these cases.

Developments in Sewage Treatment

At present there are about 500 sewer systems in use in Canadian municipalities. Some of these serve but limited areas in those communities. This number is in noted contrast to the total of 1,300 water works systems in public use. In spite of the fact that the progress experienced in the past would be regarded as substantial there is a great deal yet to be done in this field.

In sewage treatment the picture is even less attractive. Of the 115 municipalities that have treatment works in operation, 71 of these are in the Province of Ontario, in spite of the fact that so many of the large receiving waters are in this province. In this total number of plants, 52 are primary and 63 are for secondary or complete treatment. Activated sludge is used in 30 secondary treatment works in Ontario, or nearly all plants are of this type. For a number of years this is the type of plant which has been built where complete treatment is indicated. Local conditions have made this process favorable.

Perhaps it is not out of place to dwell for a moment on the processes which have led up to the present status in treatment in Canada. There is, in this development, an evidence of the swings back and forth in processes and procedures—some to be abandoned entirely, others to be revived later in a somewhat modified form.

The early disposal plants were chiefly sedimentation units, first in plain, single story tanks, later in the two-story Imhoff type. Both of these have felt the effects of obsolescence, except for small units or where local conditions make their use favorable. Only a few of the Imhoff tanks built in that period in Ontario are still in operation. New tanks of this design have not been used in municipal plants for 20 years.

Chemical precipitation was employed to a very limited degree in Canada. Now this has been abandoned, although some interest in revival is manifested. Chemicals are higher in cost in Canada than in the United States.

For secondary treatment two methods were used in the early days, contact filters and trickling filters. The latter found use in several plants before activated sludge was adopted. Following the latter's advent, and influenced by over-enthusiastic appraisal of its possibilities, trickling filters were completely lost sight of, even for small plants.

The experience with activated sludge for these small municipalities and for institutions was not successful. Too much supervision was required for the non-technical personnel which was available. The pendulum is now swinging back to trickling filters for these smaller units, and use will be made of the later developments in this process.

The Activated Sludge Process

Different factors have been responsible for the extensive use of the activated sludge process in Canada. There are now 48 municipal plants, of which 30 are in Ontario. In addition to these the process has been employed at a number of institutions such as hospitals. These plants were patterned after the English experience. Spiral flow tanks with agitation by air have been used exclusively, and until recently all air diffuser plates were the English type set in cast iron frames. The first municipal plant of the activated sludge type built in Ontario was at Brampton in 1918, where sedimentation tanks were reconstructed.

Among the factors which led to this widespread use of activated sludge may be mentioned the following: enthusiastic support of it in the early stages by the Ontario Department of Health, low initial costs, small loss of head involved, lack of appreciation of the difficulties of sludge handling, and low power costs for operation. Some of these early hopes were not well founded, but later developments, particularly in sludge handling were able to offset these deficiencies to some extent. Low electrical power charges have been a favorable feature in this process.

North Toronto Results

The experience at North Toronto with an activated sludge plant may be listed as symptomatic of Canadian problems and conditions that have been encountered. This plant was put into operation in 1929 with a capacity of 5 m.g.d. It was enlarged to 10 m.g.d. later, and is now treating an average flow of about 8 m.g.d. The raw sewage has an analysis of: suspended solids—340 p.p.m., B.O.D.—280 p.p.m., and colon count of 15 to 20 thousand per 100 cc. The treated effluent has an average composition of 17 p.p.m. suspended solids, and 16 p.p.m. B.O.D. This represents a reduction of 95 per cent in suspended solids, 94.3 per cent in B.O.D., and about 92 to 95 per cent reduction in colon, without chlorination.

Power costs in Ontario plants vary to some degree but a figure between $\frac{5}{10}$ and $\frac{6}{10}$th cents per k.w.h. may be taken to include all charges. An example may be cited in which everything over 100 k.w.h. per month is charged at one-third cents per k.w.h. Capital and operating costs are available for all Canadian activated sludge plants. While these vary widely in the methods used the average for all gives figures of some interest. These average capital costs are $14.09 per capita, and $143,-100 per million gallons designed capacity. Average operating costs for a recent year are as follows: $0.87 per capita; $35.01 per m. g. treated per day or total annual costs (capital and operation) of $1.71 per capita or $85.37 per m. g. treated per day.

Sludge Disposal

Sludge handling has been a difficult problem in Canadian disposal works. This was intensified with the introduction of the activated sludge process. Experiences with undigested sludge brought severe odor problems. Digestion in heated tanks has overcome this, and good results are general. Sludge drying has passed through different stages. Canadian conditions were unfavorable for open drying beds. Glass covering brought an improvement. In these, only sufficient heat has been necessary to prevent freezing. Favorable results have been experienced in some instances where the sludge was allowed to freeze on the drying bed, and removed either in this state or after it had thawed and dried.

Mechanical dewatering and vacuum filters has been the recognized procedure in recent years, both for large and small plants.

Sludge disposal as a fertilizer has been practised at a number of Ontario plants of smaller capacities. Here the sludge is removed either in the wet state or after vacuum filtration. This method has not been used for the value of the fertilizer, but because of economical disposal. Apart from this, little effort has been made to use sludge as a fertilizer.

Chlorination of sewage has not been utilized to a great extent in Canada. Probably local conditions have been responsible for this, but it is fully anticipated that this treatment will increase greatly in the years to come for control at sewage plants.

Conservation Schemes

Canadian climatic conditions induce severe stream problems for the summer low flows. In winter, low temperatures mask obnoxious odors. This wide variation brings extreme requirements in the degree of treatment. There is now a wider recognition of the usefulness of stream conservation. One of these, on the Grand River, has recently been put into operation in Ontario. In this case, the normal flow of the river is sufficient to provide ample dilution except for 2 or 3 months in the summer. A dam has been erected on the upper reaches of the river to smooth out these flows. Consideration is being given to similar treatment for other streams in which the flow is variable. By this, material savings may be made in treatment costs.

Management of Plants

Efforts have been made to secure adequately trained operators for sewage plants. This is not always successful. As yet no system of certification has been adopted, but this procedure is likely to develop after the war. Little political interference is encountered in the personnel management of these plants, but the salaries paid have not always attracted the most qualified.

Prospects in Sewerage

These are the features associated with Canadian sewerage systems as they exist. What of the future? There is a great deal of enthusiasm and hopeful thinking now about the prospects in this field in the postwar era. Since water works have made more rapid advances in the past it is expected that the major developments will now be in sewerage. There is a greater public demand for these facilities now than has existed for many years. Our municipalities are coming into favorable conditions in so far as capital expenditures are concerned. Little capital debt has been added for some years, and much of the old has been paid off.

Extension of Sewers

In the postwar era it is anticipated that both water works and sewerage systems will be made available to all communities of moderate size. The extension of these services will be a major factor in raising the standard of living, and it is believed that the citizens can finance these measures, and also that they will be prepared to spend the money in this direction. Much thought has been given to postwar planning and in these projects water and sewerage are regarded as the top ranking public works. If government grants are to be given these measures are likely to be favored over others. There is thus a promising attitude to-day for improving our facilities, involving environmental sanitation.

Sewage Disposal

There is in the postwar planning an opportunity to improve stream sanitation. Canada, like many other countries, has not made as great progress in the prevention of pollution as might be hoped for. Much sewage is discharged either raw or in a partially treated state. This has been due to public apathy, lack of funds, and to the fear of obsolescence in sewage treatment works. There is now no good reason for further delay.

Expenditures Involved

A survey of water and sewerage needs was made recently for the Province of Ontario, and the estimated expenditure was about 40 million dollars for new water works, sewerage and treatment plants. This does not include the many extensions which would be required in existing systems, a figure which might reach nearly as high as the other. If all Canada were included, it is conservative to expect that this figure would be double that in Ontario.

Standards of Treatment

In sewage disposal of the future close attention must be directed to the standards of treatment which should be required. These plants must incorporate two important features, namely; adequacy of treatment to protect the receiving waters, and secondly reasonable economy in first cost and in operation. Since sewage treatment is seldom a popular measure with those who are designated to raise municipal funds care will be necessary to ensure that over emphasis is not placed on economy. Sewage treatment may be considered to be expensive, but to properly assess this it must be interpreted in comparison with other municipal projects. When this is done the cost is not relatively great. If this be true, is it not better to ensure adequacy of treatment? If there must be any error, let it be on the side of safety. There is a great opportunity in the postwar period to correct many evils of the past. In Canada we look to this time to set high standards for the conservation of our natural resources, and especially water supplies. To this end, secondary treatment may be expected in many municipalities.

Much Work Is Planned

In Ontario, and probably in all parts of Canada there is expected to be a major program in sewage treatment. The city of Toronto has already started on the first stage of a treatment plant, estimated to cost 9½ million dollars. Much of this will be for the postwar period. This is but an instance of the feeling in other centers respecting this necessary activity.

Financing Sewerage Systems

The question of financing these sewer systems and disposal works is primarily one for the local municipalities, and to this end the planning is now proceeding. This planning is not postulated on the basis that outside financial assistance will be forthcoming. If it does, so much the better.

The question of governmental assistance in finance is not yet clear. It is a known fact that the Dominion Government has appointed a committee to advise on postwar reconstruction. That committee has been active, and while it is understood the report has been presented, it is not yet made public. Statements credited to members of the Federal Government might indicate a trend towards financial assistance for works of this kind. If any municipal grants are forthcoming it is believed that water works and sewerage will be in the prior group.

If federal grants become available it is not clear as to the procedure which will be followed. Will the money be paid directly to the municipalities or will it be given to the provinces to be allocated to the municipalities where it is most needed? What proportion of the cost of the projects will be paid is likewise uncertain, but it is believed that something more concrete in respect to these questions may be looked for in the not distant future.

Conclusion

From this review of developments and prospects the most encouraging feature in Canada is that there is an optimistic viewpoint on what can be done in the sewerage field after the war. Environmental sanitation will be recognized to a greater extent. Sewage treatment will be installed to abate stream pollution, and it is anticipated this treatment will not stop halfway, but will be sufficient to give adequate results for each local situation.

THE OPERATOR'S CORNER

HOLD THAT LINE!

Some weeks ago, a brief notice was published in a state health agency bulletin in which reference was made to an apparent relaxation of sewage works operation standards in that state due to wartime conditions. Whether or not this situation is general, it is a thought-provoking topic which is deserving of careful consideration before a serious problem develops.

Visits by engineers from the office of the state public health department are few and far between, and for good reason. Health department staffs are mostly functioning with skeleton organizations because of their contribution of trained men to the armed forces. Travel restrictions further hamper the field activities of these offices. Even local visitation at sewage works has dwindled away to almost nothing. These conditions may create a natural feeling on the part of the plant operator that there is no interest in his plant and his work, resulting in a lesser incentive for him to retain his pre-war level of accomplishment. Such is not the case, however. Present conditions will not be permanent and it is vital that public sanitation service be furnished at even higher efficiencies now than in time of peace.

The entrance of the United States into World War II occurred when the sewage works field was progressively raising its standards in every respect. We must keep in mind that any relaxation in these criteria constitutes lost ground that must be regained in the postwar era before progress can be resumed.

Shortage of manpower, difficulties of materials procurement and other wartime problems offer a convenient alibi for lowered accomplishment and, frequently, these problems cannot be overcome. At the same time, we should not give in to these obstacles without taxing to the utmost the conscientiousness, cleverness and ingenuity which has been so prevalent among sewage works operators heretofore.

In case you should have a visitor, surprise him to find the quality of the plant effluent as good as ever (or better); the laboratory records just as complete (or more so) and the equipment, structures and grounds to be maintained in the best possible condition. If something *must* be given up, let it be among the items of least value and easiest to resume later.

If a slogan is in order, how about "Do It Better With Less"?

W. H. W.

EMERGENCY REPAIR TO GATE VALVE ON FORCE MAIN *

By C. George Andersen

Superintendent, Rockville Centre, L. I., New York

If an operator solves a problem I believe he should write it up and give his experience to others who may have similar difficulty, or again, it may be a lead to some other problem wherein the same methods can be used. With that thought in mind we offer our experience with a 10-inch stop valve on a force main that ceased to operate because of worn threads on the stem.

The valve, installed as a stop valve, had been used for about twelve years as a throttle, regulating the sewage from the pump station to the treatment plant and in that use, the parts became worn and had to be replaced.

The problem arose due to the fact that there was no valve in the force main between the pump stop valve and the treatment plant. Explained in a few words, it meant that we had a 24-inch main more than two miles long filled with sewage and at elevations such that there was a static head of 38 feet on the valve. Two years ago I anticipated trouble because of the faulty operation of the valve and obtained estimates for the installation of a 24-inch stop valve in the force main.

The installation of a valve under pressure is specialized work, requiring trained labor and equipment. The average estimated cost was $3,500 and contractors were not anxious to do the job because of the labor and equipment situation. Conditions are no better at this time because of the war.

Hoping to relieve the continuous use of the stop valve in question, another valve was installed between the pump and the check valve, there being, fortunately, space for it. This valve then became the throttling valve and the other used only when cleaning the check valve.

Our hopes were not fulfilled. Recently, the valve on being closed, showed signs of slipping and finally stopped functioning the day we made the repair—just about four weeks after the warning—giving us time to obtain parts and equipment.

Getting to the point, considerable thought had been given to repairing the valve and one thought struck me as being practical, i.e., to have a corporation cock installed in the sleeve above the valve, which could be removed to allow a stopper to be forced in and inflated to shut the sewage and pressure off the valve (Fig. 1). That plan was adopted.

During the planning and preparation, a check was made on the exact volume and elevations of the force main, and what to do with the sewage should we reverse the flow in the force main (approximately 275,000 gal.) against the incoming sewage.

* Paper presented at Spring Meeting of New York State Sewage Works Association, Rochester, N. Y., June 4–5, 1943.

The job must be done after midnight, with the hope that our idea of stopping the pressure over the valve would be successful because of the time element. We also hoped it would not be necessary to employ and operate large portable pumps to take quickly the total volume in the force main and the incoming sewage. Sewage does clog screens protecting pumps, and added pumping facilities must be allowed to take care of that factor.

Valve parts such as bonnett stem, stem nut, gates and wedges were obtained. Our intention was to replace only the worn parts so that the job could be done quickly. A 2-inch corporation cock was cut into the sleeve above the valve as shown in Fig. 1.

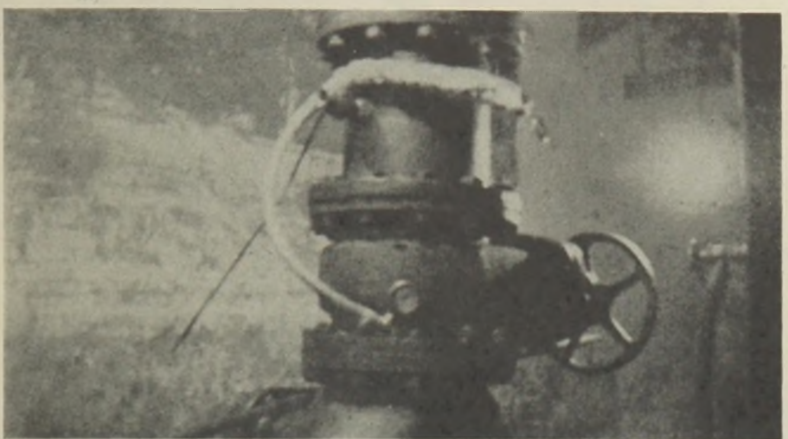

FIG. 1.—Two-inch corporation cock on pressure side of valve to be repaired.

To obtain a stopper that could be forced through a 2-inch hole and strong enough to withstand the pressure was a problem. After some search, a 10-inch canvas-covered rubber bladder was obtained from the Safety Gas Main Stopper Co. of Brooklyn, N. Y. (type C canvas-covered gas main bag, Fig. 2). The bag had a supporting steel spring connected to rings at each end of the bag, which formed with the bag when inflated. The purpose of the steel, connected to a rod, was to direct the bag and rings after insertion for pulling purposes. This bag could be rolled tightly and tied with a loose twined cord that would break easily on the inflation of the bag.

Experiments were made to test the reaction of the inflated bag under pressure. This was done by using a 6-foot iron pipe, inflating the bag at one end, filling the remainder of the pipe with water and capping the other end tightly (Fig. 3). The cap had connections for pressure gauges. Air pressure was applied up to 25 lbs. and at that pressure the bag started to slip, but did not collapse. That was our only fear, that the bag would not stand up under the actual pressures in the main.

After experimenting, the corporation cock was unscrewed and a test made as to the possibility of inserting the rolled bag stopper against the static head of 38 feet. It probably could have been done had we used a rod with a slot hooking on to the end ring of the bag and forcing it against the pressure. This was done when the stopper was inserted. However, we were unable to replace the open corporation cock against the flow and temporarily had to insert a wooden plug.

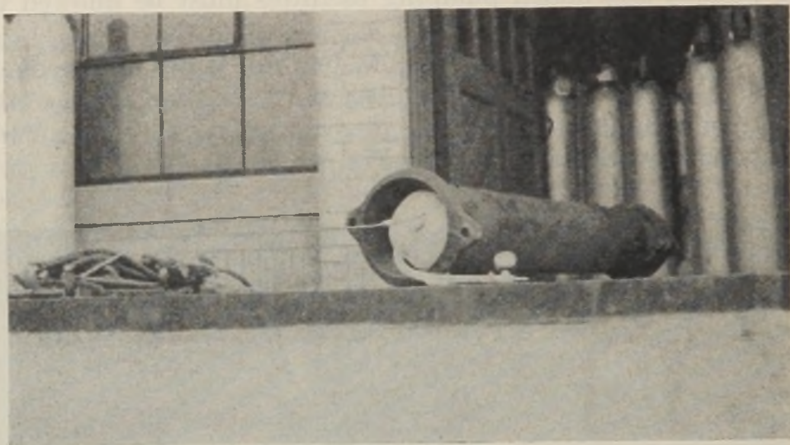

FIG. 2.—Gas main stopper bag manufactured by Safety Gas Main Stopper Co. of Brooklyn, N. Y.

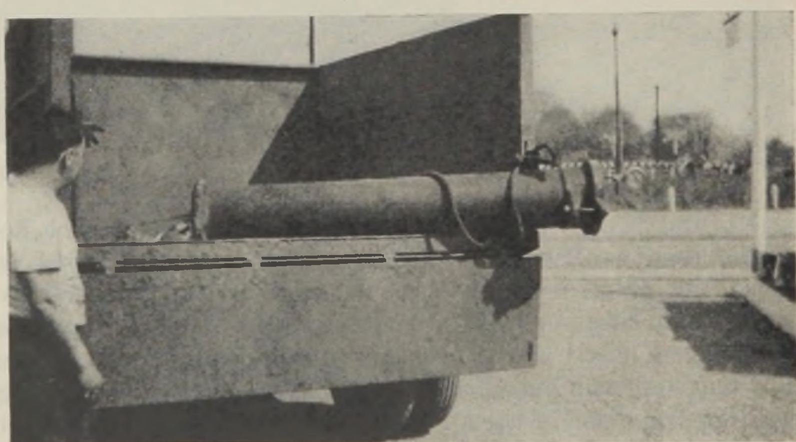

FIG. 3.—Testing the stopper bag before undertaking the repair.

The job was planned for after midnight when the incoming sewage flow was low and the sewage flow in the force main, when reversed, could be stored in the gravity sewer lines with the assistance of a portable pump discharging to a street drain emptying into a creek. The head in the force main could then be lowered to a point where it was practical to do the work planned.

At midnight the incoming sewage flow was so strong that it was impossible to do the job without more pumps. An emergency was declared and at 3 A.M. a fire engine pumper was put in service to aid our portable pump. After about four hours the pressure on the valve dropped to 10 lbs. at which time we removed the plug and inserted the tightly rolled bag against the water pressure and immediately inflated the bag with a hand pump. When inflated the bag cut off the sewage and pressure from the valve.

The stopper found to be tight, the job of removing the old valve parts and replacing with new was done very quickly. Then the stopper was deflated and easily withdrawn by the aid of the water pressure in the force main. The open corporation cock was then comfortably screwed back and closed.

When the test was made prior to doing the job, we believed that the bag could have been forced in, but our difficulty would have been getting the cock back. It may have been possible when the stopper was inflated, and the flow cut off, to slip the tubing of the stopper through the open cock and screw it in position. Then, when the job of replacement of valve parts was done, we would have had to deflate the stopper, force the tubing inside the main and close the cock, and retrieve the stopper either at the check valve or the treatment plant.

A valve could be developed with a bore large enough to allow a bag of this type cased in a chamber to be forced into a main, the chamber to be screwed in the valve before opening. An arrangement of that type would be of service in many ways. The stopper can be obtained in a chamber with a plunger, from the makers of the stopper used in our case, but has only been used on dry work such as with gas.

In completing the job by the method explained, considerable time, labor and money was saved. To have emptied the main entirely would require considerable apparatus and pumping equipment. It would be a battle for time to prevent interruption in sewer service. We returned about half the volume of the force main; clogging of the fine screens slowed up the pumping time and is a factor when obtaining pumps.

The cost of the job—equipment and labor—was approximately $150. The cost of the gas bag stopper with attachments was $7.80 and is included in the above figure.

In writing of this problem, it is not my intention to suggest the elimination of stop valves, but to aid the operator who may have a similar emergency.

SLUDGE CONCENTRATION AND BARGING AT THE ELIZABETH (N. J.) JOINT MEETING SEWAGE TREATMENT WORKS *

By Dr. Willem Rudolfs

The purpose of sludge concentration at the Joint Meeting Treatment Plant is primarily two-fold:

1. Reduction in volume of sludge.
2. Reduction in cost of barging.

* Special report prepared by Dr. Rudolfs in capacity of Operation Consultant to the Elizabeth (N. J.) Joint Meeting.

Reduction in Sludge Volume

The suspended solids present in sewage are generally classified into settleable and non-settleable solids. The settleable solids are retained in the settling basins, collected and pumped to storage tanks, while the non-settleable solids remain in the effluent. Practically all the settleable solids are retained in the settling basins, resulting in a relatively high degree of purification. The volume of sludge retained varies between 2,000 and 3,000 gallons per million gallons of sewage with an average of approximately 2,600 gallons. On storage the sludge compacts with separation of water. The water is decanted and returned to the settling basins. The compacting of the sludge is affected by various factors, principally the original concentration of the sludge, the temperature of the sludge during concentration and the character of sludge.

Table I.—*Average Daily Sludge Pumped from Settling Tanks and Liquid Decanted, 1942*

Month	Sludge Pumped, Gals.	Liquid Decanted, Gals.	Solids Conc., Per Cent	Ash of Solids, Per Cent	Reduction in Sludge Vol., Per Cent
January	93,619	39,300	6.00	20.0	42
February	88,225	34,539	5.92	21.7	39
March	87,890	43,490	5.63	22.1	49
April	89,230	39,660	5.70	20.3	44
May	83,438	35,235	6.57	22.3	42
June	91,696	40,063	5.90	25.4	44
July	95,290	41,017	5.38	26.3	43
August	97,935	45,035	5.74	29.3	46
September	94,645	35,228	5.83	23.7	37
October	93,706	41,288	5.74	21.2	44
November	92,728	44,313	5.76	20.7	48
December	91,035	37,393	5.43	21.2	41
Average	91,620	39,713	5.80	22.8	43.4

Only two of the factors can be controlled, namely temperature and time of compacting. No facilities are available for temperature control at the Joint Meeting Plant; while the time of compacting is controlled by the volume of sludge received. However, the volume of sludge during the time available for compacting can be reduced materially by proper manipulation and operation.

The present method of sludge concentration is aided by careful control of decanting liquor. Of the average daily 91,620 gallons of sludge pumped during 1942, some 39,710 gallons of water were decanted and returned to the settling tanks. This means a reduction in volume of 43.4 per cent (see Table I) or nearly 198 tons a day. This is even better than last year when the daily reduction amounted to 186.5 tons.

Increase in Sludge Concentration

The reduction in volume means an increase in solids concentration of 28.5 per cent. There is a limit in solids concentration which can be obtained and also a limit in sludge concentration which can be handled.

For instance, if the volume should be reduced to 50 per cent, the solids concentration would increase to 11.6 per cent. In other words, to obtain 7 per cent more reduction in volume the solids concentration must be increased by 30 per cent. This means that with the present set-up, the limit of volume reduction has practically been reached, because sludge with a higher concentration than about 9 per cent does not readily flow during cold weather.

TABLE II.—*Quantities of Concentrated Sludge Barged, its Concentration and Temperature and Time Required for Barging per 1,000 Tons*

Barging No.	Sludge Barged, Tons	Solids Conc., Per Cent	Ash of Solids, Per Cent	Temp. of Sludge, ° F.	Barging Time per 1,000 Tons, Min.
104	3145	8.43	22.1	54	103
105	3060	8.04	21.9	53	99
106	3075	8.73	24.3	52	108
107	2920	7.23	22.4	51	114
108	3110	8.29	22.4	52	134
109	2855	7.60	24.6	53	137
110	2905	7.40	20.8	56	127
111	2820	7.61	21.2	57	133
112	3035	7.60	20.6	62	137
113	3035	9.78	23.9	64	113
114	3350	9.64	23.8	66	91
115	3305	7.82	26.9	69	69
116	3345	8.05	27.4	70	80
117	3400	8.13	27.0	71	61
118	3375	8.35	29.5	73	63
119	3350	8.94	33.9	73	80
120	3310	9.15	37.8	71	76
121	3300	7.27	28.1	71	60
122	3260	8.13	28.9	72	69
123	3225	8.61	27.5	69	74
124	3185	8.39	24.1	68	78
125	3290	7.38	24.4	66	69
126	3275	8.00	22.0	64	82
127	3160	7.89	21.4	62	101
128	3425	8.01	20.3	59	75
129	3425	7.80	22.0	56	85
Average	3190	8.13	24.9	62.2	92

The general fact that sludge with higher concentration requires more time in handling can be seen from Table II. I have calculated the barging time required for each 1,000 tons of sludge barged during the year. With equal temperatures the time required to barge 1,000 tons is generally greater when the sludge is thicker. However, the temperature of the sludge to be barged plays an important role.

Effect of Temperature on Barging Time

The average time for barging 1,000 tons of sludge during the year was 92 minutes. The temperature of the sludge ranged from 51 to

73° F. By grouping the temperature of the sludge within rather narrow limits of 4 to 5° F. and calculating the average barging time, I find that sludge with a temperature of 51–54° requires 116 minutes per 1,000 tons, whereas sludge with temperatures of 68–73° F. required only 69 minutes per 1,000 tons (Table III). The time required for sludges with temperatures between these limits is correspondingly less. Plotting these results, it appears that there is a direct relation between the temperature of the sludge and the time required (Fig. 1). On the fig-

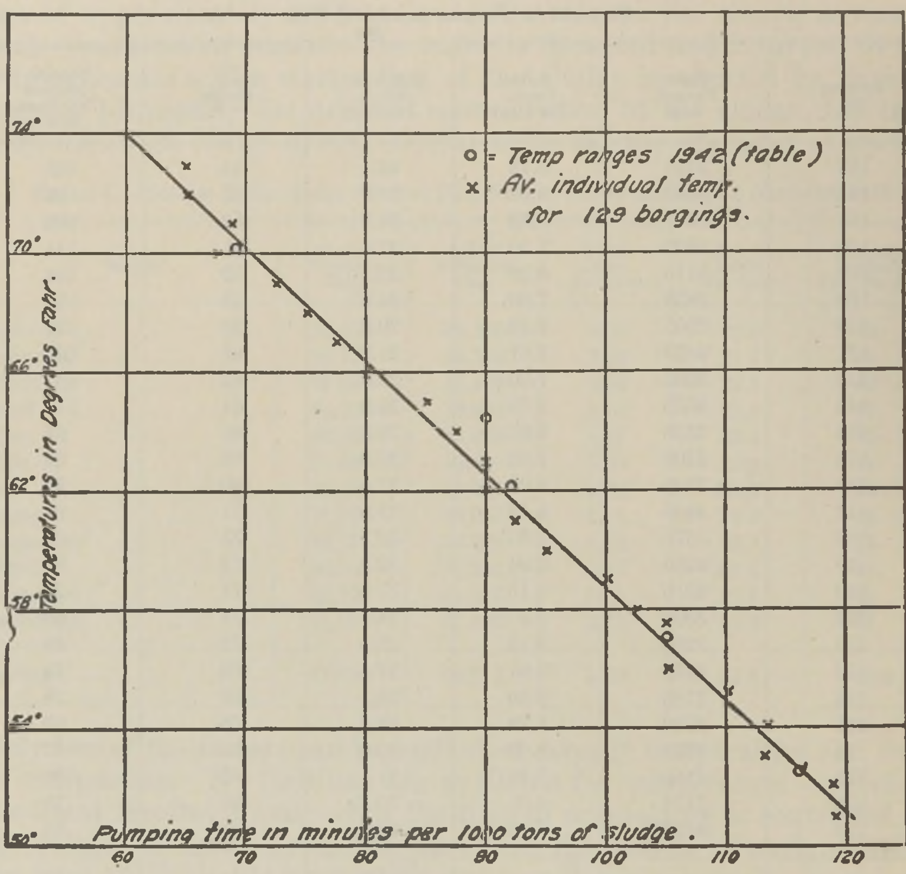

FIG. 1.—Relationship between sludge temperature and time required for pumping.

ure, I have also indicated the average individual temperatures and the time required for all barging since the beginning of operation. It is very striking that the results follow the curve closely. This means that with the present equipment the temperature of the sludge is the most important factor in barging. It further means that if any barging time when properly calculated, does not fall near the time indicated, there must be something wrong in handling or with the pumping equipment. Whenever the engineer can show that the barging time is less than indicated he has made an improvement in handling and subsequently in the cost of treatment.

FIG. 2.—Sludge barge *Carryall* being loaded with raw sludge at Joint Meeting (N. J.) Sewage Treatment Works. Boat carries 3,425 tons and makes bimonthly trips.

TABLE III.—*Relation Between Temperature of Sludge and Average Pumping Time for Certain Temperature Ranges*

No. Bargings	Temp. Range, ° F.	Solids Conc., Per Cent	Ash of Solids, Per Cent	Total Sludge Barged, Tons	Ave. Pumping Time per 1,000 Tons, Min.	Ave. Temp., ° F.
26	51–73	8.13	24.9	82,900	92	62.2
6	51–54	8.05	22.9	18,110	116	52.5
4	56–59	7.71	21.1	12,575	105	57.0
6	62–66	8.38	28.2	19,145	90	64.5
10	68–73	8.28	29.1	33,055	69	70.7

COST OF SLUDGE DISPOSAL

The cost of sludge disposal is primarily dependent upon the cost of barging. The cost of barging is mainly for loading and transport of the wet sludge. Since the volume of the sludge to be barged is determined by the concentration of the sludge, the higher the concentration of the sludge the lower the total cost. In order to make cost figures for sludge disposal comparable at different treatment plants it is customary to calculate the cost per ton of dry solids. The cost of barging sludge per ton of dry solids during the year 1941 amounted to $4.63 and for the year 1942 to \$4.34, or a difference of 29c per ton dry solids. During 1942, the total amount of sludge barged amounted to 6,840 tons on a dry matter basis. This shows an actual saving on sludge loading and barging of $6,840 \times 0.29 = \$2,003$ as compared with the previous year. This saving can be attributed (*a*) to careful methods of decantation and (*b*) to reduction in time required for loading.

TABLE IV.—*Cost of Sludge Handling Per Ton of Dry Solids Disposed*

1937	\$4.25
1938	4.00
1939	3.85
1940	4.00
1941	4.63
1942	4.34

As stated above, the limits of volume reduction by solids concentration has been nearly reached. Appreciable further reduction in cost of sludge disposal can not be expected with the present methods used.

You may be interested to know how the cost of sludge disposal at the Joint Meeting compares with that at other places. Some time ago I published a survey of available data (*Engineering News-Record,* February 26, 1942), discussing good practice in sludge disposal. It appeared that the total cost for disposal of sludge in this country varied from \$3.53 to \$7.69 per ton of dry solids. This indicates that the cost of sludge disposal as practiced by the Joint Meeting is relatively low. Only with considerable capital expenditure will it be possible to lower the cost materially. The engineer and operating force should be commended for their good work.

THE DAILY LOG *

January 2—The New Year holiday load seems to have overcome the screenings grinder electrical system, in which the fuses have been blowing much too frequently of late. Diagnosis quickly revealed that the fuse clamps were faulty and were mainly responsible for the present trouble. In the course of the investigation, however, it was found that the power feed to the grinder was considerably overtaxed by certain items of laboratory equipment which had been connected into the grinder circuit in recent years, without proper consideration of the wiring capacity. Upon completion of the minor rewiring job, the grinder functioned in fine fashion.

Two lessons here. First, when installing new electrical equipment, be sure that the power service connection is adequate for the additional load. Second, when fuses begin to blow too frequently, a complete check on the electric system may show more than one fault.

* Based on the 1943 daily records of the Urbana and Champaign (Illinois) Sanitary District.

January 14—Received the final batch of cancelled bonds and interest coupons which leaves the District entirely free of indebtedness. Must not forget to include a "mortgage burning" ceremony in the agenda of the next meeting of the Board.

January 19—Ten below zero this morning. Also much snow and ice. Imhoff tank gas vents frozen solid and clarifier traction rail coated with ice. Some fun!

January 24—Since the weather moderated two days ago it is interesting to note how the Imhoff tanks have reacted. Last Sunday, with the gas vents frozen solid and with gas belching through the slots, sounding of the tanks showed 4 to 6 feet of scum and an average of 10 feet of sludge in the four units. Today, the gas vents are all foamy and the weekly sounding revealed an increase of 2 feet in sludge depth and one foot in scum thickness, which is far more than is attributable to the solids received during the 7-day period.

Activated sludge is not the only kind that bulks!

January 27—In compliance with the request of the Salvage Division of WPB, we completed the collection of scrap metal about the plant and started it upon its way to Tokyo via air mail. In spite of our "save it, we might be able to use it sometime" tendencies, we were able to turn in 2,800 pounds of iron and steel, 15 pounds of brass and a small amount of rubber.

January 28—In trouble with the law! An inspector for the State Department of Labor called to investigate our temporary violation of the Six-Day Week law. There was no question about there being a violation, several of our operators having expressed a wish to augment their incomes by working on their days off, and we have been agreeable to the arrangement because extra labor is next to impossible to find.

To the inspector, we freely admitted the violation and advised him that we would stop the practice upon notification by his office, but we would, of course, have to tell our men that the State Department of Labor would not permit them to work on their days off regardless of whether they wished to work or not. We also advised him that any assistance from his department in securing necessary extra labor would be appreciated since the local U. S. Employment office was unable to supply us. (It occurred to us to offer the inspector a job doing something useful but decided this might be going a bit too far.)

After the usual amount of verbal sparring, the inspector departed and, as we expected, we heard nothing more from him or his department thereafter.

January 29—One of the secondary sludge pumps reported out of order. These pumps are quite sensitive since they are located above the water surface of the final settling tanks and must be primed by means of a vacuum pump.

A search for the trouble revealed that someone had been adding packing rings without regard for the position of the lantern ring, rendering the water seal entirely ineffective. Took time out immediately for a short class in pump packing practice.

February 5—Bought a new desk for the office, the old one having been purchased second-hand twenty years ago. The new one is very attractive but is somewhat uncomfortable. There does not seem to be any place to put our feet!

February 11—Packing gland stud bolts at Sewage Pump 2 no good after only ten months of service, the threads being almost entirely corroded away. We have found these studs to be the part of our pumps which requires most frequent replacement. How about it Mr. Manufacturer, could they not be made of stainless steel or other suitable corrosion-resistant metal?

February 14—Here we go again. Six below zero this morning!

February 18—What weather! The temperature touched 60 degrees above today and the Imhoff tanks are unable to decide whether to stay in winter hibernation or to erupt into the usual spring activity. They are trying to do both at the moment.

February 22—Mild weather the past several days has permitted use of the gas vent water sprays and the tanks are much improved, although there is a tendency toward foaming in some of the vents.

Engineer D. K. Harmeson of the State Sanitary Water Board visited us this afternoon to make an inspection of the plant. Too bad that all state field men are not of the same attitude and caliber as the Sanitary Water Board engineers. We thoroughly enjoyed Harmeson's visit and found him to have a sympathetic ear for our problems as well as anxious to offer helpful suggestions. Like plant operators everywhere, we welcome the all too infrequent visits of these engineers.

February 23—A new record for sludge beds cleaned in one working day established when our crew of four "scoopers" and one driver removed 108 cubic yards of dried sludge from six drying beds. Each bed is 25 feet by 100 feet. A mighty good day's work!

Bad luck struck again in the form of an accident (at his home) to one of the regular shift operators, who will be off duty for at least a week. Out all evening "beating the bushes" for a temporary replacement.

February 25—After one shift, the replacement operator hired two days ago decided that he could not stand the "night air" and quit. If there is a Seven-Day Week labor law in Illinois, we are violating it now. Two of the men are working double shifts as well as on their day off for the rest of this week!

February 27—Looks like an early spring. The trickling filters are commencing to unload. Many earthworms.

March 1—The city water pressure having been somewhat under par lately, we asked the local water company to do what they could to clean out the plant service line. Their procedure was interesting in that it embodies the same reasoning that led us to admit air into the trickling filter distribution system piping during the flushing operation (see **This Journal**, November, 1943, page 1197).

The water company crew, however, used a portable air compressor which was connected to the water service line and used to pump air into the line for several minutes. Then the air was disconnected and water pressure restored for a brief interval while faucets at the end of the line were left open. The air-water spume that emitted from the faucets carried a great deal of rust and other suspended matter. The above cycle was repeated until the discharge from the line was clear. This cleaning of the line was considered very effective but did not appreciably improve the water pressure. A leak in the system is indicated.

March 9—Considerable light oil accumulated at the surface of the Imhoff tanks last night. Source unknown.

Began calling all dry cleaning establishments.

March 12—Still getting oil but have definitely decided it is not from dry cleaners. Read an item in the newspaper stating that a temporary deficiency in the natural gas supply for the city had made it necessary to operate the local gas plant during the period March 2–9, the first time it had been necessary to manufacture gas here in nine years. Began checking with utility company officials.

March 14—Oil discharge to plant abated noticeably but gas company people do not admit responsibility.

March 20—Another sign that winter is on the wane. Profuse clumps of fungus growths coming in with the raw sewage. Not bad enough yet to suspend the grinding of screenings in favor of burial.

March 23—It was good to have Operator Johnston out for a visit, the first since his serious accident last August 10. As is common in the case of severe back injuries, recovery will be slow and his return to duty is not yet in sight.

March 26—The heaviest "slug" of oil to date came down on us last night and we decided that this matter had gone far enough! Samples of the oil were taken and it was found to burn readily when a wick was provided, indicating that it was likely to be a fuel oil. A sample was taken down to the gas plant and compared with the fuel oil used there and the similarity was so obvious that further discussion was unnecessary, although the sanitary sewer manhole at the gas company property was inspected for traces of oil. The evidence was overwhelming and corrective action was left to the company.

March 29—To put it poetically, the fuel oil mystery is now past history! A bad leak in an oil line was located in the gas plant and has now been repaired. With fuel oil as "tight" as it is in these times, company officials were more relieved at stopping the waste than were we. They estimated that about 800 gallons had been lost during this month.

March 31—Finds us in the midst of the task of replacing the drive wheel of the traction type clarifier at the final settling tank. The job has assumed the proportions of a major project!

SERVICING SLUDGE GAS BURNING EQUIPMENT *

By Walter M. Kunsch

Formerly Supt., Danbury, Conn., Sewage Treatment Plant

In starting this discussion I am assuming a rather broad definition of the term "gas burning equipment" and will include not only gas burning boilers and controls but also pipe lines, condensate, sediment, and flame traps, pressure relief valves, gas meters, and waste gas burners. Recommendations and conclusions offered are the result of personal experience with some of this equipment. No attempt will be made to cover all types and makes in general usage.

Pipe Lines

Probably most pipe lines installed for sludge gas collection are of cast iron or wrought iron. One of the most serviceable and trouble free in my experience is a bitumastic lined cast iron pipe. One metal that does not appear to be suitable for gas lines in which a moist gas is carried is brass.

Many difficulties in the maintenance of pipe lines can be eliminated by proper design. Lines should be large enough to carry peak loads of gas without excessive pressure loss. Bends or elbows should be avoided when possible. Plugged tees in place of elbows are not expensive and are a great help in inspection. A generous supply of unions should be installed for ease in disassembling and cleaning. If there is a possibility of earth movement, lines should be designed to provide for it. Many lines from digesters to control buildings are under heavy fill and a break in them would result in a long period without gas. All underground lines should, of course, be laid with a definite slope toward control chambers, where condensate may be collected.

Provided all lines are of sufficient size and of proper material, one inspection and cleaning per year should be sufficient. Particular attention should be paid to low lines or those in which it is known that moisture is present. In cleaning the piping system, flushing with water will often do a good job, provided volume and pressure are sufficient. Occasionally, cleaning with a round wire brush followed by flushing will be necessary.

Condensate Traps

Condensate traps should be installed at all low points in the system. Frequently, gas meters and waste gas pilot lines are forgotten in this respect. I believe it would be good practice to install a sediment as well as a condensate trap at the first low point between the digester and the control building. Locally built or homemade combination sediment and drip traps can, in our experience, be fabricated so as to function safely and successfully. Of the various types of condensate traps on the mar-

* Presented at the Fall Meeting of the N. E. S. W. A. on Sept. 22, 1943, Parker House, Boston, Mass.

ket, those manually controlled appear to be in favor. The frequency of removal of condensate is determined by local conditions. Manually controlled traps should be emptied frequently enough so that water will not build up to the point where it begins to fill the gas line. Those provided with two-way valves will probably require oiling of the valve stem at least once a month. The automatic type should be inspected once a month to be certain that no sediment is present which might hold the draining valve open. Those serving as both sediment and condensate traps should by all means have a gauge glass for determining the height of water. All types should be dismantled and thoroughly cleaned once a year.

Flame Traps

Flame traps in the more recent plants are of the dry type, with the flame trap element of corrugated aluminum plates, or crimped plates wound in a spiral. Some liquid sealed types are in use but are fast losing favor because of high pressure losses and limited capacity.

From personal experience with the Varec horizontal type of flame trap, it appears that these should be inspected at least once a month for any accumulation of moisture. Every three months the flame trap element should be inspected for deposits of scale or other solids accumulations. Local experience determines the necessity for cleaning. A thorough cleaning once a year would not do any harm even though the plates do not look dirty upon inspection. The same is undoubtedly true in servicing the type "B" flame trap made by the Pacific Flush Tank Co.

Pressure Relief Valves

In most plants of today pressure relief valves are either of the diaphragm or weighted valve type and, in general, these have given satisfactory performance. The old "water trap" type performed a valuable service but because of the great amount of attention required for safe operation, it has generally been replaced.

My experience with the weighted valve type has indicated that it requires rather frequent inspection and cleaning in order to insure prompt relief of excess pressure. Gas passing through the valve has a tendency to leave a sticky deposit which prevents the valve from opening at the desired pressure. After routine dismantling and cleaning of this valve was begun, no further trouble appeared.

We recently had difficulty in obtaining proper operation of a relief valve of the diaphragm type. At this installation the ¼-inch pipe connected as a vent to the atmosphere had been installed in cramped quarters and, in making the connection to the pressure relief valve, a strain had been placed on a needle valve housing, preventing the needle valve—essential in the operation of the pressure relief—from closing tightly. After relieving the strain we had no further trouble.

A frequent check of the gas pressure indicating gauge will show whether or not the pressure relief valve is functioning properly.

Gas Meters

It is my belief that most types of gas meters except the old tin case type will give good service in measuring sludge gas if they have adequate capacity, and if the operator gives routine attention to the removal of water from the meter case. Except on high capacity meters, no lubrication is required. It appears to be good practice to remove meters at least every two years for a check of accuracy and parts needing attention. In Danbury, Conn., we have been given good service by the meter shop of the local gas utility in this respect.

Gas Fired Boilers

Our experience has been entirely with the Ideal gas fired boiler. We have found that in order to keep troubles at a minimum, the following points should be observed: first, maintain boiler water outlet temperatures as close to 180 degrees as possible; second, keep the boiler in constant use if possible; third, maintain proper gas inlet pressure as advised by the manufacturer. In our experience, deposits formed on boiler sections are deliquescent in nature and if the boiler stands idle for long periods, especially in humid weather, the scale formations become sticky and may even drip down onto the gas burners. It is good practice to clean, at regular intervals, the openings between sections of the boiler, and to remove the scale from the heat absorbing pins. The burner ports will be found to need occasional cleaning.

Too high a gas pressure on the igniting pilots tends to blow them out. Manually controlled valves are usually provided on pilot lines to regulate pressure at this point.

For safety against overheating and against the entrance of gas to the boiler when the pilots are not burning, a "thermopilot valve," furnished by the boiler manufacturers, does a highly creditable job. At the same time it automatically throttles the volume of gas in order to give a constant boiler temperature under normal conditions. We have had such a valve operating for four years without giving any difficulty. However, it is best to check the safety features of this valve regularly and frequently. This can easily be done, first, by stopping the circulating pump and checking the temperature at which the safety valve closes; second, by manually stopping the gas supply to the safety pilot and observing the length of time required before the main gas supply is cut off. These safety valves have been known to fail and my best advice is to find the trouble before it finds you.

Waste Gas Burners

In these times when the dimout and blackout are the ruling regulators of night lighting, it is probable that many waste gas burners are serving mainly as waste gas "dispersers." Our own are doing just that. We have been too lazy to sit up at night and design a burner cover that would meet the blackout rules and keep on burning. Whether it ends in a burner or in a disperser, a waste gas line should be installed so that any condensate formed in it will drain toward the control building. Safe equipment for the removal of this condensate should be provided not only on the main line but also on the pilot line. The problem of maintaining a constant flame or source of ignition at the waste gas burner depends entirely upon the pilot line. My experience has been that the pilot lines clog easily and more often than not are too difficult to remove for proper cleaning. My idea of a serviceable pilot line would be a 1½-inch pipe reduced at the waste burner to ½-inch to prevent too large a gas consumption. Whether or not it would be worth the expense would depend upon local conditions.

OPERATION AND MAINTENANCE OF SEWAGE PUMPS *

By Glenn Searls

Supervisor of Sewage Treatment, Rochester, N. Y.

The New York State Department of Health requires, for new sewage pumping installations, that main pumping stations must have at least three pumps of such capacities that, with the largest out of service, the other two can pump the maximum flow, with power available from two sources where electric power is subject to interruption. Secondary lift stations should have duplicate equipment. Screening devices should, in general, be placed ahead of pumps. Pumps should be located in dry wells. The size of wet well should be such as to permit pump operation without frequent stopping and starting but not so large as to act as a sedimentation basin.

The pumps in common use for handling sewage or sludge may be classified as reciprocating and centrifugal. Sewage is also raised by pneumatic lifts called ejectors.

Centrifugal Pumps

Centrifugal Pumps have only one moving part—the impeller; they are readily accessible for cleaning and repair and are less expensive than others.

If they operate with a suction lift, some means of priming is necessary, and precautions should be taken to prevent accumulation of sewage gas or air in the suction which would destroy the priming. Priming trouble is commonly prevented by placing the pump below the sewage level in a dry well.

Centrifugal pumps for handling sewage or sludge are commonly called "non-clog," and are made with either vertical or horizontal shaft drive. Where vertical shaft pumps are located more than 8 ft. below the motors, intermediate bearings are necessary. It is impracticable to use smaller than 3-inch non-clog sewage pumps for handling crude

* Paper presented at Spring Meeting of New York State Sewage Works Association, Rochester, N. Y., June 4–5, 1943.

sewage as the bore of the average water closet is 2½ inches. Pneumatic lifts are more adaptable for small installations.

Centrifugal pumps cannot be operated satisfactorily at less than 25 per cent of their ratings; if less than this amount is to be pumped, the operation should be intermittent, allowing sufficient amount of sewage to accumulate in the wet well with the pump being controlled by float or pressure switches.

Reciprocating Pumps

In reciprocating pumps a plunger operates in a cylinder, the sewage or sludge enters through a valve and leaves through another; or a similar action is obtained by means of a diaphragm in a cylinder. The reciprocating motion is obtained by means of a crank shaft, an eccentric on the shaft, or a walking beam.

Ejectors

A pneumatic ejector consists of a closed air-tight tank into which the sewage flows, an air compressor which delivers compressed air into the top of the tank, a discharge pipe leading from the bottom of the tank, and valves and controls whereby the air pipe is closed while the tank is filling, and opened and the inlet pipe closed while the tank is discharging. Their principle use is for handling small quantities of sewage at rates too small to be handled economically by either of the above mentioned types of pumps.

Sewage Pump Requirements

Whatever the type, the most important characteristic is freedom from clogging by rags, sticks or other objects more or less common in sewage, and accessibility for removing such obstructions if they occur. Next in importance is reliability of operation, resistance to wear and erosion or other deterioration of pump parts which will necessitate repairs or replacement. Efficiency is important, but as the lift is generally small and power required is consequently low, it is of less relative importance than in the case of water works pumps.

Pump Operation and Maintenance

Where there are two or more pumps of the same size, they should be alternated every 24 hours to equalize wear, keep motor windings dry, and grease distributed in bearings.

All motors, bearings, and electrically controlled equipment should be inspected daily for overheating. Manufacturers' directions for operation and lubrication should be studied and followed carefully. Packing glands should be inspected frequently; excessive tightness should be avoided. A packing is too tight when the shaft cannot be rotated by hand.

Wet wells should be drawn to minimum level daily and deposits removed; walls, bottom, and pressure tubes cleaned and flushed with water. Grease is preferable to oil for intermediate bearings on vertical shafting. A grease to be used in bearings on pumps and shafting should be a waterproof grease which does not become frothy when coming in contact with water.

Do not overlubricate anti-friction bearings as this tends to cause overheating. A bearing having two-thirds of its raceway filled with lubricant is considered sufficiently lubricated.

Numerous details enter into the satisfactory operation of sewage pumps. The service they must render is severe. The construction should be rugged and materials used must be resistant to abrasion and wear. Because of the possibility of clogging, hand holes should be provided which give access to all parts of the pump without dismantling it.

Since the cost of pumping sewage is usually a large item in the operation of a sewage treatment system, special attention should be given to maintaining the pumps in an efficient operating condition. Pumps that are partly clogged with rags or other debris cannot deliver the gallonage for which they were designed.

Make inspections and necessary adjustments daily, renew packing whenever necessary and check bearings at regular intervals. Remove dust and dirt from motor windings with compressed air, avoiding a pressure over 80 lbs. Excessive dampness causes low resistance to windings. Motors may be dried by the use of small bowl-type electric heaters. Softened insulation may be cleaned with carbon tetrachloride and then painted with insulating varnish or glyptal lacquer.

Trouble-shooting

The following list of operating troubles is taken from the R. & U. Manual, Corps of Engineers.

A.—No flow from pump: 1. Impeller may be clogged; 2. Pump may not be primed; 3. Pump may be operating in reverse direction; 4. Pump speed is too low.

B.—Small flow: 1. Impeller partly clogged; 2. Air leaks in the suction or the stuffing box; 3. Air entering suction due to swirl of sewage in wet well or insufficient depth of suction.

C.—Pump works for a while and then loses suction: 1. Leaky suction line; 2. Suction lift too high; 3. Air or gas bubbles in the liquid; 4. Water seal plugged.

D.—Too much power required and motor overheated: 1. Speed too high; 2. Head is lower than pump rating and too much water is being pumped; 3. Mechanical defects such as, tight stuffing box, bound impeller, worn wearing rings, shaft bent out of line, or improper lubrication.

E.—Low speed: 1. Low voltage; 2. Defective electrical contact; 3. Motor overloaded.

F.—Pump starts but overload relays kick out at once: 1. Impeller bound or packing too tight; 2. Defective starting relays; 3. Improper oiling; 4. Voltage too low or too high; 5. Defective motor wiring or switches.

G.—Excessive vibration or noise: 1. Shafting out of line; 2. Worn bearings; 3. Lack of lubrication.

H.—General: In some cases where the discharge line is long and the lift high, check valves may slam due to water hammer. Spring loaded relief valves may be installed or an air chamber connected to the line.

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1. Anon., "The Operaton of Sewage Treatment Plants." *Public Works,* October, 1942, page 12.
2. Nussbaumer, N. L., "Sewage Pumping Installations and Maintenance." *This Journal,* 13, 324 (March, 1941).
3. Anon., "Pumps for Sewage and Sludge." *Public Works Manual,* page 91 (1940).

INTERESTING EXTRACTS FROM OPERATION REPORTS

Minneapolis-Saint Paul Sanitary District (1942)

By George J. Schroepfer

Chief Engineer

Advertising Sludge for Fertilizer

The experimental work involving the use of sludge cake as a fertilizer was continued by both the District and the University Farm School. An exhibit was held at the Minnesota State Fair again and the District is indebted to Mr. Raymond E. Lee, Secretary of the State Agricultural Society, for his interest and courtesy in providing exhibit space. Samples displayed were those taken from the State University Farm experimental fields. That the exhibit at the Minnesota State Fair is considered well worth while is borne out by the fact that additional information as to the use of sludge cake as a fertilizer with a corresponding increase in demand for sludge cake itself was requested especially by farmers living in the vicinity of the Twin Cities. It is interesting to point out the steady increase in the quantity of filter cake used as a fertilizer. In 1939 this quantity was 21 tons; in 1940, 2,756.8 tons; in 1941, 3,678.3 tons. For the year 1942, this quantity had risen to 6,867.3 tons, or approximately seven per cent of our total annual production.

Coarse Screen Racks Eliminated

In the 1941 report mention was made of the fact that difficulties and the cost of removing screenings from the coarse bar screens with six-inch openings had resulted in the carrying out of an experiment leading to the actual removal of the coarse bar screens in October of 1941. In more than one year of continuous operation with the screens removed, it has been determined that savings of some magnitude in the operation have been effected by the elimination of these racks, which have more than offset the small increase in maintenance costs of the one-inch, mechanically-cleaned bar screens which has resulted.

Sedimentation Summary

The settling tanks continued to function very satisfactorily during 1942. With an average detention period during the year of only 0.9 hours, as compared with a possible detention period of about three hours at present flows, the average removal of suspended solids by the settling tanks was 64.3 per cent and of the five-day biochemical oxygen demand 40.1 per cent. Sludge is pumped once each shift and a determined effort is made to secure as concentrated a sludge as possible. That such efforts have been successful is shown by the fact that for the entire year solids concentration in the raw sludge pumped from the settling tanks averaged 8.61 per cent as compared with 7.79 per cent, 8.07 per cent, and 8.00 per cent, respectively, in 1939, 1940, and 1941. As an aid in increasing the sludge concentration, weighing of sludge samples during the pumping period was continued during the year 1942.

Again during the year 1942, the automatic scum removal mechanisms were operated only during the warmer months of the year, their use being dispensed with in the winter months when the work of maintaining this equipment in operation for mechanical removal of skimmings proved to be much more of a problem than hand skimming. The skimmings removed from the settling tanks are ejected to an area south of the plant where they are covered with incinerator ash, without nuisance.

Sludge Concentration and Dewatering

Sludge from the settling tanks is pumped to concentration tanks where it is held for a short time to a usual maximum of three days for concentration from 8.61 per cent to 9.63 per cent, as an average for the year. In addition, the tanks serve as a storage means and level off variations in solids content because of changing sludge characteristics. A total of 79.8 million gallons of concentrated sludge was filtered during the year. The average moisture content of the filter cake was 66.3 per cent, and its average volatile content was 59.7 per cent.

Continued reduction in the quantity of conditioning chemicals was effected. During 1942 the quantity of ferric chloride required was 1.20 per cent of the weight of the dry sewage solids, and the quantity of lime expressed on a calcium basis was 3.44 per cent. Comparable figures for the year 1940 were 1.92 per cent and 4.76 per cent, respectively, and during 1939 were 2.1 per cent and 5.68 per cent, respectively. During 1941 these were 1.53 per cent and 3.77 per cent, respectively.

The average life of filter cloth has been increased to 493 hours during 1942, which compares with 355 hours in 1941, 326 hours in 1940, and 170 hours in 1939. The average filter rate has been progressively reduced as a means of saving chemicals, from 5.50 pounds per square foot per hour, to 3.40 pounds, both expressed on a dry basis. An average of 286.9 per cent tons of filter cake was produced daily, containing an average of 96.6 tons of dry solids. The total quantity of filter cake produced during 1942 was 99,654 tons. The quantity of sludge produced was considerably higher than anticipated at the time of design, at which time it was expected that 76 tons of dry sewage solids would be produced daily. The increased quantity is due to higher sewage strength and greater removal by the plant than originally expected.

During the year 1942 the use of hydrochloric acid containing an inhibitor in the cleaning of the drums and screens of the vacuum filters, and for prolonging the life of filter cloth, was continued. The life of the cloth was extended to an average of approximately 500 hours by cleaning the cloth with acid after approximately 300 hours of use.

Incineration Economies

In earlier reports mention has been made of the fact that it was planned to remove the preheaters and hot air fans from the incinerators so as to effect economies in operation and maintenance of these units. Removal of the preheaters in one incinerator was completed during May of 1941, the second unit during March, 1942, and the last unit during December of 1942. Operation under the improved arrangement shows that the expected economies can more than be fulfilled. As an example, the power requirements have been reduced from an average of 17 kilowatt hours per dry ton, in both the years 1939 and 1940, to 14 kilowatt hours per dry ton in 1941, and to 8.8 kilowatt hours in 1942. Even in 1942 the full effect of such economies was not possible, since all units were not converted until the close of the year. For the last two months of 1942, with operation of only converted units, the power requirements averaged approximately six kilowatt hours per dry ton of solids incinerated.

Perhaps a clearer picture of the effect of such savings in power requirements by the incinerators can be had from the following. In 1940 the kilowatt hour consumption by the incinerators was 663,489. With the conversion of one incinerator by the month of May, 1941, the use for the entire year of 1941 was reduced to 504,582 kilowatt hours. In 1942, the use had been reduced to 276,068 kilowatt hours. With all incinerators converted, the use during the early months of 1943 was at a still lower level, the consumption for the first six months indicating a total use for the year 1943 of approximately 145,000 kilowatt hours. When it is remembered that power during the year 1941 cost an average of 1.19 cents per kilowatt hour, the magnitude of such savings will be apparent.

Planned Shutdowns Beneficial

During the year 1942 the practice of conducting planned shutdowns of the treatment plant during periods of high water in the spring and fall months to insure dependability of operation during the critical summer and winter months was continued. In addition to the inspection of all the equipment in the plant, such shutdowns are necessary to inspect the intercepting sewers and control stations which are inaccessible during such times. During such shutdowns the main electrical equipment is also inspected by the insurance company which carries the coverage

TABLE 1.—*Summary of 1942 Operation Data, Minneapolis-St. Paul Sanitary District*

Item	1942 Average	
Sewage flow—ave. daily	115.1	m.g.d.
Screenings removal—per m.g. treated	0.98	c.f.
Weight per c.f.	30.0	lbs.
Moisture content	83.3	per cent
Volatile content	87.0	per cent
Grit removal—per m.g. treated	6.4	c.f.
Wet wt. per c.f.	87.8	lbs.
Moisture content	12.3	per cent
Volatile content	6.9	per cent
Detention period—primary settling	0.9	hrs.
5-Day B.O.D.:		
Raw sewage	175	p.p.m.
Settled sewage	105	p.p.m.
Removal—primary treatment	40.1	per cent
Suspended solids:		
Raw sewage	290	p.p.m.
Settled sewage	100	p.p.m.
Removal—primary treatment	64.3	per cent
Raw sludge—quantity	308,000	g.p.d.
Dry solids daily	113.3	tons
pH	6.2	
Solids content	8.61	per cent
Volatile content	63.8	per cent
Specific gravity	1.032	
Concentrated sludge—quantity	229,700	g.p.d.
Dry solids daily	95.7	tons
pH	6.0	
Solids content	9.63	per cent
Volatile content	62.5	per cent
Specific gravity	1.036	
Decanted liquor—quantity	87,800	g.p.d.
Solids content	1.10	per cent
Volatile content	64.4	per cent
Sludge filtration—hourly rate, dry solids basis	3.40	lbs. per sq. ft.
Conditioning tanks detention period	8	minutes
Lime applied (as CaO)	3.44	per cent
Ferric chloride applied (as $FeCl_3$)	1.20	per cent
Filter cake—quantity (wet)	286.9	tons daily
Solids content	33.7	per cent
Volatile content	59.7	per cent
Filtrate—quantity	210,600	g.p.d.
Solids content	0.36	per cent
Volatile content	43.1	per cent
Incineration—quantity (dry)	96.6	tons daily
Combustibles	53.8	tons daily
Water evaporated from cake	176.9	tons daily
Water added for temp. control	42.1	tons daily
Total water evaporated (per ton combustibles)	4.1	tons
Power consumption (per ton dry solids)	8.8	kw. hrs.
Oil consumption (per ton dry solids)	2.15	gal.
Operation and maintenance cost (per m.g.)	$9.90	

on these units. No unusual problems were found in connection with the treatment plant shutdown, but in the case of the intercepting sewers, segregated deposits of grit and gravel up to boulders eight inches in diameter were found in the lower-mile section and in the underpass. In previous years these sections were entirely free of deposits. The reason for the deposits is apparently the large quantity of grit entering the sewers because of the unusual runoff during the 1942 summer season. The deposits were not of much consequence as yet, but if the inspection had not been made, troublesome difficulties might have developed in later years. As it was, the underpass and sewer barrel were well flushed, which flushing restored these sections to the same flow characteristics as when the plant was first placed in operation. Too much emphasis cannot be placed on the desirability of plant and intercepting sewer shutdowns on planned occasions during the high river flows, as a means of increasing dependability during the balance of the year. Especially is this true in a highly mechanized plant such as ours. By careful scheduling of the shutdowns it is possible to reduce the period to approximately one week. In 1942 the shutdowns occurred during the following periods: April 16 to 24, and October 11 to 17.

Controlled Efficiency

Chemical treatment of the sewage as a means of increasing the degree of treatment was not required during the year. However, during the month of January, and during the months of July and August, the degree of treatment was increased by increasing the period of detention in the sedimentation tanks. This was done because river flows and dilution conditions were such as to make such higher degree of treatment desirable. During July and August the average removal of solids by the plant averaged 82.5 per cent, and the average removal of biochemical oxygen demand averaged 50.3 per cent. If necessary, this degree of treatment could have been increased by a further increase in the period of detention from an average of one hour to approximately two hours had the full sedimentation capacity of the plant been employed.

Inhibited Acid for Cleaning Vacuum Filters and Cloth

Acid cleaning of the large Oliver rotary drum filters and filter cloths is still being practiced to reduce the lime carbonate deposits which cause much of the "blinding out" of the filter cloths. Aniline oil is added to 18° Be. muriatic acid as a corrosion inhibitor. A more detailed account of the method of cleaning may be found in the 1941 Annual Report, pp. 41–43.

A thorough study of the use of aniline oil as an inhibitor of acid corrosion, using varying strengths of acid and aniline oil mixtures indicated that a 2 per cent aniline oil dosage could be used with the weaker acid solutions (up through 5 per cent HCl) while stronger acid solutions (10 per cent HCl or more) would require a 3 or 4 per cent aniline oil dosage, for maximum protection against corrosion of metal parts of the equipment to be acid cleaned.

With a 0.7 per cent HCl solution (corresponding to one carboy per filter), a 2 per cent aniline oil dosage cut the rate of corrosion 44 per cent. With a 2 per cent HCl solution, a 1 per cent aniline oil dosage cut the rate of corrosion 87 per cent. With a 5 per cent HCl solution, a 2 per cent aniline oil dosage cut the rate of corrosion nearly 97 per cent.

With a one-carboy acid bath for a filter, 310 ml. of aniline oil will reduce the corrosiveness of the acid 44 per cent for the small cost of 25 cents. For protection of the screen and the thin nailheads in the wood backing of the filters, this added precaution is justified even though the rate of corrosion with an acid solution of this strength employed is apparently quite low.

The average life of the filter cloths, with acid cleaning, is approximately 500 hours. Inhibited acid is also used in the plant for cleaning other scaled equipment such as pipe lines, spray nozzles, and valves from the filter vacuum pumps.

GARY SANITARY DISTRICT (1942)

By W. W. Mathews

Superintendent

This report describes the operation of an activated sludge sewage treatment plant handling about 100,000 population with a flow of 19.37 m.g.d. and a small Imhoff tank-trickling filter plant serving 2,000 population. The data cited herein is for the large plant.

The summary of the operating results are as follows:

Item	1941	1942
Population (est.)	100,000	100,000
Population Equivalent		138,999
Sewage, m.g.d.	19.37	20.72
Suspended Solids Removed, lb.	11,657,667	14,011,858
5-day B.O.D. Removed, lb.	8,276,834	7,927,967
Gas Production, cu. ft.	53,320,100	57,594,800
Reduction in Per Cent:		
Suspended Solids	96.12	97.22
5-day B.O.D.	94.31	94.72
Air—cu. ft. per gal.	0.52	0.46
Cu. Ft. Air per Lb. B.O.D. Removed	690	862

The cost of operation was:

Item	1941	1942
Per Million Gal.	$9.42	$8.79
Per Capita *	0.6482	0.6652
Per 1,000 lb. B.O.D. Removed	7.83	8.39

* Based on 100,000 pop. connected.

The gas production at Gary has proved higher than estimated, thus reducing power cost through the use of gas engines for air compression.

Dried sludge was given away for fertilizer use to those removing it from the beds.

Item	1941	1942
No. of Persons	4,039	4,763
Dried Sludge Removed, cu. yd	5,106	

Among other operating data are the following:

Item	1941	1942
Gas Production:		
Cu. Ft. per Cap. per Day	1.46	1.58
Cu. Ft. per Lb. Solids Added	5.6	3.7
Cu. Ft. per Lb. Vol. Solids Added	8.9	7.0
Content of Raw Sewage:		
Solids per Cap. per Day	0.337	0.304
B.O.D. per Cap. per Day	0.244	0.229

The gas contained 663 B.T.U. per cu. ft. The gas scrubbers removed 20,832 grains H_2S per cu. ft. of sponge.

During 1942 ferrous sulfate entered the sewers, averaging 41,727 lb. Fe per month as against 20,900 lb. in 1941.

Analytical data by monthly averages in parts per million for 1942:

Determination	Max.	Min.	Avg.
Dissolved Oxygen—raw	2.8	0.1	1.25
5-day B.O.D.:			
Raw	162.8	98.9	132.7
Clarified	89.4	54.9	70.6
Final Effluent	13.0	3.6	7.2
Suspended Solids:			
Raw	266.5	178.9	228.8
Clarified	120.1	81.1	99.7
Final Effluent	8.8	2.9	5.9
Return Sludge	6,993	2,226	4,533
Mixed Liquor	1,779	782	1,440

Other operating data by monthly averages for 1942 are:

Data	Max.	Min.	Avg.
Preliminary Settling Period, hr	2.27	1.68	1.95
Aeration Period, hr	5.26	4.01	4.40
Final Settling:			
Period in Hr	3.44	2.79	3.07
Gal. per Sq. Ft	778	635	717
Return Sludge—per cent	37.9	29.2	34.0
Sludge Index	371	69.5	170

The per cents of volatile suspended solids on monthly averages were:

Item	Max.	Min.	Avg.
Raw	69	54	64
Preliminary Settling	70	64	67
Final Effluent	70	58	64
Mixed Liquor	68	58	64
Return Sludge	70	58	64

The raw sludge contained dry solids ranging from 3.9 to 6.4 per cent, with an average of 4.9. The solids pumped per month ranged from 966,633 lb. to 2,144,226 lb., with an average of 1,455,812 lb.

The excess activated sludge returned to the primaries ranged from 0.1028 to 1.0917 m.g.d., with an average of 0.4793 (in per cent, respectively, 1.74; 15.42; 6.89).

The temperature in the digestion tanks ranged monthly from 61 to 102° F., with yearly averages from 69 to 92° F.

On the drying beds, 6,337,400 gallons of sludge, with an average of 7 per cent solids, was reduced to 4,400 tons as removed from the beds (at 50 per cent solids tonnage is 3,528).

The cost of operation of the plant was $66,523.80 in 1942 compared with $64,818.59 in 1941. This is distributed as follows:

Allocation	1941	1942
Salaries	$39,636.54	$44,003.41
Power	14,956.42	13,517.69
Water	959.73	1,287.54
Laboratory Supplies	346.81	465.90
Miscellaneous Tools, Etc.	8,645.09	7,249.26
Total	$64,818.59	$66,523.80

The report concludes with a brief description of the main works.

Screening by comminutors.

Sewage Pumps—3 at 20 m.g.d., driven by gas engines; 2 at 15 m.g.d., driven by motors. Head, 35 ft.

Grit Removal—2 units. 1½ min. detention at 40 m.g.d.

Primary Settling—4 clarifiers, 75 ft. square, 10 ft. water depth. 1-hour detention at 40 m.g.d.

Aeration Tanks—10 units, 300 × 30 ft. in plan by 16 ft. water depth. Spiral flow.

Final Settling Tanks—8 at 75 ft. square, 10 ft. water depth, 2-hour detention at 40 m.g.d.

Return Sludge Pumps—3 units, motor-driven centrifugals.

Sludge Digestion Tanks—8 primary units, heated and covered; 3 secondary units, unheated. All tanks 90 ft. diam., with side depth of 20 ft., with capacity of 1 mg. each. This provides 6½ cu. ft. per cap. for 170,000 population.

Sludge Drying Beds—65 units, each 42 × 125 ft., with narrow gage tracks. Total area, 7.8 acres, or 2 sq. ft. per cap. for 170,000 population.

Air Filters—Primary and secondary.

Aeration Equipment—2 units, 7,000 cu. ft. min., rotary, positive-driven by gas engines. 3 units (1 each, 5,000; 7,000; 9,000 c.f.m.) motor-driven.

Garbage Grinding—(Not used as yet.)

(Abstracted by Langdon Pearse)

THE GADGET DEPARTMENT

The devices described and illustrated here are a few of those entered in the gadget competition held at the time of the joint meeting of the Central States Sewage Works Association with the F. S. W. A. in Chicago last October. Others will be presented in future issues of this *Journal.*

First prize in the contest went to R. W. Frazier of Oshkosh, Wisconsin, for the chart-making apparatus described below. The evaporating dish drain and drying rack brought the third prize to H. T. Rudgal of Kenosha, Wisconsin. A description of the gadget which won second prize, entered by C. C. Larson of Springfield, Illinois, will be presented later.

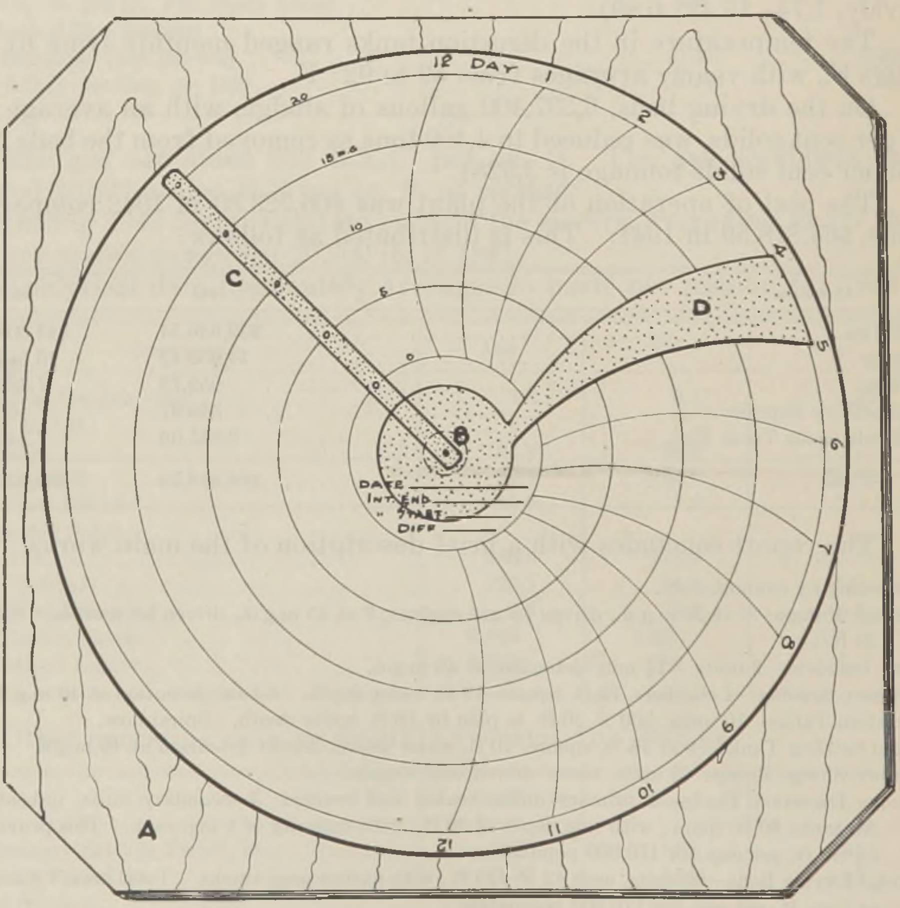

Fig. 1.—Appliances used for making charts on reverse side of used charts, Oshkosh, Wisconsin, R. W. Frazier, Supt.

APPLIANCES USED FOR MAKING CIRCULAR CHARTS

By R. W. Frazier, *Supt.*
Oshkosh, Wisconsin

The apparatus illustrated in Fig. 1 enables used, circular, meter charts to be reused by developing a new chart on the reverse side. Three parts are required; the mounting board (*A*) with center pin (*B*), the circular scribing arm (*C*) which is used for drawing the circular lines of varying diameter and the logarithmic template (*D*), by means of which the curved, radial lines are drawn. The figures denoting the value of each division (m.g.d., hour of day, etc.) are printed on the chart with a rubber stamp.

EVAPORATING DISH DRAIN AND DRYING RACK

By H. T. Rudgal, *Supt.*
Kenosha, Wisconsin

Construction details of the wood rack used in the Kenosha laboratory for drying evaporating dishes will be apparent from Fig. 2. In this

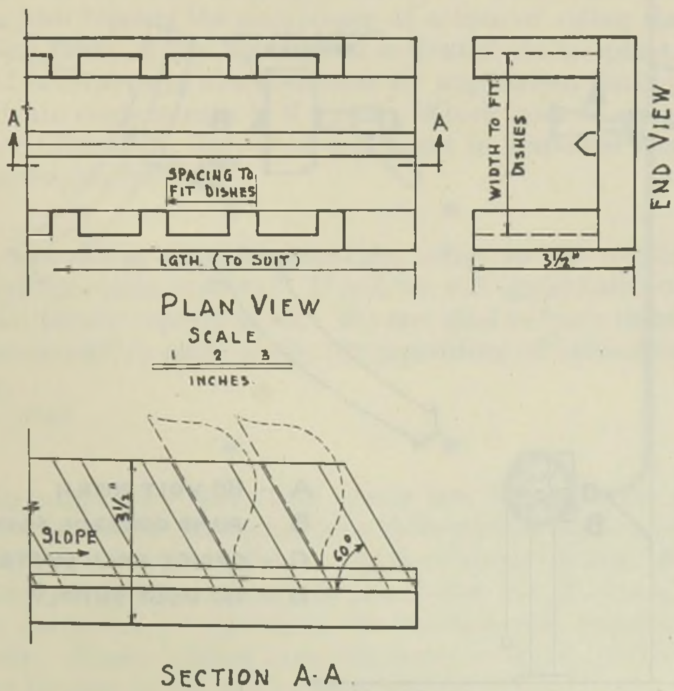

Fig. 2.—Details of evaporating dish drain and drying rack, Kenosha, Wisconsin, H. T. Rudgal, Supt.

laboratory, the rack has a capacity of 24 dishes and has proven both useful and practical, especially following a sludge survey when a large number of dishes has been in use.

WARNING SIGNAL FOR PUMP CONTROL

By R. W. Frazier, *Supt.*

Oshkosh, Wisconsin

The operation of the sewage pumps is governed by automatic float control, various units being started and stopped as the flow varies. At times, with the operators busy in other parts of the plant, the pumps may lose prime or a sudden increase in flow may require a larger pump to be put into service.

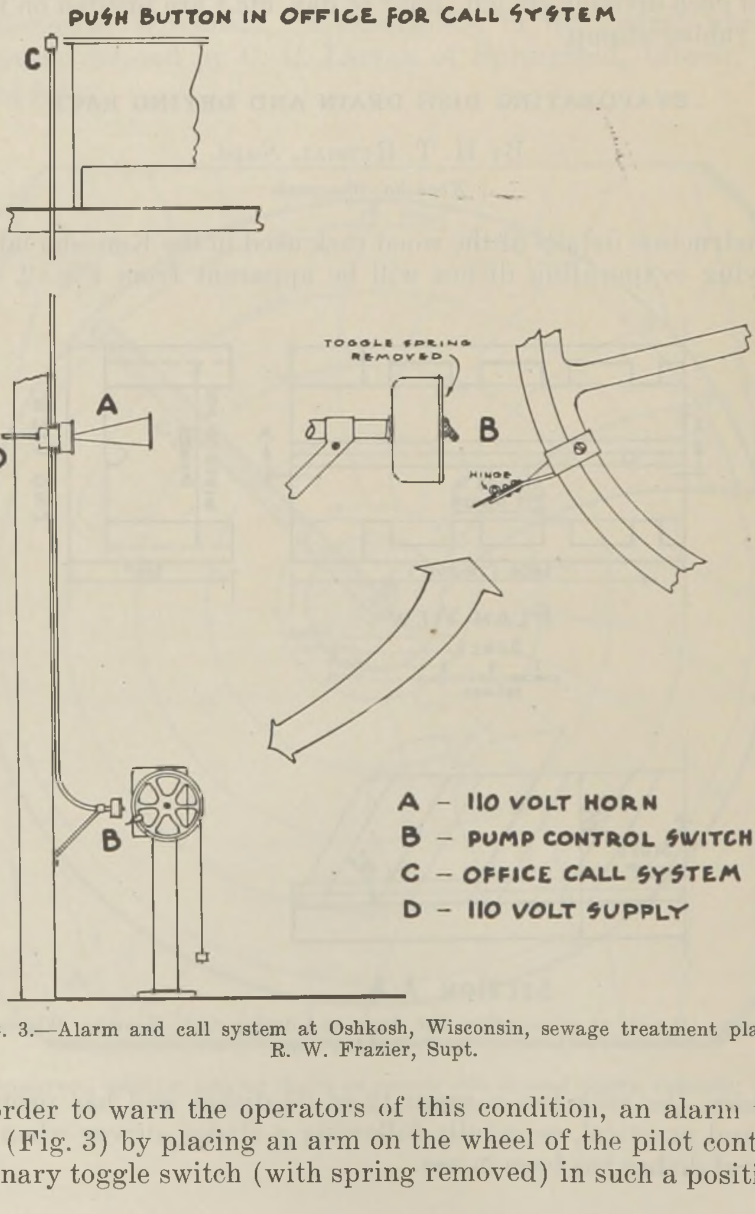

Fig. 3.—Alarm and call system at Oshkosh, Wisconsin, sewage treatment plant, R. W. Frazier, Supt.

In order to warn the operators of this condition, an alarm was arranged (Fig. 3) by placing an arm on the wheel of the pilot control and a stationary toggle switch (with spring removed) in such a position that as the wheel rotates, the arm on the wheel will close the switch. The switch is connected to a 110 volt warning horn which sounds when the switch is closed and cannot be stopped until the switch is thrown. This brings the operator to the pump room where he gives such attention to the pumps as may be necessary.

The horn is also used for calling personnel to the office from any part of the plant. A push button at the Superintendent's desk is used to transmit call signals which notify any employee that he is wanted.

TIPS AND QUIPS

Operators troubled by gas leaks at sludge digestion or storage units may be interested in the successful solution reported by Chemist C. C. Larson of the Springfield (Illinois) Sanitary District, in his 1942 annual report. When a fixed concrete cover was constructed over a large storage tank, the joint between the top of the old walls and new cover was found to leak gas. The leaks were stopped by encircling the tank at the joint with a wood band, leaving a one inch space, and by pouring hot tar into the annular opening between the wood band and the wall.

Larson also reports the occurrence of a case of rising sludge in the final settling tanks of the Springfield activated sludge plant, following a period of several days overabundant air application during which the effluent nitrate content rose to 9 p.p.m. Which goes to show that, like many other things, the degree of treatment in activated sludge plants can be carried too far!

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Is the new Federation headquarters office on the mailing list for your annual operation reports? If not, we will appreciate your sending copies of all future reports to us. We are glad to have them for reference purposes and, in some cases, for reprinting of interesting extracts from them.

Thank you!

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This tip might have been more timely last February but it will still be good next winter in plants having sedimentation tanks equipped with traction type clarifier mechanisms. At the Calumet Works of The Sanitary District of Chicago, temperatures below 15° F. bring operation difficulties due to ice formation on the traction rail, causing the drive wheel to slip. Vapor arising from the warm contents of the tanks condenses and freezes on the rail to form the ice.

Superintendent C. E. Wheeler, Jr., combats this problem by applying sparingly to the top of the rail a mixture of equal parts of permanent type anti-freeze and water. The treatment has been effective in preventing formation of the ice.

● ●

Chemical Digest, published by Foster D. Snell, Inc., tells us that high frequency electric fields are being employed in dehydrating foods and drying of plastics because of their desirable property of drying from the inside out.

Does this offer a possibility for the sewage works of the future? With so much present day emphasis on electric power production from sewage gas, sludge dewatering by exposure to high frequency fields offers an interesting idea. That is, if you have time for such things!

● ●

Speaking of new developments, it seems that nylon has found a use in sewage treatment works as a "better than the original" substitute. The following is quoted from the 1942 Annual Report on the plant at Danbury, Conn., Walter M. Kunsch, Superintendent:

"A new set of fine screen brushes installed in July, 1941, included one brush made of nylon monofilament. As at other plants incorporating fine screens, the nylon brush has given us better all around service than the hog-bristle brush. It cleans the screen well, shows very little wear after a year of service and the small amount of hair or grease that adheres to it is easily removed."

● ●

All signs point to the continued need for conservation of critical materials during 1944 if the enormous demand for military production is to be met. Sewage works administrators may expect adequate recognition of any material needs, however, according to the following perspective of WPB as stated recently by Operations Vice Chairman, L. R. Boulware:

"1. Direct war needs—shooting stuff—come first.

"2. Next most important is to provide for bed-rock civilian needs to maintain health, sanitation and transportation, enabling war workers to do their work at a peak of efficiency.

"3. WPB will strive to produce as many more needed civilian items as can be made without interfering with war production."

● ●

Via *The Wisconsin Clarifier*,* Superintendent Oscar Ward of Marshfield, Wisconsin, passes on a couple of helpful hints.

His first suggestion has to do with the conservation of rubber ball checks in sludge pumps and the prevention of passage of the balls into the discharge piping when they become worn. A 2-inch piece of 3½-inch pipe is machined to a taper for the ball seat and inserted as a sleeve in the discharge pipe at the valve. While this constricts the discharge passage somewhat, it permits the rubber balls to be used a longer time, a very timely innovation with rubber as scarce as it is now. When the rubber shortage is over, the temporary sleeves can be readily removed and discarded.

Ward also offers a method of drilling through porcelain without having the porcelain chip off around the hole. Having occasion to in-

* Published by the Conference of Wisconsin Sewage Works Operators.

stall some extra shelves in a porcelain-lined refrigerator, he glued pieces of paper over the surface at the points at which it was necessary to drill holes. After the holes were drilled, the paper was soaked off, leaving a clean, smooth job.

• •

Observations during a visit to the Texas Water and Sewerage Short School, January 31 to February 3, 1944. Oil fields, pine forests and wide open spaces . . . a predominating military motif . . . the largest short school attendance in our experience, a total registration of 403 . . . an Illinois reunion with Klassen, Schwob, Honsa, Plummer, Remsburg, Sanders, et al. . . . a "big name" program with the third hearing of Cleary's address on Latin America just as interesting as the first . . . the evident high regard in which State Engineer V. L. Ehlers is held by Texas water and sewage works operators . . . a banquet without restrictions on butter . . . a splendid resume by Col. Hardenburgh of the accomplishments of the Sanitary Corps of the U. S. Army . . . development of a stronger sewage works unit which should enable the Texas Section to move into a more prominent place in the Federation . . . a deep appreciation for Texas hospitality . . . and, as usual, we didn't get to see a single sewage treatment plant even though Texas boasts more of them than any state in the U. S.!

• •

A recent inquiry pertains to the effects of industrial wastes containing inorganic chemicals such as sodium sulfate and sodium carbonate on bacterial decomposition in an Imhoff tank. Specific concentrations at which these chemical constituents might be expected to deter bacterial activity were sought.

Our reply was to the effect that bacterial action was unlikely to be disturbed unless there was an extraordinary concentration of the sodium salts in the final mixture of industrial waste and sewage. The possibility of stimulated hydrogen sulfide production (from the sulfate content of the wastes) was pointed out, however.

Ideas and comments from the field on this interesting problem will be welcome.

• •

Active members affiliated with the Federation, but who are not now readers of *Sewage Works Engineering,* may be interested to know that such membership brings special privilege in the way of an inducement to subscribe to that excellent publication.

A book of more than 80 plant flow diagrams is given without charge to Federation affiliates who place an order for a one-year subscription. Nonmembers must pay $1 in addition to the regular subscription rate if they wish the book.

Just one more advantage of membership to add to the growing list of them!

• •

That "it is an ill wind, etc." is borne out by the 1942 annual report of the DeKalb (Illinois) Sanitary District, where wastes from a local pea cannery are received for treatment. During the regular canning season, an unusually heavy growth developed in the trickling filters, requiring periodic resting of the beds in an effort to induce unloading. In October, however, the cannery inadvertently discharged a substantial quantity of pea vine stack liquor to the sanitary sewers, resulting in a severe shock to the entire sewage treatment works. While the plant efficiency was almost nil at the time, Superintendent Henn reports:

> "Very soon after the strong, sour stack liquor went through the plant, the filters unloaded to an extent never experienced since the plant has been in operation. The stack liquor apparently killed most of the life in the beds and huge quantities of snail shells, worms and the usual humus solids were sloughed out. After this heavy unloading, no ponding is anticipated next winter."

It is also of interest to note that normal operation of the plant resumed only two days after this extraordinary shock load was received.

• •

In these days, a sewage plant operator must be a contortionist of a high order. To do his job well today, he must:

1. Keep his back to the wall.
2. Have his ear to the ground.
3. Put his shoulder to the wheel.
4. Hold his nose to the grindstone.
5. Maintain a level head.
6. Keep both feet on the ground.

Is it not so?

• •

Editorials

POSTWAR PLANNING

A recent news item from Washington depicted concern on the part of at least one official that the current deluge of advertising and publicity on postwar planning is premature. Fear was expressed that the war effort would be impeded by such planning.

While such discouraging and pessimistic viewpoints may be desirable in the preservation of a proper balance, it is quite difficult to understand them at this time. Production in many military items has already reached saturation and is being curtailed. There is no semblance of proof that postwar planning is interfering with the production of other implements of war which are still needed in increasing quantities. Whether the termination of actual combat is one or five years away should have no bearing on the plans made for the restoration of a sound peace-time economy because it is certain that the war cannot last forever.

Whether in fox-hole, submarine or bomber, every active combatant in the war is doing some postwar planning, at least to the extent of his return to his home and family and to the resumption of his peace-time work. If all of these men and women are to have peace-time employment upon their return, the planning at home must be done for them. In a recent news letter, Field Director E. L. Filby of the Committee on Water and Sewage Works Development refers to correspondence from men in military service in which they laud the motives of the Committee and encourage its functions. On the home front or battle front, postwar planning affords a medium for looking ahead to happiness and security at the end of the struggle; without such a goal, war would be completely unbearable.

Until there is cause to believe that postwar planning is jeopardizing or delaying victory, let such planning continue unabated.

"Blueprint now for tomorrow's needs!"

W. H. W.

SEWAGE WORKS PLANNING CHECK LIST

In case it may have been overlooked, this is a reminder for every city engineer, public works official and sewage works superintendent to give immediate attention to the check list published on page 479 of this issue of the *Journal*. Even if some of your postwar plans are in development, the list may bring to mind items in need of improvement which may have been overlooked to date.

Do not delay in subjecting the sewage collection and treatment facilities serving your community to this practical test. Few of such facilities will be adequate in every respect.

W. H. W.

Proceedings of Member Associations

NEW JERSEY SEWAGE WORKS ASSOCIATION

Twenty-Ninth Annual Meeting

Trenton, New Jersey, March 23–24

The Twenty-ninth Annual Meeting of the New Jersey Sewage Works Association was held at Trenton, New Jersey on March 23–24 with headquarters at the Stacy Trent Hotel. Final registration for the meeting was 325, which was the largest in history with the exception of the registration of 346 counted for the Silver Anniversary Meeting of the Association in 1940.

The technical paper "Changes in Operation of the Perth Amboy Sewage Treatment Plant" by Richard Oliver, Sanitary Engineer, Perth Amboy, New Jersey, opened the program. This paper was discussed by City Engineer Lewis P. Booz of Perth Amboy. Considerable interest was evidenced in the second paper entitled "The Interest of a Water Superintendent in Sewage Treatment on a Potable Water Shed," which was presented by Richard E. Bonyun, General Superintendent, Passaic Valley Water Commission, and discussed by W. C. Mallalieu and Arthur Wright. The morning session was concluded by the presentation of the Harrison P. Eddy Award of the Federation of Sewage Works Associations to Harry W. Gehm, Associate Chemist, Department of Water and Sewage Research, New Brunswick, New Jersey, and of the Kenneth Allen Award to Treasurer Edward P. Molitor in recognition of his past service to the New Jersey Sewage Works Association. The awards were presented by W. H. Wisely, Executive Secretary, Federation of Sewage Works Associations.

The entire afternoon technical program consisted of a symposium on "Postwar and Advance Planning" led by L. H. Enslow, Editor, *Water Works and Sewerage.* The following discussions comprised the symposium:

Blueprint Now—Who Starts It?, by E. L. Filby, Field Director, Committee on Water and Sewage Works Development.

Selling Postwar Planning to the Local Taxpayer and Governing Body, by Honorable Frank D. Livermore, Mayor of Ridgewood; Assemblyman, New Jersey.

The Trend of Industry and its Effect on the Future of Sewage Treatment, by Honorable Chester W. Paulus, Mayor of New Brunswick, New Jersey.

The Consulting Engineer in Advanced Planning, by Elson T. Killam, Hydraulic and Sanitary Engineer, New York City.

The Financial Aspects of Postwar Planning, by Honorable Walter R. Darby, Commissioner, Department of Local Government, State of New Jersey.

The Manufacturers' Dinner and Entertainment featured the evening program on March 23, all details of this function having been arranged by the Water and Sewage Works Manufacturers Association. An unusual surprise in the entertainment program was the eight-piece orchestra made up entirely of employees of the Elizabeth (New Jersey) Joint Meeting and directed by Edward P. Decher, Acting Chief Engineer. The versatility and talent displayed by this group was received enthusiastically by the overflow crowd in attendance.

Following the business session which opened the program on Friday, March 24, a symposium, "Effect of the War on Chemicals Used in Sewage Treatment," was presented. Participants in this practical and timely discussion were Richard Ochershausen, Technical Division, General Chemical Company; Ralph L. Carr, Technical Division, Mathieson Alkali Works, Incorporated; Francis Burr, Technical Division, Monsanto Chemical Company; and Harry C. Bixler, Assistant to President, Limestone Products Corporation of America.

The final technical discussion on Friday afternoon consisted of a symposium on sludge handling, treatment, and disposal. Presiding was Superintendent John Duane, of the Bergenfield-Dumont Joint Meeting. Prepared papers were presented as follows:

Collection and Pumping, by David Carmichael, Boro Engineer and Superintendent of Sewage Treatment, Verona, New Jersey.

Digestion—Operation and Control, by A. T. Kozma, Superintendent, Rutherford Joint Meeting.

Dewatering, by John K. Adams, Superintendent, Sewage Treatment Plant, Tenafly, N. J.

Disposal of Sludge and Supernatant, by George Eckert, Superintendent, Sewage Treatment Plant, Hasbrouck Heights, New Jersey.

Discussion, by Dr. H. Heukelekian, Associate, New Jersey Experiment Station, New Brunswick, New Jersey.

A lively and constructive open discussion from the floor followed presentation of these papers.

Officers elected to serve for the year 1944–45 were:

President—John Simmerman, Pitman
First Vice-President—L. J. Fontenelli, Garwood
Second Vice-President—Edward P. Decher, Elizabeth
Secretary—John R. Downes, Plainfield
Treasurer—Edward P. Molitor, Springfield

TWENTY-SIXTH TEXAS WATER WORKS AND SEWERAGE SHORT SCHOOL

The Texas Water Works and Sewerage Short School has just completed its twenty-sixth annual meeting. The meeting was held at A. & M. College, College Station, Texas, during the period January 31 through February 2, 1944. The attendance at this School broke all previous records with 403 registered. The group included water and sewage plant operators and superintendents from the municipalities and army reservations in the State as well as city managers, city engineers, and other interested persons from defense and private industries.

An outstanding program of very prominent and distinguished speakers as well as subjects of considerable importance at this particular time was presented. Among some of the speakers were Col. Harold W. Keller, Chief of the Repairs and Utilities Division, Corps of Engineers of the Eighth Service Command, who addressed the group on "Operation of Utilities at Army Posts." Mr. A. M. Rawn, President of the Federation of Sewage Works Associations, Los Angeles, California, presented the subject of "Recent Developments in Priorities and Priority Procedure" and Mr. Ray B. Plummer of the Office of War Utilities, War Production Board, Washington, D. C., explained the "Functions of the Water Division of the Office of War Utilities." "The Manpower Problem" was discussed by Capt. David Smallhorst of the Sanitary Corps of the U. S. Army, Washington, D. C.

Of considerable interest to the group was the discussion by Brig. Gen. L. F. Guerre, Director, Internal Security Division of the Eighth Service Command, on the "Use of Prisoners of War on Public Works." Some cities in Texas have already begun to draw from this source of labor on public works projects.

Monday evening a joint session was held for the twenty-two district water and sewage associations in the State. Mr. Edward J. Cleary, Managing Editor of *Engineering News-Record*, gave a review of his recent tour through South America which was illustrated with slides he had made of sanitary practices in these countries. A "Quiz Program" and "Story Telling Contest" with participation from the group proved very entertaining.

One subject which is of very timely interest and had a very prominent place on the program was the importance of postwar planning. Mr. E. L. Filby, who is the Field Director of the Committee on Water and Sewage Works Development, addressed the group on "Blueprint Now!"; V. M. Ehlers, Texas' State Sanitary Engineer, outlined the necessity of planning along sanitary engineering and public health lines, while Dean Gibb Gilchrist of A. & M. College and also Chairman of the State Post War Economic Planning Commission talked about the functions of the Commission. Since the City of Dallas, Texas, has been giving quite some thought and preparation to the matter of postwar plans, Mr. Homer A. Hunter, Superintendent of the Dallas Water Department, presented a paper on these activities.

The Water Supply Security Program was discussed by R. E. Tarbett and Carl E. Schwob of the U. S. Public Health Service and F. J. Moss of the District Office of the U. S. Public Health Service explained the new U.S.P.H.S. Standards for Drinking Water. The Internal Security Program of the Army was described by Capt. Wm. L. Avrett of the Eighth Service Command.

Major A. E. Williamson of the Office of the Co-ordinator of Inter-American Affairs in Washington summarized the activities of this office in the Latin American countries.

Mr. W. H. Wisely, Executive Secretary of the Federation of Sewage Works Associations, Champaign, Illinois, was present at the meeting and explained the objectives and progress of this organization. The group of men interested particularly in sewage treatment plant operation had a special meeting and prepared a revised constitution for the Texas Sewage Section and a special group of officers were elected to serve this Section.

Major Rolf Eliasson of the Corps of Engineers, North Atlantic Division of the U. S. Army from New York, prepared a paper for presentation on "Grease Removal." Circumstances prevented Major Eliasson's presence at the Short School but the paper was read to the group. W. S. Mahlie, Superintendent and Chief Chemist of the sewage treatment plant for the City of Fort Worth, Texas, discussed this subject also.

Mr. Tom L. Amiss, Superintendent of Water Works of Shreveport, Louisiana, and Director of the Southwest Section, American Water Works Association; and Mr. R. L. Harding, President of the Water Company of South San Antonio, Texas, and Chairman of the Southwest Section, A. W. W. A., summarized the War Time Program of the American Water Works Association.

"Water Main Cleaning as a War Time Measure" was discussed by James R. Brown of the National Water Main Cleaning Company, Chicago, Illinois; and "Anthrafilt for Water Treatment" was presented by Homer G. Turner, Research Engineer of the Anthracite Equipment Corporation at State College, Pennsylvania.

In addition to these guest speakers, many subjects relating to water and sewage practice were presented by well qualified Texas members.

Tuesday evening the group held their annual banquet. Col. W. A. Hardenbergh, Chief of the Sanitary Corps of the U. S. Army, addressed the membership and guests on the activities and accomplishments of the Sanitary Corps in this World War II. Col. Hardenbergh made a most interesting talk and outlined the outstanding and gratifying results that have been obtained through the efforts and plans of the Sanitary Corps, with particular reference to water supplies, waste disposal and malaria control.

At the banquet session, Dr. George W. Cox, State Health Officer, reviewed the progress and accomplishments in the water and sewage fields during the past year. Dr. Cox also announced the Honor Roll of Texas Water Works and Sewerage Systems and made awards of appropriate loving cups and plaques to certain ones of these cities for outstanding achievement. Several individual awards were made by the Texas Water Works and Sewerage Short School to members for special and outstanding service rendered during the past year as well as presentations of properly inscribed editions of the newly revised "Manual for Water Works Operators" to the guest speakers.

Officers elected to serve this organization during the ensuing year were:

President—W. F. Hicks, City Engineer, Paris, Texas.
First Vice President—W. N. Joiner, Water & Sewer Supt., San Marcos, Texas.
Second Vice President—Joe B. Winston, University of Texas Medical School, Galveston, Texas.
Third Vice President—S. L. Allison, Sewer Supt., Corpus Christi, Texas.
Fourth Vice President—N. E. Trostle, Water Supt., Temple, Texas.
Secretary—V. M. Ehlers, State Health Department, Austin, Texas.
Asst. Secy.-Treas.—Mrs. Earl H. Goodwin, Austin, Texas.

Mr. A. S. Hatch of the City Water Department of Houston, Texas, was elected Texas Trustee at the meeting of the Southwest Section, A. W. W. A. in Oklahoma City last October.

Officers of the reorganized Texas Sewage Works Section elected at this meeting are:

Chairman—E. J. M. Berg, San Antonio
Vice Chairman—Capt. R. M. Dixon, Dallas
Secretary-Treasurer—V. M. Ehlers, Austin
Assistant Secretary-Treasurer—Mrs. Earl H. Goodwin, Austin
Director, Federation Board of Control—W. S. Mahlie, Fort Worth

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MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Date*
Pacific-Northwest Sewage Works Association	Olympia, Washington	May 11
New England Sewage Works Association	Springfield, Mass.	May 17
Florida Sewage Works Association	Daytona Beach, Florida	May 17–19
Maryland-Delaware Water and Sewerage Association	Lord Baltimore, Hotel, Baltimore, Md.	May 19–20
Kansas Water and Sewage Works Association	Assembly Room, Municipal Auditorium, Topeka, Kansas	May 25–26
Central States Sewage Works Association	Oshkosh, Wisconsin	June 22–24
Ohio Sewage Works Conference Group	Hotel Harding, Marion, Ohio	June 21–22
California Sewage Works Association	Fresno, California	June 22–25
Iowa Wastes Disposal Association	Des Moines, Iowa	June
Dakota Water and Sewage Works Conference (North Dakota Section)	Grand Pacific Hotel, Bismarck, North Dakota	Sept. 12–13
Rocky Mountain Sewage Works Association	Denver, Colorado	Sept. 20
FEDERATION OF SEWAGE WORKS ASSOCIATIONS	Wm. Penn Hotel, Pittsburgh, Pennsylvania	Oct. 12–14
Pennsylvania Sewage Works Association	Wm. Penn Hotel, Pittsburgh, Pennsylvania	Oct. 12–14
Canadian Institute on Sewage and Sanitation	Toronto, Ontario	Nov. 2–3

Reviews and Abstracts

H. Gladys Swope

SEWAGE WORKS RECORDS

The Surveyor, 102, 505–507 (Dec. 3, 1943)

A paper on this subject by D. H. A. Price was published in *The Surveyor*, Oct. 15, 1943 (Abstracted in Sewage Works Journal, 16, 202, 1944). Various points in the paper were discussed by members of the Institute of Sewage Purification before whom the paper was presented.

E. Needham pointed out that the weakest link in records of sewage analyses was the sampling, usually done by a laborer who was poorly paid. He suggested trying to raise the standard of samplers to at least the semi-skilled class. Diameter of the neck of the sampling bottle was all important in limiting the size of solid which could be included in a sample and sampling bottles might well be standardized for all sewage plants.

J. Inkster agreed with the author that dry-weather flow did not give a true indication of average sewage strength. Direct measurement of average strength and volume of sewage over an extended period would give a better assessment of load borne by a sewage works. He emphasized the limitations of regarding consecutive points on the moving annual average as comparisons between corresponding months of successive years.

Several members agreed with Mr. Price that lineal charts were preferable to circular ones.

L. F. Moontfort said that the chief value of records lay in the use that was made of them and not in their accumulation.

K. V. Hill

REPORT OF THE RIVERS DEPARTMENT, CITY OF MANCHESTER

Two years ended March 31, 1942

Owing to the reorganization of the Department, a biennial report was issued (32 pp. and 5 tables). In 1941 the sludge steamship was blown up by a mine. A sludge ship was chartered from Glasgow. Two enemy bombs fell on the Davyhulme Works, damaging the compressors and one aeration unit. The plant is being remodeled for further experiments.

The review at Davyhulme shows a population served of 770,000 in 1940–41, and 731,000 in 1941–42, handling respectively, 70.74 and 67.74 m.g.d., a number of secondary procedures after primary sedimentation, such as primary contact beds; primary and secondary contact beds; activated sludge by bio-aeration, Simplex, and diffused-air plants. The sewage treated was strong, containing a B.O.D. of 239 p.p.m., and suspended solids of 220 p.p.m. The average effluent shows a B.O.D. of 151 p.p.m., and suspended solids of 79 p.p.m.

The activated sludge units show the following differences:

Results for Year ended March 31, 1941

Determination	Bio-Aeration	Simplex	Diffused Air*
Volume, per day, Gal.	766,800	1,465,600	
Detention in Aerators, Hr.	17.3	13.1	9.8
Horse Power per M.G.	36.7	23.7	25.0
Effluent, p.p.m.			
Nitrates	1.6	1.5	1.3
B.O.D.	15	16.6	12.3
Suspended Solids	14	14	14.7

* Average of 3 units: handling 3,934,800, 4,042,800, and 20,619,600 gal. per day, respectively.

Results for Year ended March 31, 1942

Determination	Bio-Aeration	Simplex	Diffused Air*
Volume, per day, Gal.	728,400	1,543,200	
Detention in Aerators, Hr.	18.2	12.5	9.4
Horse Power per M.G.	37.0	23.9	26.9
Effluent, p.p.m.			
Nitrates	1.3	1.5	1.25
B.O.D.	15.2	16.3	14.3
Suspended Solids	15.0	15.0	16.0

* Average of 2 units: handling 4,144,800 and 21,609,600 gal. per day, respectively.

The purification effected was as follows:

Purification Effected	Bio-Aeration		Simplex		Diffused Air	
	1940–1	1941–2	1940–1	1941–2	1940–1	1941–2
On Raw Sewage Reduction of B.O.D.	93.3	93.6	92.5	93.2	94.4	94.0
On Settled Sewage Reduction of B.O.D.	89.4	89.9	88.2	89.2	91.2	91.5

The wet sludge from the entire plant handled in 1940–41 was 351,315 tons, and in 1941–42, 415,820 tons, or 13.62 and 16.81 tons, respectively, per million U. S. gal. The major portion of solids is shipped to sea. Densified activated sludge is pumped to storage tanks and distributed on land areas. Detritus is dumped and covered with soil.

Surplus activated sludge is mixed with sedimentation tank sludge and digested with the aid of heat in primary tanks (80–85° F.) and stored in secondary tanks. The reduction in volume was 68.5 per cent in 1941 and 72 per cent in 1942. Sludge gas is burned under a boiler to heat circulating water.

As a temporary measure, sludge lagoons were built at Flixton, with an area of 11½ acres and a working depth of 8 ft. Supernatant water is removed and distributed over adjacent land. About 52 acres are farmed.

The Worthington Works serve about 47,000 population and receive about 2.36 M.G.D. of sewage. About 71.8 per cent of the sewage is treated by activated sludge. The balance is settled, part of the effluent being treated by double contact beds. The sewage contained B.O.D. 174.1 p.p.m. in 1940–41 and 199.0 p.p.m. in 1941–42, and suspended solids 79 p.p.m. and 81 p.p.m., respectively.

The average effluent showed a B.O.D. content of 15.5 p.p.m. in 1940–41 and 17.1 p.p.m. in 1941–42, and suspended solids 13 and 10, respectively.

Part of the sludge is pumped to sludge trenches and part discharged to lagoons for drainage before removal by farmers.

The Worthington activated sludge units show the following results:

Determination	Unit 1		Unit 2	
	1940–41	1941–42	1940–41	1941–42
Volume, per Day, Gal.	256,800	272,520	1,437,600	1,422,120
Detention in Aerators, Hr.	7	5.2	6.6	5.2
Horse Power per M.G.	49.4	48.3	24.1	25.3
Air, Cu. Ft. per Gal.	1.45	1.38	0.71	0.73
Effluent, p.p.m.				
Average for Two Units				
Nitrate			1.9	1.5
B.O.D.			12.8	14.6
Suspended Solids			13	10

There is also a small works at Northenden handling 120,000 g.p.d.

In the research work, a small enclosed trickling filter was operated with forced aeration on settled sewage at Davyhulme at the rate of 276 gal. per day per cu. yd. in 1940–41, and 252 gal. per day per cu. yd. in 1941–42. The results show a reduction of B.O.D. 90.6 from April to October, 1940, and 85.8 from April, 1941 to July, 1942.

The report contains several tables of cost data.

LANGDON PEARSE

SEWAGE WORKS EXTENSIONS, CITY OF WORCESTER (ENGLAND)

BY JOHN D. GIBSON

Civil Engineering (London), 39, 11 (Jan., 1944)

Before the construction of the extensions to the plant, it had been revamped and added to over a period of 40 years. There were four diffused-air aeration tanks, each with a capacity of about 0.5 m.g.d. (Imp.) of dry weather flow, and each served by four hopper type settling tanks. Waste activated sludge was pumped to the primary clarifier. Gas from the digestion of sludge was utilized in a gas engine driving an air compressor.

The new unit consists of seven aeration tanks and three settling tanks. One tank is used for reaeration of sludge, two for either reaeration or aeration, and the remaining four are for aeration only. Unlike the old units, the aeration tanks will be operated in parallel and any one tank may be taken out of service independently of the others. Each tank is 97 ft. total length, 10 ft. wide, and 15 ft. 9 in. average water depth. The ratio of diffuser area to tank area is 1:11.4. The capacity of the new unit is approximately twice that of any of the old units.

An additional air compressor was installed to provide more adequate standby capacity. About 35,000 cu. ft. of the 50,000 cu. ft. per day of gas produced was used in the gas engine driving a 1,450 c.f.m. compressor. The new compressor is driven by a dual fuel engine, operating on oil or a combination of oil and gas as the latter is available. It is a Diesel type engine and develops 150 horse power when operating on oil and 112.5 horse power when using the maximum amount of gas.

T. L. HERRICK

SEWAGE DISPOSAL BY IRRIGATION

BY B. R. SPENCER

Public Health,* 7, 15–28 (Oct., 1943)

In the Union of South Africa land disposal of sewage is necessary for a number of reasons. There are but very few places where effluents are permitted to enter the streams.

Before sewage is applied to the land it is passed through primary treatment units and in some cases secondary treatment is provided.

As is well known, the practice of land disposal of sewage dates back many centuries in China and India. The first report of the British Association Sewage Committee (1869) stated that out of 96 places with sewerage systems of any degree, only 15 applied the sewage to land. In 1870 Berlin practiced irrigation for the first time, when a 10-acre plot was used experimentally. After the test 11,000 acres were placed under irrigation, along with 25,000 acres of meadow land.

Probably the first recorded instance of the purchase of sewage for irrigation is noted in another British report of 1869. An annual fee of £600 was paid to Bromford for sewage delivered to a farm of 121 acres on which a rental of £300 was paid.

* Official organ of the South African Health Officials' Association and of the Institute of Sewage Purification, South African Branch.

The principles of irrigation are scientific, though practical experience is also required. The irrigation expert must be versatile and must have a knowledge of soils, meteorology, chemistry, geology, and agriculture. In sewage disposal by irrigation two functions are combined, raising a crop and disposing of the sewage. If circumstances are such that one function must be put in the background, that one must be agriculture.

Water requirements vary for different crops. Italian rye grass absorbs much water, and does well as long as water does not stagnate in the soil. Oats will absorb more water than any other grain. Tobacco, turnips, parsnips, and carrots are ruined by too much water and should never be flooded. Potatoes will take a great deal of water. Table I shows results of a test made a few years ago with oats and wheat, along with results of a similar test on potatoes.

TABLE I

Inches Irrigation	Bushels per Acre		Potatoes	
	Wheat	Oats	Inches	Bushels
5	33	58	7½	160
10	36	60	15	233
15	40	70	30	274
20	35	86	71	315
30	22	82	72	310

Figures on rates of application to land are shown in Table II, in which Klipspruit is compared to eight British towns. It must be borne in mind that there are wide differences in rainfall, hours of sunshine, and quality of effluent when comparing these figures.

The average rate at Klipspruit was 6,343 gallons per acre per day, or 102 inches per annum. This rate is much higher than would be used if agriculture were the prime objective. It has caused some trouble as there is no natural drainage in subterranean passages. The water table has been gradually raised. This points to the use of care in irrigating such land. An inspection hole of some kind below lands without a river frontage would be found useful. Regular observations would give a valuable guide for the application of water.

There are many systems of irrigation. The sprinkler system and the pipe and hydrant system are not applicable for large works because of the expense and the danger of aerial pollution. Subsoil irrigation likewise is ruled out by the consideration of expense. The system is subject to stoppages by root and fungal growths.

Other systems of surface irrigation are: the basin, check, Zaaidam, furrow, absorption ditch, ridge-furrow, furrow and ridge, bed and ridge, and the broad irrigation systems. The system of broad irrigation is used at Klipspruit. It is the simplest of all, though wasteful of water. It is not the best, therefore, from the agricultural point of view.

Sewage irrigation must be carefully controlled to prevent brackish conditions advancing too far. When such conditions do occur the usual remedy is deep plowing, even sub-soiling. With ordinary agricultural irrigation brackish conditions are usually caused by diffusion of salts from below to the upper soil. In such cases the farmer can flood the land and bring the salts to the surface, and then drain to the river. The sewage farm manager cannot do this because of the danger of river pollution.

About thirty years ago irrigation at Klipspruit was done on fallow lands. Experimental evidence shows, however, that such land with a soil mulch tends to hold the moisture, and today nothing but pasture lands are used. Italian rye grass is cultivated as it has the following advantages (1) it is not affected by brackish conditions, (2) it prevents erosion, (3) the blades of grass act as colloiders for colloidal matter, (4) its growth is enormous in suitable weather, (5) it is a surface feeder and requires heavy doses of humus for rapid growth, (6) it will smother weeds if sown at the proper period, (7) it will produce a high flow of milk in milch cows, and (8) it has enormous leaf surface for transpiration.

T. L. HERRICK

TABLE II

	Aldershor	Altrincham	Cambridge	Croydon	Leicester	Nottingham	Rugby	Shorwood	Klipspruit
Total Area, Acres	138.5	75.5	102.5	673.5	1,699	907	40	191	2,642
Irrigable Area, Acres	120.5	35	74	420	1,350	651	35	151	1,090
Average Area of Irrigation at one Time, Acres	40	17.5	18	70	337	300	7	51	218
Population per Acre of Irrigable Area	166	514	676	238	146	397	171	138	Unknown
Dry Weather Flow, Gal. per Capita per Day	50	44.4	45	40	36.8	27	50	28.5	35 approx.
Dry Weather Flow, Million Gallons (Imp.) per Day	1.0	0.8	2.25	4	7.25	7	0.3	0.6	7.0
Gallons of Sewage, Excluding Storm Water, per Acre per Day	25,000	46,000	121,600	57,000	21,500	23,300	42,800	12,000	31,750
Same as above, Using Whole of Irrigable Area	8,300	23,000	30,400	9,500	5,370	10,750	7,500	4,000	6,343
Soil	Coarse	Peaty	Sandy loam	Gravel loam	Stiff clay	Sand gravel	Clay	Clay	2 feet loam
Sub-Soil	Very fine sand	Sand and gravel	Sand and gravel	Sand and gravel	Dense clay	Sand and gravel	Stiff clay	London clay	Iron stone and rock

Note: Previous treatment by sedimentation in all cases.

BUFFALO SEWER AUTHORITY

Annual Report, 1942–1943

This annual report (70 pp.) is divided into six sections: History (1 p.); General Manager's Report (7 pp.); Administrative (9 pp.); Sewage Treatment (15 pp.); Sewers (17 pp.); Audit (20 pp.). The operating personnel numbers 241, of whom 12 are on military leave.

The revenue anticipated to meet budgetary requirements is derived from $825,000 secured from sewer rentals based on water consumption, and $649,011 based on assessed valuations of taxable real estate. Delinquencies for the rental based on assessed valuations from 1938–1942 have ranged from 2.8 to 3.3 per cent per 12 months.

The sewage flow averaged 150 m.g.d., with a maximum of 284 m.g.d. The precipitation was higher than in the previous year. 1,800 tons of grit were removed, and 14,426.3 tons of raw suspended solids. 4,900 lb. of chlorine per day were used, with a saving of 20,000 lb. over the prior year, with a 2 per cent increase in flow treated. The dose on the maximum day was 10,750 lb., and the minimum 2,130 lb.

The pre-aeration unit was discontinued.

The vacuum filter cake averaged 37.6 per cent dry solids, with a lower use of conditioning chemical. Acid washing of filter cloths was tried, doubling the life of the cloth. On dry solids treated, the chemical used was 7.86 per cent lime and 1.94 per cent ferric chloride.

The sludge incinerators burned 26,627 tons of cake containing an average of 49.4 per cent volatile matter. More oil was used for auxiliary fuel because of the 23.4 per cent decrease in gas production (an average decrease of 25,000 cu. ft. per day). The gas production averaged 0.73 cu. ft. per cap., with a maximum of 1.49 and a minimum of 0.13. 1.17 cu. ft. of gas was used per lb. of sludge burned.

The operating cost decreased $30,000.

Detailed data are given on operations.

The over-all primary removal of suspended solids was as follows:

Year	Solids—p.p.m.		Removal, Per Cent
	Raw	Effluent	
1941–1942	187	128	31.5
1942–1943	205	134	34.5
Five-Year Average	187	120	29.6

The over-all B.O.D. removal was:

Year	B.O.D.—p.p.m.		Removal, Per Cent
	Raw	Effluent	
1941–1942	143	119	16.4
1942–1943	127	101	19.8
Five-Year Average	137	109	20.7

The kill of presumptive *B. Coli* varied from 81.9 to 99.9 per cent, with an average of 97.9.

The solids balance is summarized:

Total Sludge Cake Burned (dry basis)		20,045,900
Chemicals		
Ferric Chloride	351,000	
Lime	1,606,600	
		1,957,600
Digested Solids Burned		18,088,300
Raw Solids Converted to Gas (160,245,200 cu. ft. at 14.7 cu. ft. per lb.)		10,901,000
Total Solids Disposed of (sum)		28,989,300
Sludge Inventory		
June 30, 1942	5,685,000	
June 30, 1943	5,549,300	
Loss		135,700
Raw Sludge Solids Loading on Digestion Tanks		28,853,600
Or		79,100 lb. per day

The maximum loading was 128,000 lb. per day.

The digesters were kept at 89.9° F.

The volatile matter was reduced from 67.4 to 54.1 per cent. The digestion on raw solids was 37.8 per cent.

The effect on the Niagara River is shown, as follows:

Year	Coliform Bact. per ml.	
	Sta. EE	Sta. H
1936–1938	323.0	134.0
1938–1939	122.0	77.6
1939–1940	10.3	18.1
1940–1941	7.1	14.7
1941–1942 (July to Feb.)	15.7	23.6
1942–1943 (Nov. to June)	17.2	16.0

Station EE is located 5.8 mi. below the treatment plant, where nine samples were collected at various points. Station H is 15.7 mi. below, where eight samples were collected.

Data are included on rainfall and river elevations, sewer patrol, repair, maintenance, and cleaning.

An industrial waste charge for unduly concentrated wastes is being planned on a rational basis, calculated per 1,000 cu. ft. of waste from volume, net chlorine demand and cost of chlorine, cost of chemicals and power, and net suspended solids.

Cost data on rentals are given.

The audit shows the fixed charges.

The operating expenses are distributed to various functions.

Langdon Pearse

A CRITICAL REVIEW OF RECENT WORK ON SEWAGE FILTRATION

By John Hurley

The Institute of Sewage Purification, Journal and Proceedings, pp. 33–52 (1942)

This paper reviews the investigations and discoveries of recent years which have aimed at increasing the work done by biological filters. The author divides these developments into the following categories: (1) High-rate operation of single-stage open filters, (2) processes involving the recirculation of filter effluent, (3) the operation of filters in series and (4) enclosed aerated filters. The published work is described and discussed with comments; particular emphasis being placed on the purification affected and rates of application.

Under the first category the investigations of Levine, Halvorson and Mohlman in the United States are reviewed. British work dealing with this phase of the problem is done at Huddersfield by Goldthorpe and at Leeds by Thompson. The author raises the question whether high-rate filtration is such a modern invention after all. He cites the work of Knowle in the *Fifth Report of the Royal Commission of 1908* as an example of high-rate filtration.

High-rate filtration utilizing the principle of recirculation of the effluent was developed by Jenks. The British work with this type of treatment was done by Watson at Shipley. The author states that Jenks was not the discoverer of the principles of recirculatory filtration. This process was used thirty years ago by Fowler at Manchester for the purification of spent gas liquor. The same process was later employed at Bradford for treating chemical effluents. The author does not agree with Fowler's criticism of the use of the term biofiltration on the basis that ordinary filters are also biofilters. Instead he favors its use because of the analogies between the biofiltration and bioaeration (Haworth or Sheffield) processes. An alternate suggestion is made to use the term "recirculatory filtration."

The history of double filtration goes back again to the period of the Royal Commission, but the interest was revived by the observations of O'Shaughnessy that a clogged filter could be opened by dosing it with filter effluent. This basic idea was utilized in the purification of milk wastes, investigations carried on under the auspices of the Water Pollution Research Board. The application of double filtration to sewage was first attempted by Staynes at Dewsbury and culminated in the large-scale experiments at the Birmingham, Tame and Rea District Drainage Board.

Early work at forced aeration was attempted by Lowcock in 1892 and Waring in 1894 at Newport, Rhode Island. Since then temperature control and forced ventilation of filters was neglected until Pruss in the early nineteen thirties revived it again. Outstanding in this respect is the research work done at Johannesburg by Hamlin and Wilson which showed among other things that the enclosed and artificially ventilated filter was able to treat in the winter, with equal purification, three and one-half times as much sewage per cu. yd. as the open filter. When the filter is covered to retain the heat, artificial ventilation becomes necessary at rates above 120 gal. per cu. yd. per day.

In England a considerable amount of work on enclosed aerated filters was done at Wolverhampton by Hurley, Windridge and Lovett.

In discussing the difficulties in proper assessment of filter performance, the author calls attention to the differences in the method of analysis and in expressing results. In determining the efficiency of the filter the percentage purification should be expressed on the basis of the filter feed and settled filter effluent. The amount of work done by the filters as expressed in pounds of oxygen removed per cu. yd. of filter capacity also leads to difficulties when comparing filters which give only partial treatment with those giving complete treatment.

The results obtained by various investigators in this paper are grouped accordingly into two tables, those giving partial treatment and those complete treatment. These tables are reproduced below:

Partial Treatment

	Type of Filter	Dosage*		5-Day B.O.D. in p.p.m.			
		M.G./A./D.	Gal./Cu. Yd.	Feed	Settled Effluent	% Purif.	Removal, Lb./Cu. Yd./Day
Levine	High-rate single-stage open	13.3	1,370	226	49	78	2.45
Halvorson		16.7	1,300	144	60	58	1.09
Mohlman		16.8	1,310	47.6	24.3	49	.30
Herrick		20.9	1,620	66.9	27.9	54	.53
Goldthorpe		10.0	880	160	72	55	.78
Goldthorpe		20.0	1,760	160	90	45	1.24
Thompson		6.2	643	197	102	48	.61
Thompson		8.5	857	294	164	44	1.01
Jenks	Recirculation	20.0	4,100	75.4	32.2	57	1.78
Watson	Recirculation	0.8	80	646	123	81	.42
Hurley	Enclosed aerated	7.2	745	375	112	70	1.98
Hurley	Enclosed aerated	9.8	1,013	255	69	73	1.88

* Imperial gallons.

The author comments, compares and discusses at some length the various results obtained. Some of the points mentioned are as follows:

(1) B.O.D. removals increase as the strength of feed increases even though the quality of effluent may deteriorate. (2) High-rate single-stage filtration under suitable conditions can be used for partial treatment and compared with the partial treatment by activated sludge process. It has the following advantages (*a*) power needed for pumping is less than that required for the activated sludge process, (*b*) the filter can stand shocks from industrial wastes better than the activated sludge, and (*c*) area required would not be large. (3) Jenks' results compare favorably with those obtained by high-rate single-stage filtration but recirculation and resedimentation increase the cost. The advantages of the Jenks' process are: (*a*) the dose per cubic yard is high which is due to the shallowness of the filter, and (*b*) recirculation balances the filter feed both as to strength and volume. (4) The sewage that Watson worked with is one of the most difficult to purify in England and is eight or nine times as strong as Jenks'. The two therefore should not be compared as Watson's purpose was to find a method which would give a better effluent from his existing installation.

Full Treatment

Type	Dosage		5-Day B.O.D., p.p.m.			
	M.G./A./D.	Gal./Cu. Yd./Day	Feed	Settled Effluent	% Purif.	Removal, Lb./Cu. Yd./Day
1. Alternating double	1.58	163	155	19.5	87	.22
2. Single filter control	.78	81	155	16.5	89	.11
3. Enclosed aerated	4.36	200	255	18.0	93	.47
4. Works filter "A"	.87	77	255	6.3	98	.19
5. Works filter "B"	.53	47	255	21.7	91	.11

In the above table items 1 and 2 should be compared together as they refer to the work done at Birmingham, Tame and Rea District Drainage Board. Items 3, 4 and 5 refer to the work done at Wolverhampton and should be compared together. Works filters "A" and "B" constitute the check for the enclosed aerated filters; item 3.

The alternating double filter treated twice as much sewage as the single filter, used as a check, and gave nearly equal purification. The enclosed filter treated approximately three times as much sewage per cu. yd. as an open filter with nearly equal purification. The enclosed filter treated 25 per cent more sewage in gal. per cu. yd. per day than the alternating double filter. B.O.D. removal per cu. yd. per day was twice as high for the enclosed filter as for the double filter, mainly due to the higher B.O.D. feed at Wolverhampton.

The enclosed filters prevent surface clogging by (*a*) inducing biological activity in the surface layers all the year around by conserving heat and (*b*) by putting a layer of coarse media on the surface of the bed. This tendency for coarser media naturally has limits since with larger sizes, contact time is reduced, but the author is inclined to emphasize the importance of ventilation and temperature in contrast with contact time. The author argues against the principle of alternating double filtration on the basis that the shifting of the natural zones of purification in the bed results in lower nitrate production.

A feature of the enclosed aerated filter at Wolverhampton is the layer of coarse material both on top and bottom of the filter with a thicker layer of finer material in the middle. The top layer is provided as an antiponding device, the finer middle layer caters to the oxidation stage and the coarse bottom aims to assist free drainage. Improved methods of distribution make the use of coarse material on top feasible. The author does not explain how the ponding of the middle finer material is to be avoided or remedied.

Enclosing the filter, in addition to maintaining a more favorable temperature, induces the worms to work on the surface due to the exclusion of light. The result of this upward migration of worms is that it prevents clogging due to their scavenging activities.

H. Heukelekian

THE TREATMENT OF TRADE WASTE WATERS AT TRADERS' PREMISES

By W. Scott

The Institute of Sewage Purification Journal and Proceedings, pp. 186–195 (1942)

The object of this paper is to set forth the experimental work for dealing with certain trade waste waters.

Felt Manufacturing.—This scheme consisted in revamping an existing plant treating acid waste derived from the manufacture of felt. The existing plant consisted of five settling tanks, operated on a fill-and-draw basis, for the removal of solids and a sludge drying area. The waste consisted of (*a*) spent dye liquor and (*b*) mill bottom where beating the wool fiber and manufacture of felt takes place. The mixture of these two types of waste is acid. Treatment with lime (7.5 gr. per gal.) gave the best results. Pressing the sludge did not prove satisfactory due to the large amount of wool fiber in the sludge. Straining out the fiber did not improve the results from pressing the sludge due to the finely-divided nature of the solids. The sludge from which the fibers were previously removed was disposed of by application on drying beds. By removing the fibers by flock catchers the amount of sludge was materially reduced.

Tar Distilling.—The discharge of this plant contains ammoniacal liquors and sodium sulfate. The liquors have a high temperature and contain heavy tarry matter at times. The ammoniacal liquor contains 4.779 per cent ammonia, 0.181 per cent phenol, and 0.0626 per cent cyanide with a 4-hour oxygen absorption value of 25,280 p.p.m. The acidity of the sodium sulfate liquor is 1.8 per cent with an oxygen absorption value of 25,890 p.p.m. A balancing tank was provided with oil traps at the inlet end.

Mercerizing, Dyeing, and Finishing.—The existing plant consists of 2 Dartmund type settling tanks and a trickling filter. The waste is variable in character, highly caustic, and contains starch, chromates, and dyes. To neutralize the causticity, sulfuric acid is used followed by sedimentation (12 hr.) and trickling filters. In order to economize on the acid a pH control recorder, with automatic regulation of the quantity of acid, was installed. The daily dose to the filters is 210 gal. per cu. yard.

Dyeing and Milling.—The dyeing waste has an acidity of 2,548 p.p.m. The dye waste did not respond to treatment with caustic soda, but the milling waste, which has no free acidity, gave a well-clarified and colorless effluent after treatment with alkali. Lime with copperas and aluminoferric was also tried without success. Sodium carbonate in place of lime with copperas and aluminoferric gave better results, but the quantities of chemicals required were too large. Chlorine to remove the color followed by neutralization with caustic soda gave the following results:

	Oxygen Absorbed (4 hours), p.p.m.
Mixture before treatment	177
Mixture after treatment	33

The scheme finally adopted was as follows: 2 settling tanks each one-day capacity worked on a fill-and-draw basis, followed by a sand filter and a settling pond.

H. Heukelekian

FURTHER STUDIES ON THE BIOLOGY OF A DOUBLE FILTRATION PLANT AT HUDDERSFIELD

By T. B. Reynoldson

The Institute of Sewage Purification, Journal and Proceedings, pp. 116–134 (1942)

This is a continuation of the work conducted in 1939–40. The biological aspects of the earlier study was reported by the same author. (See abstract in Sewage Works Journal, 13, 1010, 1941.) The period covered in the present study was from June, 1941 to June, 1942. The rate of application during this period was 600 gal. per cu. yd. on the primary filter and 200 gal. per cu. yd. on the secondary filter.

According to the author the primary factors influencing the condition of the filter are (1) temperature, (2) the rate of growth of fungi and bacteria and, (3) the rate of multiplication of the macro-fauna. The fluctuations in the strengths of sewage are considered as a secondary factor. At Huddersfield the fungus flora is confined to a species of *Oospora* which comprises the bulk of the film and the macro-fauna to *Psychoda alternata*.

The actual growth of the film is compared with the expected value calculated on the basis of the temperature of the filter. If temperature was the only factor affecting film growth, the theoretical and actual curves should parallel. In the primary filter, during the colder months (Nov.-Feb.), when the scouring effects of *Psychoda* could be neglected, the theoretical and actual film growth curves are parallel. During June to November, when *Psychoda* were abundant, actuality was far below that demanded by theory. From February to June they again were parallel. There was also a discrepancy in the expected progress and actual incidence of *Psychoda* during the period from September to May which is ascribed to toxic conditions set up by the rapid growth of fungus and sludge accumulation.

These results from the primary filter are summarized as follows:

Period	Temperature	Film Growth	Ponding	Fly Output	Film Growth Controlled by
June–Oct.	20° C.	Average	Low	Highest	Psychoda
Oct.–Jan.	Above 10° C.	High	Medium	Scarce	Limited only by temp.
Jan.–March	Below 10° C.	Scanty	Low	Few	Temperature
March–June	Rising to 19° C.	Highest	Highest	Few	Not controlled by temp. or Psychoda

The discharge of solids from the filter was erratic and unrelated to any of the factors.

Approximately the same general relationships between film growth, abundance of fly and temperature were observed in the secondary filters. The solids in the effluent showed a well defined unloading period coincident with the spring onset of larval activity.

Thus the scouring action of *Psychoda* larvae was not sufficient to combat the rate of film growth during the greater part of the year and so was unable to maintain the primary filter in a clean, open condition. The coarse secondary filter was continuously maintained in a suitable condition for good purification. The fine section of the secondary filter became ponded extensively during the cold weather.

The crux of the ponding problem lies in the relation between the rate of accumulation of growths and the rate at which they are destroyed by the scouring action of macro-fauna. In addition to normal winter ponding if the filter should become denuded of its macro-fauna an even more serious ponding may occur in summer due to the stimulation by temperature of the growth rate of bacteria and fungi, particularly the latter.

The restriction of the macro-fauna to *Psychoda alternata* at Huddersfield is disadvantageous because *Psychoda* is a warm-weather fly, and the resulting winter inhibition permits a greater accumulation of film than would normally obtain with more diversified fauna including *Mitriocnemus, Spaniotoma* and the *Enchytraeid* worms. The restriction of the fungus flora to *Oospora* is also a disadvantage for when the temperature rises in the spring above 10° C. the fungus has the immediate advantage since it is already present in quantity during the winter. During this time the flies are in process of increasing their numbers and as a result the larvae rapidly devour the fungus and clean the bed. The flies remain in ascendancy during the rest of warm period and the fungus growth is slight.

The author doubts that the flushing action in the high-rate filters actually dislodges fungal and bacterial growths except from the immediate surface of the bed. The flushing action can only be operative on the humus. It should be remembered that the dosage rates on high-rate filters are much higher in America than in England.

The toxicity of Huddersfield sewage containing large quantities of industrial wastes is at times responsible for the wholesale death of larvae resulting in excessive growth of the fungus and ponding.

H. Heukelekian

A REPORT UPON THE TREATMENT OF SEWAGE ON THE PERCOLATING FILTERS AT HUDDERSFIELD

By H. H. Goldthorpe and J. Nixon

The Institute of Sewage Purification Journal and Proceedings, pp. 101–115 (1942)

The sewage contains textile and chemical wastes. The settled effluent is strong as measured by the oxygen absorption test. The B.O.D. is relatively low due to chemical constituents which retard biochemical action. War-time activities have made the sewage difficult to treat.

Conditions at Huddersfield have become such that approximately 10 m.g.d. dry weather flow of effluent from settling tanks, containing inimical substances for biological action, have to be treated on the existing 100,000 cu. yd. of filter material at the rate of 100 gal. per cu. yd. per day. Experiments were undertaken therefore to increase the rate of application. Experiments covered a period of a year from July, 1939 to June, 1942.

This paper deals with the comparison of rate of treatment of Huddersfield sewage by single filtration on a 200-ft. diameter filter and an experimental double filtration plant with two filters each 18 ft. in diameter in series with intermediate settling tanks. The primary filter is 7 ft. deep and the secondary 6 ft. deep. Each filter is divided into two halves by a vertical watertight wall. Section A of the primary filter is filled with 2–4 in. clinker throughout. Section B of the same filter has 2–4 in. clinker at the top foot, ¾–1½-in. material in the middle 3 feet and 2–4-in. material at the bottom. The media in the secondary filter is as follows:

	Section A	Section B
Top 18 inches	4–6 inches	½–1 inch
Middle 3 feet	1½–3 inches	1½–3 inches
Lower 18 inches	3–6 inches	3–6 inches

Intermediate settling was provided between the primary and secondary settling tanks but there was no settling tank at the end of the secondary filter. Analytical determinations on the effluent from the secondary filter were conducted on the supernatant liquor after 1 hour settling in the laboratory.

The results from the primary or high-rate filter are summarized in the table below.

Rate of Application		Oxygen Absorbed			B.O.D.		
Period	Gal./Cu. Yd./ Day	Raw, p.p.m.	Section A, % Red.	Section B, % Red.	Raw, p.p.m.	Section A, % Red.	Section B, % Red.
1	603	180	30	35	174	55.1	62.1
2	679	177	18	22.6	154	47.6	50.8
3	981	204	14.8	17.1	229	—	—
4	1,303	176	8.5	10.8	131	—	—
5	567	201	20.1	25.1	216	—	—

Increasing the dosage from 603 to 1,303 gal. per cu. yd. per day decreased the filter performance. Section B with the finer material in the middle gave better results than Section A.

The results obtained from the secondary filter are summarized as follows:

Period	Rate, Gal./Cu. Yd./ Day	Oxygen Absorbed			B.O.D.		
		Raw, p.p.m.	Section A, % Red.	Section B, % Red.	Raw, p.p.m.	Section A, % Red.	Section B, % Red.
1	324	120	48.2	49.7	81	74.3	76.4
2	326	142	45.8	47.5	85	65.0	67.6
3	229	171	52.6	55.1	125	67.1	72.3
4	267	159	52.2	52.5	100	62.6	63.4
5	186	156	51.1	54.5	116	68.9	69.7

Section B of this filter with its fine upper layer gave generally better results than Section A. In considering the primary and secondary filters together the following results were obtained:

Period	Rate, Gal./Cu. Yd./Day	B.O.D. Loading, Lb./Cu. Yd./Day	B.O.D. Settled Final Effluent	
			Section A, p.p.m.	Section B, p.p.m.
1	211	.367	20.8	19.1
2	221	.340	30.0	27.7
3	186	.427	41.1	34.6
4	222	.292	37.3	36.5
5	140	.303	36.3	35.4

An interesting effect of the war and the increased industrial waste is brought out in the figures during the first period in 1939 given below.

	Per Cent Purification	
	Section A	Section B
July–August	37.4	44.4
September–December	26.3	29.6

Note: See also abstract in SEWAGE WORKS JOURNAL, 15, 976 (1943).

H. HEUKELEKIAN

BOOK REVIEW

Engineers' Dictionary; Spanish-English and English-Spanish. By Louis A. Robb. John Wiley and Sons, Inc., 1944. 432 pages. Price $6.00.

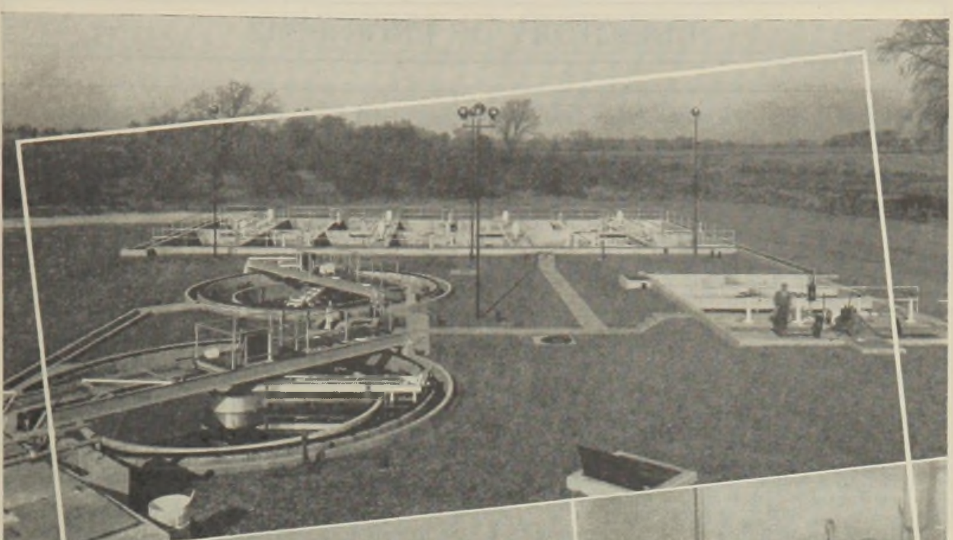
The author seeks, with considerable success, to fill the need for a compilation of the Spanish equivalents of English engineering and construction terms. In the preface, he refers to his own extensive engineering experience in Latin America and the difficulties he encountered in translating such terms into the proper English or Spanish equivalents by means of the technical dictionaries then available.

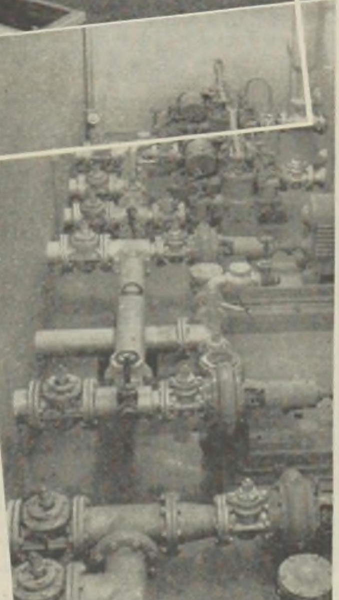
The coverage of terms pertaining to hydraulics, engineering construction and sanitary engineering appears to be most complete. In the field of sewage treatment and disposal, Spanish equivalents are provided for practically every term contained in A.S.C.E. *Manual of Engineering Practice No. 2 (1928)* together with newer terms which have come into current usage since that manual was published. This coverage extends to such proprietary terms as "comminutor" and "bio-filter." Spanish equivalents are also furnished for the chemical terms commonly encountered in sanitary engineering work.

Suitable notation is made where the Spanish equivalent is in local usage and where alternate Spanish equivalents are employed in certain of the Latin American countries. The book does not, however, supply definitions beyond a clear identification of the equivalent terms. Synonyms and multiple applications are given where necessary.

This dictionary will be of extreme usefulness to civil engineers who are currently or will in the future be practicing in Latin America. It should be valuable in the development of a technical speaking vocabulary, in technical reading and in the preparation and interpretation of specifications for engineering works. It is of compact size and sturdily bound so as to be well adapted to field use.

W. H. Wisely





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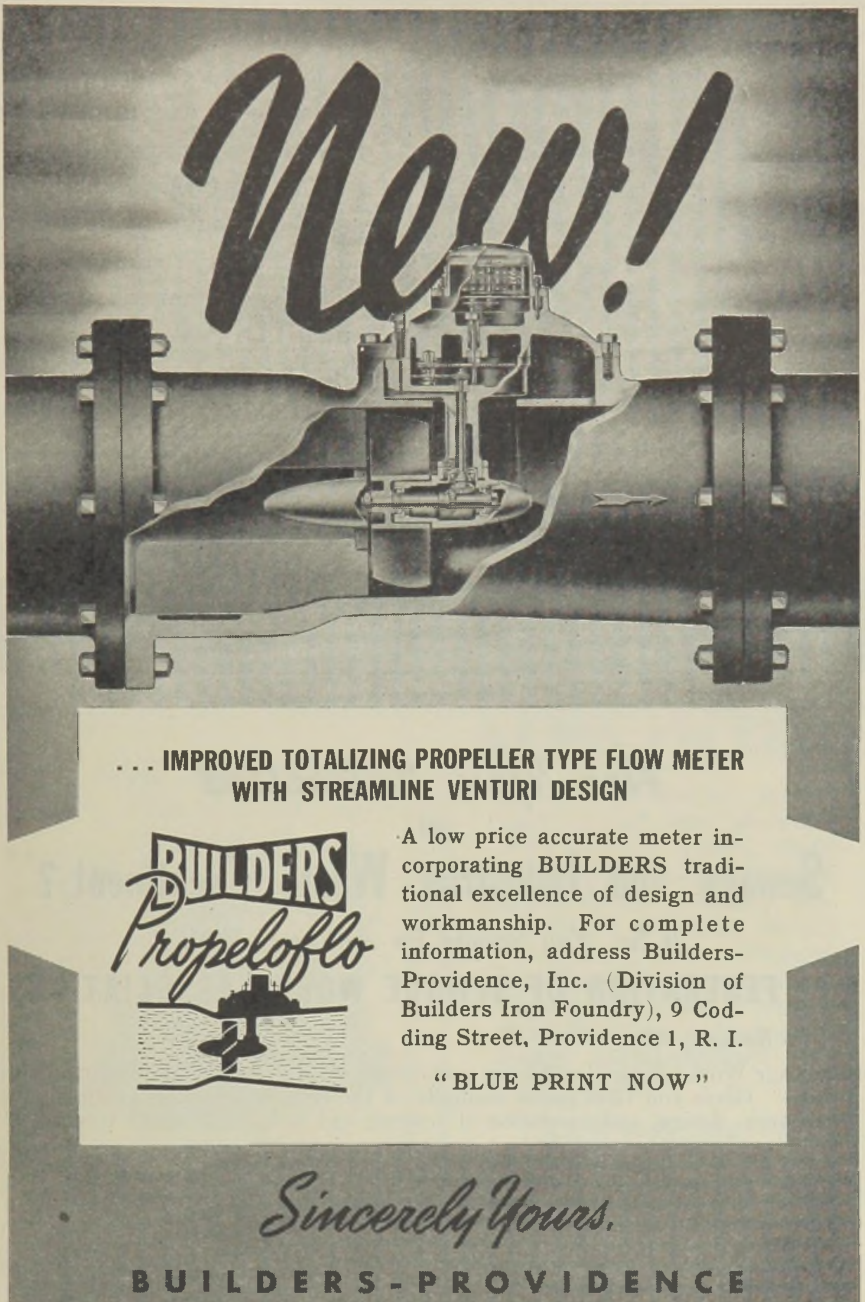
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