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Chicago—Oct. 21–23

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FEDERATION OF SEWAGE WORKS ASSOCIATIONS

SEWAGE WORKS JOURNAL

REG. U. S. PAT. OFF.

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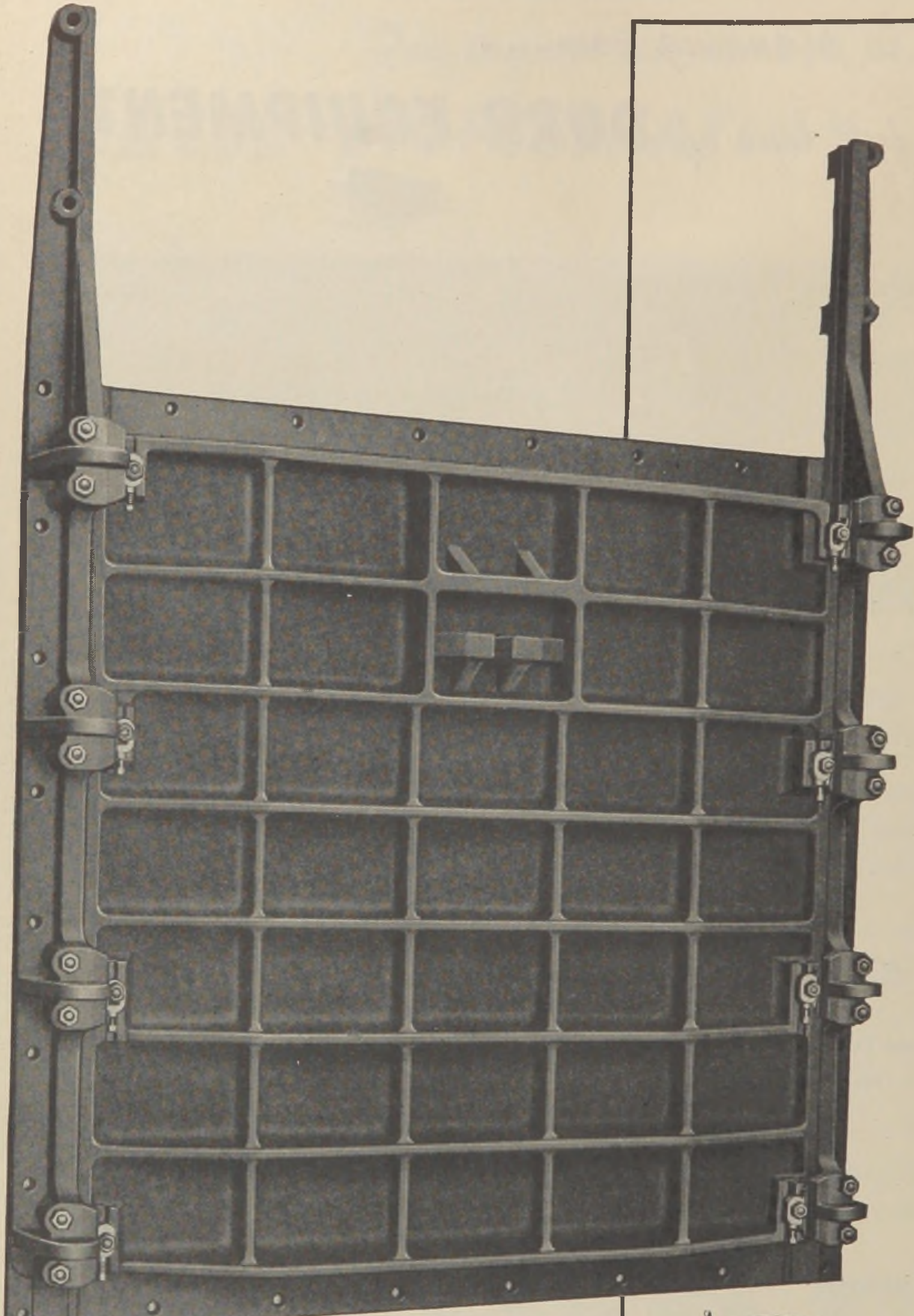


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ENGINEERING DATA

GRAVITY TYPE

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Class 2—10" to 36"
Class 3—10" to 36"
Class 4—18" to 36"

Crushing Strengths:
A.S.T.M. 3-edge bearing test method
Lb. per linear ft.

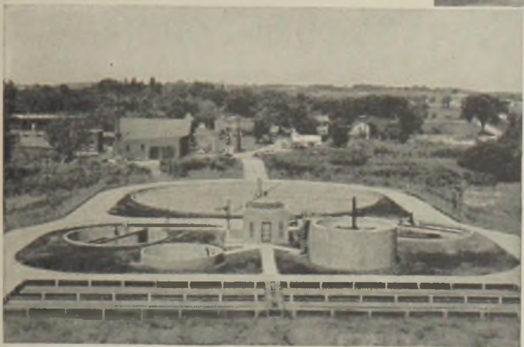
Pipe size inches	Class 1	Class 2	Class 3	Class 4
4	4125	....	....	....
5	3350	....	....	....
6	2880	....	....	....
8	3100	....	....	....
10	2580	3690	4920	....
12	2370	3850	5100	....
14	2200	3920	5150	....
16	2120	4050	5280	....
18	2030	4140	5360	6340
20	2290	4280	5850	7100
24	2340	4550	7050	8600
30	2980	5000	8180	10450
36	3500	5400	9700	12300

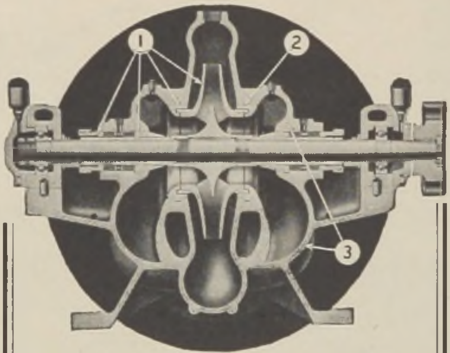
Friction Coefficient (Kutter's); n=.010

PRESSURE TYPE

Sizes: 3" to 36"

Pressure classes: Class 50— 50 lbs. per sq. in.
Class 100—100 lbs.
Class 150





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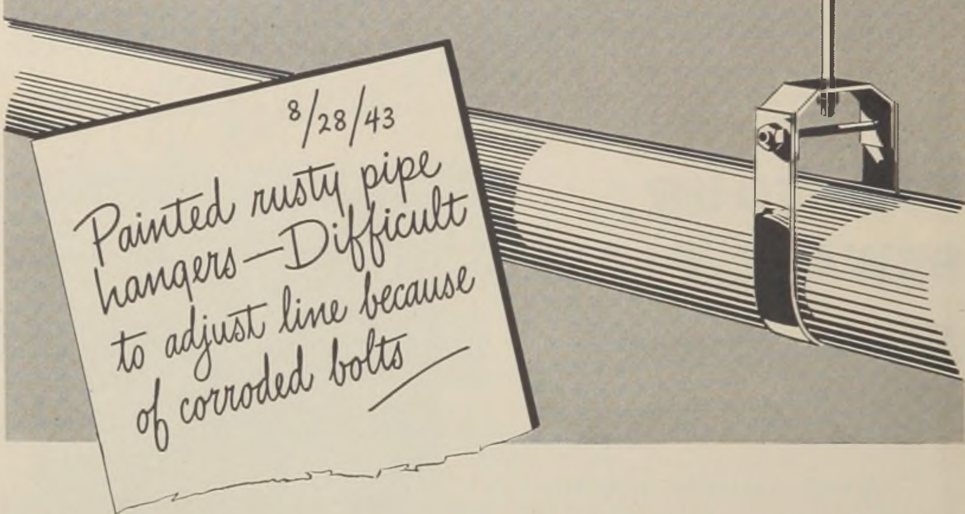
Make a Note of the little annoyances that add up to big money



They're routine jobs for your maintenance men; often, you don't even get a report on them. But it takes a lot of paint to keep rust under cover. And materials that have to be replaced regardless of your care, and the labor required, all add up to real money in a year's time.

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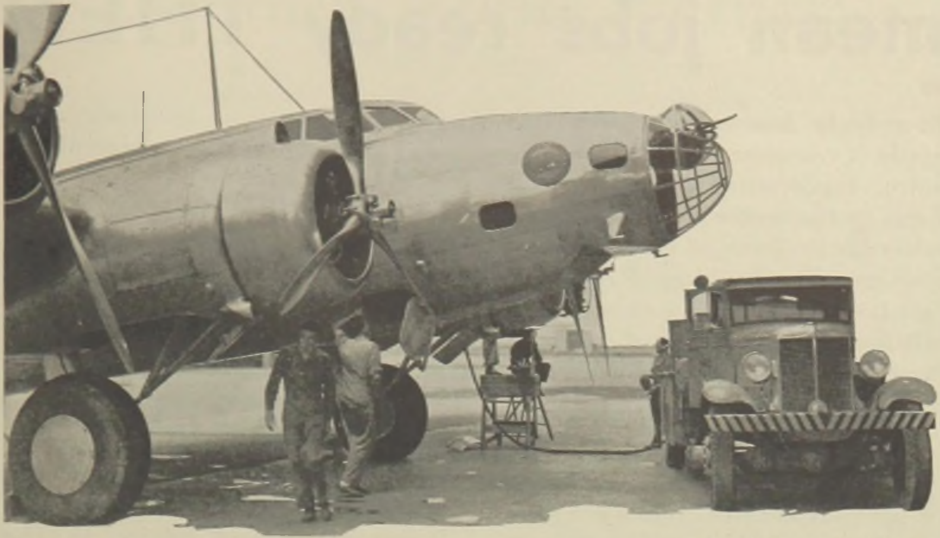

Photo by U. S. Army Air Forces

FUELING our fighters and bombers at home and at our advanced bases involves a multitude of small pipe lines.

From underground fuel caches, usually far removed from the flying line, high octane gas travels via pipe line to the field loading facilities.

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Plant Operation

ROTARY VACUUM FILTRATION OF SLUDGE AND THE EFFECT OF WAR ON OPERATION *

By James T. Lynch

Supt. Auburn, N. Y., Sewage Plant

and Uhl T. Mann

Supt. Cortland, N. Y., Sewage Plant

The purpose of this paper is to present the experiences with vacuum filtration of sludge at two plants, one at Auburn, N. Y., using raw sludge and one at Cortland, N. Y., handling digested sludge. It would be unfair to attempt to compare methods or costs of operation of these plants, as there are many factors which have a decided effect on mechanical dewatering. The nature and amount of sludge varies with the type of sewage treatment. The method of disposal after drying effects the continuity of filter operation. Industrial wastes at Auburn interfere to a certain degree with good operation while at Cortland the presence of iron waste from a steel mill is beneficial to vacuum filtration. This paper will not discuss the reasons or the cure for these factors or the many others but will confine itself to vacuum filtration of sludge.

Description of the Vacuum Filter

The rotary vacuum filter consists of a filter drum with variable-speed drive, suspended in a container or trough for holding the conditioned sludge to be filtered. The periphery of the drum is divided into a number of shallow compartments, each of which is in reality a separate filter being separated from the adjacent sections by division strips. Each section has its own vacuum and air lines connecting to the main filter valve which moves with the filter drum and revolves against a stationary valve cap to which are connected the two main section lines and the air pressure line. The stationary valve cap has recesses which provide the following cycles:

1. Vacuum to the sections submerged in the sludge for the purpose of forming the cake.
2. Vacuum to the sections exposed to the air for the purpose of drying the cake formed in the previous cycle.
3. Air blow and no vacuum at the point of cake discharge. Air dislodges cake and tends to clean cloth at same time.
4. After passing point of cake discharge there is no action until section submerges into sludge again.

* Presented at the Spring Meeting of the New York State Sewage Works Association, Rochester, N. Y., June 4, 1943.

The cycles are automatic as the ports of each section turn into position with the recesses of the stationary valve cap. The timing of these cycles on the Conkey filters, which are used at both Auburn and Cortland, may be changed by moving the valve cap by means of an adjusting bar or rod.

On the surface of the filter drum are supporting strips, wire screen and filter cloth in successive layers. The filter cloth is held in place by a spirally wound single length of wire spaced on 1½ in. centers across the face of the drum. Agitation in the Conkey filter is of the swing type. Most sludges require agitation to keep chemicals well mixed with sludge and to prevent solids and water from separating. Cake removal is accomplished mostly by gravity with the aid of the air blow and a scraper set so as not to rub on the cloth or wire.

Forced filtration as practised in vacuum filters speeds up the rate of dewatering of sludge many hundred times. This is accomplished by suction operating through the valve cap and the ports of the individual pipe lines as they come into position with the recesses in the valve cap as a result of the rotation of the drum. The suction causes the liquor to be drawn through the filter cloth, pipe lines and the valve cap to the filtrate receiving tank, from whence it is continuously discharged by the filtrate pumps. In these particular installations the suction is created by dry-vacuum pumps which first exhaust the moisture trap and then the receiving tank in creating the suction in the valve cap recesses. As the liquid or filtrate is drawn through the pipe lines, the solids are left deposited upon the surface of the filter drum in a layer or cake. As the drum revolves, the solids are partially dried by the air which is drawn through the cake.

Auburn and Cortland Equipment

Filters: Both plants equipped with 2 Conkey Rotary Vacuum Continuous Filters. Size—Auburn, 10 ft. diameter by 10 ft. long, 32 compartments, total filter area, 637 sq. ft. Cortland—5¼ ft. diameter by 8 ft. long, 16 compartments, total filter area, 260 sq. ft.

Vacuum Pumps: Two units each of the horizontal reciprocating type with a displacement of 2 cu. ft. per minute per sq. ft. of filter area furnishing a vacuum of 26 inches of mercury against shut-off.

Filtrate Pumps: Two units each of the horizontal single-stage, centrifugal type designed for pumping filtrate from a receiver under vacuum.

Blowers: Auburn uses air from compression tank supplied by two single-stage air compressors. Cortland—Two units of the rotary positive displacement type, air being used direct from blowers.

Sludge Pumps: Two units each, duplex plunger type, 10-in. plungers. At Cortland sludge flow from digesters to mixing tank is by gravity. Pumps used only to increase flow when necessary.

Mixing Tanks: Auburn—Four batch-mix tanks with agitators. Cortland—Two batch-mix tanks with agitators and variable speed bucket elevator, one continuous mix tank with agitator.

Chemical Feeders: Cortland—One variable-feed proportioning pump of the diaphragm type, for feeding ferric chloride; one variable capacity dry-lime feeder supplying a lime-slaking device. Auburn: Dry lime fed by dumping of bag lots. Carboy lots of ferric chloride fed by water-operated ejector.

Conveyors: Auburn—Screw conveyor to incinerator. Cortland—Two belt conveyors carrying sludge cake to truck.

Chemicals

Both plants began operations using hydrated lime but have changed to the fine-ground high calcium type of lime with a decided improvement being noted in both cases. With this lime the nuisance of dust is reduced and drying is faster with a better cake. High calcium lime seems to shorten the life of the filter cloth but not enough to be a serious factor.

At Cortland, when the change was made from hydrated to high calcium lime, five different brands of practically the same CaO content (95 to 97 per cent) were tried for conditioning. All tests were made on a plant scale using the lime in both dry and slaked form. In each case the per cent of lime used, method of mixing and mixing time were varied while the per cent of ferric chloride used was held constant. The pH, per cent solids and temperature of the digested sludge used in these tests were practically constant. Each run was for a duration of 2 hours and the results were recorded as lb. yield per sq. ft. of filter area per hour. From these tests of 5 high calcium limes the following was observed:

1. One brand gave excellent results, yield—10.5 lb. dry solids per sq. ft. of filter area per hour.
2. One brand produced yield of 9.9 lb. dry solids per sq. ft./hour.
3. Two brands produced yield of 8.7 lb. dry solids per sq. ft./hour.
4. One brand produced yield of 6.4 lb. dry solids per sq. ft./hour.

During these tests the amount of lime used was carefully checked and the filter cake produced was weighed on scales. It is quite possible that the physical characteristics, freshness and the ability of each to slake might have had some influence on the above results. The results on the Cortland filters showed that for this particular digested sludge the CaO content of the high calcium lime was not the only factor affecting the ability of the lime to coagulate solids for dewatering on vacuum filters.

An article by W. Rudolfs (1) shows that the CaO content of hydrated lime is not the only factor effecting its sewage coagulation power. A study of limes by Clark, Bernays and Tordella points out that particle shape affects some physical characteristics of lime (2).

Both plants at the present time are using liquid ferric chloride. Auburn originally used the anhydrous form which was not dissolved but fed in dry form by merely dumping into the mixing tank. This proved to be a highly dangerous and disagreeable task as well as uneconomical. The change to liquid has shown a 12½ per cent saving in cost with much better results. The 45 per cent solution of ferric chloride is fed by means of a water-operated ejector which dilutes the ferric chloride while impelling it into the mixing tank.

At Cortland, liquid ferric chloride of 45 per cent strength is fed by a motor-driven proportioning pump direct from carboys to mixing tank. At first the solution was diluted to 10 per cent strength. After a few weeks' operation the amount and the per cent dilution of the ferric chloride were gradually reduced until the solution was being fed at full strength (45 per cent). During this change practically no change was noted in the quality of the conditioned sludge or the amount of ferric chloride used when figured on a dry basis.

Mixing of Chemicals

At Auburn, 300 to 400 cu. ft. of raw sludge is mixed in a batch, adding ferric chloride first, followed by lime. Little difference was noted in the order of adding chemicals. Each batch lasts from 1½ to 2 hours with agitation being continued throughout the run. Difficulty in filtering the last part of the batch is often experienced and in these instances more sludge is pumped to the mixing tank and the conditioning process repeated. Variations in dose are accomplished by varying the quantity of sludge rather than the quantity of chemicals. Batch mix provides a more accurate control of the amount of chemicals used for conditioning but has the disadvantage of the breaking up of the floc due to the length of time the batch must be held.

At Cortland, digested sludge flows by gravity to the quick mix tank where slaked lime is added, followed by ferric chloride. If the order of adding chemicals is reversed the cake has a sticky characteristic which tends to blind filter cloths. Mixing times of 5, 10, and 15 minutes have been tried but best results seem to be obtained with the shortest possible mix time. The depth of sludge in the quick mix tank is usually about 1 ft. and it is continually moving due to action of gravity and the slow moving paddles. With quick mix tank and variable capacity chemical feeders it is a simple matter to vary the amount of the conditioning agents being used. This combined with the short mixing time gives the operator a very close control over conditioning.

Determination of Chemical Dose

An attempt has been made at Auburn to establish a relationship between per cent dry solids and specific gravity. This relationship seems to vary considerably, however, due to differences in the character of the sludge caused by heavy runoff, chemical treatment and industrial wastes. Charts have been made showing per cent of chemicals used for various specific gravities. Since the determination of specific gravity can be made quickly, this method is used. Using the per cent shown by the chart, the sludge and chemicals are mixed for 5 minutes and then a sample is tested on a Buchner funnel before being admitted to the filter. In making the Buchner funnel test previous experience with the test is important. There seems to be no particular standard as to how fast the sludge should dry on the funnel; but the operator can tell, after a few trials, how fast the cake must form and dry in the laboratory in order to have it work well on the plant filter. The appearance of the filtrate also serves as a guide. A pale pink clear filtrate from the funnel test indicates the best results for the usual sludge at the Auburn plant. If the funnel tests are unsatisfactory a batch may be reconditioned by the addition of more chemicals and the procedure repeated.

At Cortland, during the first months of filtering, much time was given to the testing of small trial batches using a Buchner funnel, noting the time required for cake to crack, and the amount and color of the filtrate. The pH studies showed that filtering qualities improved with each rise up to about 10.0. Any pH above 10 and up to 13 failed to affect the filtrability of the sludge to any great extent. Some laboratory work has been devoted to the filtering of elutriated sludge with excellent results; however this method has not been tried on a plant scale. The problem of chemical doses for Cortland sludge is quite negligible as the demand remains rather constant. The nature of the sludge varies very little from month to month and there is iron present in the sludge before conditioning. The iron is a result of steel mill waste consisting of ferrous and ferric sulfates and ferric hydroxide. Iron content of the sewage has run as high as 120 p.p.m. At the present time, past records are relied on to a great extent for the quantities of chemicals used in conditioning. After operation is under way the quantities are gradually reduced to a point which still maintains a good cake on the filter.

Filter Operation

Cortland filters using cotton cloths are operated at a drum speed of 13 revolutions per hour with a low level of sludge in the trough. At lower drum speeds the cake picked up is too heavy for good drying. With too heavy a cake there is a tendency for water to be discharged at the blow off cycle. This is caused mainly by the inability of enough air to pass through the filter cake to sweep the water out of the filtrate piping. Cake is removed by means of the air blow, gravity and aid of the scraper. It is not necessary to have the scraper scrubbing against the wire or cloth. Discharged cake drops onto a belt conveyor which carries the sludge cake to a dump truck. Filters are operated two days per week with the 8-hour daily run usually being completed without shutdown.

Auburn filters operate in much the same procedure except that a high level of sludge is carried in the trough and the drum speed is reduced to five revolutions per hour. Continuous operation at Auburn is sometimes handicapped by lack of sufficient incinerator capacity. One filter usually produces more cake than can be burned; as a result attempts are made to hold down cake production. One common practice is to shut down the filter at end of each batch to allow the incinerator to catch up. In this type of system it is of the greatest importance to have these two units well co-ordinated. Filter cake drops into a V-shaped hopper and is moved to the incinerator by a screw conveyor. Surplus sludge cake piles up in the hopper and must be sliced down into the screw by hand.

Filter Cloths

Auburn to date has tried several types of cotton cloths and has found that the No. 1 type gives the best results on a basis of cost per hour's use.

The slightly better results given by some of the more expensive types did not justify the additional cost. A small section of glass cloth was tried by sewing it into a hole cut in one of the cotton cloths. The results with the small section of glass cloth were only fair and probably this was not a fair test for this type of filter medium. Auburn has not tried wool because of the prohibitive cost. Following is a history of three No. 1 type cotton cloths used at Auburn:

During summer of 1940, with quite continuous operation, cloth gave 600 hours service.

Yearly average with same type cloth purchased before the war—300 to 400 hours.

Present average with wartime cloth of the same type—150 to 200 hours.

Cortland has used only one type of cotton filter cloth, the trade name being, "Clearflow Filter Cloth No. 105 HD." This is the cloth that the filters were equipped with when installed and were used for the first year of operation. Filters were operated 16 hours per week giving a total of approximately 800 hours service for the original cloths. The same type cloth purchased to replace the original covers gave about 600 hours' service. Those purchased since the war fail to give more than 350 to 400 hours' use.

The cleaning of filter cloths at both Auburn and Cortland has proved unsuccessful. If a mild solution of inhibited acid was used the cleaning effect was negligible. When a solution of sufficient strength to do a thorough cleaning job was used the cloth went to pieces shortly after. K. L. Mick (3) of St. Paul reports successful cleaning of filter cloths increasing service from 350 hours to 500 and 600 hours. At plants where operation is more continuous than at Auburn and Cortland, 300 to 400 hours is probably a matter of weeks and the cloths still have plenty of life to stand acid baths. Failure of pre-war cloths at Auburn and Cortland seems to be a matter of age rather than of hours service. From an economic viewpoint it will usually be found cheaper to clean blinded cloths or apply new ones rather than to use increased quantities of chemicals.

Records

The importance of complete operating records for a vacuum filtration installation should not be overlooked. Such data provides information as to performance, costs, need for changes and information valuable to consulting engineers engaged to design a new plant or make additions to the present plant. Operators of new plants find complete records of certain operations of established plants valuable in getting their operating procedure established. Following is a list of filtering records kept at both plants:

1. Cu. ft. sludge filtered each run.
2. Per cent solids in unconditioned sludge.
3. Per cent volatile solids in unconditioned sludge.
4. Pounds lime (CaO) per 100 lb. of dry solids.
5. Pounds ferric chloride (dry) per 100 lb. dry solids.
6. Specific gravity of unconditioned sludge.

7. pH of sludge before and after conditioning.
8. Time of each daily run in hours and minutes.
9. Number of hours' service for each accessory unit.
10. Per cent solids in filter cake.
11. Per cent volatile solids in filter cake.
12. Pounds of filter cake and pounds of dry solids.
13. Yield in pounds per sq. ft. of filter area per hour.

Problems

Since the Auburn sewerage system is of the combined type, the raw primary sludge varies with the seasons and the amount of rainfall. Failure of the grit chambers is found in the fact that while the average velocity is about 1 ft. per second the detention period is less than 10 seconds, and the grit does not have time to settle. During times of high flow, the high grit content of the sludge makes pumping to batch tanks very difficult, increases demand for chemicals and tends to blind filter cloths quite readily. During the spring months there is also a tendency for the sludge to slough off the filter drum as it is being picked up in the trough. This accumulation of partly dewatered sludge has caused the filter trough contents to overflow onto the floor at times.

Failure of filtrate pumps at Auburn has caused some trouble of late. Since this trouble has developed after several years of operation, it is probably due to chipping of carbonate scale which has been built up on the inside of the pipes of the filtrate system. These chips of carbonate are drawn into the filtrate pump and the present remedy is to clean the unit. An article by K. L. Mick (3) of St. Paul describes the successful practice of cleaning filter equipment and piping with inhibited muriatic and hydrochloric acid.

Other problems which are likely to arise after years of operation are the decrease in efficiency of vacuum pumps, making it difficult to hold the vacuum constant, and the loss of vacuum in the drum due to the shrinking action of ferric chloride on the wooden decks supporting the filter medium. Because of the destructive effect of ferric chloride, filter troughs and mixing tanks made of steel should be treated with an acid-resistant paint or their life will be short.

To replace filter cloth at Auburn it used to be necessary to remove and replace 33 half round bars of brass which were used in the grooves of the division strips between each section of the filter. The purpose of these bars is to insure a tight fit of the filter cloth between each compartment of the filter. Each bar was held in place by 17 brass screws which when removed left a hole which had to be filled before a new screw would hold. Brass bars have been replaced by half-round soft wood strips of moulding held in place by 6 finishing nails. The change netted a saving of $3.00 in cost of brass screws and 20 man-hours of labor for each change of filter cloth.

At Cortland, a muffler of 1 ft. diameter and 6 ft. long set horizontally on the discharge of the vacuum pumps rusted through in about 6 months due to the condensate draining to the lower side of the metal housing.

A replacement muffler set in a vertical position, so that moisture could drain back into the exhaust pipe, seems to have eliminated this trouble.

On the Cortland filters the valve cap was designed to provide suction to the sections as they submerged into a high level of sludge in the trough. Since a low level of sludge is used in the trough, a part of the recess in the valve cap providing vacuum for the cake-forming cycle was blocked off by means of wood and rubber cement. This blocking off of a part of the recess delayed the beginning of the cake-forming cycle and prevented loss of vacuum during the time each section was moving from the point of cake discharge to point of submergence in the low level of sludge.

Better slaking of lime was provided at Cortland by the use of a small mixing tank made from the parts of a washing machine. The purpose of this device was to provide more time for the lime to slake.

Operator's List of Advantages of Vacuum Filtration

1. Quick disposal of sludge.
2. Space requirements reduced.
3. Effect of weather on sludge drying eliminated.
4. Digestion space can be reduced, in fact, eliminated as at Auburn.
5. Eliminates cleaning of drying beds.
6. Plants more flexible, especially with digestion.
7. Successful dewatering of all types of sludge.

Facts of Auburn and Cortland Plants

	Auburn	Cortland
Population served	41,315	17,000
Type of sewer system	Combined	Separate
Average daily flow for year	5.80	5.92*
Number of men employed	13	5
Type of sludge filtered	Raw	Digested
Disposal of sludge cake after filtration	Incineration	Fill
Number of filters	2	2
Number of filters used at one time	1	1
Total filter area in sq. ft.	637	260
Type of cloth generally used	Cotton	Cotton
Average hours' use of pre-war filter cloth	300	600
Average hours' use of war-time filter cloth	160	350
Type of wire used for winding drum	Steel	Steel
Time in minutes for one revolution of drum	12.5	4.6
Average hours' use per week	33	16
Average pH of conditioned sludge	10.5	10.0
Pounds of lime (CaO) per 100 lb. dry solids	13.46	8.98
Pounds of ferric (dry) per 100 lb. dry solids	4.35	1.68
Cost of chemicals per ton of dry solids	$6.06	$3.04
Average per cent solids of sludge to be filtered	6.13	10.1
Average per cent solids of sludge cake	33.4	42.3
Average thickness of sludge cake in inches	3/8	1/2
Yield in pounds per sq. ft. of filter area per hour	2.81	9.51

* High flow caused by infiltration; present water consumption of 93 gallons per capita accounts for less than 25 per cent of sewage flow.

Effect of War on Operation

1. Increased load on treatment plant due to war time industry.
2. Loss of personnel.

At Auburn, filtering operations are on a 24-hour schedule until the job is completed for the week, usually 2 to 3 days per week. Loss of personnel may necessitate changing to a 16-hour day for filtering, thus increasing the number of days to do the week's job. This change will considerably reduce the number of man-hours available for maintenance. The chemist of the Auburn plant is now serving in the Sanitary Corps of the U. S. Army, which has meant a curtailment of laboratory work.

3. Difficulty in obtaining equipment and repair parts and the restricting of new work on planned improvements, such as grit chambers for the Auburn plant.
4. Increased cost for lower grade filter cloths.
5. Increased cost of chemicals for filter operation.

Cortland, being a small user of chemicals, is unable to purchase in carload lots due to O.D.T. regulations concerning minimum weights of cars. Smallest car of lime that can now be shipped is 35 tons which is more than a year's supply. High calcium lime is difficult to keep over the summer months because it air-slakes and breaks paper bags. Since metal containers, in which the lime can be stored safely, are no longer available, it is necessary for the Cortland plant to purchase in small quantities, which increases the cost considerably. War conditions prohibit holding of ferric chloride carboys for a period of six to seven months as was formerly done. This means that the Cortland plant must build a ferric storage tank or turn to the use of anhydrous or crystal ferric chloride.

Conclusions

1. The simplicity of operation of a vacuum filter installation depends to a large degree on the type of sludge treatment and the method of disposal of cake after filtration.
2. The most important step in vacuum filtration is the conditioning of sludge.
3. The continuous-flow method of conditioning sludge is faster, requires less attention and is usually more economical than batch-mix.
4. The efficiency of vacuum filtration of sludge can be improved by the application of laboratory results.
5. Filters require close supervision while in operation.
6. Vacuum filtration, a relatively complicated mechanical process, requires considerable care.
7. Complete operating records are of the greatest importance.
8. In these two plants the use of liquid ferric chloride and high calcium lime has simplified operation with better results at a lower cost than with dry ferric and hydrated lime.
9. Per cent of chemicals used, methods of applying and mixing are a matter of local conditions.

10. Depth of sludge in trough and drum speeds are determined by local conditions.

11. In these plants the optimum pH of conditioned sludge is about 10.0.

12. The tabulation of the facts given for the two plants is merely for information as there are too many variables to make a just comparison.

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1. W. Rudolfs, "Effect of Lime in Coagulation of Sewage." *Public Works*, **73**, 11, 15 (1942).
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STANDARD RATE FILTER OPERATION EXPERIENCES AT WESTFIELD, N. Y.*

By Joseph T. Howson

Operator, Sewage Treatment Plant, Westfield, N. Y.

One of the most noteworthy advances in the field of sewage treatment in Southwestern New York State during the past decade was the construction of a modern-type sewage treatment plant to serve the Village of Westfield. This was made possible through a P.W.A. loan and grant at a total approximate cost of $125,000. This plant superseded the original plant, which consisted of a septic tank and contact beds, both of which had outlived their usefulness.

The new plant is composed of a manually cleaned bar screen and grit channel, a double rectangular primary settling tank with mechanical sludge collection mechanism, two circular trickling filters with rotary distributors, and a rectangular final settling tank, mechanically cleaned. Sludge is treated in two separate digestion tanks, operated in series, one of which has provision for heating and gas collection. A glass-covered sludge drying bed is provided. There is a solution feed chlorinator, of 200 lb. per 24 hours capacity. Piping is arranged to make possible prechlorination 10 ft. ahead of the primary settling tank, 100 ft. ahead of the filter dosing tank, and, for post-chlorination, 10 ft. ahead of the final settling tank.

The population of Westfield is approximately 3,600, but the plant is designed for a B.O.D. population equivalent of 10,000 because of the food-processing industries in the village. Although there are five processors in the village, at the present time only two discharge their wastes into the sewer system. The sewer system is for sanitary wastes only, but because of its condition, the flow of sewage will double or even triple after a hard rain. The flow of sewage fluctuates between 0.6 m.g.d. in dry weather to as much as 3.0 m.g.d. in the spring of the year. Last August, after a severe local cloudburst, there was a flow of approximately 12.0 m.g.d. entering the plant, about 8.0 m.g.d. of which overflowed the various tanks and manholes. The nominal designed capacity of the plant is 1.5 m.g.d. During a typical day, the flow will vary between 0.7 m.g.d. at about 6 A.M., and about 1.0 m.g.d. between 10 and 11 A.M. At this rate, the per capita flow is nearly 200 gallons, showing excessive infiltration, as well as industrial waste.

The war has had little or no effect on plant operation, with the exception of increased difficulty in obtaining parts and labor. In fact, there has been a decrease in population, due to the nearly 250 men who have joined the armed services, while the fruit processors have continued to run near capacity.

The two trickling filters are of the slow rate, so called, or as has been suggested by Mr. J. A. Montgomery, high rate of application, low capacity,

* Presented at the Spring Meeting of the New York State Sewage Works Association, Rochester, N. Y., June 9, 1943.

type. They have four-arm rotary distributors, with valves on two arms, so that either two or four arms can be used. Each four-arm distributor has 80 orifices, ½ in. by 1½ to 2½ in. long, with spreader plate underneath. The distributors turn about 1 r.p.m., although the speed varies greatly with changing wind conditions. The beds are 110 ft. in diameter, with 8 ft. of limestone, laid on a concrete bottom having slotted tile on 4 ft. centers. There are concrete walls, and an outlet gate, which allows flooding of the beds to a depth of about 3 in. over the stone surface. The area of the two filters is 0.436 acre, the volume, 3.6 acre feet, approximately.

When the filters were built, the north bed was filled with stone reclaimed from the contact beds of the preceding plant, which was constructed in 1910. This stone was washed and screened over a ¾-in. mesh screen, before placing in the new filter bed. The south filter bed was filled with new limestone, specified as being between 1 and 2½ in. in size. This stone was unloaded from gondola cars into trucks, driven 1 mile to the plant, and dumped on the bed.

The majority of operating problems in the plant, especially in connection with the filters, have been of mechanical, rather than of chemical or biological origin.

From a chronological standpoint, the first operating problem experienced was the continued clogging of the distributor nozzles by leaves, in the late summer and fall. This was partially overcome by constructing a screen of ¼-in. mesh, placed over the primary settling tank effluent. Even with the screen, the nozzles have to be cleaned 3 or 4 times a week when the leaves are falling or blowing about.

After spending a couple of hours digging leaves out of filter nozzles, it is difficult to appreciate the beauty of the numerous trees which surround the plant. By the time leaves are skimmed from the two settling tanks, and removed from the greenhouse eaves troughs, and a few panes of glass replaced, where falling branches have broken them, it is hard for the operator to share the sentiment of the verse—"Woodman—Spare That Tree."

The second problem arising in connection with the filters was the great number of filter flies, in evidence from about April until late fall. Their control came about as a by-product of the control of ponding.

Some ponding of the south filter, the one with the new stone, occurred in the summer of 1940. In the late fall and winter of 1940–41, ponds covered a good proportion of the surface. To get rid of the ponds, a hose was run from the chlorinator, and chlorine solution, with the chlorinator running at 200 lb. per 24 hours, was sprayed directly on the surface of the filter. This removed the ponds, but it also inactivated the filter for about five weeks. The north filter, containing the reclaimed stone, was not ponding at this time.

Knowing that flooding of filters had effected control of ponding in other plants, this was tried next, but it met with little success. Our next attempt was to chlorinate the flooding water, holding a concentration of 10.0 p.p.m. residual chlorine after a 20-minute contact period. This eliminated the ponds for about two weeks, but it also apparently inhibited the biological activity of the filter, as it effected little improvement in the applied sewage for about three weeks. After a series of experiments, it was found that by flooding the filter at monthly intervals, and adding chlorine to the top three or four feet of water, with a residual chlorine content of from 5.0 to 8.0 p.p.m., the ponds were kept more or less under control, with no apparent harm to the filter activity.

While this system of chlorination and flooding kept ponding under control, from the standpoint of economy it left something to be desired. Each application of chlorine took from 100 to 300 lb., at a cost of $7 to $20. One beneficial side result, in addition to filter fly control mentioned before, was the cleaning out of the dosing tank piping. This cannot be cleaned with a hose, as there is no hydrant near enough for the supply of hose to reach.

While chlorination and flooding kept the ponds under control, or at least out of sight, it was difficult to reconcile the suggested theory that the filters were overloaded, with the fact that only the south filter, with new stone, ponded, while the north filter, with old stone, had no trouble. During the winter of 1942–43, with the aid of a spading fork, it was found that where there had been ponding, at a depth of six to eight in., the stone size was ⅛ to ¼ in. Inasmuch as there was no small stone on the filter surface, it is possible that the stone was placed in that condition, and covered with stone of the proper size. Possibly if the original specifications had called for screening and washing of the stone immediately before placing, this condition would not exist.

The properly graded stone over smaller sizes was somewhat similar to a condition found in the sludge bed. After our first sludge had been carted away, while raking the sand surface smooth, a veritable mine of bolt ends, broken glass and wood, wire, etc., was found about 2 in. beneath the top of the sand. It was apparently cheaper to spread a couple of extra loads of sand than to pick up the scrap.

Our next problem in connection with the filters was the slowing down and eventual stopping of rotation of the distributors, accompanied by grating noises in the pedestal bearings. As the races had been flushed, and the oil changed at frequent intervals, we were at a loss to explain the condition. The balls were all pitted deeply, worn oval, and some broken. The manufacturer furnished us with new balls and races, which were installed. In another six months, the same thing occurred. This time, we had the original engineers check the mechanism level. The north distributor was 9 in. out of level in the 110 ft. diameter, and the south, 3 in. After some investigation, it was found that when the distributors were leveled during construction, a carpenter's level was used, and nuts and washers were used as shims, instead of using the adjustment nuts furnished by the equipment manufacturer.

Since the distributor on the north filter was repaired, eight months ago, we have had no more trouble with it. The manufacturer's field engineer who supervised the job felt confident that as the machine was leveled to within ⅛ in. in the 110 ft. diameter, we would have no further trouble, and while we still have our fingers crossed, it is beginning to look as though he was right.

A problem resulting in bad odors has been in connection with the filter underdrain collection troughs. These troughs extend 65 ft. either side of the outlet, are 10 ft. wide, have flat bottoms, and pitch only 1 ft. in the 65. As there is not quite enough fall through the plant, the bottom of the trough has about 12 in. of water in it, at the low point, at all times. The filter underdrain tiles discharge above the water level.

As a result of the wide flat bottom and flat pitch, the velocity of the water in the troughs is low. Because of the low velocity, many of the solids carried by the filter effluent are deposited on the trough floor. They collect, decompose, and as they gas, lighten, and are carried to the final settling tank. Here they float in clumps on the surface of the tank, and are probably distributed through the various depths of the water, resulting in a high B.O.D. at times. A natural question would be why the troughs are not hosed out to keep the trough bottoms clean. We have 300 ft. of hose, and from the nearest hydrant to the south filter is 300 ft., and to the north, is some 450 ft. When the troughs are cleaned, the accumulated solids are broomed and washed to the outlet, carried to the final settling tank, pumped to the primary settling tank and then to the digestors. It is a 6-hour job for two men to clean the two troughs.

Another contributing factor to a poor final effluent was discovered while removing a layer of 18 in. of mud, stones, etc., that was washed into the final tank during a flood in the spring of 1942. This was the first time the tanks had been emptied, as the pumps built in the plant would not empty more than 4 ft. of the 9 ft. of water in the tank.

It was found that the floor of the tank had cracked, from the corners to the center; along the approximate center line it had raised about two inches. This resulted in the sludge scrapers scraping only one side, while the other side has a layer of sludge most of the time, up to 4 in. thick. During the past year, this was stirred up with a hose and pipe, apparently effecting some improvement in the final effluent.

B.O.D. analyses were first made in August, 1940. For this reason, the results in Table I are for the period from August 1 to January 1, in order that a 3-year period may be covered. This 5-month period covers the tomato and grape processing seasons, which are responsible for the greatest load on the plant. Of the five fruit processing plants in the village, only one handling all fruits, and one handling nothing but tomatoes, discharge into the sewer system. These fruit processors lime the waste so that the pH is over 9.6 at all times as it leaves their plants.

There is one machine shop in the village, that makes rubber bushed flexible couplings. In order to bind the rubber bushing to the metal flange, they found that the cement would hold much better if the rubber were pickled in concentrated sulfuric acid for a certain length of time. In their process, they soak the bushings in acid, using the acid over and over until the effect on the rubber slows up, when the acid is discarded. Formerly they dumped the acid over a bank. However, last year, the plumbing was changed in the plant, without benefit of plumbing permit, so that the acid sink emptied into the sewer. The amount was about 8 gallons per day, in 4-gallon batches. We had a good deal of trouble finding the source of the acid, as the front office disclaimed any knowledge of such a possibility. However, by judicious use of the back-door grapevine, the condition was discovered and stopped in a hurry. When the slug of acid reached the plant, the pH of the raw sewage dropped from its normal 6.9 to 7.0, down to less than 4.0. Even with two lime feed machines running, little could be done to raise the pH to normal. The influent to the filters at this time ran about 4.5, and the filter effluent about 5.0, as compared with the normal 7.1 to 7.2.

In Table I, it will be noted that the maximum B.O.D. of the raw sewage in 1940 was much higher than in the two years following. In 1940, one tomato processor collected all the trimmings, stems, etc., and put them through a cyclone, or extractor. The resulting dry product was carted away, amounting to about 2 truckloads a day. The liquid discharge from the extractor, amounting to a low grade of tomato juice, was emptied into the sewer.

Table I.—*5 Day B.O.D. in p.p.m.*

Average—Aug. 1 to Jan. 1

Year	Raw Sewage			Filter Influent	Filter Effluent	Final Effluent	Avg. of % B.O.D. Removals by Filter Alone		
	Avg.	Max.	Min.					High	Low
1940	257	1095	46	120.5	18.5	12.4	75.5	96	37
1941	275	792	32	143	16.6	18.7	85.9	96	63
1942	150	271	19	114	12.8	12.1	81.0	98.5	66

After a heart-to-heart talk between the plant operator and the canner, the trimmings, etc., from the 1941 pack were all hauled away in a tank truck, with a marked decrease in the strength of the sewage. Although this method of handling the waste made it necessary for a 500-gallon tank truck to work 18 to 20 hours a day, the canner voiced no objections. So far, this is the only time we have requested cooperation from a user of the sewer system, and no trouble was experienced. Perhaps the fact that, under the existing village ordinances, the use of the sewer could have been denied for industrial waste, may have had something to do with the willingness of the canner to cooperate, although, of course, this was not mentioned in the talk.

In 1940, when the waste juice was being discharged into the sewer system, the average B.O.D. of the waste from this one plant was 1600 p.p.m. In 1941, when the waste was trucked away, and only wash water was discharged into the system, the average B.O.D. was 243 p.p.m., representing a decrease in strength of 85 per cent.

In the 5-day B.O.D. analyses, the method of sampling admittedly leaves much to be desired. Grab samples are taken, and so timed that the same batch of sewage is sampled at the various stages of plant operation. The Rideal-Stewart modification of the Winkler Method is used for D.O. determinations.

Although composite samples would be a great improvement, it is rather difficult for one man to operate the plant, make all the necessary repairs, and carry out numerous other duties, and still have time to composite samples and analyze them. The thought was that even though errors were made, if they were consistent with all samples, a fair comparison and check of plant operation could be carried out.

Several times, hourly B.O.D. analyses were made throughout the day. During the period when the fruit processors were operating there was very little change throughout the day. At the times when the factories were shut down, there were expected peaks at about 11 A.M. and 3 P.M. The B.O.D. of sewage entering the plant from 8:30 to 9:00 A.M. seemed to be about average for the day.

Referring to Table I, it will be observed that the B.O.D. values of the raw sewage do not correlate with the above-mentioned decrease in strength from the one cannery effluent. However, the flow in 1941 was 71 per cent of that in 1940, and the tonnage of tomatoes packed was greater in 1941 by 20 per cent. In addition, there was no change in the sewage from the remaining cannery. The considerable drop in strength between 1942 and 1941, from 275 to 150 p.p.m., was caused by the flow in 1942 being 210 per cent of the flow in 1941, and a total tonnage of tomatoes packed 36 per cent less than in 1941. A greater drop in B.O.D. was not observed because the fruit in 1941 was of good quality, requiring comparatively little trimming, while in 1942 there was a great deal of trimming and wash water. Other B.O.D. data on filter influent and effluents are also shown in Table I.

The rate of application in 1940 was 2.32 m.g.a.d., 1.80 in 1941, and 2.78 in 1942. B.O.D. loadings were, in pounds per acre-foot per day, in 1940, 308; in 1941, 180; and in 1942, 259.

The improved removal in 1941 over 1940 may have been due to decreased loading and the regularly scheduled flooding and chlorination of the filters, mentioned before. The loss between 1941 and 1942 probably can be explained by the increased filter loading in spite of decreased sewage strength. In weekly tests, it appeared that the efficiency of the filters varied as the strength of the applied sewage; the higher the B.O.D. of the influent to the filters, the greater was the percentage of B.O.D. removal.

In examining the removals by the final tank alone, it would appear that the before-mentioned crack in the final tank bottom occurred in the winter of 1940–41, as the average B.O.D. removal in 1940 was 6.0 p.p.m., while in 1941, 2.0 p.p.m. were added.

Unfortunately, we are not equipped to analyze for nitrates, so that the degree of nitrification by the filters cannot be given. Neither can we determine suspended solids with any semblance of accuracy.

In an effort to improve filter operation, in 1941, a part of the final effluent was returned to the influent of the primary settling tank, and the filters so regulated that the south filter ran normally, with about a 5-minute rest between dosings, while the north filter ran continuously. Very little, if any, difference between operation of the two filters was noted. In 1942, the same procedure was followed, except that recirculation was taken from the sludge hoppers of the final tank. Again no definite improvement was noted.

Recirculation was at the rate of 300 g.p.m., making the rate of application on the north filter between 3.7 and 4.5 m.g.a.d., while the south filter remained about 1.8 and 2.8 m.g.a.d. in 1941 and 1942.

We had hoped to install piping this year so that recirculation to the dosing tank could be accomplished, thus maintaining the longer detention period in the primary settling tank, but for obvious reasons, this has been postponed indefinitely.

It may seem from this recital of troubles that the filters are not doing so well. In reality, the B.O.D. removal is as good as can be expected; outside observers agree with this statement.

These data were collected over too short a period of time to be conclusive, but rather serve to point out possible operational procedures which might be productive of improvement in plant operation at Westfield. It may seem that fault was found with the design and construction of the plant. Probably almost any operator new to the business could find fault with his plant. Perhaps as years of experience are accumulated, reasons may appear for certain things the tyro deems unnecessary or incorrect; things that he, daring to rush in where angels fear to tread, would have changed, had it not been for the restraining influence of his controlling board.

When explaining plant operation to a local taxpayer, B.O.D. reduction means less than nothing. However, when he is shown samples of sewage at various stages of treatment, the effect of the filters is more spectacular than any other stage. In fact, at times, the final effluent has a better appearance than our drinking water. A demonstration of this kind, coupled with a clean plant with well-kept grounds, makes for a well-satisfied taxpayer who, after all, is the employer. Such taxpayer satisfaction is a goal toward which all sewage treatment plants must work, if they are to be accorded their rightful place in the municipality, rather than being considered as a more or less necessary evil, as has so often been the case heretofore.

Discussion

By Carl J. Bernhardt

Jamestown, New York

I believe that we are all in accord with the fact that the paper which Mr. Howson has just presented is of interest not only to the operator but also to the sewage treatment field in general. He has been confronted with not only the run-of-mine type of problems that are experienced by a good many operators but also with one or two unusual ones.

We should be impressed by his statement regarding B.O.D. reduction and its significance, or rather, lack of significance, to the layman. Our experience with this valuable control test has been that it is often overlooked by some operators who could use it to good advantage and improve plant operation. An example of this can best be related by experiences gained in the operation of a sewage treatment plant serving one of the neighboring communities, having an environment similar to that of Westfield. This community has several fruit and vegetable processing plants and the wastes from each plant are pretreated to remove some of the solid material before discharge into the sanitary sewer system. The sewage, including the industrial wastes, is treated in a sewage treatment plant that includes secondary treatment with trickling filters. The plant effluent is discharged into a watercourse that occasionally has a low flow during the late summer and fall months or during the canning season. Although every ordinary precaution is used in the operation of this treatment plant, including pre- and post-chlorination and the effluent has a relatively clear appearance, there are times during periods of low stream flow where putrefactive conditions are created and are maintained in the receiving water course for a distance of over two miles below the treatment plant. In all probability, the low dilution factor of this stream is not sufficient to satisfy the oxygen demand of the sewage indicating that the latter is not satisfactorily treated. In this case, it is evident that the B.O.D. test could be used to advantage. Perhaps the present treatment facilities are overloaded and should be modified or a greater degree of treatment of the industrial waste required before discharge into the sanitary sewer system to result in a properly treated effluent having a lower oxygen demand so that putrefactive conditions in the receiving watercourse would be alleviated. We are pleased to report that the B.O.D. test is being established and will be employed at this treatment plant during the coming season and some interesting data should be obtained to guide the local officials in the solution of their problem.

Another point that should not be overlooked in Mr. Howson's paper is the cordial relationship that is maintained between the village and industry. Sometimes it requires considerable effort and very diplomatic salesmanship to promote and establish a feeling of common understanding. That such relationships be established and maintained is of utmost importance. Our experience has shown that the development and accomplishment of co-operative spirit between the operator and industry when waste treatment problems are involved is simplified if representatives of industry are invited by sewage treatment officials to share an interest in problems which are common to both. The sewage treatment plant official should not fail to and be ready to assist and advise local industries in the solution of waste treatment problems. You will find that in an atmosphere of mutual understanding both industry and community will benefit and operating difficulties influenced by industrial wastes will be held to a minimum.

A problem that has become very grave, but that has not yet completely vexed the operator, is the failure of waste treatment facilities in industrial plants to function principally due to physical breakdown and corrosion. Concerning the canning plants in particular, we have made a recent survey of all waste treatment devices in Chautauqua County and found that none of them have available sufficient replacement parts. For instance, most of the screening devices consist of a copper bronze alloy. As you know, this material is not readily available at the present time due to its high position on the critical materials list. Steel screens are not desirable because of their limited life when used in connection with certain cannery wastes and a satisfactory substitute has not yet been found. Another difficulty is bearing failure and because of the fact that the alloy used in casting bearings is difficult to obtain, ordinary breakdowns which formerly could be promptly repaired, may be extended considerably.

These are just a few of the examples of what we anticipate happening during the present season. However, we are fortunate in having established a Mutual Aid Plan for Water Service and are carrying this cooperative service into the sewerage and sewage treatment field in the form of the Mutual Aid Plan for Sewer Service in which every one of us has a part. One suggestion along this line would be broaden our program to include representatives of industry who have any connection whatsoever with waste treatment and disposal and to render advice and service as outlined in the Mutual Aid Plan. With this thought carried through to completion, the prospects of the continuance of a high standard of sewage plant operation are bright.

Discussion

By N. L. Nussbaumer

Commissioner of Public Works, Buffalo, New York

Mr. Howson has ably described the operation of a treatment plant not affected by the war. In contrast, it might be interesting to relate something about the Town of Cheektowaga, District No. 5 Plant, in which town two large war industries are located, the Curtiss-Wright Corp. and the Spencer Lens Co., both new plants, and the Buffalo Airport. In addition there has been one large Federal Housing Development constructed with 1,080 units and many privately built housing developments. The population has increased from about 9,000 to over 25,000 in less than two years. The population equivalent treated at the plant is about 33,000 persons. The daytime dry weather flow averages about 4 m.g.d. now and will probably drop to about 3 m.g.d. during the summer. During peak flows in heavy rains more than 32 m.g.d. has been received at the plant, and a relief pumping station located nearby.

The original plant had two rectangular sprinkling filters, about 100 ft. square, each equipped with fixed nozzles. The new construction included two 88-ft. diameter, 6-ft. deep filters equipped with Aero distributors, with a design capacity of 7.7 m.g.d. A distribution chamber diverts flow now in excess of 4.0 m.g.d. to the standard filters, which have a capacity of 1.2 m.g.d. During the winter, it was difficult and unnecessary to use the standard filters intermittently. It is planned to do so this summer and then to drop the point of diversion to 3.0 m.g.d.

The B.O.D. of the sewage this spring has been about 90–100 p.p.m., although normal dry weather domestic sewage has been in the past about 175–200 p.p.m. On one day in February when the influent had a B.O.D. of 90, the effluent showed 40. At this time one primary tank was out of service for repairs to the sludge removal mechanism so that the flow received only a one-hour period of sedimentation. At a later time, tests showed a B.O.D. of 108 for the influent and 35 for the effluent. No tests have been made when the plant may be considered to be under normal operation for the design flow. These tests were made by Mr. Sanderson of the New York State Department of Health.

Due to labor shortage at the plant, the Chief Operator has not been able to do much laboratory work. Consequently few results are available for comparison.

Trouble was experienced this winter during cold spells below 10° F. with the filter nozzles freezing when the flow dropped below about 1.5 m.g.d. The re-circulating pumps were stepped up so as to have a minimum flow of about 2 m.g.d. during such times. It was also found that the arms got out of alignment during the winter, one arm sagging so it was necessary to again level the arms this spring.

This plant did not experience trouble with fines being placed in the filter along with the approved size stone. When the filter was built, the filter material was first dumped on a platform adjacent to the filters, and then deposited by a crane and bucket in the filters. The fines were all left on the platform.

In this plant the sewage is pumped to the treating structures. Two-speed pumps are used. The smaller—350 to 500 g.p.m.—handles the minimum night flows nicely, and the larger—1800 to 3000 g.p.m.—handles the day flow, of course, during dry weather flow. When these pumps are placed in operation, they will run for hours alternating from low to high speed without dropping out completely or throwing in a second pump. These comparatively steady flows contribute to satisfactory plant operation.

It will be noticed that these filters are 2 ft. less in depth than those at Westfield, and that filters of less diameter here are handling flows about six times the dry weather flow at Westfield. While the results above quoted for B.O.D. removal are not high, they were made under unfavorable conditions. It is expected with a B.O.D. of about 185 p.p.m. in the incoming sewage that the final effluent will not show over 30 p.p.m. for design capacities. Chlorination during the summer is used at the rate of about 70 lb. per m.g. for pre-chlorination and 30 lb. per m.g. for post-chlorination. This combination controls odors and gives a satisfactory residual. In the winter, only post-chlorination is used.

When the war is over, it is probable that there will be a considerable reduction in the dry weather flow to the plant.

In Mr. Bernhardt's discussion, he has particularly stressed the relationships between a sewage plant operator and industries in the contributing area. This gives me an opportunity to make a few comments upon engineer and operator relationships to which reference is made in the final paragraphs of Mr. Howson's paper.

It is certainly true that mistakes which engineers make in designing a plant or deficiencies occasioned by a poor construction job fall to the lot of the operator for correction. However, some of the difficulties which operators have result from a different line of reasoning than that used by the engineer when designing the plant. Sometimes one may be right and sometimes the other. There are other things, too, which enter into the problem.

When an engineer designs a plant, he may assume that the municipality is in a position to staff the plant adequately with men who have received prior training in this class of work. He may also assume that adequate funds are available for repairs, replacements and general upkeep. Frequently it is found that the municipality desires to economize in their budget by putting on fewer men than the job really requires, or setting the salaries at such a point that good men are not attracted to the position. In addition, the first year's budget is made up without the benefit of experience from former operation and some items of expense are quite naturally left out.

Operators frequently complain, and justly so, that upon the completion of the job they do not have complete records of the plant as built, particularly where there have been changes from the original plans, that they are not instructed in the operation of mechanical equipment and that they have difficulty with repairs and adjustment to equipment, particularly while placing it in operation during the first year of the plant operation. Much of this could be overcome if the engineer's contract for the design and supervision of the construction of the plant also contained a provision for consultation during the first year of operation so that the engineer and the operator could get together, discuss the problems that arise, and attempt to overcome them in a way which the treating structures would best permit. Frequently an engineer is also able to get a better response from manufacturers on data pertaining to the operation of their equipment than the operators themselves. The best designed plants, and those which give the least trouble after being placed in operation, are those which are designed by engineers who give full consideration to operating requirements. Certainly in the case of a remodelling job or additions to an existing plant, advice from the operator is very valuable. Both the engineer and the operator desire a plant which will operate with minimum expense and unnecessary effort to give maximum results. Since their objectives are the same, their co-operation is essential.

Before closing this circle of co-operation which has been indicated to include: industries, municipal boards, operators, and engineers, one must surely include the New York State Department of Health representatives. Carl Bernhardt, Ralph Bates and George Moore, who are active in the western section, are only typical of others who give great help to all concerned in sewage matters.

OPERATION OF FREEPORT, LONG ISLAND, SEWAGE TREATMENT PLANT BEFORE AND AFTER IMPROVEMENTS *

By E. C. McKeeman

Manager Department of Sanitation

This paper will not entirely comply with its title, which was assigned to me when the difficulties and delays of wartime construction work were not fully appreciated. The contract for improvements to the Freeport Sewage Treatment Works, started in 1941, has not been entirely completed. Fortunately, the work was started before the war and the village was able to obtain the required priorities, and vital equipment was finally obtained. The time consumed in getting priorities in the early days of the W.P.B. was considerable and required several trips to Washington.

While I cannot therefore give before and after results at this time, I trust that a description of our plant and the improvements made, together with some of our operating problems and procedures, will be of interest.

The Village of Freeport

The Village of Freeport is one of a chain of residential communities along the south shore of Long Island. It is near the well-known State Park of Jones Beach; in fact one of the boulevards from the mainland to Jones Beach passes in close proximity to the sewage treatment works. Freeport is largely residential in character but includes a large propellor works and shipyards and other vital defense activities.

Typical of the south shore of Long Island, the Village is very flat with elevations ranging from 4 to 40 ft. above mean low tide. The total area of the Village is 4.82 square miles or 3,085 acres. This area is made up of 4.27 square miles or 2,730 acres of land and .55 square miles or 355 acres of water. The Village is 3.56 miles long in a north and south direction and 1.89 miles wide in an east and west direction. The southern portion of the Village is indented by several inlets of the bay providing 17 miles of navigable water frontage.

Sewerage System

The pumping station, original treatment plant and a portion of the trunk sewers were constructed in 1927 and 1928 from plans prepared by N. S. Hill, Jr. The comprehensive design of sewers was revised in 1929 by Baldwin & Cornelius Co., Inc. Village Engineers, and Clyde Potts, Consulting Engineer. The village was then divided into seven lateral districts. These were modified somewhat from time to time in accordance with the desires of the residents for sewerage. Sewers in any lateral district are constructed when application by petition is made by the residents.

* Presented at the Spring Meeting of the New York State Sewage Works Association, Rochester, N. Y., June 4, 1943.

A large part of the village is now sewered, with 3,384 connections to 68.5 miles of sewers. The population of the village has increased steadily as shown by the following figures:

1900	2,610
1910	4,836
1920	8,599
1930	15,467
1940	20,369

Not all of the village is connected to the sewer system, particularly the southern portion which was annexed in 1930. This area includes the water frontage, is generally low, and the use of cesspools in this section is difficult. Sewers were planned for this area in 1942 and it is hoped some sewers will be constructed as soon as conditions permit. In addition to sewage from the houses connected, we receive a considerable additional contribution from theatres, schools and business houses. A recent new connection from a war plant added 600 to our contributing population.

On our applications for sewer connections, the applicant states the number of persons that will use the connection. The total figure from these applications is 22,798 as of March 1, 1943. Evidently the applicants figure high, as a more probable estimate for the equivalent full time connected population is approximately 15,000.

The average flows are as follows:

1940	1,460,000
1941	1,464,000
1942	1,500,000

The average for 1943 through April is 1,638,000 m.g.d.

The trunk lines, of 10- to 27-in. pipe, total 10 miles in length. The trunks were designed for an ultimate population of 42,000 with maximum rate of 250 gallons per capita. The lateral sewers of 8 in. pipe total 58.5 miles in the six districts that have been constructed.

All of the sewage is pumped and is carried to the pumping station on Ray Street and Sportsman Avenue. The two largest trunks are 27 in. and 24 in. where they connect with the pumping station.

The pumping station as originally constructed included bar screens preceding a 30,000 gallon wet well, and three 1.5 m.g.d. pumps in a dry well automatically controlled. The station is of attractive design and has received favorable comment from visitors. Pumps discharge into 4,100 feet of force main which carries the sewage to the sewage treatment works in the southeasterly portion of the village. The original force main was 24-in. concrete and a duplicate force main of 30-in. cast iron pipe was constructed through the W.P.A. in 1936.

Sewage Treatment Works

The original plant was designed for capacity of 1 m.g.d. The plan included sedimentation tanks with hopper bottoms in two units, four sludge digestion tanks, and two glass-covered sludge drying beds, each divided into three units. A head house was provided for the sludge pumps and chlorine apparatus.

A number of improvements were made to the original plant by the operators at a cost to the village for materials only. These included remodelling of the head house to provide a laboratory over the sludge pump room, the installation of a V-notch weir and recorder, the addition of a plunger sludge pump and a sludge grinder. Much work was also done to improve the appearance of the plant by landscaping.

1935 Improvements

When the sewage flow reached and exceeded the design capacity of the plant operating difficulties were increased and study was given to various methods for increasing the plant capacity. In 1933 Mr. Lawrence Luther, Manager of the Department of Sanitation initiated some experiments on chemical treatment. These were very successful and showed that the capacity of the plant could be increased by the use of chemical treatment, and that the B.O.D. load on the receiving waters could be so reduced that secondary treatment would not be required for some time. Bids were taken in January, 1935, on additions to the plant, including a new chemical house and other units. As bids were higher than available funds, this plan was not carried out. Plans for modifications to the sewage treatment plant were then revised to include a smaller chemical house placed over one end of the sedimentation tanks, alterations to sedimentation tanks, mixing basin equipment, alterations to sludge digestion tanks, vacuum filter and other improvements. Bids were taken on this work in November, 1935, and the improvements were installed the following year. Under this contract a comminutor was installed in the pumping station together with a ventilating system for the wet well. At the sewage treatment works, mixing basins were provided by separating the first part of each of the two sedimentation tanks by walls. This made each unit approximately 20 ft. square with a hopper bottom. Apparatus for slow mixing consisted of a vertical shaft in the center of each mixing basin, with horizontal bevelled paddles operated by direct connected reduction gear and motor. An air blower connected to a pipe grid in the entrance channel to the slow mixing basin was also included for the purpose of rapid mixing, after addition of the chemical to the sewage. Two automatic Wallace and Tiernan dry feeders and a rubber lined tank were installed in the chemical house.

The sedimentation tanks were modified by the addition of baffles and by providing long weirs at the effluent end of the tanks. The sludge digestion tanks were modified to allow the collection of gas and the heating of the sludge. The open covers were replaced by fixed concrete covers with a welded steel lining on the inner side to insure gas tightness. A gas holder was included in one of the four tanks. A gas water heater, connected with a circulating pump to cast iron heating pipes in the digestion tanks, was installed in the lower floor of the head house. Another gas water heater was provided to provide hot water for the laboratory, lavatory and a new shower that was added in the head house. A portion of one of the glass-covered sludge drying beds was closed off by transite siding to provide a room for the vacuum filter. The filter is an Oliver rotary drum type, 5 ft. 4 in. by 8 ft. long, and has the usual auxiliary equipment of dry vacuum pump, filtrate pump, vacuum receiver, moisture trap, air compressor. Digested sludge is drawn from the digestion tanks to a concrete sludge tank below the floor in the filter room. The sludge is raised by bucket conveyors from this tank to the filter unit where it passes through a mixing basin with air agitation. Ferric chloride and lime are used for conditioning. The filter cake drops on to a belt conveyor which carries cake through an opening in the wall and into the adjoining room. Here the cake drops from the belt conveyor into a Royer sludge grinder which throws the ground cake into a concrete receiving pit.

1942–1943 Improvements

These improvements had the effect of increasing the effective capacity of the plant and a good effluent resulted. As the flow continued to increase, the difficulties of turning out a good effluent increased. The worst problem was the handling of the sludge. In order to remove the sludge from the sedimentation tanks, which have hopper bottoms, it was necessary to pump for a long period. This required one man's attention for practically the entire day. The procedure also had the effect of adding an excessive amount of sewage to the digestion tank so that it was not possible to maintain the proper temperature during the winter. The continued and excessive pumping also gave a continuous discharge of supernatant from the digestion tanks back to the raw sewage, which did not improve the character of the effluent. A further result of the low temperatures in the digestion tanks was a poor quality of sludge which made the operation of the vacuum filter difficult.

In 1940 another report on the sewer system as a whole, and the sewage treatment works, was made by Herbert M. Wood of Baldwin and Cornelius, Village Engineers, and Weston Gavett, Sanitary-Hydraulic Engineer. Sewer gaugings were made throughout the system to check on the capacity of the trunks. Two plans for the improvement of the plant were proposed, one a long-time improvement which included a new and larger chemical house, additional mixing and sedimentation basins and the conversion of the present sedimentation tank into sludge-digestion tanks, and other items. As the prospect of the war was then on the horizon, it was also suggested that the operation of the plant could be improved for a shorter period by less expensive alterations. When the plan was presented to the voters the Sewer Commission recommended the less expensive plan. This work has now been practically completed and the plant is rapidly getting into normal operation.

An important part of the new work was the increasing of the capacity of the pumps in the pumping station. While the original pumps had sufficient capacity for normal flows, their capacity was severely taxed on a few occasions of extreme high tide and heavy rain. Under these conditions many of the streets near the waterfront are under water and a large flow results. Two of the original pumps were replaced by two new pumps, each with capacity of 4.75 m.g.d. These pumps have slip-ring motors and variable speed control so that the flow that reaches the plant is somewhat more uniform than formerly with the small units. One of the new pumps has a combination electric motor and gasoline engine drive. The motor is vertical and engine horizontal, connected by Johnson right-angle gear drive, so that the pump may be driven by either engine or motor. The 1.5 m.g.d. pump also has a similar combination drive, so that we can keep the pump station operating in case of power failure. All pumps are Fairbanks-Morse.

The new pumps have already shown their usefulness in a recent period of high water when the recorded flow for a time was over 5 m.g.d. As the original comminutor was reaching its capacity a new and larger comminutor was installed. A small addition was added to the pumping station to house the chlorine feed apparatus which is used for pre-chlorination at the pumping station. This chlorinator had been installed in a small closet in the motor room but we were always afraid of possible damage to motors and switchboard in case of any leakage of chlorine. This danger is now eliminated by having the chlorinator in an entirely separate room. New transformers required for the new pumps were placed on a platform at one side of the chlorine house and chlorine cylinders are stored on the platform at the other side of the chlorine house. Wire fence was placed around these platforms. A new roadway to allow cylinders to be brought to the chlorine platform by truck was installed to help operation.

At the sewage treatment works the main improvements included the installation of a sludge concentration tank and the installation of a clarifying filter following the sedimentation tanks. The sludge concentration tank is 19 ft. in diameter and 24 ft. high, with a capacity of 50,000 gallons. It is of steel on a concrete foundation and has a steel roof. An activated carbon odor absorption unit is placed on top of the roof to serve as a vent and prevent possibility of odor when sludge is pumped into the tank and air forced out. With new pipe connections to this tank, fresh sludge may be pumped from the sedimentation tanks into the concentration tank. After concentration, supernatant liquor may be drawn off through swing pipe controlled by a winch and valve to regulate the location and speed of draw-off. Concentrated sludge is taken from the hopper bottom of the tank and transferred to the sludge digestion tanks.

To assist in removing fresh sludge from the hoppers of the sedimentation tanks, lead water pipes were installed in each hopper. The water service to these pipes, and other pipes where there would be any possibility of contact with sewage, is supplied from a separate line which was connected to a vacuum relief valve located above the elevation of all sewage tanks in the head house. This valve will open if the pressure is less than atmospheric and prevent any possibility of sewage getting into the water supply pipes. Double check valves were also installed on the main 4-in water supply line as an additional safeguard. The sedimentation tanks were also improved by adding new effluent weirs. Each of the two sedimentation tanks now has three new weirs connected with the effluent trough and projecting into the tank parallel to the flow. These weirs were made of ½-in. Chemstone slabs supported in angle iron frames and hung from the concrete roof. They provide approximately 100 ft. of additional effluent weir and were planned to decrease the velocity over the weir and reduce the amount of solids in the effluent.

In the 1935 construction a blower was included, to feed air in the entrance channel to the mixing basins, to give an initial rapid mix to the chemically treated sewage. It was found that this initial mix did more harm than good and tended to break up the floc, and this procedure was abandoned. In order to make use of the existing blower, air lifts were installed in the two slow-mixing basins. These have proven useful in cleaning out the sediment which settles in the hopper bottoms of these tanks and which is not kept in suspension by the existing mixing paddles.

Connections are made to the effluent trough in the sedimentation tanks to carry the tank effluent to the new clarifying filter. The filter effluent is returned to an existing chlorine detention tank, where chlorine is applied before the final effluent discharges to the outfall to the creek. The filter is of the magnetite type, furnished by the Dorr Company, and manufactured by Fraser-Brace Manufacturing Company. It is circular in type with annular filter bed 8 ft. 4 in., wide with a mean diameter 45 ft. 8 in. The influent channel is on the outside of a portion of the filter and the effluent weir inside the filter. The filter bed is composed of 3 in. of magnetite supported on a brass screen. The filter is divided into segments by rubber baffles so that there is no short-circuiting of wash water when the cleaner is passing over in operation of the bed. The filter is rated at an average rate of 2.3 m.g.d. with a maximum rate for a 4-hour period of 4.5 m.g.d. Included with the recent construction were miscellaneous improvements at the plant such as an addition to the head house to provide a separate room for the chlorinator and another separate room for the gas appurtenances. A larger gas water heater was installed for heating the sludge digestion tanks and one of the old centrifugal sludge pumps was replaced by a 4-in. duplex plunger sludge pump.

Improvements Made by Operators

Improvements made to the original plant by the operators have been described. After the 1935 improvements were completed we continued to find work to do to improve the operation of the plant. Our operators are skilled mechanics and there are few jobs that we cannot do as well as or better than a contractor would do them.

In connection with the vacuum filter for sludge dewatering we have done considerable work.

A sample pipe we installed on the discharge side of the filtrate pump is useful in checking the quality of the filtrate. We built a rig for reeling the wire when changing filter cloths.

An air-pressure gauge was installed on the air line for cake discharge.

An alarm bell connected with the filtrate pump gives alarm in case the pump motor stops and the vacuum pump picks up the filtrate.

In March, 1938, we replaced the carborundum air diffusers in the mixing tank preceding the vacuum filter with 1½-in. galvanized pipe drilled with 14–5/32-in. holes. This has worked satisfactorily to date.

When the vacuum filter was first installed, a rubber lined metal drum in which ferric chloride was shipped was used as a ferric chloride tank. To replace this we constructed a concrete tank 3 ft. square and 3 ft. deep with 4-in. walls. This tank was lined with Bitumastic No. 50 and has given good service.

We have a convenient layout for handling sludge cake from the filter, as a belt conveyor carries the cake from the filter and drops it into the Royer grinder. We have added a ground sludge bin to hold the ground sludge. This bin is 22 ft. 3 in. by 8 ft. 2 in. in plan and 3 ft. 3 in. high. We built it of concrete block plastered with cement.

General plant improvements we have installed ourselves include the installation of a 6-in. cast iron pipe for carrying supernatant liquor to the raw sewage and the substitution of 2-in. rubber hose in 3-in. galvanized electric conduit for the chemical stoneware pipe that carried the ferric sulfate solution to the raw sewage. This line is about 50 ft. long with several bends and we have less trouble with the rubber hose than with the stoneware pipe.

Safety Provisions

Every effort is made to prevent accidents and to provide for any emergency.

At the pumping station, the wet well and new chlorine room are ventilated by fans. At the plant, the chlorine feed and gas trap and equipment are in separate rooms. These rooms and also the furnace room are ventilated by a fan. To gain access to the top of the sludge digestion tank and the sludge concentration tank it is necessary to go up a stairway closed with a gate. This is posted with "Danger, No Smoking" signs and this rule is rigidly enforced by the operators.

In the head house, in addition to ventilation, we have an automatic carbon monoxide alarm. We also have a first-aid kit and gas mask. Several of the operators are members of Civilian Defense and the village Volunteer Fire Department so have ample talent to handle emergencies and first aid. The plant is attended 24 hours, and there is only one of the three shifts when one man alone is on duty. As a safeguard against accident, this man calls the village police station at certain times.

Plant Organization

As Larry Luther, the Manager of the Department of Sanitation, is now in England with the Red Cross, I have accumulated his various duties which include supervision of sewers, sewer cleaning, house connections and all work connected with the sewer system and plant. In addition to this, the operation of the garbage collection and incineration has recently been dumped in my lap. This reduces the time available for plant operation and makes an operating schedule essential. This schedule lists the duties of each man and is planned to divide the work between the operators, to make sure that no necessary work is forgotten.

In general, there are always two men on duty on the 8 A.M. to 4 P.M. shift, one of whom spends most of his time in operating the vacuum sludge filter and the other is busy with plant operation work. The maintenance man is usually on this shift and has plenty to do. On the 4 to 12 shift there are usually two men on duty, but one acts as a relief operator. As each man has one day off a week, much of the time the relief man is filling in for the man with the day off. Vacations also change the schedule.

We take composite samples through the plant. We have found that the best place to sample the raw sewage is at the pumping station at the outlet of the comminutor where the sewage is well agitated. The operators take this sample on their inspection trips to the pumping station.

As the schedule may be of interest to other operators, it is included:

1. Operation of vacuum filter (4 days) and laboratory work (2 days).

2. Pumping sludge from settling tanks to concentration tank.
   Pumping sludge from concentration tanks to digestion tank.
   Washing and skimming settling tanks, valve chamber and magnetite filter.
   Hosing digestion tanks.
   Running chemical feeder.

3. Greasing, checking and changing oil of blowers, chemical feeders, paddles, magnetite filter, sludge pumps, circulating pump, vacuum filter, compressor, Marlow circulation pump, floating cover and gas valves at plant.
   Trash pumps, auxiliary motors, comminutors and blowers at pumping station.
   Repack all pumps and valves.
   Replace cutters on comminutor.
   Oil and adjust dash pots on control board.
   Wash float tubes and replace cable when necessary.
   Clean and adjust chlorine machines.
   Clean water traps on gas lines.
   Clean grit chamber and wet well.
   Open and close all pump and force main valves.
   Install new cover on vacuum filter when necessary.
   Check radiators for water.
   Painting of buildings and equipment.
   Cutting grass and upkeep of grounds.
   Carting Ferrisul from store room to chemical house.
   Miscellaneous repairs.

4. Carting of filtered sludge.
   Mixing chemical for next run.
   Carting lime and cleaning feeder, conveyor and grinder for next run.
   Filling in on regular shifts as relief man and to assist 4–12 operator when possible.

5. Duties of operator on at 4:00 P.M. to 12 midnight.
   To be responsible for the upkeep of the pumping station, filter room, shop, tool house, digestion tank and drying bed as follows:
   Pumping station, filter room and shop:
     Keep interior and windows clean and all brass polished.
   Tool house and drying bed:
     Keep all brass polished.
   Digestion tank:
     Keep the top, stairs and room under stairs clean and all brass polished.

He is to see that the chemical feeder is kept filled and to turn same off at 11:30 P.M.
He is to inspect valves to determine whether same should be closed or open.
He is to lower the setting on both chlorine machines.
He is to make three inspections at the pumping station; the said inspections shall be made at 5:00, 8:00 and 11:00 P.M. and shall cover the grounds, pump room, chlorine room and wet well. While in the wet well he shall hose grit chamber and walls of well.
He is to change chlorine cylinders when necessary.
During the winter in the event of snow he shall keep all walks clear or spread sand in the event of sleet.

6. Duties of operator on at 12 midnight to 8:00 A.M.
Be responsible for the upkeep of the chemical house and head house as follows:
Keep the interior and windows clean and all brass polished.
He is to clean the chemical feeder and start same in the morning.
He is to change the pump at the pumping station.
He is to raise the setting on each chlorine machine.
He is to read all meters and change the flow chart.
He is to make three inspections at the pumping station; said inspections shall be made at 2:00, 5:00 and 7:00 A.M. and shall cover the grounds, pump room, chlorine room and wet well.
While in the wet well he shall hose grit chamber and walls of well.
He is to change chlorine cylinders when necessary.
He is to inspect valves and determine whether same should be closed or open.
During the winter, in the event of snow, he shall keep all walks clear or spread sand if it sleets.

It will be noted that cleaning is not forgotten. In Freeport, we are more or less seafaring men and most of us either have or use boats. A good sailor keeps his boat shipshape, with paint scrubbed and brass polished. It is therefore no hardship for us to keep our plant the same way, and after a contractor has been around messing up the plant, we don't feel happy until all the scars have been removed.

Operating Experiences

As the plant has grown and changes have been made we have learned quite a bit about how various things work. At the pumping station we have no difficulty with clogging now that we have comminutors. When the pumps start, the level in the wet well is above the pump, but when pumping stops the wet well has been pumped down below the pump. To prevent any chance of pumps losing their prime from air getting into suctiom pumps, the operators open valves on suction pipes when the wet well is full. The stuffing boxes are water sealed, which also helps.

In the recent construction a small vertical-flow grit chamber was installed ahead of the comminutors. It appears that while this collects little material, it does catch large solids like peach pits, and it seems to have reduced the wear on the comminutor knives. The comminutors are appreciated after using hand-raked bar screens.

The two force mains are used alternately to keep them clean. The cast-iron main constructed in 1936 has reduced our worries caused by occasional breaks and leaks in the old concrete line.

Chemical treatment has worked well for us. We use Ferrisul without lime, with Wallace and Tiernan automatic feeders.

We found that the initial rapid mix by air was not helpful and we get better results by omitting it and using slow mixing only.

In operating our vacuum filter we did not use lime at first but found that with our sludge some lime was needed. We keep our lime dose as low as possible. We have had considerable trouble getting a filter cloth that would give any length of service without sealing. We now use a coarser cloth than formerly, and recently hit on a scheme that promises to lengthen our runs considerably. When a cloth seemed about ready for replacement, we tried brushing it with a wire brush. It did the work as the cloth worked as good as new and did not seem to be damaged by the brushing.

Operation After Improvements

A satisfactory report on the operation of the plant with the new improvements cannot be made until the work is entirely completed and workmen and mechanics gone and the plant operated for some time under normal operating conditions.

Some of the benefits of the improvements have been mentioned. The benefit of the sludge concentration tank has been demonstrated. While before the improvements the temperature in digestion tanks was only 60°F. or less during the winter, the following temperatures were maintained last winter. Heating was started in October when the temperature in tanks was 66° F.

Temperatures

Deg. F.

	Sludge Tanks	Air
November, 1942	76	45
December, 1942	82	30
January, 1943	83	29
February, 1943	81	21
March, 1943	81	35
April, 1943	80	41

In operation, fresh sludge is pumped to the concentration tank. After settlement, the supernatant is returned at a low rate to the raw sewage and concentrated sludge is discharged to digestion tanks. The amount of supernatant discharged from the digesters is greatly reduced. As the sludge withdrawn from the digesters to the vacuum filter is more concentrated than the sludge drawn from concentration tank, some supernatant must be taken from the digestion tanks. These are arranged so that by filling a trap with water through which the gas passes, the gas forces out the supernatant at a low rate. By removing water from the trap, the gas pressure is reduced, so sludge from concentration tank can be run into digesters without any discharge of supernatant. The incoming sludge displaces the gas and forces it into the gas holder.

The purpose of the magnetite filter was to supplement the sedimentation tanks and make up for their small capacity. With this combination, a much better effluent can be obtained than would be given by sedimentation alone. While analyses may not show it, operators know that with the best of tanks occasional gobs of solids go out with the effluent. The filter acts as a safeguard to catch any such chance discharge of solids and also by further reduction of solids gives an effluent that is much more attractive in appearance than the tank effluent, with less chlorine demand and reduced load on the receiving waters.

We are now running our vacuum sludge filter with good results and can dewater as much as 620 cu. ft. of digested sludge on one shift.

The water in the creek at the outfall is much improved and the presence of fish indicates they have no objection to our effluent. A chlorine residual is maintained and we feel that the plant is performing its function in treating the sewage so that it has no harmful effects on the creek waters into which it discharges.

SEWAGE TREATMENT AT MILITARY INSTALLATIONS *

By Lt. Colonel B. F. Hatch

Corps of Engineers, Fifth Service Command

Introduction

At the inception of the present national emergency, the War Department recognized the necessity for providing adequate sanitation facilities in connection with a war construction program, which in magnitude and speed of fulfillment has no parallel in the history of our country. Consultants of national reputation in sanitary engineering were engaged to investigate the sanitation problems involved and to recommend a program of construction of water and sewage treatment plants which would safeguard the health, comfort and welfare of both our military and civilian population. On December 16, 1941, the responsibility for direction of the entire construction program for the Army, including the repair and maintenance of real property and operation of utilities, was transferred from the Quartermaster General to the Chief of Engineers by Section I, Act of Congress, December 1, 1941 (55 Stat. 787). Throughout the early stages of this construction program, the experience and knowledge of state departments of health was sought and utilized in determining available sources of water supply, necessity for water and sewage treatment and the degree of treatment which should be provided.

In sewage treatment practice, intensive studies have been carried out at sewage plants at army posts in all sections of the country. As a result, design factors have been perfected, construction methods improved and operation simplified to the end that the science of sewage disposal at army installations is now conducted on the same high plane as in municipal practice. Many of the early problems encountered have been overcome, while others are still being studied. The design and construction of such plants in this country has now been largely completed. A maintenance, repair and operation program will continue for a considerable period after the present emergency is over.

Principles of Design

Operating experience during the past two years has shown that the design of sewage treatment plants for installations of the Army should be predicated upon the following basic considerations:

(1) The degree of treatment required is established by the necessity for safeguarding the public health, preventing nuisance conditions and protecting the rights of riparian owners in the immediate locality.

(2) The type of treatment process utilized depends upon the degree of treatment required, the availability of materials and equipment, the supply of operating labor and climatic conditions.

* Presented Before the Ohio Conference on Sewage Treatment, Mansfield, Ohio, June 23, 1943.

(3) Variations in rate of flow in terms of the daily average are more pronounced at army installations than in municipal plants.

(4) Industrial wastes other than laundry wastes are not a factor. At those ordnance and chemical warfare service manufacturing plants where industrial wastes are produced, treatment separate from domestic sewage is generally necessary because of the character of the chemical wastes.

(5) Grease removal is a major problem.

(6) Sudden fluctuations in population necessitate liberal design and provision for operating flexibility by use of multiple units.

(7) Concentration of organic matter expressed in terms of suspended solids, 5-day biochemical oxygen demand and ether soluble matter is somewhat higher per capita than in average municipal sewage.

(8) Simplicity of design and operation is a virtue. Designs which contemplate the use of complicated mechanisms, an excessive amount of critical materials, or which require an abundance of highly skilled operating labor, should be avoided.

(9) Provision for infiltration of ground water into the sewerage system is necessary under unusual soil conditions, but increased flow caused by surface runoff and roof drainage is ordinarily not a problem.

(10) Ordinarily sewage arrives at the plant in a fresh condition.

Bases of Design

The average 24-hour per capita flow and strength multiplied by the normal housing capacity is used as the basis of design. However, in order to provide for variations in rate of flow and for fluctuations in population above normal housing capacity, it is necessary to apply a capacity factor to this basic figure. This capacity factor varies inversely with the normal housing capacity of the camp. Tables I and II show basic design factors and capacity factors respectively.

Table I.—*Basic Design Data for Sewage Plants*

Installation	Strength, Lb. per Cap. per Day			
	Flow G.p.c.d.	Susp. Solids	B.O.D.	Ether Soluble
Camps and Cantonments	70	0.27	0.20	0.09
Permanent Posts and Hospitals	100	0.27	0.20	0.09
	30*	0.13	0.10	1.05
Plant, Port and Storage Projects	100	0.27	0.20	0.09
	30*	0.13	0.10	0.05
Airfields	100	0.27	0.20	0.09

* Non-resident population per 8 hour shift.

From a hydraulic standpoint, provision must be made for passage of peak flows of 300 per cent of the average 24-hr. flow through conduits, pipes and equipment. Capacities of various units are designed for a 16-hr. average flow equal to 125 per cent of the average 24-hr. flow. The design is further checked to insure that the detention periods are adequate for

TABLE II.—*Capacity Factors*

Population of Camp	Capacity Factor
10,000 or less	2.0
20,000	1.5
30,000	1.25
40,000	1.10
50,000 and over	1.00

average 4-hr. flows of 175 per cent of the average 24-hr. flow. All structures and equipment must be designed for minimum flows of 40 per cent of the average 24-hr. flow.

PRIMARY SEDIMENTATION TANKS

Both one- and two-story types are used. Plain sedimentation types are ordinarily provided with equipment for mechanical removal of settled solids. Displacement capacities provide detention periods as shown in Table III. Imhoff tanks are so designed that maximum linear velocities will not exceed 1.0 ft. per min. at maximum peak flows. B.O.D. removal of 40 per cent of the total is contemplated as a result of plain sedimentation. For industrial plant, post and storage projects involving non-resident civilian population, a detention period of 2 hours is provided, based upon the average hourly rate for the 8-hr. period of maximum population.

TABLE III.—*Primary Tank Detention Periods*

Type of Treatment Works	Detention Period in Hours—Based Upon	
	16 Hr. Average Rate of Flow	24 Hr. Average Rate of Flow
Plain Sedimentation	2.0	2.5
Standard Trickling Filter	2.0	2.5
High Capacity Filters	2.0	2.5
Activated Sludge	1.2	1.5

TRICKLING FILTERS

Low Capacity.—An organic loading of 600 lb. of applied B.O.D. (5 day) per acre foot up to 6 ft. depth is used in southern climates with a 20 per cent reduction in this load for northern climates. Corresponding liquid loadings are 2.1 and 1.68 m.g.d., respectively. Distribution by either nozzles or rotary mechanism may be used. The preponderance of plants use distribution equipment of the rotary type.

High Capacity. Organic loadings of not to exceed 3,000 lb. of applied B.O.D. per acre foot are used for plants in southern climates for both single and two stage types. This loading is reduced by 20 per cent for northern climates. Loading and recirculation rates follow manufacturers' recommendations. While applied loadings may be the same, single-stage and two-stage high capacity filters are credited with ability to provide overall treatment of from 60 to 80 per cent and from 85 to 95 per cent, respectively.

Activated Sludge

Designs of aeration tanks are based upon detention periods of 8.0 hr. for compressed, diffused air and 12.0 hr. for mechanical aeration, using the 16-hr. average rate of flow.

Final Settling Tanks

Final settling tanks are designed to provide detention periods of 2.0 and 2.5 hours, based on the 24-hr. average and maximum 16-hr. average flows. Flow rates are based on actual flows, including recirculation of sewage or sludge. Where two-stage filtration is used, final settling tank capacity is exclusive of any intermediate settling between stages. Water depths should be from 8 to 10 ft. and overflow rates should not exceed 800 gal. per sq. ft. of tank area per day, based upon the average 24-hr. rate of flow.

Sludge Digestion Tanks

The design capacities of sludge digestion tanks are shown in Table IV. It should be noted that these capacities must be multiplied by the proper capacity factor as well as the normal housing capacity to arrive at the actual cubical contents. Adjustments in capacity must also be made where civilian population is non-resident and on an 8-hour shift basis.

Table IV.—*Sludge Digestion Tank Capacity*

Type of Treatment Works	Cu. Ft. per Cap. per Day	
	Heated	Unheated
Plain Sedimentation	2.0	3.0
Plain Sedimentation with Chemical Precipitation	3.0	4.5
Standard Trickling Filter	3.0	4.5
High Capacity Filter	3.0	4.5
Activated Sludge	4.0	6.0

The capacity of Imhoff tank sludge compartments is figured from a point 18 inches below the intersection of the sloping walls of the flow through compartment. This capacity is 3.0 cu. ft. per capita for southern climates and 3.75 for northern climates.

Sludge Disposal

In general, sludge is disposed of by digestion and air drying. Mechanical dewatering and incineration are not used except in special cases where industrial wastes are involved. Open sludge drying beds have areas of approximately 1.0 sq. ft. per capita. Covered beds are used only in special instances where area is limited or adjacent installations make greenhouse construction necessary. Sludge storage and drying on naturally drained areas is frequently used. In this case, areas of from 2.0 to 3.0 sq. ft. per capita are necessary.

Chlorination

Where required, chlorine is used for sterilization of effluents or control of odors. A contact period of 15 minutes based on the 4-hr. average maximum flow is used and equipment is designed to provide a dosage of 80 lb. per m. g. based on the 24-hr. average flow.

Miscellaneous Adjuncts

Screens either of the stationary, hand raked, bar type, or of the comminuting type are installed ahead of the primary tanks.

Flow measuring devices are installed in all plants. For plants serving populations in excess of 5,000 persons, recording, indicating and totalizing equipment is also provided. Measuring devices such as Parshall flumes, rectangular flumes (Palmer-Bowlus), venturi meters and weirs are used, depending on local conditions.

Laboratory

Each plant is provided with a laboratory and supplied with furniture, equipment and reagents required to make the routine tests necessary for proper plant control. Plants are classified as shown in Table V. Laboratories are equipped in accordance with this classification. Class A plants have complete equipment for all necessary chemical, biological and bacteriological analyses.

Table V.—*Classifications of Sewage Treatment Plants*

Plant Type	Per 1,000 Population Capacity			
	38 and Over	12 to 38	6 to 12	1.5 to 6
Complete Treatment with Separate Sludge Digestion	A	A	B	C
Primary Tanks and Separate Digester Primary Treatment Only	A	B	C	C
Imhoff Tank with Trickling Filter or Slow Sand Filter	B	B	C	C
Imhoff Tanks or Slow Sand Filter Only	—	C	D	D

Operation

Generally speaking, the operating problems encountered at sewage plants at army installations are no different than those with which we are all familiar at municipal plants. The grease problem can be eliminated very largely by adequate and frequent cleaning of mess hall grease traps. Recently improved designs of such traps which provide greater capacity are more efficient and since this quality of grease has a salvage value there is little excuse for excessive amounts of grease reaching the sewage plant. Enforcement of regulations such as proper cleaning of grease traps is more easily effected under military control than is possible in municipal practice.

Laundry wastes have proven to be a vexing problem at some army posts. Whenever the volume of such wastes becomes predominant, treatment difficulties arise and overall plant efficiency is lowered. Studies are now being conducted to develop methods of overcoming this problem. At one of the largest installations in the Fifth Service Command, laundry wastes are discharged through a rock crevice into underground limestone caverns. This method of disposal has been in use for about two years and so far has worked perfectly. No evidence of contamination of underground water supplies of surrounding areas, or of creation of nuisance conditions has been found.

Comparison of Design and Operation Data

Design and operation of sewage treatment works are very closely associated. The designing engineer must constantly evaluate his handiwork

Table VI.—*Sewage Treatment Works, Operating Results and Design Data, 35,000 Troop Capacity Ground Force Station*

Type—Preaeration, plain sedimentation, separate digestion, low capacity trickling filters, secondary settling, chlorination

Operating Results

Month (1943)	Load in Persons	Flow		Raw Sewage		Primary Eff.		Filter Eff.		Final Eff.	
		m.g.d.	g.p.c.d.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.
January	33,924	2.13	62.8	260	373	179	189	75.9	165	56.8	70.2
February	34,074	2.63	77.2	240	294	172	160	49.0	93.0	40.0	50.0
March	31,444	2.60	82.7	347	301	205	117	70.0	51.0	51.0	32.0
April	31,912	2.50	78.3	331	325	187	139	59.0	67.0	38.0	30.0
May	25,905	2.20	84.9	256	269	140	128	46.0	68.0	28.0	22.0
Average (5 Mos.)	31,452	2.412	76.7	286.8	312.4	176.6	146.6	59.98	88.8	42.76	40.84
Pounds B.O.D. Based on Average Flow				5,770		3,550		1,206		860	
Pounds S.S. Based on Average Flow				6,280		2,950		1,787		822	
Pounds B.O.D. per Capita (Average)				0.184		0.113		0.0384		0.0274	
Pounds S.S. per Capita (Average)				0.20		0.094		0.0568		0.0261	
Per Cent Overall B.O.D. Reduction by Units					38.4		47.6		6.0		85.0
Per Cent Overall S.S. Reduction by Units					53.0		18.6		15.3		86.9
Per Cent Reduction of B.O.D. Applied Load					38.4		77.3		28.7		
Per Cent Reduction of S.S. Applied Load					53.0		39.5		54.0		
Operation and Maintenance Cost per m.g. (Average 4 Mos.)					$27.20						

Design Data

Population	35,000 persons
Av. 24-Hour Flow	2.45 m.g.
5-Day B.O.D.	7,000 lb. per day
Suspended Solids	9,450 lb. per day
Applied B.O.D. Load on Trickling Filters	4,200 lb. per day
Residual B.O.D. Load in Plant Effluent	700 lb. per day
Applied B.O.D. Loading on Filters	460 lb. per acre foot

TABLE VII.—*Sewage Treatment Works, Operating Results and Design Data, 6,000 Troop Capacity Air Force Station*

Type—Preaeration, Imhoff tank, high capacity trickling filters, secondary settling, chlorination

Operating Results

Month (1943)	Load in Persons	Flow		Raw Sewage		Primary Eff.		Filter Eff.		Final Eff.	
		m.g.d.	g.p.c.d.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.
January	4,060	0.338	83	353	194	180	100	—	—	27	31
February	3,983	0.333	84	290	219	165	110	—	—	27	36
March	4,046	0.373	92	274	221	142	94	—	—	44	42
April	4,608	0.349	76	388	230	224	120	—	—	57	36
May	4,294	0.368	86	308	228	216	160	—	—	34	27
Average (5 Mos.)	4,198	0.352	84	322.6	218.4	185.4	116.8	—	—	37.8	34.4
Pounds B.O.D. Based on Average Flow				947		545		—		111	
Pounds S.S. Based on Average Flow				642		343		—		101	
Pounds B.O.D. per Capita (Average)				0.225		.013		—		0.0264	
Pounds S.S. per Capita (Average)				0.153		.0082		—		0.0241	
Per Cent Overall B.O.D. Reduction by Units					42.2		—		—		87.3
Per Cent Overall S.S. Reduction by Units					46.4		—		—		84.2

Design Data

Population	6,000 persons
Av. 24-Hour Flow	0.42 m.g.
5-Day B.O.D.	1,200 lb. per day
Suspended Solids	1,620 lb. per day
Applied B.O.D. Load on Filters	720 lb. per day
Residual B.O.D. in Final Effluent	240 lb. per day
Applied B.O.D. Loading on Filters	1,400 lb. per acre foot

by its ability to perform under load. Likewise the operator must understand the design principles involved and adjust his methods to the facilities available so as to produce maximum results. Whenever the designer and the operator see eye to eye on the overall problem, generally excellent results are assured in sewage treatment. (See Tables VI and VII.)

Tables VI and VII provide a measure of comparison between design factors and performance under actual operating conditions at a large ground force station and a small air force station. It is pertinent to note that the sewage plant at the ground force station operates by gravity and receives laundry wastes while that at the air force station includes raw sewage pumping, but does not receive laundry wastes. The effect of the laundry wastes is apparent in the difference in suspended solids per capita. Unfortunately, no analytical data are available for the filter effluent at the air force station, so that a direct comparison of performance between a low capacity and a high capacity filter cannot be made. While the operating data and the design factors used are not in exact agreement in either case, it is believed that these variances will become smaller as the plants reach full load and the effect of seasonal variations is more fully reflected in the operating data.

Disposal Through Municipal Sewers

Only a small part (about 10 per cent) of the sewage from military installations in this Service Command is discharged to municipal sewerage systems. Posts which utilize municipal sewers are small, the largest having a population of about 5,000. In most cases laundry wastes are not included. Hence, if proper attention is given to cleaning of grease traps, the sewage from such installations should have no effect on municipal treatment plants other than to increase the load.

Operating Personnel

In a paper presented before this Conference in 1941 the writer pointed out that there was apt to be a dearth of qualified sewage plant operators. The scarcity of trained and experienced operators has now reached a critical stage. Every effort must be made to train assistant operators if we are to keep our sewage plants, both civilian and military, operating at top performance. The Army is using the understudy method in this training program to the fullest extent possible. It is highly important that municipalities follow the same practice.

Summary

In conclusion I wish to emphasize just two points in connection with sewage treatment for army installations.

1. The designing engineer must provide for a maximum of flexibility in plant operation by providing multiple units and adequate capacities for sudden population changes.

2. The type of treatment process and the mechanical equipment utilized should be as simple as possible in order that the need for highly skilled manpower may be held to a minimum and that construction and operation delays and interruptions caused by inability to obtain mechanical equipment and repair parts may be overcome.

Sewage Research

EFFECT OF BREAK-POINT CHLORINATION ON THE BIOCHEMICAL OXYGEN DEMAND OF SEWAGE*

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Instruction

The first and primary use of chlorine treatment in sewage has been for purposes of disinfection to reduce the bacteria in the sewage effluent. Subsequent important uses of chlorine were in connection with the control of odors arising from sewerage systems and sewage treatment plants. In more recent years its use has been extended in certain instances to the reduction of the B.O.D. of sewage.

Considerable information can be found in the literature concerning laboratory and plant-scale experiments on the effect of chlorination on the B.O.D. of sewage. All of these have been made on comparatively low concentrations of chlorine. The general trend of the results reported seems to indicate that when sufficient chlorine is applied to produce a residual of about 0.2 p.p.m. after 10 minutes' contact time a reduction in B.O.D. of from 25 to 40 per cent can be expected. Some authors (1) state that the B.O.D. reduction of the sewage will be from 2.3 to 5 parts for every part of chlorine added.

The first experimental work reported on B.O.D. reduction was made by H. G. Baity and F. M. Bell (2) with the following results:

Chlorine Dose	Residual Chlorine 10 Min.	B.O.D. of Unchlorinated Sewage	B.O.D. of Chlorinated Sewage	Per Cent Reduction
5–7.5	0	77	71.1	7.4
8–9	Trace	94.3	79.6	15.5
10–15	.2 to .5	85.2	48.9	42.7
all samples		85.8	58.6	31.7

The authors reported that dosages greater than this gave no further increase in B.O.D. reduction. In their conclusions they state that "in fully chlorinated sewage there is a retarding action on biological activity as indicated by the 1-day B.O.D. being low" and that "the B.O.D. reductions are permanent, as 15-day incubations showed relatively the same effect as the 5-day samples."

Mohlman, Hurwitz, and Ruchhoft (3) in data collected at the Chicago Sanitary District reported the following results: When an average of 10.9

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p.p.m. chlorine was added to sewage to produce a residual of 0.2 p.p.m. chlorine, the 2-day B.O.D. was reduced about 25 per cent whereas the 20-day B.O.D. was reduced 17 per cent. The average reduction of the 5-day B.O.D. obtained on a number of samples was 24.7 per cent.

C. E. Keefer and G. K. Armeling (4) report the following results when 3.69 p.p.m. of chlorine was added to settled and oxidized sewage effluent:

Test No.	Temperature Incubated	Residual Cl., P.p.m.	5-day B.O.D.		20-day B.O.D.	
			Chlorinated	Unchlorinated	Chlorinated	Unchlorinated
1	20	1.0	23	40		
2	20	0.7	17	58		
3	20	0.5	25	44		
4	20	0.5	48	54	87	98
5	20	0.4	59	58	102	120

It is the general opinion of these various investigations that the B.O.D. reduction effected by the chlorine is accomplished by two processes:

1. A retardation of biological activity.
2. Direct oxidation of organic material.

The first effect would be lost immediately when the sewage entered a stream since the additional organic material and dilution water would reduce the available chlorine below the effective dose. Thus in order to produce a permanent reduction which would be effective in all situations the second action (of oxidation) would be the significant factor.

A type of chlorine treatment known as "break-point" chlorination has been employed in the water purification field for the removal of tastes and odors and for the reduction of excessive bacterial loads. In this treatment on waters containing organic material there is a point at which a slight addition of chlorine will produce a greatly diminished chlorine residual. Beyond this dosage the residual increase is equal to the dose applied. It has also been observed that it is beyond this point that the odors and tastes are removed.

From the work of Mallman and Ardley (5) it was observed that chlorinated water containing organic matter showed no immediate germicidal effect unless the amount of chlorine added was slightly in excess of that required to produce "break-point." Beyond this point the germicidal effect increased directly with the amount of chlorine added.

They also showed that the oxidation potential was constant and equal to that of water for all concentrations of chlorine up to that required to produce this "break" in the chlorine residual curve. Beyond this concentration the oxidation potential was increased in proportion to the chlorine added.

From the foregoing evidence it may be assumed that the chlorine is present in a hypochlorite or chemically combined state up to the "break-point" and that beyond this point the residual is free chlorine. It would then seem logical to believe that the reduction of B.O.D. in chlorinated sewage would be materially affected by the concentration of chlorine applied inasmuch as the B.O.D. is dependent upon the amount of biochemically oxidizable material present in the sewage.

It was the purpose of this study to determine the applicability of this type of superchlorination to sewage treatment and to determine the effect of chlorine in excess of that previously investigated or considered practical on the B.O.D. of both oxidized and settled sewage.

General Method of Study

The general procedure followed in this study was to add varying amounts of chlorine to samples of sewage in such quantities that the chlorine concentrations in the samples would cover a range great enough to include the "break-point." After a pre-determined contact time the residual chlorine in each sample was measured and the sewage de-chlorinated. Five-day B.O.D. tests, 20-minute oxygen demand tests, and oxygen consumed tests were then made on each sample. In addition, deoxygenation rates were determined for the samples in which the chlorine applied had produced significant changes in the chlorine residual curve.

The sewage used was from an institutional sewage treatment plant that received strictly domestic sewage. The plant consisted of Imhoff tanks and trickling filters. The average daily flow to the plant was about 600,000 gal. per day.

The two types of sewage investigated were (1) settled sewage taken from the effluent end of the Imhoff tank, (2) oxidized sewage taken from the trickling filter effluent channel.

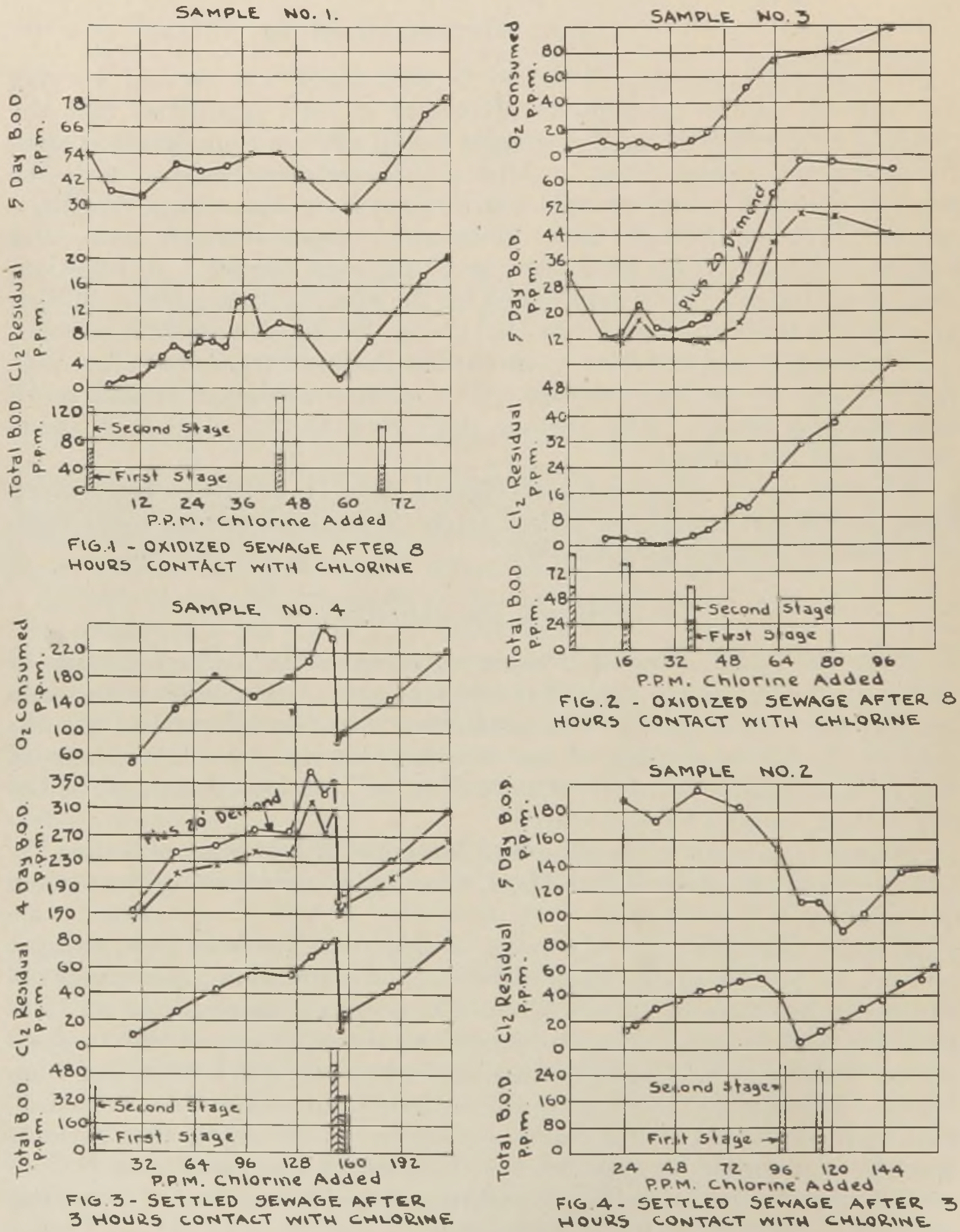
Specific Procedures

Chlorination.—Saturated chlorine water was added to liter samples of sewage to make up the desired concentrations. Corrections were made for the change in volume. The unacidified starch-iodide method (6) was used in the determination of the residual chlorine. A slight excess of sodium thiosulfate was used to neutralize the chlorinated sewage, before the B.O.D. samples were prepared.

Oxygen Consumed.—The Standard Methods (6) procedure of boiling the sewage twenty minutes with $KMnO_4$ was used in determining the oxygen consumed.

B.O.D.—The B.O.D.'s of sewage samples were made by incubating a number of bottles of the same dilution and determining the dissolved oxygen at intervals of time. When the oxygen content of the samples had been depleted to about 2 or 3 p.p.m., all the remaining bottles for each sample were combined and reaerated and again put into bottles and incubated. It has been observed by the authors on previous B.O.D. studies, that more consistant results could be obtained by setting up dilutions low enough to maintain oxygen for the duration of the experiment. Concentrations were made such that reaeration would be required at some time between the seventh and the tenth days.

The Rideal Stewart modification of the Winkler Method (6) was used in determining the dissolved oxygen. The samples were incubated at room temperature in a thermostatically controlled room, the temperature of which remained at 23° C. ±1° for the entire course of the experiment. The 20-minute oxygen demand was obtained by adding definite volumes of sewage to bottles of known oxygen content water. After twenty minutes the dissolved oxygen was determined and the demand calculated from the dilution.



Graph I.—Effect of "break-point" chlorination of the biochemical oxygen demand of settled and oxidized sewage.

Results of Study

The results of this study are shown in the accompanying figures. Figures 1 and 2, and Graph I show the effect of varying concentrations of chlorine on the 5-day B.O.D., the oxygen consumed, the total first-stage B.O.D., the total B.O.D., and the chlorine residual of two samples of trickling filter oxidized sewage.

Figures 3 and 4, and Graph I give the results on two samples of settled sewage.

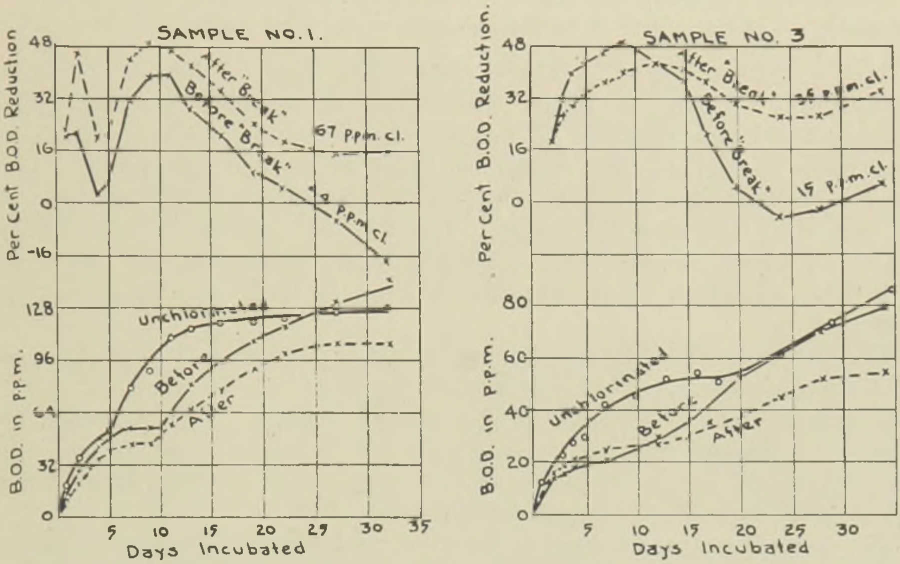


FIG. 5. FILTER EFFLUENT AFTER 8 HOURS CONTACT WITH CHLORINE

FIG. 6. FILTER EFFLUENT AFTER 8 HOURS CONTACT WITH CHLORINE

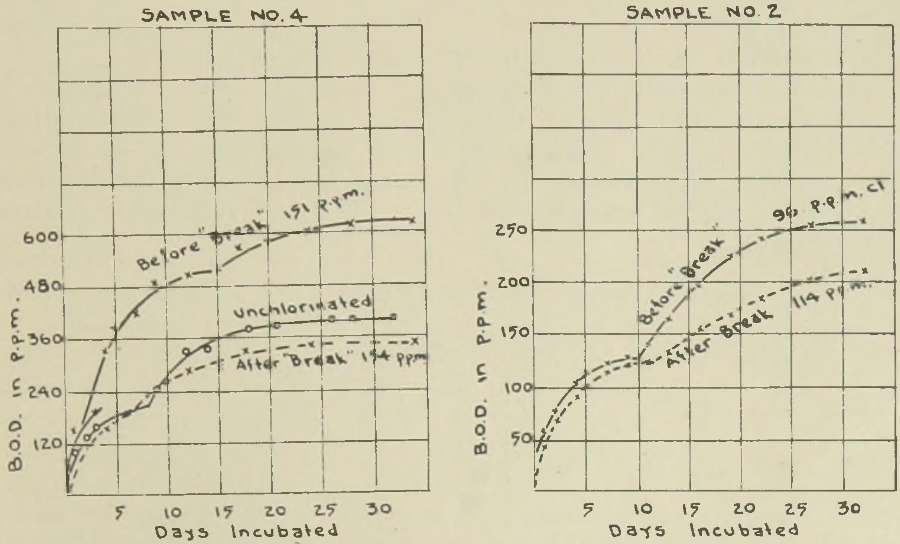


FIG. 7. SETTLED SEWAGE AFTER 3 HOURS CONTACT WITH CHLORINE

FIG. 8 SETTLED SEWAGE AFTER 3 HOURS CONTACT WITH CHLORINE

GRAPH II.—Deoxygenation curves showing effect of chlorine before and after "break-point." Samples dechlorinated after contact time.

Figures 2 and 3 show the B.O.D. with and without the 20-minute immediate oxygen demand included. The 20-minute oxygen demands of samples in Figs. 1 and 4 were not determined separately, but are included in the B.O.D.

Figures 5, 6, 7, and 8, and Graph II show the effect of various dosages of chlorine on the deoxygenation rates of the four samples of sewage, two settled and two oxidized. Several significant points on the chlorine residual curves for each sample of sewage were selected for these determinations.

Discussion

Sewage "Break-Point."—These data show that a definite chlorine "break-point" exists on either unoxidized or oxidized sewage. The amount of chlorine required to produce the break is, however, high in comparison to the dosages commonly used in sewage treatment. The amounts of chlorine required for the two samples of settled sewage used in this case were 106 and 157 p.p.m. The two oxidized sewages required 27 and 58 p.p.m. respectively. The maximum dosage usually reported for B.O.D. reduction by chlorination is from 15 to 20 p.p.m. of applied chlorine.

The differences in chlorine required to cause the break for the oxidized and settled sewage is probably due to the greater concentration of unoxidized organic matter present in the settled sewage. The variation in amounts of chlorine required to cause the break on the same sewage was probably caused by the variation of the sewage that resulted from using grab samples instead of composited samples.

The time of contact necessary for the break to develop was 1.5 hours for the settled sewage. For the oxidized sewage the required time was 7 hours. Slightly higher temperatures, a lower pH due to an increase in the chlorine concentration, as well as a difference in stability of the sewage, probably explain this difference in the time of contact necessary.

The following tabulation of data taken from the tables and graphs of this study shows that there is a correlation between the chlorine dosage required to produce the "break-point" and the total second-stage B.O.D. of each sewage. The average of four samples indicates that 1.0 p.p.m. chlorine for every 0.90 p.p.m. of second-stage B.O.D. is required to produce a "break-point."

Sample Number	Chlorine Added for "Break"	NH_3	B.O.D. of Sewage				Chlorine per P.p.m.	
			5-Day	First Stage	Second Stage	Total	NH_3	Second Stage B.O.D.
1	58		54	63	66	129		.88
2	106	14	150	not run			7.56	
3	27		32	60	30	90		.90
4	154	17	196	239	161	398	9.05	.96
5	187		155	173	217	390		.86
							Average	.90

Little correlation is seen between the chlorine required and the 5-day B.O.D., the first-stage B.O.D. or the NH_3 concentration. Several investigators (7, 8) have reported that the dosage of chlorine required is a function of the NH_3 concentration. This was observed on surface waters and well waters, where the NH_3 concentration may have been greater in proportion to the second-stage B.O.D. than in the sewage. If the chlorine reacts with all the nitrogeneous material, the ammonia may have been the predominating chlorine-demand factor in these waters.

Effect of Superchlorination on Biochemical Oxygen Demands. An analysis of the data with respect to the effect of chlorination on the oxygen demand of sewage, up to and beyond the "break-point," shows some interesting facts which have not been noticeable with the use of lower chlorine dosages as reported in the studies by previous investigators (2, 3 and 4). The most interesting observation is that, in general, with the higher chlorine dosages, the B.O.D. curves on the chlorinated sewages follow very closely in trend the chlorine residual in the sewage. The exception to this is in the low dosages of added chlorine, where a B.O.D. reduction does occur in close conformity with the reduction reported by users of the lower chlorine dosages.

The oxidized sewages showed the same trend in B.O.D. changes as the settled sewage except that no increase over that of the unchlorinated sample was observed at or prior to the break. At the "break-point" the B.O.D. was reduced to about the same as that obtained with one of the low concentrations of chlorine. Further additions of chlorine beyond the "break" increased the 5-day B.O.D. of all the sewage samples in proportion to the residual chlorine.

The immediate oxygen demand of all of the chlorinated sewages closely paralleled the amount of chlorine applied up to the "break-point." At that point the demand decreased to practically zero. With further additions of chlorine, the demand again correspondingly increased. This trend was similar to that obtained in the 5-day B.O.D. curves.

From an analysis of the deoxygenation curves, Figs. 5, 6, 7, and 8, it is evident that the total B.O.D. of the sewage is likewise affected by the concentration of applied chlorine, although unlike the 5-day B.O.D. there is no reduction with low chlorine dosages. At the "break-point," however, a permanent reduction in B.O.D. was observed for all samples, the reduction varying from 13 to 35 per cent. With dosages just short of and beyond the "break-point" the total B.O.D. of the sewage increased.

The B.O.D. reduction of the chlorinated samples did not change significantly from that of the 5-day B.O.D. until the second stage of deoxygenation was reached. Here, due to a change in the time at which the second stage started the percentage reductions varied considerably. From the beginning of the second stage, the B.O.D. reductions of all the samples except those chlorinated to the "break-point" were reduced to nearly zero or showed an increase in B.O.D. after 17 to 28 days of incubation.

Mohlman, Hurwitz, Ruchhoft (4), and Baity, and Bell (7), in their investigations on chlorinated sewage, concluded that the reduction of B.O.D. by chlorinating to a slight residual was permanent. They based their conclusions on the fact that there was little change in the B.O.D. reduction from the fifth to the fifteenth and twentieth day of incubation. These results could, however, be in accord with our findings since for most domestic sewages, incubated at 20 degrees Centigrade, the second-stage deoxygenation does not begin until the fifteenth or twentieth day and would thus give approximately the same percentage reduction as the 5-day B.O.D.

The oxygen consumed curves follow the same general trend as the 5-day B.O.D. and chlorine residual curves, except that no reduction was evident with low concentrations of chlorine. In fact the oxygen consumed was not reduced below that of the unchlorinated sewage for any concentration of chlorine applied, but was increased in proportion to the amount of residual chlorine present. Just before the "break-point" is reached a 400 per cent increase in oxygen consumed values occurred. At the "break-point" this was reduced by a considerable amount, but still remained in excess of the value for the unchlorinated sample.

These oxygen consumed values indicate that the reduction of B.O.D. with low concentrations of chlorine was due to an inhibition of biological activity and that the variation in the B.O.D. beyond this dosage of chlorine was due to a change in the stability of the materials in the sewage.

In general, it would seem from these data that although a more permanent reduction of B.O.D. is obtained by chlorinating to the "break-point," the benefits derived would not warrant the greatly increased quantities of chlorine required. For example, from the data on a fifth sample of sewage shown in Fig. 9, chlorination to 14 p.p.m. gave approximately the same

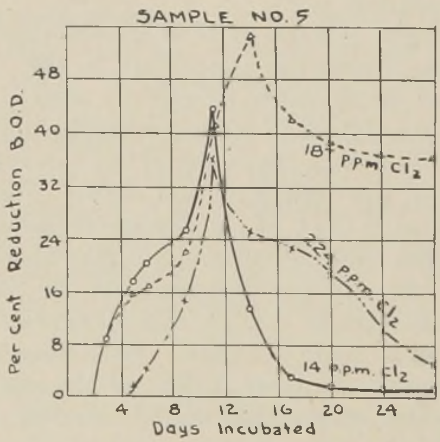


FIG. 9. PER CENT REDUCTION IN B.O.D. WITH VARIOUS CHLORINE DOSAGES.

reduction up to 11 days of incubation as the sample chlorinated to the "break-point." For most domestic sewages, this would probably continue up to 15 or 20 days. At the end of 17 days the effect of the lower dosage was reduced to practically zero, while a permanent reduction of 37 per cent was observed for the "break-point" chlorination. Thus, in order to continue the effect of chlorination beyond 11 to 20 days, 173.5 p.p.m. of chlorine would be required.

The variation in the strength of sewage during the course of a day would make it very difficult to control the application of "break-point" chlorination. An underdose of 5 p.p.m. or less would result in an actual increase in 5-day B.O.D. of about 36 per cent. Also an overdose would materially reduce both the amount and permanency of the B.O.D. reduction. However, in any method of sewage chlorination, it is important to keep the chlorine residual as low as possible if the oxygen requirements of the sewage are to be maintained as low as possible.

Summary

Studies as to the effect of superchlorination on the reduction of the B.O.D. of settled and oxidized sewages were made by chlorinating in various amounts up to and beyond the "break-point." It was found that the quantity of chlorine required to obtain the "break" was dependent upon the nitrogenous material present. The amount of chlorine required was measured by the total second-stage B.O.D. of the sewage.

The results indicate that at the end of the control period, the 5-day B.O.D. of the sewage varied directly with the residual chlorine present, with the exception of the first few parts of chlorine added. In this initial range a sharp reduction of B.O.D. occurred. This reduction is not permanent but disappears shortly after the second stage of deoxygenation begins. Coincidentally with the drop in residual chlorine at the "break-point" there was also a sharp drop in the B.O.D. At this dosage of chlorine the B.O.D. reduction was about equal to that obtained with the lower dosage of chlorine. The reduction appeared permanent in this instance in contrast to a temporary reduction in the initial range of smaller dosages.

Conclusions

The results of this study might allow the following conclusions to be drawn:

1. Sewages can be chlorinated to a "break-point." The quantity of chlorine required is dependent upon the total second-stage B.O.D. of the sewage.
2. Chlorination to the "break-point" did not result in an increased 5-day B.O.D. reduction over that obtained by the low dosages of chlorine commonly used, but the reduction was permanent.
3. The B.O.D. of a chlorinated sewage varied directly with the residual chlorine beyond the first few p.p.m. of chlorine added.
4. The B.O.D. reduction obtained with low dosages of chlorine in amounts sufficient to give a slight residual was not permanent but lasted only shortly after the beginning of the second stage of deoxygenation.

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DIGESTION STUDIES ON PAPER PULP *

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The common practice of discharging wastes from pulp and paper mills into nearby streams has resulted in the serious pollution of many watercourses, and the satisfactory disposal of these wastes has long been a problem for the sanitary engineer. The paper fiber is discharged with the white water and as mill losses at various points in the process of paper manufacture. During recent years, methods have been devised to reduce the loss of paper fiber. This has been accomplished through re-use and recirculation of the fiber-containing white water. Vacuum-decker save-alls have been installed in certain mills which are capable of discharging sulfite white water with a solids content of less than 0.15 lb. per 1,000 gallons (1).† The news mill practice filtrate from the sulfite decker save-all contained less than 0.35 lb. total solids per 1000 gallons (1).

It has been suggested that the treatment of paper or pulp mill wastes with domestic sewage might be an economical method of disposal. If paper pulp could be added to fresh sewage sludge and digested with it, it would be possible to eliminate the discharge of paper pulp fiber into the streams and thus reduce the pollutional load on the stream. Hill (2) did some work in 1937 on the digestion of paper pulp when mixed with varying proportions of sewage sludge so as to give varying carbon to nitrogen ratios. This work extended over a period of 3½ months (time during which paper pulp was added to tanks) and included carbon to nitrogen ratios varying from 20 to 52.6. His conclusions were as follows:

"1. Mixtures of paper pulp and fresh sludge when added to well-seeded sludge in separate sludge digestion tanks digested satisfactorily with a ratio of volatile pulp solids to the volatile solids in the undigested sewage sludge as high as 2.13.

"2. No noticeable deleterious effects upon digestion were noted when the ratio of carbon to nitrogen of the sludge (mixture of paper pulp and fresh raw sludge) ‡ added to the tanks daily ranged from 20 to 52.6.

"3. The volatile solids in paper pulp digested more rapidly or produced more gas than the volatile solids in the undigested domestic sewage sludge.

"4. Mixtures of paper pulp and fresh domestic sewage sludge, in which the ratio of the volatile solids in the pulp to the volatile solids in the fresh sludge ranged from 0.38 to 2.13 digested in well-seeded sludge digestion tanks without affecting the pH of the sludge during digestion.

"5. The addition of paper pulp to fresh domestic sewage sludge increased the carbon dioxide content of the gas produced by digestion."

The present study was carried on by the writer at Cornell University from October, 1939, to August, 1940, as a McMullen Research Scholar in Sanitary Engineering. Paper pulp was fed to the tanks daily (except Sundays) for a period of six months.

* This is the second of a series of papers based on two years' research at Cornell University. The first paper appeared in the July, 1943, issue of *This Journal*, page 658.

† Numbers in parentheses refer to bibliography at end of paper.

‡ Material in parentheses added by the writer.

Equipment and Materials

Thirteen experimental digestion units of a battery of sixteen were used, each unit consisting of two 55-gallon steel drums. These units were illustrated and had been used previously as reported in the first paper of this series (3).

An average temperature of 80° F. was maintained in the laboratory where the digesters were kept, by means of a thermostatically controlled Buffalo steam unit heater. Temperatures were read at the north end, center, and south end of the laboratory; the temperature differences were approximately 1 to 10° F.

The fresh and digested sludges were obtained from the city of Ithaca sewage treatment plant. The fresh sludge was drawn from the primary settling tanks through a valve on the sludge line leading to the digester and the digested sludge used for seeding was taken from the digestion tank. Fresh sludge was delivered to the University laboratory in 40-qt. milk cans three days each week. The paper pulp was received in the form of lap stock made by the sulfite process and was chemically free of all sulfite liquor, bleach water, and other impurities.

Procedure

Before the experimental work was begun, it was necessary to examine all tanks for leakage. This was done by adding some water to the tanks with all fittings and valves closed thereby compressing the air in the tank causing the water in the gage glass to rise. If there were no leaks in the tank, the water level in the gage glass would remain constant; if the level fell, the tank leaked and it was necessary to find and repair the leak or to replace the tank. When the unit was found to be gas and water tight, it was seeded with approximately 240 lb. of digested sludge.

Measured quantities of fresh sludge were added to the tanks until they functioned normally, at which time the fresh sludge feeds were replaced with mixtures of fresh sludge and paper pulp or paper pulp alone. Before loading, the paper pulp was ground in a General Electric kitchen grinder, the excess water was squeezed out by hand, and the required amount of pulp was weighed out for loading. Water was added to the mixture of sewage and pulp or pulp alone to facilitate loading. For a while, supernatant liquor was siphoned from the tanks and was used as a diluting medium but this method was discontinued since it did not agree with practice where, in all probability, water would be the diluting medium.

Supernatant liquor was siphoned from the digester through the gage glass.

Digested sludge was withdrawn through a gate valve provided for this purpose in the bottom of the tank. Since the tank had a flat bottom and the volume of the sludge removed was in the shape of an inverted cone, supernatant liquor was frequently discharged with the sludge when the rate of withdrawal was excessive. As a result, the solids content of the sludge was reduced as larger quantities of sludge were withdrawn. To correct this condition, hopper-bottomed tanks should be installed.

Gas was withdrawn from the tanks by filling them with water after measuring the volume of the gas under atmospheric conditions (0° C. and 760 mm.). Gas samples were collected at various times during the investigation and were tested for methane, carbon dioxide, carbon monoxide, hydrogen, and oxygen. The Hempel and Orsat gas testing outfits were used in making the analyses. Nitrogen was determined by difference.

Upon completion of the study, the tank contents were removed, and water was added to wash out all solid material.

Each day's feed (sludge or paper pulp) was tested to determine the total solids and volatile solids in order to determine the amount of volatile material (wet solids basis) added to tanks. These same tests were made on all supernatant liquors and digested sludges removed from the tanks. All volatile materials consumed or unaccounted for were assumed to have gone into the production of gas.

The tanks were seeded with varying quantities of digested sludge as given in Table I. In computing the quantity of fresh sludge or paper pulp

TABLE I.—*Date and Amount of Seed*

Tank	Date Seeded 1939	Amount Digested Sludge Used for Seed, Lb.
16	Oct. 11	235.08
15	Oct. 11	234.00
14	Oct. 11	257.90
13	Oct. 11	237.73
12	Oct. 11	247.52
11	Oct. 12	242.85
10	Oct. 12	247.97
9	Oct. 12	233.87
8	Oct. 12	232.42
7	Oct. 12	240.28
6	Oct. 13	242.98
5	Oct. 13	240.39
3	Oct. 13	237.83

to be mixed for a particular carbon to nitrogen ratio, the following formulae were used:

$$\frac{S_s{}^{\#} \times S_s\% \times C_s + P_s{}^{\#} \times P_s\% \times C_p}{S_s{}^{\#} \times S_s\% \times N_s + P_s{}^{\#} \times P_s\% \times N_p} = \frac{C_{\text{sludge}} + C_{\text{pulp}}}{N_{\text{sludge}}} = \frac{C}{N}, \quad (1)$$

where $S_s{}^{\#}$ = sludge solids in pounds,
$S_s\%$ = per cent total solids in sludge,
C_s = per cent carbon in sludge,
$P_s{}^{\#}$ = pulp solids in pounds,
$P_s\%$ = per cent total solids in pulp,
C_p = per cent carbon in pulp,
N_s = per cent nitrogen in sludge, and
N_p = per cent nitrogen in pulp (in this case zero).

Assuming 3.5 cu. ft. available for solids and loading at rate of 2.5 lb. solids

Table II.—*Feeding Schedule—October 14, 1939–July 6, 1940*

Quantity Material Added Daily (6-day week) in Pounds

Tank	C/N Ratio		Sludge					Sludge Pulp			Sludge			Sludge	Pulp*	Sludge	Pulp
	Theo.	Actual*	Oct. 14–Oct. 18†	Oct. 19–Oct. 21	Oct. 24–Oct. 28	Oct. 31	Nov. 1–Nov. 18	Nov. 20	Nov. 21	Dec. 6	Dec. 7–Dec. 18	Dec. 19–Dec. 20	Dec. 21–Jan. 7	Jan. 8–July 6 Varied			
16	20	20.9	3.50	3.50	4.20	7.50	7.00	8.50	7.78	—	7.78	7.00	10.50	10.50	—	9.25	—
15	20	20.9	3.50	3.50	4.20	7.50	7.00	8.50	7.78	—	7.78	7.00	10.50	10.50	—	9.25	—
14	30	32.4	3.50	3.50	4.20	7.50	7.00	8.50	6.69	0.47	7.78	7.00	10.50	6.24	0.11	6.09	0.33
13	40	43.9	3.50	3.50	4.20	7.50	7.00	8.50	5.26	0.71	7.78	7.00	10.50	4.68	0.17	4.53	0.49
12	50	54.9	3.50	3.50	4.20	7.50	7.00	8.50	4.21	0.86	7.78	7.00	10.50	3.75	0.20	3.60	0.59
11	60	67.9	3.50	3.50	4.20	7.50	7.00	8.50	3.52	0.96	7.78	7.00	10.50	3.12	0.23	2.95	0.66
10	70	77.9	3.50	3.50	4.20	7.50	7.00	8.50	3.02	1.02	7.78	7.00	10.50	2.68	0.24	2.55	0.70
9	80	89.3	3.50	3.50	4.20	7.50	7.00	8.50	2.64	1.08	7.78	7.00	10.50	2.34	0.26	2.23	0.73
8	90	101.5	3.50	3.50	4.20	7.50	7.00	8.50	2.35	1.12	7.78	7.00	10.50	2.08	0.27	1.98	0.79
7	100	111.2	3.50	3.50	4.20	7.50	7.00	8.50	2.11	2.41	7.78	7.00	10.50	1.88	0.27	1.78	0.81
6	—	—	3.50	3.50	4.20	7.50	7.00	8.50	—	0.33	7.78	7.00	10.50	—	0.07	—	0.22
5	—	—	3.50	3.50	4.20	7.50	7.00	8.50	—	0.66	7.78	7.00	10.50	—	0.14	—	0.44
3	—	—	3.50	3.50	4.20	7.50	7.00	8.50	—	1.33	7.78	7.00	10.50	—	0.27	—	0.89

* Computed for period from January 8 to July 6, 1940. † Alternate days.

TABLE-III

SUMMARY OF MATERIALS ADDED TO OR REMOVED FROM TANK

	16 Total added to or removed in lbs (1)	16 Volatile added to or removed in lbs (2)	15 Total added to or removed in lbs (1)	15 Volatile added to or removed in lbs (2)	14 Total added to or removed in lbs (1)	14 Volatile added to or removed in lbs (2)	13 Total added to or removed in lbs (1)	13 Volatile added to or removed in lbs (2)	12 Total added to or removed in lbs (1)	12 Volatile added to or removed in lbs (2)
Seed Material - lbs	235.08	7.048	234.00	7.348	257.90	8.975	237.73	7.275	247.52	8.614
Daily Loadings - lbs										
Fresh sewage sludge	1850.91	48.395	1850.91	48.395	1375.92	35.965	1135.81	29.724	990.10	26.067
Paper pulp	0.47	0.011			46.81	16.152	69.38	24.220	84.64	28.926
Lime					0.88		0.88		0.88	
Withdrawals										
Supernatants										
Fresh sludge supernatants	628.78	1.047	587.60	1.468	52.37	0.149	51.29	0.063	44.90	0.080
Composite supernatants*					403.01	0.879	425.67	1.098	296.07	0.501
Digested sludges										
Digested sewage sludges	315.76	10.745	167.59	6.179	20.28	0.905	22.42	0.193	22.45	0.916
Composite sludges*					284.16	7.935	173.88	6.465	260.08	7.194
Emptying Tanks										
Digested sewage sludge	359.35	8.532	532.22	11.705	318.82	8.864	329.81	7.879	406.84	5.725
Composite sludges*	—	—	—	—						

	11 Total added to or removed in lbs (1)	11 Volatile added to or removed in lbs (2)	10 Total added to or removed in lbs (1)	10 Volatile added to or removed in lbs (2)	9 Total added to or removed in lbs (1)	9 Volatile added to or removed in lbs (2)	8 Total added to or removed in lbs (1)	8 Volatile added to or removed in lbs (2)
Seed Material - lbs	242.85	6.630	247.97	7.415	233.81	7.881	237.42	8.878
Daily Loadings - lbs								
Fresh sewage sludge	888.13	23.294	824.65	21.686	775.13	20.669	754.33	19.815
Paper pulp	95.54	32.731	100.72	35.409	106.05	36.370	113.78	38.874
Lime	0.92		1.84		1.80		1.80	
Withdrawals								
Supernatants								
Fresh sludge supernatants	39.99	0.051	49.73	0.076	53.32	0.095	58.39	0.102
Composite supernatants*	408.75	1.425	305.55	0.818	343.18	0.951	323.41	0.959
Digested sludges								
Digested sewage sludges	23.59	0.893	23.06	1.000	18.18	0.503	23.08	0.992
Composite sludges*	184.82	6.452	191.35	6.508	160.58	5.910	183.50	6.270
Emptying Tanks								
Digested sewage sludge	394.54	6.950	408.59	7.590	464.92	6.949	478.91	5.714
Composite sludges*								

	7 Total added to or removed in lbs (1)	7 Volatile added to or removed in lbs (2)	6 Total added to or removed in lbs (1)	6 Volatile added to or removed in lbs (2)	5 Total added to or removed in lbs (1)	5 Volatile added to or removed in lbs (2)	3 Total added to or removed in lbs (1)	3 Volatile added to or removed in lbs (2)
Seed Material - lbs	240.28	9.827	242.98	9.185	240.39	9.303	237.83	8.086
Daily Loadings - lbs								
Fresh sewage sludge	711.59	19.268	401.02	11.040	401.02	11.042	401.02	11.367
Paper pulp	130.96	44.327	31.54	10.799	63.05	21.650	126.83	43.098
Lime	1.50		0.88		0.85		2.18	
Withdrawals								
Supernatants								
Fresh sludge supernatants	54.81	0.130	52.36	0.064	48.65	0.129	60.38	0.112
Composite supernatants*	335.54	0.855	176.88	0.407	205.04	0.376	274.47	0.606
Digested sludges								
Digested sewage sludges	23.18	1.033	17.21	0.758	23.09	0.847	21.46	0.796
Composite sludges*	186.17	8.441	66.23	2.541	59.52	2.279	146.24	5.919
Emptying Tanks								
Digested sewage sludge	477.46	6.661	530.99	5.601	626.36	7.271	397.59	7.254
Composite sludges*								

* Mixed sample of Sewage Sludge & Paper Pulp

	16	15	14	13	12	11	10	9	8	7	6	5	3
Unaccounted solids - lbs	35.130	36.391	42.360	44.921	49.191	46.884	48.518	50.512	53.530	56.302	21.653	31.091	47.804
Gas produced in cu ft.	560.93	532.57	546.02	540.89	509.45	5 6.86	560.91	540.77	535.16	535.30	265.22	288.21	448.06
Cu ft. Gas per lb volatile material unaccounted for	15.97	14.63	12.89	12.04	10.36	11.02	11.56	10.71	10.00	9.51	22.5	9.27	9.37
Carbon to Nitrogen ratio	20.9	20.9	32.4	43.9	54.9	67.9	77.9	89.3	101.5	111.2			
Number additions to tanks													
Sewage sludge	212	212	212	212	212	212	212	212	212	212	54	54	55
Paper pulp	1		157	157	157	157	157	157	157	156	158	158	157

(1) - Wet weight.
(2) - Dry weight

per cu. ft. of tank space per month, then

$$S_s^{\#} + P_s^{\#} = 3.5 \times 2.5 = 8.75, \qquad (2)$$

where S_s and P_s have the same significance as above.

The feeding schedule for fresh sludge and paper pulp is given in Table II. From this table it will be noted that the paper pulp loadings were discontinued after December 6. Loading was discontinued because the pH in all tanks began to drop, decreasing to as low as 6.7 in some of the tanks. All tanks received sewage sludge after this period in order to get the pH back to 7.0. It was necessary to add lime to some of the tanks to bring up the pH. Sludge and pulp loadings varied between the two sets of values given in the last four columns of Table II, depending upon whether dry or wet pulp was added.

The tanks were loaded so as to give the approximate carbon to nitrogen ratios shown in Table II. Actual carbon to nitrogen ratios are given in this table, and were computed on the basis of an approximate loading of 2.5 lb. total solids per cu. ft. of tank space per month. Tanks 3, 5, and 6 were loaded at the rate of 2.0, 1.0, and 0.5 lb. total solids per cu. ft. tank space per month, respectively.

Table III gives the pounds of material (wet weight) added to or removed from the tanks and the volatile material (wet solids basis) added to or removed from the tanks during the feeding period, which extended from October 14, 1939, to July 6, 1940.

All tanks were operated from July 6 to August 21, 24, 1940, during which time the gas was measured and withdrawn as during the feeding period although no material was added.

Results of Tests

Carbon to Nitrogen Ratios.—Hill (2) had some tests made to determine the carbon and nitrogen content of the fresh raw sludge and paper pulp. These values are given in Table IV along with values determined by the writer.

Table IV.—*Per Cent Carbon and Nitrogen in Sludge and Pulp*

	Hill		Straub*	
	Carbon	Nitrogen	Carbon	Nitrogen
Fresh Raw Sewage Sludge	43.637	2.167	41.09	1.967
Paper Pulp	43.96	0	38.86	0

* Number of samples tested—Carbon-Sludge 20
Carbon-Pulp 8
Nitrogen-Sludge 3

From the data contained in Table IV, it was possible to compute the carbon to nitrogen ratios of the various sludge and paper pulp mixtures. These values are given in Tables II and III.

Solids Characteristics.—A summary of the fresh sludge and paper pulp characteristics is given in Table V and indicates considerable variation in the per cent total solids (wet solids basis) and in the per cent volatile matter (dry solids basis) of fresh sludge added to the digesters. It was

TABLE V.—*Characteristics of Materials Added to Tanks*

Tank	Matl.*	No. Samp.†	Total Solids (Per Cent Wet Basis)	Volatile Solids (Per Cent Dry Basis)	Volatile Solids (Per Cent Wet Basis)	pH			Lb. Solids/ C.F. Tank Space/Mo.	C/N Ratio
						Av.	Max.	Min.		
16	Raw	212	3.42	76.84	2.647	5.78	7.2	5.2‡		
16	Pulp	1	24.44	99.45	24.31					
15	Raw	212	3.42	76.84	2.647	5.78	7.2	5.2		
14	1-S	29	3.74	82.25	3.071	5.82	6.1	5.2		20.9
14	2-S	13	3.27	80.81	2.634	5.87	5.9	5.7		
14	2-P	13	30.18	99.66	30.080				2.61	34.5
14	3-S	25	3.18	78.69	2.499	6.01	7.2	5.5		20.9
14	4-S	144	3.40	75.16	2.582	5.73	6.2	5.2		
14	4-P	144	43.15	99.60	42.980				2.61	32.4
13	1-S	29	3.74	82.25	3.071	5.82	6.1	5.2		20.9
13	2-S	13	3.27	80.81	2.634	5.87	5.9	5.7		
13	2-P	13	30.18	99.66	30.080					46.8
13	3-S	25	3.18	78.69	2.499	6.01	7.2	5.5		
13	4-S	144	3.40	75.03	2.578	5.73	6.2	5.2		
13	4-P	144	43.15	99.60	42.980				2.28	43.9
12	1-S	29	3.74	82.25	3.071	5.82	6.1	5.2		20.9
12	2-S	13	3.27	80.81	2.634	5.87	5.9	5.7		
12	2-P	13	30.18	99.66	30.080					60.2
12	3-S	25	3.18	78.69	2.499	6.01	7.2	5.5		
12	4-S	144	3.40	75.03	2.578	5.73	6.2	5.2		
12	4-P	144	43.15	99.60	42.980				2.26	54.9
11	1-S	29	3.74	82.25	3.071	5.82	6.1	5.2		20.9
11	2-S	13	3.27	80.81	2.634	5.87	5.9	5.7		
11	2-P	13	30.18	99.66	30.080					72.9
11	3-S	26	3.18	78.69	2.499	6.01	7.2	5.5		
11	4-S	144	3.40	75.03	2.578	5.73	6.2	5.2		
11	4-P	144	43.15	99.60	42.980				2.28	67.9
10	1-S	29	3.74	82.25	3.071	5.82	6.1	5.2		20.9
10	2-S	13	3.27	80.81	2.634	5.87	5.9	5.7		
10	2-P	13	30.18	99.66	30.080					86.0
10	3-S	25	3.23	78.84	2.542	6.01	7.2	5.5		
10	4-S	144	3.40	75.03	2.578	5.73	6.2	5.2		
10	4-P	144	43.15	99.60	42.980				2.25	77.9
9	1-S	29	3.74	82.25	3.071	5.82	6.1	5.2		20.9
9	2-S	13	3.27	80.81	2.634	5.87	5.9	5.7		
9	2-P	13	30.18	99.66	30.080					99.7
9	3-S	25	3.29	79.14	2.600	6.01	6.2	5.5		
9	4-S	144	3.40	75.03	2.578	5.73	6.2	5.2		
9	4-P	144	43.15	99.60	42.980				2.25	89.3

TABLE V.—*Characteristics of Materials Added to Tanks*—Continued

Tank	Matl.*	No. Samp.†	Total Solids (Per Cent Wet Basis)	Volatile Solids (Per Cent Dry Basis)	Volatile Solids (Per Cent Wet Basis)	pH			Lb. Solids/ C.F. Tank Space/Mo.	C/N Ratio
						Av.	Max.	Min.		
8	1-S	29	3.73	81.94	3.058	5.83	6.1	5.2		
8	2-S	13	3.27	80.81	2.634	5.87	5.9	5.7		
8	2-P	13	30.18	99.66	30.080					112.8
8	3-S	25	3.45	78.84	2.711	6.10	9.0+	5.5		
8	4-S	144	3.40	75.03	2.578	5.73	6.2	5.2		
8	4-P	144	43.15	99.60	42.980				2.31	101.5
7	1-S	29	3.73	81.94	3.058	5.83	6.1	5.2		20.9
7	2-S	13	3.27	80.81	2.634	5.87	5.9	5.7		
7	2-P	13	30.18	99.66	30.080					249.6
7	3-S	25	3.45	78.84	2.711	6.10	9.0+	5.5		
7	4-S	144	3.40	75.03	2.578	5.73	6.2	5.2		
7	4-P	143	43.41	99.60	42.594				2.29	111.2
6	1-S	29	3.60	81.90	2.955	5.84	6.10	5.2#		
6	2-P	13	30.18	99.66	30.135					
6	3-S	25	3.45	78.84	2.710	6.10	9.05	5.5		
6	4-P	145	43.06	99.59	42.883					
5	1-S	29	3.60	81.90	2.955	5.84	6.10	5.2#		
5	2-P	13	30.18	99.66	30.135					
5	3-S	25	3.45	78.84	2.710	6.10	9.05	5.5		
5	4-P	145	43.06	99.59	42.883					
3	1-S	29	3.60	81.90	2.955	5.84	6.10	5.2		
3	2-P	13	30.18	99.66	30.135					
3	3-S	25	3.45	78.84	2.710	6.10	9.05	5.5		
3	4-S	1	3.91	79.75	3.118	5.9				
3	4-P	144	43.34	99.59	42.513					

* S—sewage, P—pulp, 1—October 14–November 20, 2—November 21–December 6, 3—December 7–January 7, 4—January 8–end.

† No. of samples tested. ‡ 208 tests for pH. # 28 tests for pH.

necessary to add lime to maintain optimum pH conditions. The amount of lime used is shown in Table III. There was less variation in the paper pulp than in the fresh raw sludge.

Table VI presents a summary of the supernatant liquor characteristics of all the tanks receiving mixtures of sewage sludge and paper pulp and those receiving either sewage sludge or paper pulp. There was some difference in the per cent total solids in the various tanks. The per cent volatile solids (dry solids basis) was higher in all tanks receiving paper pulp alone, or in addition to the raw sludge, than in the control tanks. This was expected, as more volatile material was added to these tanks and possibly more fine paper pulp fibers were in suspension.

There was little variation in the pH of the supernatant liquor removed due to the fact that lime was added to all tanks receiving paper pulp, in order to maintain satisfactory pH conditions. In all cases, however, the pH in the tanks to which pulp was added was lower than that in the control tanks. (See Table III for the amount of lime added to each tank.)

TABLE VI.—*Supernatant Characteristics*

Tank	No. Tests	Total Solids (Per Cent Wet Basis)			Volatile Solids (Per Cent Dry Basis)			Volatile Solids (Per Cent Wet Basis)			pH		
		Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
16	26	0.48	2.22	0.10	47.15	64.40	8.00	0.199	0.997	0.041	7.04	7.5	6.9
15	25	0.56	2.54	0.06	47.10	63.94	3.94	0.307	1.540	0.007	7.04	7.4+	6.9*
14	3	0.59	0.87	0.27	53.08	57.41	49.29	0.279	0.371	0.130	7.1	7.3	7.0
14†	19	0.45	1.35	0.21	50.32	65.59	31.98	0.237	0.804	0.093	7.05	7.9	6.8♯
13	3	0.26	0.29	0.25	46.77	52.48	42.61	0.123	0.131	0.107	7.07	7.2	6.9+
13†	21	0.52	2.07	0.20	55.40	74.97	35.66	0.299	1.240	0.119	6.88	7.0+	6.8
12	3	0.35	0.44	0.28	50.59	55.08	44.12	0.179	0.242	0.124	7.05	7.2	6.9
12†	17	0.32	0.59	0.22	49.34	63.49	37.39	0.160	0.375	0.090	6.83	6.9+	6.7
11	3	0.28	0.30	0.26	48.93	53.05	42.96	0.129	0.140	0.116	7.05	7.2+	6.9+
11†	19	0.56	2.14	0.11	56.71	91.34	45.34	0.320	1.289	0.100	6.86	7.1+	6.6
10	3	0.32	0.38	0.24	47.67	53.03	39.16	0.155	0.202	0.094	7.0	7.2	6.9
10†	16	0.48	2.17	0.26	55.88	93.14	45.14	0.314	2.021	0.117	6.78	6.9	6.6
9	3	0.32	0.41	0.24	48.23	56.08	39.02	0.176	0.203	0.146	7.02	7.2	6.9−
9†	16	0.53	1.54	0.19	58.53	94.96	46.02	0.318	0.983	0.113	6.84	7.1	6.6
8	3	0.35	0.38	0.31	49.66	57.29	44.37	0.171	0.210	0.138	7.03	7.2	6.9−
8†	16	0.54	1.68	0.23	55.14	63.99	44.81	0.306	1.031	0.116	6.78	6.9	6.5
7	3	0.40	0.61	0.28	54.83	60.82	50.23	0.226	0.371	0.150	7.02	7.2	6.9
7†	14	0.46	1.13	0.26	56.89	63.59	52.78	0.264	0.690	0.143	6.81	7.0	6.6
6	3	0.27	0.30	0.24	46.80	50.57	43.60	0.125	0.139	0.105	7.08	7.2	6.95
6†	11	0.42	1.29	0.24	51.24	65.98	31.14	0.229	0.711	0.122	7.00	7.4	6.7††
5	3	0.45	0.69	0.30	55.42	57.56	51.81	0.254	0.397	0.160	7.03	7.2	6.95
5†	12	0.34	0.59	0.16	55.81	87.16	34.28	0.192	0.335	0.055	6.91	7.1	6.65**
3	3	0.34	0.57	0.24	47.85	56.28	45.05	0.177	0.293	0.108	7.03	7.2+	6.9
3†	12	0.41	0.85	0.26	55.24	64.64	42.59	0.226	0.369	0.111	6.89	7.5	6.6

† After addition of paper pulp.
♯ 17 tests for pH.
†† 9 tests for pH.
* 23 tests for pH.
** 11 tests for pH.

Table VII gives the digested sludge characteristics of all tanks. The values shown for total solids are variable and dependent upon the quantity of sludge withdrawn from the tank and the manner in which it was withdrawn. There was little difference in the per cent volatile solids (dry solids basis) of the digested sludge removed from either the tanks containing paper pulp or sewage sludge alone or pulp-sludge mixtures. There was little variation in the pH since lime was added to all tanks receiving paper pulp.

Table VIII gives the characteristics of the final sludges drawn from the tank. It was quite impossible to compare these sludges as the values

TABLE VII.—*Digested Sludge Characteristics*

Tank	No. of Tests Made	Total Solids (Per Cent Wet Basis)			Volatile Solids (Per Cent Dry Basis)			Volatile Solids (Per Cent Wet Basis)			pH		
		Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
16	12	6.06	9.69	3.66	58.91	74.92	53.96	3.627	7.26	2.071	7.00	7.3−	6.9
15	8	6.69	7.89	5.49	56.46	57.59	54.27	3.779	4.493	3.103	7.09	7.3−	7.0−
14	2	9.28	11.94	6.63	61.48	66.24	56.73	5.836	7.91	3.761	7.2	7.2	7.2
14*	9	5.71	7.38	1.55	58.21	61.77	54.88	3.307	4.477	0.957	7.03	7.2	6.9
13	2	6.94	8.09	5.79	57.36	57.56	57.15	3.976	4.62	3.333	7.2	7.2	7.2
13*	8	6.47	8.17	5.15	57.18	60.48	53.63	3.720	4.941	2.762	6.98	7.0	6.95
12	2	8.00	9.44	6.56	58.78	59.94	57.62	4.719	5.658	3.780	7.2	7.2	7.2
12*	10	4.87	7.73	1.19	59.22	61.29	57.43	2.890	4.474	0.694	6.98	7.1	6.85
11	2	7.59	9.14	6.04	57.66	57.75	57.58	4.376	5.263	3.488	7.2	7.25	7.2
11*	8	6.05	7.50	4.83	57.81	59.73	56.67	3.509	4.338	2.748	6.95		
10	2	8.29	9.31	7.27	56.76	57.85	55.67	4.693	5.180	4.206	7.2	7.2	7.2
10*	9	5.95	7.24	4.31	56.51	61.00	42.01	3.403	4.416	1.811	6.87	6.9	6.8
9	2	6.12	8.06	4.17	56.84	56.96	56.71	3.472	4.570	2.373	7.2	7.2	7.2
9*	7	6.23	7.43	4.35	59.20	64.22	57.55	3.676	4.393	2.670	6.92	6.95	6.9
8	2	8.56	9.71	7.40	55.64	55.96	55.32	4.762	5.430	4.094	7.2	7.3	7.1
8*	9	6.00	7.63	3.14	58.19	60.27	56.84	3.500	4.599	1.817	6.93	6.95	6.9
7	2	8.08	8.70	7.47	58.62	59.41	57.84	4.746	5.170	4.321	7.2	7.2	7.2
7*	8	7.71	8.64	7.04	58.16	62.26	56.74	4.511	5.093	3.994	6.90	6.95	6.8
6	2	8.76	10.48	7.04	54.87	59.67	50.07	4.726	5.250	4.201	7.15	7.2	7.1
6*	3	7.12	7.73	6.53	54.00	56.05	50.21	3.831	3.952	3.660	7.03	7.15	6.95
5	2	9.00	12.09	5.90	49.63	58.14	41.12	4.200	4.970	3.430	7.15	7.2	7.1
5*	3	7.32	8.52	5.91	57.56	58.83	56.24	4.217	5.012	3.405	7.05	7.2	6.95
3	2	6.58	6.60	6.56	52.10	57.19	47.02	3.626	3.752	3.500	7.15	7.2	7.1
3*	5	7.19	9.86	5.46	55.81	61.67	45.20	4.011	5.419	2.798	6.90	7.1	6.7#

* After addition of paper pulp. # 4 tests for pH.

obtained depended upon the amount of water required to wash out the solids in the tanks. There was little variation, however, in the per cent volatile solids (dry solids basis). As expected, the pH was substantially constant because of the lime additions.

Table IX includes data taken from Table III which permits the computation of the reduction in the weight of volatile material in each tank. From this table it is seen that the maximum reduction of volatile material, amounting to 90.5 per cent, occurred in Tank 8. The reduction in all other tanks receiving mixtures of paper pulp and sewage was above 85 per cent, with the exception of Tank 14. Those tanks receiving paper pulp alone had reductions proportional to the amount of feed, that is,

TABLE VIII.—*Characteristics of Material Removed from Tanks at End of Test*

Tank	No. of Tests	Total Solids (Per Cent Wet Basis)			Volatile Solids (Per Cent Dry Basis)			Volatile Solids (Per Cent Wet Basis)			pH		
		Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
16	5	4.86	8.93	0.35	47.85	53.87	42.32	2.368	4.514	0.167	7.08	7.2	6.9
15	7	4.40	9.58	0.35	48.52	53.93	43.73	2.252	5.127	0.169	7.07	7.1	6.95
14	4	5.48	9.62	2.15	50.99	55.81	46.90	2.760	4.515	1.168	7.18	7.2+	7.1
13	4	4.54	9.73	2.15	52.80	58.99	45.30	2.352	4.965	1.201	7.11	7.2−	7.1
12	5	2.56	7.05	0.53	54.26	56.82	50.99	1.393	3.895	0.279	7.14	7.2	7.0
11	5	2.78	8.46	0.29	55.21	58.99	50.83	1.548	4.694	0.147	7.06	7.1	7.0+
10	5	3.26	7.82	0.42	53.99	57.58	49.29	1.781	4.126	0.207	7.23	7.3	7.2−
9	6	2.65	6.83	0.36	53.17	57.37	48.25	1.395	3.820	0.190	7.16	7.2+	7.1
8	6	2.21	7.83	0.32	53.37	56.06	48.95	1.199	4.269	0.157	7.24	7.3	7.2
7	6	2.57	7.80	0.30	50.96	59.66	38.49	1.348	4.245	0.115	7.23	7.3	7.1
6	7	1.89	7.76	0.22	54.21	56.32	51.75	1.027	4.230	0.118	7.16	7.3	7.1
5	9	1.92	7.94	0.24	50.09	67.33	49.38	1.048	4.383	0.156	7.11	7.4	6.9
3	5	2.92	6.80	1.09	63.93	77.52	56.47	1.784	3.855	0.616	6.95	7.0	6.9

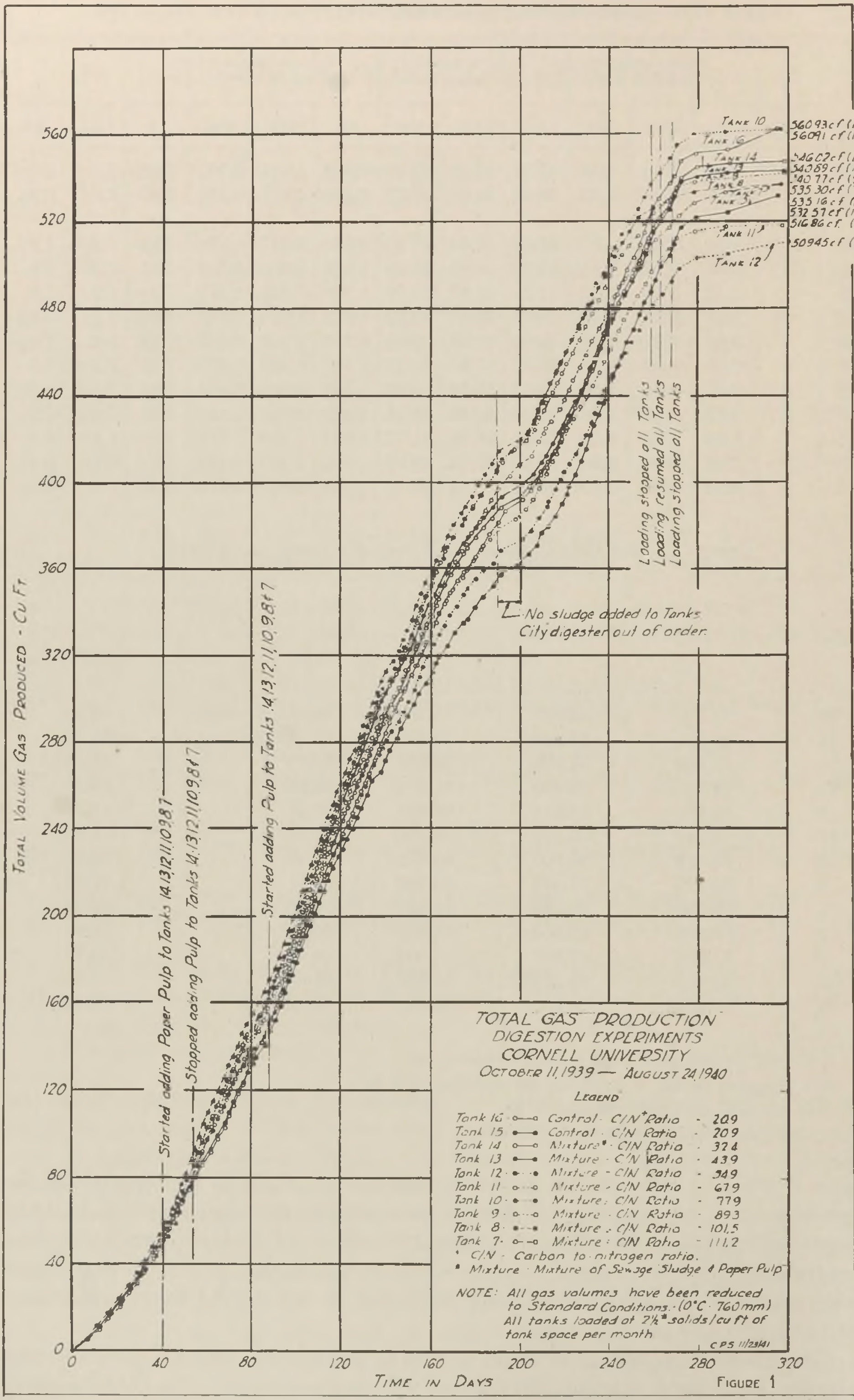
TABLE IX.—*Per Cent Reduction in Weight of Volatile Sludge Solids*

Tank	$a - b - c$*	$a - b$*	a	Per Cent Reduction	
				$\frac{a-b-c}{a-b} \times 100$	$\frac{a-b-c}{a} \times 100$
16	35.130	43.662	55.454	80.46—Control	63.30
15	36.391	48.096	55.743	75.66—Control	65.28
14	42.360	51.224	61.092	82.70	69.18
13	44.921	52.800	61.219	85.08	73.38
12	49.191	54.916	63.607	89.58	77.34
11	46.884	53.834	62.655	87.09	75.00
10	48.518	56.108	64.510	86.47	75.21
9	50.512	57.461	64.920	87.91	77.80
8	53.530	59.244	67.567	90.36	79.23
7	56.302	62.963	73.422	89.42	76.68
6	21.653	27.254	31.024	79.45	69.79
5	31.091	38.362	41.993	81.05	74.21
3	47.804	55.058	62.551	86.82	76.42

a = seed + sewage sludge + pulp added in lb.
b = digested sludge + supernatant withdrawn in lb.
c = amount withdrawn at end in lb.
All weights are those of volatile dry solids.

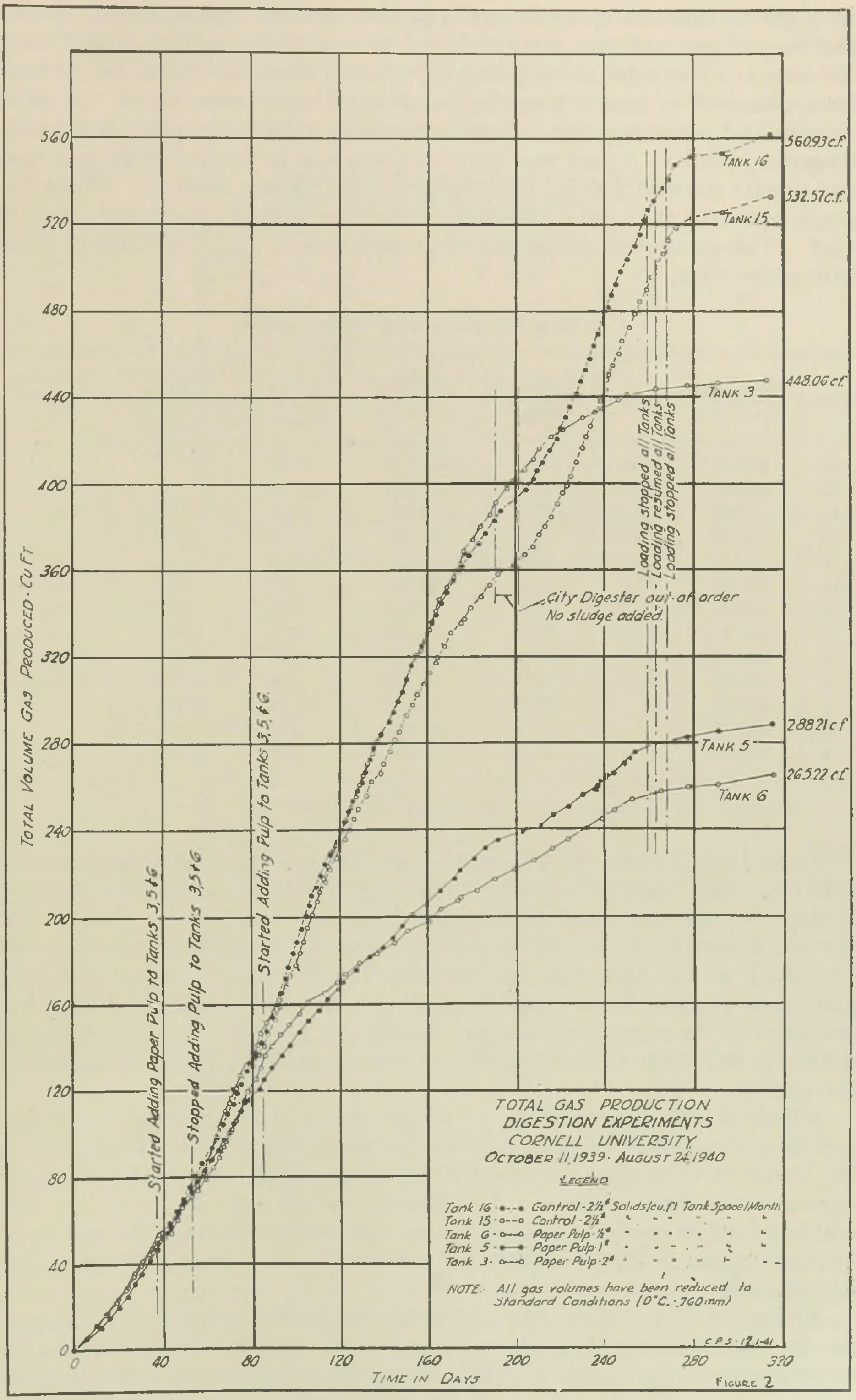
Tank 3 which received the greatest amount of volatile material had the highest reduction and Tank 6, which received the smallest amount, had the lowest reduction. In all cases, the reduction of volatile material was greater than in the control tanks. This would indicate that there was a more rapid breakdown of volatile material in the tanks receiving paper pulp than in the control tanks.

Gas Characteristics.—In Figs. 1 and 2 are shown the cumulative gas volumes produced during the period of investigation. In these figures



TOTAL GAS PRODUCTION
DIGESTION EXPERIMENTS
CORNELL UNIVERSITY
OCTOBER 11, 1939 — AUGUST 24, 1940
LEGEND
Tank 16 Control - C/N* Ratio - 20.9
Tank 15 Control - C/N Ratio - 20.9
Tank 14 Mixture* - C/N Ratio - 32.4
Tank 13 Mixture - C/N Ratio - 43.9
Tank 12 Mixture - C/N Ratio - 54.9
Tank 11 Mixture - C/N Ratio - 67.9
Tank 10 Mixture - C/N Ratio - 77.9
Tank 9 Mixture - C/N Ratio - 89.3
Tank 8 Mixture - C/N Ratio - 101.5
Tank 7 Mixture - C/N Ratio - 111.2
* C/N - Carbon to nitrogen ratio.
* Mixture - Mixture of Sewage Sludge & Paper Pulp
NOTE: All gas volumes have been reduced to Standard Conditions - (0°C - 760 mm)
All tanks loaded at 2½# solids/cu ft of tank space per month
CPS 11/23/41
Total Volume Gas Produced - Cu Ft
Time in Days
Started adding Paper Pulp to Tanks 14,13,12,11,10,9,8,7
Stopped adding Pulp to Tanks 14,13,12,11,10,9,8 & 7
Started adding Pulp to Tanks 14,13,12,11,10,9,8 & 7
No sludge added to Tanks. City digester out of order.
Loading stopped all Tanks
Loading resumed all Tanks
Loading stopped all Tanks
Tank 10
Tank 16
Tank 14
Tank 13
Tank 8
Tank 11
Tank 12
56093 c f (16)
56091 c f (10)
54602 c f (14)
54089 c f (13)
54077 c f (9)
53530 c f (7)
53516 c f (8)
53257 c f (15)
51686 c f (11)
50945 c f (12)

FIGURE 1


TOTAL GAS PRODUCTION
DIGESTION EXPERIMENTS
CORNELL UNIVERSITY
OCTOBER 11, 1939 - AUGUST 24, 1940
LEGEND
Tank 16 Control - 2½# Solids/cu. ft. Tank Space/Month
Tank 15 Control - 2½#
Tank 6 Paper Pulp - ½#
Tank 5 Paper Pulp - 1#
Tank 3 Paper Pulp - 2#
NOTE: All gas volumes have been reduced to Standard Conditions (0°C. - 760 mm)
TOTAL VOLUME GAS PRODUCED - CU. FT.
TIME IN DAYS
560.93 c.f.
TANK 16
532.57 c.f.
TANK 15
448.06 c.f.
TANK 3
288.21 c.f.
TANK 5
265.22 c.f.
TANK 6
Started Adding Paper Pulp to Tanks 3, 5 & 6
Stopped Adding Pulp to Tanks 3, 5 & 6
Started Adding Pulp to Tanks 3, 5 & 6
City Digester out of order
No sludge added
Loading stopped all Tanks
Loading resumed all Tanks
Loading stopped all Tanks
CPS - 12 1-41
0
40
80
120
160
200
240
280
320
360
400
440
480
520
560
Figure 2

total gas production in cubic feet is plotted against time in days. Before plotting all gas volumes were reduced to standard conditions (0° C. and 760 mm.). The total gas volumes were lower than those that would have been obtained in practice as the gas was collected over water. Carbon dioxide and other gases to a lesser extent are soluble in water and losses, therefore, result. A test was made of the water in the gas collection tank and results showed that it was saturated with carbon dioxide. There was much corrosion in the gas collecting tanks due to the formation of carbonic acid. The amount of gas produced in each tank is given in Table X along with other data.

TABLE X.—*Summary of Tank Results*

Tank	Amt. of Gas Produced in Cu. Ft.	C/N	Per Cent Gas Using Tank 16 as Base	Volatile Solids Consumed in Lb.	Cu. Ft. Gas Per Lb. Volatile Solids Consumed	Ratio Pulp to Sewage Overall, Oct. 14–July 6	Ratio Pulp to Sewage (Jan. 8–July 6)
16	560.93	20.9	100	35.130	15.97		
15	532.57	20.9	94.9	36.391	14.63		
14	546.02	32.4	97.3	42.360	12.89	0.45 : 1	0.63 : 1
13	540.89	43.9	96.4	44.921	12.04	0.81 : 1	1.25 : 1
12	509.45	54.9	90.8	49.191	10.36	1.11 : 1	1.86 : 1
11	516.86	67.9	92.1	46.884	11.02	1.40 : 1	2.54 : 1
10	560.91	77.9	100.0	48.518	11.56	1.63 : 1	3.20 : 1
9	540.77	89.3	96.4	50.512	10.71	1.76 : 1	3.81 : 1
8	535.16	101.5	95.4	53.530	10.00	1.96 : 1	4.40 : 1
7	535.30	111.2	95.4	56.302	9.51	2.30 : 1	4.72 : 1
6	265.22		47.3*	21.653	12.35	0.98 : 1	
5	288.21		51.4*	31.091	9.27	1.96 : 1	
3	448.06		79.9*	47.804	9.37	3.79 : 1	

* These have no significance since amount of loading is different.

From Figs. 1 and 2 one can see that gas production in all tanks was very uniform, there being only about 9 per cent difference in the total gas production for all tanks excepting those receiving paper pulp alone. The obvious flattening in the curves between the 190th and 201st days may be explained by the fact that the digester at the Ithaca sewage treatment plant was clogged from April 18 to April 30, 1940, and no sludge was delivered to the experimental plant during this period. It took about two weeks for the tanks to come back to normal operation, as can be seen from the curves.

Figure 3 shows plots of cu. ft. of gas per lb. volatile solids consumed and the ratio of pulp to sludge and carbon to nitrogen ratio. In examining the lower curve of Fig. 3, there will be seen a tendency for the curves to separate into two sections. No definite reason can be given for this without further study. It may be that the results obtained for carbon to nitrogen ratios, between 55 and 70, and the cu. ft. of gas produced per lb. volatile solids consumed are erratic.

Figures 4 and 5 show plots of total gas produced as plotted against the lb. volatile material added, minus volatile material withdrawn or, in other words, the net amount of volatile material supposedly converted into gas or remaining in the tank. From these figures one can see that the lines have a fairly uniform slope if the jagged portions are disregarded. These jagged portions are due to the manner in which the curves are plotted. It will be noted that there are many points where there is a decrease in volatile material with an increase in gas production. This was

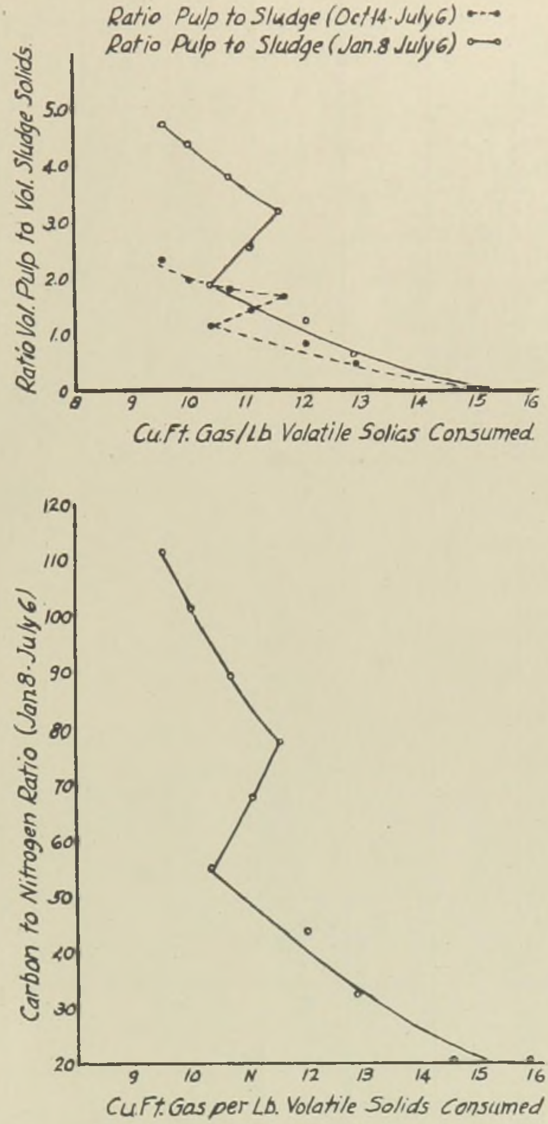
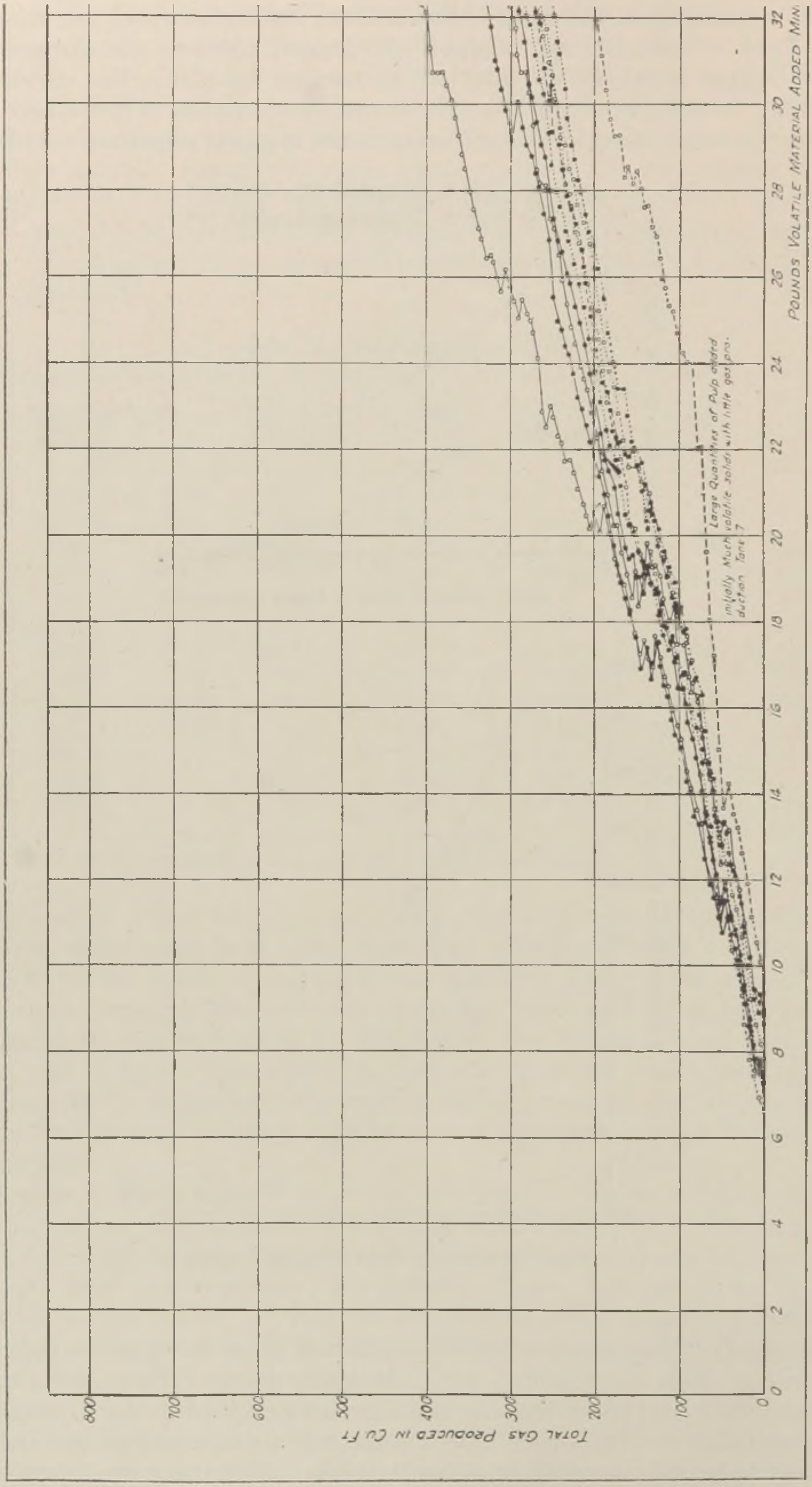


Fig. 3.

due to the fact that more solids were removed from the tank on that particular day than were added with the daily feed. The volatile solids removed were contained in either the digested sludge or in the supernatant liquor withdrawn. In other places there was an increase in gas volume with no apparent increase in volatile solids. This may be due to two


Total Gas Produced in Cu Ft
Pounds Volatile Material Added Min.
Large Quantities of Pulp added initially. Much volatile solids with little gas production Tank 7
0
100
200
300
400
500
600
700
800
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32

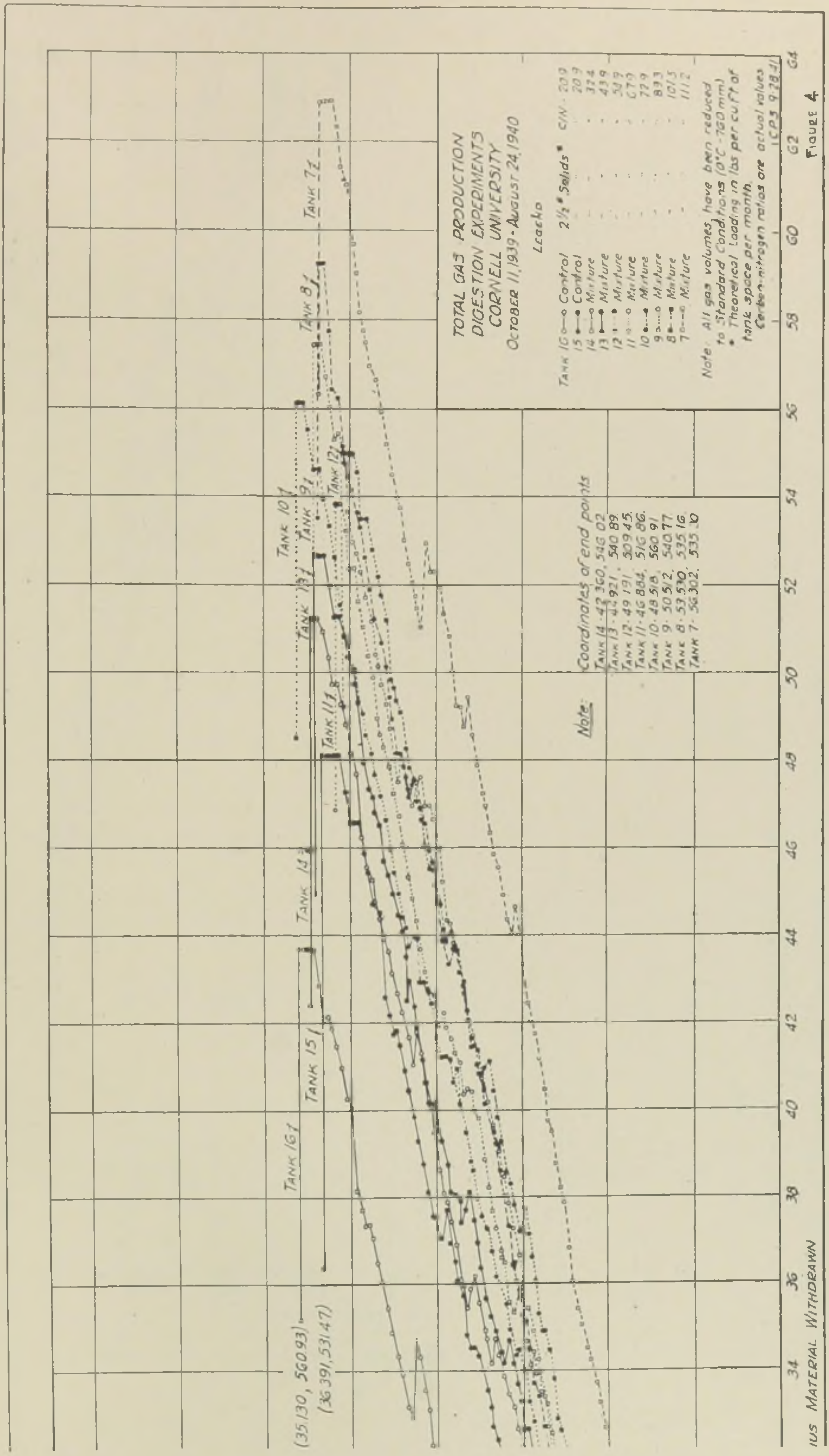
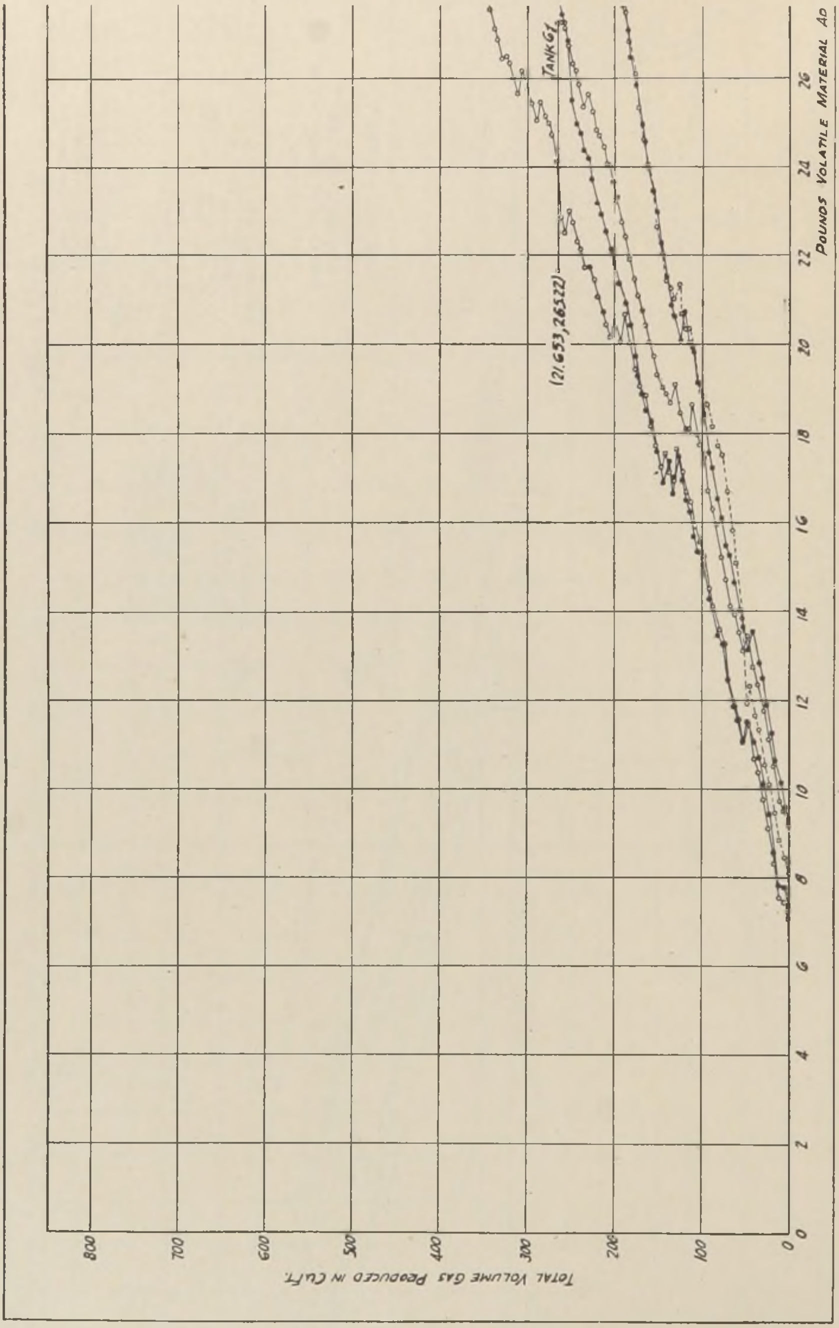
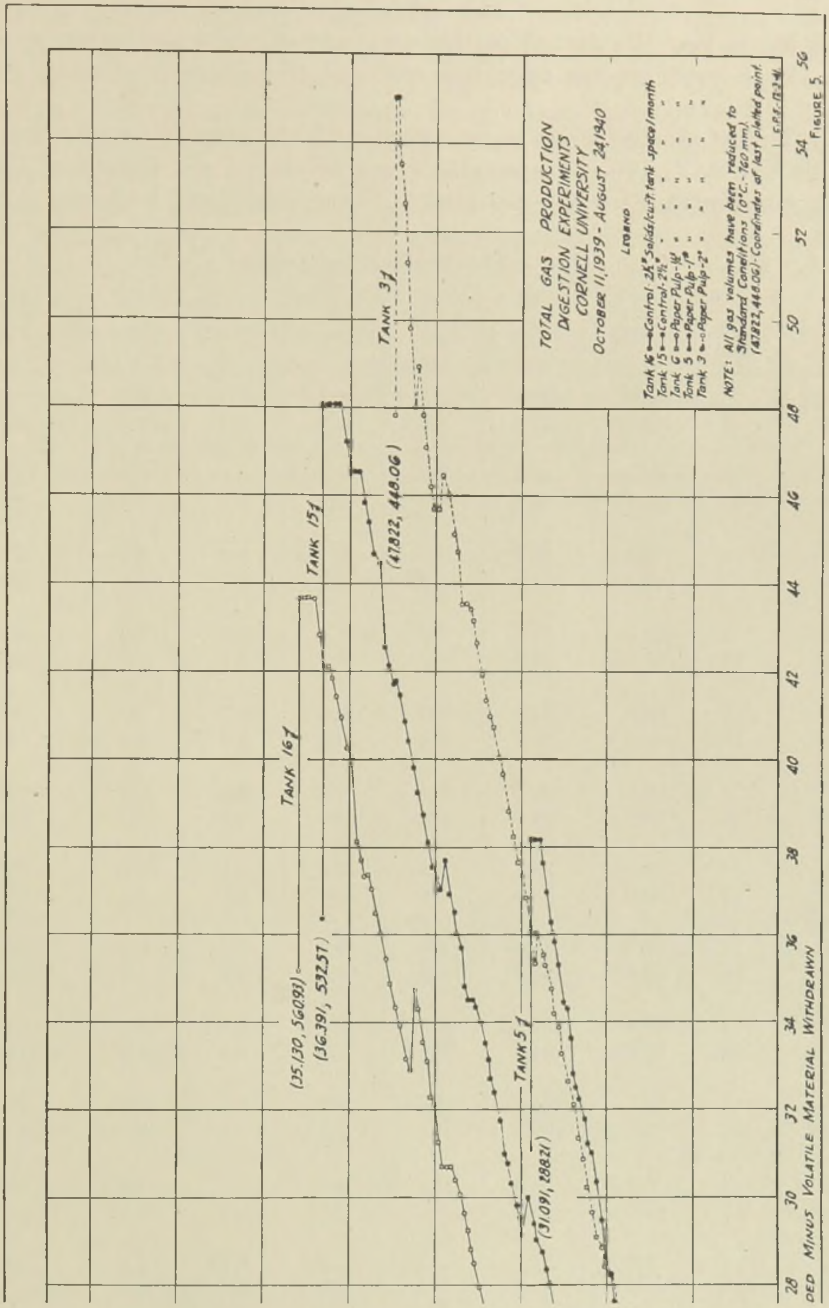

TOTAL GAS PRODUCTION
DIGESTION EXPERIMENTS
CORNELL UNIVERSITY
OCTOBER 11, 1939 - AUGUST 24, 1940
Legend
Note: All gas volumes have been reduced to Standard Conditions (0°C - 760 mm)
* Theoretical loading in lbs per cu ft of tank space per month.
Carbon-nitrogen ratios are actual values
Note: Coordinates of end points
TANK 16
TANK 15
TANK 14
TANK 13
TANK 12
TANK 11
TANK 10
TANK 9
TANK 8
TANK 7
MATERIAL WITHDRAWN

FIGURE 4


Total Volume Gas Produced in Cu.Ft.
Pounds Volatile Material Ad
Tank G1
(21.653, 265.22)
0 100 200 300 400 500 600 700 800
0 2 4 6 8 10 12 14 16 18 20 22 24 26



TOTAL GAS PRODUCTION
DIGESTION EXPERIMENTS
CORNELL UNIVERSITY
OCTOBER 11, 1939 - AUGUST 24, 1940
LEGEND
NOTE: All gas volumes have been reduced to Standard Conditions (0°C. - 760 mm). (47822, 448.06) - Coordinates of last plotted point.
TANK 16
TANK 15
TANK 3
TANK 5
(35.130, 560.93)
(36.391, 532.57)
(47.822, 448.06)
(31.091, 288.21)
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
...OED MINUS VOLATILE MATERIAL WITHDRAWN

FIGURE 5.

reasons: the first, that the solids added to the tank balanced the solids removed from the tank on that particular day, and the second, that there was gas production without any addition of volatile solids. This latter condition is best illustrated at the very end of the experiment when the tanks were continued in operation without the addition of more volatile solids.

If the last plotted point is connected with the origin by a line, the slope of this line will give the amount of gas produced per pound of volatile solids unaccounted for or consumed. These values will be found in Table

TABLE XI.—*Results of Gas Analyses*

Tank	No. Samples Tested	CH_4	CO_2	H_2	O_2	CO	N_2	C/N
16	20	68.8 a	26.6	1.1	0.2	0.2	3.2	20.9
15	17	69.5 b	25.9	1.6	0.3	0.2	2.5	20.9
14	3	66.4 c	23.5	7.8	1.5	0.1	0.5	20.9
14*	15	65.9 d	30.2	1.8	0.2	0.2	2.2	32.4
13	5	68.5 e	23.1	1.4	0.4	0.2	6.4	20.9
13*	17	64.3 f	31.3	1.4	0.2	0.1	3.1	43.9
12	4	71.3	24.2	0.8	0.4	0.1	3.2	20.9
12*	14	63.8 g	33.0	0.7	0.3	0.2	2.0	54.9
11	4	69.6	22.5	0.3	0.4	0.2	7.0	20.9
11*	18	61.9 h	33.7	0.6	0.3	0.2	3.2	67.9
10	4	69.0	23.2	0.6	0.4	0.3	6.7	20.9
10*	16	62.3 i	34.2	0.8	0.4	0.2	2.2	77.9
9	5	65.4 j	23.4	2.0	0.5	0.1	9.7	20.9
9*	13	63.3 k	34.2	0.8	0.4	0.1	1.7	89.3
8	4	65.9	24.0	0.6	0.2	0.2	9.1	20.9
8*	16	63.5 m	34.2	0.2	0.3	0.2	1.6	101.5
7	4	69.9	21.9	0.3	0.8	0.1	7.1	20.9
7*	16	62.0 n	34.6	0.8	0.3	0.1	1.9	111.2
6	3	64.4	24.3	2.8	0.7	0.1	7.8	20.9
6*	10	66.5 p	29.4	0	0.2	0.2	3.3	Pulp alone
5	2	68.2	21.9	0	0.6	0.2	9.0	20.9
5*	13	62.0 q	33.9	0.1	0.3	0.1	3.1	Pulp alone
3	4	68.0	24.4	1.3	0.5	0.2	5.8	20.9
3*	15	60.8 r	35.7	0.7	0.3	0.1	3.1	Pulp alone

* After addition of paper pulp.

Letters after CH_4 column give number of samples tested for CH_4 and H_2 and are as follows:

a—17, b—14, c—2, d—11, e—4, f—13, g—10, h—14, i—13, j—4, k—11, m—12, n—12, p—9, q—12, and r—12.

III and in Table X. In general, there was a decrease in the cu. ft. of gas produced per lb. volatile solids unaccounted for or consumed, with an increase in the carbon to nitrogen ratio.

In Table XI are given analyses of the gas samples collected at various intervals during the investigation. From these data one can see that as the carbon to nitrogen ratio increased, there was an increase in the amount of carbon dioxide gas produced with a corresponding decrease in the methane content.

An attempt was made to determine the amount of gas produced per pound of paper pulp consumed by assuming that all the material withdrawn from the tanks after paper pulp addition had begun was composed of paper pulp and sewage sludge in the ratio equal to the amount of each added to the tank during the entire loading cycle. On the basis of these assumptions and computations, it was found that the cu. ft. of gas produced per lb. paper pulp consumed in each tank varied as shown in Table XII

TABLE XII.—*Amount of Gas Produced in Cu. Ft. per Lb. Paper Pulp Consumed*

Tank	Cu. Ft. Gas/Lb. Pulp Consumed
14	6.34
13	7.18
12	4.60
11	7.24
10	8.60
9	7.20
8	6.24
7	5.83
6	6.85
5	3.87
3	6.82
Average	6.43

Effect of the Addition of Pure Paper Pulp on the Nitrogen Content of Solids Removed from Tanks.—Nitrogen determinations were made on composite samples of the final solids withdrawn from Tanks 3, 5, and 6. These showed the following nitrogen contents as determined by ammonia and organic nitrogen tests (Table XIII):

TABLE XIII.—*Nitrogen in Pulp Sludges*

Tank	Loading, Lb.*	NH_3—N, P.p.m.	Organic N, P.p.m.	Total N, P.p.m.
3	2	440.0	0.0	440.0
5	1	2,686.9	185.5	2,872.4
6	0.5	3,764.6	284.9	4,049.5

* Loading in lb. solids per cu. ft. of tank space per month.

These figures show that the available supply of nitrogen in Tank 3 was running out, which may be the reason for the reduction in the rate of gas produced in Figs. 2 and 5 at the end of the 200th day.

On the basis of these tests, it was decided to study the effect of nitrogen on the digestion of pure paper pulp. Nitrogen in some form would be added and the effect of this nitrogen on digestion could be determined by comparing the results with those obtained from tanks to which no nitrogen was added. This was made the subject for study during the year 1940–41, and will be reported in the third paper of this series.

Conclusions

The following conclusions may be drawn from the investigation conducted on the digestibility of mixtures of paper pulp and sewage sludge, at variable carbon to nitrogen ratios, when fed at the rate of approximately 2.5 lb. total solids per cu. ft. of tank space per month and paper pulp alone when fed at varying rates of 0.5 to 2.0 lb. total solids per cu. ft. of tank space per month, to heated, well-seeded separate sludge digestion tanks operated under conditions described above:

1. Mixtures of sulfite prepared paper pulp and fresh raw sludge and paper pulp alone when added to well-seeded sludge in separate heated sludge digestion tanks digested satisfactorily, although it was necessary to add lime to maintain satisfactory pH conditions in the tanks.
2. No harmful effects upon digestion were noted when the carbon to nitrogen ratio of the sewage sludge-paper pulp mixture added to the tanks ranged from 20.0 to 111.2 (for the period from January 8 to July 6, 1940) or from 20.9 to 50.1 (for the period from October 11, 1939, to July 6, 1940). The ratio of sewage to pulp varied from 1 to 0.45 to 1 to 2.30 (for the second period mentioned above) or from 1 to 0.63 to 1 to 4.72 (for the first period mentioned above). However, there seemed to be a slowing up in the rate of gas production after the 200th day of operation in Tank 3 which received the heaviest dose of pure pulp (2 lb. total solids per cu. ft. of tank space per month).
3. There was a greater loss in weight of volatile solids added to the tanks receiving paper pulp than in the control tanks.
4. The pH of the tanks receiving sewage sludge-paper pulp mixtures and paper pulp alone decreased (became more acid) in proportion to the amount of pulp added and it was necessary to add lime to these tanks to maintain satisfactory pH conditions.
5. The gas produced in the digestion of sewage sludge-paper pulp mixtures and paper pulp alone contained considerably more carbon dioxide than the gas produced in the tanks receiving sewage sludge alone. In general, the higher the carbon to nitrogen ratio, the higher the carbon dioxide content, and the higher the rate of paper pulp feed, the higher the carbon dioxide content.
6. Less gas per pound of solids unaccounted for or consumed was produced in the sewage sludge-paper pulp tanks and in the tanks receiving paper pulp alone than in the control tanks. Here again the amount of gas produced per lb. volatile solids unaccounted for or consumed decreased as the carbon to nitrogen ratio increased indicating, in general, that for maximum gas production a carbon to nitrogen ratio corresponding to or less than that of sewage sludge should be used.

7. The amount of gas produced per lb. of paper pulp consumed was less than half of that produced in consuming 1 lb. of sewage sludge, indicating the presence of more satisfactory conditions for the production of gas by bacterial action in the digestion tanks receiving sewage sludge alone. In other words, there was a more varied or more balanced diet in the control tanks, conducive to greater bacterial activity.

8. On the basis of a single test on the contents of Tanks 3, 5, and 6 for ammonia and organic nitrogen, it seems that gas production decreases with a decrease in the nitrogen content of the tank.

Acknowledgment

The author acknowledges his indebtedness to Professor C. L. Walker of Cornell University for his consultation and assistance in this work.

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OXIDATION-REDUCTION STUDIES

II. OXIDATION-REDUCTION POTENTIALS DEVELOPED IN SEWAGE AND SEWAGE-ACTIVATED SLUDGE MIXTURES

By W. Allan Moore and C. C. Ruchhoft

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Although numerous studies have been made of the oxidation-reduction potential relationships with the growth of bacteria in pure culture, very little work has been reported on these same relationships that exist in sewage and sewage-activated sludge mixtures.

In 1925, Clark, Cohen and Gibbs (1) followed the change in E_h with time in dilutions of sewage buffered at various pH values. They concluded that a variation in pH was one of the factors that affected the methylene blue decolorization time and that generally no characteristic of the potential-time curve indicated the point of passage from aerobic to anaerobic conditions.

Dickinson (2) attempted to measure the oxidation-reduction potential developed within the activated sludge floc by developing the floc upon a platinum electrode. The difference in potential between this bio-electrode and another platinum electrode when both were immersed in sewage was indicated by galvanometer deflections. The measurements were only qualitative but indicated that the oxidation-reduction potential fell during the adsorptive stage but also rose again when the adsorbed organic material was oxidized.

Just recently Rohlich, Sarles and Kessler (3) have made a study of oxidation-reduction potentials in activated sludge and sewage. They found that when aeration was stopped the dissolved oxygen content immediately fell but that a lag in the E_h drop occurred until the oxygen content was less than 1 p.p.m.

The present study deals with the oxidation-reduction potential-time relationships that occur during the decomposition of organic matter in sewage and activated sludge-sewage mixtures under low rates of aeration and also under entirely anaerobic conditions. Also the change during the digestion of sludge has been followed until stabilization of the organic material was largely completed.

Experimental

The same set-up of apparatus was used in this study as in the pure culture work reported in an earlier paper (4), except that it was unnecessary to observe aseptic conditions. The sewage used was of domestic origin having a 5-day B.O.D. of approximately 330 p.p.m. The activated sludge was obtained from the experimental plant at this station.

Results

In Fig. 1 is shown the effect of maintaining aerobic conditions in sewage upon the oxidation-reduction potential developed. Only sufficient air was used to keep the sewage aerobic as shown by dissolved oxygen determinations. If vigorous aeration had been used then a fall in potential would not have occurred but the potential would have risen to approximately 0.4 volt and remained stationary. However, it is noted that even with a low aeration rate a strongly reducing condition cannot be reached such as occurs under anaerobic conditions. The minimum potential (+0.24 volt) reached is attained at approximately the 36th hour after which a gradual rise occurs until the 72nd hour where the curve flattens out and remains flat for about 2.5 days. At this point the E_h rises sharply, which suggests

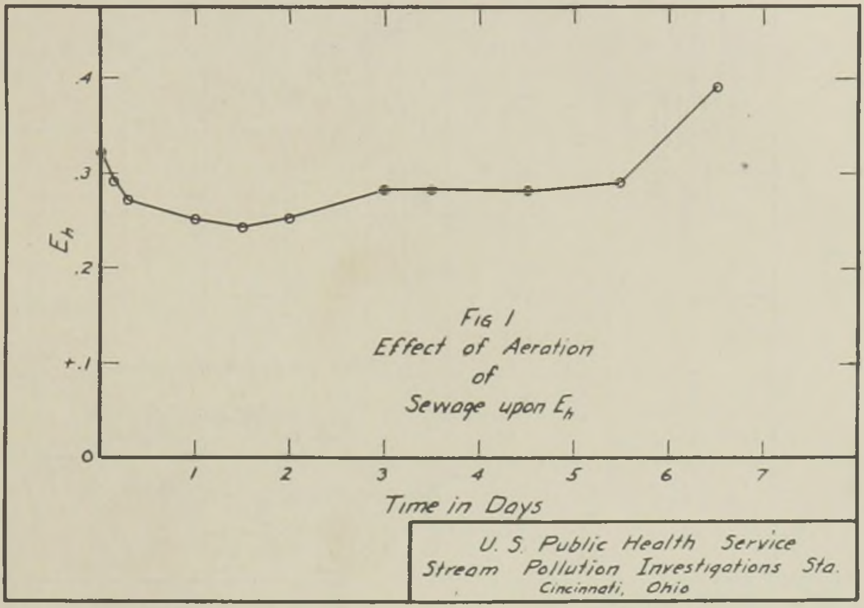


Fig 1
Effect of Aeration of Sewage upon E_h

that a large percentage of the ultimate carbonaceous demand had been satisfied. It is to be noted especially that in spite of aerobic conditions being maintained the metabolic activities of the diverse bacterial population present in sewage causes a drop in the E_h of the medium. However, as soon as the least stable compounds present in the sewage are oxidized then the ratio of oxidized to reduced material increases and the oxidation-reduction potential rises.

The effect of intermittent aeration upon the oxidation-reduction potential developed in fresh sewage was tried and the results shown graphically in Fig. 2. In this experiment the sewage was allowed to remain anaerobic for 1 hour and potential readings made. It was then aerated for 0.5 hour. This alternate aeration and quiescence was followed for 13 hours, then it was allowed to remain quiescent over night, and the same procedure followed the next day.

The potential of the fresh sewage was 0.33 volt and upon remaining quiescent for 1 hour dropped to 0.17 volt. Upon aeration the potential did not return to its original value but only to 0.29 volt, which potential was approximated in all subsequent aerations during the first day. It will be noted that during each quiescent period the drop in potential increased until the 5th hour and then decreased, which apparently indicates first an accelerated rate of oxidation followed by a slowing up of this rate. When the sewage was allowed to remain quiescent over night, a drop of potential of 0.46 volt occurred during the ten-hour period, which is not at all out of line with the decreases in potential registered in the previous few hours.

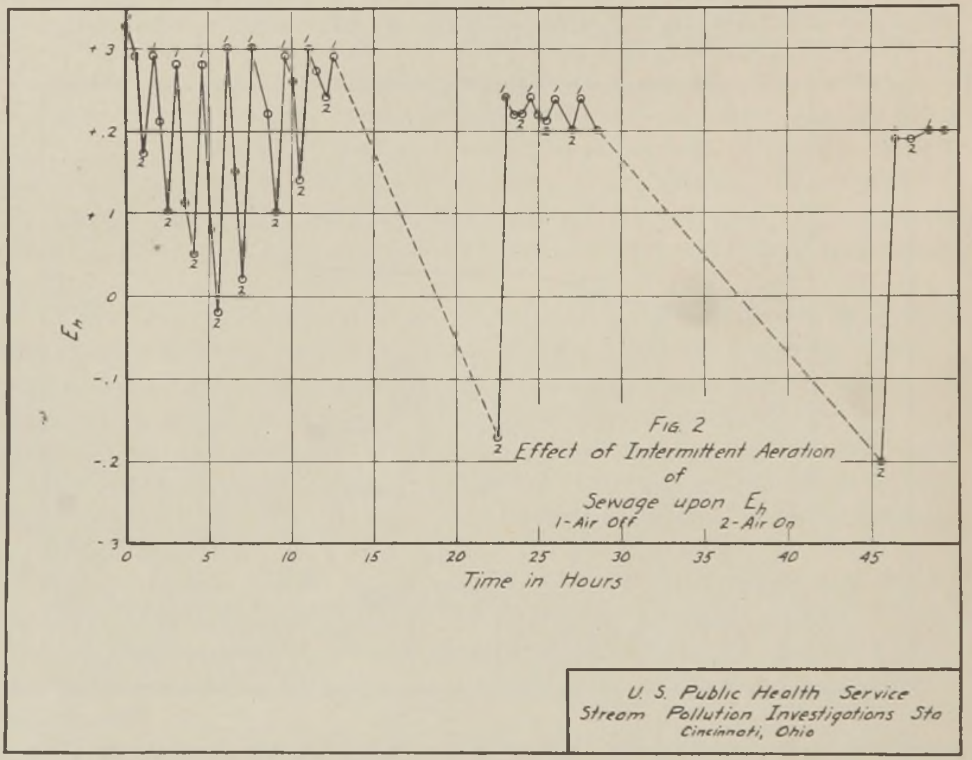
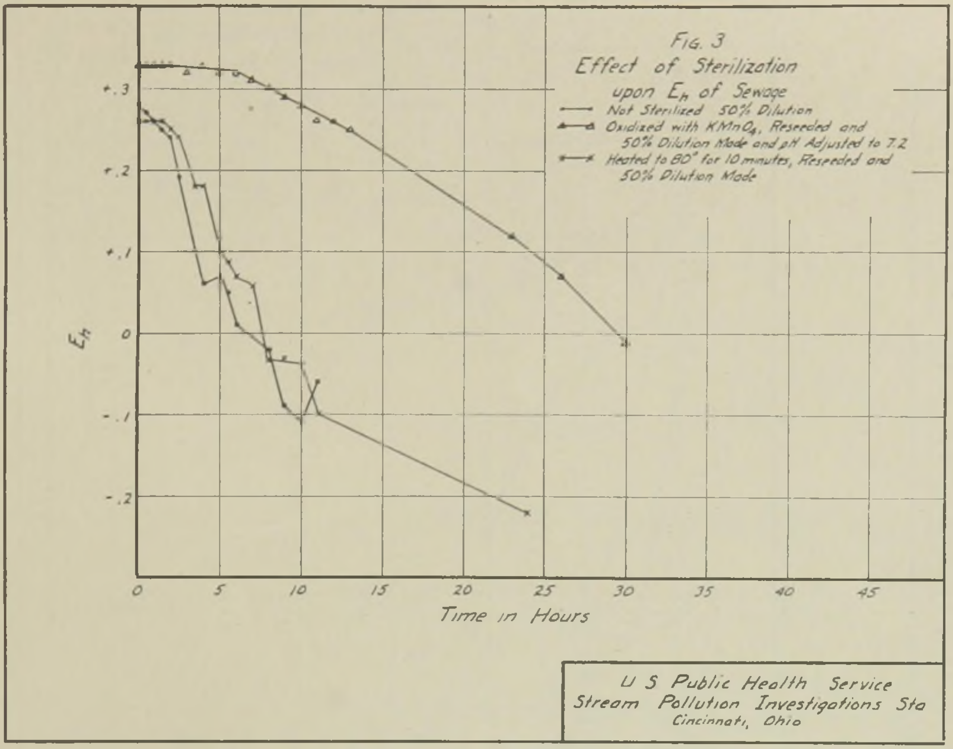


FIG. 2
Effect of Intermittent Aeration of Sewage upon E_h

Upon aerating for 0.5 hour the next morning the potential did not return to the 0.29-volt level of the preceding day but to 0.24 volt and the decreases in potential registered during quiescence were all approximately the same, being about 0.04 volt. However, on standing quiescent for 17 hours the potential dropped 0.40 volt and the aerobic metabolism changed to an anaerobic one. As before, upon aerating for 0.5 hour the E_h rose but not to the 0.24-volt level but to the 0.20-volt level, and during the subsequent quiescent period a negligible change in E_h occurred.

This shows that with fresh sewage after long periods of anaerobic conditions the E_h cannot be brought back to its original value by periods of aeration sufficient to make the sewage aerobic. It is possible that this failure to return to the original E_h upon reaeration is the result of a considerable change in the microflora of the medium and of products in or metabolism of the flora during the longer period of anaerobiosis which cannot easily be readjusted with a short period of aeration. It also suggests that all of the reducing material produced biochemically under anaerobic conditions cannot be oxidized chemically by dissolved oxygen. However, it will be shown later that when the sewage reaches a more stabilized state the potentials upon aeration following a quiescent period always attained the original level.

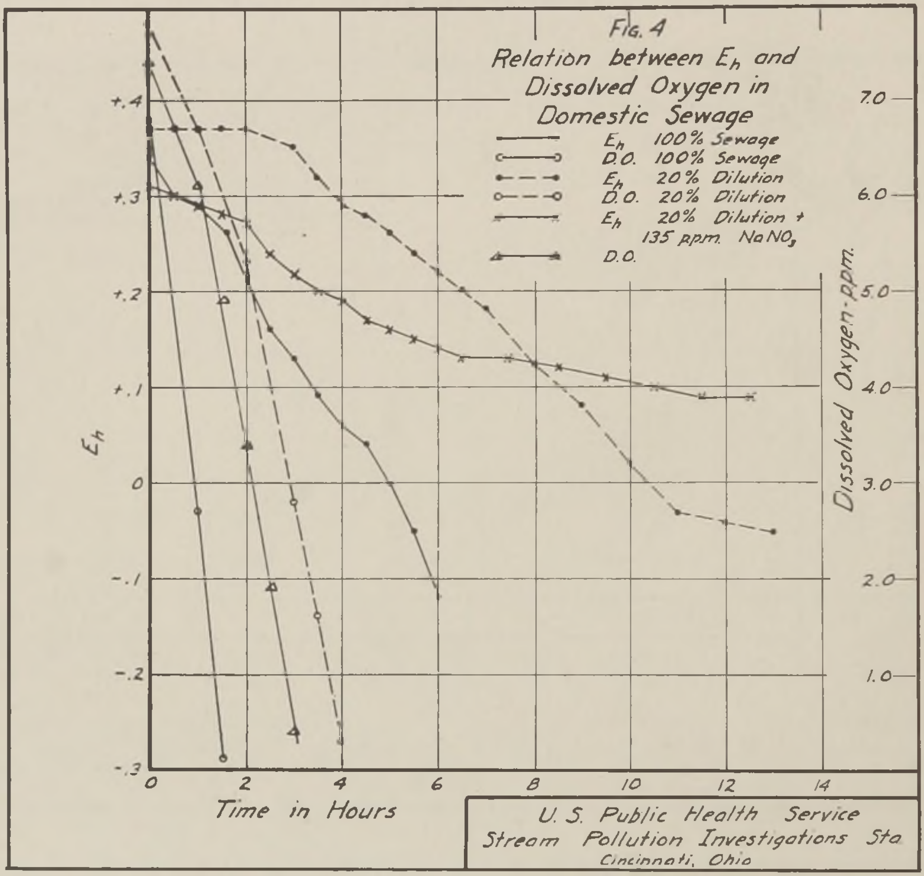
The effect of partially oxidizing the unstable material in sewage upon the E_h is shown graphically in Fig. 3. In this experiment three portions



of sewage were treated as follows: One portion was heated to 80° C. and held at this temperature for ten minutes, cooled, diluted 50 per cent and reseeded with 1 ml. per liter of aerated sewage. A second portion was treated with potassium permanganate, a 50 per cent dilution was made, the pH adjusted and reseeded. A third portion of the same sewage was only diluted. The change in E_h under quiescent conditions was then followed in all three portions.

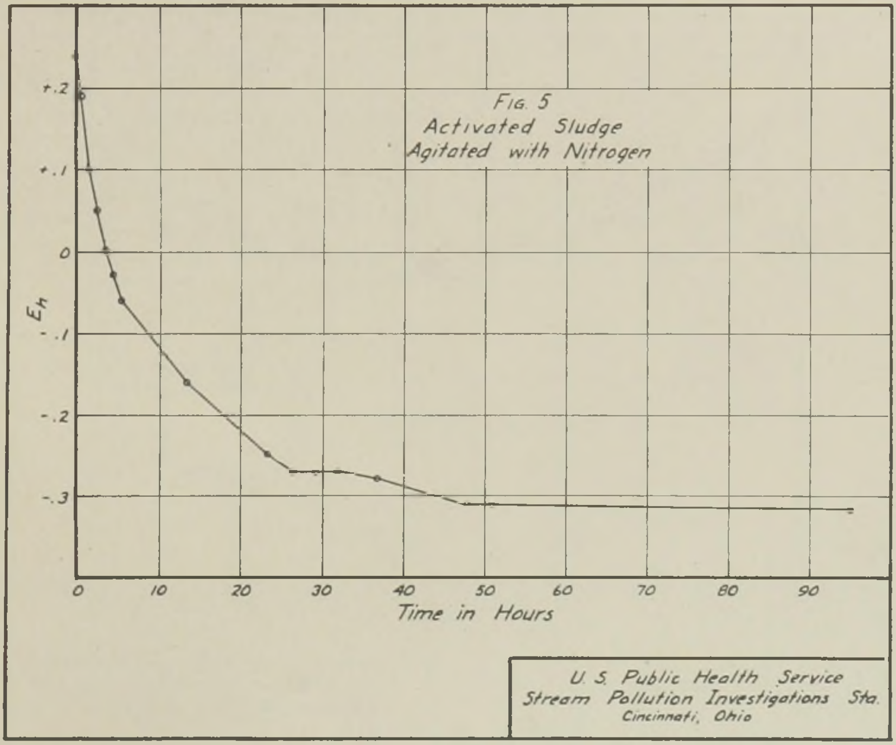
The only difference between the untreated sample and the one that was pasteurized by heat was a slight lag in the latter case, but both had reached the same oxidation-reduction level (−0.1 volt) in ten hours. However, in the case of the sample which had been treated with potassium permanganate a very slow change is noted in the E_h which at the end of thirty hours had dropped only to zero. These facts indicate that the readily oxidizable material present in sewage are first utilized in the metabolic activities of the organisms and this causes a rapid change in the E_h when additional air is not supplied. However, when these same materials are converted to a more stable state by chemical oxidation with potassium permanganate the metabolic activities of the organisms and the resulting E_h changes are much reduced.

As pointed out earlier, the work of Clark, Cohen and Gibbs with dilutions of sewage showed no point on the E_h-time curve that indicated the



moment of disappearance of the dissolved oxygen present. It was decided, however, to follow the change in E_h with time and at the same time make a quantitative determination of the dissolved oxygen present. In Fig. 4 are shown graphically the results obtained with a 100 per cent sewage, a 20 per cent dilution and a 20 per cent dilution, plus 135 p.p.m. of sodium nitrate.

In the case of the 100 per cent sewage it is noted that the dissolved oxygen had become depleted in about 1.5 hours. It is true that at this point there occurred an acceleration of the rate of change in E_h, but this cannot necessarily be accounted for on the basis of oxygen depletion, for it will be noticed that another acceleration occurred several hours after all of the oxygen had disappeared. With the 20 per cent dilution, a lag period in the E_h-time curve occurred which is to be expected. Corresponding to the end of this lag period a slight increase in the rate of oxygen utilization is noted. Between the 2nd and 4th hours, approximately 64 per cent of the oxygen was utilized but no point on the E_h-time curve denotes the point of oxygen depletion. It should also be pointed out that at the end of the lag period there was about 5 p.p.m. of dissolved oxygen present. Finally, in the case of 20 per cent dilution containing 135 p.p.m. of sodium nitrate it is noticed that a slight acceleration in the rate of change of E_h occurred when the dissolved oxygen content was about 3.5 p.p.m. but no point on



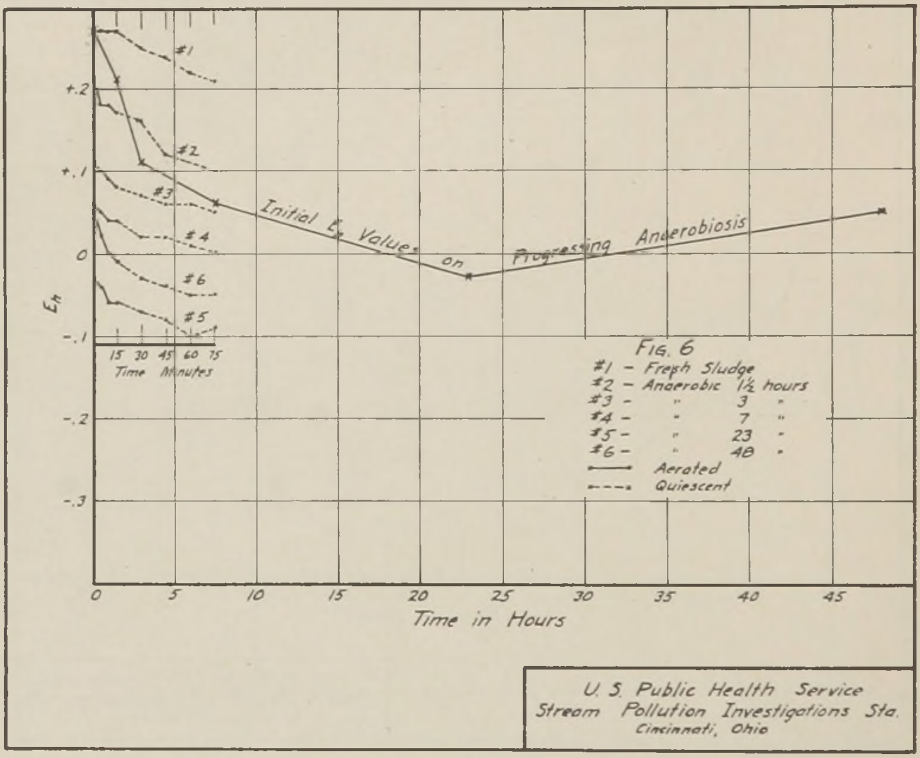
the curve denotes the attainment of oxygen depletion. As would be expected, in the presence of $NaNO_3$ a much higher oxidation-reduction potential level is reached (+0.1 volt) and maintained. At the end of 12 days this sewage was still aerobic as far as the decolorization of methylene blue was concerned, and had no odor denoting putrefaction.

These data further confirm Heukelekian's (5) findings on the prevention of septicity in sewage by the addition of sodium nitrate. These experiments indicate again that compounds of oxygen may serve as hydrogen acceptors in the biochemical oxidation of sewage. Apparently it is the presence of such compounds in sewage which retards the lowering of the oxidation-reduction potentials and prevents an abrupt fall in the potential upon the exhaustion of the dissolved oxygen supply.

Activated Sludge

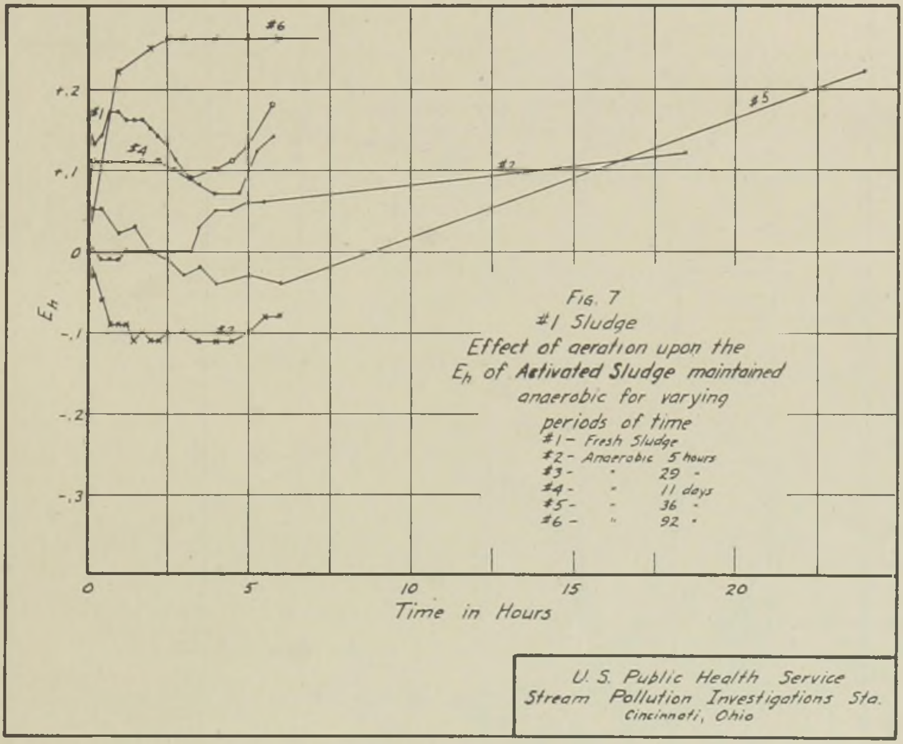
After having carried out these preliminary experiments with sewage alone, the system sewage-activated sludge was studied. In the bacterial metabolism of coli and aerogenes under anaerobic conditions (4) a reversal of potential was found within ten hours from the start of the experiment. However, when activated sludge was agitated with purified nitrogen no such reversal occurs even up to 90 hours of such agitation as shown in Fig. 5.

The sludge was allowed to remain quiescent over the week-end but no appreciable change in the oxidation-reduction potential took place. During the first 5 hours of agitation the most rapid change in E_h occurred. It will be shown in following graphs that the change in E_h with time is very much more rapid when anaerobic conditions are maintained by means of nitrogen than when anaerobiosis follows the natural course.



In another experiment a sample of activated sludge was allowed to become anaerobic and the E_h was followed at intervals for 48 hours. At each interval a portion of this sludge was taken for further study. Each portion of sludge taken was then aerated for 15 minutes after which it was allowed to stand quiescent for 1 hour, and the change in E_h was followed throughout these intervals. The results are shown graphically in Fig. 6.

It will be noted that, with the exception of the sample of fresh sludge, the E_h dropped on aeration and continued to drop during the quiescent period. However, in the 23- and 48-hour-old samples a positive drift (Curve No. 5) or no change (Curve No. 6) occurred during the last 15 minutes. It will also be noted that the initial E_h values become more negative with increasing period of anaerobiosis until the 23-hour sample is reached. However, the initial of the 48-hour sample is more positive than that of the 23-hour sample. This is shown on the long curve in Fig. 6 where the initial E_h values of the various samples are plotted against the time they were anaerobic. A comparison of this latter curve with Fig. 5 shows that the rate of drop in E_h with increasing anaerobic time and the minimum E_h value reached is much greater for sludge agitated with nitro-



gen gas than for sludge allowed to become anaerobic in the normal way without agitation.

Following the above experiment it was decided to take other samples of sludge and allow them to remain anaerobic for a longer period of time (approximately 90 days) and to follow the change in E_h upon aeration at various intervals. The results obtained are shown graphically in Figs. 7, 8 and 9. The sample studied in Fig. 9 was taken from the experimental plant when the sludge was bulking quite badly, while those in Figs. 7 and 8 were normal settling sludges.

In the case of the samples that were observed in Figs. 7 and 8, no direct similarity in the type of curves obtained for various periods of anaerobic

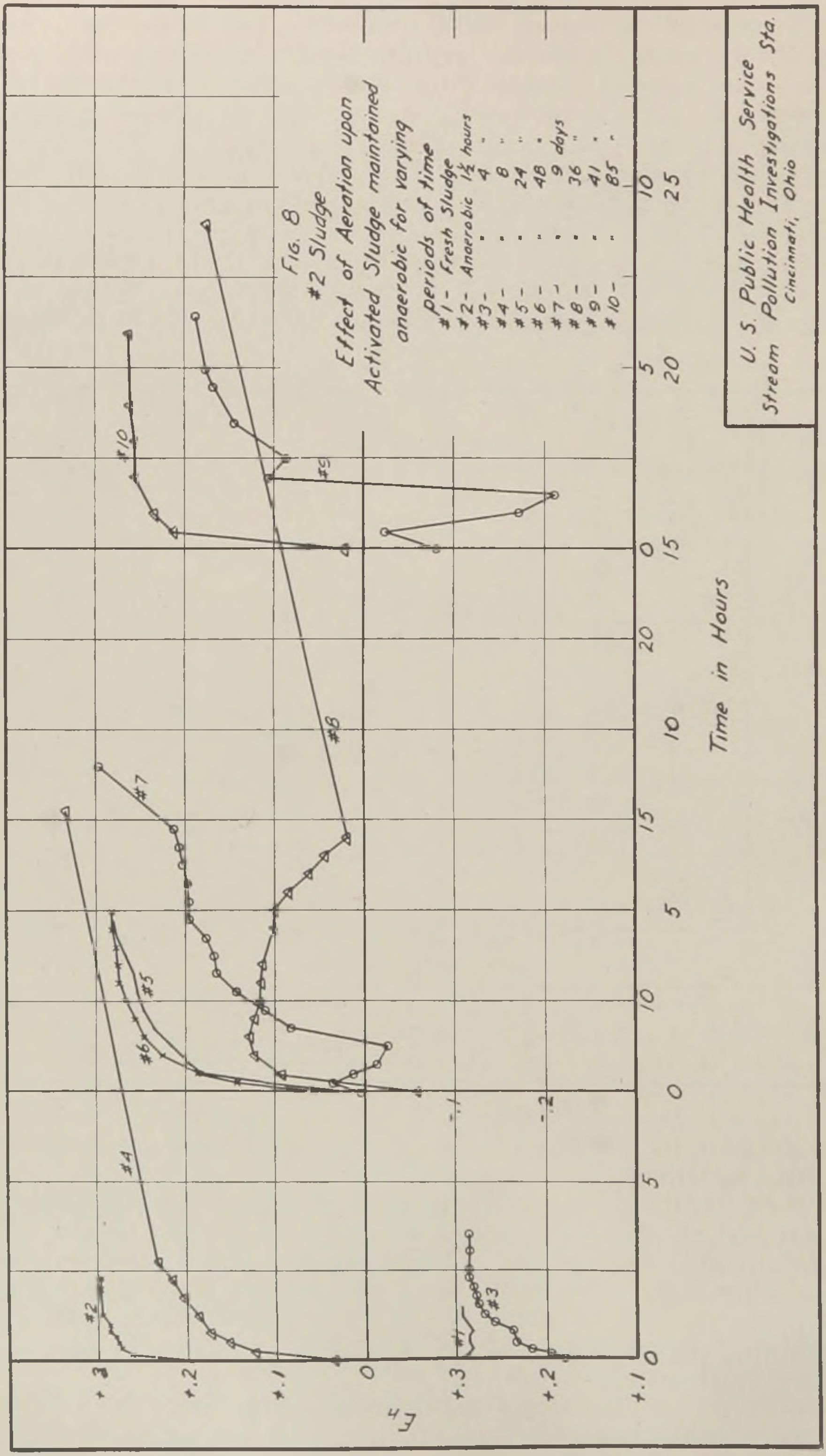


Fig. 8
#2 Sludge
Effect of Aeration upon
Activated Sludge maintained
anaerobic for varying
periods of time
#1 - Fresh Sludge
#2 - Anaerobic 1½ hours
#3 - " 4 "
#4 - " 8 "
#5 - " 24 "
#6 - " 48 "
#7 - " 9 days
#8 - " 36 "
#9 - " 41 "
#10 - " 85 "
U. S. Public Health Service
Stream Pollution Investigations Sta.
Cincinnati, Ohio
Time in Hours
Eh
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10

time is noticeable. It can be seen, however, with both sludges that the initial E_h values drop with increasing time of anaerobiosis, but that a reversal occurs within 48 hours and the end of the 90-day period. With the sludge that was bulking badly (Fig. 9) it is seen that the initial E_h continues to drop at the end of the 48-hour period and no reversal in potential occurred within this period. However, it is noted that the next sample (5 days) showed a more positive potential. This same phenomenon was observed in other samples of bulking sludge that were studied. However, at the end of the 90-day period all activated sludges (Nos. 1, 2, 3, 4 and 5a) digested at room temperature gave the same type of E_h curve.

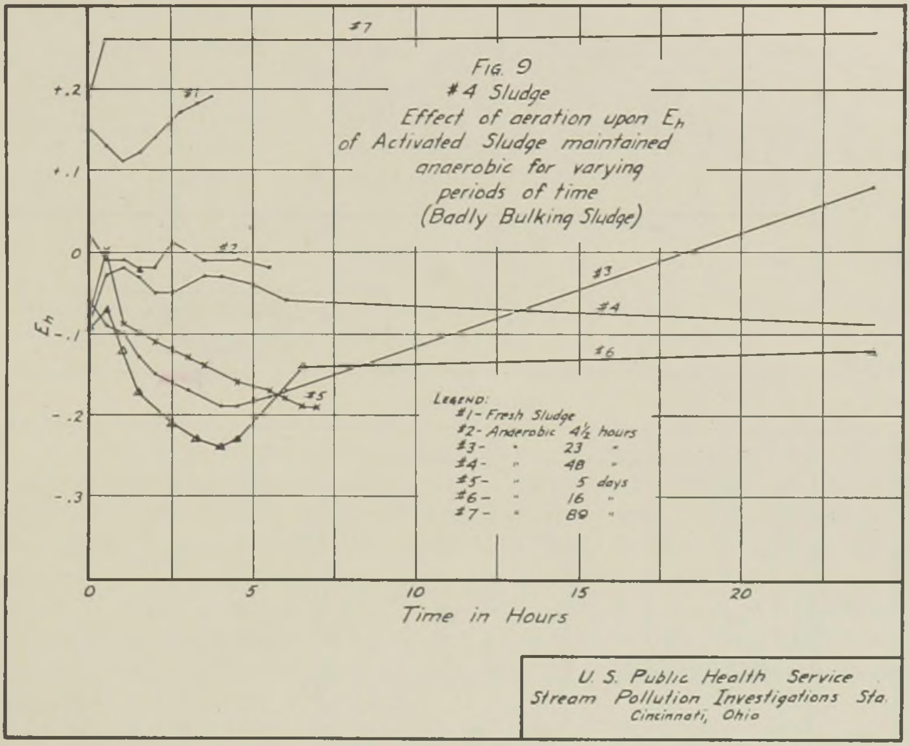


FIG. 9
#4 Sludge
Effect of aeration upon E_h of Activated Sludge maintained anaerobic for varying periods of time
(Badly Bulking Sludge)

Figure 10 shows the relation between the E_h at various periods of anaerobiosis and time up to 48 hours for four typical non-bulking sludges. In all cases a reversal of potential occurred within the 48-hour time period. Data on the initial E_h of several sludges at varying time intervals are given in Table I.

As pointed out previously, the various sludges upon aeration at different periods of anaerobiosis did not give necessarily the same type of curve. However, as shown in Fig. 11 at the end of a 90-day anaerobic digestion period at room temperature all sludges (Nos. 1, 2, 3, 4 and 5a) gave the same type of curve upon aeration regardless of the types of curves obtained at other periods and regardless of whether the sludge was normal or badly bulking sludge.

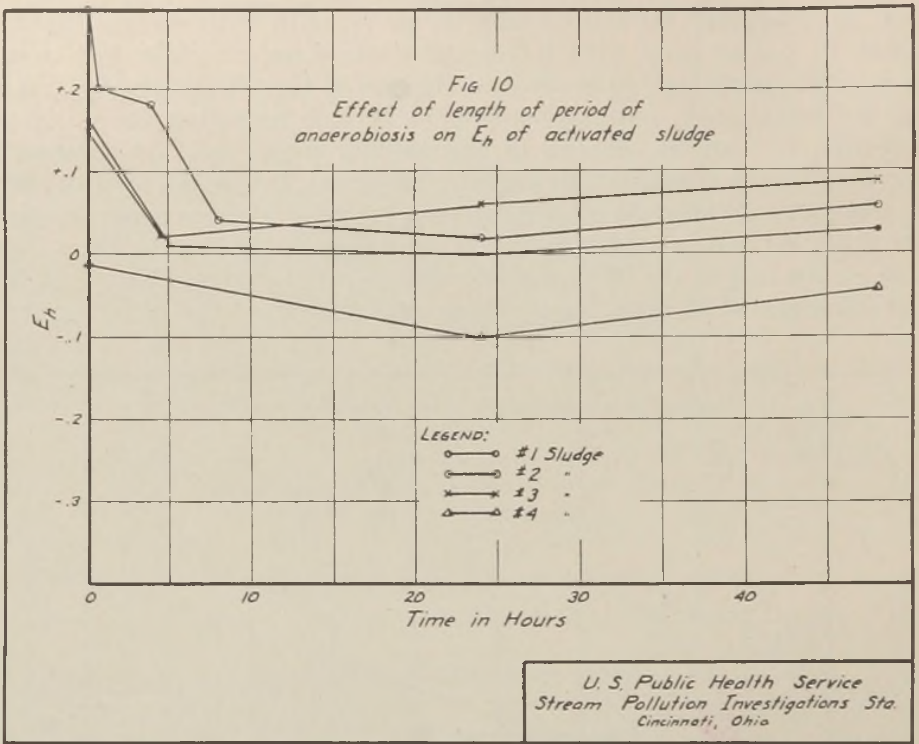


Fig 10
Effect of length of period of anaerobiosis on E_h of activated sludge
E_h
+.2
+.1
0
-.1
-.2
-.3
Legend:
#1 Sludge
#2 "
#3 "
#4 "
0
10
20
30
40
Time in Hours
U. S. Public Health Service
Stream Pollution Investigations Sta.
Cincinnati, Ohio

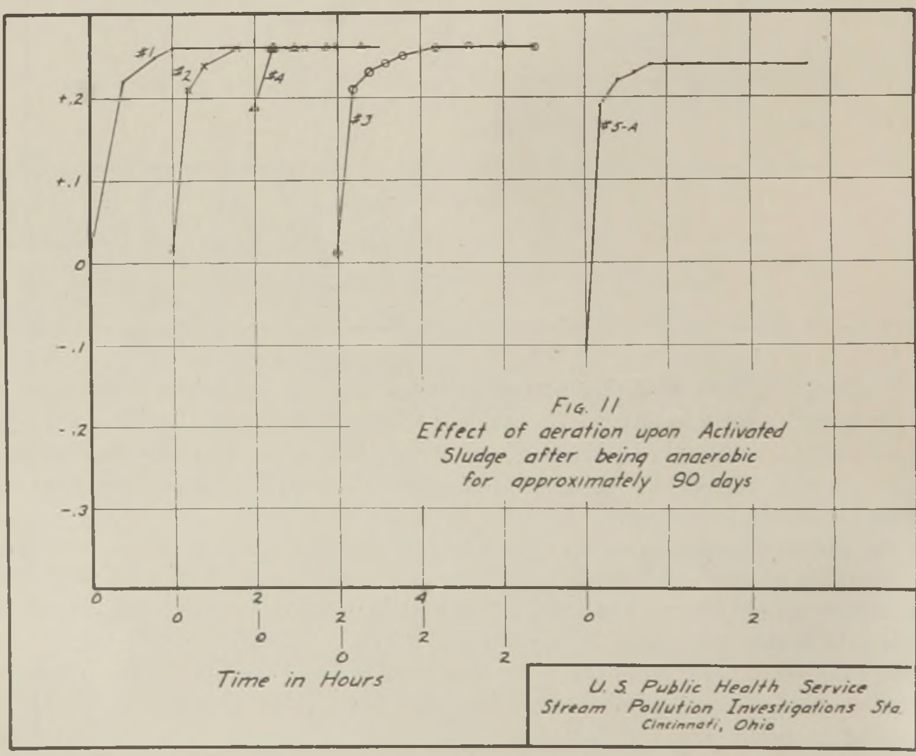

#1
#2
#4
#3
#5-A
+.2
+.1
0
-.1
-.2
-.3
Fig. 11
Effect of aeration upon Activated Sludge after being anaerobic for approximately 90 days
Time in Hours
U. S. Public Health Service
Stream Pollution Investigations Sta.
Cincinnati, Ohio

TABLE I.—*Initial E_h of Sludges at Different Periods of Anaerobiosis*

Time Anaerobic	Sludge Number						
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 5a	No. 6
Fresh	+.157	+.300	.388	.145	.103	−.014	.447
1½ hrs.		+.197					
4 hours		+.179	.120	.019	−.133		
5 hours	.012						
8 hours		+.037					
24 hours	+.004	+.016	.020	−.062		−.098	−.072
48 hours	+.032	+.059	−.062	−.093		−.034	
4 days			+.026		−.119		−.050
5 days				−.075			
6 days					−.099		
9 days		+.004					+.066
11 days	+.070			−.091	−.098		
15 days					−.076		
23 days						+.007	
36 days	+.059	−.057					
38 days			−.110				
41 days		−.080					
45 days						−.084	−.026
Approx 90 days	+.009	+.022	+.013	+.191	+.026	−.014	.428

Discussion

As would be expected the maintenance of aerobic conditions during the decomposition of organic material present in sewage prevents the attainment of strongly reducing conditions. However, it is shown that the metabolic activities of the various bacterial species present in sewage does effect a lowering of the oxidation-reduction potential (from +0.32 to +0.24 volt) in the presence of oxygen. When a passage from aerobic to anaerobic conditions is allowed to proceed naturally, then more intense reducing conditions are set up as evidenced by a lower oxidation-reduction potential (−0.22 volt in 24 hours).

From the effect of oxygen in preventing the development of strongly reducing conditions in the substrate as pointed out above it would seem that the E_h-time curve should show a point characteristic of the moment of oxygen depletion. However, as shown previously no such characteristic is found, the system passing smoothly from an aerobic state to an anaerobic one with no indication of oxygen depletion.

The presence of other hydrogen acceptors (NO_3, SO_4, etc.) retards the development of strongly reducing conditions. It is suggested that it is the presence of such compounds in sewage which is responsible for the absence of any indication of the point of oxygen depletion on the oxidation-reduction potential curve.

Although the rate of oxygen utilization was not determined directly in these experiments, an examination of the deoxygenation and oxidation-reduction potential curves in Fig. 4 indicates that no correlation between the rate of oxygen utilization and the potentials developed in the system would be expected.

In the work with the activated sludge-sewage system it was shown that when anaerobic conditions were brought about by agitation with nitrogen gas, the drop in potential was faster than when anaerobiosis was allowed to proceed naturally. In view of the fact that oxygen depletion has apparently little effect on the E_h-time curve and that in such a system deoxygenation should be complete within an hour, it seems hardly possible that this difference in rate can be ascribed to the presence of dissolved oxygen. The only logical explanation for this difference is the accelerated contact between the bacterial floc and the substrate liquor provided by agitation. This agitation as shown in previous oxidation studies (6) increases the reaction velocity over that possible in the quiescent sludge in response to diffusion alone, and hastens the attack on other hydrogen acceptors in the liquor.

In this study of sewage and the activated sludge system it must be borne in mind that only qualitative results can be obtained due to the complexities of the materials under investigation. This fact is brought out when one considers the reactions on aeration of various samples of sludges at different periods of anaerobiosis. One of the two similarities between the normal sludges was that a reversal of potential occurred within 48 hours.

The second similarity, applying not only to the normal sludge but also to the bulking sludges as well, was the type of curve obtained after 90 days of anaerobiosis. At this period upon aeration the E_h rose sharply to $+0.24$ to 0.26 volt and flattened out, evidently indicating that the sludges were well stabilized.

Summary

1. The flora of domestic sewage effect a lowering of the oxidation-reduction potential from about $+0.3$ volt to about -0.2 volt as quiescent sewage becomes anaerobic. If the sewage is aerated at a low rate a decrease in the oxidation-reduction potential is effected, but to a much smaller degree. The above changes are entirely similar to those previously found for pure cultures in sewage under equivalent conditions.

2. If the easily oxidizable material present in sewage is first oxidized chemically, the rate of change of E_h with time is greatly diminished, when the sewage is allowed to stand without aeration, and intensely reducing conditions are not established.

3. Study of the correlation between deoxygenation of sewage and the E_h reduction shows that no point on the E_h curve indicates passage from aerobic to anaerobic conditions. There is no break as anerobic conditions set in, but the E_h continues to fall in a normal manner.

4. When activated sludge is allowed to become anaerobic, the E_h falls to about 0 and, though a reversal in potential occurs within 48 hours, remains low for the ninety-day period of observation. When this sludge is allowed to become anaerobic and is agitated with nitrogen, the rate of E_h fall is greater and potentials of -0.3 volt are reached.

5. After intermediate periods of anaerobiosis activated sludges give various E_h results upon reaeration.

6. Following a 90-day digestion period at room temperature all digested activated sludges upon reaeration show rising E_h results having asymptotic values of about +.25 volt after an hour.

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EFFECT OF TEMPERATURE ON SLUDGE CONCENTRATION *

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Concentration of sludge is affected by several factors, among which time and temperature of compacting are of considerable importance. The practical significance of inducing increased sludge concentration is obvious for digestion, sand bed drying, vacuum dewatering and incineration.

The character of the sludge to be concentrated is of greatest general importance and is a factor which cannot be readily controlled, except by addition of chemicals. The effects of initial concentration, time of compacting and temperature during concentration vary for different types of sludges and can be controlled artificially to a more or less extent.

The work recorded pertains primarily to the effect of temperature on fresh solids and ripe sludge concentration and deals incidentally with the effect of initial concentration and time of compacting of the sludge for the purpose of indicating variations to be expected in handling fresh solids and digested sludges. Results on heat concentration of activated sludge and mixtures of activated sludge and fresh solids will be reported at a later date.

Materials and Methods

The materials used were fresh solids and ripe sludges collected at different sewage treatment plants. The sludges used varied in initial concentration from 0.5 to 6.2 per cent for fresh solids and from 0.5 to 7.9 per cent for ripe sludge. The sludges were allowed to compact for periods up to 192 hours and kept at constant temperatures of 10, 20, 37 and 55° C. The sludges were allowed to reach the required temperatures, then thoroughly mixed and left quiescent for observation, measurement and analyses. The volume of sludge occupied was measured at frequent intervals and the location of the sludge indicated. At the higher temperatures the total volume of sludge and liquor expanded initially on account of embedded gases.

Results

Fresh Solids.—Concentration of thin fresh solids is most rapid during the first 12 hours of storage. With the increase in initial concentration of sludge, time becomes an increasingly important factor. The effect of temperature increases with time. The effects of temperature on sludge concentration during the first 6 and 12 hours are illustrated in Fig. 1. Sludges having an initial concentration between 5 and 6 per cent are but slightly affected at temperatures from 10 to 20° C. during these few hours. When the temperature is raised its effect becomes more apparent. With increasing time the effect of temperature on sludges with higher initial

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concentrations becomes more pronounced. The practical application for short time concentration is that, with sludges of any given initial concentration, the higher the temperature the greater the liquor separation. Liquor separation continues with time.

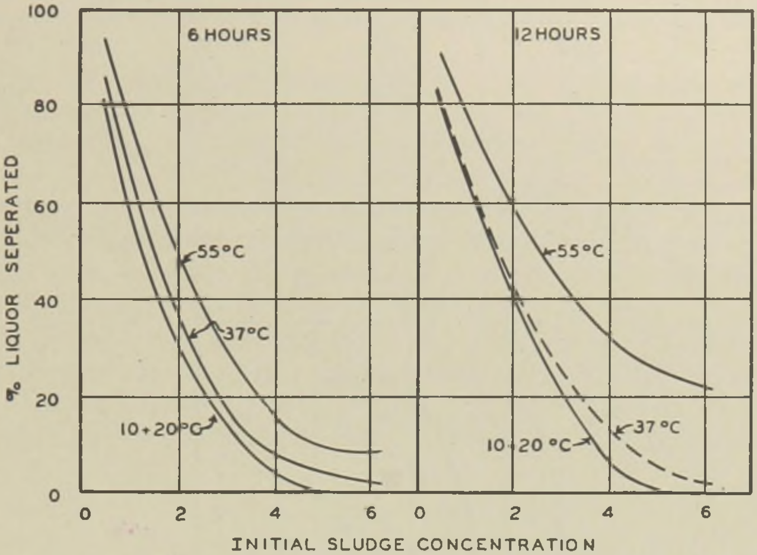

FIG. 1.—Effect of temperature on short time concentration of fresh solids.

Sludges with initial concentrations of 2 to 3 per cent solids require in practice most frequent thickening. Short-time concentration, with the aid of temperature, results in considerable separation of liquor, and the actual increase may be material. A few figures with initial sludge concentrations of 2, 3 and 4.5 per cent will illustrate this:

Initial Per Cent	Increase in Concentration, Per Cent After 6 Hours	After 12 Hours
2	30–90	50–150
3	12–40	20– 65
4.5	2–15	3– 30

The percentage increase in solids concentration varies with the temperature.

In order to obtain higher concentration the time required increases. The effect of temperature on fresh solids concentration after a period of 96 hours is illustrated in Table I. The results are based upon sludge volume, regardless of its position (bottom or top). This is usually of importance in the early stages of compacting, when only a portion of the sludge may be floating. With time all fresh solids float, but compacting continues. From the results it is evident that the original concentration of the sludge is of importance in obtaining a certain concentration in a specified time, but temperature overbalances the effect of the initial concentration. Curves plotted from results obtained at frequent time intervals, especially those showing the volume of sludge occupied, show a regular pattern.

TABLE I.—*Effect of Temperature on Fresh Solids Concentration After 96 Hours (Expressed in Per Cent Solids)*

Temp. °C.	Initial Concentration, Per Cent			
	0.5	2.0	4.5	6.0
10	3.12	4.02	5.15	6.30
20	3.33	4.04	5.94	6.63
37	6.25	10.50	11.50	11.70
55	5.00	7.40	8.60	9.25

The relation between the original sludge concentration and compacting at different temperatures after 96 hours is shown graphically in Fig. 2. Con-

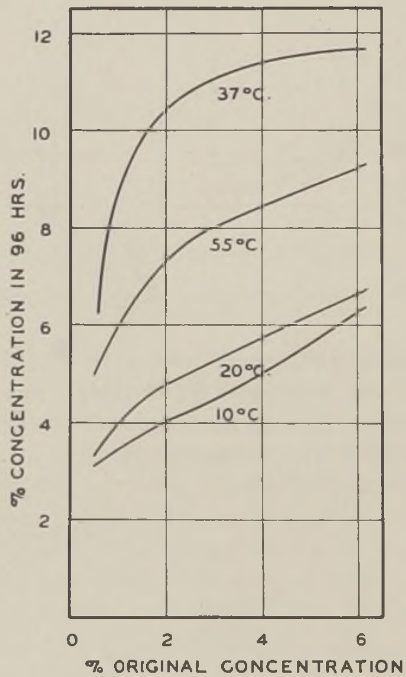

FIG. 2.—Relation between original sludge concentration and compacting at different temperatures, expressed in per cent solids concentration.

centration of sludge continues for a considerable period of time until a maximum concentration between 15 and 20 per cent solids is reached. The time required to reach a maximum concentration for a given type of fresh solids depends primarily upon temperature.

Attention is called to the degree of sludge concentration obtained at 37° C. as compared with other temperatures. Whereas during the first few hours of concentration the compacting increases with rising temperatures, the degree of compacting accelerates at 37° C. with time. Study of the detailed data and plotted curves shows that the relative time necessary for the sludge to reach a certain concentration changes by continuous compacting at the higher temperatures. The time required for the sludge compacting at 37° C. decreases with decreasing concentration, as compared with sludge compacting at 55° C. For instance, the superiority of 37° C. over other temperatures becomes evident after 48 hours, with 0.5 per cent original concentration, but it requires about 80 hours before it becomes pronounced with an original sludge concentration of 6.2 per cent solids.

As might be expected the concentration reached after a given time of compacting at a definite temperature depends upon the initial concentration of the solids. The lower the initial concentration the greater the percentage increase in concentration for a given time. Although the relative increase in concentration during the first 120 hours is materially greater for the lower than for the higher initial concentration, it requires additional time to reach the same final concentration. The additional time required is in proportion to the initial concentration.

If the per cent initial concentration is plotted against the per cent increase in concentration after a definite time a set of curves is obtained, though differing in position for different temperatures; which are all of the same type. This is illustrated in Fig. 3. The shape of the curves indicate

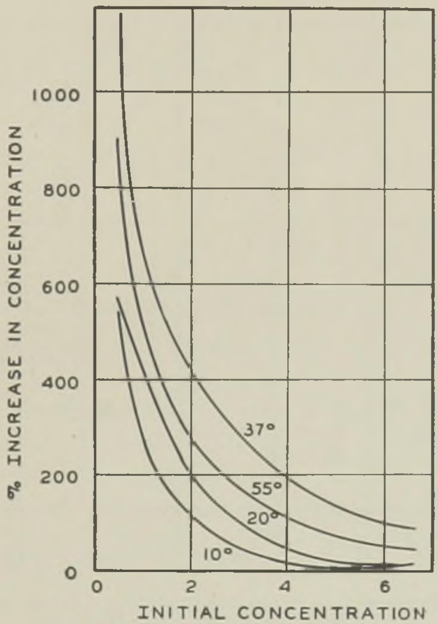

Fig. 3.—Relation between percentage increase in concentration and initial sludge concentration at different temperatures after 96 hours.

that there is a certain definite relationship between the percentage increase in concentration and temperature. As can be expected the lower the initial concentration the greater the percentage increase. It is reasonable to assume that if compacting were allowed to continue for a long enough period, all of the various curves would approach the same value.

If the percentage initial concentration is plotted against log per cent increase, approximately straight lines are obtained (Fig. 4).

From the previously shown curves it is evident that temperature is of considerable importance in the compacting of fresh solids. The importance of temperature increases with time. It also appears that the maximum effect of temperature is exerted in the neighborhood of 37° C. These two observations are more clearly shown by plotting the temperature

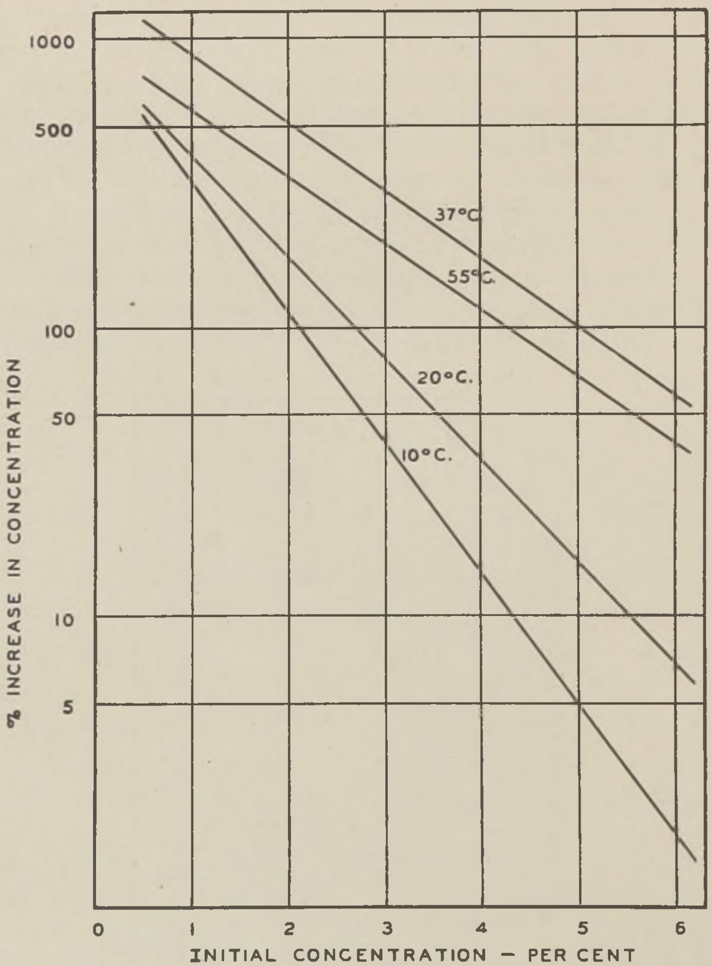

Fig. 4.—Effect of temperature and initial concentration on the percentage increase in fresh solids concentration (after 96 hours).

against per cent solids concentration at specific times of compacting (Fig. 5). Examination of the curves shows that compacting is greatest at 37° C., regardless of the initial concentration. After a period of 120 hours compacting the temperature effect is more pronounced than after 96 hours. Continued time of compacting does not increase appreciably the final concentration at the supposedly optimum temperature of 37° C. At different temperatures compacting continues after 120 hours, but the sludge subjected to these different temperatures does not necessarily reach the same high solids concentration as at 37° C. Other factors, indicated by Hatfield (1), Babbitt and Caldwell (2), Rudolfs and West (3), exert their influences.

The compacting of the sludges takes place at the surface of the liquor. This floating and subsequent compacting appears to be related to the activities of gas-forming organisms. Evidence to support this suggestion is indicated by the fact that some time must elapse before the greater effect at 37° C. is evident, that short-time compaction is greatest at 55° C. and that the compacting at 20° C. requires longer time. It is further indicated by comparing compacting of fresh solids at this temperature with the increase in concentration of ripe sludge (see below).

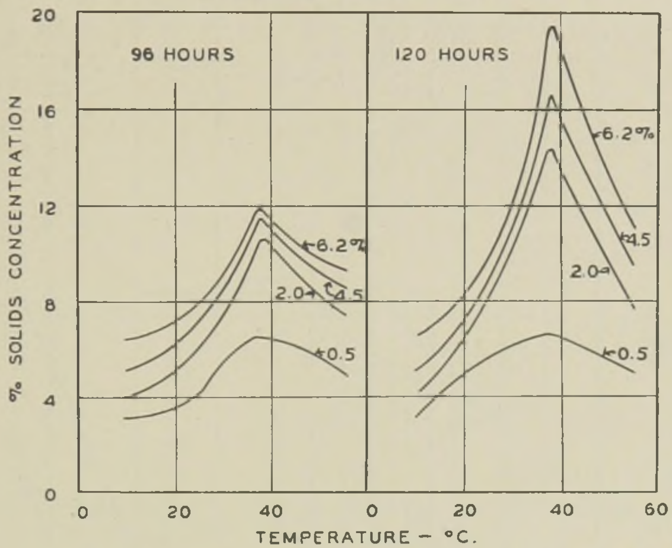

FIG. 5.—Effect of temperature on fresh solids concentration after specific times of compacting.

With increasing temperatures the sludge is lifted more readily to the surface. Gas production (mainly CO_2) increases, aiding in flotation. The gases escape more readily when the sludge is at the surface than at the bottom. Disturbance of the layered sludge becomes less and the sludge continues to concentrate. After some time bacterial action has produced considerable acidic compounds which retards gas formation, leaving the sludge undisturbed. At lower temperatures the rate of gas production is slower, so that it takes longer before the sludge is lifted. Gas formation and acid production may be slow enough to cause only part of the sludge to rise to the surface. Continuous gas production takes place from the sludge at the bottom, which on rising may be trapped in or below the sludge layer at the top, resulting in a slower rate of compacting.

At a higher temperature gas production is so rapid that the sludge may actually expand during the first hours of storage. Escape of the gas is gradual and more time is required for concentration.

Naturally, if the temperature of the sludge is raised sufficiently (cooking) to change the physical character of the sludge a considerably greater degree of sludge concentration may be expected, but the disintegration of sludge particles, together with the separation of grease, produces a liquor entirely different from that obtained by relatively short-time compacting.

When the percentages increase in concentration is plotted against time on logarithmic scales, a number of points fall in a straight line. In general, the curves so obtained may be divided into three phases. The phases are illustrated in Fig. 6 for sludges of various initial concentrations stored at

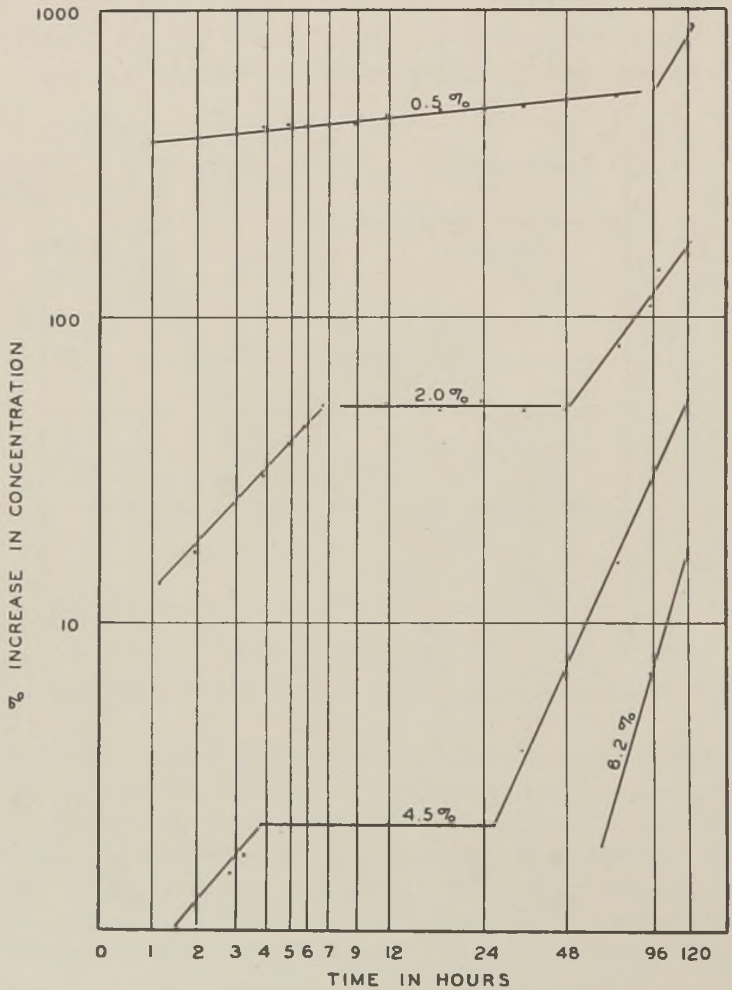

FIG. 6.—Illustration of phases of compacting of fresh solids with different initial concentrations and subjected to storage at 20° C.

20° C. During the first phase a rapid layering or settling of particles takes place, resulting in a greatly increased concentration. The second phase shows a reduced rate of compacting with all sludge on the surface. The third phase indicates the usual rapid rate of compacting of a layered sludge from which gas can be readily expelled and becomes acid enough to retard bacterial action. With increasing initial sludge concentrations the compacting continues but the percentage increase in concentration is slower.

The phenomena observed are not restricted to sludge subjected to 20° C., but are similar at other temperatures. This is illustrated in Fig. 7,

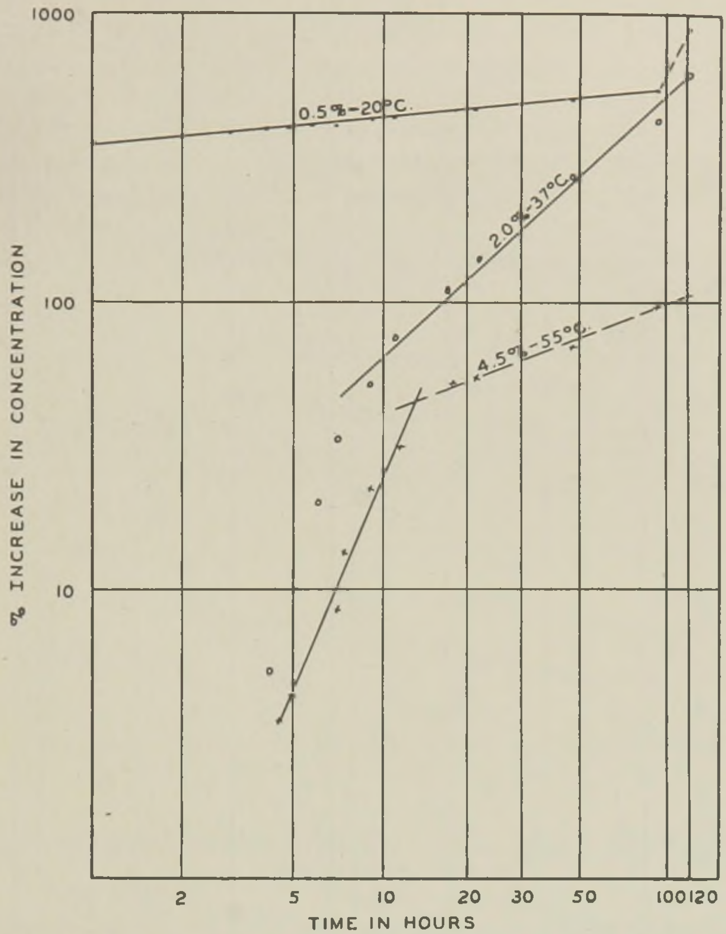

FIG. 7.—Behavior of fresh solids concentrating at various temperatures.

where sections of curves constructed from some results for different sludge concentrations, subjected to various temperatures, are plotted on a logarithmic scale. These illustrations of single experiments do not necessarily represent the actual rates of layering and compacting encountered under all conditions, but are given to indicate the processes involved and the probability of a straight line phase of true compacting. If it is correct that compacting follows a straight line, definite mathematical formulae may be developed.

Ripe Sludge.—The physical character of the sludge is an important factor in compacting. Fresh solids have a jelly-like structure which is destroyed to a great extent by digestion. Although temperature changes the viscosity of the liquor, the character of fresh solids liquor is different from the ripe sludge liquor. One of the primary objects of digestion is to increase the drainability of the sludge, and it may be expected that ripe sludge with the same initial concentration and subjected to the same temperature as fresh solids should compact at different rates. Results obtained with ripe sludges of different initial concentrations stored at definite temperatures for varying lengths of time (Fig. 8) illustrate the

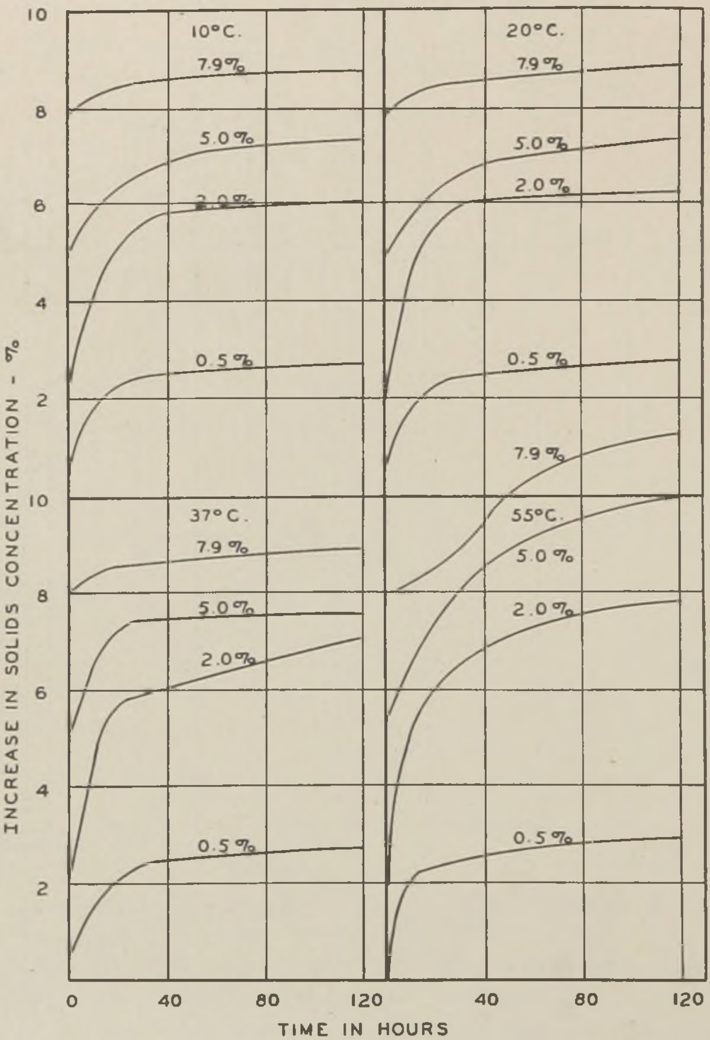

Fig. 8.—Effect of temperature and initial concentration on compacting of ripe sludge.

progress of compacting. There is a certain uniformity in the curves indicating the effect of initial concentration as well as the effect of temperature. The first part of all curves shows a rather rapid rise similar to the increase in concentration observed for fresh solids, followed by a gradual increase of concentration or compacting.

The effect of temperature after 72 and 120 hours' storage is graphically shown in Fig. 9. It is evident that the most pronounced effect is exerted at 55° C. as compared to 37° C. for fresh solids. It is further of interest to note that the effect of the higher temperature is related to the initial sludge concentration. This is better shown when the increase in concentration is plotted against the initial concentration (Fig. 10). The rate of compacting in a given time is highest with the lowest initial concentration, gradually decreasing with increasing initial solids concentration. With increasing initial solids concentration the time factor increases in importance. It appears, therefore, that compacting of ripe sludge is affected by the initial concentration, time and temperature. In practice, where a given concentration is reached in a definite time, temperature becomes a major factor in the rate of concentration or reduction in volume of sludge.

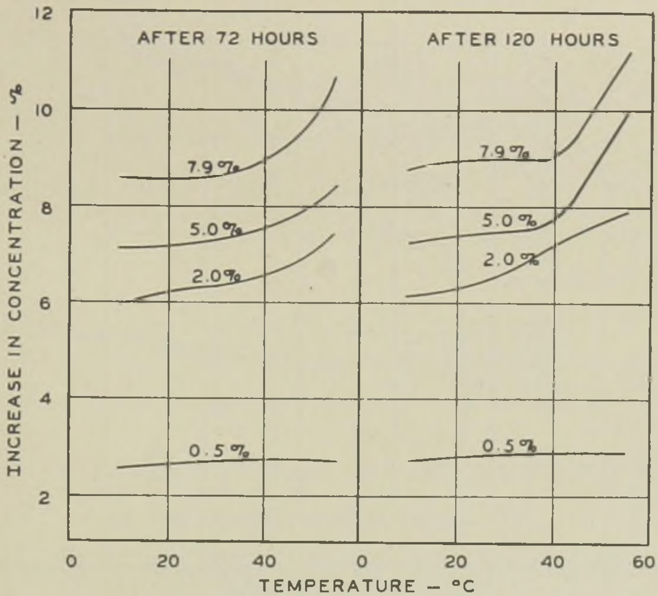

Fig. 9.—Effect of temperature after 72 and 120 hours on compacting of ripe sludge with different initial concentrations.

Gasification of ripe sludge is less than of fresh solids during compacting. Moreover, the physical structure of the ripe sludge has changed, resulting in rapid release of entrained gas; no appreciable acid is formed, hence the mineralized sludge sinks to the bottom. Under such conditions the higher the temperature the greater the rate of compacting, so that ripe sludge will compact better and at a greater rate at 55° C. than fresh solids. This may indicate that the optimum temperature of compacting of ripe sludge is not necessarily at 55° C., but may be higher. Under all temperature conditions the initial concentration of the sludge and time allowed for compacting are important factors.

It is perhaps of greatest interest to the plant operator to know the volume of sludge which may be expected after a given time, when the initial sludge concentration is from 2 to 5 per cent solids and the sludge is held at a certain temperature. Results plotted logarithmically (Fig. 11) show the reduction in volume which may be expected after various times at different temperatures. The reduction in volume increases with temperature in a definite time. Because of the initial sludge concentration factor, sludge of 2 per cent concentration shows a greater volume reduction than a 5 per cent sludge when subjected at the same temperature, but requires additional time to reach the same high solids concentration as the sludge with a greater initial concentration. The actual volumes of sludge with an original concentration of 2 per cent are reduced to about one-quarter of the volume after 120 hours. The volume of sludge with an original concentration of 5 per cent solids is reduced to one-third to one-half in the same length of time, depending upon the storage temperature.

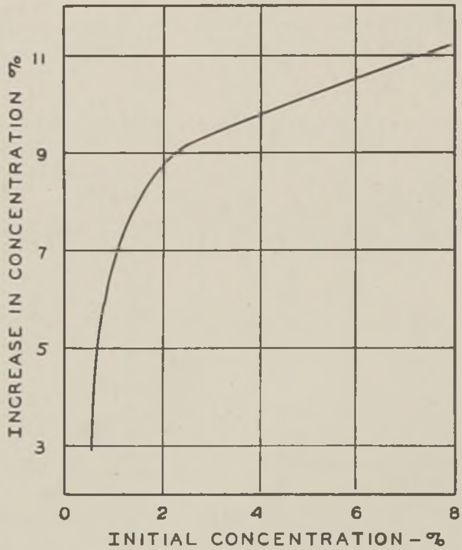

Fig. 10.—Effect of initial concentration on sludge concentration after 120 hours when subjected at 55° C.

Discussion

The rate of concentration of fresh solids and ripe sludge proceeds in related steps and appears to be continuous. Layering, compacting or concentration therefore are essentially the same phenomena as settling, namely, removal of free water. Theoretically there should be no limit to the concentration of solids as long as free water is present. The physical structure of the solids or the character of the material determines the quantity of water which is held, but the rate of water removal is affected by environmental factors. In the early stages of settling and compacting the original concentration of the solids is important, with increasing importance to be assigned to temperature as compacting proceeds. During the entire period of settling and compacting, the time factor is essential, hence the longer time is allowed the greater the settling and concentration. After a maximum concentration of solids, under practical time limits, the remaining free water must be removed by spreading the sludge in relatively thin layers over a porous medium. Temperature continues to play a role in dewatering. To increase the rate of water removal chemicals are used to bring the dispersed particles together and allow more water to drain. During the early stages of settling and compacting, dispersed particles also come together and it appears therefore that settling, layering, compacting and dewatering are terms indicating differences in rates of concentration. If this is correct, mathematical formulae for settling are applicable to concentration of sludge and formulae for compacting can be used for settling. All that is required is a change in the value expressing the rate or the magnitude of the constant.

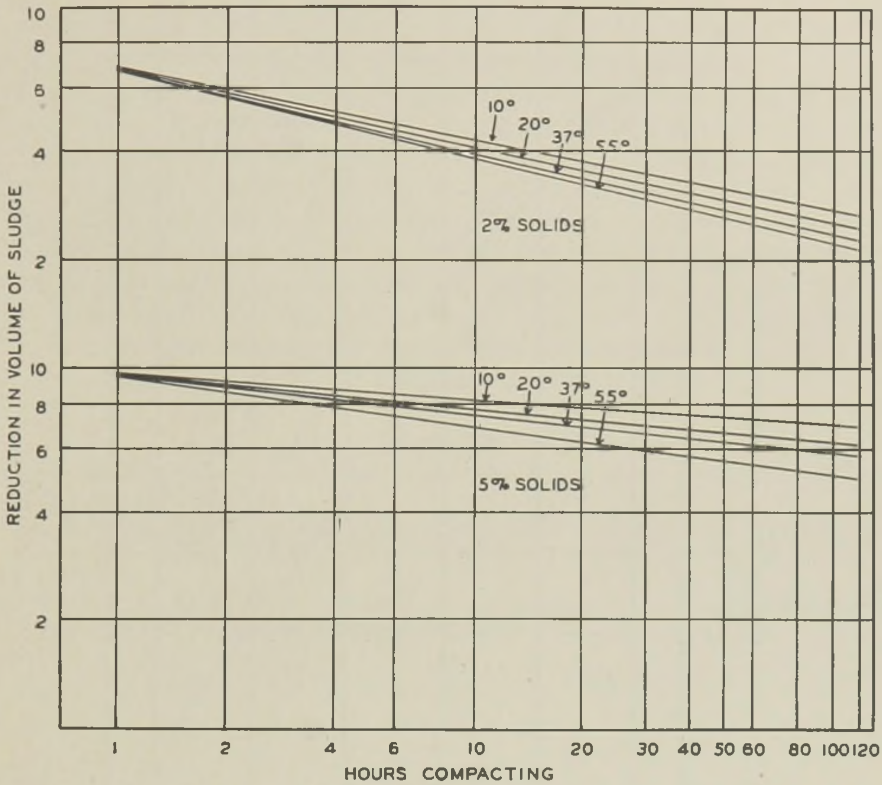

FIG. 11.—Compacting of ripe sludge on storage.

The fact that fresh solids compact at a different rate than ripe sludge or activated sludge, is attributable to the character or water-holding capacity of the sludge. It can be expected therefore that the effect of temperature on ripe sludge concentration is less than on fresh solids or activated sludge. Since the nature and size of the ripe sludge particles are more uniform than fresh solids, the effect of temperature should be more uniform.

The effects of temperature, time of compacting and initial concentration of sludge are similar for ripe sludge and fresh solids. Because the reduction in volume of sludge increases with temperature in a definite time, it may be expected that the volume of fresh solids retained in settling tanks for equal periods of time will be smaller in summer than in winter, unless the storage time is prolonged to such a degree that gas expansion of the fresh solids takes place. The gas expansion will then result in floating of sludge. Floating of sludge may be a desirable method of compacting for ultimate sludge disposal, but becomes detrimental to purification of the liquor when allowed in settling tanks.

The rate of compacting of fresh solids under varying temperature conditions is different from the rate of compacting of ripe sludge. A comparison of compacting of ripe sludge and fresh solids at two different

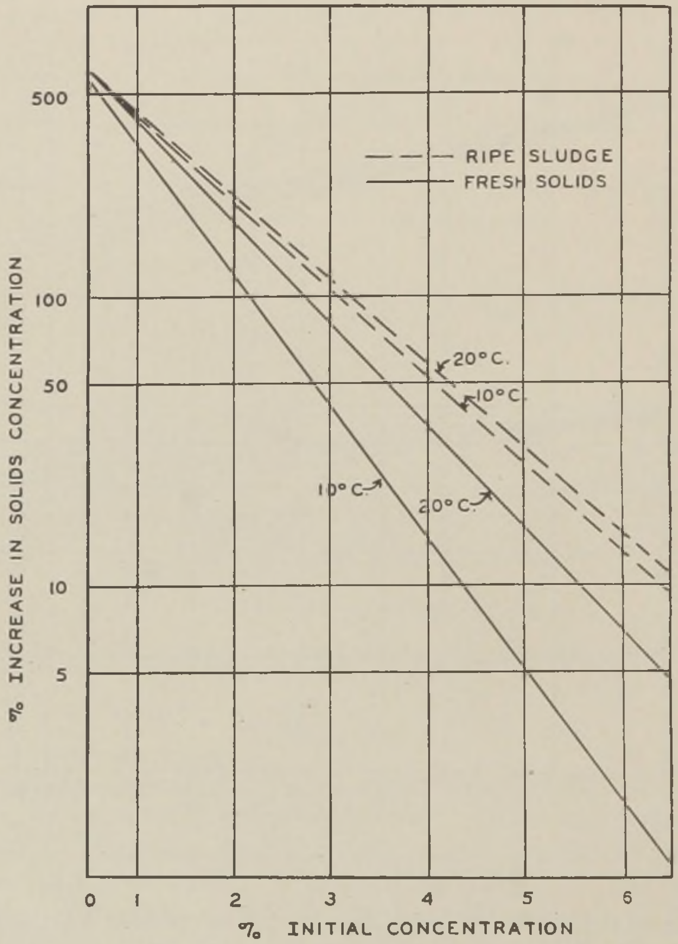

Fig. 12.—Comparison of fresh solids and ripe sludge concentration at two temperatures after 96 hours storage.

temperatures (Fig. 12) illustrates this and also indicates what may be expected when fresh solids and ripe sludge are left quiescent.

Ripe sludge stored for compacting does not float like fresh solids, even on prolonged storage. Sludge digestion systems, where the sludge is digested in one tank and stored for after-digestion and compacting in another, will be able to produce denser sludge than single digestion storage units. Unfortunately, the digestion capacities required are frequently calculated on the total digestion and storage capacity available. This may lead to rather violent disturbance in the digester on account of gasification and little if any separation of liquor from the sludge, so that a thin sludge is discharged to the secondary tank, requiring additional time for compacting.

Pre-heating of sludge before discharge into digesters as a method to increase the rate of digestion has been practiced. The possibility of pre-heating thin sludge to induce liquor separation may be of interest.

Summary

Studies were made to determine the effect of temperature on the compacting and concentration of fresh solids and ripe sludge. Sludge concentration is considered to be the same phenomenon as settling, layering, compacting or dewatering. Sludge concentration is primarily affected by the character of the sludge, its initial concentration, time and temperature. With increasing temperatures the rate of compacting increases. Fresh solids compact at a different rate than ripe sludge. Gas formation during storage of fresh solids is a factor. Within the limits of temperature tried, the optimum temperature for fresh solids concentration appears to be in the neighborhood of 37° C. and for ripe sludge 55° C. The temperature effect is more uniform for ripe sludge than for fresh solids. Fresh solids float but continue to compact, whereas ripe sludge sinks.

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THE OPERATOR'S CORNER

Conducted by W. H. WISELY, Executive Secretary*
Federation of Sewage Works Associations
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THE SECOND WARTIME SANITATION CONFERENCE—AN ESSENTIAL MEETING

When the Fourth Annual Meeting of the Federation convenes at Chicago's Hotel Sherman on October 21, what a difference there will be from the First Annual Meeting held at the same place in October, 1940—just three years ago! The initial meeting was held in time of peace, at least in the U. S.; the 1943 meeting will be pervaded by the theme of war, for this is to be a Wartime Sanitation Conference in every respect. Many old friends, away in military service, will be missed, while just as many new members will be attending and profiting by the 1943 Conference. Only in enthusiasm will there be a parallel between the two gatherings since the Federation is still advancing from the impetus of the revitalization which came from the 1940 meeting.

By this time, there has been opportunity for everyone to review the program, designed by Chairman Gilcreas and his committee to include the myriad of new problems that have confronted the sewage works field under the conditions of war. The timely topics and the array of recognized leaders who will present them offer more than adequate evidence that the 1943 Wartime Sanitation Conference will be worth attending. All federal war agencies consider the provision of adequate sanitation service to be essential to the war effort—your attendance of the Conference will aid you in improving such service to your community in spite of the many difficulties of the times!

It is most apparent that much civilian travel today is non-essential in character. When you are enroute to the Conference at Chicago, you may certainly consider that there is real justification for the transportation space occupied. At the same time you will be co-operating with the O.D.T. and will enhance your trip by making early space reservations, doing your traveling between Tuesday and Friday of each week, and by not carrying excessive baggage. The exchange of information, new knowledge and relaxation which will accrue from attendance of the Federation's Second Wartime Conference will more than offset the minor traveling inconveniences which may be involved.

* Also Engineer-Manager, Urbana and Champaign (Ill.) Sanitary District.

SUMMARY OF EXPERIENCE IN DIFFUSED AIR ACTIVATED SLUDGE PLANT OPERATION

This review of activated sludge plant control practice is based upon data and comments furnished by some 25 hardy plant superintendents and chemists, who, even in these "questionnaireable" days, found the time to set forth their procedures in a most detailed blank form. The complete co-operation of the following contributors is gratefully acknowledged:

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Wheeler, C. E., Jr., Engineer of Operation (Calumet Plant), Chicago, Illinois

It is with some trepidation that this topic is undertaken for study as part of the program of *The Operator's Corner* to review actual operation procedures in all sewage treatment processes, in the light of the recent comprehensive report on activated sludge plant operation and control compiled by Langdon Pearse, *Chairman*, and the Sewage Disposal Committee of the American Public Health Association (see *This Journal*, **14**, **3** (January, 1942). It is intended here to present additional data and comment on practical methods of controlling the principal operating variables, thus supplementing in modest fashion the elaborate Committee Report referred to above. Only diffused-air activated sludge plants are represented in this study; practice in mechanical aeration plants is planned to be presented later.

Insofar as the operator is concerned, there are five primary variables over which control can be exercised in an activated sludge plant.

1. Concentration of mixed liquor solids.
2. Rate of sludge return.
3. Rate of air application.
4. Aeration period.
5. Condition of the sludge.

These variables must be correlated into balance under the local conditions of load imposed upon each individual plant, and varied to meet seasonal and other fluctuations in load. Furthermore, the operator must view the variable factors as being interdependent, in the sense that any adjustment made in one of them may require manipulation of one or more of the others.

As a preliminary to the operation practices followed in the plants contributing to this summary, general data concerning each are given in Table I. It will be noted that a wide range in size, type, design and loading is represented.

Table I.—*General Information Regarding Contributing Plants*

Plant	Average Flow (M.G.D.)	Average Primary Sedimentation Period (Hr.)	Aeration		Average 5-Day B.O.D. Raw Sewage (p.p.m.)
			Type	Aeration Period (Hr.)	
Chicago (Calumet)	85	0.25	Spiral	4.0	93
Elyria, Ohio	2.5	1.67	Spiral	5.5	353
Findlay, Ohio	2.3	3.1	Spiral	5.5	405
Ft. Wayne, Ind.	17.6	1.3	Spiral	8.6	199
Hackensack, New Jersey	3.2	3.2	Comb. (1)	12.0	200
Indianapolis, Ind.	53.3	None	Spiral	8.4	272
Lancaster, Pa. (North)	3.3	2.9	Spiral	13.7	209
Lima, Ohio	7.7	1.4	Spiral	4.8	134
Mansfield, Ohio	3.1	2.3	Comb. (1)	7.4	237
Muskegon Hts., Mich.	1.2	3.1	Comb. (1)	6.3	322
New York (Wards I.)	184	1.2	Spiral	4.5	167
North Toronto, Ont., Can.	7.3	2.0	Spiral	6.0	280
Omaha, Nebr.	3.3	2.0	Sw.D. (2)	7.5	241
Pasadena, Calif.	9.5	None	Sp. & R.F. (3)	6.9	151
Pomona, Calif.	1.7	—	F.D. (4)	8.3	—
Pontiac, Mich.	4.2	0.9	Spiral	5.0	208
Rockville Centre, N. Y.	2.3	0.8	F.D. (4)	4.4	292
San Antonio, Tex.	22	0.5	Spiral	5.9	225
Springfield, Ill.	8	2.0	Spiral	8.7	165
Tenafly, New Jersey	0.7	—	Spiral	7.3	144
York Twp., Can.	3.1	None	Spiral	4.3	—

(1) Combination diffused air and paddles.
(2) Swing diffusers.
(3) Both spiral and ridge-and-furrow tanks.
(4) Fixed diffuser tubes.

Concentration of Mixed Liquor Solids

Most authorities regard control of the mixed liquor solids concentration, accomplished by apportionment of the activated sludge from the final settling tank between return and waste, as the most important of all operating variables. Certainly the recognition of this fact in recent years, with the resulting trend toward reduction of mixed liquor solids from the very high values formerly carried, has marked a notable advance in control practice.

Table II lists the average and range in mixed liquor solids carried in the aeration tanks of 21 plants. Thirteen of the plants reported show average

TABLE II—*Mixed Liquor and Return Sludge Control*

Plant	Mixed Liquor Solids (P.P.M.)		Return Sludge		Average Sludge Index
	Average	Range	Ave. Return Rate (%)	Ave. Solids (P.P.M.)	
Chicago (Calumet)	2,850	1,720–3,870	22	15,700	45
Elyria, Ohio	2,270	700–3,600	29	11,600	52
Findlay, Ohio	1,500	500–4,000	26	5,000	150
Ft. Wayne, Ind.	2,320	1,400–4,100	27	9,700	111
Hackensack, N. J.	1,600	900–2,500	23	10,000	130
Indianapolis, Ind.	2,500	400–3,700	41	8,000	98
Lancaster, Pa. (North)	3,100	2,700–3,600	31	13,800	49
Lima, Ohio	1,720	1,140–3,110	33	7,200	92
Mansfield, Ohio	1,040	940–1,140	20	3,650	346
Muskegon Hts., Mich.	900	400–2,000	41	4,300	100
New York (Wards I.)	1,770	1,075–3,050	45	4,775	170
North Toronto, Ont.	2,300	1,500–3,500	19	13,500	93
Omaha, Nebr.	1,685	1,240–2,300	45	4,320	74
Pasadena, Calif.	1,100	980–1,340	12	6,700	189
Pomona, Calif.	—	—	—	—	—
Pontiac, Mich.	2,500	2,000–3,000	20	—	125
Rockville Centre, N. Y.	730	410–1,084	3.5	26,700	40
San Antonio, Tex.	1,500	—	42	4,200	210
Springfield, Ill.	1,750	725–2,500	30	6,500	121
Tenafly, N. J.	2,340	2,120–2,670	34	12,550	103
York Twp., Toronto, Can.	570	370– 800	38	—	—

concentrations of 1,500 to 2,500 p.p.m. to be used; at only three is the average less than 1,000 p.p.m. Four plants are also shown to average concentrations over 2,500 p.p.m., with the highest value (3,100 p.p.m.) at Lancaster, Pennsylvania. The variation in aeration solids carried, as indicated by the range in each plant, is interesting because the difficulty of close control is illustrated.

With the exception of one or two cases reported, it will be noted that lower sludge indices are achieved where mixed liquor solids in the higher ranges are carried and that higher sludge indices seem to accompany low mixed liquor solids values. This possibly indicates that sludge of better settling characteristics and higher density is usually obtained in the mixed liquor solids range of 2,000 to 3,000 p.p.m. than at lower concentrations, substantiating the general belief that more stable operation under shock loads is to be expected in the higher range.

At Calumet (Chicago), Wheeler endeavors to hold 2,500 to 3,000 p.p.m. of mixed liquor solids, although the upper limit is often exceeded during and following storms when the ash content of the sludge increases. It is considered desirable to hold the volatile solids content of the mixed liquor above 1,500 p.p.m. in this plant. Brunner at Fort Wayne is also primarily interested in the volatile content rather than the total suspended solids in the mixed liquor, reporting as follows:

"Control of the mixed liquor solids is maintained at 1,500 p.p.m. volatile solids rather than any optimum value of suspended solids. It is necessary to run on this basis because of frequent slugs of river water which bring in fine silt and thus add weight to the solids. If we were to waste on the basis of a 2,000 p.p.m. suspended solids level during these periods, we would not have much active sludge in the mixed liquor."

At Indianapolis, Bloodgood has found it desirable to carry the highest mixed liquor solids concentration possible with the amount of air available:

"It is our belief that more solids can do more work if adequately supplied with air. Every effort is made to keep the mixed liquor solids at a uniform concentration so as to eliminate the piling up of solids in any particular part of the plant. The solids are determined daily from composite samples and the amount of sludge to be wasted is gaged from the concentration found to be present."

Andersen at Rockville Centre, N. Y. (Fig. 1), at which plant the activated

Fig. 1.—View of aeration tanks at Rockville Centre, N. Y. Blower house at right.

sludge treatment is followed by mechanical filtration of the effluent, defines the optimum mixed liquor concentration as "only that quantity (of solids) requisite to purify properly the sewage, while also insuring an excess of oxygen to maintain the health of the biological life." A very active sludge is present in this plant, averaging 88 per cent volatile solids. Operating conditions are also unusual in that an extremely dense return sludge (27,000 p.p.m. solids) prevails in normal operation. Under these conditions of balance, it has been possible to eliminate the effluent filtration for the past eight months with "the sludge index, settling of solids and sludge production stabilized to an apparently foolproof extent."

Larson (Springfield, Ill.) and Lehmann (Hackensack, N. J.) refer to the common need for adjustment of the mixed liquor solids to seasonal variations. Comparison of practice in these two plants, however, furnishes an excellent example of the effect of local conditions on plant control. Heavy loads received for treatment at Hackensack in summer months require about 2,000 p.p.m. of mixed liquor solids concentrations as against 1,600 p.p.m. in winter. At Springfield, higher volatile matter percentages in summer permit some reduction in the suspended solids carried. Turner (Mansfield, Ohio) (Fig. 2) checks occasionally for varying trends by trying

Fig. 2.—Sewage treatment works at Mansfield, Ohio. Primary settling tank at right.

lower and higher concentrations but thus far has always returned to a value of about 1,000 p.p.m.

Physical features of plant design may limit the flexibility of solids control, as at Muskegon Heights, Michigan, where the air capacity and sludge return facilities are critical. Superintendent Anderson states:

> "The solids concentration is governed by the load received from the primary tanks, dissolved oxygen in the final settling tanks in comparison with that in the last aeration tank, nitrate production and to a large extent upon our sludge withdrawal facilities. The latter have never permitted carrying more than 2,000 p.p.m."

Allen at Pasadena gives primary attention to the concentration of solids in the return sludge and finds that the mixed liquor solids concentration is controlled incidentally. His experience indicates 6,500 to 8,000 p.p.m. of return sludge solids results in best operation with about 1,200 p.p.m. of mixed liquor solids. Return sludge solids are estimated twice daily by centrifuge determinations.

Based on the experience represented here and some reference to the A.P.H.A. Committee Report noted previously, the following summarizing comments regarding mixed liquor solids control are offered:

1. Concentrations of 1,500 to 2,500 p.p.m. of suspended solids in the mixed liquor appear to constitute general practice, although values above or below this range are often encountered where plant limitations and unusual local conditions are involved.

2. There appears to be an increasing trend toward recognition of the volatile matter content of the mixed liquor solids as a control factor rather than the suspended solids. This appears logical since the volatile matter is actually the active constituent of the sludge. A minimum volatile solids concentration of 1,500 p.p.m. is recognized as a control threshold in two of the plants represented.

3. It is suggested that there be no hesitancy in varying the mixed liquor solids to meet seasonal variations in load and temperature.

4. The importance of keeping the mixed liquor solids concentration within any limitations imposed by the air supply is emphasized. Proper operation cannot be obtained when the solids content is so high that the available air supply is inadequate to maintain an aerobic environment.

5. While low concentrations of solids may result in economy of power (for air supply) the volatile content and activity will be high whereas high solids concentrations usually yield less active but denser sludges which are more conducive to stable operation under shock loads and afford a somewhat higher degree of purification.

6. The rate of activated sludge accumulation or build-up is usually greater when the mixed liquor solids concentration is in the low range; the resulting high volatile content is desirable from a fertilizer production standpoint but entails closer control in avoiding septicity during compaction in the final settling tank.

7. High mixed liquor solids concentrations are ordinarily advantageous from the sludge disposal standpoint, since part of the volatile matter is oxidized during the aeration process and the greater stability of the sludge permits it to be concentrated to a lower moisture content before waste to disposal facilities.

Rate of Sludge Return

The rate at which the activated sludge is returned to the aeration tanks generally determines the condition of the sludge. Too low a rate of return may result in septicity and consequent bulking and other evils; too high a return rate may not allow sufficient time for concentration in the final settling tank and thus results in a light, voluminous sludge, creating problems in disposal of the excess going to waste. Obviously, the rate of return is important as regards mixed liquor solids control and a balanced procedure must be achieved.

Rates of return (expressed as percentages of the sewage flow), with return sludge suspended solids data, are listed in Table II. Of the 21 plants listed, 8 employ return rates between 20 and 30 per cent, 10 employ rates between 30 and 45 per cent and only 3 return at rates under 20 per cent. The very low return rate of 3.5 per cent practiced at Rockville Centre is largely explained by the very high solids concentration of 26,700 p.p.m. in the return sludge. In winter, the solids concentration becomes as high as 35,000 p.p.m.—a remarkable condition when the unusually high volatile content (88 per cent in mixed liquor) is considered.

Examination of the return sludge suspended solids data contained in Table II indicates that it is difficult to determine a "normal" range. Nine of the plants achieve return sludge concentrations of 4,000 to 8,000 p.p.m. and seven plants report average values between 10,000 and 15,000 p.p.m. As is to be expected, it will be noted that the concentration of return sludge solids is generally, although not always, lower at the higher rates of return.

The A.P.H.A. Committee Report includes an interesting analysis of return sludge practice in the data showing the "ratio of return solids to incoming solids at aeration tanks" (*This Journal*, **14**, 23 (January, 1942)). Ratios between 10 : 1 and 39.6 : 1 are shown for eleven plants; however, seven of these plants reported ratios between 10 : 1 and 20 : 1. These figures may possibly be better visualized if regarded as "pounds of suspended matter returned as activated sludge per pound of suspended matter in the sewage received for treatment at the aeration tank."

In his regulation of the rate of sludge return, the operator is almost always guided by the depth of accumulation or sludge blanket in the final settling tanks. Too deep a sludge blanket may result in septicity of the sludge and upset of the biological balance; too shallow or no blanket may yield a thin, poorly concentrated return sludge. Seasonal changes in temperature and volatile content of the sludge often necessitate variation in the return rate.

At Fort Wayne, Brunner gives much credit to the air-lift bubbler piping (Fig. 3) which affords a constant indication of the sludge depth in the final

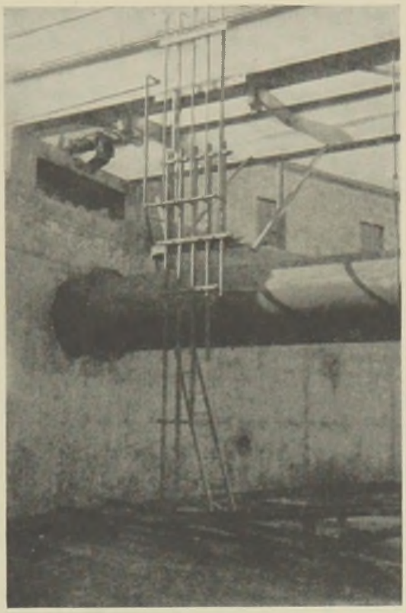

Fig. 3.—Air-lift bubbler for sludge blanket determination in final settling tanks at Fort Wayne, Ind.

settling tanks at that plant. An excessively deep sludge blanket due to bulking or insufficient return is revealed immediately by the bubbler system and the return rate is increased accordingly. Automatic sludge level indicators utilizing photo-electric cells have been employed with varying degrees of success.

Lehmann at Hackensack considers the sludge blanket level as a most important control and makes hourly observations for the purpose of return sludge flow regulation. Particularly close supervision of the sludge blanket is also necessary at Pasadena, where generally high temperatures and high volatile matter content induce rapid septicity in the sludge accumulation if held too long in the final settling tank for thickening. Similar difficulty is experienced at Omaha, where packinghouse wastes and surges of septic sewage solids from the combined sewers after rains create a problem. Ahrens reports that increased rates of sludge return at such times maintain the sludge in better condition and are beneficial in freshening the mixed liquor. This not uncommon practice of returning sludge at very high rates to smooth out shock loads is suggestive of the recirculation theory as applied to modern trickling filter treatment—concentration of the return sludge being sacrificed for the dilution effect of the effluent in which the sludge is suspended. The thin return sludge, however, introduces other problems in connection with waste and disposal.

Smith at Lima employs an increased sludge return rate at the apparent onset of bulking of sludge, which common operation difficulty will be discussed in more detail later. A semi-automatic return sludge rate controller has been developed at the Lima plant, by adapting a weighted plug valve to the return sludge pump discharge piping. The arrangement is shown

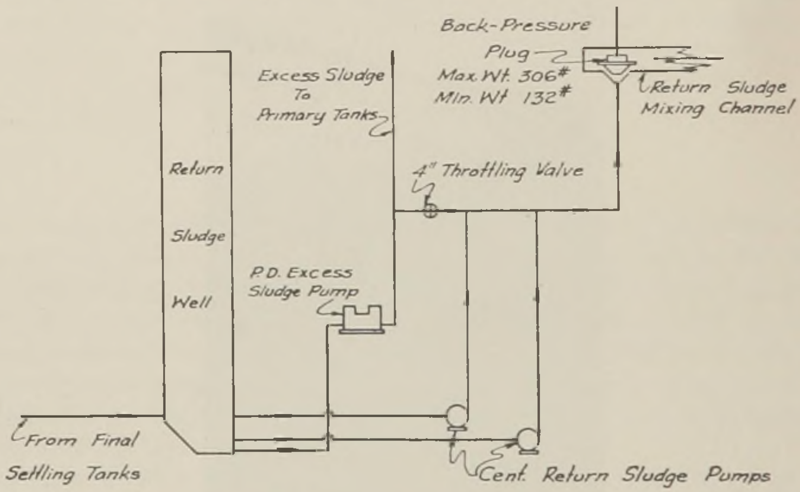

FIG. 4.—Diagram of return and excess sludge control arrangement at Lima, Ohio. E. E. Smith, Superintendent.

diagrammatically in Fig. 4 and its operation is described by Smith as follows:

"A 4-inch valve in the return sludge pump header continuously discharges excess activated sludge to the primary settling tank for removal from the secondary system. The amount of such excess sludge is affected immediately by a back-pressure plug (Fig. 4) in the discharge of return sludge to the mixed liquor channel and *generally* by the settling rate of aerated sludge in the final settling tanks through control of the suction lift of the return sludge pump. Specifically, operating directions call for the individual sludge discharge valves between the final settling tanks and the return sludge well to be throttled at all times sufficiently only to hold the sludge line in the final settling tanks at the edge of the vertical side-walls, maintaining the three foot cone in the final tanks full of sludge. If the rate of settling increases (or, conversely, the hourly percentage settling decreases) the more compact sludge will require less volume in the return and excess flows, the opposite conditions obtaining with a slower settling sludge.

"The back-pressure plug in the return sludge discharge, with empirically determined amount of weight will proportion the excess flow according to the rate of return and, indirectly, the sludge settling rate. Operating directions also call for some correction when the solids in the aeration effluent exceed a set figure. Thus, for the summer of 1941, when the solids in the aeration effluent exceeded 1,500 parts per million, the 4-inch return sludge bleeder valve was closed and the 50 g.p.m. excess sludge diaphragm pump operated for the three-hour period between 5:00 and 8:00 a.m. the day following that on which the determination of aeration effluent suspended solids was made. This three hour pumping seemed to be sufficiently in excess of the normal production of secondary solids so that no great deviation from the desired amount of solids followed such procedure.

"The arrangement may be called semi-automatic control of mixed liquor solids, as the system involves no effort on the part of the superintendent to make any detailed schedule of excess pumping as such. During the earlier part of the year when run-off provided a weaker combined sewage, the setting of 1,000 p.p.m. for aeration effluent was easily obtained by increasing the weights on the return sludge discharge plug. In addition to relieving the operators from the necessity of guessing at the number of hours of excess sludge pumping, this system has the following advantages:

"(1) Nearly eliminates the operation of the excess sludge pump, with its eight rubber diaphragms and four rubber ball valves, avoiding their maintenance.

"(2) Greatly reduces power for direct excess sludge pump motor operation, saving about $10.00 per month.

"(3) Has an apparent beneficial effect on primary settling, in that acting as a coagulant, the results from adding continuously small amounts of excess activated sludge are preferable to adding the same volume over shorter periods."

Rate of Air Application

Maintenance of aerobic conditions throughout the activated sludge process (aeration and final sedimentation) is essential to proper operation. Since the provision of an adequate air supply at suitable pressure almost always constitutes the principal operation cost item, the operator must exercise such control of air application that there is a sufficient quantity to afford stirring of the mixed liquor with a residual of dissolved oxygen in the mixed liquor during aeration, but to avoid the waste of power, undesirable changes in the activated sludge and over-nitrification of the effluent which occur when the air application is excessive.

The quantities of air applied in the plants represented in this review of operation practice are shown in Table III, and are expressed in cubic feet per gallon of sewage treated as well as cubic feet per pound of 5-day B.O.D. removed. The latter unit is rapidly gaining favor among operators as being most informative and more indicative of the manner of air utilization. Of the plants listed, nine show air requirements of 350 to 850 cu. ft. per pound B.O.D. removed and at only two, Omaha and Rockville Centre, is it found that more than 1,500 cu. ft. is required. The maximum application of 2,180 cu. ft. per pound B.O.D. removed at Rockville Centre may be explained by the intensely dense and active return sludge, which has been commented upon previously. In reviewing these data, it must be kept in mind that strict economy of air application is not so essential at plants equipped with sludge gas engine operated blowers such as at Findlay (Fig. 5), Ft. Wayne, Omaha, Rockville Centre, Springfield and others, in which circumstances liberal quantities of air may be used.

On the basis of the sewage volume treated, the average air application values in Table III range from 0.35 to 2.0 cu. ft. per gallon, with fairly general distribution between these limits. The variation in applied air in

Table III—*Applied Air Quantities and Mixed Liquor Oxygen Content*

Plant	Applied Air (Cu. Ft.)			D.O. During Aeration (P.P.M.)		
	Per M. G.		Ave. Per Lb. B.O.D. Removal	Inlet	Midpoint	Outlet
	Average	Range				
Chicago (Calumet)	0.35	0.22–0.52	500	—	—	1.5–5.0
Elyria, Ohio	0.94	0.65–1.55	1290	—	—	—
Findlay, Ohio	0.70	0.30–1.00	840	0	1.0	3.0
Ft. Wayne, Ind.	0.99	0.49–1.65	835	0.8	2.0	5.2
Hackensack, N. J.	0.60	0.41–1.10	640	0–3.0	0.5–3.0	0.5–3.0
Indianapolis, Ind.	1.78	0.83–4.80	1020	—	—	2.0+
Lancaster, Pa. (North)	0.70	0.50–0.90	830	1.8	—	5.2
Lima, Ohio	0.99	0.45–1.52	1415	2.2	5.0	4.9
Mansfield, Ohio	0.37	0.21–0.40	370	—	—	2.9
Muskegon Hts., Mich.	0.47	0.29–0.57	345	0	1.0	2.3
New York (Wards I.)	0.57	0.38–0.75	470	—	—	3.4
North Toronto, Ont.	1.00	0.70–1.30	620	—	—	—
Omaha, Nebr.	1.36	1.02–1.86	1650	—	—	3.2
Pasadena, Calif.	1.62	1.47–1.89	1450	—	—	3.8
Pomona, Calif.	1.80	0.95–3.00	—	—	—	3.0
Pontiac, Mich.	1.10	—	1470	—	—	5.0
Rockville Centre, N. Y.	2.00	1.70–2.30	2180	Tr.	1.5	2.5
San Antonio, Tex.	1.34	—	970	—	—	—
Springfield, Ill.	0.75	0.43–1.10	950	2.0	4.0	6.0
Tenafly, N. J.	1.47	0.90–2.30	1295	—	—	—
York Twp., Toronto, Can.	1.70	1.60–1.90	—	4.6	2.7	2.7

each of the plants is not entirely due to manipulation by the operator because the unit "cubic feet per gallon" is subject to variations in the rate of sewage flow received for treatment. Comparison of the cubic feet per gallon values with the figures representing cubic feet per pound B.O.D. removed in the plants at Chicago Calumet, North Toronto, Omaha and San Antonio will indicate clearly how misleading the former basis of expressing air application may be.

The concentration of dissolved oxygen in periodically collected samples of mixed liquor is the most commonly employed control for determination of the adequacy of air application (Table III). The frequency of such mixed liquor sampling and dissolved oxygen determinations varies from 1 to 12 times daily, with most operators using a routine 4-hour schedule. From Table III it will be observed that many operators determine the mixed liquor dissolved oxygen content at the inlet and midpoint of aeration as routine control in addition to D.O. determination at the aeration tank outlet. Brunner at Ft. Wayne supplements his 12-hour aeration tank effluent sampling routine with a dissolved oxygen survey through each aeration tank at least once a month.

The mixed liquor dissolved oxygen data in Table III illustrate the progressive increase in residual oxygen which is nearly always found to occur during aeration. Although it is not uncommon to find a complete absence of dissolved oxygen at the aeration tank inlet, it is generally held desirable for some residual to be present throughout the entire aeration period. Residual oxygen must certainly be present at the midpoint of the aeration period if normal results are to be obtained. The midpoint oxygen concentration is considered the primary control at Toronto.

It has been demonstrated experimentally and in practice that a normally active sludge uses, in the first two hours of aeration, about 50 per cent of the total amount of air it requires. This finding constitutes the basis for the practice of tapered aeration, whereby air application is heaviest at the inlet end of the aeration units and gradually reduced to a minimum at the outlet end. Most of the larger plants do not employ tapered aeration although the principle has many enthusiastic supporters.

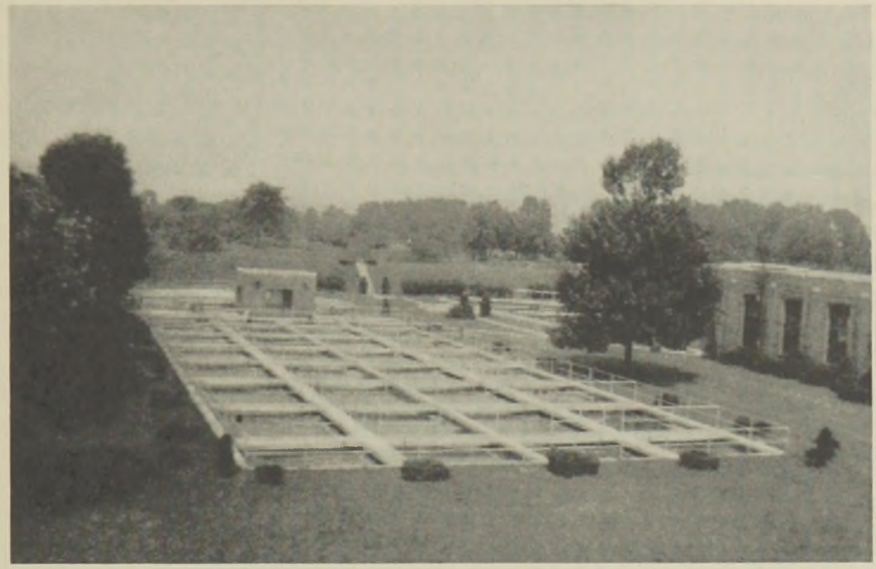

Fig. 5.—Activated sludge plant at Findlay, Ohio.

In controlling air application by means of the dissolved oxygen content of the aerated mixed liquor, Lehmann at Hackensack seeks to maintain from 1.0 to 2.0 p.p.m. and makes adjustment on the basis of observations every two hours. Such unusually close control appears to be required by a sensitive activated sludge which affords a narrow margin between under and over-aeration. At Omaha, Ahrens considers 1.5 p.p.m. as the lowest desirable dissolved oxygen limit. A minimum of 2.0 p.p.m. appears to be the most commonly recognized control value and is employed at Ft. Wayne, Indianapolis and other plants. Wheeler at Chicago (Calumet) encounters seasonal factors which lead to the use of a 1.5 p.p.m. control in summer and 2.0 p.p.m. in winter. At Wards Island Edwards finds it desirable to have about 5.0 p.p.m. at the aeration tank outlets at all times.

The dissolved oxygen content of the plant effluent is, of course, a most important item and is often recognized as the principal control, as at Lima, or is considered in conjunction with the mixed liquor oxygen concentration, as at Ft. Wayne, Wards Island and Omaha. At Lima, Smith attempts to maintain at least 3.0 p.p.m. of dissolved oxygen in the plant effluent and finds that 3.5 to 4.0 p.p.m. must be held in the aerated mixed liquor to achieve the desired end result.

Brunner (Ft. Wayne) and Turner (Mansfield) direct attention to the particular significance of mixed liquor dissolved oxygen determinations made at critical flow periods during the day. Turner is guided entirely in adjustment of air application by the decrease in dissolved oxygen which occurs during the peak load period of 10:30 A.M. to 2:00 P.M. If the dissolved oxygen drops as much as 75 per cent in this time, air application is increased; if the drop is as low as 50 per cent, less air is used. This procedure appears to have particular merit where shock loads are received.

Where there is poor flexibility of air supply, as at Elyria, or inadequate blower capacity as at Muskegon Heights, the mixed liquor oxygen content can be controlled only by variation of the concentration of mixed liquor solids carried. Barton (Findlay) and Rhoads (Lancaster) find it desirable to maintain a constant rate of air application and to make adjustment only by increasing or decreasing the mixed liquor solids, even though no design limitations affecting the air supply are involved in these plants.

An interesting observation is offered by Lehmann regarding use of the mechanical paddles used in combination with diffused air at Hackensack. It is found that a decrease in mixed liquor dissolved oxygen occurs when the paddles are started, apparently demonstrating their effectiveness as a mixing device. The paddles are operated only during the summer months of heaviest load.

At Tenafly, New Jersey, Adams finds that more air must be applied than is required for biological balance of the activated sludge in order to maintain proper admixture and circulation of the mixed liquor.

Aeration Period

Although discussed here as an operating variable, the control of the aeration period by actually varying the detention time in aeration units is not common in practice, since few diffused air activated sludge plants have the excess aeration tank capacity necessary to make the procedure possible. It is feasible, however, for the operator to utilize the available aeration tank capacity in various ways, as by reaeration or by "adjusted aeration" (used at Findlay, Ohio), both of which procedures are discussed below.

The aeration periods available in the plants represented in this study are shown in Table I. At ten of the plants listed, periods between 4 and 6 hours are found; at five plants, the aeration periods are within the 6 to 8 hour range and periods in excess of 8 hours are reported at the remaining six plants. In view of the wide variation in available plant capacity thus indicated, it is not surprising that there exists such a broad range in operating practice in regard to mixed liquor solids concentration, rate of sludge return and rate of air application. All of these more readily controlled variables must be adapted to suit the less flexible aeration period.

Longer aeration periods usually yield a higher degree of purification with more advanced nitrification. At some plants, at which algae growth in the outlet watercourse may present a problem, such higher nitrification may be a disadvantage rather than desirable. Short aeration periods ordinarily require more "high-pressured" operation, unless a weak sewage is received for treatment, and demand more care on the part of the operator in developing and maintaining a well-conditioned activated sludge. The plant having liberal aeration capacity is usually less subject to upset by shock loads, as at Lancaster, Pennsylvania, and Pontiac, Michigan. At Pontiac, the activated sludge plant is augmented by a separate trickling filter plant, hence a constant, controlled sewage flow is handled by the former works, greatly simplifying all phases of operation.

Lehmann at Hackensack suggests the desirability of plant design details permitting flexibility in aeration capacity. Faulty hydraulics apparently make it impossible to remove aeration tanks from service as may be desired.

Return Sludge Reaeration.—Routine, continuous reaeration of the return activated sludge before admixture with the aeration influent sewage is practiced in only two of the plants contributing to this study, *i.e.*, San Antonio and Pasadena. At the latter plant, a 45 to 80 minute reaeration period is utilized primarily as a means of return sludge distribution. Reaeration is employed at Muskegon Heights on occasion "to lighten a too heavy sludge and to relieve floating sludge conditions in some cases." Anderson (Muskegon Heights) refers to the highly volatile activated sludge, particularly since packinghouse wastes have been received, and difficulty in properly conditioning the sludge with an inadequate air supply as being the causes for resorting to reaeration. When the sludge approaches a septic condition, reaeration is accomplished by discharging a portion of the return sludge to the last aeration tank, at a point about 25 feet from the outlet end. Air application to this unit is correspondingly increased.

The following local conditions justify the practice of return sludge reaeration by Berg at San Antonio:

1. A strong sewage containing industrial wastes, subjecting the plant to abrupt increases in load as when sudden flushing of sewers occurs.
2. High prevailing temperatures which induce septicity in the sewage and activated sludge solids.
3. Budgetary restrictions on power purchases, resulting in some limitation of air supply.
4. Unusually wide variation in rates of sewage flow, resulting in extremely long final settling tank detention periods in the early morning hours.

A reaeration period of about 0.9 hour is employed at San Antonio, as compared to the mixed liquor aeration time of 5.9 hours. The reaerated sludge averages about 4,200 p.p.m. and settles to 88 per cent after 30 minutes as compared to 1,500 p.p.m. and 33 per cent, respectively, for the mixed liquor. Air application was at the rate of 880 cu. ft. per pound of 5-day B.O.D. in the aeration influent sewage although Berg concludes that 1,000 cu. ft. per pound applied B.O.D. is the minimum quantity which will maintain a well-conditioned sludge under San Antonio conditions.

There are two fundamental principles in general acceptance which should be recognized when return sludge reaeration is considered: first, that the air application facilities must be of adequate capacity to maintain aerobic conditions in the reaeration unit and, second, that prolonged absence of food is likely to render the sludge inactive and low in oxidizing capacity.

"Adjusted Aeration" (Findlay, Ohio Procedure).—An interesting routine is employed by Barton at Findlay, Ohio, during low flow periods to reduce the aeration time and to minimize the effect of surge flows which result in disturbance of the final tank sludge blanket with loss of sludge floc at the weirs. The method involves alternating the operation of the two aeration units at eight-hour intervals by the simple expedient of closing the valve on the discharge pipe to the final settling tank, thus permitting the unit thus shut off to "idle." The water level raises in the idling unit, creating an increased back pressure at the plates and diverting most of the air to the working unit. The resultant idling and working cycle actually effects a substantial measure of reaeration of the sludge and has apparently eliminated the surge influence at Findlay. In times of normal sewage flow, both aeration units are operated in parallel and in conventional fashion.

Condition of Activated Sludge

The condition of the activated sludge at any time reflects the end-point of all manipulations by the operator, hence is his most important guide. Were it not for the lack of constancy of the character and quality of the sludge, the operation of an activated sludge plant would offer no complications of consequence. The observations upon which most dependence is placed at this time in determining the condition of activated sludge are:

1. Appearance and odor.
2. Settling characteristics and density, observed by laboratory observation of the rate of settling and computation of the sludge index.
3. "Activity," as observed directly by measurements of the rate of oxygen utilization or as estimated indirectly from the proportion of volatile matter present.
4. Microscopical examination to ascertain the types and prevalence of the biological life present.

Other determinations of such factors as pH and dissolved oxygen afford information concerning the environment of the sludge.

Appearance and Odor.—When in good condition, activated sludge is ordinarily light to moderate brown in color, becoming dark brown to black as septicity may occur. The odor of well-conditioned sludge is sharply musty and not unpleasant but turns sour and disagreeable when in a very bad state. The flocs making up good quality sludge are of moderate size and have clearly defined edges; a poor sludge usually appears to take the form of spongy, fluffy masses. During times of extreme low temperatures, the flocs may become quite small and dispersed.

Settling Properties and Density.—The settling properties of activated sludge are the most significant indices of the sludge condition since efficient operation is dependent upon the ready separation of the sludge from the treated liquor in the final settling tank. Well-conditioned sludge normally occupies about 20 to 30 per cent of the mixed liquor sample volume after five minutes settling in a graduated cylinder. The most common manifestation of poor sludge condition is "bulking" (to be discussed in detail below), in which state the sludge particles become light, enlarged and difficult to remove by sedimentation. The sludge index is an expression of the density of the sludge and is more informative than the settling test alone since it takes into account the amount of sludge solids contained in the mixed liquor sample. Sludge index values below 100 are generally considered representative of well-conditioned sludge although satisfactory operation may be accomplished with sludges having indices in the order of 200, as at Ward's Island, Pasadena and San Antonio. It may be significant that the activated sludges in these plants are all of high volatile matter content. The effect of industrial wastes containing solids of high or low specific gravity should also be recognized in the interpretation of sludge index values and, particularly, in the determination of optimum operating ranges for a specific plant.

Sludge Activity.—The determination of sludge activity by measurements of oxygen utilization as developed by Bloodgood at Indianapolis has been adopted at a number of plants. By means of a machine developed for the purpose (see *This Journal*, **10**, 927 (November, 1938), the amount of oxygen, in p.p.m. per hour, used by samples of mixed liquor from each aeration tank, is determined daily. This rate of oxygen utilization is termed the "sludge demand." The samples are taken from the outlet end of the aeration tank and concentrated to a standard value of 0.5 per cent solids for the measurement. The sludge from this test is then fed with synthetic sewage to produce a 0.5 per cent mixture and the rate of oxygen utilization again determined by the machine. The last determined rate minus the sludge demand yields an oxygen utilization rate, expressed in p.p.m. per hour, denoted by Bloodgood as "sludge activity." For best operating results at Indianapolis, the sludge demand must be kept in the range of 25 to 50 and the sludge activity should not exceed 70 to 100 p.p.m. per hour. The procedure is found useful in controlling air, mixed liquor solids, rate of sludge return and in ascertaining the shock overloads from industrial wastes. Further details will be found in *This Journal*, **10**, 26 (January, 1938).

Other devices, including the *Odeeometer*, have been used for determining rates of oxygen utilization by activated sludge and sewage-sludge mixtures.

In at least eight of the plants represented here, important significance is attached to the volatile matter content of the activated sludge as an operation control. Rhoads and Bolenius at Lancaster, however, find that there appears to be no uniform relationship between the volatile content and general characteristics of the sludge, but point out that this is probably due to industrial waste variations. At Chicago (Calumet) and Ft. Wayne, the primary concern appears to be maintenance of the volatile suspended solids content of the mixed liquor above a minimum of 1500 p.p.m., in order that a sufficiently active sludge will obtain. At Wards Island, Mansfield, Muskegon Heights and other plants, operating difficulties and increased air requirements are attributed largely to high volatile solids contents of the return sludge. Turner at Mansfield reports that the volatile content of the return sludge solids averages about 80 per cent, which may explain the high prevailing sludge index (346). Increased quantities of slaughterhouse wastes received at Muskegon Heights raised the volatile suspended solids in the influent sewage from 65 per cent to 80–85 per cent, adding complications in operation control. The industry has been requested to install adequate grease removal and rate-of-flow control facilities in an effort to minimize the influence of the wastes.

Edwards, in comparing data from the New York Wards Island and Tallmans Island plants (*This Journal*, **12**, 1077 (November, 1940), shows a marked relationship between the volatile solids content of the return sludge and the sludge index. The relatively high sludge index of 170 at Wards Island is held to be caused by the high volatile solids content of 76.1 per cent. Edwards suggests the sludge index may be a relative figure as an indication of bulking and that the variance in sludge indices encountered in comparing plant data may be explained by the differences in volatile matter content.

Edwards and Anderson (Muskegon Heights) both refer to the requirement of additional air application when the volatile content of the sludge is high, indicating that another important operation control relation may exist. There appears to be considerable justification for greater emphasis on the volatile solids determination in the mixed liquor and return sludge as an operation control, as well as for extensive study of the significance, interpretation and application of such data.

Microscopic Examinations.—Determination of the activated sludge condition by microscopic observation of the number and types of organisms present is practiced at most of the plants contributing to this study, however, the frequency of such examinations varies widely. At nine plants it is reported that the microscope is used "occasionally"; weekly sludge examinations are made at Lancaster and Pontiac; Edwards reports that five to six observations are made weekly at Wards Island. The occasional examinations made at Mansfield, Pontiac and Springfield are augmented by daily checks when the sludge index is high or when the sludge condition is otherwise doubtful. Bloodgood states that microscopic observations are made seldom at Indianapolis "as it is believed that by the time there is a change in flora it is too late to make the necessary changes in operation procedure for maintenance of a good activated sludge."

At Wards Island, Edwards considers protozoa and filamentous forms as of most importance and finds flagellates to be numerous with low dissolved oxygen conditions. Larson at Springfield considers a preponderance of rotifera with ciliates such as *vorticella*, *carchesium*, *stentor*, and *paramoecium* to be present when the sludge is in good condition, an unsatisfactory sludge being characterized by the presence of *amoeba* and filamentous types including *Sphaerotilus natans*. Most common practice, typified by the procedures at Lancaster, Mansfield and Pontiac, is to check primarily for the filamentous growths, as these forms are almost always prevalent in a poor sludge and are readily identified.

Other Measures of Sludge Condition.—Lehmann at Hackensack employs pH determinations on mixed liquor samples during aeration as an indication of the degree of oxidation of the sludge. He finds that a drop in pH occurs during normal operation and that bulking occurs otherwise. Too low a pH, of course, is evidence of septicity and must be avoided by higher return rates. At Omaha, Ahrens also includes routine pH determinations on the mixed liquor and return sludge among his observations for sludge condition. Adams at Tenafly finds best operation to take place at a pH of 6.8 in the return sludge and includes the determination in his daily routine.

Determination of the ammonia, nitrite and nitrate nitrogen on the plant effluent are obviously informative regarding the oxidizing and nitrifying properties of the activated sludge and are commonly performed as routine analyses. From 1 to 2 p.p.m. of nitrates in the plant effluent is generally considered to indicate a sufficiently nitrifying sludge. Effluent nitrate contents of more than 5.0 p.p.m. are unusual since most operators consider it uneconomical to carry nitrification beyond this point. At Pasadena, where high temperatures entail constant vigilance against bulking, Allen considers the presence of at least 1 to 2 p.p.m. of nitrates in the effluent as an important safety factor. Anderson at Muskegon Heights has found that methylene blue stability determination affords a quick and simple check on nitrate production and includes this test on the plant effluent in his routine. Immediate loss of color is considered to indicate a complete absence of nitrate nitrogen. Anderson also suggests that the turbidity determination may give indication of upset in sludge condition even though results of other determinations may appear satisfactory.

Bulking of Activated Sludge.—Well-conditioned activated sludge settles rapidly from the aerated mixed liquor leaving a sparkling, highly oxidized plant effluent. Loss of the rapid settling property and increase in the sludge index is usually an early indication of deteriorating sludge quality. As the flocs increase in size and lose density, the sludge blanket in the final settling tank increases in depth until the natural currents in the tank carry some of the solids over the weirs with the plant effluent. Avoidance of such bulking of the sludge is the most common problem encountered in operation and activated sludge plants in which it has never occurred are indeed rare. Of the plants represented here, "chronic" bulking is reported at four; one or more instances of bulking each summer are experienced at eight; at nine of the plants bulking is reported to occur infrequently or only "occasionally in mild form." Included in the last group are the plants at Hackensack, where no bulking has occurred in the past two years, and at Rockville Centre, where there have been no such difficulties in the past eight years, improved operation control being credited for these records in both cases.

The reported causes of bulking are summarized as follows:

1. Loss of balance between operation variables due to carelessness or relaxed vigilance in control is offered as the primary cause in six plants. Too high or too low mixed liquor solids concentration and inadequate air application are mentioned as specific reasons.

2. Shock loads from industrial wastes are held responsible for the bulking experienced at five plants. Toxic wastes as from paint manufacture and metal plating plants, wastes of high organic content as from packinghouses and distilleries, and wastes containing appreciable quantities of oil and grease are considered most likely to result in interference. At Muskegon Heights and Lancaster, the industrial waste influence has been minimized by requiring such industries to effect removal of objectionable components and provide for uniform rates of discharge to the sewer system.

3. At four plants, high volatile matter concentrations, occurring usually in dry summer months when the raw sewage solids are likely to be septic, are blamed for activated sludge bulking. Onset of bulking following a rain which flushes out septic solids from combined sewers after a prolonged dry period is common. Similar effects are reported when a concentrated supernatant liquor from digestion tanks is returned to the raw sewage (Omaha and Hackensack) and when the primary sedimentation tanks fail to retain completely the waste activated sludge solids discharged thereto at high rates (Omaha and Springfield).

4. Consistently overloaded plants are almost always operating under a condition of chronic bulking, a situation obviously beyond control of the operator. War time population increases, together with boron wastes from citrus fruit packing industries, has brought this condition at Pomona, Cal. Commenting on bulking experience at Lima, Smith states, "when an activated sludge plant is operated at full load under summer conditions, as the Lima plant was in 1942 for over 50 per cent of each day, bulking will occur." Many plants not now troubled with bulking will undoubtedly experience the problem as design loads are approached and exceeded in the future, unless plant expansion is accomplished in pace with increases in domestic sewage and industrial waste flows.

Wheeler at Chicago (Calumet) considers the infrequency of bulking at this plant to be due to the relatively low volatile content of the sewage received. At Pasadena, Allen has been unable to associate any specific causes to the sludge bulking which occurs at irregular intervals, however, relatively high temperatures such as prevail in California are generally believed to accelerate bulking.

It will be evident that continuously careful and vigilant attention to the control of mixed liquor solids, return sludge rates and air application will prevent many instances of bulking. Industrial waste survey and control will minimize cases resulting from such sources. In other cases bulking may be prevented by improvement in supernatant liquor quality or by alternate methods of disposal. At Hackensack, elimination of a heavy supernatant liquor, together with a higher mixed liquor solids level (1,600 p.p.m.) and improved dissolved oxygen control during aeration, have successfully prevented bulking for the past two years. Where shock loads from industries are likely to be received, it is desirable to have such knowledge early so that measures may be taken to prevent bulking. The industrial waste "slugs" received at Decatur, Ill., and Lancaster, Pa., are of such nature that pH determinations on the raw sewage at intervals during the day are regular procedure. An abrupt change in pH signals that a "slug" has arrived and enables adjustment in air supply or return sludge rate to be made before damage to the activated sludge takes place. Barton at Findlay and Adams at Tenafly use the methylene blue stability test on samples of the primary effluent for the same purpose, immediate loss of color being taken as indication that air application and sludge return should be increased to meet a shock load. This determination is routine at 8-hour intervals at Findlay.

In the earliest stages of bulking, operators appear to be in general agreement that additional air application, increase in rate of sludge return and, if possible, reduction in the applied load to the aeration tanks, are the proper operating adjustments. Ahrens at Omaha supplements these controls with the return of plant effluent to the sewage entering the primary tanks during the low night flows, thus reducing detention periods and freshening the aeration influent sewage.

At five of the plants included in this review, *i.e.*, Lancaster, Lima, Mansfield, Tenafly and Wards Island, chlorination of the return sludge has been found efficacious in destroying the filamentous organisms, such as *Sphaerotilus*, which usually infest bulking activated sludge, as well as in reducing the high initial oxygen requirements of the sludge. Return sludge chlorination is relied upon as a routine remedy for bulking at the above and many other plants although some instances have been reported in which the treatment was not completely successful. For best results, it appears that the treatment should be instituted as soon as bulking becomes imminent with the chlorine applied at carefully controlled rates.

Probably the best information available on return sludge chlorination comes from Lima, Ohio, where Smith has employed the method since 1934, from which experience it has been concluded that it is the only uniformly successful remedy for bulking in this heavily loaded plant. Application of chlorine to the return sludge is begun when the aerated mixed liquor settling test shows the sludge to occupy more than 20 per cent of the sample volume after one hour settling. In arriving at the optimum chlorine dosages, Smith has recognized the concentration of solids in the return sludge as an important factor and expresses the chlorine dosages on this basis. Since 1936, chlorination of the return sludge has been required 3 to 12 times a year, the dosages averaging about 8.5 p.p.m. chlorine for each per cent suspended solids in the return sludge and ranging from 3.9 p.p.m. to 14.9 p.p.m. for each per cent solids. These dosages represent an average of 6.5 p.p.m. and a range of 3.0 to 11.7 p.p.m. of chlorine on the basis of the volume of return sludge flow. From the Lima experience, Smith concludes as follows:

"1. Return sludge chlorination for correction of bulking has been practiced at Lima for nine years with success.

"2. Chlorine should be used for correction of bulking only, not for prevention.

"3. The amounts observed at Lima to be required for quick results are not less than 6 p.p.m. based on return sludge flow or less than 8 p.p.m. for each per cent of solids in return sludge.

"4. Nearly complete recovery from bulking may be expected at Lima within seven days after the beginning of chlorination of return sludge, and recovery has been effected on many occasions after as few as three days chlorination.

"5. With effective reliance upon chlorination as a corrective of bulking, power requirements for air compression may be reduced to the minimum, and the combination of the above considerations should result in marked economy of operation."

When bulking is beyond control, *i.e.*, application of the above remedies fails to bring about restoration of a properly conditioned activated sludge, most operators agree that all or part of the bulky sludge must be wasted and a new sludge developed. At Indianapolis, waste sludge is readily disposed of by discharge to lagoons, hence all of the bad sludge is wasted. Where sludge wasting and disposal facilities may be limited, however, it is not always possible to effect complete wastage of the bulked sludge in a reasonable length of time and a part of the original mixed liquor solids may be retained. Ahrens at Omaha wastes the mixed liquor solids to about half the desired concentration and uses an increased rate of sludge return while the new sludge develops. Anderson (Muskegon Heights) retains about 300 p.p.m. of the bulked mixed liquor solids when redeveloping an activated sludge even though he is not restricted in waste sludge disposition facilities. At Findlay, Ohio, Barton notes marked improvement in the condition of the mixed liquor solids in 5 to 10 hours after purging of the final tank contents through the plant is commenced.

Edwards (Wards Island), Larson (Springfield) and Turner (Mansfield) refer to the benefits derived from a rain while sludge is bulking. This remedial effect is generally ascribed to the reduction of the volatile matter concentration in the sludge, resulting in better density and lower initial demand for oxygen.

Application to the mixed liquor of lime, copper sulfate and pulverized clay has been attempted as a corrective for bulking activated sludge but has not proven uniformly successful up to this time.

Other Operation Problems

Rising Sludge at Final Settling Tanks.—At almost half of the plants represented here, difficulty has been experienced at some time or another with the rising of large masses of the sludge to the surface of the final settling tank. At Fort Wayne, Hackensack, Pasadena and Springfield, the condition has been noted to occur when nitrification is high as is common when the sludge is over-aerated. The most common opinion on the cause of this condition is that the nitrates are reduced in the sludge blanket as the dissolved oxygen is depleted, resulting in the ebullition of nitrogen bubbles which carry the sludge masses to the surface. Correction is usually accomplished quickly by decreasing the air application. The plant at Hackensack appears to be particularly susceptible to this condition and the mixed liquor dissolved oxygen content must be held below 2.0 p.p.m. to avoid it. Bloodgood eliminates the condition by increasing the sewage load to the unit causing trouble, thus furnishing additional bacterial food. When increase in load is not feasible, he suggests that the mixed liquor solids be reduced.

Rising sludge masses may also occur with the onset of septicity in a final settling tank blanket of very dense sludge, as at Muskegon Heights, where reaeration of the return sludge is employed as the remedy. Smith at Lima increases the return rate and applies a fine spray of water at the tank surface to break up the sludge masses, on the rare occasions that the problem has been encountered.

Munroe at the York Township, Toronto plant suggests that sludge rising due to septicity in hot weather may result from the failure of the sludge collectors to keep the tank bottom clean, directing attention to the desirability of care in maintaining proper adjustment of the plows or flights.

Oil and Grease.—In about a third of the plants contributing to this study, varying degrees of difficulty are reported to have resulted from the discharge of oils or grease to aeration units. Oils are usually received in "slugs" after accidental loss to the sewers or temporary breakdown of industrial separators. Grease is more likely to be a day-to-day problem since few industries provide adequate facilities and care in removing it from process wastes, particularly if the grease is in an emulsified state, difficult to separate.

Rapid and damaging reactions are reported to occur when a quantity of oil comes in contact with activated sludge, as experienced at Chicago Calumet, Fort Wayne, Hackensack and Omaha. In every case, air requirements were greatly increased and the clarifying and oxidizing capacity of the sludge immediately reduced, as evidenced by increase in the B.O.D. and suspended solids content of the plant effluent. Coating and impregnation of the activated sludge particles, interfering with the absorption of oxygen is believed to be the direct effect of the oil. At Fort Wayne, Brunner reports that a 3,000 gallon "shot" of fuel oil necessitated increase in air application from about 1.0 to 1.75 cu. ft. per gal. to hold 2.0 p.p.m. of mixed liquor dissolved oxygen. Receipt of 8,000 gallons of fuel oil at the Omaha plant completely destroyed the activated sludge, entailing a new start. Several discharges of a petroleum-base oil have been received at Hackensack, and, although treatment efficiency is affected, the condition has been correctible by increased air application while the oil is present.

Grease may to some extent affect the activated sludge in a manner similar to oil but is believed to exert its greatest influence in the form of an organic overload. A combination of industrial oil wastes with grease solvent wastes constitutes a real problem at Muskegon Heights. At Elyria, Collier reports averages of 105, 33 and 3 p.p.m. of grease in the raw sewage, primary effluent and final effluent, respectively, yet is more concerned with the grease disposal problem at the sludge digestion tanks than with the effect on the activated sludge. Adams at Tenafly states that determinations made several years ago revealed that the normal activated sludge at this plant contained about 20 per cent of ether-soluble grease but that attempts to correlate the grease content with the condition of the sludge were unsuccessful.

Chironomus Larvae.—In a few plants, a troublesome problem is created by the bloodworm or larvae of the *chironomus* fly. This insect has caused serious interference with operation of activated sludge units at Muskegon Heights and Findlay. Anderson (Muskegon Heights) furnishes an excellent commentary on the problem:

"The production of bloodworms in sewage is due primarily, I believe, to stale sewage and warm temperature. We have a considerable number of flat sewers and when the temperature of the sewage reaches about 70° F. the treatment plant usually becomes infested with bloodworms which have caused a great deal of difficulty with the operation of the aeration plant.

"The worms form cocoons of sludge, about one inch in length by one-eighth inch diameter, which adhere to the walls of the tanks and finally break loose and float on the surface of the final settling tanks, due to entrained air or because the particles of sludge have become septic. The sludge may float in the original cocoon form or a very thin film of sludge may cover the entire tank surface. Also, small masses of sludge may rise to the surface causing very unsightly conditions and a loss of sludge. Invariably, during the period of infestation, the sludge is heavy, settles rapidly, and is in a semi-septic state.

"We finally reached the conclusion that the best remedy was to remove all of the sludge from the final settling tank sumps as rapidly as it was deposited. However, this required a return rate up to as high as 70 per cent and, when discharged to the entrance of the aeration unit, it shortened the aeration period and reduced efficiency. We then installed a sheet metal pipe from the return sludge chamber to a point about 25 feet from the discharge end of adjustable weirs so that the required portion of return activated sludge may be discharged to the first aeration tank with the remaining portion being discharged to the final aeration tank. We have four aeration tanks and larger amounts of air are applied at the first and last tanks during this method of operation. The method has prevented any sludge from floating on the final settling tanks during the past six years and apparently reduces the period of infestation to three to four weeks. Samples are collected for the laboratory and the rate of settling is watched closely, for when the period of infestation ceases the sludge index may rise rapidly and cause bulking. When the sludge index reaches about 150 we return to the normal method of operating the aeration unit."

At Findlay, Barton describes the effect of *chironomidal* infestation as "devastating." Copper sulfate has been found efficacious in preventing the adult fly from laying eggs but is valueless after the eggs are deposited. After the larvae are present, practice at Findlay is to waste all of the infested sludge and start anew.

Maintenance of Air Diffusers

Among the most troublesome problems of physical maintenance of activated sludge plants is that of clogging and restoration of air diffusers. Diffuser clogging has become chronic in some plants after only a few months of operation; at others, no such difficulties have arisen in years. Among the latter are Pomona, Cal. (Fig. 6), where air diffuser tubes were used without being cleaned during a fifteen-year period; Springfield, Ill. (Fig. 7), where no clogging of plates has been experienced in almost fourteen years; and the plants at Findlay and Muskegon Heights which have been operating five years or more without experiencing diffuser clogging. Probably typical of average experience is that at Fort Wayne, which plant has been operating about 2½ years and where it is now necessary to replace the plates in one aeration tank and to institute a general schedule and procedure for restoring clogged plates. At Pasadena, Allen finds that annual cleaning of the plates in the older ridge-and-furrow tanks is required, usually after heavy rainy seasons, while some of the plates in the new spiral-flow tanks have not required cleaning in six years.

At some plants in which clogging is not a serious problem, a regular plate cleaning schedule is followed as a preventative. Harris at North Toronto drains the aeration tanks for plate cleaning operations once each year even though no appreciable increase in applied air pressure occurs in that interval. Diffuser plates at Omaha (in mixed liquor channels) and at Lancaster are occasionally "flushed" by the application of large quantities of air, this being the only attention required as yet in these relatively new plants.

Cause of Diffuser Clogging.—Although the direct cause of the diffuser clogging may not always be apparent, the following reported causes are typical of general experience:

1. Industrial wastes containing ferrous iron in sufficient concentration to form a hydrate as they are oxidized during aeration, which hydrate deposits on the top of the plate and penetrates into the surface pores. Clogging from this cause has been minimized at Chicago Calument by

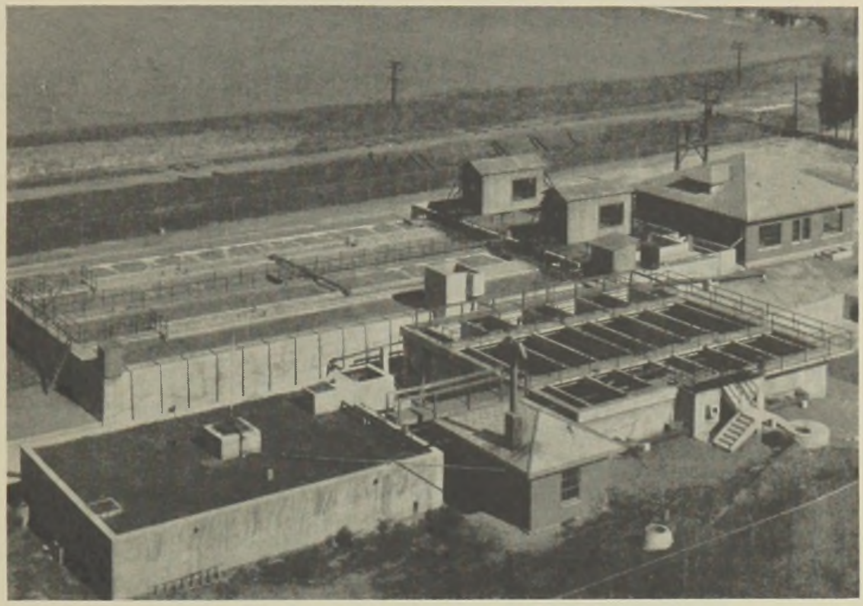

FIG. 6.—Tri-city sewage treatment works at Pomona, Calif. Serves cities at Claremont, La Herne and Pomona.

diversion of pickling liquors from the sewers; such wastes in an average concentration of 65 p.p.m. total Fe in the settled sewage at Elyria create a serious clogging problem.

2. Organic growths which accumulate on the plate surface and restrict the pore openings, experienced at Indianapolis, Wards Island and Tenafly (only in old tanks in which the plates are of low permeability—no trouble at more porous plates in new units).

3. Grease accumulations on top of plates, reported at Pasadena and Toronto.

4. Dirt and soot deposited on the underside of the plates by the applied air. Reported at Fort Wayne and Indianapolis. Recent examination at Fort Wayne also revealed an accumulation of paper fibers from the paper-cloth air filters.

5. Sand and silt impregnations at the top surface of the plates has caused trouble at Pasadena, Fort Wayne and Toronto.

6. Hard water scale is held responsible for the diffuser clogging encountered at Lima, Ohio.

Clogging of plates by activated sludge solids which subside to the bottom when the air supply may be interrupted by power failure or mechanical

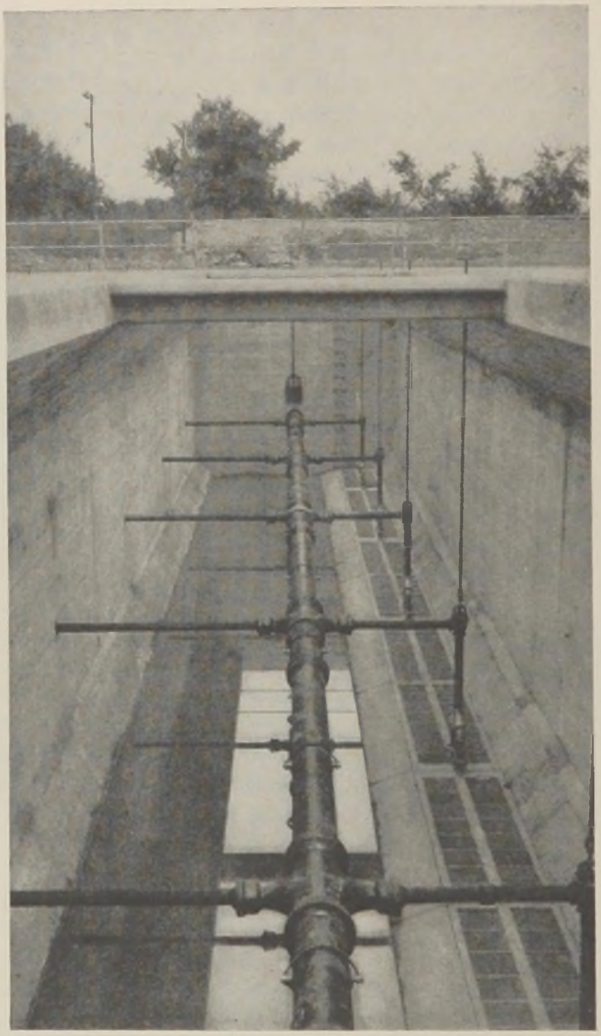

FIG. 7.—Empty aeration tank at Springfield, Illinois, showing air piping and plate containers.

break-down, is mentioned by several operators. When an aeration unit is to be removed from service for any reason, the application of air should be continued until the tank contents are drained to a level below the diffusers. Turner (Mansfield) and Adams (Tenafly) note that the diffuser plates clog more quickly when small quantities of air are being applied. Allen at Pasadena observes that the accumulation of grease deposits and silt at the plates increases rapidly when the plates become partially clogged.

Methods of Cleaning.—Diffuser cleaning procedures reported are summarized herewith:

Plant	Diffuser Cleaning Procedure
Chicago Calumet	Ferrous iron deposits. Plates cleaned in place 2 to 3 times yearly. Washing and brushing followed by application of solution of equal parts water and sulfuric acid, to which sodium dichromate is added. Acid left in contact several hours, sometimes overnight. Second application given if clogging severe.
Elyria	Ferrous iron deposits. Plates cleaned in place annually. Deposits removed by application of hot flame which "spalls off" plate surface. Blow-torch used on silica plates, oxy-acetylene flame on carborundum.
Indianapolis	Organic growths, soot, dirt. Removable plates cleaned every 2 years. Plates are boiled in 6 per cent caustic solution for 5 hours, washed thoroughly and submerged in 10 per cent muriatic acid solution for 18 hours. No satisfactory method for cleaning plates grouted in place found as yet.
Wards Island	Organic growths and deposits. Plates cleaned in place every 1 to 2 years. Tanks drained, plates washed with hose, swept with deck brushes and allowed to dry (Fig. 8). Solution of 25 per cent caustic soda applied and left in contact for 24 hours. Caustic treatment repeated on plates in first pass. Plates put into operation without rinsing out caustic.

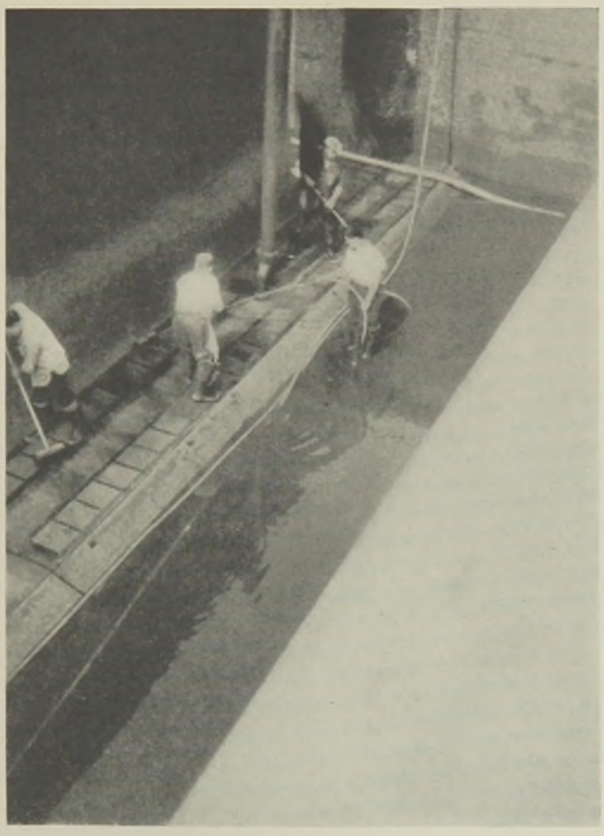

FIG. 8.—Cleaning diffuser plates at Wards Island plant, New York City.

Plant	Diffuser Cleaning Procedure
Hackensack	Organic deposits. Plates removed for cleaning annually. Soaked in 20 per cent caustic soda solution, rinsed freely and drained. Dipped into strong nitric acid solution and rinsed.

Plant	Diffuser Cleaning Procedure
Mansfield	Organic deposits. Plates removed for cleaning every 2 years. Boiling and strong caustic solution followed by rinsing gives 96 per cent recovery of permeability.
North Toronto	Grease accumulations. Plates cleaned in place annually. Four holders at a time connected to low-pressure steam line and plate surfaces brushed vigorously with stiff-bristle brush. Thin, greasy scum removed thus.
Toronto	Plates cleaned in place twice yearly. Water jet at 110 pounds pressure with vigorous sweeping with street brooms, while plates subjected to normal air pressure, removes sand and silt. Grease accumulations removed by low pressure steam application as at North Toronto.
Pasadena	Grease and silt. Plates in old ridge-and-furrow units cleaned annually. First washed in place with high pressure nozzle, followed by application of acid and rinsing. Treatment usually successful but if not, plates are replaced.
Rockville Centre	Diffuser tubes cleaned in place weekly. Air valve on pipe to each diffusion unit closed and temporary hose connection made to city water supply. Flushing by water in this fashion has maintained tubes in good condition for eleven years. (Probably involves cross-connection to water supply, however.)
Lima	Hard water scale. Plates treated annually in place by application of weak muriatic acid solution.
Omaha	Chicago swing diffusers. Raising of diffuser units (Fig. 9) to enable them to be washed off with hose once a month, has sufficed during first 18 months of operation of plant. Air pressure increase of about 0.5 lb. per sq. in. noted between cleanings.

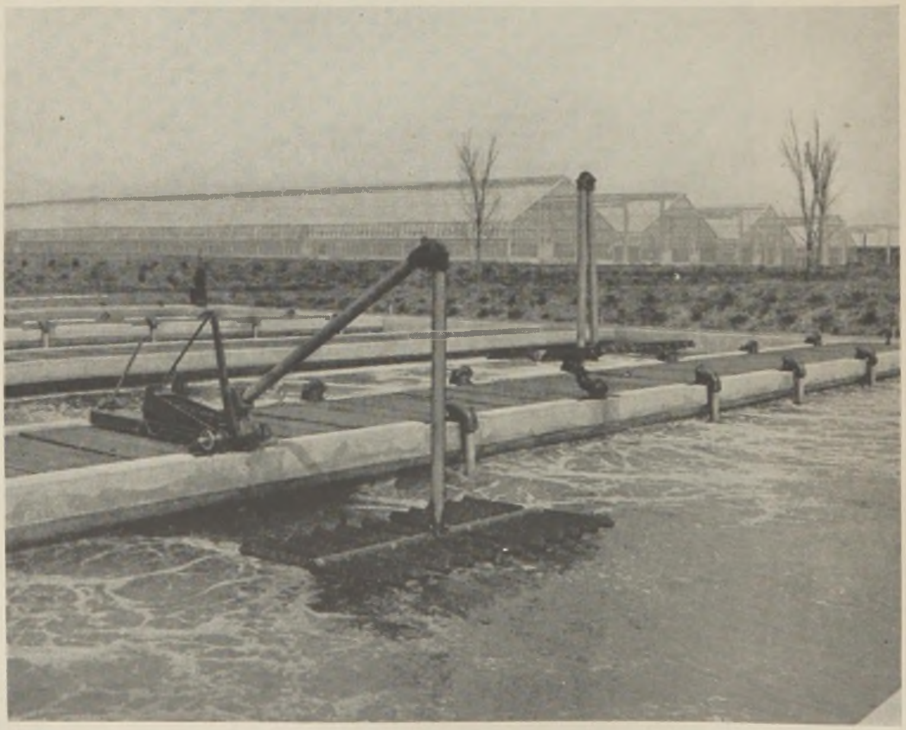

FIG. 9.—"Swing diffusers" raised for inspection and maintenance, Omaha, Nebraska.

When replacement of diffuer plates becomes necessary Allen (Pasadena) recommends that all plates in the same row or holder be changed at the same time. Use of a new plate in a holder containing old ones has been observed to disrupt the uniformity of air distribution because of the higher permeability of the new plate.

It should be noted here that the Sewage Works Practice Committee of the Federation is undertaking a comprehensive study of the diffuser maintenance problem, the topic having been assigned to a subcommittee headed by Superintendent John J. Wirts of the Easterly Sewage Treatment Plant at Cleveland, Ohio. An authoritative manual of practice on this widely experienced problem is anticipated.

Waste Activated Sludge Disposal

Because of the high moisture content of waste activated sludge, its disposition almost always involves some difficulties which often influence control of the entire plant. Some problem associated with waste sludge disposal is reported at all but five of the plants represented here.

The most common method of effecting concentration of the waste activated sludge is by discharge to the raw sewage so that the waste solids are removed with the raw solids at the primary settling tanks. That this procedure is not without shortcomings is indicated by the fact that of twelve plants employing the method, only three fail to report some difficulty. Concentration of the waste activated sludge at the primary tanks at San Antonio has been found definitely unsatisfactory, probably due to the high temperatures which induce rapid septicity, and the high activated sludge index which prevails in that plant. At Fort Wayne, Muskegon Heights and Springfield, primary sedimentation efficiency is reduced when the waste sludge is light or bulking and some of the waste sludge solids pass on to the aeration tanks, imposing a recirculating load. Since increased waste is usually desirable under bulking conditions, inability to remove and concentrate the waste sludge is a serious limitation in the restoration of proper conditions at the activated sludge units. Lehmann (Hackensack), Brunner (Fort Wayne) and Larson (Springfield) emphasize the importance of frequent removal of the waste activated-raw sludge mixture from the primary tanks to avoid rising of sludge masses from the sludge hoppers. The air-lift bubbler device (Fig. 4) used at Fort Wayne for observation of sludge blanket elevations in the final settling tanks, has also been installed at the primary tanks so that excessive and overlong sludge accumulation can be avoided. At Lancaster, Mansfield and North Toronto, the waste activated-raw sludge mixture is high in moisture content, resulting in large quantities of digester supernatant as well as thin digested sludges. Alum is used to advantage in facilitating air drying of the thin digested sludge produced at North Toronto. Smith attributes the generally satisfactory removal and concentration of waste activated sludge in the primary tanks at Lima to the semi-automatic arrangement (Fig. 5) employed to control the rates of waste and return flow. To summarize this experience, it would appear that concentration of waste activated sludge at the primary tanks is reasonably satisfactory when the waste sludge is of low index, and that waste at low, uniform rates with frequent sludge removals from the primary tanks are highly desirable.

Separate decantation or concentration units are used at Rockville Centre before mixing the thickened waste sludge with raw sludge prior to digestion. Andersen reports no difficulties. The waste sludge is chlorinated at Wards Island to expedite concentration in the four final settling tanks used expressly for this purpose; concentration to 3 per cent solids is difficult, however. The concentrated sludge at Wards Island is pumped into tankers and disposed of at sea about 35 miles from the plant. Prompted by the need for sludge concentration at Findlay, Barton has conducted laboratory experiments on the thickening of the raw-waste activated sludge mixtures after dilution with digester supernatant liquor. One interesting but unexplained finding is that a 50 per cent water separation after settling occurs with a ratio of equal parts of supernatant and the mixed sludges, whereas a 40 per cent water separation is achieved when one part of supernatant is added to two parts of the sludge mixture. Plant scale facilities are not available at Findlay for further studies.

At Chicago Calumet, Tenafly and Toronto, the waste sludge is conditioned with chemicals and dewatered on vacuum filters. Adams at Tenafly finds that the character of the waste sludge exerts an appreciable influence on the dewatering operation; a light sludge giving poor filter yields while a heavy sludge will not cling properly at the bottom of the filter drum. The sludge index of the mixed liquor is adjusted to remedy these conditions.

The primary and waste activated sludges at Indianapolis are discharged to open lagoons for digestion and drying. The only problem as yet encountered is in bringing about removal of the dried sludge from the plant. About 25,000 to 35,000 cubic yards per year are sold and hauled away by local users but this is not quite up to the annual production.

Probably the best method of waste activated sludge disposal reported here is that employed at Pasadena. The sludge produced is pumped to the sewers of the Los Angeles County Sanitation District, whence it is treated and disposed of by that District. Allen (Pasadena) reports no difficulties!

BARK FROM THE DAILY LOG *

By Ben H. Barton

Guest Contributor, Chief Operator, Sewage Treatment Plant, Findlay, Ohio

January 5—A roving inmate of the County Home slipped, unobserved, into the office where he enjoyed quantities of operator's tobacco.

January 6—The digester overflow line frozen at 1° below. Thawed with a kerosene torch.

January 7—Same frozen again at 3 below. Left it that way.

* Excerpts from 1942 Annual Report of the Findlay, Ohio, Sewage Treatment Plant.

January 8—Same burst at 7 below zero. Left it that way.

January 9—Gasometer now frozen. Oil seal is used but melted snow and condensation from warm gas creep in to freeze before there is time for separation from the oil in the seal. Thawed by steam hose.

January 13—Ohio Conference Executive Committee meeting here. Interest manifested in "fuzzy" growth in our final effluent. Examination by Calkins in Toledo plant reveals "about equal amounts of sphaerotilus and protozoa and plenty of both."

January 29—Accumulated sludge in lagoon making gas; audibly, visibly and odoriferously; temperature max. 31. Lunar halo observed.

February 26—Discs and guides in sludge 8-inch valve from No. 1 Primary Tank worn out. Some fancy manipulations required to open valve so tank could be drained. Guides rebrazed in valve body. Discs borrowed from another valve pending receipt of new ones.

March 13—(Friday) Chevrolet sedan in park lily pool. Drunk driver.

April 30—Oily viscuous accumulated waste from local oil company reconditioning plant for used oil-drums, received in quantities and of liverish consistency to partially plug the bar-screen openings.

June 1—Digester power wiring "shorted" to conduit. Excessive moisture.

June 2—1,500 gallons skimmed milk did not affect the plant.

June 6—Caustic "white-waste" in sewage from Cooper Corp. water treatment. Remonstrated against dumping lime sludge in the only available space for our digester overflow. We'll need that space.

FIG. 1.—Sewage treatment works at Findlay, Ohio. Primary tanks at left background. Main building center. Screen-garbage building at right.

June 8—Digester water-seal blown repeatedly. Gas production too fast for available pipe capacity. Oil on aeration tanks.

June 19—Raw sewage pump selector-switch out of service. Float completely disintegrated by corrosion.

July 5—Shortened digester chain drive with offset link, to take up the accumulated wear of ten years constant operation.

July 18—White waste, pH 6.6, looks and smells like sour milk, knocked return sludge for a loop. Purged final and aeration tanks of all sludge, insofar as possible.

July 21—More white waste, pH 6.9; probably skim milk.

July 23—Another epidemic of digester seal blowing. Bigger pipe needed.

August 3—Chironomid fly cocoons observed in final tank launder ring. Started dosing with copper sulphate solution in primary effluent flumes.

August 7—Chironomid observed too late. All final tank sludge going over the weirs like a curtain. Secondary units out of service for cleaning. Primary treatment only for sewage.

August 8—Cleaning final tank. Draining aeration tanks for cleaning.

August 9—No. 1 aeration tank clean and back in service. Horrible odors from tank No. 2 in process of cleaning.

August 10—Filled final tank from No. 1 aeration tank. Started return sludge after rigorous sump cleaning. Building new sludge.

August 12—Primary tanks badly upset. Sludge on top. Feeding milk of lime for pH adjustment. Too many little red worms from secondary.

August 13—Plenty of little green chironomid flies coming in for landings on the final tank to lay their eggs. Feeding lime at screens for primary tank acid correction and copper sulphate in primary effluent to deter flies from laying eggs.

August 15—Stopped lime dosage. Sufficient sludge built up to waste.

August 18—Feeding HTH solution into return sludge hopper to improve activated sludge.

September 20—New coil put in gas engine magneto. This seems the only source of trouble with this engine.

September 25—Oil-drum waste in sewage in morning. White boiler waste in afternoon. Both wastes are caustic. To neutralize the caustic, the quicklime ordinarily applied to green garbage before grinding is omitted.

September 28—Multitudes of fish swarming into the effluent stream from the sewage treatment plant seeking vital dissolved oxygen which is low in the river water. Carp are of huge size and there are thousands of them as well as catfish and others.

October 3—Cleaning and painting. Garnet cloth for sanding machines is quite efficacious for removing rust accumulations on pipe railings. No. 2½ grit seems to fit the bill best.

October 7—Receiving caustic white waste. Garbage formerly fed to hogs brought to plant. Hogs are sick. No wonder.

October 16—Rehabilitating screen room. Steel sash came "unstuck" and were welded good as new with Water Works portable welder. Steel galvanized door in wet well top also welded. More white caustic boiler waste from Cooper Corp.

October 17—Detritor troubles from here on. Traction wheel worn out. Delivery promised in February, 1943.

October 22—Leak in Rawson Park water line repaired. A zipper over this line would be convenient to save digging.

October 31—Rusty-red, caustic waste. Looks like paint removed from the "Marathon" oil-drums. This waste is readily settleable and would be much easier to treat at the source than in the sewage. Greatest difficulty is its caustic nature, which must be neutralized for optimum treatment by activated sludge. Quicklime omitted from garbage to permit needed neutralization by garbage acids. This procedure seems to be largely wishful thinking but is probably more helpful than we know. Facilities for treatment with exhaust from the gas engine may be required for neutralization of the several caustic wastes arriving at indeterminate periods.

FIG. 2.—Findlay, Ohio aeration tanks at right rear, main building at center.

November 11—Celebrated Armistice Day by washing the pump room walls. Grape seeds, crushed peach pits and grit added to ordinary sludge-drawing troubles. Check valve in north sump pump worn out. Parts traded about to keep it drying. Detritor trouble rather acute.

November 17—High rate sphaerotilus production rectified by recirculating from the bottom of the final tank back to primary treatment. This involves additional pumping cost but results justify it.

November 20—Floating sludge in primary tanks due to above recirculation was complicated by the old familiar white caustic waste.

November 27—The spare cable for the First Street pump float mechanism was commandeered or confiscated by the waterworks for their switchboard mechanism. This is critical material.

December 3—Fire hydrant frozen at 3 above. Thawed with wood fire to prevent bursting. Did the paint no good.

December 17—Detritor inoperable. Garbage to dump, well limed.

December 21—Installed a Buckeye Ditcher caterpillar idler wheel on detritor. Entirely satisfactory. Can grind garbage again.

December 25—Xmas. Approaching the end of the year with a good taste in the mouth. The Mayor distributed his usual gift of a box of delicious candy to each employee. An extra for this plant to make up for some of the year's troubles.

OBSERVATIONS OF A CONSULTING ENGINEER ON PLANT OPERATION *

By Frank C. Tolles

Havens and Emerson, Consulting Sanitary Engineers, Cleveland, Ohio

In giving me an opportunity to talk in an operation meeting, your Program Committee may be conducting a psychological experiment—just to see what a non-operator has got to say upon the subject. At that, this may not be so dumb, because, unquestionably, the outsider sees things through different eyes. In any case, that is the viewpoint I am taking—that of the outsider.

Approaching this subject and in report of experiences in the field, I note that in conducting a stranger about, most plant operators begin at the beginning of the works, and continue on so that one sort of floats along with the sewage in its travel through the plant. This may appear obvious and a small matter, but it helps wonderfully as to geography, and it saves the visitor from complimenting you upon the appearance of what he thinks is the final effluent, while wondering, privately, why it is so dirty.

Beginning at the beginning then, I have to report that most of the plants visited in search of observations start off with a series of iron

* Presented at Annual Meeting of Ohio Conference on Sewage Treatment, Mansfield, Ohio, June 23, 1943.

slats stuck down into the sewage channel—racks or screens as they are called. In the first plants visited, these slats or screens were quite clean and thus prompted the thought that their function was that of streamlining the flow. Other operators, however, were found to cover the bars with a mat of miscellaneous material—material which I would be embarrassed to describe in any detail. I take it that these two procedures—clean screens and dirty screens—reflect two schools of thought in the treatment of sewage. Be that as it may, this outsider's viewpoint and observation is that the screens look much better when they are clean, even if the stuff does catch and has to be pushed through with the rake which is generally provided for that purpose. Speaking of rakes, I suggest an element of surprise to the visitor when he steps on one of these things which has been cunningly hidden in nearby grass. This form of practical joke may be alright for most visitors, but is doubtful if the visitor happens to be the Chairman of the Council Finance Committee.

Some plants I have seen include pumps. These pumps often appear to be dripping water all the time they are running. I heard someone say something about glands, but apart from the physiological fact that pumps have glands, subject, I presume, to mumps and other ailments, I was struck by the diversity of practice in handling the drippings. One very neat method is to conduct them into some sort of a channel, but, in many installations, arrangements are made to have the water spread over the floor and preferably with an undercoating of grease. I can see the advantage of this to the operator in ease of observation as to whether the water is running properly, and in discouragement of casual wanderers; to the layman, however, the reaction is unfavorable.

The pump room at many plants is at or close to what might be called the operator's boudoir, and many men have done much to fit these places up for comfort. The results are particularly happy where the sewage plant is located close to the city dump for it is then quite possible, and not too laborious, to draw on the dump for at least one rocking chair, a lamp, or even a brass bed, with other odds and ends. The effect is quite chummy and cozy, especially if allowed to accumulate a patina of aged dust.

Most works—at least of my acquaintance—include tanks. The names or the purposes are often confusing, but tanks they are. My chief observation of these was that some operators have evolved the practice of coating the surface of the water or sewage with a spread of oily and greasy material. Frankly, I do not think it looks very pretty, and it is apt to be smelly, but it must take a lot of labor to cover the tank in that fashion and so keep down the mosquitoes. From that health angle it may be worth looking into.

My favorite spot, however, is where they locate those stone beds with sprays on them—the sprays that come and go. I never tire of watching these, and particularly to observe the whimsical way some of the sprays are headed or how some of them spout and also the manner of locating pools. It is all reminiscent of the fountains one sees where mermaids and dolphins squirt water at each other. It is probably no secret, but

I am told that remarkable effects can be obtained by inserting bits of matches or other items into the spray heads. However accomplished, it appears desirable to avoid any monotony in the spray pattern.

There are other things, plenty of them, that impress the lay visitor, but what I have said may give the general idea. In fact, after I had mentioned some of these matters to one of my operator friends, he said I was really talking about good housekeeping and without much point, for, said he, most of those operators are happily married and well trained in housekeeping. And it is true that as one wanders about, it is often possible to visualize an operator simply by looking at his plant. These fellows who must put everything away and even shelve their pipe fittings by size and kind—obviously they are prissy people who insist on running the plant. Some plants, you know, appear to run the operator.

But I do not want to be too dogmatic, as, doubtless, there is a reason for everything. These are war times which entail difficulties, and particularly as coupled to the loss of personnel which many plants have sustained. Switching from the mechanics of operation to the economics, it is obvious that, in these days, deficiencies or breakages of plant and equipment cannot always be remedied by a quick call to the hardware store or the supply house. Taken by and large, operators—an ingenious people—have met their emergency needs in splendid fashion, in part by substitutions, but, more usually I believe, by using their wits. This, however, by its deferment of replacements serves to burden present equipment and implies a dependence upon the future.

Post-war planning or, better yet, just plain advance planning is rife and doubtless every operator is consciously or unconsciously formulating a list of needs which he expects to satisfy when the markets are open to him. From the manufacturer's standpoint, there is no doubt that the opportunity will offer. In fact, the wartime development of substitute materials and devices will probably widen the choice for plant and equipment replacements. Some uncertainty, I believe, applies to the financing end, for the tax burden will continue to be heavy and the pay envelope smaller; accordingly, the local financing resources of municipalities may be curtailed. Those communities which are now upon a sewer rental basis will probably be in a better position if there be no marked depreciation of the dollar.

Despite uncertainties—perhaps because of them—deliberate planning appears called for. In some cases this will involve only a listing of replacements, but in other instances major items of plant and equipment may be necessary. Considering the possibilities of federal aid in financing projects which are ready, it would be well could plant additions be carried to the blueprint stage. The operator should himself assume the responsibility for initiating any such planning.

There is another phase of wartime disposal of wastes which operators will appreciate. I refer to the emergency conditions which have had the effect of lowering the standards of cleanliness which we seek to maintain in our streams. I do not mean that there has been any definite let-down of Health Department attitudes, but we cannot but be cognizant not only of overload, but that many temporary works of doubtful utility have been built, and even that the discharge of untreated wastes has been tolerated of necessity. I have no knowledge of how our own Health Department looks at this situation, but it would be only human to expect the pendulum to swing in the direction of standards higher and more rigid than usual. In fact, I know of at least one public agency that is biding its time to bear down. The moral, if any, in this is that we should anticipate and prepare for raising the performances of plant and to do our planning in the light of such a requirement.

Still another point I would bring up as applicable to sewage plants as well as to all other utilities. I refer to the development of the procedures which will be followed under conditions of emergency from any cause—whether act of war or just plain accident. Doubtless, most operators carry in their heads an instinctive knowledge of what resources avail when the unusual or the unexpected happens—what to do when main pumping breaks down or in the event of a power failure or a simple chain breakage, or even an explosion; what to do to safeguard lives, to protect equipment and to restore or substitute for plant functions. The forward thinking operator will be mentally prepared when the emergency arises, but how much better to work it out in advance by cool unhurried thinking and then to set it down in the operators' manual where all may read. It is, of course, impossible to foretell in full detail what may occur, but it is very feasible to type both the accidents and the countermeasures and so to get the jump on the situation. Just planning, that is all.

This is a homely talk which pleads for high standards of plant maintenance and forward planning which reflects an intelligent appraisal of the future in all its aspects. I make no apology for a presentation which is homely and concerned with routine. Great things can be achieved in the heat and exaltation of enthusiasm but—and particularly in these confusing times—it takes a rare degree of sticktoitiveness and even courage to plug along effectively in the routine of the commonplace—which, after all, constitutes the greater part of our life and living. Gentlemen, I wish you well in your routines; and may these never grow dull but ever alert.

THE GADGET DEPARTMENT

A STARCH DISPENSER FOR USE IN D. O. TITRATIONS *

(A Convenience in D.O. and B.O.D. Determinations)

Submitted by Minneapolis–Saint Paul Sanitary District

When making the thiosulfate titration for dissolved oxygen, Standard Methods calls for the addition of 1 to 2 ml. of starch solution just before the end-point is reached. In this laboratory the starch solution is kept in a large bottle on a shelf and dispensed directly into the titration flask

* Entered in Gadget Contest at Fifteenth Annual Meeting of the Central States Sewage Works Association, held at Minneapolis, Minnesota, on June 18–19, 1942.

through a semi-automatic pipette by a quick turn of a stopcock. A model of the apparatus is shown in the accompanying illustration, which is a view from the rear.

In this model a small bottle of starch solution is shown mounted on the support rod at the top right of the picture. The starch is siphoned through glass and rubber tubing and through a control stopcock (shown just below the double burette clamp and just to the left of the support rod) to the measuring tube shown just to the right of the titration burette at its center. On this measuring tube there is a mark at the 2 ml. point

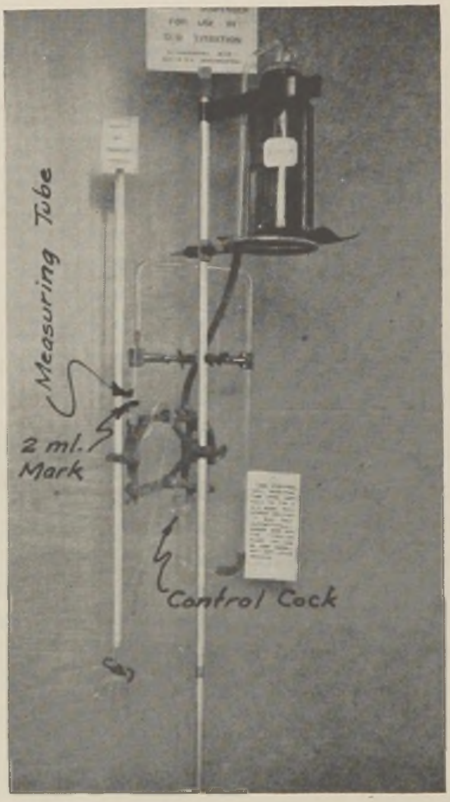

FIG. 1.—Starch dispenser for use in D.O. determination, Minneapolis–St. Paul Sanitary District.

(shows faintly in the picture). A quick twist of the control stopcock will fill the measuring tube to the mark and the measured portion of starch then automatically siphons over into the titration flask through the S-shaped piece of glass tubing, shown attached to the bottom of the measuring tube. The delivery tube is carried down and fastened close to the tip of the titration pipette.

With but little practice this operation can be done very rapidly and with practically no interference with the titration. Where a considerable number of D.O. titrations are made, this device speeds up the work. Besides, such a gadget is always fun to operate and takes some of the monotony out of life.

INTERESTING EXTRACTS FROM OPERATION REPORTS

THE JOINT MEETING (NEW JERSEY) SEWAGE TREATMENT WORKS—1942

By Edward P. Decher

Acting Chief Engineer

During the year 1942 the Joint Trunk Sewer and Sewage Treatment Plant (Elizabeth, N. J.) serving twelve municipalities in Essex and Union Counties, N. J., operated on full time service without interruption with the same satisfactory performance as in previous years.

Description of Plant.—The treatment plant (Fig. 1) is located in the southeast section of the City of Elizabeth, a short distance inland from

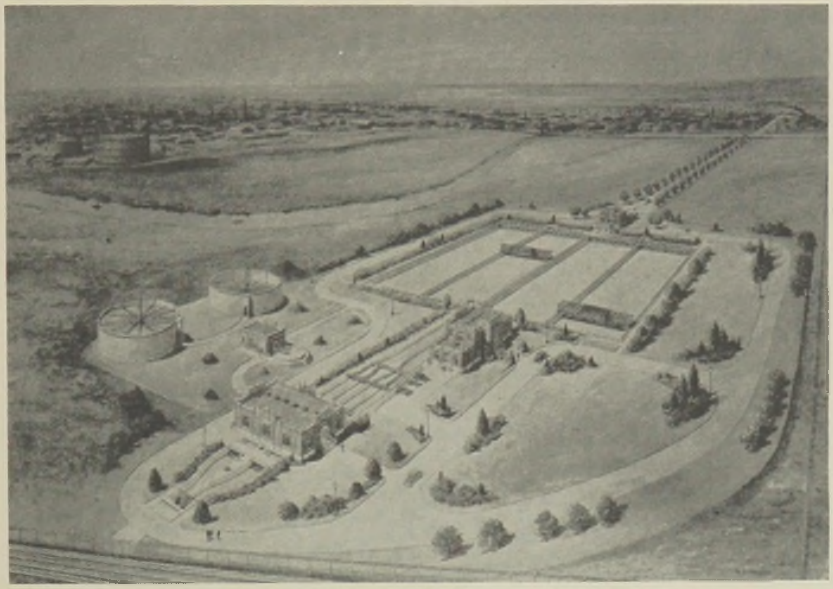

Fig. 1.—Artist's reproduction of Joint Meeting (N. J.) Sewage Treatment Plant.

Arthur Kill (Staten Island Sound), which separates New Jersey and Staten Island. The present capacity of the plant is 100 m.g.d. at two hours settling tank detention. During the year the average daily flow handled was 37.407 m.g.d., which was 9.407 m.g.d. more than was handled during the year of 1941 (Fig. 2). The increase in flow was due to the connection to our system of a portion of the sewage from the City of Elizabeth. The plant is provided with an unusual reserve for future growth and is constructed and operated in such a manner as to require only a small fraction of replacement cost.

The plant site is 28 acres in area, some 30 per cent finished to suitable grade and the balance meadow land allowing room for future expansion, and providing sufficient area for the disposal of grit for many years to come.

The sewage arrives at the plant by means of a twin influent flume, having a total capacity of 172.5 m.g. From this point sewage is directed into the desired channels by means of a swing gate. The sewage then passes through the stationary bar racks (3-in. spaces), which bar racks are manually cleaned. The material removed is disposed of by burying in the adjacent meadow land and covering with earth. The sewage then passes through mechanical screens ($\frac{3}{4}$ in. spaces), screenings being removed by a metal belt conveyor and ejected pneumatically into a special receiving hopper from which the materials are then fed manually into the screenings grinder and returned to the sewage.

FIG. 2.—Pump room in administration building, Joint Meeting Sewage Treatment Plant.

The plant is equipped with four rectangular grit chambers. However, under present conditions and during times of normal flow, only two of the four grit chambers are used. The grit is removed mechanically, as the sewage flow passes through, by means of a continuous Straight Line chain scraper and an inclined screw conveyor which deposits it on a conveyor belt to pneumatic ejectors with final disposal as fill on our meadow land.

The sewage then flows to two, or more, as may be required, of the four rectangular settling tanks, each tank being 75 ft. in width and 280 ft. in length (Fig. 3). The average depth below high water is 13.85 ft., giving a detention period of approximately 2 hours and 20 minutes.

The clarified effluent from the settling tanks is measured by Venturi meters and then passes through the twin outfall sewer to the diffusion chamber, where it is diffused into the tidal waters of Arthur Kill approximately 20 ft. below the surface.

From our experience, we have found that the best results in the removal of suspended solids can be obtained when using two settling tanks instead of four. However, during certain times of the year we found that it was necessary to use three, and sometimes four tanks in order to maintain the percentage of efficiency on removal of suspended solids.

The fresh sludge is mechanically removed from the settling tanks by Mieder machines and pumped into two separate concrete storage tanks, each tank having a capacity of 626,000 gallons. During the storage period the concentration of sludge takes place by control decantation. We still find that the sludge in the storage tanks stratifies and the internatant liquor must be removed at different elevations in order to obtain the most satisfactory results.

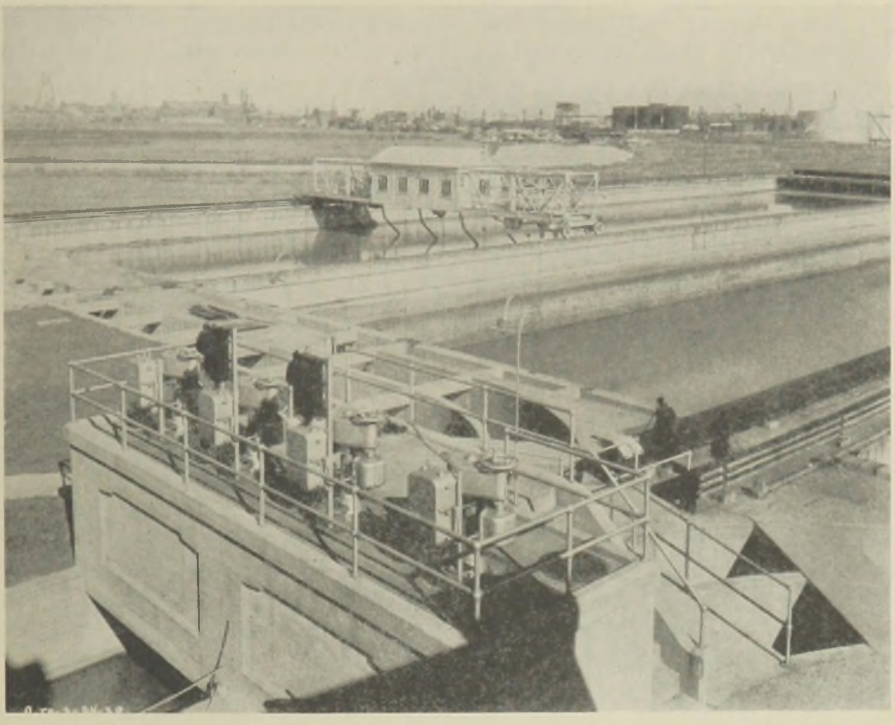

FIG. 3.—Influent end of settling tanks showing Mieder sludge collecting machine in operation. Joint Meeting Sewage Treatment Plant.

Sludge Disposal by Barging to Sea.—The loading of the sludge barge is dependent upon the state of the tide and weather conditions. Normally, the interval between bargings under the rate of flow now prevailing is every two weeks at which time the concentrated sludge is pumped into sea-going barges for final disposal at sea.

All sludge handling is done by pumping and the use of compressed air. However, we find that during certain periods of the year, mainly during the winter months, a certain amount of water must be added during barging operation in order to obtain efficient removal and to meet the tide condition, which is an important factor in casting off the barge when loaded. The water used for this purpose is the incoming sewage taken from the influent channel and adds no extra cost to the Joint Meeting.

Only 22 bargings took place during the year 1941 which totaled 75,920 tons, the average solid content being 7.84 per cent; whereas during the year of 1942, 26 barge loads were sent to sea, which totaled 89,050 tons, an increase of 13,130 tons, and the average solid content was 8.26 per cent. The increase in tonnage was brought about by the additional sewage from the City of Elizabeth, with some increase in flow contributed from the contracting municipalities.

All barging operations continued at night in accordance with government regulations. In other words, the barge was loaded during the night and taken out to sea and dumped during the daytime period.

Personnel Handling.—By request of the Joint Meeting several years ago, some of our employees had taken special courses under the able direction of Dr. Rudolfs at Rutgers University which consisted of laboratory practice and routine in connection with sewage treatment. With the loss of our chemist to the armed forces and being unable to engage

TABLE 1.—*Summary of Operation Data (Joint Meeting Plant)*

Item	1942 Average	
Population served	360,000	
Sewage flow	37.407	m.g.d.
Per capita daily	103	gal.
Screenings removal	136	c.f. per day
Per m.g. sewage	3.64	c.f.
Grit removal	128.4	c.f. per day
Per m.g. sewage	3.43	c.f.
Primary sedimentation:		
Detention period	2.27	hrs.
5-Day B.O.D.—Influent	240	p.p.m.
Effluent	143	p.p.m.
Removal	40.5	%
Suspended solids—Influent	194	p.p.m.
Effluent	64	p.p.m.
Removal	67.0	%
Sludge concentration:		
Sludge quantity from clarifiers	91,619	g.p.d.
Solids content	5.8	%
Decanted liquor quantity	39,713	g.p.d.
Concentrated sludge solids content	8.26	%
Sludge barging—quantity	226	tons per day
Per m.g. sewage treated	6.04	tons
Cost for year, including wharfage	$33,830.20	
Per ton sludge barged	$ 0.38	
Sludge disposal cost per m.g. sewage	$ 2.48	
Total operation cost—per m.g.	$ 7.91	
Per capita per year (1942)	$ 0.30	

another chemist, it was necessary to place the assistant foreman on sewer maintenance in the laboratory to take over this work which was done without extra cost to the Joint Meeting, thus paying a dividend on the foresight which permitted the men to take these special courses.

Rotating of our employees at the treatment plant on all operations and the breaking in of the sewer maintenance men on treatment plant operations has proven very successful, and gives us more flexibility in times of emergency and sickness, or whenever anything occurs which is not predictable.

AURORA (ILLINOIS) SANITARY DISTRICT—1942

By Walter A. Sperry

Superintendent

Weed Control at Profit.—The use of alfalfa to cover the backfield portion of the grounds has been more than satisfactory in that it kept a good appearance and tended to control weed growth. However, the original seeding was six years old and was beginning to "run out." The fields were plowed, harrowed and planted with a hybrid corn, maturing in 105 days and well adapted to the Aurora area, which corn was planted on shares with a neighboring farmer. The corn was reported to be among the best fields roundabout for a considerable area, probably due to the alfalfa grown previously, as well as to being the first corn crop ever planted on this ground. As nearly as could be estimated, there was a yield of about 600 bushels from 7.5 acres, a rate of 80 bushels per acre. Many ears were a foot long or better. Primarily, sewage men are not necessarily good farmers. In these days of short labor we would not want to repeat this experience; however, it was as profitable a change-crop as could be planted and was necessary for the good of the alfalfa field, which will again be used. Since a portion of the corn is still in the crib, no figure is available for the plant's share of money return.

Tractor Accessory.—Acquired a Stockland grader with a hitch for use behind the tractor. This machine has a six-foot blade and was manufactured by the Foote Gear and Machine Works of Minneapolis. It fulfilled a long-felt need for maintenancing the roads, trimming the sludge pile and clearing snow from the plant drive in the winter time. Experience with a caterpillar type of tractor indicates that one drawback is the tendency of the roadway, over which it travels, to build-up, crown and pack hard due to dirt carried and deposited from the track system. From time to time these "crowns" must be gone over with the scraper and cut down and the roads leveled.

Painting Experience.—Re-coated the walls of the screen house, clarifier house and the sludge meter room with a Federal government formula for preparing whitewash by the addition of salt, yellow soap and alum which tends to harden and make weatherproof. It was thought that this would be rather well suited to the constantly moist condition of these buildings and would neither rub off or scale. The results, however, were disappointing since this material did not give as good service as such water paints as Modex, which have been used heretofore. The condition in the clarifier house, however, is severe since the walls are often frost-coated where exposed to the weather.

Lesson in Boiler Operation.—In July one section of gas boiler No. 1 developed a crack. This was the first boiler difficulty of this type in four years. Welding proved a questionable method of repair due to the following or "leading" of the crack so that a new section was purchased. After assembly, however, a small crack developed in an adjacent section, but this was taken care of satisfactorily by the use of an internal treatment of aluminum powder made for this purpose. It is possible the lesson from this incident is the need to maintain all the burners lit so as to get an even distribution of heat, rather than the use of fewer burners.

Wartime Maintenance.—Rebuilt the tipping bucket of the sludge meter. This meter is in much the same condition as the incinerator. It has given good service for several years but should be entirely rebuilt due to breaking and rusting of the parts. It is hoped that it can be patched, as needed, until plate steel is more normally available.

The gas collecting dome of Digester No. 2 is approximately 56 in. in diameter and 15 in. high and sits in a water seal on top of the digester. During the year this dome corroded through and had to be either repaired or replaced. Due to metal shortage and because the pressure to which it is exposed is low, it was repaired by placing around it a sheet iron form with an annular space of about 2½ inches. This space was poured with a rich concrete, reinforced with metal lath. The dome was topped with the same concrete mixture, except for the clean-out manhole. The repair, to date, has been quite satisfactory. It is anticipated that it will last for many years and that the other domes can be similarly treated when necessary.

The piston in the Carter sludge pump developed grooves and holes and needed replacement. In this case, we were able to use the old piston as a pattern and have a new one cast in a local foundry—an example of the type of emergency repair which must be attempted in these days of priorities and scarce material.

Extra Sludge Beds Pay Dividends.—No unusual circumstances arose in 1942 in the operation of the sludge beds. It should be noted, however, that the dividends earned from the eight extra beds built in 1940–41 fully justified the money invested. Due to the severe winter, the volume of sludge and the man shortage, it would have been practically impossible to operate without the additional bed space. In the winter of 1941–42 we had plenty of men and at times as high as 10 to 12 men at work. In the winter of 1942–43 we did well to have four men at work and sometimes but two.

Filter Flies Controlled.—There was no appearance of the psychoda fly and there has been no observance of achorutes for the second or third year now. All during the winter time the stone near the surface is well coated with masses of lumbriculus. There is a distinct feeling that the presence of lumbriculus has something to do with the apparent disappearance of the achorutes and possibly the fly.

H_2S Removal by Flotation.—The river valve (for dilution) was not in use during the year in order to produce a maximum concentration of hydrogen sulfide in the raw sewage for the operation of the pilot plant erected the latter part of 1941 for the purpose of studying the effect of a flotation unit on the aeration and removal of the hydrogen sulfide content, also, its possible advantage in causing flocculation of raw sewage as a preliminary to settling. It was difficult to get conditions favorable for operating the plant so that the amount of data accumulated was rather small and not satisfactory. The hydrogen sulfide content of the raw sewage remained low despite the withdrawal of dilution water. It was probably offset by large volumes of ground water coming in from the Southeast Interceptor sewer system. There were, however, a sufficient number of results obtained to definitely indicate a 70 to 80 per cent reduction in hydrogen sulfide content following the flotation treatment. It was disappointing not to get any evidence on the flocculation effect on suspended matter.

The equipment was dismantled in the fall of 1942 but evidence obtained by the pilot plant was sufficiently supported by experience at one or two other plants where the flotation process is used ahead of settling that it left no question but that it would be effective in reducing the hydrogen sulfide content of the sewage applied to the filters. The Engineering Department has prepared detailed drawings looking toward the installation of four units of this equipment in a spare clarifier unit as an addition to the plant and for postwar consideration.

Metal Corrosion Experiments.—The relationship of hydrogen sulfide to materials of construction is one of definite importance to sewage plant operation. The experiment of a series of metals exposed to moist plant gas was begun in 1941 and continued throughout the year 1942. It will be recalled that 30 odd samples of metals of various composition were continuously exposed to plant gas under moist conditions and that a few were exposed to gas under dry conditions. Careful note is taken of the volume of gas passed, its water content in grams per cubic foot and an occasional weighing of the metals. Thus far no corrosion other than discoloration has occurred to the metals exposed to dry gas, as would be expected. In the case of the moist exposure of the metals—aluminum, lead, and zinc are consistently free from any evidence of corrosion. All copper-bearing metals show corrosion effects. Many of the special ferrous alloys show little effect. These metals have been exposed since about May, 1941. The experiment will probably be terminated about December 31, 1943.

Gas Pipe Failure.—As a direct corollary to the metal study and the hydrogen sulfide content it was necessary to entirely replace all of the gas piping leading from the digesters to the distribution end at the meters in 1942. This piping was two inch Byers black wrought iron. It went into service December, 1929 and has been in service for more than twelve and one-half years. This pipe lost 44 per cent of its weight and dropped from 3.65 pounds per foot to about 2.0 pounds. It had begun to puncture slightly. It was not strong enough but that too vigorous use of pipe tongs would crush it. It could no longer be rethreaded.

Consideration was given to replacing it with "extra heavy" wrought iron pipe, galvanized. Extra heavy pipe weighs 5.0 lb. per foot but the cost increases from approximately 31 to 65 cents per foot. Galvanizing would have involved special processing and at a considerable added increase in cost. It did not appear, therefore, that the more than double cost, exclusive of galvanizing, would offer sufficient life to make the additional investment wise, although our metal experiment indicated that the galvanizing would have added materially to the life of the pipe since zinc showed no corrosion effects from hydrogen sulfide.

TABLE I.—*Summary of Operation Data* (*Aurora, Illinois*)

Item	1942 Average
Tributary population	49,000
Sewage flow (daily)	7.74 m.g.d.
Per capita	158 g.p.d.
Screenings removal	1.17 c.f. per m.g.
Grit removal	3.45 c.f. per m.g.
Volatile content	43.9 %
5-Day B.O.D.:	
Raw sewage	123 p.p.m.
Primary effluent	74 p.p.m.
Removal—primary treatment	39.8 %
Filter effluent	22 p.p.m.
Final effluent	16 p.p.m.
Removal—complete treatment	87.0 %
Suspended solids:	
Raw sewage	175 p.p.m.
Primary effluent	78 p.p.m.
Removal—primary treatment	55.2 %
Filter effluent	48 p.p.m.
Final effluent	28 p.p.m.
Removal—complete treatment	83.8 %
Sludge digestion:	
Raw sludge quantity per m.g. sewage *	2,655 gal.
Solids content (primary sludge)	4.9 %
Volatile content (primary sludge)	72.5 %
Transfer sludge to second stage:	
Solids content	2.6 %
Volatile content	55.7 %
Gas production (daily)	53,720 cu. ft.
Per m.g. sewage	6,940 cu. ft.
Per capita daily	1.1 cu. ft.
Per lb. volatile solids added	8.75 cu. ft.
Administration and operation costs:	
Per m.g. treated	$11.97
Per capita per year	$ 0.69

* Primary sludge plus filter humus.

Once or twice each year it was necessary to clean the piping of a deposit of iron-sulfur mixture which collected in hard masses. This accumulation could occasionally be washed out with some pounding on the pipe. At times it was necessary to take the pipes down to clean them. This material appeared to be an iron-sulfide mixture of varying composition and apparently had a tendency to collect at elbows and other obstructions. A chemical examination of three samples of this material indicated free sulfur ranging from 4.8 to 13.2 per cent, a total combined sulfur content ranging from 13.7 to 30.0 per cent, which was equivalent to 25.6 to 56.1 per cent of iron sulfide. This left an iron and dross content of from 35.2 to 69.6 per cent.

The drip traps on the gas lines were originally placed at the delivery end of the gas lines near the meters. These drip traps were found almost completely stopped up with a mass of this iron-sulfide mixture. Before placing the new gas line, the position of one of these traps was changed from the delivery end of the line to the head of the line at the digester. This was on the theory that if the bulk of the water were extracted from the gas quickly, the corrosion effects on the pipes would be somewhat reduced.

CORRECTIONS

Superintendent R. A. Anderson advises us that an erroneous statement in the 1942 Annual Report of the Muskegon Heights, Michigan, Sewage Treatment Plant, extracts from which were published in *This Journal,* 15, 742–746 (July, 1943), should be corrected. Writes Mr. Anderson:

> "In the 1942 Annual Report of the Sewage Treatment Plant, Muskegon Heights, Michigan, it was incorrectly stated that the General Chemical Company had advised against the use of alum on a sewage of high organic content. The statement should have been to the effect that the requirement of excessive amounts of aluminum sulfate for coagulation of the raw sewage is due to the septic condition of the sewage. If the plant is equipped for the addition of chlorine to the raw sewage before coagulation, the amount of alum required would be greatly reduced."

In regard to the operation data published for the Findlay, Ohio plant, also in the July, 1943 issue of *This Journal,* the *Corner* offers apologies to Superintendent Ben H. Barton and its readers for reporting erroneous values for gas production and operation cost. In the tabular summary on page 741, the gas production (waste not included) should have been reported as 9,413 *cu. ft. per million gallons.* The plant operation cost in the same summary should have read $8.66 per 1,000 pounds 5-day B.O.D. removed

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TIPS AND QUIPS

A special bulletin (Number 11) on prevention of weight-lifting injuries, issued by the Labor Standards Division of the U. S. Department of Labor, will be worth reading by sewage plant workers. Weight-lifting injuries are exceedingly common and usually average 7 to 19 weeks of disability.

The most common causes of injuries incurred while lifting and carrying heavy objects are listed in the bulletin as follows:

1. Lack of lifting and conveying equipment.
2. Overtaxing physically fit workers—through the worker's failure to use or the supervisor's failure to require the use of available mechanical equipment, or through management's failure to set a reasonable limit on the weight of objects to be lifted or carried, and to control the pace and duration of the work.
3. Lifting the wrong way, which results in undue strain on certain muscles and ligaments—notably in the back and groin.
4. Lifting by employees not physically capable of handling the job.
5. In team lifting—lifting by two or more workers—the unco-ordinated efforts of the team members, resulting in too heavy a burden upon one or more.
6. Poor housekeeping, resulting in insecure footing and tripping and slipping hazards.

* * *

Bernard Rowntree, Assistant Secretary of the Carmel (California) Sanitary District, writes us regarding the "pinched-nose" attitude of the general public toward the sewage works field as a profession. It appears that a sewer construction foreman happened to mention in Mr. Rowntree's presence that his wife was ashamed to acknowledge his occupation as a "sewer man." Rowntree asked, "Would your wife be ashamed if you were a doctor?" When the foreman responded with an emphatic negative, Mr. Rowntree continued, "All right, all most doctors are doing is trying to cure people *after* they get sick, but your occupation is most important in *preventing* people from getting sick and you should be proud of your work if it is well done!"

Which no one can deny.

* * *

Contrary to what appears obvious, Fig. 1 is not exhibited here to illustrate the surface cracking at a bed of air-dried sludge. According to

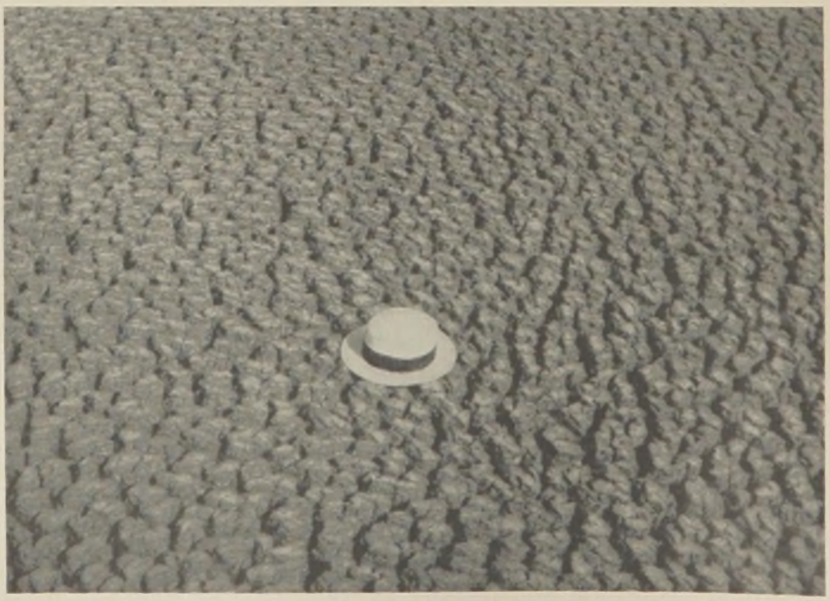


Fig. 1.—Well-dried sludge?

C. C. Larson, Chemist and Assistant Superintendent of the Springfield (Illinois) Sanitary District, it is "a bird's-eye view of a sewage plant operator who is up to his ears in work."

This is a pre-war photograph, of course. Nowadays, even the hat would be submerged in a welter of questionnaires, orders, forms, etc.!

* * *

Training of sewage treatment plant operators has always been given a leading place in Wisconsin, where the Annual Short Course given at the state university has become an institution. State Sanitary Engineer L. F. Warrick informs us that, as a war measure, the state-wide school is being replaced temporarily by several sectional schools. Says Mr. Warrick:

> "Our objective in these sectional schools has been to train the new operators and 'lend leasers' that are taking over operations during the war period. Our first school, held at Neenah-Menasha in May, was well attended and considerable interest was shown in the plan for holding sectional schools of two day's duration, with the instructional work carried out in municipal sewage treatment plants adequately equipped for demonstrations and laboratory control tests."

The man-power problem constitutes a shortage of *properly-trained* personnel. The activity in Wisconsin is one of the answers.

* * *

If a novel idea * of the City Council of Bismarck, Missouri takes hold elsewhere, there is likely to be a number of municipal sewer superintendents listed among our industrial leaders and moving picture actors as payers of huge income taxes. In an effort to reduce excessive wet weather flows, the Council has provided for a bonus of $1.00 to Sewer Superintendent Sloan for each roof downspout connection to the public sanitary sewer system that he locates and eliminates.

Thar's gold in them thar tiles!

* * *

Some evidence of the effect of weathering in a sludge stock pile is contributed by Chemist Gordon C. Laidlaw of the Greater Winnipeg (Canada) Sanitary District, via the 1942 annual report of the District. Carefully collected samples of sludge cake (from vacuum filters) deposited on the pile in 1942 and in 1941 were taken for analysis, results of which are as follows:

	1941 Sludge Cake	1942 Sludge Cake
pH	6.65	7.10
Per cent volatile in dry solids	41.0	49.5
Per cent dry solids	55.4	39.9
Per cent of dry solids:		
Free Ammonia (N_2)	.002	.08
Organic Nitrogen (N_2)	1.49	1.82
Phosphate (P_2O_5)	1.49	1.85
Sulfide (S–)	.003	.011
Insoluble Iron Oxide, Aluminum Oxide and Silica	47.0	40.0
Calcium (CaO)	6.55	5.99

* *Bulletin* of the Missouri Water and Sewerage Conference, April, 1943.

It would appear that, in the first year of storage, there is an appreciable change in the stocked sludge due to leaching and further decomposition.

* * *

What comes after September? Why October, of course, with the Second Wartime Conference (Fourth Annual Meeting) of the Federation. And the best tip of all is—*do not fail to attend!*

SECOND WARTIME CONFERENCE
FEDERATION OF SEWAGE WORKS ASSOCIATIONS
HOTEL SHERMAN, CHICAGO, ILLINOIS
OCTOBER 21–23, 1943

Editorial

PRE-VIEW OF THE CHICAGO WARTIME CONFERENCE

I believe the feature of our Chicago Wartime Conference will be, not the discussion of wartime problems, not the technical chemical and engineering papers, not the operators' roundtable, and not the entertainment, but rather the inconspicuous and unfeatured paper by Dr. Maxcy presented by Dr. Howe at 3 P.M. Thursday on "The Relation of Sewage Treatment to the Transmission of Virus Diseases." This title hardly looks like news, but if one substitutes "Poliomyelitis" for "Virus Diseases," Dr. Maxcy's paper becomes important news. His paper should be heard by all of us interested in the disposal of sewage for protection of the public health, because there is a great deal of misinformation concerning the role of sewage in dissemination of polio, and we need some practical advice on this subject by the best medical authority we can get.

In the January issue of *This Journal,* the writer reviewed, as carefully as his limited knowledge permitted, the history of research on the etiology of polio, and suggested that it was the duty of the sewage works profession to become better informed on this subject, if necessary by the appointment of a Committee on the Relation of Poliomyelitis to Sewage. In this same editorial, Dr. Maxcy was mentioned as the outstanding epidemiologist on polio, and recipient of the largest grant, $300,000, from the National Poliomyelitis Foundation, for the study of the disease. In June, it was planned to ask him to appear on the October program, and he kindly consented to prepare a paper, but stated it would have to be presented by his colleague, Dr. Howard A. Howe, as he (Dr. Maxcy) will be on a special mission that will make it impossible for him to attend the Conference. Dr. Howe has worked alongside Dr. Maxcy for a number of years and is thoroughly familiar with the work that has been done at The Johns Hopkins University and elsewhere on the epidemiology of polio. He can therefore lead an active discussion of the present theories regarding sewage as a factor in the transmission of the disease.

Although the virus of polio has been recovered from sewage a number of times in recent years, especially during epidemics, there still seems to be little progress in the study of the mode of entrance of the virus into the human organism. It has been demonstrated that the virus is discharged in the excreta, but the mode of entrance is far from clear—whether by means of flies, mosquitoes, water, food, or, more likely, person to person contact.

It is possible that further research may demonstrate more clearly whether or not polio must be regarded as a water-borne disease, similar to typhoid fever. If so, we must add another disease to the list of those for which sewage treatment, and especially chlorination, provides one means of control. The work at the University of Michigan by Dr. Ridenour *et al.* has been directed toward studies of the efficiency of methods of sewage treatment and water purification in removal of the virus. We are fortunate to have Dr. Ridenour present to discuss Dr. Maxcy's paper.

There is a large burden of proof on the medical research men to indicate whether secondary treatment or chlorination of sewage effluents, fly and insect reduction, or other more complex and expensive measures are necessary for control of polio. Until it is more clearly shown, however, that sewage is the source of infection or the reservoir of virus in epidemics of polio, the installation of expensive additional sewage treatment solely for the purpose of rendering the virus ineffective is far from justifiable. We believe Dr. Maxcy is in accord with this viewpoint, but Dr. Howe will be able to present his and Dr. Maxcy's conclusions from the medical standpoint.

Other intensely interesting topics are listed on the Conference program. Mr. Greeley will discuss "high-pressure" biological treatment, drawing analogies between filters and activated sludge, and referring to Army experiences with all types of biological treatment, including the Hays Process. He has had unique opportunity to study this topic and will give information of value. Dr. Eliassen will present data on grease removal at Army sewage treatment plants and thus will throw more light on this spot-lighted question of grease removal from sewage. Industrial wastes in wartime will be discussed by the writer, particularly certain wastes peculiar to the war effort and their effect on sewage works operation and stream pollution problems.

All day Friday will be devoted to wartime problems, featured by the lead-off by our representative in the W P B at Washington, A. M. Rawn, followed by discussion by C. W. Klassen of manpower requirements of the Army, and wound up by Morris Cohn's panel on post-war problems. Fortunately we will have Mr. Filby present on this panel, to discuss "Blueprint Now" (see page 970).

Saturday morning the operators will have a long and uninterrupted session from 8:45 until 11:30, to discuss topics assigned by Leader John C. Mackin, as well as unassigned topics dear to the hearts of operators.

The significant and important address by Prof. Gordon M. Fair on "The Outlook for Sewage Disposal in the Latin-American Countries" is scheduled for the Federation Luncheon, Thursday noon. What could be more timely in a Wartime Conference?

Finally, the entertainment need not be overlooked, even though of minor importance in a Wartime Conference. The Ladies' Committee has been especially busy in arranging an interesting and attractive program. For the men, the smoker will be held Thursday night and the dinner dance will attract everyone Friday evening. Harry Schlenz, Chairman, says "just remember the last Chicago Convention."

For many, the manufacturers' exhibits will be of most interest. To date, thirty-eight booths have been assigned; indicating a highly successful show. Reading of the Advertisers' Contributions in this issue (page 985) will prepare the visitors for the interesting developments that are taking place in manufacturers' research and development divisions, despite war restrictions.

The Local Committee has worked hard to assure a successful convention, and Wellington Gilcreas has spent a great deal of time on and applied excellent judgment to the technical program.

For all these reasons, the Second Chicago Convention promises to exceed the First of 1940 in interest, significance and importance. Therefore we trust your reservations are made, both train and hotel. See you at the Sherman!

F. W. Mohlman

Editor's Note: We regret to announce the death of Paul Molitor, Sr., at Chatham, N. J., in August. Since 1910 he had been Superintendent of the Madison-Chatham Joint Plant, thus giving him one of the longest terms of service in one city of any operator. Mr. Molitor was born Nov. 6, 1875 and lived practically all his life in Chatham. He was a Captain in World War I, and was one of the founders of the New Jersey Association. His silvery head was usually seen at the Federation's conventions, and he will be missed—even more so, undoubtedly, by the New Jersey Association. His son, Edward P., is Treasurer of the New Jersey Assn. and a Director of the Federation.

Proceedings of Local Associations

CALIFORNIA SEWAGE WORKS ASSOCIATION

Sixteenth Annual Convention—A War Conference

Fresno, California

June 10-13, 1943

Smoker and Get-together: President Carl M. Hoskinson called the convention to order at 8:00 P.M., June 10, in the Patio Room of the Hotel Californian by welcoming 107 members and guests to the Sixteenth Annual Convention of the California Sewage Works Association. He then turned the meeting over to Harold L. May and a highly successful and most enjoyable informal "Smoker and Get-together" was under way. The attention of all present was focused at the buffet table on which was spread a plentiful supply of sandwiches, salad, relishes, beer, and soft drinks. These refreshments were furnished through the courtesy of five manufacturers whose representatives are members of the Association. A new sound film "Health and the Cycle of Water" was presented by courtesy of the State Department of Public Health, Bureau of Sanitary Engineering. This picture was an excellent presentation of the history and need of water and sewage treatment. Diagrammatical sketches illustrated the various types of sewage plants and the principles of their operation. This sound picture was very timely in that it preceded the following two day program on plant operations, maintenance and control. After an hour or so of story-telling and getting acquainted, the meeting was adjourned at 10:30 P.M.

How to Operate the Plant: With 137 present, President Hoskinson opened the War Conference at 10:00 A.M., June 11. After distributing a fourteen-page syllabus containing the authors' outline of papers to be presented, he turned the meeting over to William A. Allen for the rest of the day.

"How to Operate the Plant" was the theme of all papers programmed for the day, and Mr. Allen explained that each formal presentation of 25 minutes or so would be followed by 20 minutes of discussion. He also pointed out that the purpose of these papers was to offer basic instructions in the principles and application of certain of the processes in sewage treatment.

Henry J. Miles, Associate Professor of Civil Engineering, University of Southern California, presented a paper on "Separate Sedimentation." Harold L. May, Engineer for the Palo Alto Water and Sewer Division presented a paper on "Separate Sludge Digestion." A paper on "Combined Sedimentation and Digestion," prepared by Roy E. Ramseier, Senior Sanitary Engineer, and Gilbert C. Hanes, Associate Sanitary Engineer, both of the U. S. Engineer Department, Pacific Division, was given by Mr. Hanes. Frank S. Currie, Consulting Engineer, San Bernardino, talked about trickling filters. Chlorination was discussed by R. T.

Gardner, Division Engineer, Wallace and Tiernan Sales Corporation, Los Angeles. The last paper of the day, "Sludge Disposal," prepared by G. A. Parks, Assistant Engineer, City of Los Angeles, was read by Wm. J. O'Connell, Jr. After taking time out for dinner, the meeting was reconvened by Mr. Allen at 8:00 P.M. with 92 present. As the evening had been set aside for "Questions and Answers" many problems facing the operators were discussed.

How to Care for Plant Equipment: With F. Wayland Jones presiding, the Saturday morning session, based on the theme "How to Care for Plant Equipment," got under way at 9:00 A.M., June 12, with 88 present. The purpose of the papers in this group was to offer instruction on selected subjects connected with operation of sewage plant equipment. The first paper was presented by A. B. Shearer, Manager of the Marine County Sanitary District No. 1, on the subject, "Pumps and Pumping Stations." Clyde C. Kennedy, Consulting Sanitary Engineer, San Francisco, gave a paper on "Sludge and Scum Removal Equipment." A paper prepared by Vinton W. Bacon, Assistant Engineer with the Los Angeles County Sanitation Districts, on the subject, "Digester Heating and Mixing Equipment" was read by H. K. Palmer, due to the fact that Mr. Bacon had been called to active service on June 10 with the U. S. Public Health Service Reserve as an Assistant Sanitary Engineer. A paper on "Sewage Flow Meters and Registering Device" was presented by Ewald M. Lemcke, Maintenance Engineer, Orange County Joint Outfall Sewer. Two papers were presented on the subject of motors and electrical equipment; one by Alonzo Hatch, California-Oregon Paper Mill and the other by J. P. Price, Electrical Engineer, General Electric Company, San Francisco. The last paper of this group was on "Paints and Painting" and was presented by H. W. Davey, Acting Chief Operator, of the Bakersfield sewage treatment plant.

The Saturday afternoon session was entirely devoted to the subject, "How is the Plant Working." Richard D. Pomeroy, Consulting Chemist from Pasadena presented a three-hour demonstration and explanation of tests to use in control and in measurement of loadings and efficiencies of treatment plant units. Tests pertaining to sedimentation units were: settleable and suspended solids, and sludge concentration. Tests for digestion tanks were: pH, alkalinity, organic solids, and volatile acids. Tests for activated sludge units and trickling filters were: sludge settling, relative stability, dissolved oxygen, and bio-chemical oxygen demand. Miscellaneous tests presented were for sulfides, grease, and residual chlorine.

Annual Banquet: One hundred and twenty-three members and guests attended the annual banquet in the Ballroom of the Hotel Californian. Guest speakers for the evening were Dr. W. L. Halverson, Director, Department of Public Health for the State of California, and Homer Buckley, State Director of Civilian Protection. Other guests at the head table were Charles Gilman Hyde, University of California; Edward A. Reinke, Senior Sanitary Engineer for the State Health Department; Dr. Wm. F. Stein, Fresno County Health Officer; Dr. E. H. Coleman, City of Fresno Health Officer; W. Frank Rantsma, Chairman of Local Arrangements, Mrs. Rantsma, Mrs. Carl M. Hoskinson, Mrs. J. C. Albers, and all of the Association's officers and directors. The spirit of the evening was immediately set off by community singing led by the irresistible singing of John B. Gill. Later in the evening, Mr. Gill favored the members by singing several solos accompanied at the piano by Mrs. Carl M. Hoskinson.

After dinner, Mr. Homer Buckley was introduced by President Hoskinson and presented a brief but detailed review of the new War Powers Act recently passed by the State Legislature and explained how the State War Council under the direction of Willard Keith was planning to put into effect the measures necessary to insure civilian protection in times of emergency. The State is to be divided into a northern and southern section which in turn will be divided into six and four districts, respectively, and coordination and mutual aid will be effected through existing public agencies. Mr. Buckley stressed the point that "it can happen here" and that the greater the successes of our war effort, the greater would be the probability of an attack on this coast. Danger from sabotage, especially in the form of forest and watershed fires, was considered very important and probable. Mr. Buckley considered that the small city will be of vital importance in helping the larger cities of military importance during times of emergency. Mr. Buckley praised the past work of the Association's Committee on Emergency Sewerage Protection and requested that the Association evaluate the experience so gained and suggest to the War Council the most expedient means whereby the proposed plans may be put into immediate effect.

Dr. Wilton L. Halverson was then introduced by President Hoskinson and presented a very timely and interesting address on the subject "Tropical Diseases and War." Tropical diseases were defined by Dr. Halverson as those diseases usually associated with areas subject to heat and humidity, where hoards of insects are present, where infection is known to exist and usually where living conditions are in a sub-economic status. Diseases in general can be segregated into those diseases found only in temperate zones, only in tropical zones, and those found in both tropic and temperate zones. Typhus fever is now endemic in the Mediterranean area and North Africa. Control by delousing has been simplified by use of pyrethium powder sprinkled on the body and clothes. Epidemic typhus with a mortality of 50 per cent is not a problem in the United States at present and will not be unless the entire economic system breaks down. Considerable progress has been made in the use of vaccines, however, for protection from epidemic typhus. Plague is known to exist in 20 counties in California as well as in eleven western states and the general belief is that plague had existed in this country prior to 1900 rather than being imported by foreign ships. Plague is present in the Mediterranean and North Africa area and rats are known to be plentiful in the Solomon Islands. The importance of malaria was pointed out by the fact that in India alone there existed 100 million cases annually with from three to ten million deaths. Less progress has been accomplished in the control of malaria than in any other disease. There are reported to be 180 varieties of *anopheles* mosquito, 160 of which are responsible for transmitting malaria. In California, only the *anopheles maculipennis* carries this disease. Present prophylactic methods of control call for one million pounds of atabrine for the U. S. Army alone and nine million to supply the whole world. Filariasis is now very important in the South Seas. It is one of twelve or so varieties of a group of diseases transmitted by the bite of mosquitoes and flies. Swelling of arms and legs typifies this disease which sometimes is delayed as long as eight months after infection. Dr. Halverson ended his comprehensive summary with a brief review of the training programs now under way to teach medical personnel how to recognize and handle the tropical diseases.

Operators' Breakfast: With Harold L. May as toastmaster, 29 operators and other members met at a 7:00 A.M. breakfast on June 13. After going through the informalities which have typified these breakfasts in the past, serious consideration was given to how the operators, through the Operators Committee, could assist in future meetings. It was decided that suggestions could be made to the Program Committee as to the type of subject matter to be presented at future meetings.

How to Keep the Plant Running in War Time: With President Hoskinson presiding, the third day of the War Conference was opened at 9:00 A.M. with 85 present. Harold F. Gray, Sanitary and Hydraulic Engineer of Berkeley presented a very timely paper prepared in conjunction with Wm. J. O'Connell, Jr. and titled "Emergency Land Disposal of Sewage." The paper was illustrated with slides. A discussion, prepared by C. G. Gillespie, Chief, Bureau of Sanitary Engineering, State Health Department, was read by Arthur Reinhardt, Assistant Sanitary Engineer of the same department. W. L. Knowlton, Consulting Engineer for Los Angeles, and W. F. Rantsma, Deputy Commissioner of Public Works for the City of Fresno, also discussed the paper.

Emergency protection and mutual aid for sewerage works were discussed. Charles Gilman Hyde, Professor of Sanitary Engineering at the University of California, opened the discussion on this subject by briefly discussing the importance of the State Senate Bill No. 1 which established the new State War Council. He also gave the history of the Association's Sewerage Protection Committee and summarized what it has accomplished in its work with the old State Defense Council. Mr. Homer Buckley, State Director of Civilian Protection described how the new State War Council was designed to function and asked what the Association could do to re-activate the committee and to plan a method of cooperative effort with the War Council. Harold F. Gray, reviewed the conclusion arrived at by the Emergency Sewerage Protection Committee, and E. A. Reinke stated that the first necessary step is to find out where the large and small cities and towns need help. The whole subject was open to general discussion and questions were brought up dealing with the guarding of sewage plants, protection of large sewers by locking manhole covers, potential dangers from petroleum products entering the sewers by acts of untrained help, and many other questions on how the new War Council was going to reach and cooperate with the individual town.

A discussion was held on manpower and operation of sewerage works. Roy E. Ramseier, Sanitary Engineer, Pacific Division, U. S. Engineers

Department, opened this discussion by reviewing the present program sponsored by the U. S. Engineers Department in Washington for the training of engineers in the specialized field of sanitary engineering with special emphasis on water and sewage treatment and disposal, waste disposal, and pest and rodent control. The training course is referred to by the initials E.S.M.W.T. which stand for Engineering, Science, and Management War Training. The course lasts four weeks with 8 hours a day and six days a week and is under the direction of Professor Hyde at the University of California.. Twenty-two members of the present class attended this convention as a part of this training in sewage treatment and disposal problems. Mr. Ramseier also mentioned that they are considering a training course for sewage plant operators in cooperation with this Association's Committee on Emergency Training whereby inexperienced men hired to operate Army plants are first farmed out to the appropriate civilian plant for practical training.

Mr. Ramseier called on B. D. Phelps, Assistant City Engineer for the City of San Diego, and J. C. Albers, City Engineer for Glendale, for further discussion and then, in open discussion, the following points were brought out: Use of plant construction men to operate the plant; use of women and older men; reduce need for manpower by eliminating all possible unnecessary work; providing living quarters at the plant; transportation difficulties to isolated sewage plants; vacation arrangements by double pay; use of one chemist by a number of plants requiring laboratory control.

Priorities and Replacement of Sewage Works Equipment: As Mr. C. R. Compton, Assistant Chief Engineer of the Los Angeles Sanitation District, was unable to be present, Mr. William A. Allen took over as discussion leader and read Mr. Compton's prepared discussion on this most important subject. K. A. Keirn, Division Manager for Wallace and Tiernan Sales Corporation, and E. B. Besselievre, of the Dorr Company at Los Angeles, presented further discussion and stressed the importance of assigning the proper priority number to each order. Mr. John S. Moffat, War Production Board Branch Manager at Fresno, then presented a very understandable picture of the War Production Board's regulations and interpretations as well as answering and clarifying many questions.

Business Meeting: President Carl M. Hoskinson called the business meeting to order at 3:00 P.M. with 33 members present. The following committee reports were presented:

Emergency Sewerage Protection	Harold F. Gray
Membership	Ray E. Ramseier
Legislative	Harold Jeffrey
Journal	Jack H. Kimball
Committee on Certification	K. W. Brown, read by Harold L. May
Publicity	Kenneth A. Keirn
Industrial Wastes	W. T. Knowlton
Emergency Defense Training	William A. Allen
Operators	Harold L. May

The report of the Secretary-Treasurer was presented. The detailed financial report was referred to and the net worth of the Association as of

June 6, 1943 was revealed to be $226.64. Aside from expenditures for the Journal, the cost to operate the Association for the past term was a little over one dollar per member or just equal to the income per member. Attention was called to the fact that 43 members, or 16 per cent of the total membership are now in the military service, divided as follows: Army, 23; Navy, 12; and U. S. Public Health Service, 8. There are 22 Army camps and 2 Naval Bases represented in the Association. The Secretary read a recent news release from the Federation's Secretary, W. H. Wisely, announcing the Fourth Annual Meeting of the Federation. The meeting is to be the Second Annual Wartime Conference and is to be held in Chicago on October 21 to 23, 1943. All committees have been appointed and the conference will keynote sanitation activities under wartime conditions. Mr. A. M. Rawn, recently appointed engineering consultant to the War Production Board, is scheduled to appear to define priorities procedures for those engaged in sewerage construction, operation, and maintenance. The Secretary also announced a membership drive sponsored by the Federation with a $25.00 War Bond reward to the member in any Association obtaining the most new members before Dec. 31, 1943. By unanimous vote the members expressed their appreciation to *Western City* and especially to its Editor and Manager, Winston R. Updegraff for his assistance and courtesy in publishing the last issue of the Journal.

Honorary Membership—Charles Gilman Hyde: President Hoskinson announced that the Governing Board had received the following petition signed by thirty-four members requesting that the Board nominate Charles Gilman Hyde for Honorary Membership in the Federation of Sewage Works Associations. The Board had previously approved this petition and authorized William A. Allen, California's representative on the Federation Board of Control, to make the nomination at the appropriate time. The Board decided, however, to request the expression from the membership. On a motion by Harold F. Gray, seconded by E. B. Besselievre, the action of the Governing Board was unanimously approved.

Amendment to By-Laws: As required by the Constitution and By-Laws the members were notified by mail of the details of the proposed amendment, as follows:

Article II—Dues, Section 1—Annual dues shall be as follows:

> "for those members whose residence or chief place of business is in an area served by another Member Association of the Federation of Sewage Works Associations, who are members of such other Associations receiving all publications of the Federation therethrough, and who do not desire to receive duplicate copies of the publications of the Federation, the sum of one dollar"

It is proposed to insert the above amendment between paragraphs (c) and (d) of Section 1.

On a motion by Marvin Anaya, seconded by Harold F. Gray, the proposed amendment was approved.

Election of Officers: President Hoskinson called on Harold F. Gray, Chairman of the Nomination Committee for the following report:

President—1944		Richard D. Pomeroy
First Vice-President—1944		Frank S. Currie
Second Vice-President—1944		Keeno Fraschina
Secretary-Treasurer—1944		J. A. Harmon
Director	1945	Harold L. May
Director	1946	Grover L. Walters

Respectfully submitted,

Harold F. Gray, *Chairman*,
E. A. Reinke,
R. T. Gardner,
B. D. Phelps.

On motion by Roy E. Ramseier, seconded by Thomas M. Gwin, the report of the Nominating Committee was accepted and the secretary instructed to cast a unanimous ballet for all the candidates nominated.

Since there was no further business, President Hoskinson turned the meeting over to the newly elected president. After acknowledging the gavel, President Pomeroy adjourned the meeting at 4:00 P.M.

Jack H. Kimball
Past-Secretary-Treasurer

PENNSYLVANIA SEWAGE WORKS ASSOCIATION

Sixteenth Annual Conference

Harrisburg, Pennsylvania

June 9, 1943

The program opened with greetings to the Association by the mayor (in person) of the City of Harrisburg at 10 A.M. in Hotel Penn-Harris.

Ninety-four were registered at the meeting and 105 were at the luncheon, at which time Mr. A. S. Bedell, Past President of the Federation, and Colonel W. A. Hardenburgh spoke. Mr. H. E. Moses was toastmaster.

The program for the meeting included " Operating Experiences at Army Sewage Treatment Plants " by Major Rolf Eliassen; " Governmental Regulations and Priorities on Sewerage " by A. M. Rawn; and " Solving War Time Pollution Problems with Minimum Use of Strategic Material " by C. L. Siebert and F. B. Milligan.

At the business session the following officers were elected:

President	T. S. Bogardus
First Vice-President	L. D. Matter
Second Vice-President	Wm. J. Murdoch
Editor	J. R. Hoffert
Director	F. S. Friel
Secretary-Treasurer	B. S. Bush

Bernard S. Bush, *Secretary*

Federation Affairs

FEDERATION FURNISHES PRIORITIES SERVICE

Through the co-operation of Director Maury Maverick, of the Government Requirements Branch of WPB; Henry M. Evans, Chief of the Sewerage and Sanitation Section, and A. M. Rawn, the Federation's Vice President and consultant to WPB, it has been possible to furnish all members of the Federation with a complete file of all current priorities orders and regulations applying to the sewage works field. The material was distributed by direct mailing to the membership early in September.

Comprising the mailing were Order P–141, the general preference rating order; Form 2814, the preliminary application for new construction; Form 2814.3, the outline of information to accompany Form 2814 when applying for a project priority; CMP Regulation 5–A, governing materials and supplies for maintenance of storm sewers; Priorities Regulation No. 3; and Bulletin No. 2, which outlines the procedures involved in applying all of the above orders. If, for any reason, a member has failed to receive this material, a set of the pamphlets may be secured from the Executive Secretary of the Federation, Box 18, Urbana, Illinois.

FUNCTIONS OF GOVERNMENT UNDER WAR CONTROLS

PAMPHLET NO. 2

SEWERAGE AND REFUSE DISPOSAL

Government Division

War Production Board

Washington, D. C.

Foreword

The Government Division of the War Production Board is an agency designed to assist all non-military units of the government, federal, state, county, municipal and local, in obtaining priorities and allocation assistance for all material requirements.

Coupled with this is another task, which is the basic duty of the entire War Production Board, to wit: that of conserving all possible essential materials for the war effort.

The Government Division has made extensive studies of the needs of government, and is in a position to advise appropriate sub-divisions of the War Production Board of the needs of local government. Conversely it is prepared to appraise public civilian agencies what to expect in the way of critical materials from the Board.

This pamphlet is a second in a series of factual reports. Others will be published promptly as the status of the several government functions is completely programed.

Maury Maverick, *Director,*
Government Division

General Statement of Contents

This pamphlet discusses the sewerage and refuse disposal facilities and needs of the civilian population of the nation. It relates how to plan for new construction for extension of existing systems and for maintenance, operation, and repair to the end that neither efficiency nor the service which sewerage and refuse disposal facilities are designed to give will be seriously impaired.

Civilian Needs and Facilities

In continental United States there are about 6,500 sewage treatment plants serving a civilian population in excess of sixty million and thousands of industrial establishments. In size, the sewage treatment plants range from individual works in large cities treating hundreds of millions of gallons of sewage daily to small institutional plants, each serving a couple of hundred individuals. In quality of work accomplished, the plants differ widely, some effect a complete separation of the water from the substances which make it sewage, while others merely remove a small portion of the solids carried as suspended matter leaving natural purification processes to do the remainder of the job. Every plant is designed to accomplish what is required to prevent nuisance and menace to health in the area which it serves. That this objective is not always achieved is attributable to a wide variety of circumstances not discussed here.

The total population served by sewerage systems in the United States is nearly one hundred million. More than a million miles of sewers in sizes ranging from 6 in. to 20 ft. in diameter comprise these great service networks while pumping stations by tens of thousands serve to lift sewage from one level to another. The national investment in sewerage and refuse disposal exceeds ten billion dollars.

The purpose of sewerage and refuse disposal justifies the vast investment. Without adequate waste disposal, urban population in this or any other country supplied with ample domestic and industrial water could not long exist. In order to adequately protect his life processes, man must be removed from close proximity to his filth and conversely the filth must be moved from his habitat. Sewers accomplish this job for liquid household and industrial waste. Refuse collection and disposal do the trick for garbage, rubbish, street sweepings and the like. During periods of great national stress, it is doubly important that sewage and refuse collection systems fill the role for which they are designed.

Development of Sewage Treatment Processes

During the three decades prior to the present national emergency, sewage treatment has been developed to a high degree of efficiency. Depending upon the end desired, the means available will accomplish any degree of treatment from the removal of coarse suspended solids to almost complete separation of water from its suspended or dissolved solids. In addition to sewage treatment plants built to correct public health hazards a great many have been built for public convenience to protect aquatic life in rivers and lakes, reduce pollution of playground and recreation areas and eliminate olefactory and visual nuisances.

Restrictions Imposed by the National Emergency

The national emergency brings another picture of sewerage into focus. For the duration, at least, construction of sewage treatment and refuse disposal plants must be limited to those which are essential to the war effort, or to public health and safety. Construction of new sewers or systems thereof must satisfy the foregoing criteria or may under certain circumstances be constructed where there exists a well recognized potential public health hazard. For every project under consideration these requirements of essentiality must be fulfilled before priority assistance will be proffered.

The National emergency imposes other restrictions upon construction:

(*a*) Only minimum requirements shall be met.

(*b*) Processes or means employed shall be those which will require a minimum use of critical materials (that is, if two methods achieve the same objective, the one which requires the least critical material in its construction will be favored).

(*c*) Temporary buildings and structures must be used wherever possible.

(*d*) All possible solutions shall be explored to the end that the job be accomplished with the use of as little critical materials as possible. Sights which are directed at prewar standards of construction must be considerably lowered if priority assistance is to be forthcoming.

Application for Priority Assistance for Construction

Heretofore priority assistance for construction of sewerage systems, including sewers, pumping stations, and sewage treatment plants, as well as for refuse disposal plants, has been granted pursuant to application submitted to the Government Division, WPB, on Form PD–200, or in some instances by letter furnishing substantially the same information as PD–200. In order to complete the PD–200 application it was necessary to design the project so that materials breakdown might be clearly indicated, thus the applicant was required to go to the expense of designing the project before he knew whether or not it was to be judged essential. If it were judged essential, no one was hurt, but if the applicant had gone to the expense of designing and then been refused priority assistance on the basis of non-essentiality, he felt justly aggrieved at having had to spend his funds unnecessarily. The following simplified procedure has now been adopted:

PD–200 has been redesignated WPB–617, but is otherwise basically unchanged. However, the application form comes to the applicant accompanied by two additional forms 2814 and 2814.3. The two 2814 forms contain instructions, definitions and questions. After reading the instructions and definitions, both the applicant and the Sewerage and Refuse Disposal Branch of the Government Division of the WPB will have reached a mutual understanding of general terms employed and general rules regarding design and project limitation. By answering the questions appropriate to the project being applied for, the applicant will supply the WPB with enough information to permit the latter to determine the project's essentiality or lack thereof.

The questions asked in 2814 and 2814.3 may be answered without having to completely design the project. They are questions basic to the preliminary consideration of a sewerage or refuse disposal project.

Response to forms 2814 and 2814.3 are intended to be returned to the War Production Board prior to submission of Form WPB–617 (formerly PD–200) but if the applicant is sufficiently convinced of the essentiality of his project to risk the cost of completely designing the works without awaiting advice as to essentiality, he may submit the WPB–617 with the response to forms 2814 and 2814.3. Direct all replies to War Production Board, Washington, D. C., attention: Government Division, Sewerage and Sanitation Branch.

When the information requested in 2814 and 2814.3 is received in the Washington office of WPB, the project will be processed for essentiality and the applicant notified of the Board's decision. If favorable, the applicant may then proceed to design his project and submit application in accordance with the requirements of WPB–617 (formerly PD–200). In the preparation of the final plans and specifications, the rules and regulations of war time design and construction must be observed.

Limited Construction Under P–141, July 5, 1943

Minor additions to systems is permitted under the provisions of P–141, July 5, 1943. This Order will be discussed in length hereinafter. It is, however, pertinent at this point to point out that "operating supplies" as defined in P–141 includes job materials up to $1,500 for underground additions and expansions and $500 above ground, excepting buildings, provided the operator does not exceed imposed quantity restrictions in inventory withdrawals or materials acceptance without special authority. P–141, July 5, 1943, also prescribes a method of procedure for construction and extension to serve rated projects.

Purchase of Equipment, WPB–541 (formerly PD–1A)

Priority assistance for the purchase of capital equipment where no construction is involved may be obtained pursuant to an application on Form WPB–541 (formerly PD–1A) or such special form as may be applicable. This includes such items as machine tools, trench pumps, portable compressors, etc., etc. The rules of preparation are attached to the forms, but the applicant will be well advised to state his needs in ample and conclusive terms in order that the Board may fully justify whatever action it takes. Such applications should be filed in the War Production Board field office or in the case of special forms in such place as may be prescribed.

Preference Rating Order P–141. M. R. & O.

P–141, July 5, 1943, is the preference rating order for maintenance, repair, and operation (designated MRO) of sewers both separate and combined as well as sewage pumping stations and treatment works. It excludes all transactions effected by P–141, July 5, 1943, from the provisions of CMP–5 and CMP–5A (June 4, 1943). Following are its general provisions:

(1) It assigns a preference rating of AA–1 to supplies for MRO but warns against using the rating to obtain scarce materials susceptible of elimination without serious loss of efficiency.
(2) It assigns the lowest rating given to a rated project to construction of sewerage facilities to serve such project but qualified this with the provisions that WPB authority is prerequisite to commencement of construction of such facilities.
(3) It prescribes the method for obtaining controlled materials, steel, copper, and aluminum.
(4) It prescribes the certification for use in applying the AA–1 rating and allotment symbol by an operator to deliveries of material for use in maintenance, repair and operating supplies. It provides that the ratings assigned by the Order may be extended by a supplier by use of the certificate prescribed in Priorities Regulation No. 3, and the ratings assigned to extensions of systems to serve rated projects may be applied by use of the certification prescribed in Priorities Regulation No. 3.
(5) It establishes the year 1942 as the base year for MRO costs and with certain exceptions divides the year into four quarterly periods so that customary seasonal procedure in purchase and expenditure may be followed by the operator.
(6) All references to " classes " of material are eliminated excepting where it is desired to replace materials sold from inventory.
(7) It provides that an operator whose cost for supplies in MRO in 1942 were $1,000 or less and who anticipates that that amount will not be exceeded in the year under consideration, is exempted from the limitation prescribed in current quarterly periods, i.e., he can spend his money any time he wants during the whole year, but not to exceed $1,000. If his actual requirements exceed that amount, he must apply for an increased quota by letter in triplicate addressed to the War Production Board, Washington, D. C., Ref: P–141.
(8) It provides for an increase in expenditures for MRO proportional to increase in dry weather flow from year to year and also for expenditure for repairs in excess of ordinary allowances, following calamitous circumstances. It permits replacement of materials sold from inventory and for the reuse of salvaged materials.
(9) It excludes chemicals and fuel from MRO supplies, i.e., the cost of these are not included in the base year costs or the current year expenditures.
(10) It provides for exceeding quarterly or annual allotments of supplies upon specific authority from the Board. This provision is of great importance and value to the opeartor in that it gives him the opportunity to exceed the limitations of the order in pursuance to a letter, telegram, or telephone communication to the Sewerage and Sanitation Branch, Government Division, WPB, Washington, D. C., provided adequate showing of need is made.
(11) The cost of the $1,500 and $500 limited extensions and expansions must be included with other expenses for MRO supplies, they are not in addition thereto unless specifically authorized.
(12) The restrictions upon construction of extensions to serve customer premises (house connections) have been eliminated from the Order, provided that no iron or steel pipe shall be used by the operator except in the minimum quantities required in making necessary connections. That portion of a house connection within the

property line may be built by the property owner, who, of course, must comply with the provisions of L–41. P–141–A, which dealt with such extensions, was no longer necessary in view of the revised Order and has been revoked.

CMP Regulation 5A (June 4, 1943)

CMP Regulation 5A provides a method whereby governmental agencies may obtain maintenance, repair and operating supplies. This Regulation assigns an AA–1 rating and the MRO symbol for refuse and garbage collection and disposal and an AA–2 rating for storm sewers. This Regulation prescribes a form of certificate to be used in applying the rating and symbol. It also contains quantity restrictions which are substantially the same as the quantity restrictions in P–141, but with certain differences which should be carefully studied. It also contains a provision to the same effect as the provision in P–141, exempting users of less than $1,000 worth of MRO per year from the quantity restrictions. It provides that relief from the quantity restrictions may be applied for by filing a letter in triplicate with the Government Division, War Production Board, Washington, D. C. This Regulation may not be used to obtain MRO for sanitary sewers or storm sewers which are a part of a combined system because this is covered by P–141, but the Regulation may be used to obtain MRO for storm sewers operated as separate systems and for refuse and garbage collection and disposal. The ratings may not be used to obtain any item on Lists A, B or C of Priorities Regulation No. 3. If any item on List B cannot be obtained without a preference rating, application should be made on WPB–541 (formerly PD–1A) filed at the local WPB field office.

Application and Rating Forms

Agencies engaged in supplying public sewerage services should secure a copy of preference rating Order P–141, July 5, 1943; those engaged in refuse collection and disposal and in the operation and maintenance of storm sewers should secure CMP–5A (June 4, 1943) and PR–3 (July 16, 1943): those who desire to purchase equipment where no construction is involved should secure and make application on Form WPB–541 (formerly PD–1A), and those who desire to build sewers, sewage and storm water pumping stations, sewage treatment plants and refuse incinerators should secure Form WPB–617 (formerly PD–200) and Forms 2814 and 2814.3. All of these may be secured from the Regional or District WPB office or from WPB, Washington, D. C.

Changes in Orders

Changes in orders and in order numbering will appear from time to time. Such changes are unavoidable and are designed to keep orders current with changing conditions. All available sources of publicity will be utilized in approsing interested individuals of such changes. The best source of such information is the District WPB office. Inquiries are invited.

The Sewerage and Sanitation Branch of Government Division, WPB, has been established to render assistance in problems implied by its name. All are invited to use these facilities to the fullest extent.

BLUEPRINT NOW!

COMMITTEE ON WATER AND SEWAGE WORKS DEVELOPMENT

WATER AND SEWAGE WORKS DEVELOPMENT

Every city in North America is entitled to have, and with good management is able to pay for an adequate, safe and satisfactory water supply—and as a good neighbor to other cities, likewise, with good management is able to dispose of its wastes in a manner that offends neither its own citizens nor its neighbors' citizens.

This is the broad premise that has activated four associations in the field of municipal sanitation to join in organizing and financing a "Committee on Water and Sewage Works Development." The associations are:

New England Water Works Association
Federation of Sewage Works Associations
American Water Works Association
Water and Sewage Works Manufacturers Association

Mr. Abel Wolman, Professor of Sanitary Engineering at Johns Hopkins University, will act as chairman of the committee. Mr. Wolman is immediate past-president of the A.W.W.A.; past-president of the A.P.H.A.; Chairman of the War Manpower Commission's Committee on Sanitary Engineering Personnel; formerly chairman of the National Resources Board's Committee on Water Pollution; etc., etc. The Committee members in addition to Mr. Wolman are:

C. H. Becker, Mgr., Hydrant & Valve Dept., R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.
E. S. Chase, Cons. Engr., Metcalf & Eddy, Cons. Engrs., 1300 Statler Bldg., Boston, Mass.
C. A. Emerson, Cons. Engr., Havens & Emerson, 233 Broadway, New York, N. Y.
R. W. Esty, Supt., Water Dept., 17 Hobart St., Danvers, Mass.
H. E. Jordan, Secretary, American Water Works Association, 500 Fifth Avenue, New York 18, N. Y.
C. A. McGinnis, Johns-Manville Sales Corp., 22 East 40th St., New York, N. Y.
S. B. Morris, Dean, Stanford University, School of Engineering, Stanford University, California.
G. J. Schroepfer, Chief Engr., Minn.-St. Paul San. Dist., Box 3598, St. Paul, Minnesota.

Staff activities of the Committee will center at the office of the American Water Works Association, 500 Fifth Avenue, New York 18, N. Y. E. L. Filby of Kansas City, Mo., has been secured on a leave of absence basis from his work in the Black & Veatch organization to act as Field Director of the Development Committee work. The field contact service (to the extent possible with manpower and funds available) will deal with state, regional and local groups having an interest in water and sewage works planning. The Committee will also sponsor a bulletin or printed promotional service (likewise limited by manpower and funds) to provide guidance in carrying on the work in local communities.

Believing that adequate water supply and intelligent waste collection and disposal are within the reach of every city, the committee on "Water and Sewage Works Development" plans to stimulate the following activities to the cities of North America:

1. An appraisal of the needs for water and sewage works improvement or construction.
2. The development of orderly programs for meeting these needs in the order related to their value to the city or the region.
3. The preparation of detailed plans and specifications for the needs of first importance as soon as arrangements can be made.
4. Consideration of, and development of methods for funding the necessary construction.
5. Reappraisal of authority under which the contemplated projects can be carried on as well as the legal basis for funding such operations. (Promotion of legislation whenever needed.)
6. Definite scheduling of the construction program. (Immediate purchase of land and rights of way if part of the projects.)

* * * * * * * * * * *

It is fully realized by the Committee that the work it proposes to attempt is but a part of the general pattern of public works and that there are numerous other groups and organizations, well organized and financed, that will be furthering the general overall program of public works. The American Society of Civil Engineers, United States Conference of Mayors, the American Public Works Association, International City Managers' Association, the U. S. Chamber of Commerce and other non-governmental agencies are progressing in their efforts to have a cushion of public works ready for postwar days and are aggressively promoting their programs. State governmental agencies have been authorized, financed and are now actively functioning, as in New York, to attain similar objectives. To these and other groups with similar broad objectives, the Committee on Water and Sewage Works Development, pledges its active co-operation and willingness to work in any and every way possible. Our slogan "Blueprint Now" may be freely used. The water and sewage works sector, upon which we will concentrate our efforts, is but one along the postwar battlefront and we are mutually dependent upon all forces, that this worthwhile program be successfully accomplished.

For the Committee:
by
ABEL WOLMAN, *Chairman*
and
E. L. FILBY, *Field Director*
August 15, 1943

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

FOURTH ANNUAL CONVENTION

Wartime Conference on Sanitation

FEDERATION OF SEWAGE WORKS ASSOCIATIONS
IN CONJUNCTION WITH
ANNUAL MEETING OF CENTRAL STATES SEWAGE WORKS ASSOCIATION

October 21–22–23, 1943
Chicago, Illinois
Sherman Hotel

Program

Wednesday Evening

P.M.
8:30 Pre-convention Get-Together—Louis XVI Room
Pre-convention Registration—Louis XVI Room

Thursday Morning

A.M.
9:00 Registration—Exhibit Hall
Inspection of Exhibits—Exhibit Hall

TECHNICAL SESSIONS

Grand Ballroom

Presiding: GEORGE J. SCHROEPFER

10:30 Introducing the Fourth Annual Convention of the Federation of Sewage Works Associations—"Wartime Conference on Sanitation"
GEORGE J. SCHROEPFER
Greetings from Chicago
HON. EDWARD J. KELLY, Mayor

11:00 Business Meeting—Federation of Sewage Works Associations
Report of Secretary
Report of Committees
General Business

12:00 Federation Luncheon—Louis XVI Room
Speaker: Gordon M. Fair
The Outlook for Sewage Disposal in the Latin-American Republics

Thursday Afternoon

Grand Ballroom

Presiding: A. M. Rawn

P.M.

1:30 High Rate Biological Sewage Treatment
Samuel A. Greeley

2:00 Discussion
Frank A. Marston
R. M. Dixon

2:15 Industrial Wastes in Wartime
F. W. Mohlman

2:45 Discussion
LeRoy W. Van Kleeck

3:00 Relation of Sewage Treatment to the Transmission of Virus Diseases
Kenneth F. Maxcy, M.D. Paper to be presented by Howard A. Howe, M.D.

3:45 Discussion
G. M. Ridenour

4:00 Grease Removal at Army Sewage Treatment Plants
Rolf Eliassen

4:30 Discussion
Harry W. Gehm
Richard D. Pomeroy

4:45 Effect of Various Treatment Processes on the Survival of Helminth Ova and Protozoan Cysts in Sewage
Eloise B. Cram

5:15 Discussion
W. D. Hatfield

5:30 Adjournment

8:30 Smoker. Bal Tabarin

Friday Morning

Grand Ballroom

SYMPOSIUM ON WARTIME PROBLEMS

Presiding: Kerwin L. Mick

A.M.

9:00 Priorities
A. M. Rawn

9:30 Discussion
Frederick G. Nelson
Donald E. Bloodgood

9:45 Personnel Problems under Wartime Conditions
C. W. Klassen

10:15 Discussion
William M. Wallace

10:30 Maintenance of Sewerage Systems in Wartime
John H. Brooks, Jr.

11:00 Discussion
Roy L. Phillips

11:15 Problems of Sewage Treatment Plant Operation under Wartime Conditions
William W. Mathews

11:45 Discussion
Roy S. Lanphear

12:00 Adjournment

12:15 Luncheon Period—Non-programmed
Luncheon of Central States Sewage Works Association—Louis XVI Room

Friday Afternoon

Grand Ballroom

Presiding: George J. Schroepfer

P.M.

1:30 The Chlorination of Sewage and Industrial Waste
Harry A. Faber

2:00 Discussion

2:30 Symposium—Post-war Problems
Leader: Morris M. Cohn

1. The Consulting Engineer and Post-war Planning
C. A. Emerson
2. The Canadian Point of View on Post-war Problems
A. E. Berry
3. Post-war Projects of Sewage Works Equipment Manufacturers
W. B. Marshall
4. Aims and Methods of Operation of the Committee on Water and Sewage Works Development
E. L. Filby
5. A Municipal Post-war Project for Sewerage Developments
Clyde L. Palmer

5:30 Adjournment
Annual Meeting—Central States Sewage Works Association—Grand Ballroom

7:30 Dinner Dance—Grand Ballroom

Saturday Morning

A.M.

8:00 Operators' Breakfast Forum—West Room
Leader: John C. Mackin

8:45 The Use of Sludge in the Victory Garden Campaign
A. H. Niles
Henry A. Riedesel
David Backmeyer

9:45 Secondary Treatment—Present and Future
ARTHUR S. BEDELL
A. W. WEST
LINN H. ENSLOW

10:30 The Question Box

11:00 Wartime Operating Problems in Municipal and Army Sewage Treatment Plants
ROLF ELIASSEN
MARTIN A. MILLING
EDWARD C. CARDWELL

11:30 Broad Conservation Program—War Production Board
H. LLOYD NELSON

12:00 Award of Attendance Cup
Adjournment

12:30 Business Meeting, Board of Control, Federation of Sewage Works Associations, and Dutch Treat Luncheon—Gray Room

Reviews and Abstracts

TREATMENT OF SEWAGE ON PERCOLATING FILTERS AT HUDDERSFIELD

Discussion

The Surveyor, 101, 425–426 (December 11, 1942)

Treatment of sewage at Huddersfield by percolating filters and activated sludge has become increasingly difficult. Sewage to be treated on the filters is strong and contains toxic chemical wastes. Effluent from the preliminary sedimentation tanks contains 220 p.p.m. of B.O.D., with a bacterial count of only 243,000 per ml.

Experiments on miniature units with rapid rates of filtration proved promising and led to the construction of two 18 ft. diameter filters, one to be used as a primary unit and the other as a secondary, each unit being divided into two complete units. The primary filter is 7 ft. deep, one section of which contains media two to four in. in size: media in the other section is two to four in. for the top foot, ¾-in. to 1½-in. mid-three feet, two in. to four in. bottom three feet. The secondary filter was built as follows:

	Section A	Section B
Top 18 in.	4 in. to 6 in.	½ in. to 1 in.
Mid 3 ft.	1½ in. to 3 in.	1½ in. to 3 in.
Bottom 18 in.	3 in. to 6 in.	3 in. to 6 in.

Two intermediate sedimentation tanks were provided between the primary and secondary filters, each having a capacity of 2,400 gal. and providing 3.3 hr. displacement when the primary filter was dosed at 6.0 M.G.A.D., and two hours displacement at 10.0 M.G.A.D

From December, 1938, throughout the summer of 1939 more consistently satisfactory results were obtained by applying sewage to the primary filter at 603 gal. per cu. yd. per day and 290 gal. per cu. yd. per day to the secondary, than with single filtration at 90 gal. per cu. yd. per day.

The outbreak of war in September, 1939, brought a change in the toxicity of the sewage. Rates of dosage on all filters had to be reduced and the ratio of the rates of filtration, double to single, fell from 2½ to 1½ gal. per cu. yd. per day.

K. V. Hill

A CUBIC YARD OF PERCOLATING BED MATERIAL AND A FEW ASSUMPTIONS BASED ON EXPERIMENTAL EVIDENCE

By H. H. Goldthorpe

The Surveyor, 102, 177–179 (April 23, 1943)

The surface area and voids in percolating filters containing different size media, and the time of contact of sewage applied at various rates to filters containing different media is discussed; also the effect of distribution upon time of contact and degree of purification obtained.

Tables are included presenting the surface area per cubic yard and the percentage of voids for media ranging in size from ¼-in. crushed stone to standard brick. For example, 2-in. crushed stone is indicated as having an area of 60 sq. yd. per cu. yd. and 45 per cent voids; 4-in. crushed stone has 30 sq. yd. of surface area per cu. yd. and 45 per cent voids. If surface area were the only factor in purification, similar effluents should be produced by twice as much 4-in. stone as 2-in. Experiments by Levine are quoted to indicate that this is not the case.

Efficiency with more continuous dosing at low rates should be higher than intermittent dosage with high rates.

A lengthy table indicating time of contact in filters containing different size of media and dosed at different rates is included. Time of contact in a percolating filter increases with decreasing size of medium, thickness of growth of the medium, degree of roughness of the surface of the medium, and frequency of deposing applied to the surface. The following times of contact for different size filter media and different conditions of cleanliness of the media is tentatively suggested:

Size of Medium	Clean	Fair	Heavy Growth
Above 1 inch	5%	10%	15%
Below 1 inch	8%	15%	25 to 30%

The author also discusses the oxygen demand exerted by solids in filters of various degrees of cleanliness.

K. V. Hill

CONTACT AERATION FOR SEWAGE TREATMENT

By John Hurley

The Surveyor, 102, 183–185 (April 30, 1943)

The author discusses an article by L. B. Griffith appearing in *Engineering News-Record.*

Experimental work at Waco, Texas, is reviewed. Data on the performance of the Hays Process plant at Elgin, Texas, are presented. The author comments on use of the three hour maximum flow condition in the basis of the design. He points out the mechanical advantage of this type of aerator as likely to eliminate short-circuiting. Analysis of plants treating municipal sewage indicates the rate of reduction of B.O.D. to be about 0.0508 lb. per hour for each 100 sq. ft. of contact surface. Air supply for contact aerators is designed to give an even distribution of air between contact plates. This is to assist in maintaining uniformity of vertical flow of aerated liquid between the plates, as well as aiding in the continuous unloading of biological growths. A properly designed air grid will give adequate aeration with about 0.33 cu. ft. of free air per min. for each sq. ft. of aerated water surface. No sewage or sludge need be recirculated.

Some of the features of a satisfactorily operated plant are:

(1) An overloaded unit does not "go out" quickly—it merely spreads the first zone of coagulation through the plant, resulting in a one-stage treatment. In the case of an underloaded plant, the organisms may crowd into the first stage of aeration where all of the zones of purification will arrange themselves.
(2) Since in this treatment the flow, as in a natural stream, is continuous through the plant, successful operation is not dependent upon complicated recirculation of sewage or sludge.
(3) Each unit, including aeration tanks, serves as a settling unit.
(4) Reduced short-circuiting within the aerators assures that every square foot of contact surface will be biologically effective.
(5) Practically no clogging occurs because of continuous unloading and air scrubbing.
(6) For small plants the operation is simple, and some plants have been operated by an untrained operator with only four hours' attention a day. Large plants have considerable mechanical equipment and require continuous and more skilled operation.
(7) No nuisance results from odor or filter flies.
(8) The degree of treatment is comparable with the best types of processes used today, and tests have shown the effluent to be very high in nitrates, indicating complete oxidation.
(9) The plant can be built as a one-stage treament if 80 to 90 per cent reduction is adequate. This results in considerable saving in first cost and operation.

(10) Loss of head through small plants need be only 6 in. to 2 ft.
(11) Total detention period for complete two-stage treatment of typical municipal sewage is (about four hours for average three-hour maximum flow rate, or six hours for average flow. Therefore, a compact and economical design can be made. Furthermore, the aerator depth can be adjusted to meet foundation conditions by using any desired plate depth between 4 and 8 ft.
(12) In typical plants approximately 0.9 cu. ft. of air per gallon treated is adequate against a total pressure of only 4½ lb. per sq. in., which costs about 33 per cent less than the same amount of air at a pressure of 7 lb. per sq. in. usually required in activated sludge plants. Recent designs of air distribution systems have tended to increase the aeration efficiency an appreciable amount.

The author cites previous work done by many experimenters on contact aerators and points out that they have their good and bad points. He summarizes by stating that the Hays Process is an interesting development of known processes and that there is evidence that it can produce good results. To compete with the improvements in filters and activated sludge techniques which are likely to be available after the war, the Hays Process will need to prove itself much superior to previous ventures in contact aerators.

K. V. Hill

SEWAGE TREATMENT AT AIR–TRAINING SCHOOLS IN WESTERN CANADA

By Flight Lieutenant R. A. McLellan

Water and Sewage (Toronto), 81, 15 (May, 1943)

It is of interest to review the accomplishments in the way of sewage treatment at the various schools and stations operated under the British Commonwealth Air Training Plan. This discussion is confined chiefly to projects in Saskatchewan and Alberta, and a few developments in British Columbia and the Maritime Provinces.

In the summer of 1940, when engineers of the R. C. A. F. took over field supervision, little thought had been given to the problem of sewage disposal. Speed was required in providing sewage disposal facilities as the schools had to be placed in operation as soon as buildings were sufficiently completed. Hence, designs were simplified as far as possible. At that time little information was at hand regarding increases in the size of the stations.

Wherever possible the services of an adjacent municipal system were utilized, and in all such cases the cities and towns were fully co-operative. Facilities at earlier installations included coarse screens and single-story settling tanks. Where further treatment was required contact or filter beds were used, and in some cases facilities for chlorination were provided. It was soon found that these installations would be unsatisfactory, particularly where the establishments were to be increased.

In the design of plants for projects started late in 1940 consideration was given to more efficient and modern types. Study of the problems, particularly as regards the availability of equipment, led to the adaption of a two-story mechanized tank followed by a low-rate trickling filter with revolving distributor. Fourteen of these were authorized late in 1940 and were placed in operation early in 1941.

A figure of 50 Imp. gal. per day per person was used for design. It was assumed that the total daily flow would take place in 16 hours. These figures have since been revised, a figure of 60 Imp. gal. per day now being adopted. Also, the flow throughout the 24 hours is more uniform than expected. Abnormally high flows were noted when the first stations were placed in operation, in some cases as high as 100 Imp. gal. per person per day. This was serious at places where the water supply was limited, and conservation methods were instituted with good results.

The figures for sewage characteristics used in design were 0.27, 0.17, and 0.09 lb. per capita per day, for suspended solids, 5-day B.O.D., and ether-soluble matter, respectively.

Digestion tank volumes were based on 1.5 to 2.0 cu. ft. per person, assuming digestion temperatures between 80 and 90 degrees. In some cases unforeseen increases in population resulted in digester volumes of about one cu. ft. per person. Digestion has been satisfactory despite the reduced volumes. Sludge is heated with coal, electricity or natural gas, depending on the size of the installation and the location. It was not considered practical using sludge gas in such small plants with the uncertainty of a steady supply.

The first low-rate filters were designed for a loading of 500,000 gal. per acre-foot. After the filters were placed in operation the schools grew so rapidly that the capacities were inadequate. New units were added but the design basis was changed to 350,000 gal. per acre-foot. The filters are 5½ to 6 ft. in depth, with rock graded between 2 in. and 3½ in. to 4 in. in size.

Coarse screens are provided at all plants and they have been found to be very important. Grit chambers have not been found necessary except in one or two instances where too much sand entered the digester.

Grease traps have been added for kitchen wastes in later installations but sufficient attention is not usually given them. A new type of separator is now being installed which must be cleaned to prevent overflowing.

When populations over 2,000 are to be provided for the cost of low rate filters, particularly if they are to be covered, adds materially to the cost of the project. Accordingly, consideration is given to high-rate filters and biofilters in designs for projects where the population goes over that figure.

Results obtained thus far indicate the following general guides for plants of this nature:

(1) Single-story primary settling or septic tanks should not be considered for plants serving more than 750 persons.
(2) For populations between 750 and 2,000 persons, two-story tanks, preferably mechanically equipped, should be used and followed where necessary by low-rate trickling filters.
(3) Biofilters should be considered for camps of over 2,000 persons and in some cases for as small as 1,500 persons.
(4) Primary clarification followed by chlorination should be used unless further treatment is indicated.
(5) Underground filter beds should not be considered in Western Canada.
(6) Wooden trough distributors are not satisfactory and should be used only in very small installations.
(7) Sludge digestion tanks should be heated for satisfactory operation.
(8) Small clarifiers do not require covering even in Western Canada, but sprinkling filters should be covered.
(9) Chlorination of raw sewage does not appear to serve any useful purpose in these plants.
(10) Coarse screening should always be used.
(11) Hangar floor drainage should not be allowed in the sewage.

T. L. Herrick

TEXTILE MILL WASTE TREATMENT AND RECIRCULATING FILTER FOR SLAUGHTER-HOUSE WASTES

By E. F. Eldridge

Michigan Engineering Experiment Station, *Bulletin 96* (September, 1942), 21 pp.

Report of Experimental Studies and Recommendations for Waste Treatment at Yale Woolen Mills, pp. 1–18. Wastes from this mill were derived from five separate locations: the dye room, the washing and shrinking room, the boiler room, toilets, water softeners and filters. The dye and washing rooms contributed the major process wastes. A total of 414,500 g.p.d. of waste required treatment. Changes were made in the mill sewer system in order to segregate the wastes which required treatment and a pilot treatment plant was constructed. Since the dilution in the receiving stream was expected to handle a portion of the pollution load, effective solids removal was deemed sufficient treatment. The B.O.D. of the wool dye wastes approximated that of domestic sewage but was high in suspended solids. The cotton liquor and cotton rinse had B.O.D. values averaging approximately 84,000 p.p.m. and 1,600 p.p.m., respectively, with suspended solids of the order of 50,000 and 8,000 p.p.m.

The pilot plant consisted essentially of an equalizing tank, coagulation and settling tanks together with the necessary pumps and equipment for feeding alum, ferric chloride and hydrated lime. Lime and ferric chloride produced the best results. Suspended solids removal average 83.4 per cent and B.O.D., 72.4 per cent. Pilot plant test runs made without the equalizing tank demonstrated the need for one. Equalization was necessary in order to smooth out temperature and composition fluctuations. Runs were made using both the continuous flow and batch process methods.

Studies of sludge production indicated that the volume of sludge would be about 2.0 to 2.5 per cent of the volume of waste treated and that this sludge would have about 2 per cent solids. Vacuum filtration appeared to be the most satisfactory process of reducing the sludge volume. Filtration studies made with a filter test leaf showed that the sludge could be concentrated by this means to a moisture content of 75 to 77 per cent.

On the basis of pilot plant studies recommendations for a full scale treatment plant were made. Treatment units recommended were: screen, equalizing tank, flash mixer, chemical feed machines, coagulation tank equipped with paddle stirring mechanism, settling tank, magnetite filter, sludge tank, vacuum filter and a building for housing vacuum filter and chemical feed equipment.

The Recirculating Filter for the Treatment of Slaughter-House Wastes, pp. 18–21. A high rate recirculating trickling filter handling effluent from a septic tank was installed to serve the Telfer Packing Company at Owossa, Michigan. The effluent from the septic tank enters a holding tank which has a capacity of 4,200 gal. equal to the maximum daily flow of waste after separation of the clear water. Waste is pumped to the filter from the holding tank by means of 48.8 g.p.m. centrifugal pump. This pump is also used to remove sludge from the final settling unit. The filter is 14 ft. in diameter and 6 ft. deep. The waste is applied by means of a rotary distributor. The filter media is hard granite rock screened to 3 in. to 4 in. Filter effluent discharges to a hopper bottom, settling tank having a capacity of about 2,000 gallons corresponding to a detention time of 40 minutes at 48.8 g.p.m.

As a result of a two day survey it was found that the over-all B.O.D. removal by the plant was 99.2 and 96.6 per cent. Flows were 4,200 and 3,070 g.p.d. and the corresponding raw waste 5-day B.O.D. values, 2,200 and 1,750 p.p.m, respectively.

The cost of the filter and tanks, not including the septic tank, was less than $600. Operating costs are limited to the cost of power consumed by the pumps plus the labor required in connection with sludge disposal. Sludge is hauled to a field about once a week. The odor nuisance which formerly existed in the receiving stream has been entirely eliminated.

Paul D. Haney

THE STREAM CONTROL COMMISSION

State of Michigan, Sixth Biennial Report, 1941–1942 (50 pp.) (1942)

This report is a record of the activities of the Stream Control Commission in the field of water pollution control in the State of Michigan. Of particular interest is a brief review of the industrial waste control. In the pulp and paper mill industry, the studies have shown that fiber losses can be limited to one per cent of paper production and the waste flows to 20,000 gal. per ton of product. Oil wastes are controlled successfully along the lines laid down by the American Petroleum Institute. Separators similar to those at refineries are in service at various forging works, and are proposed for war industries to avoid fire hazards. Cannery wastes are varied. Under war conditions, a new treatment problem arises with the wastes from dehydrating potatoes, for which fine screening and grit collection are on trial.

In the milk industry, the utilization of concentrated wastes is the first step in control of pollution from milk processing plants, such as return of buttermilk and cheese whey to farmers for stock feeding. In two instances whey is dried for market as poultry food. Where treatment of residual wastes is required, the re-circulating biological filter has been tried, and also a form of activated sludge.

In the beet sugar industry the re-circulation method of control of straight house wastes has been adopted by a majority of plants. By-product recovery of mono-sodium glutamate from Steffens wastes is used by 5 out of 6 plants using the Steffens process.

In the chemical industry need has developed for the control of brine waste and acid discharges, through delivery to and dispersion in large bodies of water. A phenol waste treatment plant is being enlarged with supplemental treatment of the filtered wastes by the activated sludge process.

Tannery wastes are under study, particularly as to sludge disposal.

Cyanide wastes are still troublesome, and many destroy fish life. Impounding is inadequate. One motor company has installed treatment by decomposition with sulfuric acid followed by aeration to handle cyanide and chrome acid wastes.

Research on the control of water itch is still under way. Infested beaches have been given chemical treatment, for temporary relief. The identity of the natural hosts of the itch is being sought.

LANGDON PEARSE

NINTH BIENNIAL REPORT OF THE STATE WATER COMMISSION, CONNECTICUT, YEARS 1940–1942

The report indicates the variety of industrial wastes found in the state. Among the more important are the metallurgical, textile, paper mill, sand and gravel washing and oil wastes. Special research has been conducted on the effect of textile wastes on chlorine treatment of sewage.

In the paper industry one plant in 10 years has cut the waste from 100,000 to 15,000 gal. per ton of product and reduced the loss of fiber from 2,500 to 100 lb. per day, representing a recovery value of about $100. The revolving drum type save-all with 60 to 80 mesh wire has been longest in use. With 80 mesh wire, the following results are expected:

Type of Product	Suspended Matter Lb. per 1,000 Gal. Influent	Effluent
Facial tissue	4.0	0.7
Paper board	3.5	2.5
Insulating board	1.7	0.8

Adequate sedimentation will usually remove about 75 per cent of the suspended solids.

In the metallurgical field, research is continued to develop a practical method for recovery of wasted metal. In 1941 approximately 3,130,000 lb. of copper and 2,280,000 lb. zinc were discharged in liquid wastes. Cyanide and acid metal wastes are still under scrutiny. In chromium plating, the use of acid barium sulfide and lime has proved helpful (see 8th Biennial Report). In Connecticut one plant recovers copperas from acid pickling wastes from iron and steel work.

The washing of sand and gravel carries silt and other wastes into the streams. In many cases an abandoned gravel pit serves as a settling basin. Cleaning of such basins is frequently neglected.

Oil wastes of certain types can be treated by separators. One plant recovered from 1,000 to 2,000 gal. of usable oil per week. Grinding and cutting oils require different treatment, with the use of chemicals and sedimentation.

Research work was carried on at Wesleyan University on chromium plating wastes; the effect of sulfur and vat dyes on chlorine demand (which led to use of equalizing tanks at the factory, and doubling the chlorinating apparatus at the sewage works); the disposal of wastes from a casein fiber textile plant; the treatment of wastes from soluble cutting and grinding oils (such wastes may run an oxygen consumed as high as 11,000 p.p.m.) by the use of alum or ferric sulfate and lime; and the effect of copper on sludge digestion (cf. 8th Biennial Rep. Copper slows up the time for developing gas production, the greatest source of trouble occurring in starting new plant digestors).

At Yale, the research on metallurgical wastes in the brass industry divided the problem into (*a*) concentration of waste waters and (*b*) treatment of concentrated and spent strong pickle liquors to recover the metals, preferably by chromium oxidation, either electrolytically or chemically. The procedure is described in detail, but no recommendation is made on choice.

LANGDON PEARSE

REPORT ON A POLLUTION SURVEY OF SANTA MONICA BAY BEACHES IN 1942—MADE TO CALIFORNIA STATE BOARD OF HEALTH

BY C. G. GILLESPIE, 69 pp. (1943)

This is a detailed report on the pollution by sewage of beaches of Santa Monica Bay to determine if areas existed from which the public should be excluded. As a result a quarantine was established in 1943 on the beach from 14th Street in Hermosa Beach to Brooks Avenue north of the Venice pier in Los Angeles, a stretch approximately 10 miles long.

Since 1894, Los Angeles has disposed of sewage in Santa Monica Bay at Hyperion. By 1912, complaints from beach cities to the south became intense, and have continued, extending to Venice on the north. In 1925 the fine screening plant and a 5,000 ft. submarine outfall were installed at Hyperion. No improvements were made in the last 18 years. The population sewering to the outlet has grown from 500,000 in 1920 to 1,787,000 in 1942. The disposal system is inadequate and the outfall leaks badly.

In 1942 sewage flow averaged 143 m.g.d. with a dry-weather maximum of 194 m.g.d. About 160 tons of dry suspended solids are discharged into the bay daily, including 8 to 10 tons of grease.

The currents in the bay prevent the formation of sludge banks on the ocean floor, yet the surface and wind-induced currents are predominantly inshore from the submarine outfall, particularly in the summer.

The fine screens only remove 3 to 8 per cent of the suspended solids and practically no grease. Sewage debris and sewage organisms grossly pollute 10 miles of beach. Because of conditions changing with the wind, no one can know when or where the beeches are safe within the 10 mile stretch.

It is estimated that 40,000,000 people visit the beaches of Santa Monica bay in a year, and of these 20,000,000 frequent the 10 mile stretch now quarantined.

The report covers in detail the sewage disposal facilities of Los Angeles city, including fine screens (revolving drum type, 14 ft. diam. 12 ft. long; 6 units with 1⁄16 by 2 in. openings; 2 with 3⁄32 by 2 in. openings; 10 tons of dry screenings removed per day) and the chronology of events.

In the investigation bacterial samples were collected every week for the determination of *Escherichia Coli* (referred to as *E. Coli*). Sanitary observations were made twice a week on the beaches and the sleek field, as well as the screening plant. Wind movements, number of bathers, rainfall, etc., were checked.

The sleek fields were sketched and noted 74 times in the year, with direction of movement.

Most of the beaches are given some form of cleaning by hand or tractor rakes. On a busy day in July, 1942, one million people used the beaches on the bay, including 470,000 on the quarantined stretch. Nearly 40 per cent are bathers.

As a limiting standard, 10 *E. Coli* per cc. was used for assured safety for recreational use of surf water. An excess above the standard 20 per cent of the time, is allowed before deciding the length of beach which violates the standard.

Sewage grease passes through the fine screens. About 8 to 10 tons a day discharges into the ocean, congealing readily into specks or froth. It floats and is wind blown. It is difficult to remove from the bodies of bathers. Some take a "gasoline bath." Other sewage debris includes matches, feces, soap and rubber goods. The observations are detailed in the text, with monthly diagrams of *E. Coli* and grease bands.

Special bacteriological studies were made of salt water forms of *E. Coli,* the density of *E. Coli* at outfall and adjacent stations, and survival tests. *E. Coli* were found in grease particles and in the air bearing ocean spray. Paratyphoid A and B were isolated in November, 1942, within 200 to 300 ft. of the outfall; in the surf and along the beach, and in the raw sewage. One case of paratyphoid was noted in a lifeguard, incapacitated for 6 weeks.

The California State Board of Public Health held the condition a menace to health. Unlike explosive epidemics originating from water, milk and foods, cases of sewage born diseases from polluted surf or beaches may scatter and the source be unsuspected. However, enteric diseases among people in the area are " three times as frequent in proportion to population in this area as they are in other parts of California.

Note.—The report presents a clear picture of a beach pollution survey, in convincing detail, which should be widely read.

LANGDON PEARSE

THE ROLE OF HUMUS IN SOIL FERTILITY AND ITS MAINTENANCE BY THE UTILIZATION OF AGRICULTURE AND HABITATION WASTES

BY A. R. P. WALKER, *Public Health* (So. Africa), 7, 17–30 (1943)

The author summarizes briefly the problem of fertilization of the soil, the need of organic material or humus, and the lack of knowledge thereof a few years ago by the new settlers in South Africa. From the decay of organic material in the soil, humus results, which improves the physical properties of the soil, effects the oxidation of protein compounds to ammonia (and later to ammonium nitrate) and offers a habitat for micro-organisms, mineral salts, and nitrogenous bodies. The chief sources of organic matter are the root system of crops left in the ground, green manuring in which a leguminous crop is grown and turned in, and farmyard manure, either natural or artificial.

In the warmer climates where the average soil temperature exceeds 77 deg. F., humus does not accumulate in the soil but is continually destroyed in arable land by the greater activity of the micro-organisms. Following a plea for the utilization of organic wastes in improving soil fertility, the author points out that compost is not intended to supersede mineral or artificial fertilizers. Humus and artificials supplement one another in a balanced combination.

Compost is defined as " the product obtained by the rotting of organic material, chiefly vegetable in origin, by the action of fungi and bacteria, with the ultimate formation of humus." This process goes on in a state of Nature. The Chinese for over 4,000 years have practiced intensive composting. The Romans in the second century B.C. composted farm residues, sewage, and straw.

Recently, Howard proposed a system at Indore, India, for composting. On a prepared floor in the compost pit, 6 inches of waste vegetable matter is deposited. This is covered with 2 inches of farmyard manure, then sprinkled with earth (urinized if possible), and mixed with wood ashes, if available. The proportion of mixed waste to farmyard manure should not exceed 3 : 1 by volume. Successive layers of the sandwich are built up until the material in the pit after fermentation is 3 feet thick. The layers should be kept moist, but not wet. After 2 or 3 weeks, the pit contents should be turned and watered if necessary. A second turn and watering follows at the end of 6 weeks from the start. The mass has then crumbled and turned black. In 3 months from the start, the carbon nitrogen ratio has fallen from from 33 : 1 in the original mix to 12 : 1. The humus is then ready for the land. In India such compost shows (on an air dry basis) 20 per cent organic matter, 0.9 per cent nitrogen, 0.5 per cent phosphate (P_2O_6) and 2.2 per cent potash (K_2O). In Rhodesia the content may be 0.8 per cent N., 0.4 per cent P_2O_5, 1.0 per cent K_2O, and 1.9 per cent lime. Of this a dressing of 5 tons per acre is used, usually reinforced with phosphate.

Domestic wastes may be handled in a similar manner, in special pits. A layer of refuse 3 to 4 inches thick is placed in the pit (2 feet deep, 500 cu. ft. capacity). Another layer is placed on a slope, then night soil is added and raked in. Successive layers are added to a depth of 2 ft. in 2 days. Two inches of refuse are left on top. After 5 days, the contents of the pit are turned with drag rakes. After 10 days more, the mix is again turned; after 1 month from start the material is removed and stacked in heaps 4 ft. high for ripening. After another month it is ready to use.

Compost has been made with refuse (probably garbage) and sewage sludge (applied wet), in the proportion of 2 parts sludge to 1 part refuse. This is turned 2 days, 6 days, and 10 days from start. After 14 days the mix is removed and stacked to ripen. After 10 weeks more it is ready for use. At Maidenhead, 6 tons of humus are recovered from 25 tons of refuse. In England, such material sells for 9 shillings ($1.80) per ton.

Other micro-biological methods have been applied at Kensington and Harrow (England), where the refuse is sprayed with a bacterial culture and deposited in cells holding 180 tons each, where for 16 days it ferments.

Warning is given that household refuse may not be suitable for composting unless properly sorted.

Sewage sludge is frequently used the world over for fertilizer when air-dried. In Johannesburg, the demand exceeds the supply.

The author notes some differences of opinion among authorities in Great Britain, South Africa, and the United States on the value of sewage sludge as a fertilizer. He urges that the proof of successful use over many years is what counts.

In the discussion, McLachlan points out the value of compost to gardeners near towns. Wilson points out the value of digestion of sewage sludge in reducing the grease content. Timson claims that in Southern Rhodesia the value of composting is definitely established.

Langdon Pearse

Note by L. P.

Those interested in compost for garden purposes may refer to *America's Garden Book* by L. and J. Bush-Brown (Edn. 1941), pp. 7–16, in which compost making is described, with a method for hastening decomposition by adding 75 lb. ammonium sulfate, 50 lb. superphosphate, and 100 lb. ground limestone per ton of material. The pile should be kept moist and turned every few months. Similar artificial composts are recommended by various agricultural experiment stations (*e.g.*, University of Florida, Agric. Expt. Sta. Press Bull. 517 (1938), "The Production of Artificial Manure on the Farm" by F. B. Smith. He recommends per ton of litter or straw a mix of 67.5 lb. ammonium sulfate, 22.5 lb. superphosphate, and 60 lb. limestone. Another reagent would be a mix of equal parts cyanamid and ground rock phosphate). The reviewer has used the procedure in his garden for a number of years. Under present war conditions, sulfate of ammonia is not obtainable. For those with a permanent garden, manure or sludge can be tried as a substitute to hasten bacterial action. Smith suggests a layer of 4 to 6 in. of material to be composted, then 2 to 3 in. of manure on top, then wet thoroughly; continue building up the heap with alternate layers. This compost has the same value as ordinary farm manure. Smith states that the practice of making artificial farm manure cannot be recommended for general farm use.

LOCAL ASSOCIATION MEETINGS

Association	*Place*	*Date*
Canadian Institute on Sewage and Sanitation	Niagara Falls, Ont. (Hotel General Broch)	Oct. 28–29, 1943
Central States	Chicago, Illinois (Hotel Sherman)	Oct. 21–23, 1943
Federation of Sewage Works Associations	Chicago, Illinois (Hotel Sherman)	Oct. 21–23, 1943
Georgia	Atlanta, Ga.	Oct. 7–8, 1943
New England	Boston, Massachusetts (Parker House)	Sept. 22, 1943
North Carolina	Winston-Salem, N. C. (Hotel Robert E. Lee)	Nov. 1–3, 1943
North Dakota	Grand Forks, N. D. (Ryan Hotel)	Oct. 5–7, 1943
South Dakota	Mitchell, S. D.	Sept. 15–16, 1943
Rocky Mountain	Denver, Colo.	Sept. 16–17, 1943

ADVERTISERS' CONTRIBUTIONS

ALUMINUM COMPANY OF AMERICA

Pittsburgh, Pa.

ALUMINUM IN SEWAGE DISPOSAL PLANTS

Because of its resistance to corrosion, strength, and lightness, aluminum had proved its merit in sewage disposal plants throughout the country before Pearl Harbor. Large quantities of aluminum were being used for such equipment as screen house racks, diffuser plate holders, sludge-handling equipment, grating, stirring arms, vents, valves, and other apparatus which is directly in contact with raw and partially-treated sewage, and it also found many architectural applications on sewage disposal plant buildings. Like many other things, sewage disposal plant equipment has now become one of the war casualties, since the government is taking the entire output of aluminum to meet increased demands for planes and other war equipment.

Engineers who are looking ahead to the peacetime uses of aluminum will do well to consider the recent developments in this light-metal industry. The war expansion program has greatly increased the production facilities available for making aluminum. In 1939 the total output of aluminum in the United States was 327,000,000

FIG. 1.—An aeration tank with aluminum diffuser plate holders at Southerly Plant, Cleveland, O.

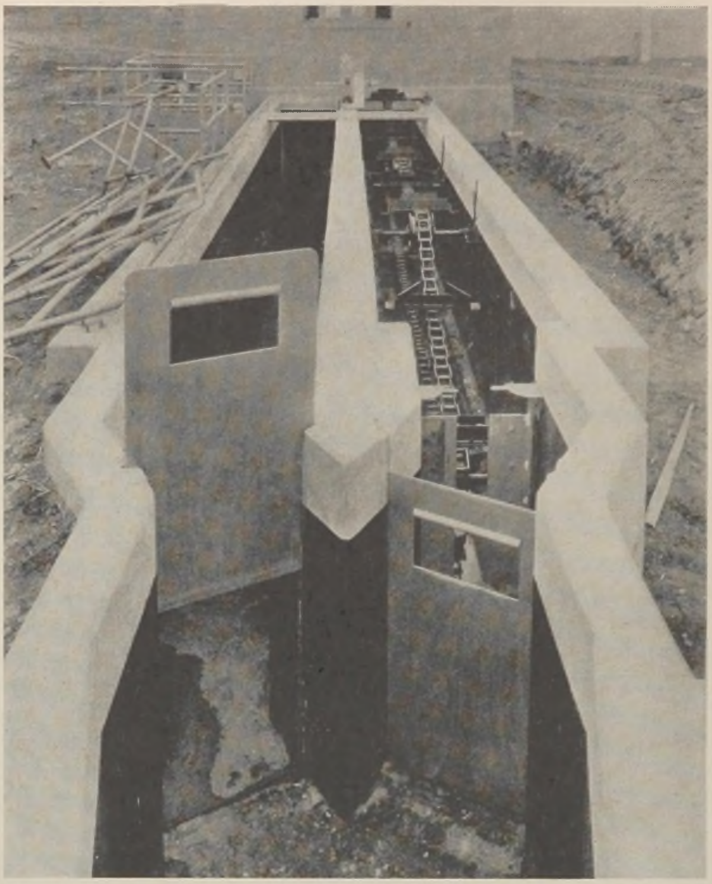


FIG. 2.—Aluminum slide gates at Rutherford Sewage Plant, New Jersey.

pounds, but it is conservatively estimated that our country will have the capacity for producing 2,100,000,000 pounds of the metal by the end of 1943. To accompany this 700 per cent increase in output has been a 25 per cent reduction in the cost of aluminum ingot. The price per ingot pound has been revised steadily downward from 20 cents in 1939 to its present all-time low of 15 cents.

There is also a greatly increased number of workers who now possess the so-called "know-how" of making aluminum. To meet wartime quotas, thousands of additional workers have been trained in the various phases of aluminum production. In addition, improvements in alloys and methods of manufacturing will make aluminum more useful in post-war applications. Many of the alloys now being used for wartime applications will be adapted to sewage disposal applications after the war. A new extrusion process has been developed that turns out seamless hollow shapes, and step extrusions are now possible in many structural parts. Considerable progress in torch and furnace brazing will facilitate assembly operations on many parts and structures.

Aluminum conduits are light in weight and place less burden on their supports. Cast aluminum diffuser plate holders of the Burger design simplify installation and maintenance of diffuser plate holders (Fig. 1). Plates are removed without the danger of breakage and holders carrying a

FIG. 3.—Aluminum floor grating, skylights, tread plate, conduit, and paint in Incinerator Building of Southerly Plant, Cleveland, O.

number of plates can be handled as units.

Stop gates of aluminum do not rust or stick in the guides (Fig. 2). Aluminum grating is not-slip, non-corrosive, and permanently high in strength (Fig. 3). Raw sewage passes through coarse screens and screening containers of aluminum and any harmful gases given off, such as hydrogen sulfide, do not harm the metal.

Aluminum paint has been invaluable as a means of retarding corrosion and improving appearance throughout sewage plants. The tiny aluminum flakes in the paint interlock so well with one another that the underlying metal is well protected against corrosion, and the even metallic surface sheen gives the entire plant an appearance of cleanliness.

Maintenance cost of interior and exterior structural parts are minimized when aluminum is used, as it resists the elements and the harmful gases which seriously attack some of the other metals. For example by washing Alumilite finishes with mild soap and water, moisture-holding pockets of dust and dirt are removed and the metal remains bright and shiny.

While no new developments in aluminum have been forthcoming for submerged apparatus since pre-war days, nevertheless, the present applications of aluminum in sewage plants are being watched with an eye to the future. The present in-service uses will furnish fairly definite information upon which to design with confidence larger and more complicated apparatus.

When the war ends, aluminum will also return to the many applications from which it has been divorced for the duration—ready to meet the peacetime needs of the sewage disposal industry.

THE AMERICAN WELL WORKS

Aurora, Illinois

MANUFACTURERS OF PUMPING, SEWAGE TREATMENT, AND WATER PURIFICATION EQUIPMENT

DIGESTER SUPERNATANT TREATMENT; INDUSTRIAL WASTE TREATMENT

Many sewage treatment plants, especially those that are not greatly over designed, have a problem in handling digester supernatant. If supernatant liquor is applied to the plant influent without prior treatment it upsets the normal aerobic biological processes. Anaerobic digester supernatant has a tremendous ability to seed fresh sewage and start septicity. Consequently, when discharged into a primary settling tank, it may convert the entire flow from fresh to grossly stale sewage.

Activated sludge and high rate filters are especially affected by digester supernatant. With strong anaerobic supernatant to treat, these processes fall off in efficiency. Effluents become turbid and high in biochemical oxygen demand.

The American Well Works has developed a high rate self-contained filter which is employed to aerate and completely stabilize anaerobic digester supernatant liquor. The filter consists of a bed of graded anthracite media supported by a false bottom which forms a backwashable underdrain system. Supernatant is applied to the surface of the media by a rotary aerator which gives uniform dosage over the entire area.

The rotary aerator applies the supernatant in thin, wide films, reducing the intensity of unit area loading to a minimum. The liquor trickles uniformly throughout the entire volume of the bed and maintains an optimum contact between itself, the atmosphere and the surfaces of the media. The height of rotary aerator above the bed aids in supplying the oxygen requirements of the supernatant liquid.

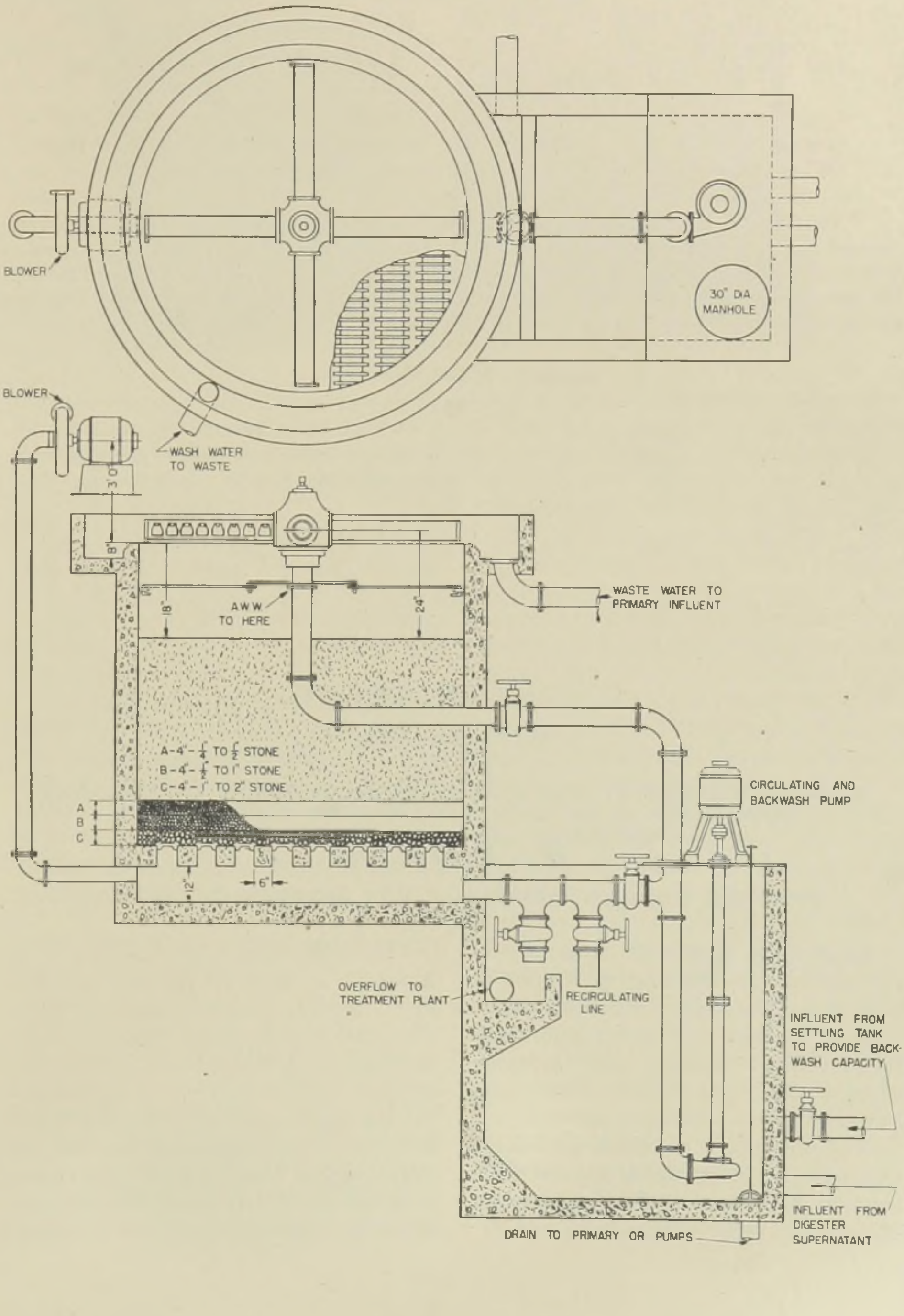
The supernatant is recirculated through the unit at a high rate. A period of 60 minutes recirculation is generally enough to cause the liquid to lose 90–95 per cent of its B.O.D. and to completely change the supernatant from an anaerobic to aerobic state. The effluent contains 5–8 p.p.m. of dissolved oxygen, and is completely stabilized.

Anthracite media is used because of its smooth shiny surfaces which are easily backwashed free of the particles filtered from the supernatant. Backwash water is obtained from final settling tanks and the waste wash water is discharged to primary settling tanks. One pump serves both recirculation and backwashing functions. Backwashing is infrequent and keeps the filter at its peak efficiency.

The Rapid Rate Filter completely satisfies high avidity for dissolved oxygen through the efficient oxygenation resulting from the thin films of liquid trickling through the fine contact media in combination with the air circulation. Flocculation and filtering takes place within the unit giving a clear effluent.

The treatment of these wastes can be accomplished on a batch or continuous basis, depending upon individual job requirements. In either case the waste is recirculated through the filter at a high rate.

The Rapid Rate Filter can be successfully used on industrial wastes that have high soluble B.O.D. treatable by biological processes. Laundry wastes,



canning wastes low in solids and high in B.O.D., and many industrial wastes are successfully handled by this unit.

The following results are from the treatment of digester supernatant and laundry waste.

SUPERNATANT TREATMENT

Test	Untreated Supernatant	Treatment Period		
		40 Min.	60 Min.	4 Hrs.
D.O. (p.p.m.)	0.0	8.0 (85% Sat.)	8.0	8.0
5-day B.O.D. (p.p.m.)	1500	300	250	250
*Putrescibility	1 Hour	4 Days	4½ Days	4½ Days
(20% additions)		Control sample remained blue 4¾ Days		

* The putrescibility test is employed to measure the relative ability of anaerobic supernatants (treated and untreated) to cause putrescence in a given sample of fresh waste. A control of organic waste was made up and seeded to simulate fresh sewage. To samples similar to the control was added 20 per cent of supernatant in the raw and various stages of treatment. The time for bleaching of methylene blue was used as the measure of relative putrescibility.

LAUNDRY WASTE TREATMENT

Test	Untreated Laundry Waste	Treatment Period					
		15 Min.	30 Min.	45 Min.	1 Hr.	2 Hr.	3 Hr.
D.O. (p.p.m.)		6.5	6.8	7.2	7.4	7.4	7.4
5-day B.O.D.	720	316	273	257	232	186	145
pH	11.0	10.0	9.0	9.0	9.0	8.5	8.0

CHAIN BELT COMPANY

Milwaukee, Wis.

MANUFACTURERS OF REX CHAIN—REX CONCRETE MIXERS, REX SPROCKETS—REX TRAVELING WATER SCREENS, REX ELEVATORS AND REX CONVEYORS, ESTABLISHED 1891

THE REX UNI-FLO CONVEYOR FOR MOVING CHEMICALS

Where such chemicals as alum, ferric chloride, and lime are purchased in bulk by large sewage treatment plants, a very flexible, economical and dust-free means of handling and conveying them is provided by the continuous stream type of conveyor-elevator. A unit of this type is the REX UNI-FLO Conveyor-Elevator which has been developed by Chain Belt Company of Milwaukee, Wisconsin.

The REX UNI-FLO conveyor combines in a single unit, the functions of a feeder, conveyor and elevator. The unit can be used vertically, horizontally, at any degree of incline, and around vertical curves. A unique and distinguishing feature of the REX unit is the use of a pivoted flight on the conveyor chain, which a positively driven cam tips to a steep angle when the conveyor is discharging. The chemicals

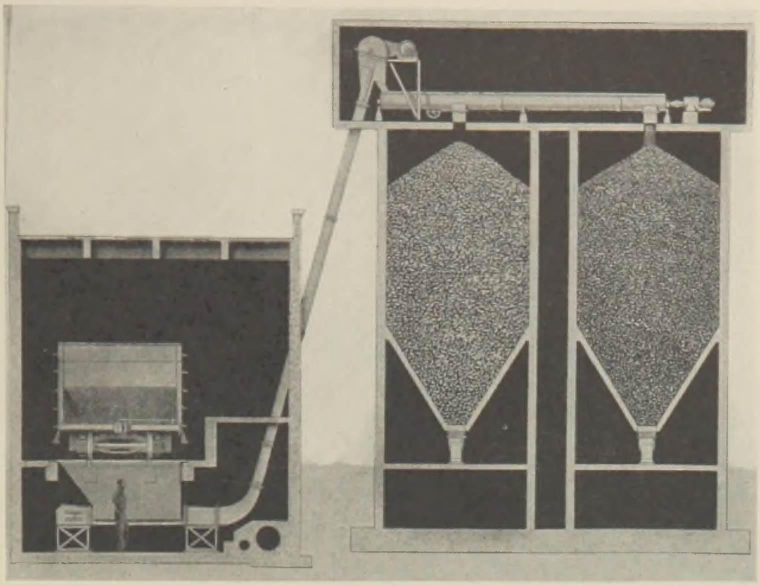


Fig. 1.

are conveyed in a continuous stream in a dust-tight casing that takes up much less space than other conventional types of conveyors.

The complete flexibility of layout that is possible with this unit, together with the small space it takes up, makes it just as adaptable to modernization of existing plants as to installation in new construction.

The illustration (Fig. 1) pictures the REX UNI–FLO handling chemicals at the Allison Engine Division of General Motors Corporation, Indianapolis, Indiana (Burns & McDonnell, Kansas City, Engineers). The arrangement is typical of what can be accomplished by use of this type of equipment.

THE IMPROVED REX REVOLVING SKIMMING PIPE

The design and construction of REX Revolving Skimming Pipes have been improved to a high degree which insures ease of installation and operation. Other attributes so necessary to this type of equipment include a water-tight seal, no freeboard limitation, high structural strength, and the ability to operate multiple units independently.

There are three types of skimming pipes available, the difference being in the method of operation. For the average size job, the pipe is simply provided with an operating lever. For the larger application, where considerable weight is involved, there are two types available. The skimmer pipe may be operated either through a chain drive from a small hand-operated gear reduction unit (Fig. 2), or through a set of gears. In any case, the outstanding feature of design is the patented, oil-resisting rubber seal.

The seal is of a special extruded shape, with a spring steel bar insert, designed to insure an effective water-tight seal, but at the same time to permit easy operation of the pipe. No adjustment of the seal is necessary after once properly installed since a slight misalignment of pipe and collar will not impair its effectiveness. The seal is of long life, not being affected by oil, mild acids, or alkalies found in sewage, and, when ultimately necessary, is readily renewed.

When accurate control of scum removal is essential, as is often the case in the treatment of industrial wastes,

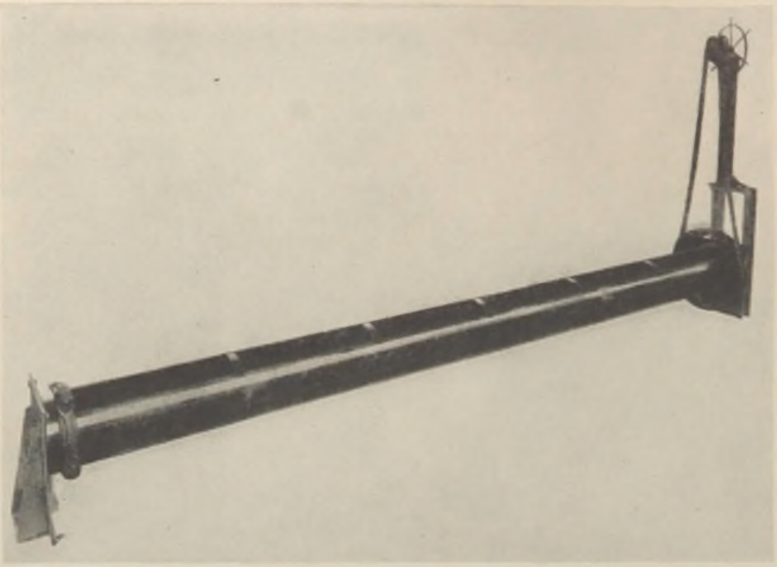


FIG. 2.

the worm-gear operated skimming pipe is to be desired.

As shown in the accompanying photograph (Fig. 3), a cast iron, cut-tooth worm wheel and worm are rigidly mounted on a structural steel support. The worm shaft revolves in babbitted bearings and the worm wheel revolves on a bronze bushing. The revolving pipe is thus free to float inside the worm wheel so that slight misalignment of the pipe will not affect the mesh of the worm and worm wheel. Recesses in the worm wheel engage

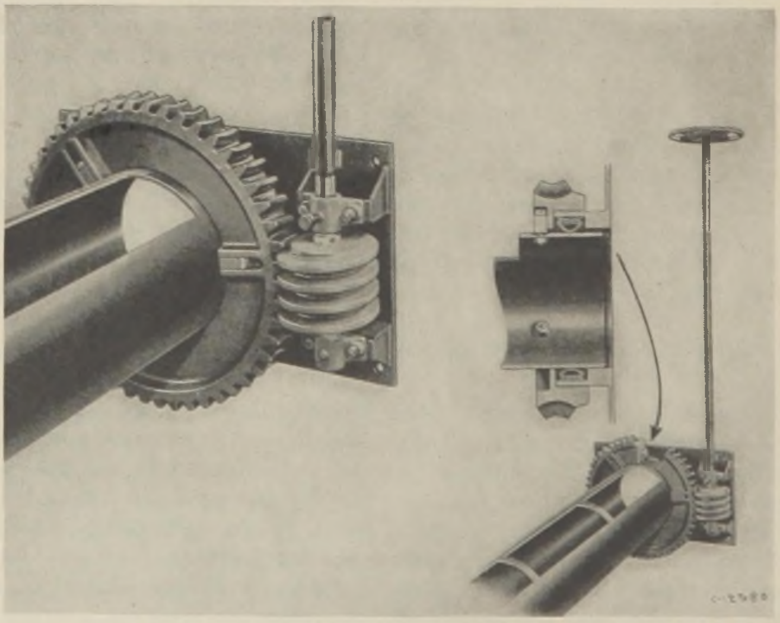


FIG. 3.

Fig. 4.

lugs, bolted to the pipe, to turn the pipe as the worm is turned. Sufficient mechanical advantage is provided so that only slight pressure on the hand operating wheel is necessary to turn the pipe and allow easy, accurate adjustment.

REX AERO FILTER OPERATION

Figure 4 shows a REX Aero-filter in operation at a typical sewage treatment plant serving a U.S. navy base. Designed to receive a B.O.D. load of 3000 lb. per acre foot, recent analyses show the filter to be loaded at 4345 lb. per acre foot. In spite of this overload, the plant is accomplishing a removal of 83.5 per cent. Suspended solids reduction are in line, averaging 82 per cent. This is a striking example of the value of the REX Aero-filter, its ability to take an overload without adverse effect.

The design is conventional with provision made to recirculate plant effluent back to filter only at low flows.

CHICAGO PUMP COMPANY

2300 Wolfram Street, Chicago 18, Illinois

WIDE-BAND AIR DIFFUSION SYSTEMS WITH SWING DIFFUSERS AND STATIONARY DIFFUSERS, COMMINUTORS, SCRU-PELLER PRIMARY SLUDGE PUMPS, FLUSH-KLEEN SEWAGE LIFT STATIONS, COMBINATION AERATOR-CLARIFIERS, RAW SLUDGE PUMPS, PLUNGER SLUDGE PUMPS AND WATER SEAL PUMPING UNITS

Concurrent with Chicago Pump Company's policy of offering operation service as well as equipment for the activated sludge process, during the last two years our sanitary engineers have been conducting research projects at various army and navy establishments where the type of wastes created certain problems not ordinarily encountered in normal domestic wastes. Because of these special conditions it was necessary to determine new capacity factors and operation procedures for the activated sludge process.

In order to study these unusual conditions, pilot plants were set up in which the aeration period and other variable operational functions could be controlled. From these pilot plants, data were accumulated which made it possible to select the proper capacity factors and operation procedures for effecting the characteristic high degree of purification of the activated sludge process for these establishments under widely varying sewage flows and strengths.

The war has also brought new problems in treating various types of industrial and laundry wastes. In cooperation with various industries and laundrys we set up pilot plants to determine the proper method of treating these wastes. As a result the Chicago Wide-Band Air Diffusion System has been adapted to the treatment of many of these special wastes.

SWING DIFFUSER FOR CHANNEL AERATION

Outstanding among our new equipment developments during the last year have been new models of the Swing Diffuser for channel aeration in medium and small size channels of activated sludge sewage treatment plants (Fig. 1). The new models do not have knee joints as does the standard model, which is still used in large channels.

Channel aeration keeps the return sludge fresh and active and prevents settling in the channel. Maintenance of the fixed type diffuser media in channels has been a serious problem in the past because the whole plant had to be shut down in order to clean the plates or tubes. The new model Swing Diffuser for medium size channels can be raised completely out of the channel for maintenance of the diffuser tubes without interrupting the flow in the channel or the operation of the plant. A manually operated portable

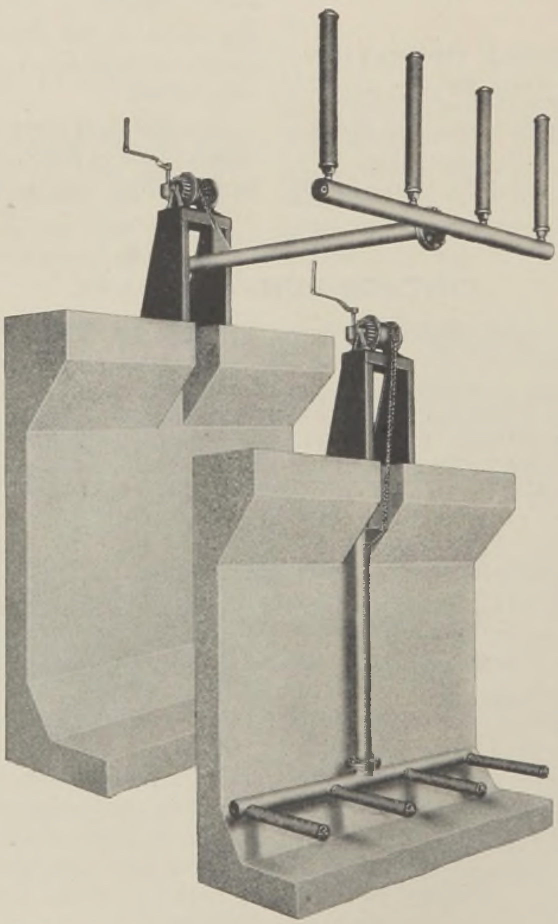


Fig. 1.—New model Chicago Swing Diffuser for medium size channel aeration and for small aeration tanks.

hoist raises the Swing Diffuser to a horizontal position where the tubes are easily accessible from the opposite wall of the channel.

This new model of the Swing Diffuser is also suitable for use in small aeration tanks, such as are usually required in industrial or laundry waste treatment plants.

For small channels a removable type of diffuser has been developed which does not require a hoist. A union in the hanger pipe near the top of the channel wall permits raising of the aeration assembly by hand. An orifice is provided to control the amount of air through each unit, as with all Chicago air diffusion units.

All the advantages of Chicago Wide-Band air diffusion are maintained in these new models.

TUBE CLEANING RESEARCH

Our engineers are conducting extensive research in co-operation with sewage plant superintendents to determine the cause of diffuser tube clogging so that proper cleaning methods may be applied. The type and method of cleaning necessary to restore the effectiveness of the tubes depends upon various factors peculiar to individual plants.

Apparatus and procedure for testing tubes have been developed to determine the effectiveness of various methods of cleaning.

FLOAT OPERATED FLOW METER

An inexpensive, float-operated flow meter has been perfected for accurately recording the flow direct in m.g.d. through small plants. It can be easily installed by the operator.

The flow is recorded on special charts developed by the Chicago Pump Company for 90° "V" notch weirs and 3 in. and 6 in. Parshall Flumes.

ACTIVATED SLUDGE WITHDRAWAL CONTROL

Telescoping valves of various sizes have been designed by Chicago Pump

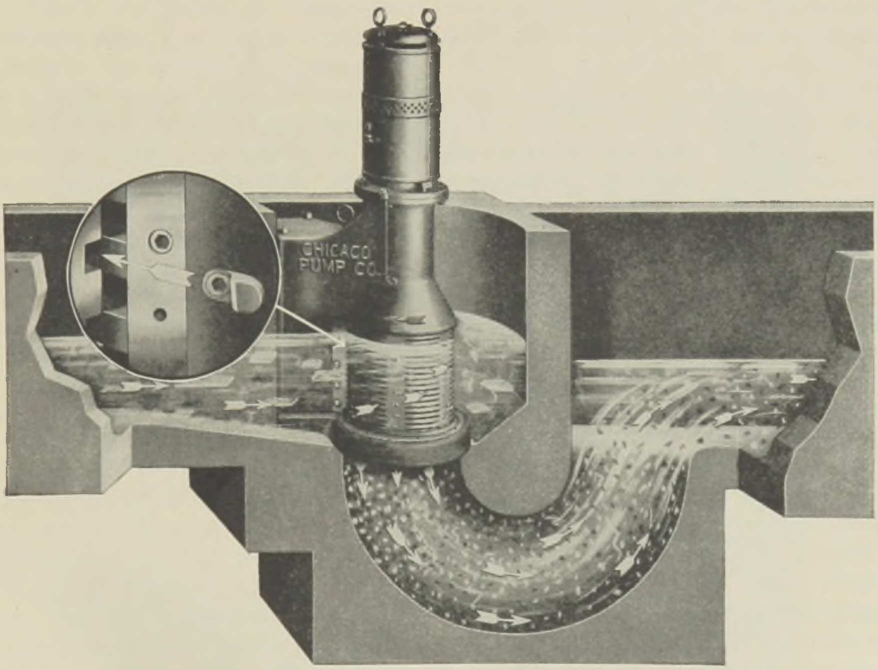


Fig. 2.—New, harder metals are expected to increase many times the life of these cutting members of the Chicago Comminutor.

Company engineers for controlling the withdrawal of activated sludge from two or more final settling tank hoppers.

An indicator on the mechanism simplifies its regulation for control over a uniform rate of withdrawal.

COMMINUTION RESEARCH

As new, harder metals are developed, our engineers experiment with their use in the cutting members of Comminutors. Results to date indicate that the life of Comminutor cutters can be increased many times.

Although Comminutor cutters have been known in the past to give efficient service for two or three years before requiring sharpening, experience has shown that the life of the cutting parts decreases as the amount of grit in sewage increases.

Grit will have considerably less effect on Comminutors that are soon to be equipped with cutting members of the new, harder metals (Fig. 2).

CLIMAX ENGINEERING COMPANY

General Sales Offices, Chicago, Ill.; Factory, Clinton, Iowa

BLUE STREAK ENGINES, GAS—GASOLINE—BUTANE. ELECTRIC GENERATING SETS AND SWITCHBOARDS. OIL FIELD PUMPING AND DRILLING ENGINES. INDUSTRIAL POWER UNITS. GREY IRON CASTINGS

GAS ENGINES FOR SEWAGE TREATMENT PLANTS

The pioneer in the early 30's who had the courage to install or recommend a gas engine for operation on sewage gas can now, in the early 40's, find ample justification for his foresight in hundreds of sewage treatment plants throughout the United States. There have been very few failures and such as have occurred have been largely a result of misapplication. The sewage gas engine is today accepted by engineers and operators as a dependable source of power (Fig. 1). The only danger we see ahead of us in this field is that there may be too much confidence in the gas engine to the end that not enough engineering knowledge is employed before the engine is selected for the service. No two plants are exactly alike and success or failure can depend entirely on whether or not sound engineering has been employed. By "failure" we do not necessarily mean an engine that will not operate or will not be reasonably dependable. "Failure" is where the installation does not effect the maximum savings possible as a result of economy of operation, which includes maintenance cost.

In most instances a plant serving an equivalent population of 15,000 or more can justify the installation of a gas engine. Plants serving 30,000 or more definitely can effect considerable savings unless there are some unusual local conditions which would militate against the gas engine such as very favorable power rates, other uses for the gas produced, plant layout, etc. The problem with the smaller plants is that pumps, blowers, etc., are too small in power demand to justify the direct application of a gas engine and the only way a gas engine can be utilized is direct connected to a generator to furnish power for individual motor drives. This means an unavoidable loss of at least 25 per cent between the prime mover and the driven unit. The generator must be oversize to provide sufficient current for motor starting. As the engine and generator must be of sufficient size to take care

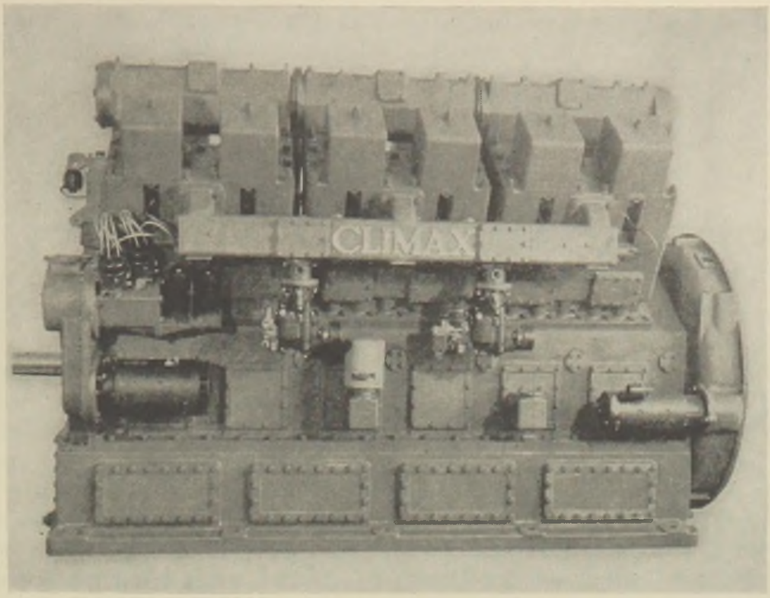


Fig. 1.—New Climax 12-cylinder, V-type Sewage Gas Engine rated 205 hp. at 720 r.p.m., for driving pumps, blowers or generators.

of the maximum demand, it is difficult to maintain a favorable load factor, with resulting lowered economy. For these reasons the smaller plants are handicapped in converting the gas to mechanical power.

Plants serving equivalent populations of 30,000 or more usually have pumps or blowers which require 25 or more horsepower. In such instances an engine applied directly to the unit offers an opportunity for maximum

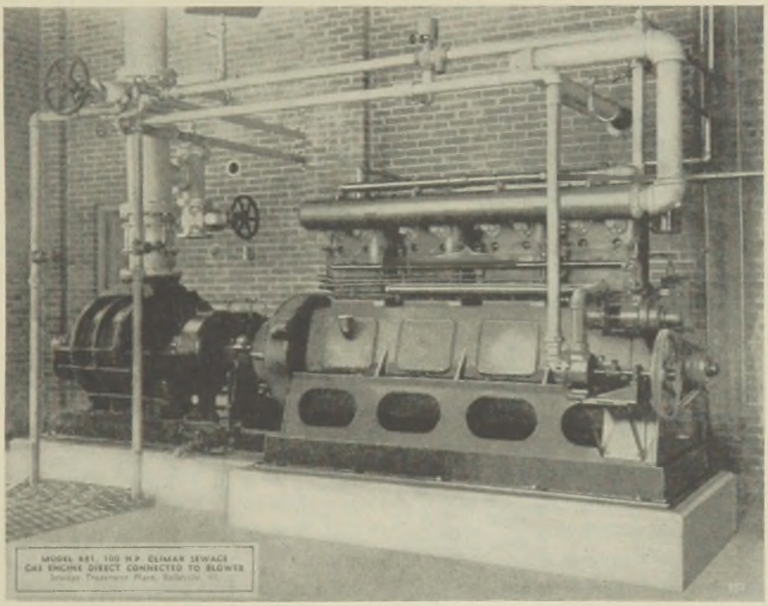


Fig. 2.

economy as there is no power loss through transmission (Fig. 2). It is obvious that as larger plants are considered, individual engine drives make possible the use of all the gas produced in the most economical manner. A separate engine-driven generator can produce power for lighting and for small motors scattered about the plant.

Where sewage treatment plants are originally equipped with gas engines, as a result of the wisdom of the designing engineer, the owners are seldom conscious of the enormous savings that are being made as compared with the use of purchased power. The results are conspicuous, however, when a plant originally operated by means of purchased power is converted to gas engine power. Such a conversion was made by the Aurora Sanitary District, Aurora, Ill. (equivalent population approximately 50,000). In the spring of 1936 two 75 hp. gas engines replaced electric motors direct connected to centrifugal pumps. In the fall of 1940 the District installed two 35 kw. gas engine driven generators. The entire plant load has since then been carried by the gas engines, without any connection for outside power and without a single power interruption. The total installed cost of the two 75 hp. engines was $8,521 and the earnings (savings) credited to them during 81 months of operation to the end of 1942 was $27,570. The total installed cost of the engine-generator units was $9,800 and the earnings credited to them for 25 months was $3,645, or a total saving since the first engines were installed of $31,215. Comparable results can be and are being obtained in other plants either converted to or originally equipped with gas engines.

Savings indicated are not surprising when we take into consideration that the fuel used is a by-product of sewage treatment. Also that the gas engine, properly selected and applied, has a thermal efficiency of 25 per cent. Furthermore, at least 50 per cent of all the heat (power) of the gas consumed in the engine can be recovered from the jacket water and exhaust and utilized in the plant. Under what other conditions can a prime mover show an overall thermal efficiency of 75 per cent, using a fuel that costs nothing to produce?

During the present emergency it is difficult to obtain the necessary priorities to improve old plants or install new ones, but we know of three plants which recently have been able to secure priorities and they are adding individual gas engines to supplement engines previously installed. Many plants now using gas engines have indicated a desire to add additional units as soon as they are available.

THE DORR COMPANY, INC.

570 Lexington Ave., New York, N. Y.

During the past year we have had little time to devote to new developments in sewage treatment work as most of our effort has been spent on the production of a large amount of equipment for military camps, bases, and ordnance works. In the interest of saving critical materials, a number of innovations have been introduced such as the use of wooden scum baffles and weirs on Clarifiers, wood walkways instead of steel, and even fabricated timber rake arms on the Clarifiers. The use of lightly reinforced concrete domes on digestion units has resulted in the saving of large amounts of critical materials, as formerly these were made of fabricated steel plate. There is no doubt but that some of these economies will persist in post-war

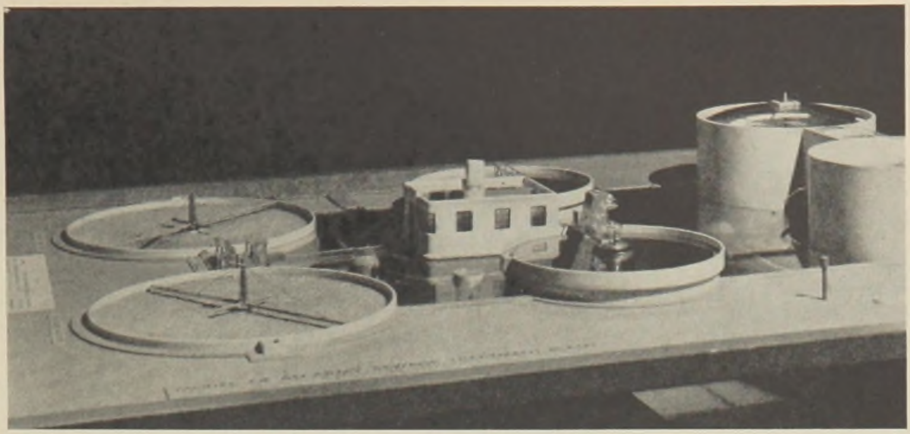


FIG. 1.—Two-Stage Biofilter Plant Model, built for the Corps of Engineers of the Army, Construction Division, Repairs and Utilities Branch.

structures showing the direct benefit of war-time necessities.

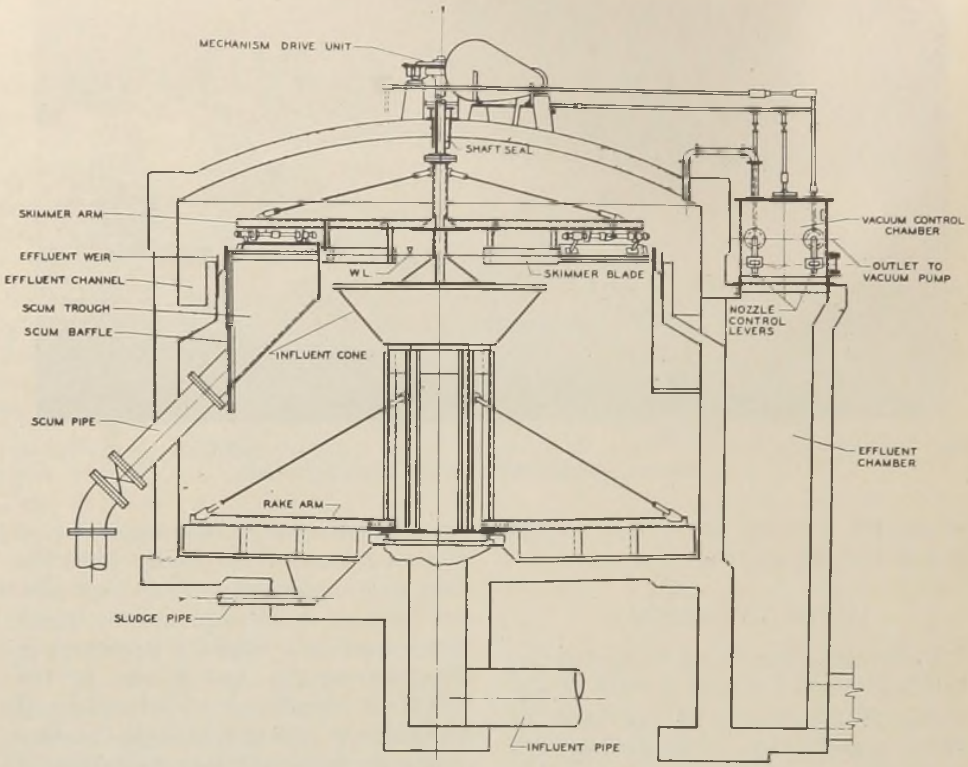
BIOFILTRATION

Biofiltration continues to occupy the field and there are now a total of upwards of 200 plants in operation or under construction. Designs have become more standardized as operating experience indicates (Fig. 1). The need for multiple units to take care of varying load conditions has proven unnecessary, and it is even feasible to design a plant for the ultimate requirements and operate it at reduced capacity corresponding to lower initial load requirements. This is possible because septic conditions can be avoided during times of low loading conditions. The operator need not be concerned about holding the sewage too long in his plant but on the contrary it is benefited by greater detention and continued contact with the recirculated sewage.

Single-stage Biofiltration seems to satisfy most requirements, thus yielding to a simplified layout virtually automatic in operation. In single-stage plants in many localities where operating loads do not exceed original design assumptions, B.O.D. removals of well over 85 per cent have been obtained. One aspect found to be essential for satisfactory operation is continuous return of the sludge from the final or humus tank. Very long contact between this sludge and the liquor in the final tank causes a reduction in dissolved oxygen and a rise in the B.O.D. of the effluent. Fortunately, it is possible to return this sludge in comparatively large volumes regardless of dilution as the solids reenter the Primary Clarifier and settle with the raw sludge.

VACUATOR

The use of vacuum flotation for grease removal in sewage treatment plants has been applied in several installations and the results fully confirm earlier expectations. The Vacuator has one advantage of doing what is ordinarily an unsightly, messy job under cover where it is not visible to the casual visitor. It improves the general appearance of the plant where grease removal in separate units is required. The Vacuator consists of three elements, an aerator, de-aerator, and Vacuator proper. The aerator is for the purpose of introducing into the feed, the maximum amount of finely divided air bubbles so important in the flotation of grease. The de-aerator is for the purpose of releasing any large air bubbles which might be



SECTIONAL ELEVATION

Fig. 2.—The Dorrco Vacuator.

retained and which serve no purpose in the flotation process. De-aeration takes place very rapidly, usually in a section of the channel feeding the Vacuator.

The Vacuator proper (Fig. 2) is a cylindrical dome-covered tank operating under a vacuum of about 9 in. of mercury. Feed enters the tank through a center draft tube and overflows a peripheral weir. Two or more skimming blades attached to a central revolving shaft scrape the scum into a trough, which drops down a barometric leg.

The total loss of head through the system is seldom more than 6 or 8 in. and consists only of the pipe friction, weir losses and miscellaneous entrance and exit losses. Once the flow through the Vacuator has been established, siphonic action causes continuous flow as long as the air is exhausted from the liquid in sufficient volume to prevent any breakage.

Scum removed from the Vacuator has a moisture content of 90 to 92 per cent and occasionally it is necessary to add dilution water before pumping to the Digester.

The material is digested in the Digester with the usual sludge solids although large volumes of inorganic grease or oil require special consideration.

SLUDGE DIGESTION

The Dorr Multdigestor, with all the advantages of two-stage digestion in a single tank, has been installed in numerous military treatment works (Fig. 3). In this unit mechanical mixing

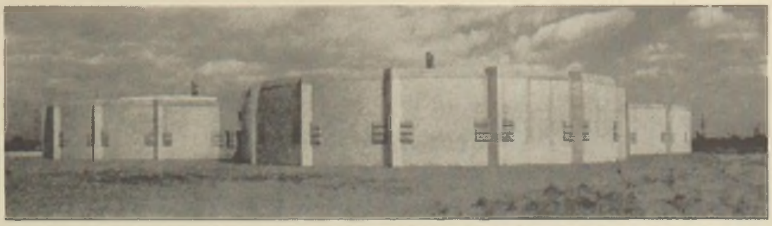


FIG. 3.—Hammond, Indiana. The Hammond, Indiana sewage treatment plant went into operation late in 1941 with a design population of 100,000 and an average design flow of 40 M.G.D. The architectural excellence of this plant is typified by the two primary tanks of the Dorr Multdigestion Systems, which are shown in the photo.

Each of these two Systems consists of a fixed steel dome primary, and a secondary with a steel gasometer. The side of one of these secondaries may be seen at the extreme right. Sludge is thickened prior to digestion in a special Dorr Thickener.

and vertical heat exchangers, both of which are removable, are provided in the primary stage. Automatic sludge transfer is provided and once the operator sets the levels, he has little to concern himself about.

The visible sludge feeding arrangement has proven very practical as operators are now able to judge the density of the material they are pumping into the Digester. Possibly one of the greatest errors in treatment plant operation is pumping excessive quantities of water along with the sludge solids into the digestion tank. This can readily be controlled with this new arrangement.

For smaller plants or where stage digestion is not desired, a single-stage unit with mechanical mixing and heat exchangers has also found wide application in military plants.

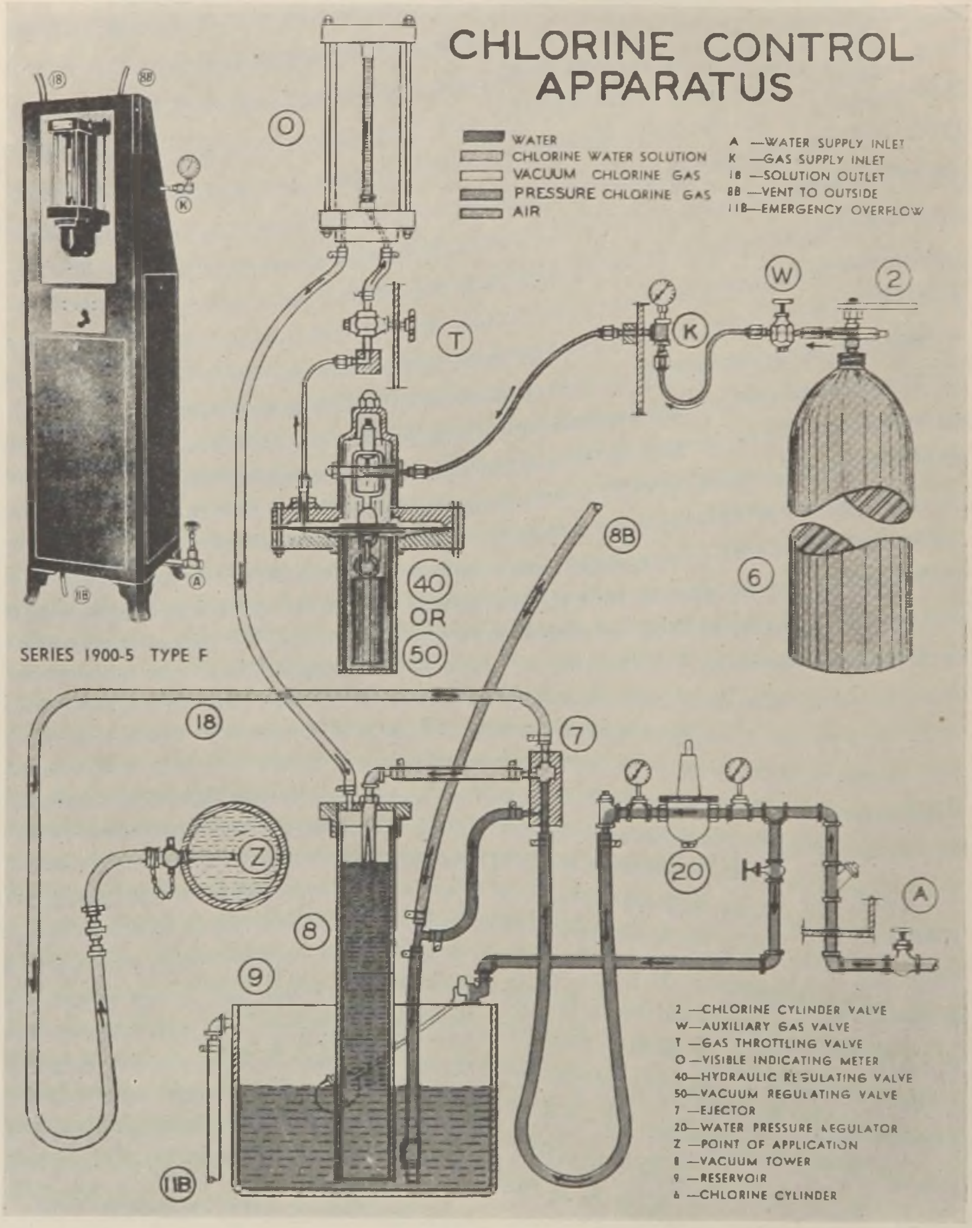
EVERSON MANUFACTURING CO.

214 W. Huron St., Chicago 10, Ill.

The great advance made in the field of chlorination by the entire industry is well demonstrated in one of our installations.

The War Department's new Pentagon Building at Arlington, Va., across the Potomac from Washington, is the world's largest office building with facilities for about 60,000 persons. Among the other features is a complete sewage plant which has the problem of extreme variations in volume. They installed a SterElator with a capacity of 3 to 330 lbs. of chlorine per 24 hours, a ratio of 110 to 1 without changing orifices. So perfect has this operation been that the SterElator Building is rapidly becoming a special point of interest in Washington for visiting engineers. A regular visitors' register has been installed by Mr. John T. MacMahon, the operating engineer, who gladly shows visitors the operations of this most modern Sewage Disposal Plant.

A special feature is the visible indicating solution manifold which enables the operator to proportion the solution to several points of application according to the volume and need at each point.


CHLORINE CONTROL APPARATUS
WATER
CHLORINE WATER SOLUTION
VACUUM CHLORINE GAS
PRESSURE CHLORINE GAS
AIR
A —WATER SUPPLY INLET
K —GAS SUPPLY INLET
18 —SOLUTION OUTLET
8B —VENT TO OUTSIDE
11B—EMERGENCY OVERFLOW
SERIES 1900-5 TYPE F
40 OR 50
2 —CHLORINE CYLINDER VALVE
W—AUXILIARY GAS VALVE
T —GAS THROTTLING VALVE
O —VISIBLE INDICATING METER
40—HYDRAULIC REGULATING VALVE
50—VACUUM REGULATING VALVE
7 —EJECTOR
20—WATER PRESSURE REGULATOR
Z —POINT OF APPLICATION
8 —VACUUM TOWER
9 —RESERVOIR
6 —CHLORINE CYLINDER

FLEXIBLE SEWER ROD EQUIPMENT CO.

9059 Venice Blvd., Los Angeles 34, Calif.

MANUFACTURERS OF A COMPLETE LINE OF UNDERGROUND PIPE-CLEANING TOOLS

To save time and labor in these days when manpower must be conserved, Flexible Sewer-Rod Equipment Co. offers a full line of modern sewer cleaning tools that make it possible to continue necessary pipe-cleaning operations with fewer men and in faster time.

With these modern tools, it is unnecessary to dig up the town to clean underground pipe or to remove stoppages. Three men can clean 2000 ft. of sewer per day and most emergency stoppages can be removed in half an hour. Thus, sewer-cleaning, so necessary to American health and morale, may be continued without interruption in spite of present scarcity of trained labor.

FLEXIBLE POWER DRIVE

The use of the improved Flexible Power Drive substitutes mechanical power for man power in sewer-cleaning operations. Operations are on the same principle as when hand turning with ratchet turning handles, but the power drive turns the rods into the line mechanically at a continuous speed, approximately five times the speed of hand turning. It is ideal for use in removing roots, scale, sand, mud, slime, sludge, rock and gravel. It is made of cast steel to combine strength with lightness and portability. Equipped with a new type safety clutch, the Briggs and Stratton motor applies power through two pulleys at two speeds. Further speed adjustment is possible by regulation of the throttle. One lever controls all operations.

When a universal drive shaft is added, the motor may also be used to operate winches.

EZY ROD LINE PULLER

The new rod line puller is another time and labor saving tool, used to remove rods from the line after they have been worked to the farthest end. Simply set up the rod line puller as shown in the illustration (Fig. 1), fasten the end of the rod to a rope tied to the truck and move the truck forward easily, applying the power slowly and steadily. The rods will be removed in a fraction of the time needed when they are pulled by hand.

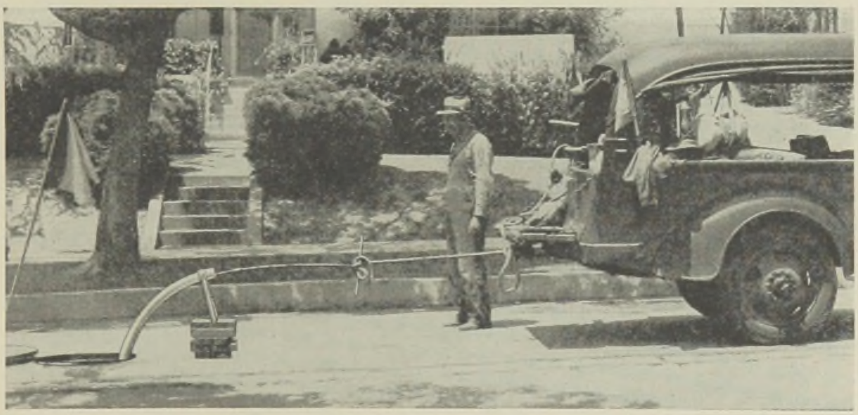


Fig. 1.—Rod line puller.

EZY ROD REEL AND STAND

The improved Ezy rod reel may be used either with the stand as shown for operation from the pavement (Fig. 2)

FIG. 2.—EZY rod reel and stand.

or it may be quickly and easily mounted on the side of service trucks. The new reel does away with the need for hooking and unhooking when winding or unwinding Flexible rods.

When used with the Ezy Reel Stand, the reel stands at a 45 deg. angle with the pavement in perfect balance. The stand is made of rugged material, carefully welded to assure the strength needed for rough usage. The three legs of the tripod are quickly screwed or unscrewed to the center spider, making the entire assembly easily portable.

A COMPLETE LINE

Flexible offers a complete line of all tools needed for underground pipe cleaning for all types of jobs.

GENERAL CHEMICAL COMPANY

New York, N. Y.

ALUMINUM SULFATE FOR SEWAGE CLARIFICATION AND SLUDGE CONDITIONING

Sewage plant operators are finding aluminum sulfate extremely useful for two treatment jobs in their plants, i.e. (1) for clarification of the raw sewage, and (2) for conditioning sludge to facilitate dewatering.

SEWAGE CLARIFICATION

The chemical treatment of sewage was extensively practiced during the years prior to the turn of the century. Aluminum sulfate, or just plain "alum" was used in many of the plants at that time. Today our mechanized plants employ chemical treatment with far greater success than the plants of 1900. "Alum" continues to be enthusiastically used as the coagulating chemical in the plant of today.

When aluminum sulfate is added to sewage a chemical reaction takes place between the "alum" and the alkalinity present in the sewage. An insoluble aluminum hydroxide is formed which is better known as "alum floc." This hydroxide is a gelatinous precipitate that enmeshes fine suspended solids and color in the sewage, and carries such material with it as it settles to the bottom of the settling tank. This action in a sense might be likened to a superfine screen sweeping downward through the sewage and taking with it the solids in suspension. Actually the coagulant does more than this for it will remove colloidal material, some of the soaps and greases and a portion of the soluble material that is responsible for the B.O.D. of the waste (Fig. 1).

SLUDGE DEWATERING

Digested domestic sludge ordinarily requires 2 to 3 weeks to dry during the summer months and 4 to 8 weeks dur-

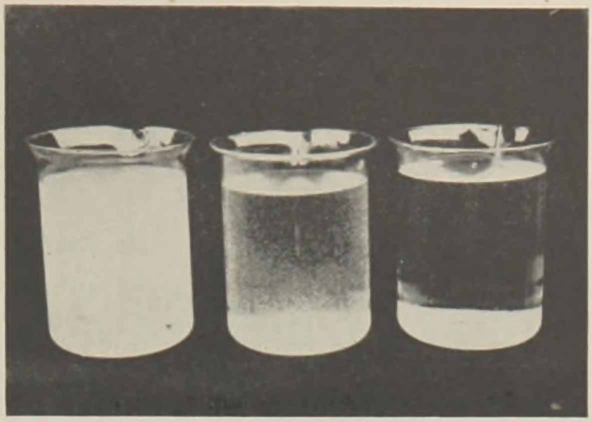


FIG. 1.—Beaker at the left contains a turbid industrial waste. Center beaker illustrates the effect of alum coagulation. Right beaker demonstrates the remarkable clarification obtained by the treatment.

ing the winter months in a large section of the country. Other areas where seasonal rain-falls are experienced know the difficulties in removing sludge from sand beds in a reasonable length of time. Aluminum sulfate is being used to shorten the time required for drying sludge on sand beds. One municipality actually has been able to spade sludge from the beds in 4 days after treating with "alum."

"Alum" reacts with the bicarbonates of the sludge to produce aluminum hydroxide in the sludge. The soupy black sludge is converted to a "curdled" mass. The bond between the water and the sludge solids is broken by the reaction, and a copious rush of water pours from the underdrains of the sand drying bed. In addition to the coagulation effect where the sewage solids are brought together in clumps, the reaction with the bicarbonates releases large quantities of carbon dioxide gas. The gas tends to float the coagulated sludge particles. Flotation of the solids prevents their sealing over the surface of the sand bed, thus permitting even faster draining away of the water. The carbon dioxide gas in rising through the sludge mass tends to make it porous and therefore susceptible to faster drying through evaporation (Fig. 2). The porosity of the

FIG. 2.—Both beds were poured on the same date. Alum treatment has caused deep cracks to form in the one bed, compared to the smooth wet surface of the untreated bed.

treated sludge is not only evident on the sludge surface, but extends through the depth of the sludge. This has been shown to be true many times by plants where treated and untreated sludge of the same filling date have been exposed to rain. Rain quickly percolates through the porous treated bed but usually ponds for days on the untreated sludge mass.

GRAVER TANK AND MFG. CO., INC.

East Chicago, Indiana

MANUFACTURERS OF SEWAGE TREATMENT, WATER CONDITIONING, AND CHEMICAL PROCESS EQUIPMENT THE "FLEXIDRIVE" CLARIFIER

A RECENT DEVELOPMENT FOR PRIMARY AND SECONDARY SETTLING TANKS

As the latest addition to a complete line of clarifiers consisting of stationary bridge type mechanisms, Reactivator Clarifiers, and Multitray Settlers, Graver offers the new "Flexidrive" (Fig. 1). This equipment was designed to conserve critical materials and speed up the time required for installation with unskilled labor for wartime construction, but has since been improved to incorporate all possible advantages engineers would look for in a clarifier mechanism.

The construction embodies a central tubular pier serving as an inlet duct, scraper arms and drive bridge resting on a ball bearing turntable, and an inlet well built integral with the scraper arm support. The equipment is driven by a thrust wheel, engaging the tank wall below the liquid surface. The reactive forces are calculated so that ample power is available for all operating conditions, yet the equipment cannot be overloaded. The drive bridge is connected to the scraper arms through a truss member with "knee-action" arms, and all working parts have heavy

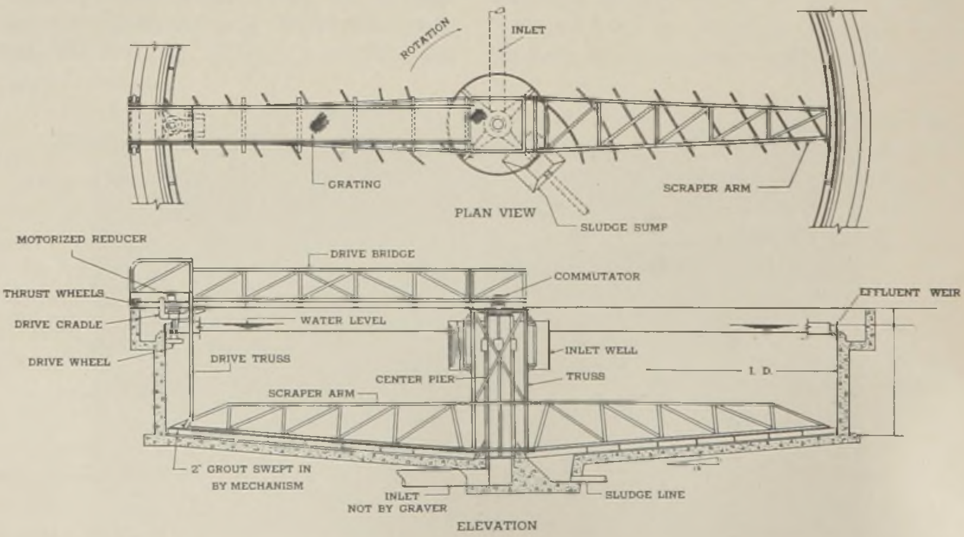


Fig. 1.—Graver Flexidrive Clarifier.

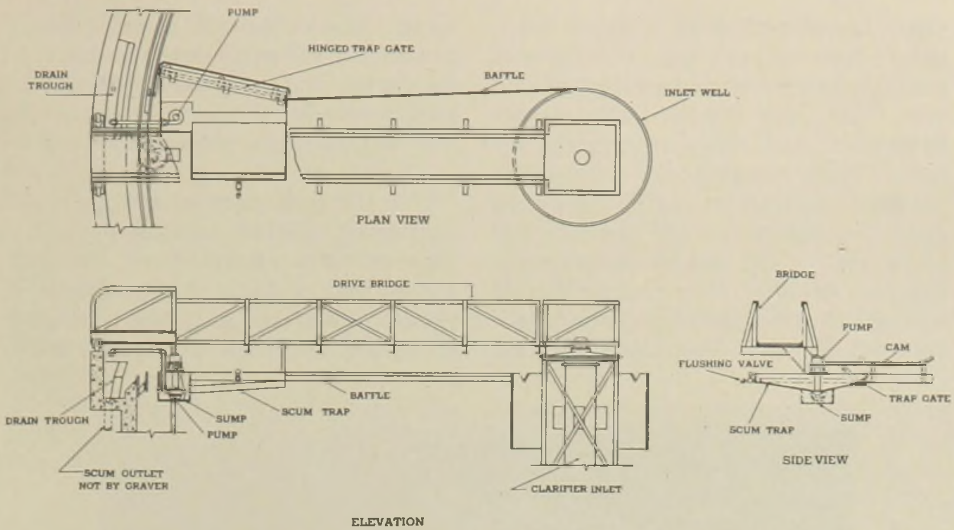


FIG. 2.—Automatic Skimmer for Graver Flexidrive Clarifier.

hinged connections so that the equipment can easily follow irregular contours in the tank construction, vertically as well as horizontally. The peripheral drive avoids the use of heavy high-reduction gears and operates with a low torque.

The basic principles of sludge collection used in the "Flexidrive" clarifier are the same as on all of our other designs. Scraper speeds are held to "streamline" velocities, rarely exceeding 7 to 10 ft. per minute in large units, and the sludge is brought to the central sump within the average retention time of the tank. Depending upon the size of the tank, retention time, and nature of the sediment, two, three, or four scraper arms can be used, although two arms are standard for normal sanitary sewage applications.

Coinciding with the design of the "Flexidrive," Graver developed a new automatic skimmer (Fig. 2).

Rather than scraping the scum into a trough or removing it mechanically, the scum is collected in a large shallow pan. At a fixed position a baffle is raised positively trapping all scum, and the contents of the collecting pan are transferred by means of a non-clogging pump into a scum trough, conveniently located inside the effluent launder or outside the tank. The entire scum removal device rotates with the drive bridge of the clarifier and a fixed cam actuates the mechanism once every revolution. A simple timing gear installed in the clarifier turntable assembly permits adjustment from once every revolution to once every twenty revolutions so that scum removal can be varied to suit the actual rate of formation.

INERTOL COMPANY, INC.

General Office and Factory: 470 Frelinghuysen Ave., Newark, N. J.

PROTECTING SEWAGE WORKS STRUCTURES IN WAR TIME

Corrosion and deterioration, traditional foes of sewage works engineers, to-day are saboteurs at work in every plant. For plants must run smoothly, often in spite of peak wartime loads and in spite of priorities, which means getting along with what equipment you have. The only solution is to protect your plant and equipment to the utmost. While formerly the painting of essential machinery and equipment could be deferred until the original protective coating was completely gone, it is now advisable to remember the old saying "A stitch in time saves nine." By touching up and repainting as soon as rust breaks through at more than 5 per cent of the surface, the necessity of taking the equipment out of service for sandblasting or similar time-consuming and costly surface preparations will be avoided.

For the protection of sewage works structures, the bituminous grades of INERTOL have always given outstanding service and are still available at pre-war quality and prices. In place of the colored Ramuc Enamels which

FIG. 1.—Activated Sludge Sewage Treatment Plant at Newark, N. Y. Designed by Glenn D. Holmes and Earl F. O'Brien, Syracuse, N. Y. Inertol Protective Coatings used on all concrete and steel structures.

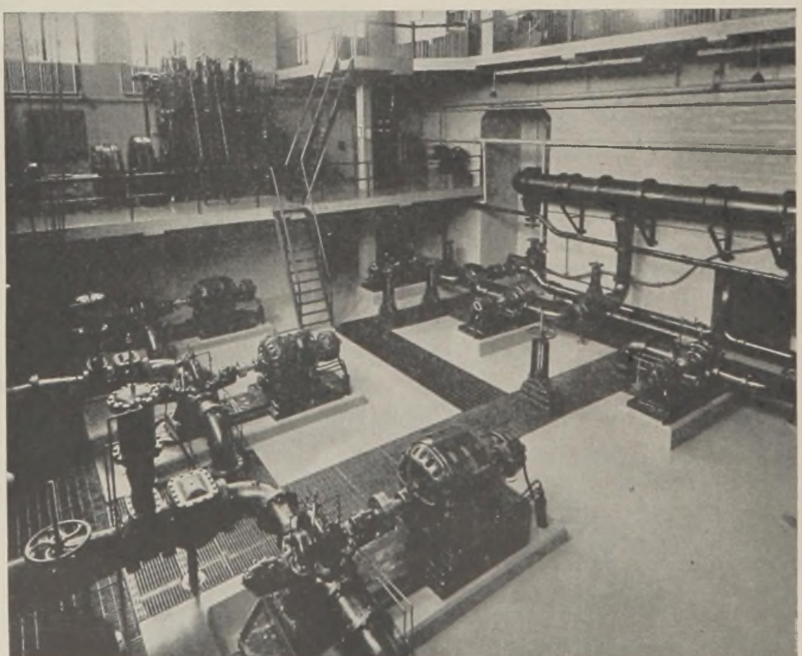


FIG. 2.—Mt. Clemens, Mich., Pumping Station. All pipes and pumps are protected with Inertol Standard. The floor of the Pumping Station is painted with Ramuc Enamel Gray No. 308.

were based on rubber and have "gone to war," INERTOL chemists developed substitute grades which are available in the same colors and are giving good service and complete satisfaction under all but the most severe conditions. These substitute enamels, based on domestic resins, are identified by the letters RE (standing for replacement) following the original trade marks. For purposes which may overtax the protective properties of these replacement grades, operators and plant superintendents are advised to sacrifice appearance to utility and call for INERTOL bituminous coatings.

By analyzing the particular problems of each customer and by keeping abreast of new developments, INERTOL chemists with their intimate knowledge of maintenance problems in sewage plants may be depended upon to furnish satisfactory coatings meeting the special requirements of sanitary engineers and sewage plant operators. INERTOL's consultive service is free and entails no obligation on the inquirer's part. For full particulars write to Service Department, Inertol Company, Inc., 470 Frelinghuysen Ave., Newark, New Jersey, or 64 South Park, San Francisco, California.

INFILCO, INC.

325 W. 25th Place, Chicago, Ill.

ACCELO-FILTERS, ACCELO BIOX PROCESS, ACTIVATORS, CLARIFIERS, SKIMMERS, ROTARY DISTRIBUTORS, AUTOMATIC DOSING SIPHONS, AUTOMATIC PROPORTIONERS, ACCELATORS, CHEMICAL FEEDERS, MIXERS, COAGULATORS, VENTURI TUBES AND CONTROLLERS

NEW DEVELOPMENTS

Activities directly related to the war effort have prevented the continuation of our normal development work. Some mechanical improvements have resulted from these war installations which will be available for post-war sewage treatment plants. The Accelo Biox Process described below is a new Infilco offering for high rate activated sludge treatment.

ACCELO BIOX PROCESS

The new Infilco Accelo Biox Process (accelerated bio-oxidation) for which patents are pending, is a high rate activated sludge process developed as the result of discoveries made by Mr. J. A. Logan at the Harvard Sanitary Engineering Laboratories.

Previously work had been done at these laboratories under the direction of Professor Gordon M. Fair directed toward obtaining more uniform utilization of oxygen throughout the aeration period of the activated sludge process. The fact that most of the B.O.D. reduction occurs in the first 30 to 60 minutes has long been known and has perhaps been responsible for numerous attempts to improve the efficiency of the process.

The development of the respirometer showed that an initial high rate of oxygen utilization corresponds with the peak B.O.D. reduction as related to the so-called "clarification period." Obviously increased efficiency would be accompanied by leveling and raising the oxygen utilization or respiration curve so as to secure uniform utilization of oxygen throughout the aeration basin. Attempts to straighten and level this respiration curve were made during 1938 under the direction of Professor Gordon M. Fair and were followed by the investigation of J. E.

McKee during 1940–41 which resulted in the development of a load distribution method.

Considering the problem in the light of this previous work it occurred to Mr. Logan that it could be possible to discover a better method of increasing the efficiency which might result in a new high rate activated sludge process. Several different methods were investigated. He found that direct recirculation resulted in raising and leveling the respiration curve; the degree of straightening being dependent on the recirculation ratio. He discovered that by direct recirculation of mixed liquor through the aeration tank, the load was forced farther back along the tank so as to create a tendency for those portions of the tank nearest the outlet to do as much work as those nearest the tank inlet. Moreover active aerobic organisms recycled in this manner were immediately available for additional pollute adsorption during the period required for reactivation of returned settled sludge from the final sedimentation tank.

A series of bottle experiments were made in four-liter flasks using detention periods of 1, 2, 3, 4, 5 and 6 hours with and without direct recirculation. To obtain simultaneous reactivation and to obtain full advantage of the "clarification period," it was decided to use one-hour passes for the tests involving recirculation. Results of these experiments were better than anticipated. The direct recirculation seemed to provide uniformly high B.O.D. reduction even at a detention period of one hour. The tests also indicated a tendency for the suspended solids in a particular flask operated at a given rate to become adjusted to the applied organic load. An increased organic load caused an immediate increase in the suspended solids content. Sludge autolysis followed such organic overload under normal loading conditions but the suspended solids content decreased slowly.

To avoid the general criticism of bottle experiments operated on the fill and draw basis, it was decided to revamp an existing pilot plant for continuous operation (Fig. 1). It was hoped that a series of pilot plant runs would serve to check the efficiency of direct recirculation at various detention periods and to verify or disprove theories developed by the excellent results obtained in the flask experiments.

Results of the pilot plant operation are summarized in the accompanying Table I. These results indicate increased biological oxidation efficiency; the results obtained by a 3-hour aeration period with a 1-hour pass being comparable to those obtained from the conventional activated sludge plant using 6 hours aeration.* The pilot plant operation also indicates that the activated sludge system may be employed to obtain B.O.D. reductions

* EDITOR'S NOTE: Note, however, that no controls of the "conventional" type were run for comparison with the results shown in Table 1.

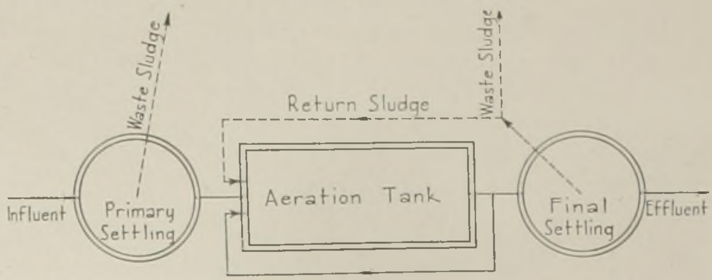


FIG. 1.—Accelo Biox (Accelerated Biological Oxidation). A High Rate Activated Sludge Process (Patent Pending).

ACCELO BIOX PROCESS

TABLE 1.—*Summary of Pilot Plant Results Averaged from the Daily Results*

Run No.	Suspended Solids		Sludge Index	5 Day 20° C. B.O.D.				% Reduction		
	P.p.m.	% Vol.		Raw Sewage	A*	B*	C*	A*	B*	C*
6	3135	81.4	185	169	28.0	19.9	11.9	82.4	87.0	92.9
5	2226	80.9	123	160	21.5	12.3	8.3	85.8	91.6	94.5
1	3837	—	139	167	—	22.8	13.0	—	85.2	92.1
4	1679	82.5	263	236	19.1	12.8	6.9	92.8	93.9	97.3
3	1722	79.5	86	127	26.7	14.1	8.1	71.8	89.4	92.9
2	1364	78.9	92	86	17.0	10.8	5.1	85.5	84.1	92.7

Run No. 6—1 hour detention, 30-minute passes.
" 5—2 hour detention, 60-minute passes.
" 1—2 hour detention, 60-minute passes.
(100 per cent sludge return)

Run No. 4—3 hour detention, 60-minute passes.
" 3—4 hour detention, 60-minute passes.
" 2—4 hour detention, 2-hour passes.

A*—60-minute settling in graduate.
B*—pilot plant effluent plus 30 minutes additional settling.
C*—pilot plant effluent filtered through coarse filter paper.

N.B. According to Imhoff (37) the overall B.O.D. reduction for an activated sludge plant varies from 85–95 per cent, including primary and final settling basins. The pilot plant runs do not include primary settling.

equivalent to those obtained from other types of treatment, using shorter aeration periods without the usual activated sludge plant upsets.

The Accelo Biox Process may be used with either diffused air or mechanical aeration (Fig. 2) at a substantial saving in initial investment and in addition a saving in power cost of operation.

FIG. 2.—Infilco Activators at St. Johns, Overland, Mo.

LAKESIDE ENGINEERING CORPORATION

222 W. Adams St., Chicago, Ill.

AERO-FILTERS

Unquestionably the high capacity filters now being used in sewage treatment plants are today attracting as much attention and discussion as any other method of sewage treatment. The Aero-filter, which makes use of low momentary rates of sewage application to the filter surface, has been in commercial use since 1936. Some of the plants have been quite successful while other installations, for one reason or another, have failed to produce high grade results. Experience with a large number of installations has quite definitely shown that the Aero-filter will give B.O.D. reductions on a par with standard trickling filters and that stable effluents can be produced when the plants are properly designed and operated.

Some of the factors which have heretofore caused inferior results are: Inadequate settling capacity, the use of filter stone of a size smaller than that recommended by the backers of the Aero-filter Process, improper design of the underdrain system to provide plenty of room for the passage of air, failure to keep the distributors in continuous operation, excessive quantities of oil in the sewage, filter loadings in excess of 2.5 lb. per cu. yd. of rock (maximum filter loadings of 2 lb. per cu. yd. of rock are recommended), and the use of single stage where two-stage filters should have been used. Multiple-stage treatment is recommended for sewages with a B.O.D. in excess of 250 p.p.m. where a high degree of purification is desired and in the case of sewage strengths in excess of 400 p.p.m. B.O.D.

Disc distributors for filters 34 ft. and less in diameter and multiple-arm distributors equipped with centrifugal type nozzles for larger filters are recommended. These provide a maximum of sewage aeration and a minimum rate of application per square foot of filter surface per minute, two features which are very essential for good operation.

Recirculation of the final effluent back to the filter during periods of low raw sewage flow should be provided and should be automatic in operation rather than hand controlled, in order to insure uninterrupted flow of the liquor to the filter surface. The recirculation should be in sufficient quantity to maintain a good spray on the filter at all times.

Filter loadings as high as 18,000 lb. per acre foot have been used with Aero-filters. The results from these plants show that with filter loadings up to 2 lb. per cu. yd. of rock the percentage removal by the filters remains constant while above the 2 lb. loading the percentage reduction of the B.O.D. by the filter rapidly declines.

Various publications dealing with the results produced by high capacity filters have shown the overall reduction of the B.O.D. without proper emphasis upon the efficiency of the primary clarifier or the loadings applied to the filter. In making comparisons of various types of trickling filters more emphasis should be placed upon the operation of the filter itself, for after all the loading applied to the filter versus the loading removed by the filter provides a real basis for making comparisons.

Some difficulty has been experienced by reason of matches clogging the 7/8 in. orifices of the distributor nozzles. The backers of the Aero-filter are now prepared to supply a nozzle with a different type of cap in which matches will not lodge. The elbow connection between the nozzle and the rotary arm heretofore used has now been dispensed with and the nozzle is directly connected to the arm by means of a union, thereby making it possible to rod the 1¼ in. throat without removing the nozzle, should an obstruction in the throat occur.

LAMOTTE CHEMICAL PRODUCTS COMPANY

Towson 4, Baltimore, Md.

LAMOTTE POMEROY SULFIDE TESTING SET

The LaMotte unit for sulfide studies of both liquids and gases fulfills a long felt need in routine operations. This unit may be used in determining the following: (1) total sulfides, (2) hydrogen sulfide, (3) dissolved sulfides, (4) hydrogen sulfide in air and gases.

Fig. 1.—LaMotte Pomeroy Sulfide Testing Set.

The apparatus has been designed for use in the field as well as in the laboratory and maintains the same high degree of accuracy in both instances. The development of the unit was carried out in cooperation with Dr. Richard Pomeroy and has been produced for the purpose of providing complete facilities for these studies. The LaMotte Pomeroy Sulfide Testing Outfit is furnished with or without the accessory kit, for studies in air and gases.

In the determination of hydrogen sulfide, an immediate analysis is of the utmost importance, and the ability of the operator to make the determination at the time of sampling cannot be over estimated. The entire procedure is simple and easy to perform.

LAMOTTE IMHOFF CONE SUPPORT (ALL METAL TYPE)

Another LaMotte development is the new "life-time" type of Imhoff Cone Support. It's design is based upon

Fig. 2.—LaMotte Imhoff Cone Support (All Metal Type).

the familiar laboratory tripod and it is of all metal construction except for the special fiber ring which prevents metal-to-glass contact. It is light, sturdy and much more easily kept in a sanitary condition than the usual wooden type of support. Another important factor is the fact that the calibrated part of the cone, when suspended from this new support, is readily visible from any angle of observation.

MICRO pH DETERMINATIONS

The new LaMotte Micro Hydrogen Ion Testing Set, Model B, is applicable for a wide field of useful pH studies. The essential feature, of course, rests with the fact that in conducting accurate pH tests with this model, less than 0.5 ml. of sample is required. The procedure is simple, accurate and extremely rapid. Samples may be highly colored or turbid and not interfere with the accuracy of the test, since the presence of such factors is compensated for in the improved LaMotte technic. A determination can be made in one minute or less.

FIG. 3.—Micro pH Outfit.

The standard unit is complete with buffer mixtures, calibrated glassware, LaMotte indicator solutions (range 5.2–8.4) special matched glass cells, sampling pipettes and the LaMotte Micro Comparator Rack. The pH range of the standard unit may be extended either on the alkaline or acid side by the simple addition of the necessary buffers and indicators. All items are furnished in a compact carrying case; hence, the unit may be conveniently set up at any desired location for a series of rapid pH studies.

LAMOTTE PHOSPHATE COMPARATOR. (BOILER FEED WATER)

LaMotte has improved the method for determining phosphates in treated feed water. The new comparator embodies several important features which contribute greatly to the convenience in performing the test. In the first place the comparator is much reduced in size over that of its predecessor, and is much easier to handle. In the second place only two reagents are involved, one of which is in tablet form, thereby eliminating at least two volumetric measurements, and adding greatly to the economy of the unit. The reagents will retain their sensitivity until entirely consumed.

FIG. 4.—LaMotte Phosphate Comparator (Boiler Feed Water).

The unit comes complete with color standards for the range 10 to 100 p.p.m. PO_4, comparator tubes, phosphate reagents A, and BC, one marked dilution tube, two measuring pipettes, and instructions.

LINK-BELT COMPANY

2045 W. Hunting Park Ave., Philadelphia 40, Pa.

IMPROVED GRIT WASHING

An improved design of baffles has been added to the highly efficient Link-Belt Grit Collector and Washer, to insure clean grit under any conditions of flow.

In the modern grit chamber, the mechanism employed has two objectives. The *first* is to collect the settled material and operate at such a speed as will keep most of the organic material in suspension so that it will be carried out of the chamber over the effluent weir. The *second* is to wash the collected grit free of putrescible and organic material and elevate the cleaned grit above the water level,

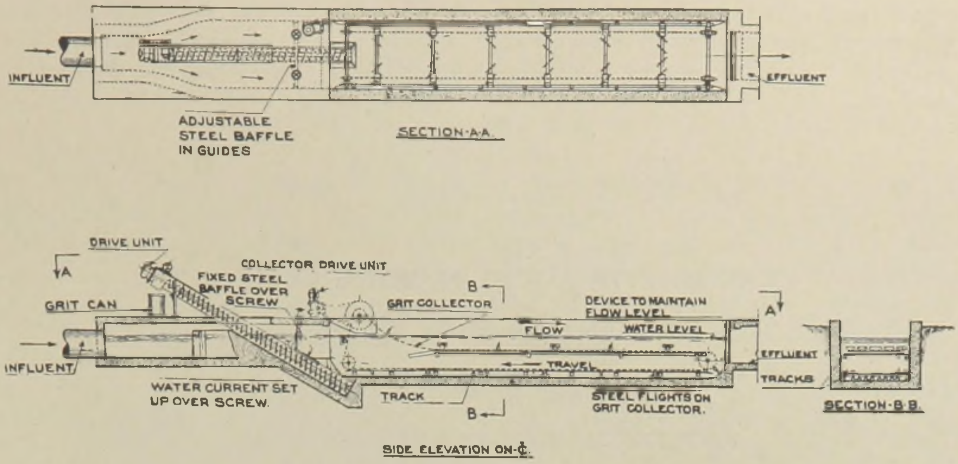


Fig. 1.—Plan and Elevation Drawing of Link-Belt Straightline Grit Collector and Washer, showing arrangement of collector mechanism and screw conveyor washer.

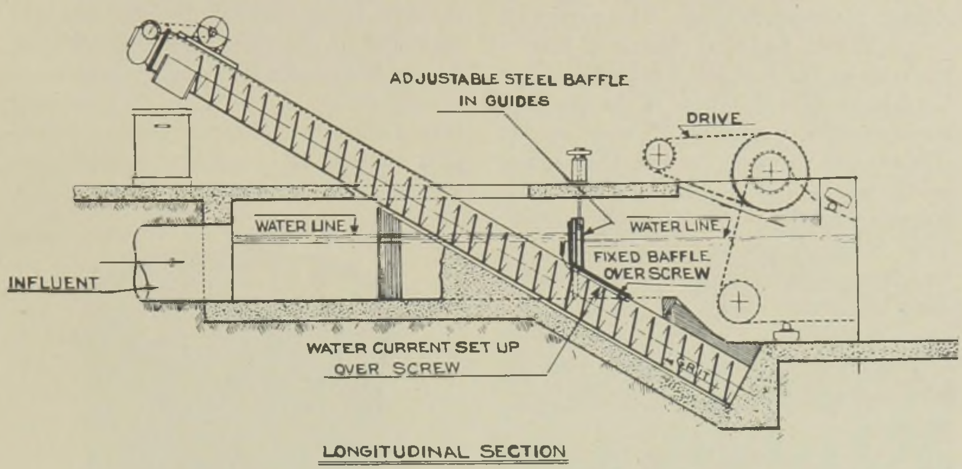


Fig. 2.—Longitudinal Section of Link-Belt Grit Collector and Washer.

where it is discharged to a suitable container.

The Link-Belt Straightline Grit Chamber mechanism was designed to perform these two functions efficiently. The grit collector is provided with pitched flights that turn the settled material over and over while moving it to one side or to the center of chamber, where it is picked up by the washing and dewatering screw. The screw elevates the grit as it is being washed and dewatered.

It was to insure the effective sweeping back into the flow, of all organic and putrescible matter washed out by the screw, that the adjustable and fixed baffles shown in the two illustrations (Figs. 1 and 2) were designed.

To obtain the best results under normal flow conditions, grit should be removed at periods of average flow. The adjustable baffle can be regulated to divert sufficient sewage over the dewatering screw to definitely control the quality of grit being removed.

In several plants where these baffles have been installed and operated for some time, the putrescible matter in the washed grit has averaged less than 1 per cent. No wash water is required; only the sewage is used as a washing medium.

These baffles are particularly effective in plants where the extreme low night flows cause excessive settling of organic matter in the grit chamber.

MABBS HYDRAULIC PACKING COMPANY

431 South Dearborn St., Chicago, Ill.

THE MABBS RAWHIDE PACKING

PACKING SLUDGE AND SEWAGE PUMPS

The packing of sewage and sludge pumps presents quite a problem to the sewage plant operators. The nature of the material handled requires that a packing be used which does not become hard in service; because if the packing hardens, the particles of grit in the sludge and sewage imbed themselves on the surface of the packing and thus become implements of destruction. They begin to cut and score the shafts and in a short time the operator has to shut the pump down to renew or replace the shaft. This takes time, labor and expense, and is something that the owner can ill afford under present conditions.

There is a packing on the market that through many years of actual service has proved itself to be a really desirable packing for sewage purposes, namely, the Mabbs Rawhide Packing. This packing, if kept wet or damp, will never harden in service. It will always remain soft and will not hold any particles of grit upon its surface. They are either washed away or work back into the body of the packing, thus preventing the shafts from becoming cut or scored.

A brief description of how this packing is made will quickly reveal why Mabbs Rawhide Packing does not harden in service. The packing is made of raw cowhides which are cured by a mechanical process which permits the hide to retain its natural oils and makes it very soft, pliable and durable. The hide is dressed down to the correct thickness, cut into strips and braided into a square packing, with the exception that sizes ¼ in. and smaller are made of one solid strip.

Rawhide packing needs no lubrication, except water, and when it is wet it's as slippery as an eel and practionally frictionless. It is the ideal packing for sludge and sewage pumps.

The Mabbs Hydraulic Packing Company, Chicago, originators of Rawhide Packing, will be pleased to furnish literature and samples free of charge.

MUELLER CO.

Decatur, Illinois

PLUMBING, WATER AND GAS PRODUCTS

A most important item in the sewage plant is the sluice gate that controls the flow (Fig. 1). These come with flat or spigot frame, the first being bolted onto the wall and the latter having a spigot that projects back into the wall. It is absolutely imperative that in the installation these frames be free from distortion or undue strain. Any improper mounting of the frame to the wall thimbles or the concrete will spring the seat out of line. This, without doubt, will cause the gate to leak, or create further difficulty in opening and closing the gate. To correctly install a sluice gate all wall thimbles and anchor bolts to be imbedded in concrete should be placed before the concrete is poured and be so braced that they will remain in perfect position until after the concrete has set. The gate should be completely assembled at the time of installation so as to make certain that the frame will not be sprung when bolting to the wall and thereby throw the gate seat out of line.

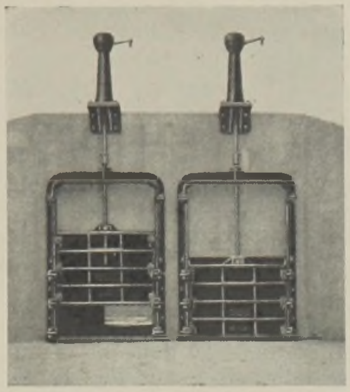


Fig. 1.—Mueller-Columbian Sluice Gates with Non-rising Stem and Adjustable Wedges. Connected to hand operated floor stands by short extension stems.

Numerous plants require gate valves in the control of sewage. Here, as with sluice gates, it means long term economy to secure the best valves available. Due to the fact that the mechanism is fully enclosed there is less likelihood of incorrect setting of a gate valve. The inner working parts, however, are vital to the proper operation of the valve. When a valve fails to close properly, the trouble can be traced to several causes. The discs have become sprung, or improper seating has caused the discs to scrape over the seat rings, or incrustation has formed on the discs. Any of these things can cause a valve to leak badly in time, requiring its replacement eventually. Mueller-Columbian gate valves have a unique 4-point wedging mechanism which applies pressure at the outer edges of the discs. It is so constructed that the discs cannot scrape over the seats. Likewise, precise clearances are arranged for so that in opening the gate all incrustations are neatly sheared off without damage to the seats or the discs. If servicing is ever necessary the entire mechanism can be removed in one piece by taking off the bonnet.

Too much stress cannot be placed upon the proper setting of all floor stands if equipment is to last many years. Any twisting, distortion, or incorrect alignment is certain to interfere with the smooth operation of gates and valves. In many cases the stem will not be long enough to reach the floor stand and extension stems must be added to them. It is good practice to have an adequate number of stem guides as no stem should have an unsupported length greater than ten to twelve feet. Stem guides can be had plain but preferably should be bronze bushed for greater life.

The matter of what type of floor stand to use depends upon individual conditions, but in any case the stand should be the kind that can be oiled or serviced readily and be operated with a minimum of effort. Mueller-Columbian makes manually operated floor stands of every type. For remote control they make electric and hydraulic stands (Fig. 2). The hydraulic model can be mounted directly on the yoke of the valve or installed above it by using an extension stem.

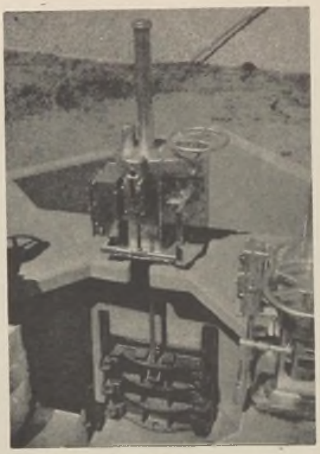


Fig. 2.—Mueller-Columbian Sluice Gate with Rising Stem Operated by Electric Floor Stand. Note hand wheel for operation of gate in the event of a power failure.

If you are looking to the future in your plans do not forget that ordinary iron parts are subject to wear and chemical action. It is essential that those parts subject to constant use should be of bronze. All Mueller-Columbian equipment has more than the usual amount of bronze. But even such small things as rustproof cadmium-plated bolts do not make up the whole picture, important as they are. The reputation of the firm behind the products you use should be considered. This is your real assurance of dependable performance over long periods. The Mueller Co. was founded in 1857. Eighty-six years of working in the water and sewage field has resulted in a vast store of knowledge on what is best under various conditions. This firm offers the services of their engineering department for suggestions, specifications, or estimates. There is no charge, of course, for these services.

PACIFIC FLUSH–TANK COMPANY

4241 Ravenswood Ave., Chicago, Ill.

SEWERAGE TREATMENT AND SEWAGE EQUIPMENT EXCLUSIVELY SINCE 1893

THE P.F.T. SUPERNATANT LIQUOR TREATER

Despite the exercising of care by plant operators to draw off only the best supernatant liquor, it is still extremely high in solids, large in volume, and it imposes an extremely heavy B.O.D. load on the portion of the plant to which it is returned.

The upsetting effect of returning untreated supernatant liquor eventually creates a condition where a bulkier sludge is being transferred from settling units to the digester. This necessitates the return of still greater volumes of supernatant liquor, thus developing a self-pyramiding cycle of trouble.

Disposal of untreated supernatant liquor on sludge drying beds has not proved to be feasible as the sand layer rapidly becomes clogged and odors develop from uncompletely digested material entrained in the sand.

As sufficient stream flow is rarely available to permit disposal of supernatant liquor by dilution, it is obviously desirable to subject the liquor to a degree of treatment which will allow its return to the main plant without harmful effect on the over-all process.

Full-scale operating units already installed have demonstrated that the P.F.T. "Atomizing" Aeration-Settling unit effects striking reductions in both the B.O.D. and suspended solids content of digester supernatant liquor. Solids removed are returned in greatly reduced volume to the digester, and the liquid effluent, containing appreciable amounts of dissolved oxygen, is reduced to a strength comparable to that of a normal raw sewage, which will not upset sedimentation and secondary treatment processes. Furthermore a reduction of volume of material in the digester is effected, providing additional space for raw solids, thereby increasing the effective capacity of digestion units.

Figure 1 shows a typical plan and section for a P.F.T. Supernatant Treater installation at Marietta, Georgia, to treat supernatant from two 50 ft. diameter digesters.

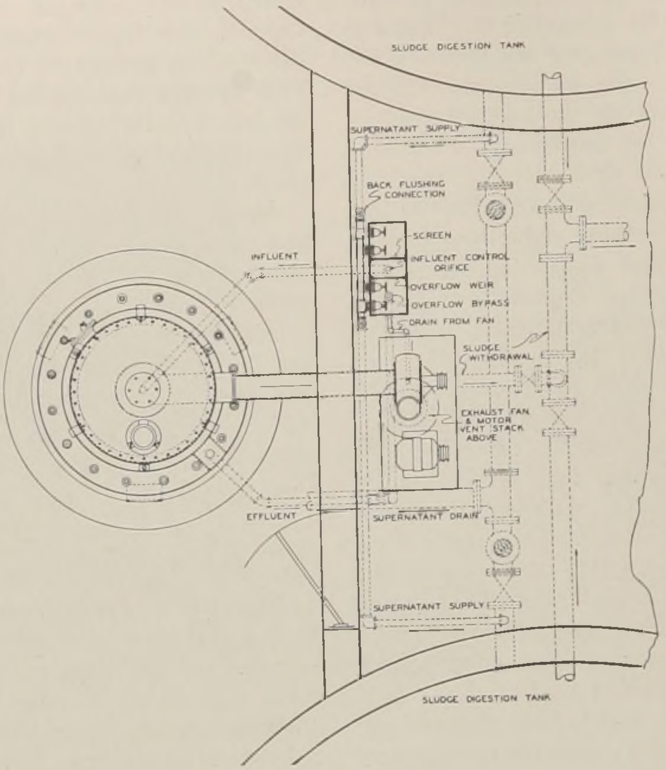
Briefly the action of the unit is as follows: The fan exhausts air from the aerator box setting up a vacuum of about 3 in. water column within the box. The only source of air for the fan is the open end of the tubes or "tuyeres" in the lower plate of the aerator box. Air rushing through them draws supernatant liquor up with it, giving the appearance of a miniature water spout under the center of each operating tuyere. On reaching the top of the tuyeres, the liquor breaks up into a spray of finely divided particles in intimate contact with the entering air. Separation of the aerated liquor particles and the air takes place within the box, the liquor discharges through the central bottom outlet, and the air is drawn off through the take-off duct and fan. After being subjected to the blasting action of the tuyeres, the liquor passes down into the settling portion of the main tank, then upward through the effluent take-off cups into the effluent trough, thence through a return line to the main plant.

As the aeration box circulates liquid at a much greater rate of flow than the influent rate of flow, the raw liquor is given several "turnovers" or aeration cycles in the process. Settled solids are drawn from the sludge hopper of the tank at intervals, the frequency and duration of drawoff periods being dependent upon the solids content of the raw liquor.

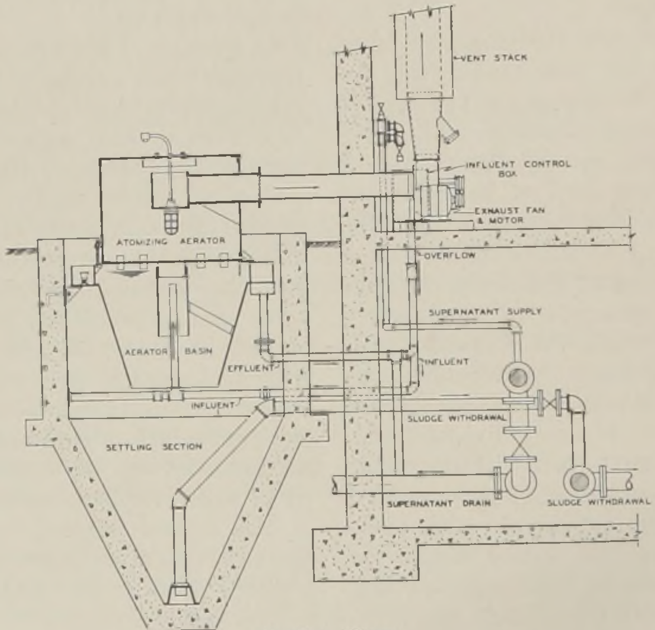
Due to the compact nature of the unit, very little space is required, even for the larger plants. The availability of a series of standard units adapted to various digester capacities permits selection of the proper size of treatment unit to allow daily handling of the supernatant liquor with only 6 to 8 hours of operation. Liquor is withdrawn from the digester at a low constant rate during the period of operation of the unit.

In the case of multiple digesters, one treatment unit can serve 2 or 3 digesters by operating at 24 hours per day and withdrawing supernatant liquor from the digesters on a staggered basis.

Typical results obtained from this method of treatment of digester supernatant liquor at an army camp installation are recorded in Table I, and results from a municipal plant are recorded in Table II. As there were wide variations in strength of the raw liquor, per cent reduction figures are not particularly significant. Of interest, however, are the striking uniformity of values for both solids and B.O.D. in the treated effluent, regardless of the raw liquor strength, and the reductions down to the B.O.D. and suspended solids strength of raw sewage. The presence of dissolved oxygen in



Plan View.



Section View.

Fig. 1.—P.F.T. Supernatant Treater.

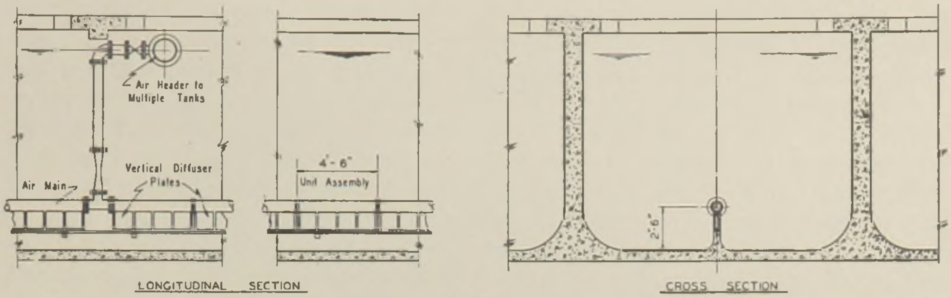
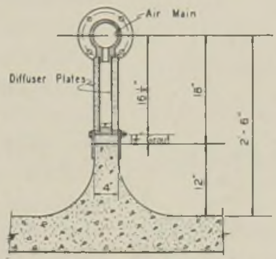


Fig-2

RFT COMBINATION AIR MAIN AND VERTICAL AERATION PLATE HOLDER



PFT AERATOR PLATE HOLDER INSTALLATION DETAILS

TABLE I.—*Aeration Period, 10 Min.; Settling Period, 45 Min.*

No. of Turnovers	Total Solids			Suspended Solids			5 Day B.O.D.			Effl. D.O. in P.p.m.
	Infl.	Effl.	% Red.	Infl.	Effl.	% Red.	Infl.	Effl.	% Red.	
4.0	13212	976	92.5	—	—	—	1500	255	83.0	—
3.7	1840	1140	38.0	912	412	55.0	205	115	44.0	1.0
3.7	3064	1240	60.0	2216	148	93.5	373	115	69.2	—
3.7	1328	1180	11.2	480	353	26.5	202	110	45.6	1.6
3.7	2932	1182	59.7	1968	425	78.4	400	170	57.5	1.6
3.7	3282	1260	61.6	2208	445	79.9	318	120	62.3	1.6
2.8	1410	1132	19.7	440	336	23.7	173	140	19.1	1.0
2.8	2436	1144	53.0	1656	384	76.8	345	95	72.5	2.0
2.8	1320	1132	14.3	472	400	15.3	198	178	10.1	1.3

TABLE II

Aeration Period Minutes	No. of Turnovers	Settling Period Hours	Suspended Solids			5 Day B.O.D.		
			Infl. P.p.m.	Effl. P.p.m.	% Red.	Infl. P.p.m.	Effl. P.p.m.	% Red.
18	5.8	1.1	6192	200	96.8	1539	204	86.5
20	5.8	1.1	4212	204	95.0	1185	183	84.5
24	7.5	1.1	1804	182	89.8	672	169	74.7
36	11.2	1.1	2816	201	92.7	873	187	78.5

the effluent is important from the standpoint of its benefit in the main plant process of treatment.

Advantages inherent in the P.F.T. "Atomizing" Aeration-Settling unit for treatment of digester supernatant liquor are: (1) Produces a treated effluent which may be returned to the main plant without causing operating difficulties; (2) simplicity of operation and maintenance; (3) extremely low operating cost; (4) increases effective capacity of digestion tanks by making possible reduction of liquor contents of digester, allowing more space for sludge additions; (5) no chemicals required; (6) no odor nuisance.

P.F.T. VERTICAL AERATION PLATE HOLDERS

P.F.T. vertical aeration plate holder assemblies located along the longitudinal center line of activated sludge aeration tanks provide effective air distribution and eliminate the "dead core" often found in spiral flow aeration tanks.

The design of these units has been adapted from the installations made by Wm. M. Piatt of Durham, North Carolina. These installations, using vertical porous plates of low permeability for efficiency of air diffusion, have reported no difficulties with plate clogging.

The P.F.T. vertical aeration plate holders in combination with an integrally cast air main are made in unit sections for 8 standard porous plates. These plates are installed in the holders in a vertical position, 4 on each side of the air main, which is located above and between the two rows of plates. Each section is provided with flanged end connections requiring only simple assembly to install the complete air distribution system.

A typical installation of P.F.T. vertical plate holders as shown in Figure 2 will consist of one or more relatively long narrow tanks of such dimensions that the width of the tank does not exceed about 125 per cent of the effective water depth. A row of P.F.T. vertical plate holders and integral air main assemblies is placed on the longitudinal center line of the tank adjacent to the tank floor. A single connection to the P.F.T. air main assemblies will be made near the inlet end of the aeration tank. The size of the integral air main will be dependent upon the length of the tank and the volume of air to be handled. At present the unit sections are available with either 4 or 6 in. main. Two installations are successfully operating incorporating aeration tanks 200 ft. long with 4 in. air main units supplied by a single header connection.

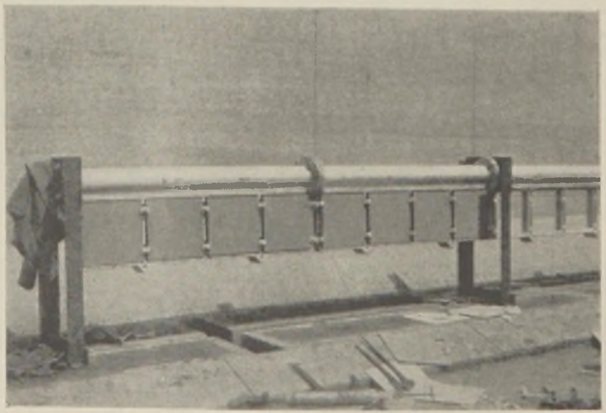


FIG. 2.—Test Installation P.F.T. Aeration Plate Holders at Southwest Plant, Sanitary District of Chicago.

Fig. 3.—Installation of P.F.T. Aeration Plate Holder in Aeration Tank.

The porous plates of standard 12 in. square size are easily removable, being secured in place by through bolts and clips. The seal between the aeration plate and the holder may be made either with a mastic compound or a suitable gasket. This removable plate feature allows an easy installation of new plates or the removal of clogged or broken plates either for special cleaning or replacement.

The porous plates in a vertical position insure uniform air distribution throughout the full length of the tank regardless of rate of air flow. Slight discrepancies in the elevation of the plates will have little effect on the rate of air discharge of the individual vertical plates. An increase or decrease in rate of air flow will automatically cause more or less of the plate to become fully effective in air diffusion. The plates being in a vertical position and slightly off the floor of the aeration tank eliminates the possibility of solids settling on the surface of the plates either at times when the air is off due to power or mechanical failure or at times when tank may be dewatered. Actual operating experience has shown that there are no "blind spots" or "dead plates" when starting up after the air has been shut off or when tanks are put back into service after dewatering.

Some advantages of P.F.T. vertical plate holders are: (1) Uniform and effective air distribution throughout tank length regardless of variation in air flow; (2) simple installation due to integral air main construction; (3) plates readily removable; (4) plates being off the floor and in vertical position allows no settlement on plate surface, thereby reducing clogging and "blinding" difficulties.

PITTSBURGH EQUITABLE METER CO.

Pittsburgh, Pa.

He Stubbed His Toe on an Idea Worth Millions!

Queer, how some industries get started. A young mining engineer stumbled over a leaky plug cock and it led to sales of millions of dollars worth of lubricated plug valves. Sven J. Nordstrom, a mechanical engineer, was directing the erection of a mill in the Pueblo of Pachuca, Hidalco, Mexico, back in 1914. At the plant were several tanks for agitating ground ore

FIG. 1.—Gear-operated EMCO-Nordstrom Valves handling concentrated sewage sludge.

in cyanide solution. Mr. Nordstrom stubbed his toe on one of the plug cocks; then noted the valve was leaking. He couldn't turn it. It was frozen tight. "Why," mused Nordstrom, "couldn't a plug cock be made workable by applying some sort of lubricant with hydraulic means whereby pressure would raise the plug sufficiently to loosen it?"

He pondered. Finally he hit upon the idea of a pressure lubricated plug cock. He conceived the Nordstrom Valve.

Now manufactured by the Merco Nordstrom Valve Company, a subsidiary of the Pittsburgh Equitable Meter Company, and distributed through their nation-wide facilities, the Nordstrom Valve is meeting with the increasing acceptance of waterworks and sanitary engineers (Figs. 1 and 2).

Company spokesmen say that basically this valve is of the simple plug cock type, the history of which dates back to the days of the Pharaohs. Comprised essentially of a tapered plug and body, Nordstroms utilize a primary dynamic principle—that of turning a member within a closed chamber. But in the Nordstrom design, the plug is lubricant-sealed under pressure. A mere turn of the lubricant screw on the top of the valve distributes the lubricant to all internal surfaces through grooves in the body and plug.

It is stated that this lubricant serves a triple function. First, it provides a plastic, viscous seal between the plug and the seat, preventing leakage. Sec-

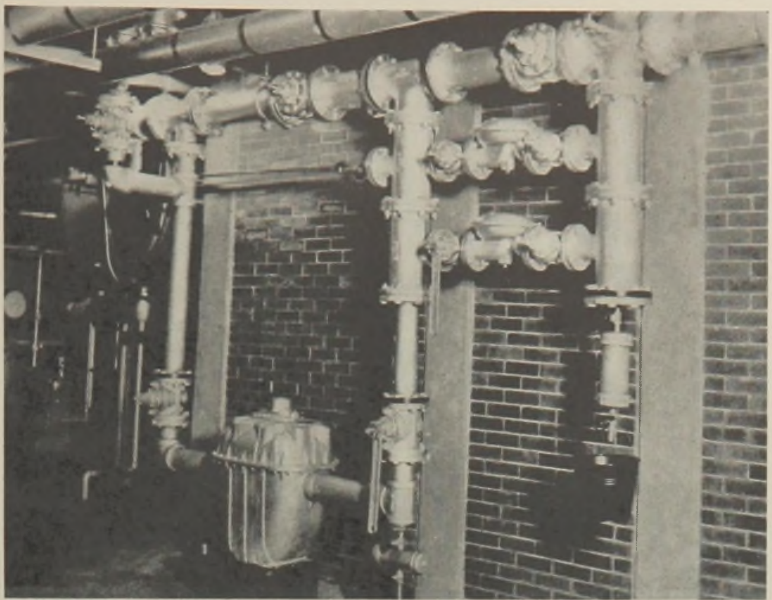


FIG. 2.—Gas generated is measured by an EMCO Sewage Gas Meter, lines are controlled with Nordstrom valves.

ond, it protects the surfaces against corrosion and erosion, channeling and other wear-producing hazards. Third, it provides a method for hydraulically jacking the plug free in the event of sticking.

The manufacturers are particularly proud of the accomplishments of this valve in helping to produce vital material for war. Practically every new plant in America engaged in synthesis processes is said to be utilizing Nordstrom Valves. Special alloys and hard facing of contact surfaces have provided hitherto undreamed-of applications. One hundred octane aviation gasoline, butadiene, nitrated glycerine and cellulose for explosives, synthetic rubber—all are being manufactured with the help of these control mediums.

Nordstrom Valves are made in a complete range of sizes from ½ in. through 30 inches. Of especial interest to the sanitation field are the 3-way and 4-way multiport types where it is said that one Nordstrom can often do the work of two, three or even four conventional valves according to the arrangement of flow-ways, ports and degrees of turn.

ROYER FOUNDRY AND MACHINE CO.

176 Pringle St., Kingston, Pa.

ROYER SLUDGE DISINTEGRATOR GOES ON WAR BASIS

Changing machine construction to meet war-time conditions is exemplified in the Royer Sludge Disintegrator, which is being used more extensively than ever this year to convert sewage sludge cake into fertilizer.

The two illustrations show the Model "NSO" portable gasoline Royer, an engine driven unit with a capacity of 5 to 8 cu. yd. of sludge per hour. Fig. 1 shows this machine before it was put on a war-time basis; and the other

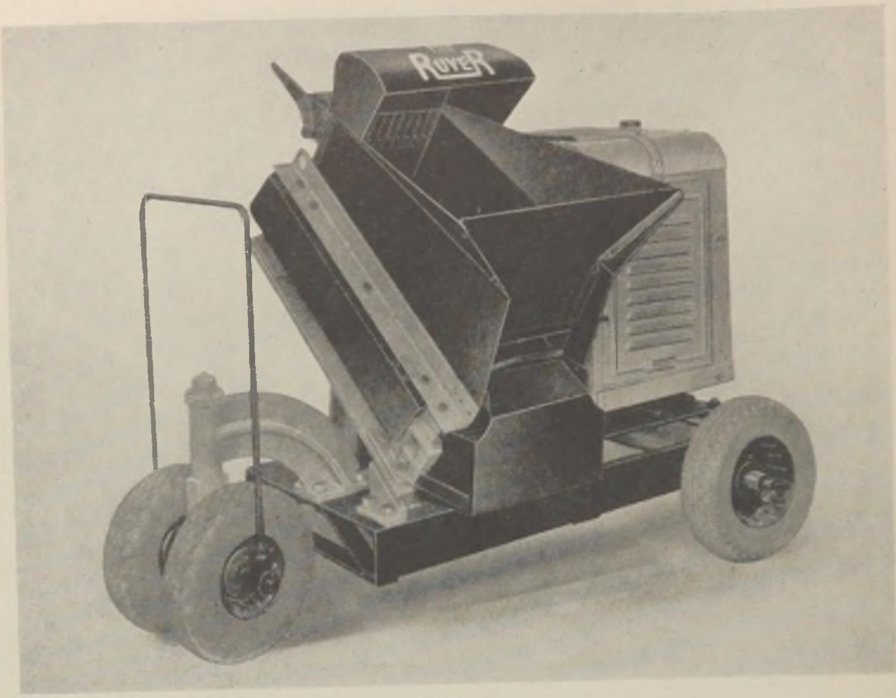


Fig. 1.

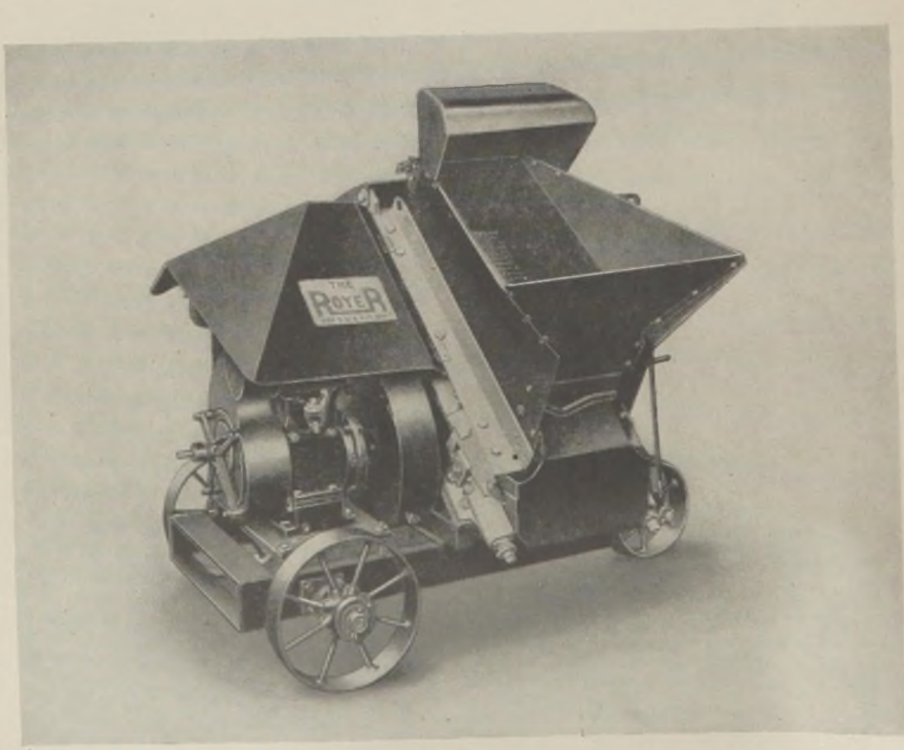


Fig. 2.

(Fig. 2) with alterations. Rubber tires have given place to steel wheels, which will be used on all Royer models until rubber tires again are available. Constructional changes have been made for the purpose of conserving critical metals and reducing weight, without any sacrifice of ruggedness or operating efficiency. One of these changes is noticeable in the illustrations. The metal cabinet over the engine has been replaced by a hood, which is so designed that dust and loose material will not fall on the engine. Similar changes have been made in all the twelve Royer portable and stationary models.

The Royer Sludge Disintegrator is helping an ever-increasing number of sewage disposal plants to play an important, though little publicized, role in the war effort. A sewage plant cannot manufacture guns, planes and tanks; but it can produce valuable fertilizer, which is needed just as urgently. The call for increased food production necessitates more fertilizer. With certain pre-war sources of fertilizing material cut off, it is imperative that every possible source of fertilizer be utilized to the utmost.

Sewage sludge is comparatively rich in nitrogen, with smaller quantities of other plant foods. Digested or activated sludges not only contain nitrogen, but phosphoric acid and potash as well, surpassing in fertilizing value most animal manures. While the elements for increasing all food crops are present, the sludge cake as it comes from the drying beds is hardly in condition for general use as a fertilizer, although it may be marketable to a limited extent. The sludge must be properly prepared in an assimilable form before its fertilizing values can be realized. It was for this purpose that the compact, rugged, easily operated machine known as the Royer Sludge Disintegrator was developed.

The operating mechanism of the Royer consists of an endless belt of tough, resilient composition, upon which are mounted rows of steel teeth or sprigs to accomplish the thorough shredding, mixing and aerating of the sludge cake. The belt travels at an angle of 45 degrees, and the teeth are so shaped and the rows so spaced that caked, lumpy and matted material does not become impaled, but cascades and rolls over and over on the rapidly moving teeth, where it is reduced to pea size. The moisture content of the sludge is also reduced. Sticks, stones and trash gravitate to the bottom of the belt, where they are retained by a gate which is opened from time to time to remove this trash.

The disintegrated sludge is carried up to the discharge opening, where it is ejected in such a manner that all particles fall clear of the machine. The arc of fall can be regulated so that the discharged material is loaded directly onto truck or pile.

This material is an effective fertilizer, suitable for commercial food crops or Victory gardens. In the latter, it has compensated to a large degree for lack of experience on the part of many gardeners. At a number of sewage plants, enrichening chemicals, such as ammonium sulphate, phosphate or lime dust are mixed with the sludge in the Royer to produce a high strength fertilizer. Sewage disposal plants report that fertilizer prepared with this machine is readily marketable. Some of them put it up in bags and sell it under various trade names. Any seasonal surplus finds use in the city parks.

Operation of the Royer is extremely simple. The operator turns on the power, which may be electric motor, gasoline engine or belt-to-tractor, and shovels the sludge from the drying beds into the hopper, which is located at a convenient shoveling height. Twelve models of varying capacity are available. The machine is designed and built to assure minimum maintenance expense as well as low operating cost.

The number of Royers in service recently passed the 5,000 mark. With this machine, many sewage disposal plants which formerly burned or buried their sludge have eliminated this expense and are now selling the sludge at a substantial profit, and at the same time are helping to increase the nation's food production.

A recent bulletin, "Profits from Sewage Sludge," will be mailed on request by the Royer Foundry and Machine Company, Kingston, Pa.

W. A. TAYLOR & COMPANY

York Road & Stevenson Lane, Baltimore 4, Md.

SPECIALISTS IN COLORIMETRIC CONTROL EQUIPMENT
pH—CHLORINE—PHOSPHATES—WATER ANALYSIS

TAYLOR BOILER WATER COMPARATOR

Prevention of corrosion and scale formation in boilers is of the utmost importance at this time. The Taylor Boiler Water Comparator is designed to accomplish this by control of pH and phosphates. It consists of a High (5–100 p.p.m.) or Low (0–25 p.p.m.) Phosphate Comparator, 3 pH color standard slides, cresol red, phthalein red, acyl red (pH 7.2–11.6) and all accessories necessary for making both tests. All slides work on the same base. Each slide contains nine standards. Determinations are made by moving the slide in front of the test sample until a color match is obtained and reading the pH or phosphate content directly from the values engraved on the slide. Either Phosphate Comparator can be obtained separately.

TAYLOR MIDGET DALITE LAMP

Difficulty is often experienced in making colorimetric determinations at night and in dark places. This Taylor Lamp gives uniform daylight conditions and thus is also ideal for routine testing even in daylight. It works on any 110-V circuit and can be used with any Taylor Comparators. The Comparator sits in front of a dalite glass at such an angle that readings can readily be made by the operator.

TAYLOR WATER ANALYZERS

Designed for the determination of ammonia, nitrates, nitrites, chlorine, iron, manganese, silica, etc. It is rugged in construction and introduces a new simplicity in methods of water analysis. Eliminates the handling of cumbersome, fragile and expensive Nessler tube standards as all standards are enclosed in plastic slides on which the various values are engraved in white. This outfit works on the same principle as the pH and phosphate comparators.

TAYLOR-ENSLOW SLIDE CHLORIMETER

Consists of a base and slide, 3 molded Pyrex cells and 2 vials of orthotolidine with 0.5 c.c. pipettes. Either of 2

slides can be supplied, 0.0–1.0 or 0.0–3.0 p.p.m. Taylor Super Chlorimeter, with range of 0.2–8.0 p.p.m. is similar in operation except that 5 c.c. test tubes are used instead of molded Pyrex cells.

UNITED STATES PIPE AND FOUNDRY COMPANY

General Offices: Burlington, N. J.

CAST IRON PIPE FOR SEWERS

The use of cast iron pipe for sewers is steadily increasing throughout the country. Many new sewage treatment plants are being built, some in conjunction with a new sewer system and others to augment an already existing system. Furthermore, major revisions are being made in large numbers of existing treatment plants, not only to increase their capacity but to provide more complete treatment that will produce an effluent of better quality. Treatment costs money; the amount of money is almost directly proportional to the volume treated. Logically, therefore, every gallon of water that seeps into the mains through leaky joints, cracked pipe or from other sources not only crowds the sewer but costs good money to convey it through the various treatment stages.

Cast iron pipe possesses three outstanding properties that are most important for present day sewer construction:

1. Tight pressure type joints that prevent infiltration, thereby reducing treatment costs and incidentally eliminating trouble with tree roots.
2. Compressive strength to resist heavy earth loads due to deep fills over the pipe. Beam strength to withstand stresses caused by earth movement. Bursting strength to resist internal pressure when used as a force main or when pressure might temporarily occur due to floods.
3. Long life that has been proven by years of satisfactory service, consequently permitting a low annual amortization charge on the original investment.

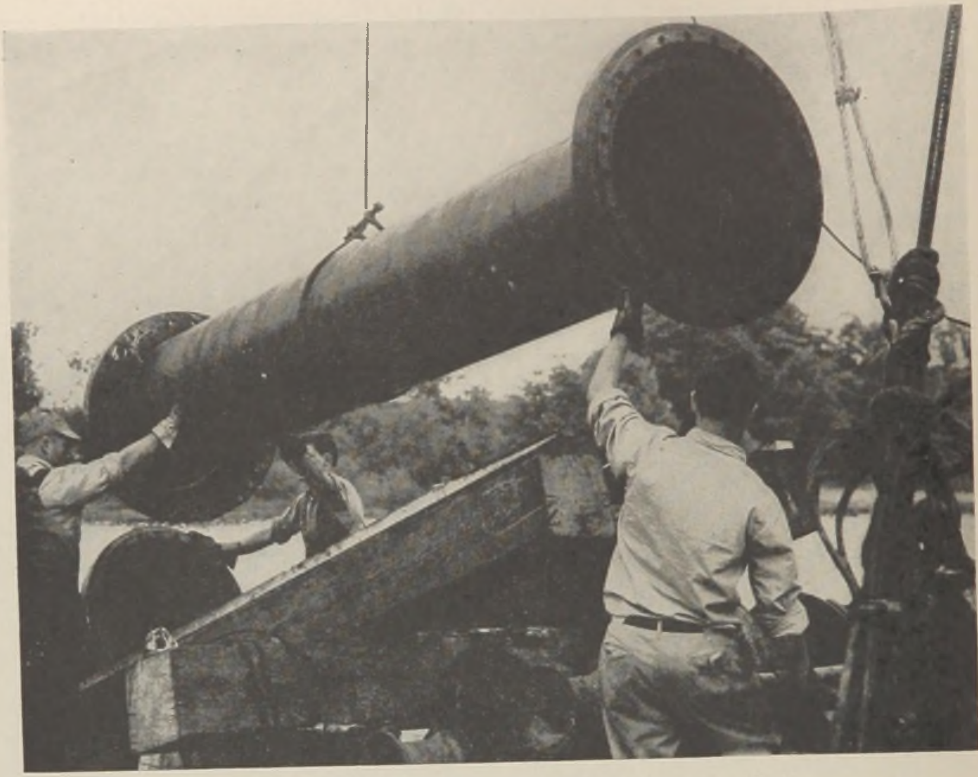
There are many instances in various parts of the country where cast iron pipe has been installed in sewage disposal systems for flow mains, force mains, stream crossings, outfall sewers and in treatment plants.

Cast iron flow lines are generally installed where the pipe are laid in water saturated soil to eliminate troublesome and costly infiltration.

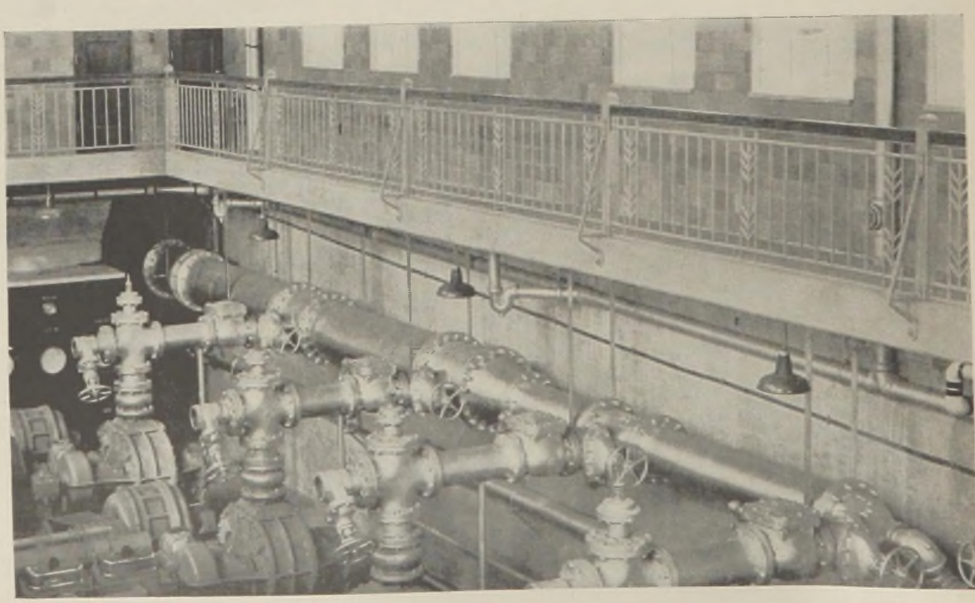
Cast iron force mains are being installed at a steadily increasing rate due to the growing demand for sewage treatment. Treatment plants are usually located some distance away from the more densely populated sections of a community. Frequently, it is not possible to have gravity flow to the plant. In those cases the sewage flows into a sump and is then pumped through a force main to the treatment plant. Illustrated here is a cast iron flexible joint force main being laid on the bottom of a river.

Cast iron outfall sewers have been widely and satisfactorily used to convey sewage, in most cases treated and in some cases untreated, out into a body of water for final disposal.

Cast iron pipe and fittings are used extensively to transport the sewage through the various treatment stages. One of the illustrations shows these products installed in a recently completed sewage treatment plant.



20 in. Usiflex Joint Pipe for sewer force main across river.



Cast iron pipe and fittings installed in a sewage treatment plant.

THE VAPOR RECOVERY SYSTEMS COMPANY

2820 North Alameda St., Compton, California

CONSULTANTS, DESIGNERS, AND MANUFACTURERS OF GAS CONTROL AND TANK EQUIPMENT

Sewage disposal units today incorporate operating gas control refinements comparable to the most highly specialized process plant installations in the world. With many years experience in the gas control and safety equipment manufacture, The Vapor Recovery Systems Company has developed a line of gas control safety devices for sewage treatment plants that embody the latest engineering designs in this field (Fig. 1).

In the Multiple Digester Gas System, "Varec" approved Pressure Relief and Vacuum Breaker Valve with Flame Arrester is installed on the digesters and gas storage tanks to maintain system operating pressure and to protect the vessels in case of fire from without. Being constructed of aluminum throughout, they are noncorrosive, easily inspected, and maintained.

"Varec" approved Flame Traps are installed throughout wherever there is a possibility of fire inside the plant piping. These units are made of corrosion resisting aluminum and afford a positive flame stop. All "Varec" Flame Arresters are approved by the Underwriters' Laboratories.

To maintain system pressure at the waste gas burner, a "Varec" Pressure Relief and Flame Trap Assembly is installed. This unit consists of a sensitive diaphragm—operated regulating valve in conjunction with a "Varec" Flame Arrester, into which a thermally operated by-pass valve is built. In case of fire in the system, this by-pass valve automatically closes the regulating valve, providing a positive flame check.

"Varec" approved Waste Gas Burners are manufactured with a wide ca-

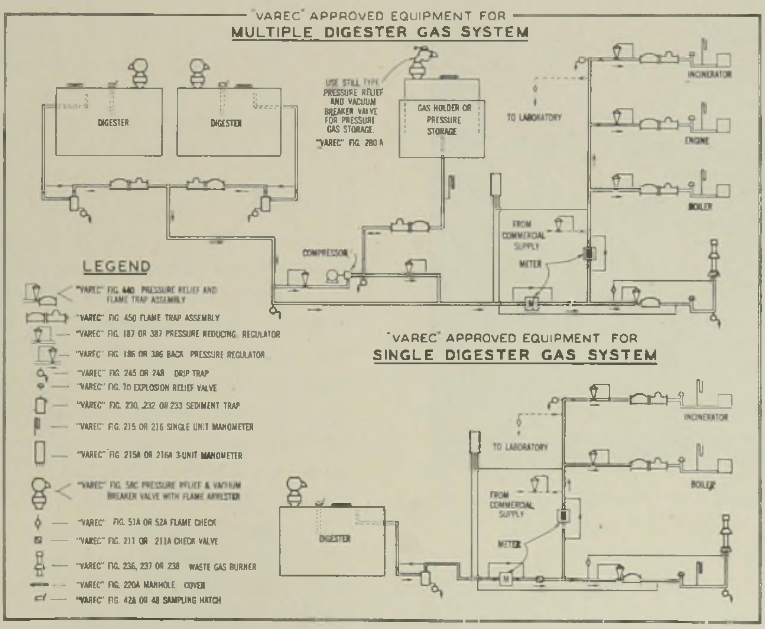


FIG. 1.—Illustrating the simplicity of maintaining and inspecting "Varec" Vent Unit.

pacity range and are furnished either with or without pedestal mounting, as required. The pilot valve gas line is protected by the installation of a "Varec" approved Flame Check.

To handle sudden surges in pressure due to explosions or momentary plant fluctuations a "Varec" approved Explosion Relief Valve is installed in the system. Being dead weight loaded, it insures a positive and foolproof relief valve.

In plants where the gas is used to operate boilers, engines or other equipment, a "Varec" approved Pressure Regulating Valve is installed in the gas line to each piece of equipment. These valves are set to operate at a lower pressure than the "Varec" Pressure Relief and Flame Trap Unit, thus making sure that all the gas required is available for useful work before any is allowed to go to the waste gas burner.

"Varec" approved Manometers are used through the plant for indicating system pressure. They are obtainable

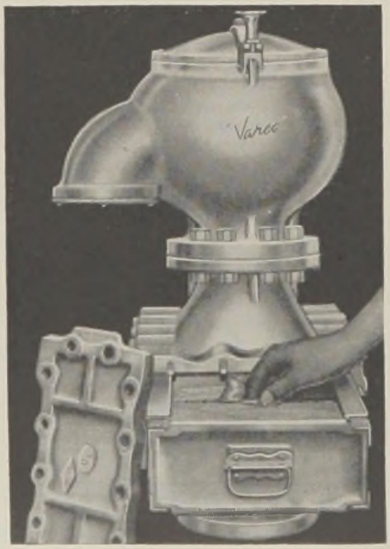


Fig. 2.—Equipment for Multiple and Single Digester Gas Systems.

in single or triple reading units with or without push button control. This latter feature is a built-in push button type valve that keeps the manometer shut off until the button is pushed. It is another "Varec" engineered feature incorporating safety devices for should the manometer glass break, no dangerous gas is allowed to escape from the system.

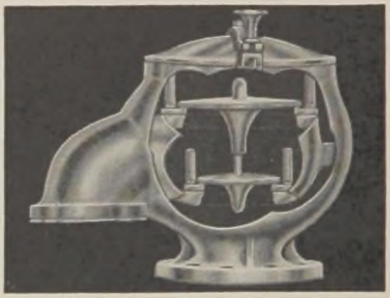


Fig. 3.—Cutaway sectional view of new "Varec" approved Pressure Relief and Vacuum Breaker Valve.

One of the basic design fundamentals in gas plant engineering is to keep the lines drained and free from moisture. A full line of "Varec" approved sediment traps and condensate drip traps is available to meet this requirement.

The "Varec" approved Check Valve is required in a system operating at low pressure. Designed for this purpose, its aluminum clapper reduces the pressure required to keep it open.

"Varec" non-sparking and gas tight manhole covers, installed on all tanks, provide a quick entry into the tank.

"Varec" Gauge and Sampling Hatches are also gas tight and non-sparking and have a foot pedal design to facilitate taking samples and gauges.

All "Varec" Regulating and Control Equipment is flow tested in the most modern type laboratory. Curves are published from each piece of equipment and can be used to determine the most economical size for each specific installation.

Due to the government restrictions on critical material, The Vapor Recovery Systems Company has developed a new Pressure Relief and Vacuum Breaker Valve illustrated in

Figures 2 and 3. These valves incorporate the standard features of the regular relief valves plus many engineering features developed especially to meet war time needs, viz: hyperbolic static-balanced pallets insure less "blow-down"; pallet guides are not exposed to corrosive tank vapor; expanding streamlined passageways eliminate directional changes and eddying currents; wind drift is eliminated by scientific design; materials are used having best thermal, electrical potential, and noncorrosive factors in combination; replaceable seats guarantee minimum maintenance expense.

All "Varec" equipment is pre-tested to actual field installation; pallet guiding system positively prevents binding or freezing, drainage throughout the unit is complete—no condensate can accumulate.

Twenty years' experience is built into every unit.

WALLACE & TIERNAN CO. INC.

Newark, New Jersey

CHLORINE CONTROL AND CHEMICAL FEED DEVICES

CHLORINATION IN ACTIVATED SLUDGE PROCESS

During the period of unusual conditions occasioned by the war, much can be learned that will be applicable to normal times. The increased populations in various centers of war activity have often overloaded sewage treatment facilities, at a time when simple expansion of the plant cannot be accomplished due to shortage of both labor and materials. The measures taken to combat operating difficulties which have resulted from this overload are worthy of consideration with a view toward improved effluents and higher capacities even after return to normal times.

In plain sedimentation and trickling filter plants the use of chlorination for improved plant efficiency is widespread. In addition to its function of sterilization of the effluent, chlorination serves to control odors, increase sedimentation, aid in grease removal, and reduce the B.O.D. Up to the present the use of chlorination as an adjunct to the activated sludge process has not had wide application. However, the excellent results obtained in some plants may herald a greatly increased use in the future.

Chlorination has successfully been used in activated sludge plants for (1) effluent sterilization, (2) sludge thickening, (3) control of bulking, (4) aid to aeration.

EFFLUENT STERILIZATION

The use of chlorination for this purpose is too well known to merit further comment. The chlorine solution is applied to the effluent and sufficient contact time is provided to insure the degree of bacterial kill required.

SLUDGE THICKENING

Application of chlorine to the sludge thickener has proved to be effective. Increased concentration of the sludge being pumped to the digestors has the same effect as increasing the digestor capacity by a percentage equal to the percentage increase of the solids concentration. The increased concentration can be attributed to more than one factor. The chemical action of the chlorine on the ammonia and other sludge constituents facilitates separation of the solids from the liquor. The reduction of bacterial action also has an important role in the thickening process. With a lessened bacterial action the gas production is decreased. Since gas acts to buoy up the solids a reduction of quantity will increase the settling characteristics of the sludge. Lastly, the reduction in septicity of the sludge allows it to be held in the thickener for a longer period which also results in a greater sludge concentration.

BULKING SLUDGE

The successful operation of an activated sludge plant depends upon a fine balance of many factors. When any one part becomes "sick" there is a tendency for the entire plant to ail. One ailment, seemingly common to all, is "bulking sludge." Among the many causes for this "disease" is the presence of a small filamentous organism known as sphaerotilus. When these organisms reproduce too rapidly they tend to clump together, trap gas in their masses and cause the sludge to expand, sometimes to the extent that it all comes to the surface. In other words, the sludge becomes bulky and will not settle properly. When such a sludge is pumped to the aeration tanks, proper coagulation becomes impossible and the settling property of the sludge in the final tanks is still further impaired. Where the trouble is due to sphaerotilus, the addition of a small amount of chlorine (3.0–5.0 p.p.m.) to the returned sludge has proven to be an effective control measure.

In control of bulking sludge by chlorination it is just as important to know when to discontinue chlorination as when to start it. One operator has solved this difficulty by watching the level of the sludge blanket and the Mohlman sludge index. When the sludge blanket begins to lift and the sludge index rises above 70, chlorine is added at a rate varying between 6 and 15 p.p.m. With the return of the index to 70 and the sludge blanket to 9 or 10 feet, chlorination is stopped and not restarted until the combined indices again begin to rise.

Other operators depend upon appearance alone, while still others have specialized and arbitrary rules for the start and stop of chlorination. In any event the successful control of bulking depends upon the skill and judgment of the operator.

AID TO AERATION

The problem of treating sewage would be greatly simplified if the quantity and strength of the sewage to be treated were uniform. The physical set-up of most plants is such that little or nothing can be done to control the quantity of sewage. In connection with attempting to maintain a more uniform quality of sewage, pre-chlorination is often used. This practice has been confined almost exclusively to types of treatment other than activated sludge, since an over dosage of chlorine ahead of an activated sludge plant upsets its operation. However, by means of recently developed potential control equipment, it is now possible to chlorinate to a sub-residual level. By means of this control, peaks of high demand sewage can be materially trimmed off, thus making for smoother plant operation.

One plant that has used this system quite successfully is the Fort Wayne, Indiana Treatment Plant (Fig. 1). At this location chlorination is used for odor control and prevention of sewer line disintegration at a point about two miles from the plant itself. As the sewage enters the treatment works it is further chlorinated so that its demand after chlorination is in the neighborhood of 3 p.p.m. The rate of feed of this second chlorinator is determined by potential control equipment.

The effect of this pre-chlorination materially assists in achieving the results which have been aimed for in such methods as tapered aeration. It is well known that a large percentage of the

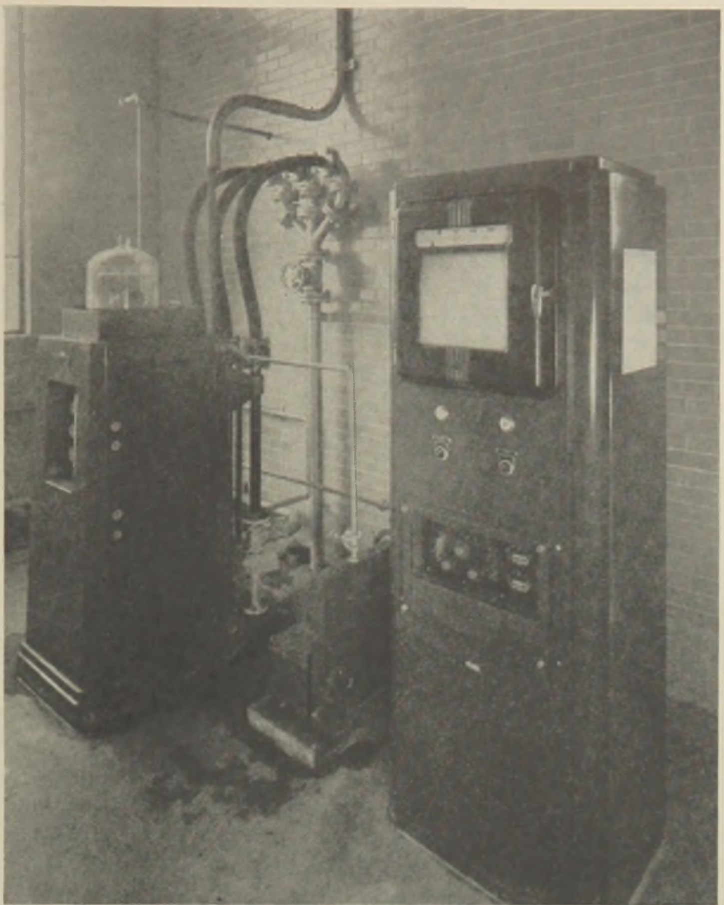


FIG. 1.—Wallace and Tiernan Potential Control Chlorinator Equipment at Fort Wayne, Ind., Sewage Treatment Works.

oxygen demand occurs during the first half hour of aeration. Chlorination reduces the amount and the length of time of the oxygen deficiency in the early stages of the aeration chamber.

In conclusion it appears that increased knowledge and improved method of control has made chlorination a valuable asset at existing plants, and has demonstrated the advisability of its design into new activated sludge plants for the purpose of improving the operation and increasing the capacity.

YEOMANS BROTHERS COMPANY

1433 Dayton Street, Chicago, Ill.

MANUFACTURERS OF YEOMANS PUMPS, SHONE SEWAGE EJECTORS, ROTARY AIR COMPRESSORS, VACUUM PUMPS AND SEWAGE TREATMENT EQUIPMENT

THE YEOMANS "WATER-WHEEL" DISTRIBUTOR

Designed for use in connection with sewage purification plants of small communities, the Yeomans "Water-Wheel" distributor applies settled sewage to a trickling filter. Working in combination with any primary sedimentation tank, it will handle the sewage from a small community or isolated schools, hospitals or other institutions and provide proper purification. It is equally efficient in open or covered filters (Fig. 1).

Mechanism consists of a rotating distributing arm of channel sections from which the sewage is fed to the filter bed by a series of V-notches, with spreader plates spaced in such a manner that even distribution is assured. The rotating trough is actuated by means of a water wheel through bevel gearing and is supported by a box-section beam which also conveys the sewage to the center of the rotating trough.

Liquor from the primary sedimentation tank passes into a small feed box inside the water-wheel box. Overflow weirs are provided on the sides of the feed box so that excess liquor not required to turn the wheel will be diverted from it to the bottom of the wheel box. This feed control, combined with partial immersion of the lower part of the water wheel as the inflow increases, serves to hold down the speed of the rotating trough so that uniform distribution through the V-notches will be maintained under all conditions of flow. Frequent clogging and cleaning of spray nozzles as occurs in small reaction-type distributors are eliminated by the V-notches.

Since the water wheel is of the bucket type, continuous distribution is assured at all inflows. Consequently, dosing chambers and siphons are not required. All of the liquor passes from the water-wheel box through the square-tube supporting beam to an outlet through which it falls into the trough. It is obvious that with the open trough instead of a closed pipe arm, with large area V-notches instead of the small area nozzles required in the reaction-type distributor, trouble with clogging is eliminated in the "Water-Wheel" distributor.

This distributor can be used with whatever type of primary sedimentation tank the sanitary engineer may prefer, and two or more "Water-Wheel" units can be connected to a primary tank to handle greater flows. Present designs of the "Water-Wheel" distributor can be furnished for filter beds with diameters from 5 to 25 feet. Maximum capacity is about 65 gallons per minute with a head of 2 ft. from filter media surface to liquor level in the sedimentation tank. This volume is considerably greater than would be allowable with a 25-ft. diameter filter bed except in cases of very weak sewage, but in determining the diameter, it should be noted that no center well for support of the distributor and inlet pipe is required. The entire area of the bed is effective for treatment.

Thus a 25-ft. diameter bed, "Water-Wheel" equipped, will handle sewage from a community of 270 or 338 persons, based on a flow of 100 gallons per capita per day and 6 ft. stone depth of filter media. The first figure, 270 persons, is derived from the basis of 4,000 population per acre foot; the second, 338 persons, on 5,000 population per acre foot. Installation will require approximately 43 cu. yd. of concrete, 110 cu. yd. of filter media and 466 sq. ft. of underdrain.

Shipping weight of the 25-ft. diameter "Water-Wheel" distributor unit assembled and crated is about 1,100 pounds. It is shipped in one piece if desired. It is only necessary for the contractor to set the unit in the filter bed; level the cross-beam and the distributor trough by means of leveling screws furnished with it; and connect the effluent pipe from the sedimentation tank to the inlet tee on the wheel box. Maintenance is easy. Horizontal and vertical shafts are grease packed at the factory and will operate for an indefinite period without attention. Any intelligent man can give the unit all the care it may need.

SOUTH ST. PAUL, MINN., PACKING-HOUSE WASTES, PNEUMATIC EJECTOR

In 1941 the Yeomans Brothers Co. designed and built for the City of South St. Paul an automatic Pneumatic Ejector for handling packing-house waste and sewage. The ejector design was developed under specifications of Consoer, Townsend and Quinlan, Consulting Engineers, Chicago. The ejector had to be of such design to successfully handle grit and settleable sewage solids ordinarily removed in 30 minutes settling of domestic sewage, plus grit, grain, cinders, sand, undigested hay and other wastes from the slaughtering of cattle, hogs, and sheep and calves.

Due to the complex and bulky nature of the material to be handled the conclusion was reached that the use of centrifugal or displacement pumps would involve excessive maintenance cost and also result in frequent interruption of service due to clogging difficulties.

The Yeomans Pneumatic Ejector furnished consists of a completely automatic system with full automatic sequential control (Fig. 2). The receiving tank is of steel construction, circular with a conical hopper bottom and long-radius discharge ell. The discharge pipe runs underground a considerable distance and terminates at an overhead control tower. The ejector is designed to handle 30 cu. ft. of wet material per minute.

A unique feature of the ejector is that no valves of any kind are used or needed in the discharge line. A large area automatic inlet flapper valve is located on the top of the receiver. This valve permits free passage of all material when open and is operated by gearing and a reversible air motor. A neoprene ring on the flapper insures positive seating at each closure.

The waste material is delivered into a hopper on top of the receiver by conveyors. When the level of the material reaches a pre-determined point in the receiver the pilot controls stop the conveyor and automatically close the inlet flapper valve. When this valve has seated, the main air supply valve opens and admits compressed air and the material is ejected (Fig. 3). The compressed air can be used expansively for the ejection cycle as the control is adjustable. When the air in the receiver

FIG. 1.—Yeomans Water-Wheel Distributor.

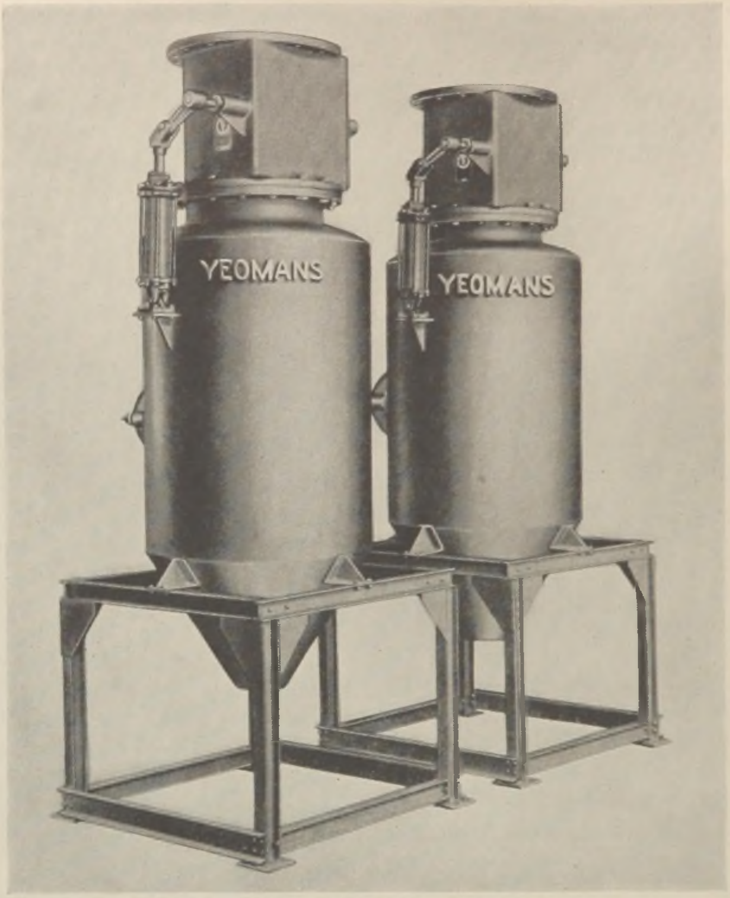


Fig. 2.—Automatic Ejectors at South St. Paul.

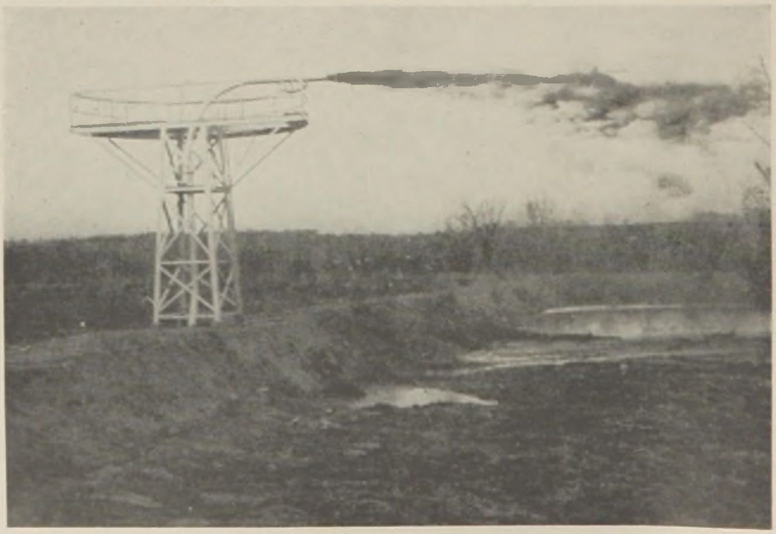
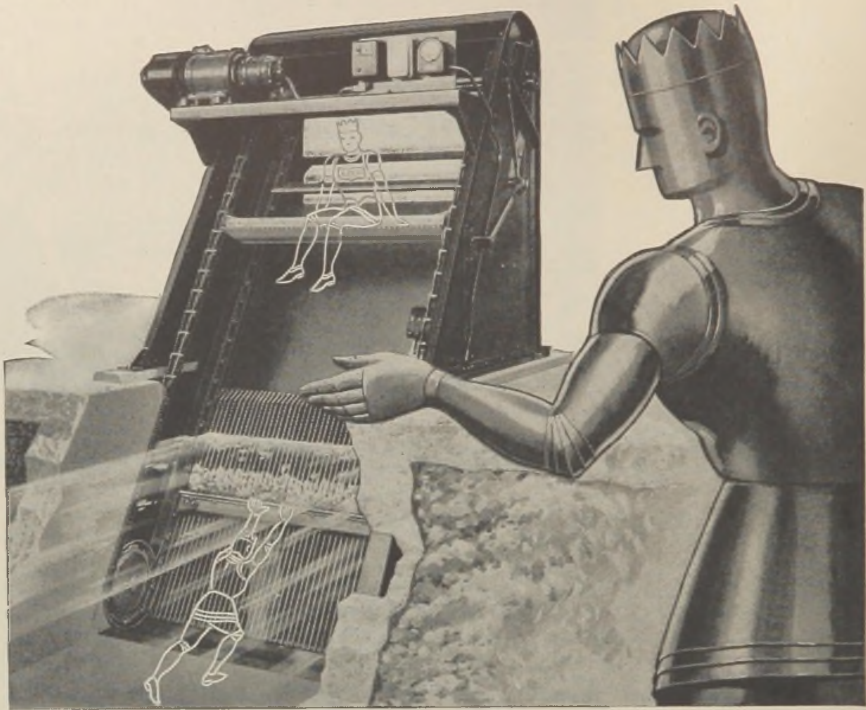


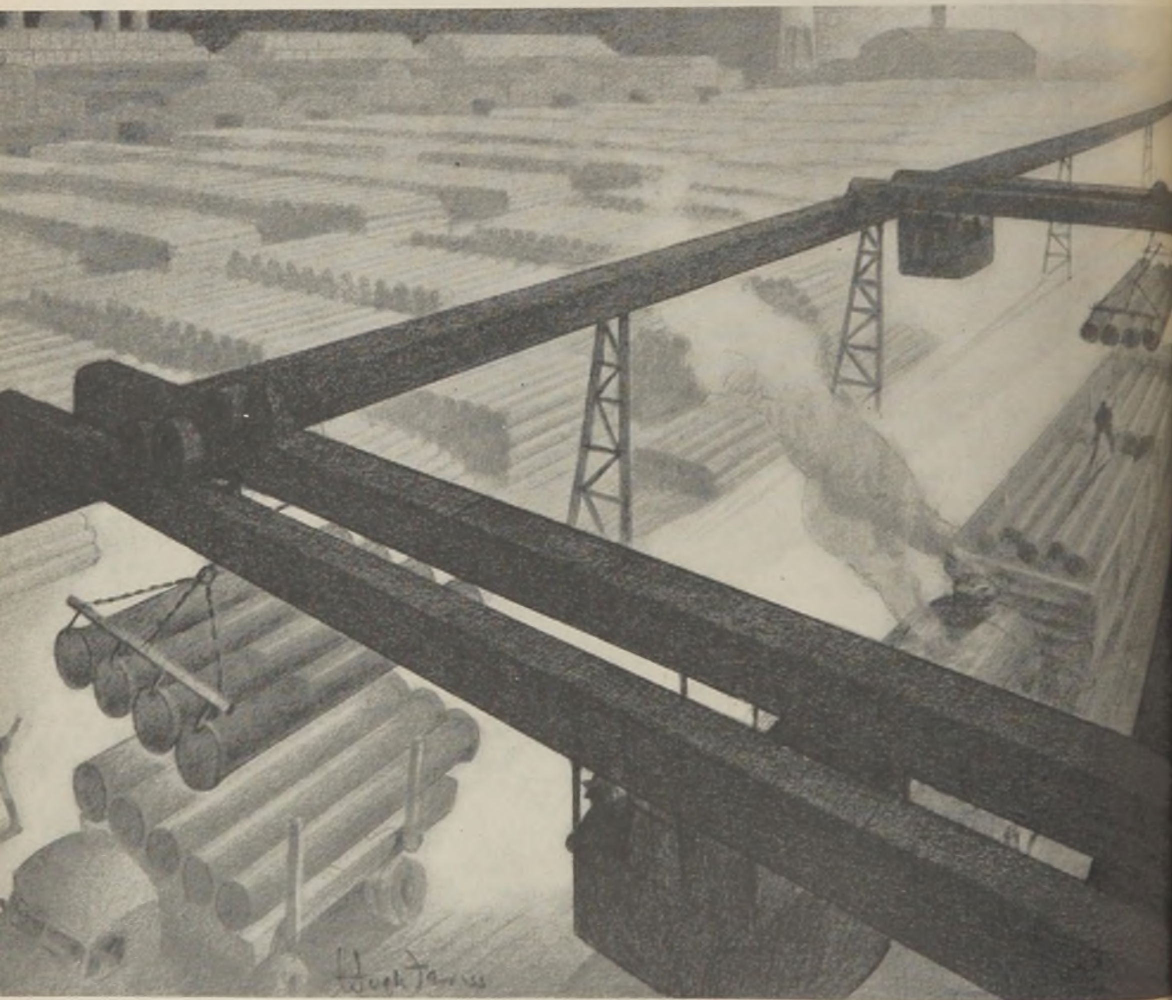
Fig. 3.—Pneumatic Ejector Discharge at South St. Paul.

has blown the discharge line clear, the pressure drops to atmosphere. At this point the flapper valve is opened and the conveyor started for another cycle. Each step in the program is adjustable and under the control of the operator. Manual attention required is of a supervisory nature only.

An idea of the bulky character of the waste material handled by the ejector can be had from the fact that after it is discharged to the sludge lagoons, it is burned.

Mr. W. H. Cropsey, plant superintendant, advises that the ejector operates for a period of 22 hours each day with the rate of discharge varying from eight minutes to thirty minutes.





Pipe storage and shipping yard at one of our plants, drawn by Hugh Ferriss.

From today's research and planning will come the Pittsburgh-National Water Meters, EMCO Sewage Gas Meters, and Nordstrom Lubricated Plug Valves of tomorrow

Generals Plan Tomorrow's Battle While Winning Today's

ON the far-flung battle fronts of the World, brave United States Soldiers, Sailors and Marines are being directed by military strategists in waging the most scientific war ever fought. This is a war of men and machines. Weighted in our favor is the fact that our machines are products of the same industrial ingenuity that has made America the greatest nation of them all—the men who use them are those who, both by heritage and training, will provide the skilled hands to guide the way to ultimate victory.

Planning ahead is important. Sooner or later the war will end and Sewage Disposal Plants and the manufacturing firms who supply equipment must be prepared to meet the changed conditions and ensuing problems that the cessation of hostilities will bring.

That we may keep to the forefront of progress, the research and development program of the Pittsburgh Equitable Meter Company and Merco Nordstrom Valve Company has been greatly accelerated. Our post-war planning is beyond the formulative stage. To be sure, the war must first be won, and to this end the productive capacities of our plants are now devoted, but like generals, industry, too, must plan for tomorrow's battle while winning today's. We all must take steps to insure that the things for which we are fighting will be perpetuated in a better peacetime world to follow.

We're Helping Win Today's Battles, Too!

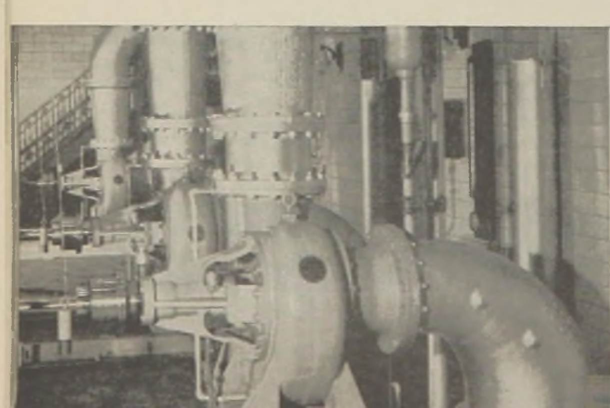
The normal peacetime business of this company and its subsidiaries is designing and building meters, valves, regulators and similar equipment for measurement and control. At present the production of our five factories is entirely devoted to direct war goods and high priority items that contribute to essential military, naval and civilian services.

PITTSBURGH EQUITABLE METER COMPANY

MERCO NORDSTROM VALVE COMPANY
Main Offices, Pittsburgh, Pa.
NATIONAL METER DIVISION, Brooklyn, N. Y.

BOSTON, BROOKLYN, BUFFALO, CHICAGO, COLUMBIA, HOUSTON, KANSAS CITY, LOS ANGELES, MEMPHIS, NEW YORK, PITTSBURGH, SAN FRANCISCO, SEATTLE, TULSA

PITTSBURGH NATIONAL CO SEWAGE NORDSTROM



for SEWAGE DISPOSAL

IT is our aim that Worthington equipment, produced during this difficult period, shall accomplish two purposes . . . first that it shall serve effectively, and without interruption, on the important jobs which it fills . . . and second that, in so doing, it shall make new friends, and retain the confidence of old ones.

To those plants where Worthington equipment is now in use, we offer the services of our district office engineers, and our headquarters staff, in checking conditions and performance, with a view to assuring continued operation at top efficiency. The counsel of these specially qualified engineers is always available.

WORTHINGTON PUMP AND MACHINERY CORPORATION
General Offices: **HARRISON, NEW JERSEY**

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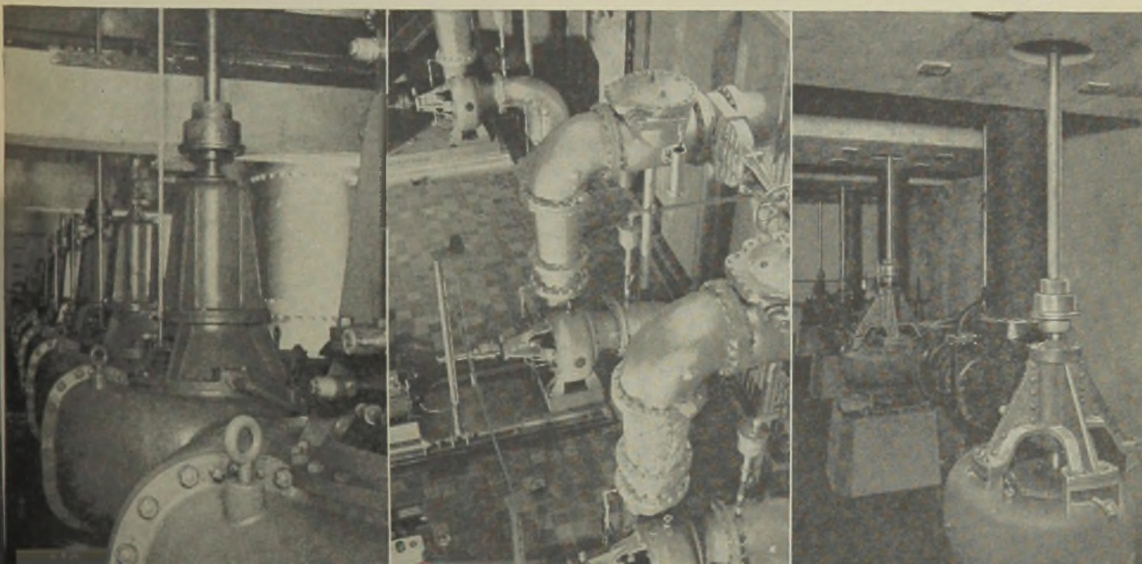
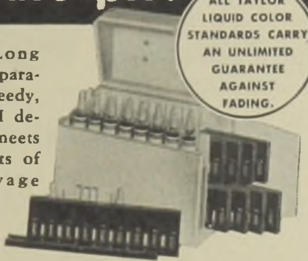
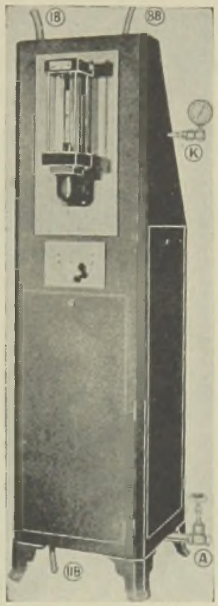


DIRECTORY OF ENGINEERS

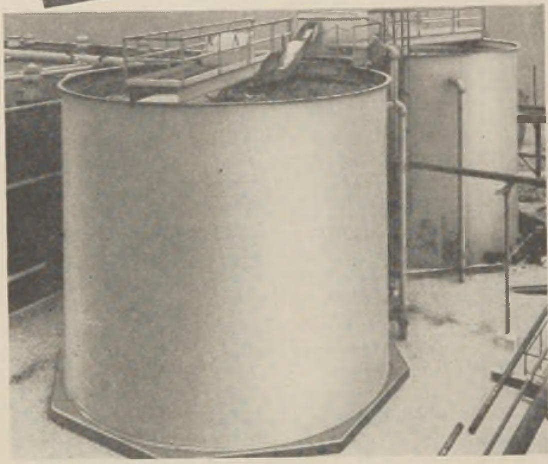
DIRECTORY OF ENGINEERS





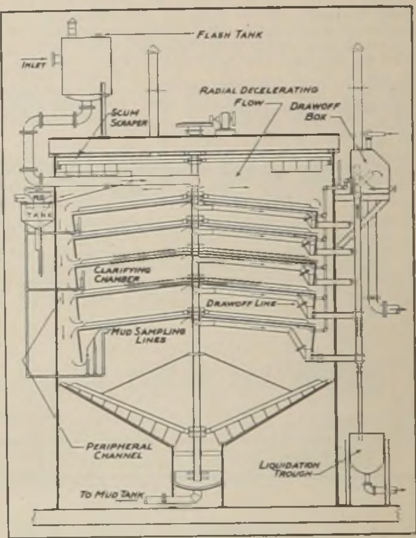
TO MEET EVERY CLARIFICATION NEED - - - - -

Graver CLARIFIERS



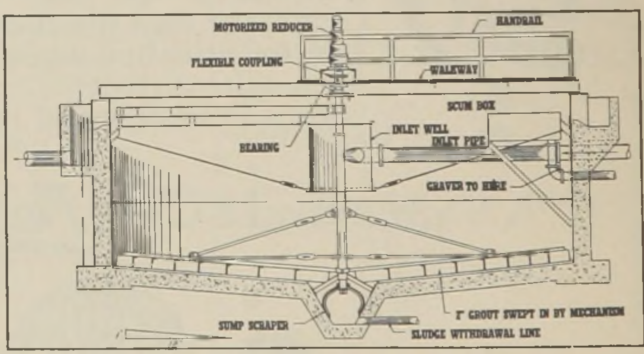
Left: Graver Reactivator Clarifier

Below: Graver Multi-Tray Clarifier



GRAVER designs, builds and installs clarification equipment for every type of problem arising in connection with sewage treatment, industrial waste disposal, water treatment, and chemical processing. Among the many types now in successful operation are Primary and Secondary Sludge Collectors, Multi-tray Clarifiers, and Reactivator Clarifiers.

Whatever your needs in this line, you'll find it to your advantage to consult Graver. We'll gladly work with you or your consulting engineer, and a request for consultation incurs no obligation.



Graver Primary Clarifier

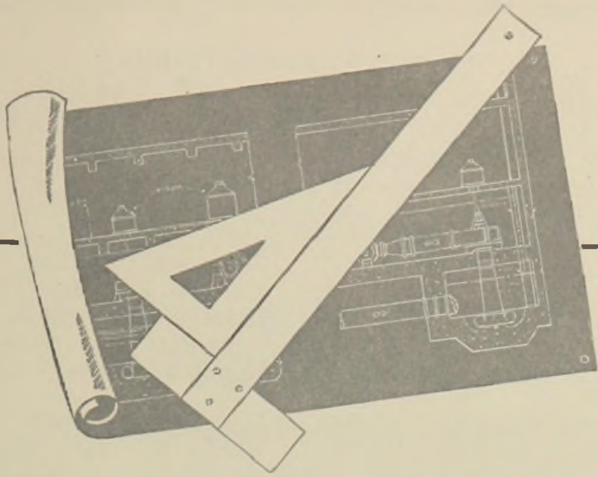
GRAVER TANK & MFG. CO., INC.

4809-41 Tod Avenue, East Chicago, Indiana

NEW YORK CATASAUQUA, PA. CHICAGO TULSA

GRAVER Sewage Equipment

43-41-W



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ARTHUR A. CLAY, ***Advertising Manager***

SEWAGE WORKS JOURNAL

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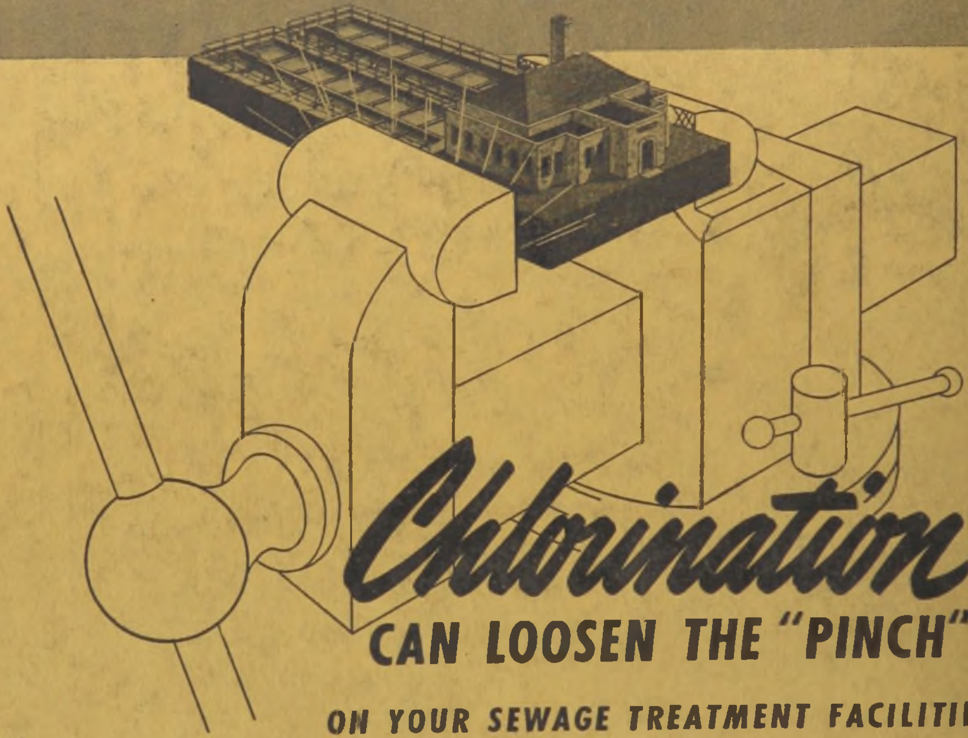
EXPANSION *ruled out?*



Chlorination
CAN LOOSEN THE "PINCH"
ON YOUR SEWAGE TREATMENT FACILITIES

In the majority of cases, sewage disposal plants must make their present equipment suffice for the duration of the war. Perhaps the demands on your plant are becoming increasingly difficult to handle.

Although not a substitute for adequate plant capacity, chlorination can help greatly to keep that capacity at an efficient maximum.

Chlorine applied in advance of settling will aid in eliminating foaming and scum, and prevent ponding. It will help to maintain the full effectiveness of filters, and insure a safe, unobjectionable effluent.

Your Wallace & Tiernan representative will gladly cooperate with you on your sewage problems, by suggesting ways by which you can utilize your present chlorinator installation to the utmost advantage.

SA-156

"The Only Safe Sewage is a Sterilized Sewage"

WALLACE & TIERNAN CO., Inc.

MANUFACTURERS OF CHLORINE AND AMMONIA CONTROL APPARATUS

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