SEWAGE WORKS JOURNAL

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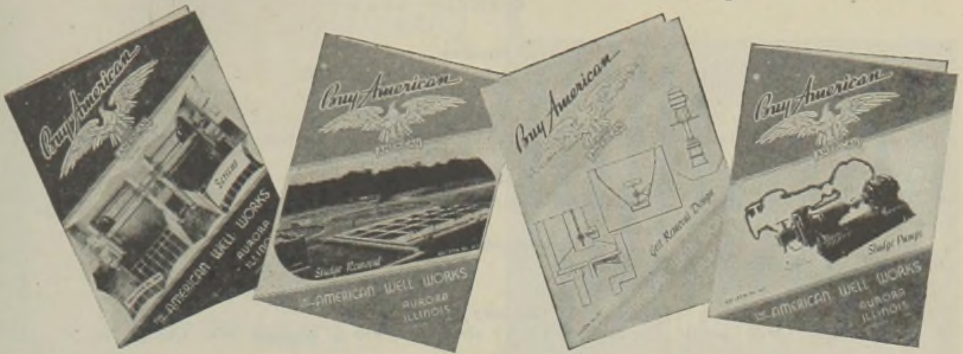

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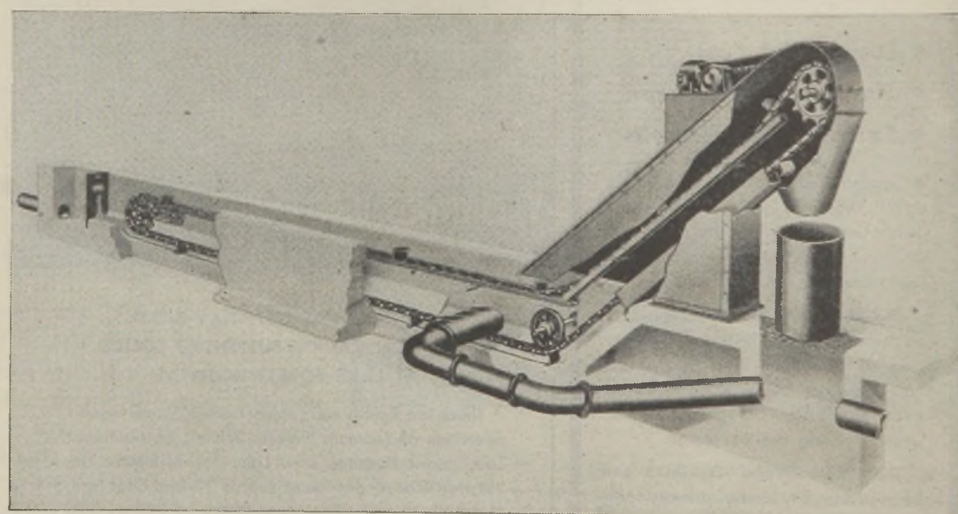

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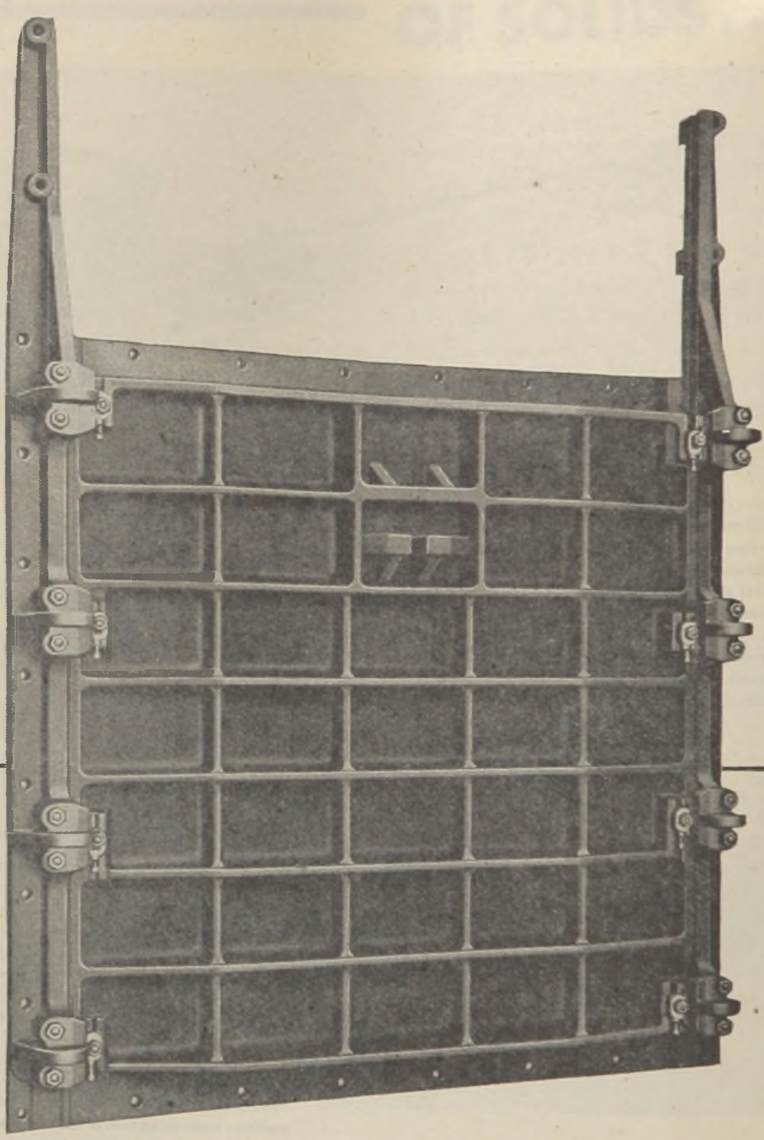

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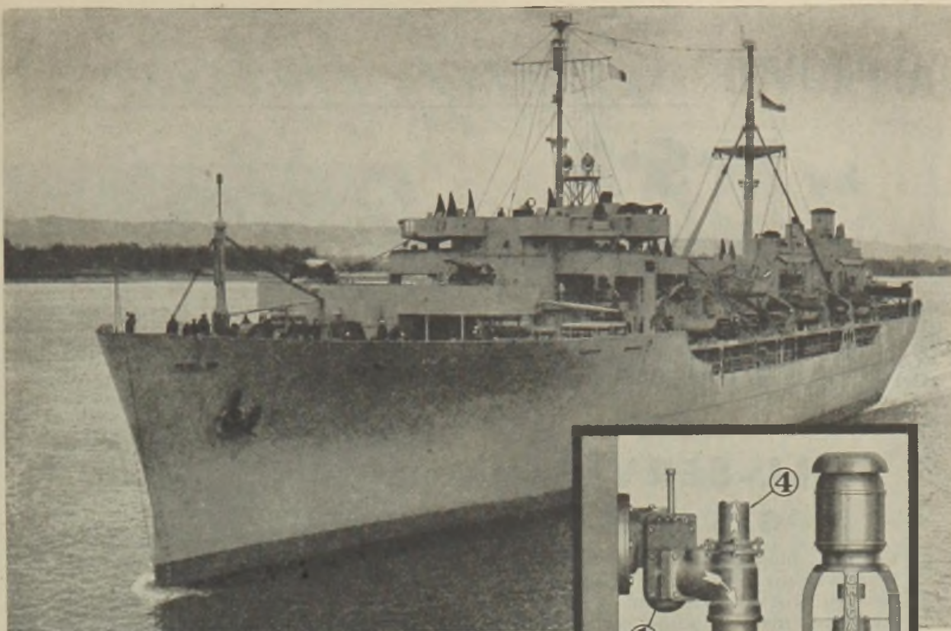

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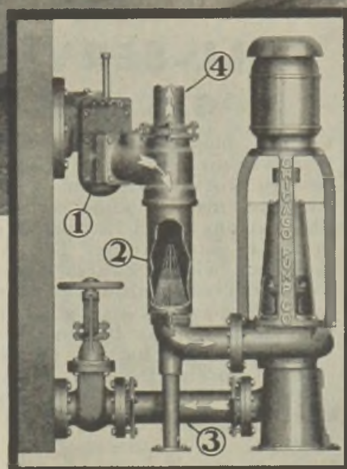

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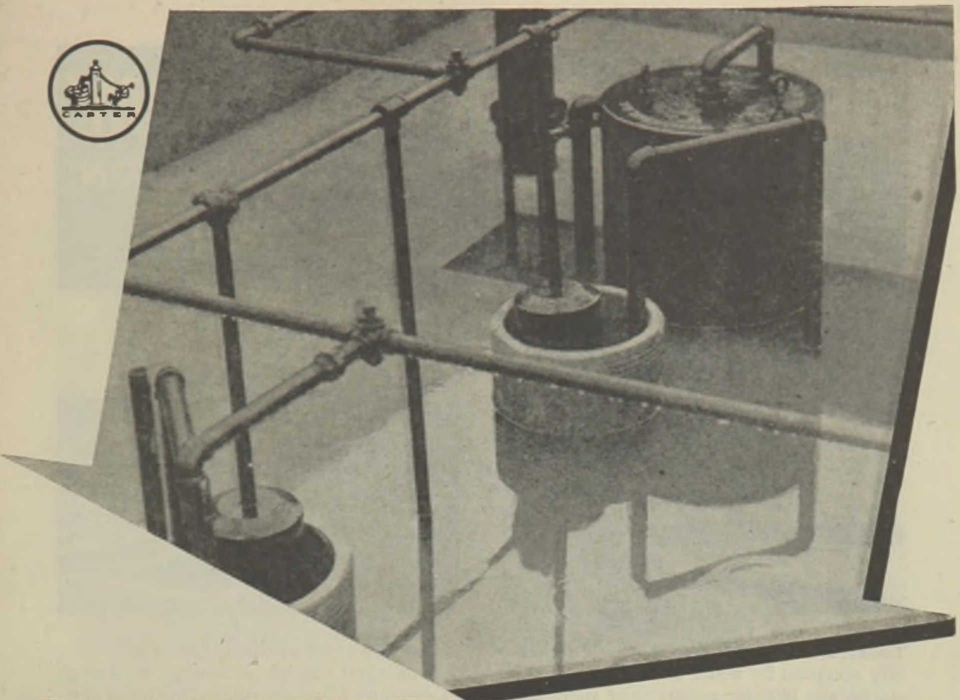

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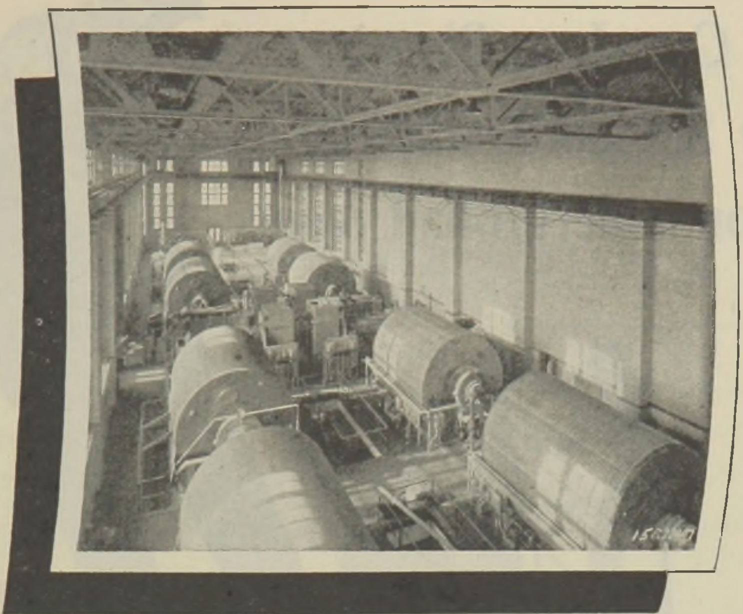

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Plant Operation

LOCATING LOST SEWERS AND MANHOLES *

By E. T. Cranch

Director, Department of Public Works, New Rochelle, N. Y.

I hope all your records are so good that you have no lost sewers or manholes, and that this paper will be of only academic interest to you. But if some of you have sewers, drains and manholes for which you have no records or for which available records are inaccurate, then, perhaps, some of my experiences during the past year may be of practical interest.

The settlement of New Rochelle, New York, was started in 1688, and it has enjoyed a consistent and rapid growth since then. It was incorporated as a village in 1858 and became a city in 1899. The 1940 Federal Census gives the population as 58,408. The area of the city is 10½ square miles.

The population area of the city has largely expanded by individual real estate developments to which were assigned definite names, such as Residence Park, Halcyon Park, Highland Park, etc. In the early days, each real estate developer tried to be exclusive and laid out dead end streets. The streets were laid out with the definite intention of not connecting with the streets of any other development. Within recent years, this situation has been corrected by the creation of a City Planning Board which has set up a master city plan, and every developer must have his plans approved by the planning board before he can start work; also, all plans for sewers and drains must now be approved by the Department of Public Works and the construction inspected by that department.

For many years, however, sewers and drains were installed by the developer under no city supervision; no maps were submitted to the city, and in some cases I have found the developer had no map showing the course of the pipe. I have found instances where the developer has laid pipes across lots, and when he sold the properties crossed by the pipe he retained no easement covering the repair or maintenance of the pipe.

I have found one instance where in 1894, by order of the Board of Health, the city laid a 15-inch drain meandering along the course of a brook across lots, filled in the bed of the brook over the pipe and never secured any easements from the property owners. A few years ago it became vitally necessary to increase part of this drain to 36 inches, and the city had to pay a substantial amount for the easement,

* Presented at Seventeenth Annual Meeting, F.S.W.A., Pittsburgh, Pa., October 12–14, 1944.

although the 15-inch pipe had been occupying the same property for over forty years.

Last year I had occasion to investigate a situation where there were constantly recurring floods. I found a 24-inch vitrified tile drain completely plugged. From a point where an open brook entered this pipe, it was approximately 1,000 feet to the first manhole. The city had no plan of this drain. I contacted the developer and found he had no plan, but I took him to the location and he showed me, as well as he could remember, the course of the drain, which, it seemed, followed a reverse curve. The drain was laid with open joints, and went through a swampy area in which there were a number of willow trees. This led me to believe that the stoppage was in all probability caused by the entrance of willow roots into the drain. This spot was too far away to be reached satisfactorily with flexible sewer rods from either opening in the drain. We therefore decided to put in a manhole in the swamp area. After four days of digging we finally located the drain at a depth of about 5 feet and opened it. We found the pipe completely filled with roots and it took almost two weeks of work to clear the line. This experience made me feel that there ought to be some means of locating underground sewers and drains. I was familiar with the use of the M-Scope in locating underground water mains. So I asked the salesman to try it out on this drain with flexible sewer rods inserted in the drain. We got 238 feet of rods in the drain, placed the transmitter on the rod and also, by means of the wire and clip provided, connected it to the rod. With the receiving set we were able easily to follow the course of the curving drain for about 200 feet. At this distance the signal became rather faint, but one man with keen ears followed it for the full distance of 238 feet. We then rigged up the transmitter and receiver on the carrying sticks and went over the line to see if by any chance we might find any hidden manholes. At one point, right over the line we got a sharp signal, and started to dig feverishly for the manhole, only to find that a steel barrel hoop was buried in the ground. However, this demonstration satisfied me that the instrument could be used satisfactorily, both for the purpose of locating tile drains or sewers and buried manhole covers.

At another time, to relieve a flood condition, we wanted to install a new catch basin in the middle of a block and connect it to an existing drain at a manhole shown on the map at about the point we wanted. There was, however, no evidence of the manhole on the ground. With the M-Scope we located the manhole within a few minutes, just off the paved area, and under about 3 inches of sod. This time it was really the manhole.

Another time the map showed a drain manhole on the east side of the street at a certain intersection. The M-Scope gave no signal on the east side of the street but gave a clear signal on the west side of the street and, sure enough, we found the manhole about 8 inches deep under the macadam pavement.

We had a sewer and a drain running through a private right-of-way.

The map showed a manhole on each. The sewer and drain had been installed 14 years ago. For the past several years, periodic efforts had been made to locate the manholes, but without success. This right-of-way had several angles in it. It passed through a fine estate and the property was so thickly landscaped with evergreen, paths, gardens, etc., it would have been almost impossible to have resurveyed the right-of-way without doing real damage to the property. With the M-Scope we located and uncovered both manholes within an hour.

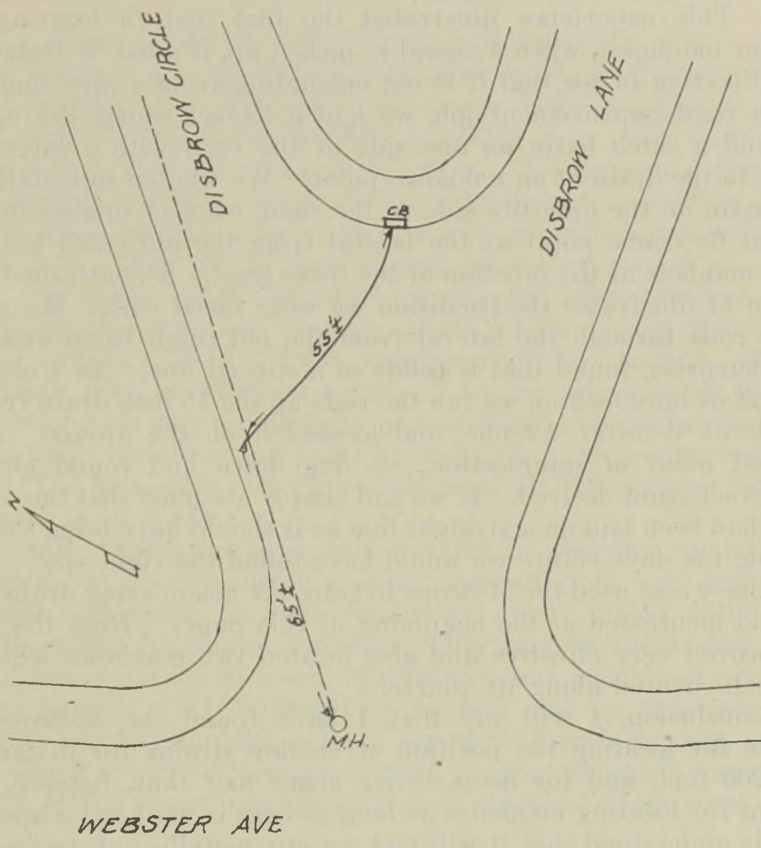

FIGURE 1.—Location of point of intersection of catch basin lateral and main drain simplified by use of M-Scope at New Rochelle, N. Y.

One manhole was covered with about a foot of dirt and the other with about 3 inches.

Another time we tried to follow the course of a drain about 15 feet deep, which ran through territory covered with thick brush, so that it was impossible to follow the line directly from the manhole. The first open land was almost 200 feet away from the manhole and transmitter, but no signal whatever could be picked up there. We cut an opening in the brush about half way back, and were able to pick up the signal at that point. For deep drains it is necessary to limit the distance from the transmitter.

Another failure we had was in trying to find a couple of catch basins that we thought were located near an abandoned railroad bridge, where the land is thick with brush. Following along the gutter we picked up a signal on each side of the road and thought we had located the catch basins, but digging down we found nothing. I then found I could follow the signal clear across the road. There is a 24-inch drain at this point, installed by the old railroad company, and apparently 24-inch cast iron pipe was used across the road. I am waiting to have the brush cleared away, when I will make a further search for the catch basins. This experience illustrated the fact that in locating catch basins or manholes, when a signal is picked up, it must be tested from every direction to see that it is not emanating from a pipe line.

In a road improvement job, we had a 15-inch storm drain in the road, and a catch basin on one side of the road with a lateral connecting to the drain at an unknown point. We wanted to install a new catch basin on the opposite side of the road, connect this basin to the drain at the same point as the lateral from the old catch basin and build a manhole at the junction of the three lines. The attached sketch (Figure 1) illustrates the condition we were faced with. We ran the flexible rods through the lateral from the old catch basin and, much to our surprise, found that it followed a curved line. As a check for the point of intersection, we ran the rods up the 15-inch drain from the manhole at Webster Avenue, and located it on the ground. At the indicated point of intersection, we dug down and found ourselves at the exact point desired. If we had simply assumed that the original lateral had been laid on a straight line as it should have been, we would have dug for days before we would have found the right spot.

We have also used the M-Scope to trace the meandering drain laid in 1894 and mentioned at the beginning of this paper. Here the instrument proved very effective and also located two manholes which had long been covered along its course.

In conclusion, I will say that I have found the M-Scope very effective for locating the position of shallow drains for distances of about 200 feet, and for deep drains about half that distance. It is excellent for locating manholes as long as care is used in its operation, and it is understood that it will pick up any metallic substance underground, be it a manhole, barrel hoop or pipe line.

THE PROS AND CONS OF SEWER VENTILATION *

By Richard Pomeroy

Partner, Montgomery and Pomeroy, Consulting Chemists, Pasadena, Calif.

Purposes of Sewer Ventilation

There are six principal reasons for ventilation of sewers, as follows:

1. *To eliminate lethal atmospheres.*—Every year lives are lost because workers go unprotected into sewers where the atmospheres will not support life. The exact reason for death is undetermined in many instances, but from the data available it is clear that oxygen deficiency is by far the commonest cause. The oxygen deficiency is generally due to the absorption of oxygen by the sewage, and to a lesser extent to displacement of the normal air by gas which has leaked into the sewer or which has been generated by decomposition of organic matter. In many cases the effect of oxygen deficiency may be intensified by the presence of toxic gases which reduce the oxygen-carrying capacity of the blood, notably hydrogen sulfide. In some cases death may be attributed entirely to the presence of this gas. Carbon monoxide may occasionally be a problem, and the increasing use of cyanides in metal plating baths presents the hazard of poisoning by HCN. (The maximum safe concentration of HCN in sewage from this standpoint is 10 p.p.m.)

Adequate ventilation will help greatly in clearing up lethal atmospheres, yet no reasonable amount of ventilation will prevent the occasional occurrence of toxic conditions. Only masks will provide complete safety for sewer workers. This may be illustrated by the death of two workmen in a well-ventilated sewer which had previously shown a perfectly safe atmosphere by test and by experience. An industrial concern dumped a large amount of sulfuric acid into the sewer, which dissolved ferrous sulfide present in small amounts on the walls of the sewer, producing H_2S in amounts which were quickly fatal.

2. *To eliminate explosive atmospheres.*—Explosive atmospheres in sewers may occur from leakage of fuel gas into the sewer or from the discharge of volatile flammable liquids. The literature contains many references to explosions from these causes. A suitable program of routine testing will generally reveal dangerous gas leaks, and a strict policy in respect to dry-cleaning establishments or other industries which may discharge flammable liquids should reduce the occurrence of explosive mixtures. Yet at best a hazard may still remain, which can be further reduced by suitable ventilation.

3. *To reduce corrosion of concrete by hydrogen sulfide.*—Large

* Presented at Seventeenth Annual Meeting, F.S.W.A., Pittsburgh, Pa., October 12–14, 1944.

concrete sewers are frequently subject to attack by H_2SO_4 which is formed by oxidation of H_2S on the walls of the sewers. The rate of attack of the concrete is proportional to the sulfide content of the sewage. For a 9-foot sewer of the Los Angeles County Sanitation Districts it was calculated that the content of dissolved sulfides in the sewage should not average more than 0.1 p.p.m. in order to assure a 100-year life for the structure. Many sewers in regions where sulfides have not been considered a serious problem are nevertheless suffering slow attack which will terminate their lives before they have outlived their usefulness. Even where the sewers are of clay pipe, there may be damage to concrete in manholes, and to manhole steps. Forced-draft ventilation can be used to dry out the inside of the sewer, thereby retarding or preventing the conversion of H_2S to H_2SO_4.

4. *To prevent corrosion of plumbing in buildings by gases from the sewer.*—Recent studies have shown this to be a serious problem even in locations where sulfide concentrations have not previously been considered of much importance.* If sewer air containing even minute amounts of H_2S passes into the plumbing, sulfide corrosion results. The corrosion product formed under these conditions is voluminous, and the first sign of trouble is a stoppage in the plumbing. The fact that the stoppage may be due to corrosion is generally not understood. Ventilating procedures which maintain a slight negative pressure in the sewer prevent damage of this sort.

5. *To prevent escape of odors from the sewer.*—If the sewage is odorous because of the presence of certain industrial wastes, or because of a high content of H_2S, objectionable odor conditions may develop in the vicinity of manholes or near household plumbing vents. This condition is apt to be especially bad where there is an interruption of the normal flow of the sewer atmosphere, which generally is downstream, by a depressed section (inverted siphon). This leads to the expulsion of air from the available outlets for some distance above the obstruction. Agitation of the sewage, as by drops, further accentuates the problem. Even ordinary fresh sewage may cause a serious odor nuisance in unfavorable circumstances. Ventilation may be used to prevent such escape of odors.

6. *To prevent or diminish sulfide generation in the sewage.*—Whether or not sulfides develop in a stream of sewage depends, among other things, on the amount of oxygen absorbed at the surface of the stream. Oxygen absorption is proportional to the oxygen content of the atmosphere. In the absence of ventilation the oxygen concentration may drop considerably below normal. However, some ventilation always takes place, if for no other reason than the rise and fall of the sewage. In most sewerage systems the ventilation is sufficient, even without any measures specifically for this purpose, so that significant oxygen depletion is limited to quite small areas. Sulfide concentrations are not often influenced to any great extent by ventilation.

* Pomeroy, "Corrosion of Iron by Sulfides." To be published in *Water Works and Sewerage.*

Methods of Sewer Ventilation

There are three principal ways in which ventilation is accomplished. The relative effectiveness and suitability of these methods are considered in the following sections.

1. *Perforations in manhole covers.*—A few perforations in the cover will generally dry out the inside of a manhole sufficiently so that corrosion of the concrete and metal is reduced far below what it would be in the absence of this amount of ventilation. No appreciable drying of the sewer itself is accomplished in this way. The danger of odors is increased. The occurrence of lethal atmospheres is diminished, but ventilated manhole covers can by no means be relied upon to make sewer atmospheres safe. Explosive mixtures may be more quickly dissipated than when the manhole covers are not perforated but the holes provide additional points at which ignition may occur, as from a carelessly tossed match or from a spark produced by a passing vehicle. Thus the explosion hazard is not appreciably diminished by this method of ventilation.

If the manhole is in a location such that storm water can flow over it, even in small amount, perforations in the cover will take considerable amounts of water into the sewer. In systems that are supposed to carry only sanitary sewage, the increase of flow on this account may be very great. If the manhole is in an unpaved street considerable amounts of dirt will get into the sewer.

It is evident that the relative advantages and disadvantages of perforated manhole covers must be weighed in each situation. Certainly, perforated covers cannot be universally specified, nor is it proper to condemn such covers completely, for in most sewerage systems there are some locations where their use is advantageous.

2. *Ventilation through house plumbing vents.*—This method of ventilation is comparable to perforated manhole covers in effectiveness. It has an advantage in that the air tends to go up through the vents, and to leave a slight negative pressure which draws air down through the manhole covers. The discharge of sewer air by the vent is less likely to cause odor nuisance than a similar discharge at the street level, yet nuisances do arise from the vents under unfavorable conditions.

In order that plumbing vents may be of any substantial benefit to the sewer atmosphere, it must be possible for the air to make a circuit. Plumbing vents have very little effect if the sewer is tightly closed, but if they are used in conjunction with perforated manhole covers the resulting air current will largely prevent sulfide corrosion in manholes. Also, explosive atmospheres are quite rapidly dissipated. Sulfide concentrations in the sewer atmosphere are not appreciably diminished, nor is the inside of the sewer itself dried sufficiently to make any difference in the rate of corrosion.

The possibility that odorous sewer gases may escape through plumbing vents led some engineers in the past to favor main traps between the house plumbing and the public sewer, and some cities formerly passed ordinances requiring that these be installed. This practice has now largely been abandoned except for locations where odor conditions are especially bad. A realization of the possible benefits of ventilation through house vents has led to a general condemnation of main traps, and, in a swing to the other extreme, many plumbing ordinances have required 4-inch vents. This is unnecessarily large from the standpoint of the original purpose of the vent, for a pipe 3 inches or even 2 inches in diameter is adequate to relieve air pressures. It is a questionable procedure to require the property owner to install a large vent in order to ventilate the public sewer.

House vents have one serious disadvantage. As pointed out in the discussion of purposes of ventilation, the passage of sewer air containing H_2S into plumbing will cause sulfide corrosion. Hence this method of ventilation is not an appropriate way to improve the atmosphere of the sewer if H_2S is present. Of course, plumbing vents are essential, and even if they are only 2 inches in diameter enough sewer gas may go into the plumbing to cause damage unless preventive measures are used. Installation of main traps may be resorted to, but consideration should be given to the responsibility of the sewer authority to control sulfides in the sewage or by other means prevent this damage to private property. Summarizing the case for ventilation through plumbing vents, it may be said that the benefits are not great. and may be more than offset by sulfide corrosion of the plumbing.

3. *Ventilation by forced draft.*—This is best accomplished by blowers which draw air out of the sewer at suitable points. In Melbourne, Australia, this method has been used for several years. The most extensive work along this line in the United States has been done by the city of Los Angeles, which has three ventilation stations in operation, serving three different purposes. These are described in papers by Studley (*S.W.J.*, **11**, 264–70, 1939) and Smith (*Calif. Sew. Works Jour.*, **15**, 71–79, 1943). The installations are as follows:

(*a*) North Outfall. This station (Figure 1) is located in the middle of a 6-mile section of a 9.5-ft. by 12.3-ft. semi-elliptical sewer. Two 75-horsepower blowers discharge 44,000 cu. ft. of air per minute from stacks 80 ft. high at a velocity of 200 ft. per second. The purpose is to prevent disintegration of the sewer. When ventilation is applied for this purpose it must be thorough enough to dry the walls of the sewer and thus stop the activity of the bacteria which convert H_2S to H_2SO_4. Mere dilution of the H_2S in the air is of little benefit, for the oxidation of the sulfide on moist, active sewer walls is very rapid, apparently being limited only by the rate at which the gas diffuses to the walls. Ventilation has effectively dried the Los Angeles North Outfall, and apparently has stopped disintegration completely. On the basis of reported results at a previous station half as large, ventilating half of this six-mile section, it appears that an average of 60 lbs. per day of H_2S is being removed from the sewer. If oxidized, this would produce about 180 lbs. of sulfuric acid. In a year this would be sufficient to disintegrate 100 cu. yds. of concrete, or to attack the exposed sewer walls in this section to a depth of 0.06 inch. This degree of attack seems slight in a few years, but for a structure which might have a useful life of 100 years it is disastrous. It is not likely that all of the H_2S escaping from the sewage is removed with the exhausted air, for on the dried walls there may still be some oxidation, but in this case the product is free sulfur.

Effective drying of a sewer can be accomplished with reasonable power costs only for a limited distance from the ventilating station. This distance varies in proportion to the diameter of the sewer. If an attempt is made to increase the distance of effective drying by exhausting more air, this requires an increase in power varying approximately as the fifth power of the distance. Small sewers would require relatively frequent stations, which would involve a cost probably greater than the cost of other methods of corrosion control. Hence this procedure is most appropriate for large sewers.

(*b*) Fletcher Drive. A 40-horse power blower exhausts 7,000 cu. ft. per minute, discharging this through a stack 80 ft. high. The purpose is to eliminate complaints due to the escape of odors from manholes and plumbing vents, caused by an inverted siphon. It is completely successful in accomplishing this, and it also has dried out the inside of manholes in a large area.

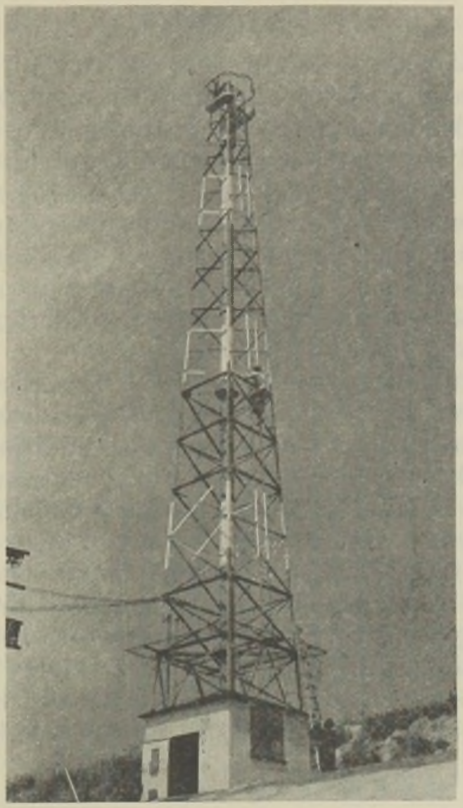

FIG. 1.—Forced ventilation removes dangerous gases and reduces corrosion. This station serves an outfall sewer in Los Angeles.

(*c*) Slauson Avenue. A blower driven by a 7.5-horsepower motor exhausts 2,500 cu. ft. of air per minute. This is deodorized by sprays of sodium carbonate solution and is then discharged through a stack 70 ft. high. This station serves to eliminate explosive atmospheres which formerly existed in the Slauson Ave. sewer, and which have caused several violent explosions.

These three stations of the city of Los Angeles are completely successful in accomplishing their major purposes, and other incidental benefits accrue at the same time. Notably, the maintenance of a slight negative pressure in the sewer prevents the passage of sewer air into the plumbing of buildings, and thus prevents sulfide corrosion of such plumbing.

Forced ventilation is certainly the most effective ventilation procedure, yet it does not follow that it is a cure-all, nor that it has a place in all sewerage systems. The chief limitations on the extent of its usefulness are: cost, difficulty of finding suitable locations, the problem of deodorizing the exhausted air or discharging it in a way that will not cause nuisance, the fact that in many sewerage systems ventilation is unnecessary, and the possibilities of alternative methods to accomplish the same benefits.

Conclusions

Decisions as to what is required in the way of ventilation should be based upon a careful survey of conditions, which will include routine tests for combustible gases in the sewer atmosphere, oxygen determinations, sulfide analyses of the sewage and sewer air, and a survey of industrial wastes which may have an effect on the sewer atmosphere. If sulfides are absent, and if explosive atmospheres are not found, there is little reason for any special ventilation procedures. The source of explosive atmospheres must be investigated, and eliminated if possible. Sulfides in the sewage require consideration of the several possible methods of sulfide control.

If control of sulfides in the sewage is not practical, alternative procedures for control of corrosion must be considered. For example, procedures have recently been devised for addition of ammonia to the sewer atmosphere to counteract sulfuric acid formed by oxidation of H_2S. It would require 60 lbs. per day of ammonia to neutralize the amount of sulfuric acid which would be formed by oxidation of the H_2S being exhausted from the Los Angeles North Outfall. Even if a three-fold excess were used to assure complete protection, the cost would be relatively small and might compete with forced ventilation.

While ventilation is not a cure-all, it is highly probable that its field of usefulness is broader than has generally been realized, and that the years ahead will witness increasing use of these procedures.

CONTROL OF INFILTRATION AND STORM FLOW IN THE OPERATION OF SEWERAGE SYSTEMS *

By Ralph W. Horne

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Infiltration is the leakage of ground water into a sewer through defective sewer joints or sewer structures.

The results of a survey made by sending 54 questionnaires regarding the subject matter of this discussion to all Massachusetts municipalities having a population of 15,000 or more indicate that out of 32 municipalities which replied to the questionnaire, less than 16 per cent had any information regarding rates of infiltration. Other data obtained from the questionnaires are discussed later herein.

Excessive ground water infiltration may cause substantially increased operating costs of sewage pumping stations and treatment works and, furthermore, it reduces the sewer capacity otherwise available for carrying sewage. Infiltration sometimes carries silt and fine sand into the sewers, which later may be deposited in them, or at pumping stations and treatment works.

Storm flow in sanitary sewers will encroach seriously upon sewer capacities at times of intense precipitation and may materially increase the annual operating costs. Flooding of sewers and the property connected to them is apt to result from the admittance of storm flow.

The effects of infiltration and storm flow in sanitary sewers are far more pronounced and serious than in other kinds of sewers, because of their relatively smaller capacity in proportion to the area served; and this discussion relates primarily to sanitary sewers.

It is important in following the discussion to have in mind the distinction between sanitary sewers and other kinds of sewers commonly in use. The definitions of sewers which follow agree with those adopted by the American Society of Civil Engineers and the American Public Health Association.

Two kinds of sewer systems are in common usage, namely, separate systems and combined systems:

1. A separate system of sewers is one in which sewage and storm water are carried in separate conduits. These separate conduits are termed sanitary sewers and storm sewers.

2. A combined system of sewers is one in which sewage and storm water are carried in the same conduits.

The two kinds of sewers which comprise a separate system of sewers are defined as follows:

1. A sanitary sewer is one which carries sewage and excludes storm and surface water; it is intended to exclude ground water also.

2. A storm sewer is one which carries storm and surface water, street wash, and other wash waters, or drainage, but excludes sewage.

* Presented at Seventeenth Annual Meeting, F.S.W.A., Pittsburgh, Pa., October 12–14, 1944.

Sanitary sewers are generally adopted in preference to sewers planned to carry storm water, if pumping or treatment of the sewage is involved and if funds available for construction and operation are limited. Smaller sizes of sewers generally are used in a sanitary sewer system and less total volumes of sewage are carried annually in a sanitary sewer system than in sewer systems which do not exclude storm water. Both these factors are in line with efforts to keep costs of construction and operation at a minimum. As stated previously, this discussion deals primarily with infiltration and storm flow in sanitary sewers.

Rates of Infiltration in Sewers

The rates of ground water infiltration in sewers will be found to vary considerably depending on the height of ground water levels and the perviousness of the natural soil. Rates of infiltration also will vary with the quality of workmanship, with the kinds of sewer pipe, the number and kinds of sewer joints, with the precautions taken to avoid unequal settlement of sewers and their appurtenant structures, and with the precautions against other causes of structural failures.

Observed rates of infiltration in sewers extend over a wide range—from considerably less than 10,000 gallons per mile of sewer per 24-hour day to as much as 1,400,000 gallons per mile per day. Some rates of infiltration concerning which the writer has firsthand knowledge are shown in Table 1. The rates of infiltration will be seen to range from 5,500 gallons per mile per day to 1,400,000 gallons per mile per day.

The lesser rate of infiltration was obtained in a sewer system built almost entirely with vitrified clay pipe in 3-foot lengths and reinforced concrete pipe in 8-foot lengths; all the joints in this sewer system were made with bituminous jointing compound poured in place while molten. The manholes and other appurtenant structures were built largely of reinforced concrete.

The sewer in which the high infiltration rate of 1,400,000 gallons per mile per day occurred was built with vitrified segmental blocks laid in cement mortar and the manholes were built with brick masonry, having 8-inch thick walls and a 4-inch thick concrete foundation slab. The outsides of the manhole walls were plastered. The sewer was built below ground water level and much of the leakage was through defective joints between the segmental blocks. The municipality owning the sewer was refused permission to connect it with the North Metropolitan Sewer System of the Boston Metropolitan area until the excessive leakage was corrected.

A reasonably liberal allowance to specify for infiltration in new sewers is 30,000 gallons per mile per day if measured under high ground water conditions and 20,000 gallons per mile per day under low ground water conditions. However, good workmanship and the use of suitable materials may well be expected to reduce these allowances by one-half or more, whereas poor workmanship, unsuitable materials and unfavorable construction conditions might easily more than double the aforesaid allowances.

TABLE 1.—*Infiltration in Sewers*

City	Sizes of Sewer (Inches)	Material of Sewer*	Kind of Joint Material	Length of Sewer (Miles)	Number of Service Connections	Ground Water Conditions	Kind of Sub-Soil	Rate of Infiltration (Gallons per mile per 24 hrs.)
Brockton, Mass.	6 to 32 ×48	V.C. B	Cement Mortar and Bituminous	100.0	About 9,000	Medium	Semi-Pervious	About 6,000
Cranston, Rhode Island	8 to 42	V.C., R.C. A.C.	Bituminous	35.0	3,380	Low	Pervious	Under 7,500
Cranston, Rhode Island	8 to 39	V.C. R.C.	Bituminous	26.0	3,180	Low	Pervious	Under 5,500
Gloucester, Mass.	21	V.C.	Bituminous	0.18	39	High	Semi-Pervious	26,600
Gloucester, Mass.	24	V.C.	Bituminous	0.37	7	High	Semi-Pervious	38,600
Gloucester, Mass.	27	R.C. 4′ lengths	Plastic Bituminous Compound Placed cold	0.51	100	High	Very Pervious	109,000
Gloucester, Mass.	30 and 36	R.C. 4′ lengths	Plastic Bituminous Compound Placed cold	0.44	24	High	Very Pervious	120,000
Marlborough, Mass.	6 to 20	Mostly V.C.	Bituminous	37.0	2,690	High	Semi-Pervious	50,000
Saugus, Mass.	8 to 30	V.C. R.C.	Bituminous	2.3	120	High	Semi-Pervious	33,500
Saugus, Mass.	10 to 24	V.C. R.C.	Bituminous	1.3	30	High	Semi-Pervious	28,200
Taunton, Mass.	8 to 36	V.C. B	Mostly Cement Mortar	30.8	About 3,400	Low	Semi-Pervious	19,800
Walpole, Mass.	12 to 30	V.C., C.I. and R.C.	Bituminous	2.9	—	High Low	Semi-Pervious Semi-Pervious	48,200 25,000
Webster, Mass.	8 to 12	V.C.	Cement Mortar	2.4	About 500	Low		16,000
Webster, Mass.	8 to 18	V.C.	Cement Mortar	1.3	—	Low		16,500
Webster, Mass.	8 to 12	V.C.	Cement Mortar	3.8	—	Low		10,000
Woburn, Mass.	30	S.B.	Cement Mortar	1.1	None	High	Pervious	1,400,000

* Abbreviations Used: V.C. = Vitrified Clay; R.C. = Reinforced Concrete; A.C. = Asbestos-Cement; S.B. = Segment Block; B = Brick; C.I. = Cast Iron.

Cost of Infiltration

At Cranston, Rhode Island, where a complete sanitary sewer system including sewers, pumping stations and an activated sludge type of treatment works, recently was built under the writer's supervision, the cost of pumping and treating sewage, exclusive of labor and capital charges, amounts to about $14.00 per million gallons. The present total cost of pumping and treating the infiltration is estimated at somewhat over $2,000 per year for about 60 miles of sanitary sewers. The following items are presented to show the effect of various assumed rates of infiltration upon operating costs at Cranston:

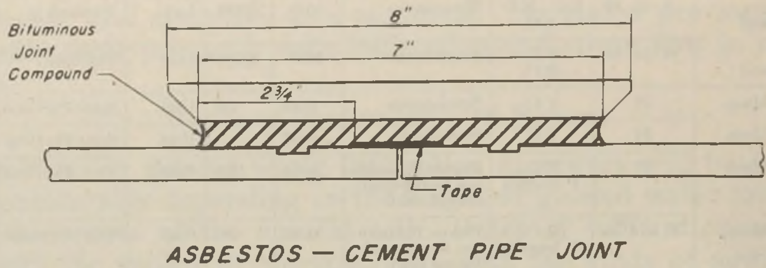
(1) Infiltration for 60 miles of sewer at 10,000 gallons per mile per day = 219 million gallons per year.

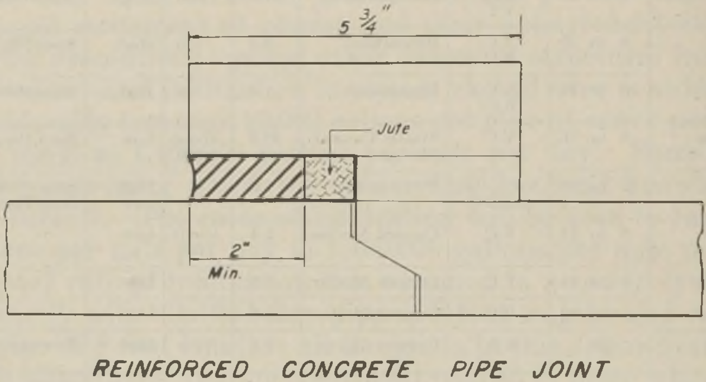
(2) Operating costs to pump and treat the annual infiltration at infiltration rate of 10,000 gallons per mile per day = 219 million gallons at $14.00 per million gallons = ... $3,066 per year

(3) Operating costs for infiltration at rate of 20,000 gallons per mile per day = ... $6,132 per year

(4) Operating costs for infiltration at rate of 30,000 gallons per mile per day = ... $9,198 per year

The preceding items indicate that each increase of 10,000 gallons per mile per day in the average rate of infiltration represents an increase in operating costs of $3,066 per year. Each increase of 10,000 gallons infiltration per mile per day would cost about $50.00 per year per mile of sewer and represents an investment of $1,667 per mile, using a 3 per cent interest rate.





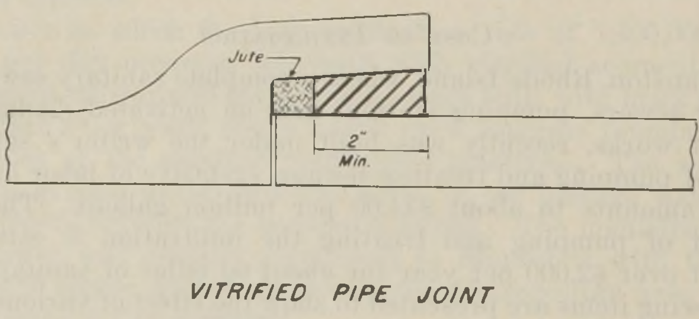


FIGURE 1.—Typical joints for sewer pipe.

At Cranston, bids for the various kinds of sewer pipe were compared using a basis which took account of the price bid and the cost of infiltration for the different kinds and lengths of pipe. The several kinds of pipe included vitrified pipe in 3-foot lengths, reinforced concrete pipe in 4-foot lengths and 8-foot lengths, and asbestos-cement pipe in 13-foot lengths.

In comparing the pipe bids a rate of infiltration was assigned to the different kinds of pipe on the basis of the area of joint surface around the outside of the pipe barrel per unit length of sewer. An infiltration ratio was adopted for the different kinds of pipe based on unit joint surface areas, the value 1.0 being used for the pipe having the smallest area of joint surface per unit length of sewer.

Typical joints for the three more common kinds of sewer pipe are shown in Figure 1 and comparative pipe lengths and number of joints for vitrified pipe and asbestos-cement pipe are shown in Figure 2.

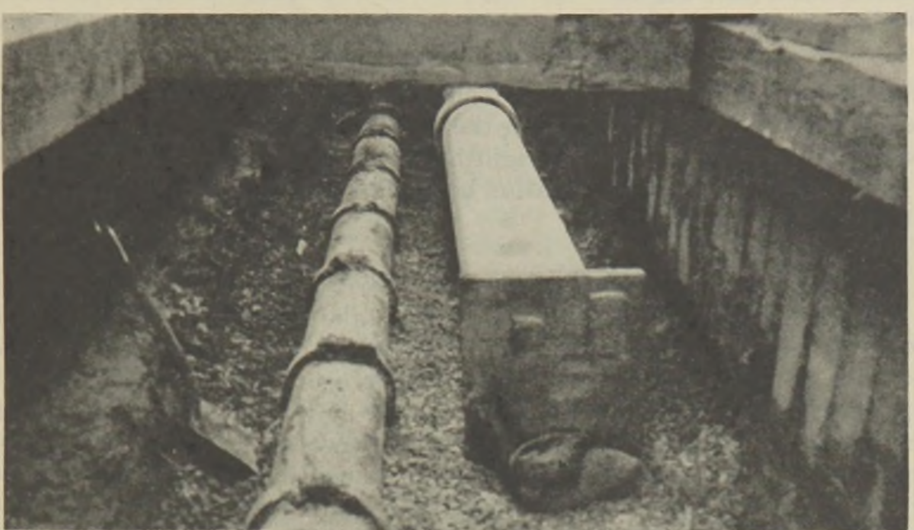


FIGURE 2.—Vitrified clay and asbestos-cement pipe sewers laid in same trench. Note spacing of joints and gravel bedding.

A maximum infiltration rate of 30,000 gallons per mile per day was adopted for the kind of pipe having the largest infiltration ratio and the infiltration rates assigned to the other kinds of pipe were adopted as that proportion of 30,000 gallons represented by their respective infiltration ratios; thus a pipe having an infiltration ratio equal to one-half the largest infiltration ratio would be assigned an infiltration rate of 15,000 gallons per mile per day.

The estimated annual cost of pumping and treating the infiltration per foot of sewer was calculated for each kind of pipe upon which bids were received, and this cost was capitalized at the prevailing interest rate and added to the bid price per foot of pipe in determining which of the several bids was most favorable. Table 2, which follows, shows prices bid for pipe, infiltration ratios, estimated infiltration costs and the total figures used in comparing the various pipe bids.

The figures shown in Table 2 indicate the relative costs of infiltration for the several kinds of pipe. As an example of the effect of taking account of infiltration costs, it will be seen that although the bid price per foot of vitrified pipe was 50 cents less than the price for reinforced concrete pipe in 8-foot lengths, still the allowance for the cost of

TABLE 2.—*Pipe Prices and Infiltration Costs*

Kinds of Pipe (18-in. size)	Pipe Price per Foot Including Pipe and Y Branches	Infiltration Ratio	Costs per Foot of Sewer		
			Annual Operating Costs for Infiltration	Annual Operating Costs Capitalized @ 3%	Pipe Price Plus Capitalized Operating Costs for Infiltration
Reinforced concrete (8-ft. lengths)	$1.55	1¼	$0.012	$0.39	$1.94
Vitrified clay (3-ft. lengths)	1.05	3⅛	0.029	0.97	2.02
Asbestos-cement (13-ft. lengths)	1.86	1	0.009	0.31	2.17
Reinforced concrete (4-ft. lengths)	1.49	2½	0.023	0.77	2.26

infiltration made the reinforced concrete pipe 8 cents per foot less costly than the vitrified pipe on the basis of the figures used for comparing bids, as shown in the right-hand column.

It is important that infiltration be held to a minimum, in the interests of municipal economy.

Some Causes of Infiltration

No infiltration of ground water will take place in a sewer if the sewer is above ground water level. Infiltration of ground water into a sewer system usually may be traced to defects in the sewers and their appurtenances. Ground water also may enter the sewers through underdrains intentionally connected to the sewers, and serving to collect ground water from sewer construction trenches and from the underdrainage systems provided as protection against wet cellars and basements. Ground water also may enter the sewers, after leaking into cellars and basements through piping provided to drain them. Infiltration in sewers is difficult to correct and the most satisfactory way to control it is by taking proper precautions at the time of original construction, and by making tests to see that there is no excessive infiltration before putting new sewers into service.

Defects in sewers and their appurtenant structures which may permit ground water infiltration are as follows: (1) leaky sewer joints, (2) cracks and leaky joints in manholes and other sewer structures and (3) cracked and broken pipes and conduits.

By far the greatest volume of infiltration is through leaky sewer joints if the sewer is built of sewer pipe, brickwork or segmental blocks; if built of monolithic concrete the sewer conduit should be reasonably free from infiltration, provided the concrete work is first class. Infiltration through defective manholes and other sewer structures generally is second in volume to the infiltration through sewer joints. A less volume of infiltration originates from cracked and broken pipes and conduits than from the two other sources.

Some Precautions Against Infiltration

Formerly, cement mortar or neat cement was used almost exclusively for making sewer joints and, in fact, joints of this kind are still used extensively. Later there was limited usage of joints made with a mixture of sand and sulfur, melted and poured in place. At present the use of bituminous joint compound appears to be gaining popularity and there has been a tendency in numerous municipalities where cement mortar joints were formerly used to change to joints made with bituminous joint compound.

Infiltration through cement mortar joints frequently has resulted from improperly filled joints, from the washing of joints by failure to control ground water level and drainage water before the mortar has set, and from shrinkage cracks in the joint material. An acceptably watertight cement mortar joint can be made if the proper mortar mixture is used (1 part cement and 2 parts sand should be satisfactory); if the joint surfaces are thoroughly cleaned before joint material is placed; if the joint is completely and solidly filled and the mortar is placed so as to overfill the joint well beyond the face of the bell; if the joint material is held firmly in place by properly wrapping with burlap or other suitable cloth; if no ground water or drainage water is allowed to wash the joint before it has satisfactorily set; and, finally, if the joint is permitted ample opportunity for the mortar to cure properly without being disturbed.

Infiltration through joints made with bituminous joint compound may be due to failure of the compound to adhere thoroughly to the bells and spigots of the pipes; it may be due to bubbles in the joint material, or to separation of the filler material in the compound, or to failure to fill the joints properly with jointing compound. Use of bituminous joint compound will produce first class, relatively watertight joints if the surfaces of bells and spigots of the pipes are thoroughly cleaned and dry before the compound is poured; if the compound is heated to the proper melting temperature; if the inert filler in the compound is not allowed to separate from the compound while melted; if the joint is thoroughly filled; and if the compound is chemically inactive to acids, alkalies and other solvents found in sewage. Joints made with bituminous joint compound can be promptly backfilled because the compound solidifies rapidly and yet remains sufficiently plastic over a long period of time to permit normal pipe line settlement to take place without damage to the joints or rupture of the pipe line. No curing of the joint compound is necessary.

Stoppers should be tightly jointed into unused Y branches placed for future service connections. Special precautions should be taken to insure a tight joint between the vitrified service pipe and the cast iron soil pipe of each house drain.

The foundations upon which sewers are laid must be sufficiently stable to eliminate abnormal settlement which would cause excessive joint deflection and damage the joints.

Brick sewers and segmental block sewers are not the best choice for use where they will be subjected to ground water pressure. Their construction involves far too many joints and consequently they are not nearly as suitable to exclude ground water infiltration as are sewers built either with pipes of vitrified clay, concrete or asbestos-cement, or sewers built with monolithic concrete.

Vitrified clay sewer pipes may be obtained in lengths of 2 feet and 3 feet; reinforced concrete sewer pipes may be obtained in lengths of 4 feet and 8 feet; and asbestos-cement sewer pipes may be obtained in 13-foot lengths. Use of the pipes of longer lengths reduces the number of joints needed and is more favorable to low infiltration than the use of short length pipes.

Infiltration of ground water through cracks and leaky joints in manhole structures, regulating chambers and other structures appurtenant to the sewers usually results from defects in the joints of brickwork or cracks in concrete work. No doubt much more infiltration takes place in the average sewer system through leaky brickwork than through cracks in concrete structures. Manholes built with a good grade of brick, having joints in brickwork properly filled with cement mortar, and supported on a stable concrete slab foundation, should be acceptably tight against infiltration, provided the outside of the brickwork is thoroughly plastered with cement mortar to a height safely above the level of high ground water. The use of concrete or a combination of brickwork and concrete for manhole structures will be found to give the greatest freedom from infiltration through these structures. Figure 3 shows a manhole structure built with a combination of concrete and brickwork and Figure 4 shows the use of sectional steel forms for a concrete manhole.

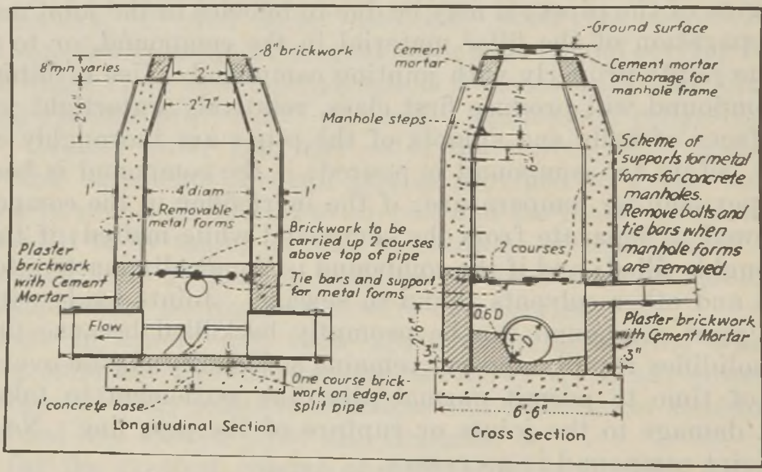


FIGURE 3.—Manhole built of concrete and brick.

Cracked and broken sewer pipes and cracks in monolithic concrete sewers will result in ground water infiltration if below ground water level. These defects in sewer pipes and conduits frequently are caused by unsatisfactory foundations and unsuitable bedding of the pipe lines. An excessive external loading of pipe lines by deep backfills, high embankments over the pipes or extra heavy live loads may also cause sewer breakage.

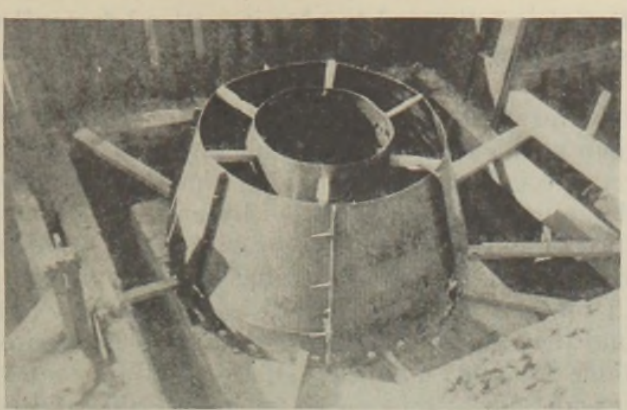


FIGURE 4.—Sectional steel forms in place for pouring concrete manhole.

Where sewer trenches are dug in good foundation materials, even bearing for the pipe lines should be afforded by thoroughly bedding the pipes in granular material such as clean gravel. Good granular material well compacted beneath and around the pipe lines will afford them sufficient lateral support so that they may safely carry considerably greater loadings than would otherwise be possible. Failure to appreciate the value and importance of proper bedding and ample lateral support for sewer pipes has been the cause of many cracked and broken sewers, accompanied by infiltration of ground water. Figure 5 indi-

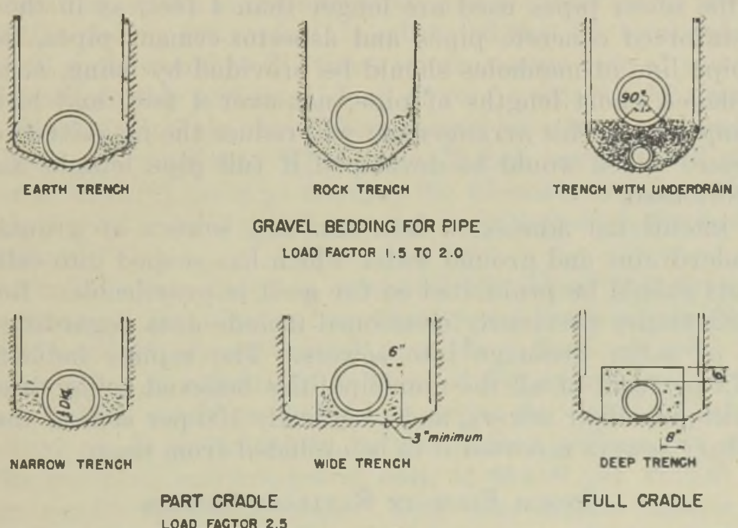


FIGURE 5.—Typical methods of pipe bedding and cradling.

cates methods of bedding and cradling sewer pipes to improve their load-supporting ability or "load factor." The "load factor" is an expression of the ratio of resistance to failure which pipe properly bedded or cradled will have as compared with its safe loading indicated by the usual three-edge bearing tests. Thorough bedding of sewer pipe in granular material is estimated to give it a "load factor" of 1.5 to 2.0 and the use of concrete cradle should produce a "load factor" of 2.5 or more.

The use of cement mortar or neat cement for sewer pipe joints produces rigid joints which are apt to result in cracked and broken sewer pipes, if any appreciable settlement of the pipe line takes place.

To guard against infiltration caused by uneven settlement of sewer pipes, the pipes should not be laid or supported on an unstable foundation. Material of unsatisfactory bearing qualities should be removed from beneath the sewer to such depth as necessary to reach a good foundation and the material so removed should be replaced by gravel or other suitable granular material. If the depth of material to be removed is so great that its removal is not practicable and economical, a platform of timber or concrete may be placed as foundation to distribute the sewer loads and to reduce unit soil loadings to a safe figure. The use of pile bents instead of a supporting platform may be found necessary; and the bents should be spaced at suitable intervals to support the sewer load, the piles being driven a proper depth into firm material, or deep enough in yielding material to support their loads by skin friction.

Uneven settlement between sewer pipes and adjacent manholes, or other sewer structures, may result from unequal soil loadings and this may be corrected by making suitable provisions to support the structures and to distribute the loads equally over the bearing material. Where the sewer pipes used are longer than 4 feet, as in the case of some reinforced concrete pipes and asbestos-cement pipes, flexibility of the pipe line at manholes should be provided by using, adjacent to the manholes, short lengths of pipe, not over 4 feet, and bituminous joint compound. This arrangement will reduce the magnitude of bending stresses which would be developed if full pipe lengths and rigid joints were used.

The intentional admission into sanitary sewers of ground water from underdrains and ground water which has seeped into cellars and basements should be prohibited so far as it is practicable. Replies to the questionnaire previously mentioned include data regarding the admission of cellar drainage into sewers. The replies indicated that nearly 75 per cent of all the municipalities believed cellar drainage is not admitted to their sewers, and practically 100 per cent of those having sanitary sewers reported it to be excluded from them.

Storm Flow in Sanitary Sewers

The most common sources of storm flow in sanitary sewers are the intentional discharge of roof water into the sewers and the leakage of storm water runoff through openings in and around manhole covers.

Roof Water

Roof water may find its way into sanitary sewers through downspouts, or roof leaders, connected directly to the sanitary sewer system.

Whenever it is necessary to provide means for disposal of roof water, it should if possible be discharged into storm sewers and not into sanitary sewers.

Data obtained by questionnaire indicate that 85 per cent of the Massachusetts municipalities having sanitary sewers do not believe that roof water is admitted and 90 per cent of the municipalities having combined sewers admit roof water. About 80 per cent of the municipalities with sanitary sewers reported an ordinance prohibiting the admittance of roof water, and in about 70 per cent of these places, a fine was provided for violation of the ordinance. The fines ranged in magnitude from $1.00 to $1,000 but in general were in the neighborhood of $20.00 to $25.00. Nearly all of the municipalities felt that they did not experience any serious difficulty in enforcing their roof water ordinances. It therefore would seem proper to conclude that, where roof water was reported as entering sanitary sewers, only a limited number of roofs were permitted to be connected, and these to meet an urgent need which could not otherwise be readily satisfied.

Cost of Roof Water in Sanitary Sewers

Estimates have been made by analyzing the new sanitary sewer system at Cranston, Rhode Island, to indicate the effect upon construction costs and operating costs which would result from the universal admittance of roof water into the city's sewer system. Assuming a rainfall intensity of three-quarters of an inch per hour for a storm of one hour's duration, which is not excessive, and a runoff of 85 per cent of the rainfall reaching the roofs, it is estimated that the total rate of runoff from all roofs would be 3⅓ times the maximum rate of sewage flow. To accommodate this additional load of roof water would require that instead of a 42-inch main sewer there should have been a 72-inch sewer, laid at the same gradient. This large 72-inch sewer would doubtless have cost at least 2½ times as much as the 42-inch sewer, and there also would have been a substantial increase in the cost of the rest of the sewer system.

An estimate of the increase in annual operating costs for pumping and treatment of the volume of roof water was made assuming that 85 per cent of a 40-inch annual rainfall upon the roofs would enter the sewers. The volume of rainfall to be handled for approximately 66 miles of sewers, which would be needed to serve the tributary area when fully developed, is estimated to be 280 million gallons per year, for which the pumping and treatment cost, at $14.00 per million gallons, would be nearly $4,000 per year. This total annual volume of roof water is estimated to be almost twice the total actual volume of infiltration for the same sewers, under Cranston's low rates of infiltration.

The foregoing figures as to costs of construction and operation show that the universal admittance of roof water into a sanitary sewer system would be an expensive luxury, although it seems proper to plan to admit to sanitary sewers the storm flow from roofs in limited congested areas if no other means were available for its disposal.

Storm Water Runoff

Generally the leakage of storm water runoff into sanitary sewers results from the flooding of manhole tops during storms of relatively high intensity when the storm water sewers are not able to remove the storm water runoff with sufficient rapidity, or when no system of sewers is provided to carry storm water.

An analysis of the rainfall records and records of daily volumes of sewage flow at Cranston, Rhode Island, has been made in an effort to interpret how much the leakage of storm water runoff into the sewers adds to the total volume of sewage flow.

Records of the total sewage flow on days when rainfall occurred were compared with the total sewage flow on days when there was no rainfall. This comparison showed an increase in total sewage flow on rainy days, varying with the intensity and duration of the storm. For a storm amounting to about ¼-inch or less in 24 hours there appeared to be practically no increase in total sewage flow unless the storm was of relatively high intensity, and even then the increase did not exceed about 200,000 gallons per day; for a total rainfall of ½-inch in 24 hours the increase in sewage flow ranged from about 100,000 gallons per day to about 350,000 gallons per day, according to whether the storm was of high or low intensity. For a total rainfall of one inch in 24 hours the increase in flow of sewage ranged from about 300,000 gallons per day to about 550,000 gallons per day; and for a total rainfall of 2 inches in 24 hours the increase in sewage flow ranged from about 750,000 gallons per day to about 1,000,000 gallons per day. Figure 6 presents these data in diagrammatic form. The flow of sewage was from a total length of about 66 miles of sewers, and the data indicate that a total 24-hour rainfall of 2 inches increased the flow between 11,400 gallons per mile per day and 15,200 gallons per mile per day.

Estimates based on records of the total number of storms of various magnitudes occurring during a two-year period in the Cranston area indicate that the total annual increase in sewage flow caused by leakage of storm water runoff into the city's separate sewer system would be in the neighborhood of 16 million gallons per year, or about 240,000 gallons per year per mile of sewer. This quantity does not represent a large item of annual costs, and the sewer capacity which it would require is not an important factor.

At Cranston there was no storm water sewer system or drainage system, except in limited areas, and no doubt the volume of storm water runoff entering the sanitary sewers by leaking through manhole covers was somewhat larger than it would be if a system of sewers or drains were provided to remove rapidly storm water from the ground surface. It was found that the greater part of the leakage through manhole covers occurred in localities where the covers were subject to flooding during the more severe rainstorms. Some of the leakage was eliminated by plugging the four ventilation holes in the manhole covers and by making sure that the covers fitted tightly down upon the frames. The frames and covers, when purchased, had their bearing surfaces machined to afford a reasonably good fit.

So far as is practicable the location of manholes in gutters or in other depressions should be avoided.

Conclusions

It is logical to conclude from the facts presented herein that:

(1) Infiltration of ground water into sanitary sewers varies greatly in different sewer systems. Leaky sewer joints are the most productive source of infiltration. Infiltration can be controlled within prac-

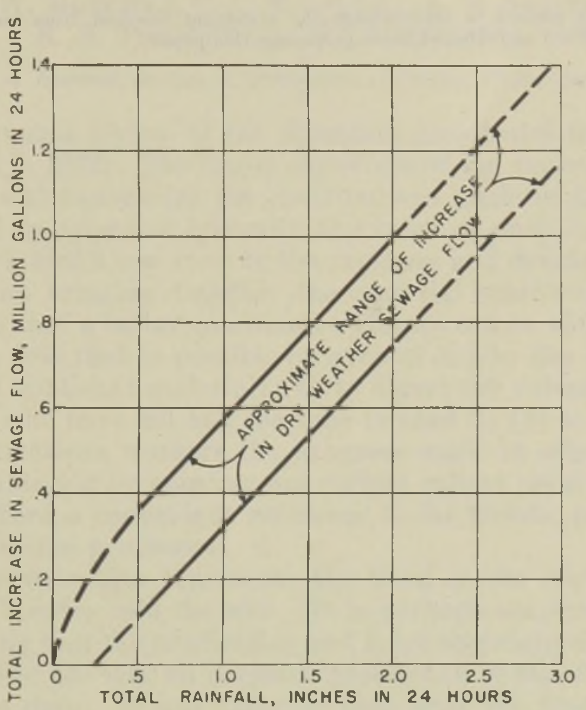


FIGURE 6.—Effect of leakage of storm water runoff through manhole covers in increasing dry weather sewage flow in about 66 miles of sanitary sewers at Cranston, R. I.

tical limits if proper precautions are taken in constructing and testing the sewers. The cost of infiltration may be a considerable item of annual expense where pumping or treatment of the sewage is involved. Infiltration should be held to a minimum.

(2) Cement mortar is extensively used for making sewer pipe joints, and tight joints can be made if proper care and attention are given to the work; however, the use of bituminous joint compound has gained much popularity in recent years. Bituminous joint compound appears to possess all the good qualities of cement mortar for making sewer pipe joints and in some respects it appears to be superior.

(3) The importance of properly supporting sewer pipe lines and of properly bedding and cradling the sewer pipes should be clearly recog-

nized as a necessary precaution against breakage, caused by trench loadings and the resultant infiltration.

(4) Admittance of roof water into sanitary sewers is a costly practice if permitted on a large scale; however, it is reasonable to plan to admit roof water from limited congested areas if there is no other suitable means for its disposal.

(5) Leakage of storm water runoff into sanitary sewers through ordinary openings in and around manhole frames and covers does not seriously increase the total sewage flow and is not a large item of annual cost.

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Sewage Research

A CRITICAL REVIEW OF THE LITERATURE OF 1944 ON SEWAGE AND WASTE TREATMENT AND STREAM POLLUTION

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The 1944 annual review of the literature constitutes the thirteenth since the start in 1932. The broad objectives of the review have been: (1) to collect and summarize the contributions made in the published literature; (2) to appraise critically the value of such contributions; (3) to furnish a bird's eye view of the progress and developments during the year by bringing together the material scattered in various publications so that a better coordinated picture can be obtained by the workers in the field than is possible by current day-by-day disconnected reading of the published material; (4) to digest the voluminous literature for those who have not had the time to read it; (5) to bring to the attention of American workers the progress made in other countries; (6) to arouse interest by pointing out certain salient points in the articles; (7) to afford a convenient reference to the trends, progress, and developments in the profession.

The 1944 review also represents the third in the series since the United States's entry into the war. It is perhaps surprising and certainly gratifying that the predictions and fears entertained at that time as to the effect of the war on research production in this field have not materialized to date. It was expected that after the first year of the war, when the backlog of pre-war investigations was exhausted, a sharp decline in the number of technical papers would take place. The maintenance of the pre-war level in the number of published articles reviewed has been accomplished despite a sharp curtailment of articles received from abroad. Of late the Gesundheits Ingenieur has become available, which shows the interest of German workers in sewage treatment and fails to reveal any major trend in more primitive types of land disposal or lowering the standards. It shows increasing interest in high rate filtration. A more detailed view of the situation in Germany will have to await the end of the war. In Britain the interest of the workers in high rate filtration and in modifications of the activated sludge process has been maintained. The ever present problem of industrial waste treatment in England has been aggravated by war production, but here again there appears no sign of lowering the bars.

The maintenance of pre-war level of the number of published articles in this country indicates the continued interest in the field, and a determination, despite the war, to cope with added problems arising from it without allowing any great deterioration of stream conditions. It also reveals considerable ferment, planning and preparation for the postwar era to tackle the unsolved problems of pollution and treatment. It is, therefore, safe to assume that without the war there would have been a natural increase in the number of articles published, and that there has been only a levelling off during this period.

Naturally, there has been some shift of interest and emphasis in the problems, as revealed by greater preoccupation with the treatment and disposal of industrial wastes, with emergency devices of treatment and disposal such as on land and lakes, additional results from the operation of army camp plants, grease removal and salvage.

There has been no additional evidence as to the possibility of transmission of poliomyelitis through sewage or water. The possibility of the transmission of this disease or other virus diseases is not, however, definitely eliminated.

The results of the most comprehensive pollution survey ever undertaken of a large drainage area, namely, the Ohio River Pollution Survey, referred to last year, has been submitted to Congress and published as House Document No. 266. It is not possible to summarize the wealth of material contained therein. In connection with the question of transmission of disease, attention is called to the Epidemiological Studies reported in the third volume. In probing as to the causative agents of intestinal disorders of gastro-enteritis, striking experiments were conducted on human volunteers who drank Berkfeld filtered sewage, apparently sterile, or with only a few coliform and other organisms. Definite and characteristic symptoms of intestinal disturbances were noted. The possibility of passage of certain vibroid organisms, spirochetes, *Pseudomonas*, virus, toxins and other chemical agents as incriminating factors is suggested, although the evidence is fragmentary and inconclusive.

The section of the report containing the industrial waste guides contains valuable information on brewery, cannery, coal washery, coke, distillery, meat, milk, oil, paper and tannery wastes.

The organization of the paper pulp and paperboard industry as the National Council for Stream Improvement marks another effort on the part of a large industry (others being dairy and steel) to solve the problem collectively. It indicates the cognizance taken by the industry of the problem and its intention to do its share of stream pollution abatement in affected localities, by organized research.

Another noteworthy event of the year is the publication of Professor Phelps's book on stream sanitation which should prove of great value to students, teachers and investigators alike, interested not only in streams but also in sewage and waste treatment problems.

The progress report of the committee of the Sanitary Engineering

Division on Sewerage and Sewage Treatment (146) summarizes and reviews the advances made since the last report in 1941 in the field of stream pollution, sewage treatment and waste disposal.

Attention is also called to the publication of the manual on "Occupational Hazards in the Operation of Sewage Works," published by the Committee on Sewage Works Practice of the Federation of Sewage Works Associations. In the present review no attempt has been made to include the work published in this field.

The Research Committee would welcome comments, criticisms, and suggestions with a view toward improvement of the annual review to make it more serviceable and useful to the profession in general. It is possible that certain phases are overemphasized while others are not emphasized enough.

GENERAL

(*See also* Stream Pollution Section)

Germicides and Their Action

The various theories of the action of chlorine and chlorine compounds in killing micro-organisms is discussed by Chang (42). Carefully conducted experiments to substantiate the killing mechanism of chlorine and chlorine compounds on *E. histolytica* cysts are reported. It was demonstrated that gaseous chlorine and the chlorine in compounds such as HTH, di- and mono-chloramine, halozone and succinchlorimide actually penetrated into the cysts. The cyst penetrating power of gaseous chlorine was the greatest, followed by HOCl, halozone, dichloramine, succinchlorimide and monochloramine in descending order. The cyst penetrating power and cysticidal efficiency of the different chlorinating agents ran parallel. Between pH 2.0 and 5.0, most of the chlorine exists as HOCl. At pH above 8.5 a very small amount of HOCl is formed and most of the chlorine exists as OCl^- which has no cyst penetrating or cysticidal action. The action of chlorine and chloramine compounds on cysts was attributed to the active chlorine which may oxidize or chlorinate the proteins in the cell. Oxidation by nascent oxygen is considered unlikely. It was found that definite destructive changes occurred in cysts exposed to minimal cysticidal doses of chlorine. The possibility of similar and other mechanisms in bactericidal action of chlorine is suggested.

The importance of undissociated molecules as differentiated from their ions of antiseptic compounds such as sodium benzoate and salicylic and sulfurous acids as the toxic principle, is emphasized by Rahn and Conn (158), and hence these antiseptics are greatly more efficient in acid solutions. The benzoate, salicylate and SO_3^{--} and HSO_3^- ions are comparatively ineffective. It is the undissociated benzoate, salicylate and H_2SO_3 that have the greatest germicidal effect. The difference in the efficiency of undissociated molecules and the ions of the same acid may be explained on the basis of penetration of the cell membrane.

In pulp, paper and paperboard mills, coliform bacteria and certain related species are the chief slime forming bacteria according to Sanborn (178). Pollutional types of coliform bacteria are effectively eliminated by chlorine and chloramine treatments. The eradication of mucoid forms is more difficult due to the gelatinous material in which the cells are embedded. Most of the coliform organisms found in slime growths from mills belong to the *Aerobacter* group of which *Aerobacter cloacae* is the most prevalent species. In order to eradicate the types resistant to chlorine a great number of chemicals were tested of which the following gave good results: trichlorophinate fractions, metallic salts of chlorinated phenols, chlorinated isopropyl phenols and various alkyl derivatives of halogenated phenols.

Isolation of two fungi from extremely acid solutions (pH 0.2 to 0.7) containing 4 per cent copper sulfate was reported by Starkey and Waksman (192). These organisms grew well in extremely acid media (pH 0.3–1.0) and one fungus grew at pH 0. These fungi were able to grow in media saturated with copper sulfate. The tolerance to acid and copper sulfate is believed to be the highest yet recorded for any living organism.

Anderson (6) determined the toxicity of various substances found in industrial wastes using *Daphnia magna* as test organism. The threshhold concentrations for immobilization of daphnids by forty-two substances were given.

Loss of Vitamin During Decomposition

Riboflavin, pantothenic acid and nicotinic acid in the aerobic composts of plant residues were found to increase during the first two weeks, accompanying the rapid initial microbial development, according to Starkey (191). As the decomposition of the organic matter progressed, vitamin content markedly decreased, so that well composted materials had a lower vitamin content than the initial plant residues. Under anaerobic conditions there were not so great increases in vitamin content during early stages of decomposition.

Isolation of Pathogenic Organisms from Sewage

From 106 samples of sewage in Buenos Aires examined by Ferramola, Monteverde, and Leiguarda (64), 11 samples contained members of the *Salmonella* group. The greater number of positive samples were obtained in the summer. Four positive isolations of the same organisms were made from the La Plata River.

Phosphorus and Sewage Treatment

The removal of fertilizing elements from sewage and plant effluents is considered an important item in stream pollution control by Sawyer (180) for the following reasons: (1) the maintenance of the quality of surface water supplies; (2) the control of algae growths; (3) the control of deoxygenation rates in polluted streams; and (4) conservation of fertilizing elements. According to the author the removal of such fertilizing elements as nitrogen and phosphorus by sewage treatment processes would be worthwhile for the above mentioned reason. The treatment of sewage by ferric chloride would help remove the phosphorus. To remove the nitrogen and the phosphorus, the author suggests the addition of carbonaceous matter to sewage and the conversion of these elements to organic forms in the sludge produced by the activated sludge process. As a practical measure of approach the author suggests the use of certain carbohydrate wastes such as sulfite liquor. Under unusual conditions such an objective may be necessary and feasible, as in the Lake Region in Wisconsin where even treated effluents are claimed to have a deleterious effect on the receiving waters.

In England, Jenkins and Lockett (97) have estimated the loss of phosphorus during sewage treatment. The removal of phosphorus by treatment at the Coleshill Works of the Birmingham Drainage Board and at Mogden of the Middlesex Main Drainage Works is calculated to be 54 and 40 per cent, respectively, of the amount present in crude sewage.

Biological Population of Sewage Treatment Plants

A method of assessing the protozoan population of sewage treatment plants is described by Barker (20). It is suggested that such a study provides information regarding the interrelationships of various forms and species and may indicate the efficiency and the state of the purification process. The same author (19) as a result of a survey of the protozoan population of three treatment plants comes to the conclusion that the protozoan fauna of sedimentation tanks is restricted. In aeration tanks the fauna is dense and diversified. Trickling filters show a few instances of seasonal prevalence of certain types such as the winter prevalence of naked rhizopods (*Amoeba actinophora*), small flagellates (*Oikomonas stenii*) and a few ciliates (*Chilodon*).

ANALYTICAL PROCEDURES

The successful use of an automatic residual chlorine indicator and recorder was reported by Caldwell (38). The intensity of the blue color produced by ortho-tolidine in the alkaline range, with residual chlorine, was recorded through a photoelectric cell. The range of 0 to 1.5 p.p.m. residual chlorine had a sensitivity of about 0.01 p.p.m.

Allen (4) adapted the benzidine hydrochlorine method for sulfates to sewage. With care in the technic of washing and aging of the moderately insoluble benzidine sulfate complex, a fair degree of accuracy may be expected, particularly in sewage of high sulfate content.

A simple field test for determining chlorides with the use of mercuric nitrate and S-diphenylcarbozone was reported by Kaye and Castillo (105).

Pereira's colorimetric method for determining iron by means of protocatechuric acid was applied to feces samples (149).

An easier method of determining suspended solids according to Mathis (126) consists of centrifuging 50 ml. sample for 20 minutes, decanting the supernatant, drying the residue in the tube for one hour, and cooling from 2 to 5 hours before reweighing the tared tube. Settled sewage and plant effluent samples check the Gooch method within 0.2 mg.

Fischer and Symons (65) discuss the technic of determining settleable solids by the difference between total and nonsettleable suspended solids.

The importance of standard technic, the reactions, the reliability of results, and the interpretive value of the oxygen consumed test was clarified by Cameron (40). "It is a good relative test but lacking in the absolute sense chemically and it does not bear any essential relationship to biochemical needs."

A modification of the relative stability test for sewage using brilliant cresyl blue, thionin, and methylene blue, by Hopper and Briscoe (89), was interesting. Sewages having a relative stability of less than 25 per cent could be tested in one-half the time by substituting brilliant cresyl blue in place of methylene blue. If 2.7 per cent thioglycollate was added the samples could be tested in one-fifth the time.

A method for the determination of low concentrations of carbon monoxide, reported by Polis, Berger and Schrenk (152), should prove helpful to those interested in detecting poisonous gases as hazards in sewers and sewage treatment plants.

DISPOSAL WITHOUT TREATMENT

Revival of interest in land disposal of sewage occasioned by emergency war conditions warrants the recording here of the literature pertaining to it. Application to land is practiced, according to a United States Public Health Service survey, in 103 municipal plants in the United States, most of them in small communities. O'Connell and Gray (141) consider such disposal valuable not only as an emergency measure but as a legitimate, effective and practicable method for treatment of sewage and industrial wastes under certain conditions. Various phases of land disposal, lagooning and ponding of sewage are discussed in a creditable manner.

The application of this problem to South African conditions is discussed by Spencer (190). Sewage is applied on land either after primary or secondary treatment. Of the two functions of sewage irrigation; namely, disposal of sewage and raising of crops, the latter can be considered secondary. The various methods of irrigation are discussed.

The disposal of raw army camp sewage into three inter-connected land-locked lakes is reported by Trubnick (207). Studies were conducted to determine the extent of pollution and self-purification. The B.O.D. decreased from an average of 43 p.p.m. below the point of discharge of sewage to 22 p.p.m. at the outlet of the third lake. The B. coli similarly decreased from 413 per cc. below the point of discharge to 5.5 per cc. at the outlet of the third lake. Sludge banks were formed and gasification observed in the first lake but none in the lower lakes. The numbers of plankton organisms were exceedingly high. The high alkalinity of the water in the lakes was used up by the sewage. The D.O. decreased but was not completely depleted. At times D.O. reached values above saturation due to the plankton. Greatest purification took place in the first lake.

Müller (135) has set the dilution required in Germany for discharge of sewage into pure streams as follows: biological treatment 1:20, settling 1:40, chemical treatment 1:20–1:40. Calculations show that the relation between sewage produced and total runoff is 1:24 so that settling alone is insufficient. Since insufficient land is available for land disposal, sewage should be treated biologically before discharge.

SEDIMENTATION

Steinour (193) has presented a study of sedimentation in simple systems under conditions of laminar flow. As an initial step the effect of concentration on the rate of fall of uniform well-dispersed spheres was investigated both theoretically and experimentally using, first, suspensions of tapioca particles in oil and, later, uniform microscopic glass spheres. Empirical solutions of functions of concentration were obtained. These studies were then extended (194) to suspensions of uniform angular particles, using closely sized emory particles, both flocculated and nonflocculated. Except for the value of an experimental constant, one rate equation applied to both states, provided the flocculated suspensions were highly concentrated. Comparison with the tests on uniform spheres indicated that a portion of the liquid suspension medium was carried down with the angular particles during their fall. In the third article (195), rates of sedimentation of concentrated flocculated suspensions of various finely divided solids are reported. Each solid embraced a wide range of particle size and was tested at a series of concentrations. The equation previously developed was, in general, supported by the new data.

Bushee (37) presents a method of using a control section to regulate velocities in grit chambers of rectangular cross section. The method consists essentially in determining the relationships so that the straight line depth versus cross sectional area curve of the rectangular grit chamber lies as closely as possible to the depth versus quantity/velocity curve of the control section over the range of flows being considered. A graphical method for determining these relationships is described, using a free-flowing Venturi flume as a control. The author states that "The method is perfectly general and can be used for any type of control section for which a curve can be drawn." In the example given of a four-foot wide chamber, as the flow varied from 3.16 to 11.9 c.f.s. the velocity varied from 0.97 to 1.03 feet per second.

Gifft (73) describes methods of using the Sutro weir and Parshall flume for controlling velocities in grit chambers. Several charts are presented for aiding in the solution.

CHEMICAL AND MECHANICAL TREATMENT OF SEWAGE

Berry (27) says that the chemical precipitation of sewage has been employed to a limited degree in Canada during the years past but that it has generally been abandoned, although some interest in its revival has been manifest. The cost of chemicals is higher in Canada than in the United States.

Baxter (21) states that the ferric sulphate added to the primary tank effluent in the Guggenheim process plant at Anderson, Ind., varies from 2 to 6 p.p.m. of Fe and that the average dosage for a 17-month period was 3.6 p.p.m. of Fe. He further states that the 5-day B.O.D. of the raw sewage is 157 p.p.m. and of the primary effluent 59 p.p.m. The report goes on to say that lime is added on rare occasions to the influent of the primary settling tanks to maintain the pH of the primary effluent at 7.6. In addition to the sanitary sewage, the Anderson plant receives steel mill pickling liquor, chrome plating wastes, pickling liquor from aluminum forgings, canning factory wastes, packing house wastes, and the wastes from a sodium silicate manufacturing plant. It would seem quite possible that a combination of these industrial wastes may have a beneficial effect and account for the extremely high removal of B.O.D. in the primary treatment process.

Gehm (72) reports experimental work on the determination of bacterial reduction by chemical treatment. The work indicates that the addition of ferric chloride results in remarkable bacterial removals even with wide ranges in pH values. The high reductions of both total bacteria and *B. coli* occurred when the pH was lowered below 4.0 or raised above 8.5.

Wood (221) describes a coagulating process comprising the diffusion of carbon dioxide through the liquid containing the coagulate matter and having a pH not less than that at which calcium carbonate can exist in a liquid. This is followed by the addition of a coagulant to reduce the pH an additional 1.0 to produce the desired coagulation.

In a report on the Brighouse Disposal Works (14) it is stated that intermittent lime precipitation is used to take care of flushes of wire pickling refuse to the sewage treatment works. The lime addition is controlled by a pH recorder.

Hoak, Lewis, and Hodge (87) present their procedures for the determination of the basicity factor which can be used as a means of comparing the relative neutralizing values of limestones and limes. The authors say that their method should be useful to operators of water, sewage, and industrial waste treatment plants.

Laboratory experiments with mechanical flocculation of suspended solids reported by Popel (154) indicate that the adsorption of finely divided material is aided and that the time is reduced. Flocculation is increased with increasing quantities of suspended solids and by mixing different types of waste or by artificially increasing the suspended solids by adding return sludge. The practice enhances the rate of settling of suspended solids in trickling filter effluents but has no economic value in the settling of good activated sludge. Plant experiments showed that flocculated and settled effluents had 15–20 per cent lower oxygen consumed values than quiescently settled raw sewage.

Gehm (71) discusses the characteristics of sewage affecting clarification by preflocculation. Settleable sewage solids do not act appreciably as adsorbing surfaces for the non-settleable solids. Clarification by preflocculation is brought about by the coalescence of non-settleable particles. It follows as a corollary that the return of fresh solids does not enhance clarification. Particles of 15–40 microns which constitute the greatest portion of sewage solids are removable by preflocculation.

GREASE REMOVAL

Grease as a source of difficulties in sewers and sewage disposal plants, both in municipal and army installations, and grease salvage as a source of revenue have been the subject of considerable discussion during the year. It was the subject of a symposium in which the different aspects of the problem were examined. Dawson and Kalinske (51) developed a laboratory test to rate the capacity of grease interceptors. The results showed that the efficiency of grease removal decreased with increasing rates of flow and also decreased after the grease accumulation in the interceptor had reached a definite amount.

A fire due to the discharge of gasoline and oil into one of the storm drains in Baltimore led to the passage of an ordinance requiring the storage of such materials (106). The city pays a company for collecting the waste which is recovered. The effect of grease on collection systems and on the maintenance of sewers was discussed by Cohn (48). The practice of salvaging grease in New York City plants was described by Donaldson (55). The skimmings from settling tanks are removed. The quantities of skimmings removed, moisture and grease content are given. These are sold to a contractor under certain stipulations. Sale and recovery of grease from skimmings is also being practiced in The Sanitary District of Chicago (145).

Experiments dealing with various auxiliary methods of grease removal were reported by Eliassen and Schulhoff (60). They found that diffused air or mechanical aeration, aerochlorination and vacuum flotation had no effect on increasing the grease removal over removal accomplished by plain sedimentation. However, the different methods tried took grease out of sewage and relieved the load in the skimmers of the primary settling tanks. The removal of grease by vacuum flotation was the subject of another paper by the same authors (59). Pilot plant experiments conducted on army camp sewage showed that grease removals of from 45–67 per cent could be obtained by this method. The authors state that removals obtained by vacuum flotation "should be satisfactory as long as primary sedimentation follows the vacuum flotation unit."

McCaskey and Vermette (128) gave a general discussion of grease in sewage at army camps. The effect of grease on sewage treatment plant operation was discussed by Nelson and Lauer (138).

The quantity and value of grease extracted from domestic sludge was discussed by Brandon (33) as it applied to conditions prevailing in England. It was reported that the grease content of fresh solids decreased from 23.3 per cent to 9.7 per cent on dry basis after five weeks on sludge drying beds. Because of the high percentage of unsaponifiable matter the value of grease is not great.

TRICKLING FILTERS

Practically all of the literature on this subject in 1944 discusses high rate filters in one way or another. The general tone seems to be an acceptance of high-rate filtration as a proven process but the several methods or means proposed to attain these high rates are still the subject of much controversy, either expressed or implied.

Hurley (93) reviewed the recent developments in the field of biological sewage filtration with the view of assessing the work done by (*a*) high rate operation of single stage open filters (*b*) processes involving recirculation (*c*) operation of filters in series and (*d*) enclosed aerated filters. The results of various investigations dealing with these different processes are compared on the basis of rates of application, percentage purification effected and pounds of B.O.D. removed. The processes are divided in general into two groups (*a*) partial treatment and (*b*) full treatment. The Levine, Halvorson and Jenks processes are considered as partial treatment. It is shown that B.O.D. removals increase with the strength of feed even though the quality of the effluent may deteriorate. High rate filtration as a means of partial treatment has certain advantages over partial treatment by the activated sludge process. The alternating double filters and enclosed aerated filters are considered as full treatment processes.

Experimental work to increase the rate of application of sewage on the filters at Huddersfield, England, is reported by Goldthorpe and Nixon (75) with the object of increasing the work done by the overloaded existing filters. With loadings of 0.3–0.42 pounds B.O.D. per cubic yard per day, the B.O.D. in the final effluent varied from 20 to 40 p.p.m. with a B.O.D. in the raw sewage of 180–200 p.p.m.

Reynoldson (164) discusses the biological aspects of the experimental work at Huddersfield. Correlations between temperature, film growth ponding and numbers of *Psychoda* flies are made, indicating again that under favorable temperature conditions (20° C.) when the number of flies is high, the film growth is kept in check by the scouring action of the flies and ponding is at a minimum. Under 10° C. the flies are few but film growth is kept in check by the temperature limitation. The greatest film accumulation and worst condition of ponding occur during the period of March to June with temperatures rising to 19° C., when film growth is not kept in check by either the temperature or *Psychoda*. The restriction of the macro-fauna to *Psychoda alternata*, as is the case in Huddersfield and many other plants in this country, is considered disadvantageous because, it being a warm-weather fly, its activities are restricted in the winter and do not start in the spring soon enough to overcome the ponding. A more diversified fauna would be active over a wider range of temperature and would be more desirable. Consideration should also be given to the temperature optima of film forming fungi. If they are such that remain active at low temperature, then their activities in early spring will increase to such an extent as to result in ponding before the *Psychoda* can counterbalance the increased growth.

Bacterial reductions by filters were studied by Allen, Tomlinson, and Norton (5). The reductions from the primary and secondary filters of the alternating double filters operating at an average rate of 240 gallons per cubic yard per day were compared with that of a single filter operating at the rate of 60 gallons per cubic yard per day at the Minworth plant in Birmingham, England. The results showed that the bacterial reductions were greatest in the low rate, single stage filter and the least in the primary unit of the double filter. The reductions in each filter were greater in the warm period than in the cold. There was no definite correlation between purification as measured by B.O.D. and bacterial reduction.

The biofiltration process has been studied experimentally in England. Rose (170) reported on the results of a small plant at Oxford. The treatment process consists of two filters in series with primary and secondary settling tanks. Recirculation is from the underflow of the primary filter to the primary clarifier and from the secondary clarifier to the secondary filter. The application of raw sewage on total media is 800 gallons per cubic yard per day. The B.O.D. of the raw sewage was reduced from 300 p.p.m. to 40 p.p.m. in the final effluent. Clogging of the secondary filter was overcome by increasing the size of media from 1½ inches to 2½ inches. The high turbidity and suspended solids in the final effluent commonly encountered in biofilter plants is attributed to the breaking up of the solids on pumping.

By continuous dosing, as opposed to intermittent application at high instantaneous rates, Thompson and Watson (205) at Leeds, England, were able to demonstrate that the trickling filter was much more efficient, *i.e.*, the loading per cubic yard could be increased with no loss in removals.

Along this same line, remodeling of existing trickling filters at Sioux Falls, South Dakota (86) and San Bernadino, California (122) was completed and showed that additional capacity can be realized from existing installations at relatively low cost by proper attention to dosing and/or recirculation of effluent.

Acting on the theory that additional aeration within the bed is needed to prevent ponding, Goldthorpe (76) has designed and installed at Huddersfield, England, vertical aeration ducts three inches I.D. placed at ten-foot centers throughout the bed area. He also advocates the use of a specially constructed brick as a filter medium; this brick is designed to retain the sewage in shallow pools and thus increases the detention. No results on the performance of these novel ideas have as yet been published.

Imhoff (96) compares recirculation with dilution by rain. With recirculation a heavier sewage can be treated on shallower beds. The recirculated effluent adds oxygen, nitrates, organisms and enzymes to the sewage, makes it fresher, reduces odor and flies and helps purification. The disadvantage is increased power cost.

The biological film in trickling filters absorbs the colloidal and soluble materials, the accumulated material is partially destroyed by liquefaction and gasification and the insoluble material is washed out or held as sludge, according to Pönninger (153). Maximum loading is determined by the rate of absorption and decomposition. The limit of loading depends on the strength of sewage, quantity of film and air supply. For high rate filters two conditions are necessary: (1) low B.O.D. of influent and (2) high surface loading. With weak sewage no suspended solids are retained, sludge does not form, *Psychoda* breeding does not occur and odors do not develop. Recirculation of effluent reduces the strength of sewage and results in low nitrate formation. Filters receiving the limit of loading discharge sludge long before it can be nitrified. Loading expression preferred by the author is volume applied per unit volume of stone (M^3 sewage per M^3 stone per day). To prevent clogging, the author tried dilution of sewage with higher application to the filter so that sludge is washed out. Artificial aeration was also tried. The volume and velocity of the flow through the filter exerts a washing or flushing effect. About 50 per cent of the total oxygen demand is ascribed to the sludge. The reduction of air supply affects only the destruction of the sludge without affecting the purification of sewage. In low rate filters, resting, in order to furnish aeration time, may be substituted by artificial aeration. Whereas a filter operated with intermittent dosing clogs rapidly, no clogging occurs with artificial aeration. Since with weak sewage or recirculated sewage, sludge formation is at a minimum. *Psychoda* larvae do not become predominant. When they are numerous they should be left alone as they destroy the sludge. With unnecessarily long aeration, a part of the nitrogen in the sludge may become available for nitrification. The fertilization of receiving water is not affected whether nitrification takes place in the filter since the total nitrogen is the same.

Popel (155) calls high rate filters "washing trickling filters." Washing should not be considered as mechanical action only but the biological action should also be considered. Popel found that the efficiency of trickling filters depends upon (1) B.O.D., (2) utilization of surface area, (3) depth of filter, (4) volume and surface loading, (5) oxygen excess in air and (6) temperature. Up to a B.O.D. of about 500 p.p.m. in the applied sewage, the purification is about 80 per cent without recirculation. Surface area depends on the form and type of media and size. The influence of either of these factors is small. Rough surfaces induce clogging. With equal loadings and temperatures, a filter six meters deep is about twice as efficient as a unit one meter deep. Recirculation gives an effect similar to increasing the depth of the filter. A 1:1 recirculation has the same value as increasing the depth from 1 to 6 meters. With a 2:1 recirculation, the efficiency is similar to a filter 15 times deeper.

The late Samuel Ellsworth (61) recounts his experiences with a biofiltration plant at an army post showing 75 to 90 per cent B.O.D. reduction at loadings up to 5 lbs. B.O.D. per cubic yard per day. Griffin (79) elaborates somewhat on Ellsworth's observations indicating that New England experience is in line with the more comprehensive observations at army camps by Kessler and Norgaard (108) for high filtration plants.

Marston's analysis (125) of high rate and standard filters indicated that the former plants are much more susceptible to temperature, having a markedly lower efficiency in the winter than in the summer months. His substantiating data cover only a limited period at one plant but indicate a trend which should be checked by additional data.

Work done in England (5) on the comparison of total bacterial count and *B. coli* in the effluents of standard trickling filters (60 gal. per cu. yd. per day) and high rate double filtration with daily alternation of the order of the filters at 240 gal. per cu. yd. (total yardage) showed considerably higher removal of organisms by the low rate unit despite the fact that both units gave almost the same B.O.D. removals. This is a small, although occasionally an important, advantage for low rate filters. Similar results were reported years ago in this country.

One of the most significant contributions to the status of high-rate filtration in 1944 was the Joint Statement of Policy of the Wisconsin, Minnesota and Iowa health departments (8). This body recommends maximum clarification rates of 1200 and 600 gal. per sq. ft. per day for primary and final clarifiers, respectively, a minimum continuous dosing rate of 10 m.g.a.d., a maximum loading of ¾ pounds B.O.D. per day per square foot of filter surface (3.38 lbs. per cu. yd. per day for 6-foot filters), a minimum depth of 6 feet, etc. Based on a formula derived, the effluent B.O.D. is predictable for a given combination of daily rate of flow (m.g.a.d.), recirculation ratio and strength (B.O.D.) of settled sewage. In view of satisfactory results reported with 3-foot depth filter beds, the 6-foot minimum depth appears to be conservative. The introduction of still another unit for expressing filter loading (lbs. B.O.D. per square foot per day) adds to the already confusing picture of how best to express filter loading.

Bachmann (15) and Winfield (217) discuss filter operation. Also a round table discussion (7) on this subject brought out several tried and true solutions for some of the common operating problems—ponding, flies, distributor clogging, etc.

Kirchoffer (110) describes a small plant built to treat milk wastes on trickling filters without using a primary clarifier.

Patents

Trebler (206) and Fischer (66) disclose certain clarifier and filter combination arrangements whereby a single tank structure performs the functions of primary and secondary clarifier in a trickling filter plant. Reybold and Fischer (162) and (163) obtained patents on clarifier-filter combinations in which a filter bed surrounds the clarification tank. Shook's re-issue patent (188) covers the recirculation of filter effluent back to a point between the primary clarifier and the filter. Kamp (104) discloses a rotary distributor which is fed through siphons at the ends of the rotating arms.

ACTIVATED SLUDGE

Theory

Bloodgood (29) has presented data from the Indianapolis plant to show that the capacity of an activated sludge plant is dependent upon the concentration of the B.O.D. of the sewage. The capacity of the plant varies with the temperature but there is a lag of one month before the full effect of the temperature change is observed. He proposed that the rated capacity of activated sludge plants be based upon the millions of gallons of sewage treated daily of a stated B.O.D. strength and at a specified temperature.

Starting with the premise that the most desirable characteristics of aeration tanks are uniform turbulence and efficiency of mixing, Thomas and McKee (204) have investigated various factors influencing longitudinal mixing in an effort to develop a fundamental understanding of the process. The degree of turbulence, the mean velocity of flow, the length of the tank, the number of baffles were factors studied. They have developed a theory of mixing to improve control of the activated sludge process and believe that baffles are needed, especially in designs using tapered or step aeration.

In a study of oxidation-reduction measurements in activated sludge-sewage mixtures, Rohlich (169) found that as sewage or sewage-activated sludge mixtures were aerated, the oxidation-reduction potential increased from 0.1 to 0.375 volts. When aeration stopped, the dissolved oxygen dropped to 0.0 p.p.m. in about 40 minutes but the potential remained at 0.375 volts until the dissolved oxygen dropped below 1.0 p.p.m. and then it gradually fell to 0.250 volts in the next 60–80 minutes.

Pillai and Subrahmanyan (151) isolated the protozoa *Epistylis* from mucilaginous masses on the sides of an activated sludge tank. The isolated protozoa were as active as the normal activated sludge in the purification of sewage. They believe that aerobic purification of sewage is essentially due to protozoan activity and that the bacteria play only a secondary part.

Modified sewage aeration, a modification of the activated sludge process which yields any degree of treatment between sedimentation and activated sludge, has been further studied by Setter and Edwards (185). The degree of treatment is controlled by the air supply, the aeration period and the amount of returned solids. For partial treatment, low air supply and small tank capacity are needed and dense sludge will be produced. For more complete treatment, a greater air supply and tank capacity are required and a less dense excess sludge is produced. By combining some of the important variables into the "effective aeration period" and correcting for temperature and the amount of biological culture returned to the aeration tank, it appears possible to predict the percentage of suspended solids or B.O.D. removal which can be obtained.

Chase (43) discussed the theory and practice of the aeration aspects of high rate activated sludge or modified sewage aeration. Evidence of investigations and operation of plants shows that aeration periods shorter than those used in standard activated sludge plants can yield effluents of various degrees of purity between sedimentation and activated sludge. Where conditions warrant, the high rate activated sludge treatment offers a means for substantial economies in construction and operating costs as compared with conventional activated sludge.

Gould (77) reported that the proposed Owls Head, Newtown Creek and Rockaway plants of New York City, now under design, will be of the modified sewage aeration type.

Operation

In a report on three years' operation at the Gary, Indiana, plant, Howson and Mathews (92) state that it is necessary to neutralize the large volume of pickling liquor which arrives at the plant with lime to avoid interference with biological processes. By co-operation with the industries, the time of discharge of pickling liquor is known and at such times, the return sludge is sent back to the primary clarifiers to aid in the removal of suspended solids and iron in those units. Although the air used averaged only 0.45 cubic feet per gallon of sewage, the dissolved oxygen in the effluent from the aeration tanks averaged 7.9 p.p.m. The suspended solids in the aeration tanks averaged 1,350 p.p.m. The use of more than the required amount of air was justified as it delayed clogging of the diffusers. To combat clogging of the diffuser tubes by iron, the application of warm petrolatum to the tubes was helpful.

At Jackson, Michigan, Cameron (39) reduces clogging with an occasional dose of chlorine and with increased air for 24 hour periods to blow out the plates. All plates were removed and cleaned in a chromic acid bath in 1942.

Bloodgood (30) has derived a relationship between the percentage of return sludge by volume, the mixed liquor solids and the sludge index and by means of a nomograph gives a method for calculating the quantity of return sludge needed.

Veitch (213) states that for the West End plant at London, Ontario, the total capital cost was $268,473 or $4.17 per capita. The total operating cost was $24.23 per capita of which $8.38 represented capital charges and $15.85 operating expenses. For the whole of Canada, the average capital cost has been $8.72 per capita. At the West End Plant, the most satisfactory type of air distribution is by means of perforated pipes hung at three-foot intervals from a rail suspended along the center of the tank above the sewage level. The perforated pipes are placed crosswise in the tank just above the bottom. The whole mechanism, 120 feet long, moves slowly back and forth, a distance of three feet. This method of diffusion is said to be simple, effective and low in maintenance cost.

The new control center at the Milwaukee plant has been described by Richardson and Maiers (166). It will be possible to maintain continuously the concentration of solids in the aeration tank within one per cent.

The results of laboratory experiments dealing with the effect of chromium compounds on the purification of sewage by the activated sludge process were reported by Jenkins and Hewitt (98). Operating on a batch basis, the first addition of 10 p.p.m. of Cr as chromate to sewage had no effect on nitrification but subsequent additions stopped it. Purification was similarly affected. Dosages of chromate below 10 p.p.m. had less effect and with 1 p.p.m. no effect was noticed on nitrification. Chromium in the chromous state is not so inhibitive as chromate.

Bloodgood (31), in a review of the recent developments in the activated sludge process, calls attention to the importance of air supply and loading. To increase the work done the concentration of organisms must be augmented and an optimum environmental condition (oxygen supply) must be created for them. Uniformity of operation is essential. Mixed liquor concentration should not fluctuate without a definite purpose more than 200 p.p.m. in 24 hours. An optimum mixed liquor concentration is one that permits complete oxidation of sewage, allows D.O. in all parts of aerator and yet is not too high to use up the oxygen supply. The importance in operation control of sludge index, settling test, oxygen demand of the sludge, and D. O. in mixed liquor is pointed out. Bulking is attributed to overloading either by increased sewage concentration or by limited air supply. To recover from bulking the author recommends wasting of sludge, reduction of flow and development of new sludge. Rising sludge occurs on the other hand with insufficient load and overaeration. Turbid effluents may be produced both in under and overloaded plants.

Beard (22) gives an account of the efforts made to improve the performance of a Hays treatment plant in an army camp. Each time a change was made the performance improved for a time and then suddenly, with no apparent cause, it deteriorated again. Some of the improvements tried were better distribution of air supply, and removal of digester supernatant liquor from the sewage flow. The plant has operated most of the time at 70 per cent of the design capacity.

CHLORINATION

Chlorination Applications

The applications of chlorination in the treatment of sewage and industrial waste were reviewed by Faber (63), together with comments on its future utility. Only disinfection, B.O.D. reduction, and the control of odors and septicity are considered well established uses. Certain other applications are sometimes successful, sometimes not. If the full possibilities of chlorination are to be realized, it cannot be regarded as a simple process; it is emphasized that the action of chlorine may be controlled and modified by combining it with other substances. A restatement of chlorination applications for effluent disinfection and for other uses in sewage treatment was provided in a paper by Bell and Heiss (24).

Preliminary recommendations for safe practice in chlorine installations at sewage treatment plants were presented in a manual prepared by the Sub-committee on Occupational Hazards of the Committee on Sewage Works Practice of the Federation (212). An appendix to the manual details forty-four accidents which have occurred at sewage works; none involving chlorine is reported. Snell (189) described the construction of a simple and inexpensive hypochlorite feeder developed for temporary use in sewage treatment at small Army installations.

In postwar planning for two large sewage treatment plants, consulting engineers recommended the inclusion of chlorination. Prechlorination to provide capacity for a 12 p.p.m. dose is one of the proposed additions to the Akron, Ohio, plant (83), and prechlorination as well as effluent disinfection are included in the high rate activated sludge plant recommended (132) for Los Angeles.

Chlorination for Disinfection

The New York State requirements and standards of design for disinfection in sewage treatment, as given by Bedell (23) are: A minimum of 15 minutes contact and of 0.5 p.p.m. residual are usually required, prechlorination of a settled effluent is ordinarily expected, and chlorination capacity to provide doses of 18, 12, and 6 p.p.m. for effluents from sedimentation units, trickling filters, and sand filters respectively are recommended.

After-growths in chlorinated sewage were discussed by Howard (91), who emphasized that under favorable conditions, regrowth occurs but that most pathogenic microorganisms are among those readily destroyed by chlorination. At Chichester, England (53), trickling filter effluent is chlorinated to protect a tidal channel used by bathers and for growing shellfish. A chlorine dosage of 5 p.p.m. apparently accomplishes the desired purpose.

At the Buffalo, N. Y., plant (35) where disinfection and solids removal provide the required degree of treatment, sewage flow averages 150 m.g.d. and an average dose of 4 p.p.m. or 4,900 pounds of chlorine per day was used in the 1942–43 period. A reduction of 20,000 pounds of chlorine over the preceding year was accomplished by close attention to dosage control, despite a 2 per cent increase in sewage treated. The kill of presumptive *B. coli* varied from 81.9 to 99.9 and averaged 97.9 per cent. More detailed data, illustrating the reduction in pollution of adjacent bathing beaches accomplished by effluent chlorination at the Cleveland Easterly Sewage Treatment Plant, were published (218).

Chlorination in Trickling Filter Treatment

In a discussion of the operation of trickling filters, Bachmann (15) recommended that odors from septic sewage may be controlled by prechlorination of the raw sewage to provide a small residual in the primary clarifier effluent. Pooling may be eliminated by applying a high dosage of chlorine during the low night flows and the same treatment has given the best results in controlling filter flies of any chemicals tried. As a remedy or corrective for filter pooling, Wisely (99) specified a chlorine dose of 15 to 20 p.p.m. in the settled sewage. This has been found successful and does not disrupt filter operation.

At San Bernardino, California, Livingston (121) found that the regular application of chlorine over an eight-hour period once each week controls filter flies on trickling filters which have fixed nozzles. Chlorination of the primary effluent at the Rotterdam, New York, plant and its effect on filter operation was reported by Winfield (217). A heavy chlorine dose (52 to 60 p.p.m.) was applied for two successive nights, resulting in the complete disappearance of a serious pooling condition. This also caused unloading of the filter to begin promptly and to continue for about 30 days. Nitrification remained good throughout this period; B.O.D. of the filter effluent increased until it reached 103 p.p.m. but then decreased to 20 p.p.m.—the lowest B.O.D. experienced at this plant. It is expected that similar treatment will be required each spring, since it is recognized that an additional load of solids is placed on the filters during the cold months of the year when primary units operate with lower efficiency.

Chlorination in Activated Sludge Treatment

In activated sludge plants at army camps, Koruzo (114) reported chlorination of return sludge with a 5 p.p.m. dosage has been found effective treatment in the prevention of bulking. Partial chlorination of waste activated sludge and of digester supernatant has also resulted in improved plant operation. Eckert (57) described the successful treatment of digester supernatant by chlorination to permit return of the liquor either to primary units or to aeration tanks, and to prevent odor nuisance when the liquor is discharged to lagoons. Reduction in B.O.D. and "modifying the carbonate equilibrium" (*i.e.*, decreasing the alkalinity and lowering the pH value) are credited to the improvement resulting from chlorination.

Chlorination in Industrial Waste Treatment

When industrial wastes are treated with domestic sewage, the load imposed may be out of all proportion to the volume of waste handled. The principal factors affecting cost and efficiency of handling are three: volume, solids content, and chlorine demand of the waste.

Municipalities are recognizing that industry should be assessed a fair charge for the resulting increase in treatment. Buffalo, New York, (201) has a special additional charge for industrial waste based on these three factors. The cities of New Brunswick, New Jersey, (143) and Cranston, Rhode Island, (10) have adopted rate charges based on volume ($22 per m.g.), solids ($5 per ton), and chlorine demand ($5 per 100 pounds) of the industrial waste.

Chlorination Research

Wattie and Butterfield (215) reported a detailed study of the influence of pH and temperature on the bactericidal effect of chlorine on *Esch. coli* and *Eber. typhosa.* They call attention to the "change over" in sensitivity to chlorine with increasing pH values between pH 7.0 and pH 8.5; at pH 7.0 and below, *typhosa* strains were consistently more resistant than *coli* strains, while at pH 8.5 and above the reverse was found. In general, the two strains were about equally sensitive to chloramine. At normal pH values, approximately 40 times more residual chlorine as chloramine was required to produce a 100 per cent kill of *Esch. coli* in the same time intervals. This data is pertinent to problems of sewage chlorination, since added chlorine may be expected to form chloramine type compounds.

Laboratory studies by Allen (3) related percentage chlorine demand satisfaction to disinfection by determining the effect on bacterial numbers of adding various quantities of chlorine to sewage.

A chlorine potential cell apparatus was reported in the development stage at the Buffalo, New York, plant (34). It is intended that this unit will function as a controller to provide automatic dosage of chlorine to the sewage and thus prevent over or underdosage.

Eliassen and Schulhoff (59), using experimental laboratory apparatus, reported aero-chlorination was found to have no effect on the removal of grease by a vacuum flotation process. In a study limited to Army sewage plants, the same authors (60) found that the inclusion of chlorine in preaeration—with diffused air or by mechanical means—accomplished no increased removal of grease by sedimentation or by vacuum flotation.

McCarthy (127) found chlorine dioxide and bromine less effective as bactericides than chlorine. Both agents were more affected by organic matter than chlorine.

The development of a practical method for generating chlorine dioxide (202) and its application to the treatment of potable water is of interest, though this new material appears to have no immediate application in sewage treatment. Chlorine dioxide has an available chlorine content of 250 per cent but, because it is more reactive than chlorine, the disinfection of polluted water has been found to require more chlorine dioxide than chlorine.

A survey of research projects (174) shows chlorination to be under investigation for a number of new applications in sewage and waste treatment problems. The recommendation (63) that a thorough study of the chemical and physical reactions involved in more specialized applications of chlorine is pertinent to study of these problems.

SLUDGE DIGESTION

Research

In continuing his studies involving the digestion of paper pulp, Straub (197) studied the effect of adding salts containing nitrogen on gas production. It was again found necessary to add lime to the digestion tanks in order to maintain proper pH conditions. The use of ammonium sulfate produced hydrogen sulfide odors and was replaced by sodium nitrate. This salt added to the digesting paper pulp increased the nitrogen content of the gas, decreased the methane content and caused a more complete destruction of volatile solids.

Experimental studies of the effects of different types of fats and oils on the rate of digestion, gas production, and gas composition, extent of grease destruction, and fuel value of the sludges is reported by Rudolfs (175). Gas production and fuel value vary directly with the amount of grease present in a sludge. In general, the rate and degree of grease decomposition are greater than the destruction of other volatile matter present in sludges. As gas producers, soaps evidently lead the list with animal fats and vegetable oils following.

Operation and Control

Schlenz (181) describes the operation of a "controlled digestion" system wherein it is possible to direct the course of digestion to accomplish sludge stabilization in a shorter time. The system embodies various tanks, piping, circulating and transfer pumping equipment to provide a thoroughly flexible control of the digestion process. Continuous or frequent circulation of the supernatant liquor with its rich seeding value is furnished, and chemicals may be added to this liquor for controlling the formation of volatile acids and ammonia nitrogen. Provision is also made for selection and production of relatively clear supernatant to be removed from the system.

In the cited plant scale tests of this system, instances are detailed where ammonium sulfate was added for ammonia nitrogen control and for dispersing scum. It is assumed that the ammonium ion added supplies the nitrogen necessary for proper biological activity. In this respect it should be noted that in the foregoing reference (197) the use of ammonium sulfate was abandoned because it developed hydrogen sulfide and caused odor nuisance.

Heukelekian (85) discusses the various factors entering into digester operation and control and aptly states that with our present knowledge, generalization does not adequately convey any picture of the manifold reactions involved in intelligent control of digestion. He concludes that both the process of biolytic hydrolysis of organic solids and methane fermentation should be evidently accelerated to the same extent, if further increase in the efficiency of digestion is to be expected. He does not believe that the addition of inorganic nitrogenous compounds such as ammonium sulfate is the answer in gaining this efficiency. In the tests tabulated by Schlenz (181) the high rate of recirculation of well seeded supernatant evidently accelerates to the same extent the two essential processes listed by Heukelekian.

Heukelekian's paper is a general discussion of digester operation and other papers on sludge digestion by Kozma (115) and Eckert (57). Kozma briefly discusses some elements of tank design, operational objectives, and control. Eckert discusses, among other things, the disposal of digester supernatant.

Scum

McDonald (130) gives an account of methods adopted and results achieved in the elimination of a rapid increase in scum layer in four digesters, due to the accumulation of mineral oils and greases, at Springfield, Massachusetts. This is a recital of studies and remedies of numerous bothersome treatment conditions due to industrial wastes containing petroleum products.

Johnson (100) relates how the large increase in scum producing solids at Buffalo, New York, necessitated draining one of the digesters in order to make pipe repairs so that better equalization of sludge loading in all four tanks would result. Although the digester was out of service 5 months, the repair work resulted in tripling the gas production in the tank.

A final summary of the contributors to the 1943 round table discussion on scum problems in digestion tanks is presented by SEWAGE WORKS ENGINEERING (11).

Supernatant

The foregoing references to Schlenz, Kozma, Eckert, and Heukelekian, and to Howson and Mathews in the following (*see* Gas Utilization) all deal with various problems relating to digester supernatant. Schlenz details methods for selection and clarification of supernatant and its recirculation to soften scum deposits. Heukelekian deals with the general principles of the subject and defines good and bad supernatant. Kozma refers to Backmeyer's plant scale tests at Marion, Indiana, (16) involving elutriation of all solids entering second stage digestion for the purposes of stopping gasification and solids flotation, achieving better concentration of final sludge solids, and the production of a clearer supernatant. Howson and Mathews claim that the wide variations in digester supernatant solids do not affect the plant efficiencies at Gary.

Liming

The relative merits of various kinds of lime for use in sludge digestion tanks are briefly discussed and summarized by Doman (54).

Digestion Temperature

Sewage Works Engineering (171) presents a round table discussion on operating temperatures in digestion tanks.

Heating digesters

Bacon (18) enumerates the difficulties experienced and corrective measures used in operating hot water coil heated digestion tanks and shows how coilless preheating of sludge by low pressure steam injection eliminates some of these difficulties, while achieving greater operating flexibility and decreasing costs.

Digestion Gas, Its Production and Utilization

Practical general information about the production of digestion gas, its ingredients, properties, collection and utilization is concisely presented by Hyde (95).

Imhoff Tank Gas

The use of Imhoff tank gas for general purposes in a plant serving 32,000 persons at San Angelo, Texas, is described by Burden (36). The author shows that covering the gas vents of Imhoff tanks for collecting gas does not reduce the efficiency of these tanks but makes operation easier, provides an effective control of foaming, and effects plant operating economies. The collected gas furnishes fuel for a 25 h.p. gas engine-driven sludge pumping unit, domestic gas service for three residences, and for open furnaces where screenings and skimmings are incinerated. The speed of the engine pumping unit is float controlled.

Gas from Separate Sludge Digestion Tanks

At Muncie, Indiana, digestion gas production, according to White (216), averages 60,000 cubic feet daily of which 40,000 cubic feet are used in a 90 h.p. gas engine direct connected to a blower, for heating digestion tanks and the laboratory, and in a gas engine pumping unit. This unit is float controlled and permits varying the engine speed and pumping capacity from 4 to 10 m.g.d.

At Marion, Indiana, the treatment plant serves about 30,000 population, the gas production is about 50,000 cubic feet daily, which increases to 90,000 cubic feet daily in the summer months due to the addition of ground garbage to digestion. Backmeyer (17) details the satisfactory experience gained at this plant with 3 Climax gas engines operating on this gas for sewage pumping, compression of air for activated sludge, vacuum filter operation, etc. The annual power savings are almost $7,800.

The value of sludge gas as a source of power in a larger Indiana plant, *i.e.*, Gary, serving about 100,000 population is related by Howson and Mathews (92). The authors estimate that the use of sludge gas for power generation at this plant has saved about $21,000 annually during the past three years. This is in line with the savings at Marion.

The per capita gas production is relatively large at both plants and perhaps larger at Marion. Backmeyer logically attributes the large gas yield at Marion to the addition of ground garbage to digestion.

At the Bowery Bay plant in New York (13) digester gas is utilized for heating and all principal power purposes such as pumping and air compression. Two 800 h.p. gas engines and two 560 kw. A.C. generators are used.

There is an ample supply of gas in most of the foregoing plants. When it comes to providing gas at all times in order to maintain the optimum of plant operating economies the story may be somewhat different. The importance of records for this purpose is told by Rudgal (172). In order to provide an adequate gas supply for gas-engine driven pumping units and for heating purposes, especially during the severe winter months, a reliable record system is used at Kenosha, Wisconsin (50,000 population). This system is used for regulating and rationing raw solids pumped to digestion. The procedure involves good sampling, careful laboratory technique, reliable records, graphs showing solids balance, and computed amounts of raw sludge held in storage and pumped to digestion.

Use of Gas for Sludge Drying

At Springfield, Massachusetts, the quantity of gas required for heating the digestion tanks and for flash drying of vacuum filter cake from 65 to 5 per cent moisture is described by McDonald (129).

Servicing Gas Burning Equipment

Kunsch (116) relates experience in servicing digestion gas burning and control equipment, pipe lines, flame traps, valves, meters and waste gas burners.

Ground Garbage

The digestion of ground garbage along with sewage sludge is rather extensively practiced in this country and in this year's review is mentioned in connection with the foregoing references to Marion (17) and Gary (92), Indiana. Schlenz (182) also describes a system for controlled digestion of garbage solids in a special garbage digestion tank. The garbage is ground in digester supernatant and put in perforated containers which travel submerged in the garbage digester for ten days. This tank is seeded by supernatant from sewage sludge digestion tanks which also receive the liquid from the garbage digester.

Tank Insulation

The use of porous volcanic glass or pumice in concrete for insulating digestion tanks in a region having severe winter, *i.e.*, Preston, Idaho, is described by Harding (81). The digestion gas is used for heating as well as keeping the water seal on the second stage digester from freezing in winter.

Design

A general description of some unusual features incorporated in the design for sludge handling and digestion facilities at the projected Hunts Point plant, New York, is presented by Langdon (120). The primary and waste activated sludges will be heated in an accessible location before entering the digestion tanks, thus eliminating the placing of heating coils within the tanks. The sludge heat converters are also designed to obtain a better heating efficiency than is customary with coils. As emergency heating equipment for maintaining full heat transfer capacity at all times, direct steam heating, similar to that employed at Los Angeles (18) (160) is provided. Plentiful and continuous circulation of sludge during digestion is provided. Second stage tanks will be used for sludge concentration and production of supernatant liquor. The removal of liquor will be through a supernatant selector.

SLUDGE DISPOSAL

Use of Sludge as Fertilizer

Niles (140) discusses the fertilizing value of sewage sludge. The history of China confirms that sewage sludge has something that promotes growth other than the amounts of nitrogen, phosphoric acid, and potash determined from chemical analyses. Sludge research at Toledo, Ohio, shows the presence of 29 various elements in the sludge, many of which have been established as essential to plant growth. Also, the presence of growth-promoting substances (indole and skatole) are mentioned as contributing factors in its added value.

Wisely (219), commenting on the paper by Niles, points out the problem of the large plant in seeking a market for heat-dried sludge either as a soil conditioner or as a base for fortified fertilizers, as distinguished from the higher moisture content of drying bed or vacuum filter cake produced at the small plant where the real problem is to get it off the plant property, with revenue from its sale of secondary importance. The tendency has been to overlook the latter phase of the problem. Hope is expressed that sufficient interest can be created to encourage agronomists to extend their past investigations sufficiently to settle the "plus value" question in positive fashion. The suggestion is made that the current impasse might be overcome if the United States Department of Agriculture undertook a study of several years' duration to investigate thoroughly, by approved methods, the efficiency of the various types of sludge (in the liquid and dry forms) in various types of soils in connection with the growth of major crops produced over the nation. Further investigation of the public health aspects could be included in this work.

McDonald (129) reports the sale of about 1200 tons annually of primary digested dried sludge at $5.00 per ton F.O.B. at Springfield, Massachusetts. Drying is accomplished with a Raymond flash drier using sludge gas as fuel.

In an operators' forum, conducted by Mackin (124), Van Kleeck, Backmeyer, H. A. Riedesel, P. W. Riedesel and Niles discussed the use of sludge in the Victory Garden campaign. Pertinent comments were:

1. Use of sludge can be promoted by interesting the state agricultural stations.
2. Heavy applications of sludge may retard plant growth, especially for early crops. Lighter applications are indicated for best results.
3. Refuse incinerators built in conjunction with sewage treatment plants offer a cheap source of heat for primary sludge drying.
4. Sludge conditioned with lime as well as ferric chloride does not appear to be too alkaline for average soils and most vegetables. Substantial bacteria kill is afforded by lime-conditioning of sludge.
5. The thin spreading of digested sludge cake on vegetable gardens in the fall is recommended as one means of reducing possible health hazards.
6. At Marion, Indiana, liquid digested sludge has been used as fertilizer on Victory Gardens.
7. The Rockford Sanitary District in Illinois has pushed the utilization of its sludge for fertilizing pasture land used for supporting cows. The lack of any health hazard is emphasized.
8. The possibility of parasitic infections from sludge as the war progresses was again brought out. Long digestion periods, grinding of sludge, freezing, and drying are all aids in reducing parasitic organisms in digested sludge.

A total of 9280 tons of raw solids filter cake was disposed of for agricultural purposes in 1943 at the Minneapolis-St. Paul plant (183). The nitrogen content of the sludge cake varied from a minimum of 0.93 to a maximum of 2.47 per cent. The low nitrogen content was associated with low volatile matter content in the cake (40–45 per cent) and the high values with high volatile matter in the cake (70 per cent). The average phosphorus content was 0.94 per cent (P_2O_5).

Stecher (196) objects to the use of undigested sludge for agricultural purposes in Germany despite the greater manurial value.

Due to lack of labor preventing the disposal of sludge by drying on sand beds, Kunze (116a) reports the utilization of liquid sludge by farmers carting it away in tanks at Zwicken, Germany. Sludge from 40 people was applied per acre. Good results and no difficulties were encountered.

Ransome (159) discusses the methods and results obtained with straw sludge composts in England. Alternate layers of straw and either dried or wet sludge of a total depth of 6 feet are made on underdrained ground. In the case of dried sludge, the heap is wetted with water or sewage effluent. Fermentation in the compost pile raises the temperature to 160° F within a few days. In the course of three months the straw is well rotted and the sludge broken down. It is stated that the manure obtained looks like farmyard manure with a similar analyses except that the nitrogen is considerably higher and potash lower.

Sludge Dewatering

Schroepfer (183), in reporting the operation data for the Minneapolis-St. Paul Sanitary District sewage treatment plant, records that the per cent solids in the raw sludge increased from 8.29 to 9.47 in the concentration tanks. Vacuum filtration gave a filter cake with an average moisture content of 66.6 per cent with average dosages of 1.12 per cent of ferric chloride and 3.05 per cent of lime on the basis of dry solids. This represents a considerable reduction in the dosage of chemicals from previous years. These economies were effected as a result of improvements and better operation and at the expense of reducing the filter yields from 5.50 to 3.47 pounds per square foot per hour. It is stated that if a greater number of filters was available, a greater saving could be effected by further reducing the filter rates. The life of filter cloth was 461 hours. In order to combat the incrustation of sludge distribution lines from conditioning tanks to the vacuum filter and also in the vacuum lines, woodwork and screens of the drum, hexametaphosphate was added continuously to the sludge along with lime and ferric chloride. The results were negative. Attempts were made to solve the incrustation problem by pH control nearer the stability point. As a result, the pH of the filtrate was reduced gradually from 11.7 to 8.9. After 6 months operation with lower pH values considerably less build up of incrustation had taken place, but instead a gelatinous accumulation appeared on the drum and screens.

Pearse (144) reports that at present Chicago is selling all the sludge produced for admixture with fertilizer. The output in 1942 was 51,730 tons at 5.97 per cent ammonia and 2.45 per cent P_2O_5. Because of the uncertainty of prices in postwar times and since additional equipment for enlargement of incineration facilities is unavailable at present, other provisions are being made for sludge disposal. Recent developments in Chicago in sludge drying, according to Pearse (145), consist of the sale of scum, construction of lagoons and disposal of fly ash.

Adams (1) reviewed in excellent fashion the various methods of sludge dewatering. The problems of dewatering raw activated sludge at Tenafly, New Jersey, are discussed in some detail. Some Tenafly sludge is dried with the aid of ferric chloride as a coagulant on covered sludge beds. By using four or five per cent ferric chloride, a one-inch thick sludge cake is removed after ten to twenty hours of draining. The major portion of the sludge is dewatered on vacuum filters and flash dried, the source of heat being a garbage and rubbish incinerator.

Heukelekian (85), in discussing dewatering of digested sludge on open sand beds, related some interesting observations, made in South Africa, on the effect of rain. Its effect is not so considerable as is generally supposed and varies according to the length of time the sludge has been on the bed before the rain. When rain falls before drainage has stopped, all the rain passes right through the sludge and the bed, just as though there had been no sludge. There is no tendency to absorb the rain. When rain falls after drainage is complete and while evaporation is a major factor, the rain does not drain through the bed but is absorbed by the sludge. The cracks are reduced in size and the drying time is increased. When rain falls after the sludge is thoroughly dried out and the cracks are large, extending down to the surface sand, it is not absorbed to any large extent by the sludge but flows rapidly through the bed.

Sludge Concentration and Barging

Rudolfs (173) and Decher (52) report on methods of sludge concentration and barging at the Elizabeth, New Jersey, Joint Meeting sewage treatment works. The purpose of sludge concentration at this plant is to reduce the volume of sludge and, hence, the cost of barging. In 1942, the percentage reduction in sludge volume averaged 43.4 per cent. There is a limit in sludge concentration which can be handled because of difficulties in getting sludge of more than nine per cent solids to flow readily during cold weather. The cost of sludge handling per ton of dry solids disposed was $4.34 in 1942. Since the range in cost for disposal of sludge in this country varies from about $3.50 to $7.70 per ton of dry solids, the cost of sludge disposed as practiced by the Joint Meeting plant is relatively low.

General

The literature during the past year lacks the usual descriptions of new developments in sludge disposal and no major advancements were made in the design or operation of vacuum filters, centrifuges or other dewatering processes. While much remains to be accomplished, the necessary research and experimentation will undoubtedly await our victory on the war fronts.

MECHANICAL EQUIPMENT

War conditions are requiring greater care in the maintenance of equipment. This is stressed by the Committee on Sanitary Engineering of the American Society of Civil Engineers when it is stated (146), that one feature of war conditions is the added emphasis on civilian maintenance of equipment and structures in sewage pumping stations and treatment works. Crawford (50), Cody (47), Cohn (49) and others are cited by the committee as among the authorities upon which their statement is made. Other articles on maintenance have been contributed. Woolston (222) points out the importance of proper motor maintenance because of the critical materials used in their manufacture. Nelson (137) emphasizes the necessity for maintenance and repair of centrifugal pumps. In a round table discussion (7) interest was centered on the maintenance of all equipment, mechanical and otherwise. Price (157) points to the need for maintenance when he states: "Proper care of mechanical and electrical equipment is of particular importance in these times of critical materials and priorities." Shearer (187), in an article on "Sewage Pumps," mentions no new type of pump but devotes attention to maintenance, and Pearse (147) brings out the problem of maintenance in war time and the need for preparation of civilian defense.

Most mechanical equipment mentioned in the literature during the year is of a familiar type that has been in use for some years. For example, Carmichael (41) discusses the various types of sludge pumps including both reciprocating and centrifugal pumps. Adams (1) discusses sludge drying equipment now in use. Bacon (18) reports on digester heating and mixing equipment and shows a flow diagram for the Los Angeles County Sanitation Districts joint disposal plant which includes extensive mechanical equipment such às steam boilers fired with digester gases, sludge concentrating equipment and pumps. McLean and Puttee (131) describe the design, operation, and maintenance of sixteen lift stations in Winnipeg, involving the use of much mechanical equipment.

The literature of 1944 is not completely devoid of new applications of equipment nor of variations to fit changing conditions. Klann (111) describes the equipment of a sewer service truck which replaces fire hose and hydrant methods of sewer cleaning that were dangerous and costly. Wisely (220) likewise describes maintenance equipment which is desirable on sewer maintenance trucks. White (216) describes a new gas engine driven pumping unit at the Muncie (Indiana) treatment plant and Nelson and Lauer (138) describe the use of a Vacuator in a unique installation for the removal of oils and greases. Langdon (119) mentions an arrangement of water jets for the prevention of ice formation on exposed grease removal equipment.

Looking into the future Langdon (119), in describing postwar planning in the design of the Hunts Point plant, paints no lurid picture of a new world in mechanical equipment following the war.

Two summaries of available equipment together with the latest advances therein have appeared. One appears in Water Works and Sewerage (161), in which a number of authors describe the features of equipment and its operation. The other appears in This Journal (186) in a section devoted to the manufacturers of equipment where they have been given rein to describe their products. These include: aluminum floor grating and other aluminum products; Everdur metal in equipment; rapid rate filters backwashed similiarly to rapid sand filters in water purification; automatic control and measuring devices; stirring and concentrating devices for sedimentation and digestion tanks; air diffusers; clogless pumps; biofiltration equipment; a combination of thermophilic and mesophilic digestion equipment; and improved proportional flow chlorinator; a line of ingenious sewer cleaning equipment; a garbage grinder especially adapted to dual disposal of garbage and sewage; rotary distributors; automatic dosing devices; skimmers; mechanically cleaned bar screens; lubricated plug valves; improved incinerator furnaces; supernatant digesters; gas meters; blowers; sludge grinders; laboratory equipment; and waste gas burners.

INDUSTRIAL WASTES

Interest in the industrial waste problem in 1944 led to formation of a new trade organization in the pulp and paper industry. Programs of technical societies such as the American Society of Civil Engineers, The American Chemical Society and the Federation of Sewage Works Associations devoted considerable time to discussions of liquid wastes from various industries and methods of treatment and disposal. The United States Public Health Service issued a most comprehensive report on the results of its studies of industrial wastes in the Ohio Valley. A two-day meeting at Purdue University, Lafayette, Indiana, was devoted wholly to discussions of industrial wastes by experts from all parts of the United States. Editorials in various technical journals called attention to the magnitude of the industrial waste problem and the necessity for immediate study of methods of treatment or disposal in preparation for postwar construction.

Most of the papers presented at these industrial waste conferences were not published in 1944, and are not included in this review.

In Los Angeles, Gray (78) reports that industries must apply for a permit to discharge liquid wastes into the sewers, which permit may be refused if the wastes are of objectionable type. Pickling and winery wastes have been received, copper wastes are objectionable. For wastes that can be treated in admixture with sewage, the additional cost should be estimated, based on volume, suspended solids, and B.O.D. Any of these characteristics above those of normal human sewage would be subject to a charge for treatment. The basis could be per $1,000 assessed valuation. This type of charge is held to be equitable.

Uhlmann (208) describes the arrangement at Celina, Ohio, a small town of 5,000 population. Wastes from vegetable canneries (asparagus, peas, beets, tomatoes, kraut, pickles, etc.) plus milk powder and stearic acid processing, increased the population equivalent of the sewage by 10,000 in 1942 and 6,800 in 1943. The plant consists of chemical pretreatment, activated sludge and sludge digestion. Total operating costs were $6,751 in 1942 and $6,572 in 1943, to which the industries contributed $2,400 each year. This amounted to $7.30 and $9.00 per 1,000 lb. B.O.D. removed. Thus, for a cost of about $8 per day, the industrial wastes were handled by the city, relieving the industries of a considerably greater cost if the wastes had been treated independently.

The basis of charge for treatment of the industrial wastes at Buffalo has been reported by Symons (200) (201). Excess costs are added to the normal sewage rental charge based on volume, the excess costs being computed on the chlorine consumption plus chemicals and power used for disposal of solids. The wastes are analyzed for chlorine demand and suspended solids content. Average sewage results are 5.6 p.p.m. chlorine demand and 157 p.p.m. suspended solids. The special charge for 1,000 cubic feet of wastes amounts to 0.136 cents for each p.p.m. chlorine demand and 0.00305 cents for each p.p.m. suspended solids determined by the above sewage analysis. It does not appear economically feasible to apply a special charge when the rate is less than 1 cent per 1,000 cubic feet of volume of waste.

Charges at New Brunswick, N. J., (109) for industrial wastes are $22 per m.g.d. flow, $5 per ton sludge solids, and $5 per 100 lb. chlorine demand. One industry contributes 2 m.g.d. flow but the solids are equivalent to only 10,000 population, whereas another industry discharges solids for a community of 200,000 persons, as contrasted to New Brunswick's normal population of 35,000.

The application of charges in England, under the 1937 Act (Drainage of Trade Premises) has been discussed by Hurley (94) of Wolverhampton and Porthouse (156) of Manchester. Both authorities deplore the exemption of charges because of the peculiar English theory of "prescriptive rights," and state emphatically that all wastes should be subject to charge, whether received prior to, or after, March, 1937. Surveys of wastes should be made, the main data being maximum daily flow, maximum hourly rate, average flow, and analyses to show suspended solids and strength, based on the 4-hour oxygen consumed test. In some cases pumping costs may have to be added. Exemption of laundry waste seems illogical. The Act should be enforced, with some modifications, on a national basis.

In litigation over treatment of packinghouse wastes at Sioux Falls (88), the South Dakota Supreme Court held that a contract between the industry and city was void, and that a capital payment of $70,000 by the industry, and $2,500 quarterly, do not give the industry any vested rights in the equipment or operation of the sewage treatment works. The points of the decision were that (*a*) the city cannot bind itself to treat all sewage delivered to the treatment plant, (*b*) police powers cannot be bargained away by contract, (*c*) the city cannot grant vested rights for private sewers, (*d*) the city must be free to disconnect any sewers, and (*e*) the law does not recognize any joint partnership between the city and an industry. It is suggested that the city can grant a temporary permit, but the joint treatment plant is operating at present with no such permit, and contributions to operating costs continue to be made by the industry.

Another case of litigation concerning copper and oil wastes at Kenosha, Wisconsin, (172) was decided against the industry in the Appellate Court, but reversed by the Wisconsin Supreme Court. Negotiations between the city and industry continue, however, in an effort to solve the problem equitably.

Oil Wastes

At Baltimore (107) contractors remove waste oil from garages, cleaners and industries, and are paid $500 to $3,000 per year by the city for such collection. From 150,000 to 450,000 gallons are collected per year, and this waste is treated in a 1,500 gal. tank with sulfuric acid and heat from steam coils, sludge is removed, clay is added to the liquid oil, and it is cooked 8 to 10 hours with steam at 600 to 800° F. The highly volatile fractions are distilled off, the residue cooled to 200° F., filtered, cooled and sold as reclaimed oil.

Oil wastes at Springfield, Mass., (130) resulted in scum 6 ft. deep in the digesters, and interfered with digestion. Later scum alone, high in oil (82 per cent ether soluble) was handled in one digester, sludge in the other three. The oil is drawn off the scum digester, filtered through a 40-mesh screen, and used for No. 5 fuel oil.

Pulp and Paper

The pulp and paper industry has organized a National Council for Stream Improvement (70) to study the longstanding problem of disposal of wastes from pulp and paper manufacture. This is in addition to other agencies (mentioned in last year's review, refs. 173 and 255). The National Council plans to carry on widespread investigations, to supplement research studies at Mellon Institute.

A study of paper mill waste disposal at the Kalamazoo Valley paper mills in Michigan (58) showed that 110 tons of suspended solids and 27,428 lb. 5-day B.O.D. were discharged in a flow of 45.1 m.g.d. Four mills made about 600 tons of paper board per day from old-paper stock and sulfite or kraft pulp, and the remaining thirteen mills produced about 870 tons of high-grade book or writing paper per day from the same general stock. Ink washer wastes and whitewater wastes are of most importance. Many mills, but not all, utilize recirculation and savealls of various types. A pilot plant was operated at two board mills, and two paper mills. Various coagulants were used, lime appearing to be best. With a dosage of 502 p.p.m., reductions of 66.0 per cent of the suspended solids (324 to 110 p.p.m.) and 54.8 per cent of the B.O.D. (from 51 to 23 p.p.m.) were obtained. Coagulation for 20 minutes and sedimentation for 2 hours was recommended for large-scale treatment. Lagoons for sludge disposal should have a capacity of 1,000 cubic feet per m.g.d. waste, based on 6 months' storage. On vacuum filters, cakes of 70 to 75 per cent moisture can be obtained.

Acid Wastes

The effect of dilution on sludge formed by neutralizing acid wastes with lime is discussed by Rudolfs and Rudolfs, Jr. (177). The strong acid wastes, consisting primarily of sulfuric and hydrochloric acids, were treated with various alkaline substances. The speed of reaction was greatest with soda ash, followed by dolomitic hydrate and calcium hydrate and was slowest with calcium carbonate. Dolomitic hydrate required the least amount and calcium limestone the highest amount to bring the pH value of a given quantity of acid to 4.0. On a cost basis also, dolomitic hydrate had the greatest advantage. Smaller volumes of sludge were formed as the dilution of the acid waste increased. With dolomitic hydrate, a dilution of 67:1 reduced the mineral acidity to 0.35 per cent and prevented all sludge formation.

The use of upflow limestone beds for neutralization of acid wastes was studied by Gehm (68). Beds 2 to 4 feet deep, of 8 to 30 mesh limestone, were effective at rates of 20 to 100 gallons per square foot per minute, provided the waste contained less than 5,000 p.p.m. acidity, or was diluted to that strength or less. The pH can be raised to 4.2, and still further to 8.0 by aeration to remove the CO_2. Pickling liquor was more difficult to neutralize.

Hoak (87) recommends determination of the neutralizing value of limestone or lime by treatment with excess acid and back-titration. Dolomitic limes form less sludge than high-calcium. Pulverized limestone is cheapest and produces a rapidly-settling compact sludge, but does not precipitate iron in pickling liquor, for which lime must be used. Quicklime provides the highest possible basicity at lowest cost, but the sludge settles slowly and lime dust is irritating to the workmen. Hydrated lime is most expensive, but it reacts quickly and the sludge settles more rapidly than that produced by quicklime.

Acid wastes containing copper and oil, from a small-arms ammunition plant were treated with lime (82). Storage for one hour equalized the pH, lime was added to pH 9 or 10, flocculation was continued for 30 minutes, and sedimentation for 1.5 hours gave an effluent with 32 p.p.m. suspended solids, 1.4 p.p.m. copper and 12.0 p.p.m. ether extract, as compared with 469, 16.1 and 213 p.p.m., respectively, in the raw waste.

Wastes from the manufacture of viscose rayon (167) are treated in a full-scale plant at Front Royal, Virginia. Wastes from the viscose process are alkaline and contain caustic soda and viscose from spillage, and filter cloth washings. A second group of wastes are acid, from the spinning bath wastes. A third group of wastes contains alkaline sulfides, soap and other alkaline liquors. The treatment plant includes a balancing tank, a dosing chamber, a circular filter 6 feet deep and 120 feet in diameter, and a final settling tank. Acid and alkaline wastes are used to neutralize each other, the sulfide waste is then added and the total applied to the filter. The pH of the influent is 10.5, of the effluent usually 7.0, but sometimes as low as 3.5. B.O.D. applied to the filter was 500 lb. per acre ft.; application at 2 m.g.a.d. gave 95 per cent removal. Some losses of acid have occurred which were partly equalized in the final tank. The effect on the filter is not discussed.

Pickling Wastes

The treatment of pickling liquor and wash waters at the Fontana, California, steel works is of interest (203). The receiving tank stores one day's production of liquor and wash waters, and is 30 ft. in diameter and 10 ft. deep. Limestone of 100-mesh is added in the first of three tanks, each 14 ft. in diameter and 10 ft. deep. Air is blown through the slurry, which passes through the two similar tanks, with recirculation of sludge from the third back to the first tank. Final settling occurs in a circular tank 35 ft. in diameter. The effluent is re-used in the rolling mills, along with chlorinated, treated sewage effluent. Sludge is dried on sand beds.

Swindin (199) has discussed the various processes for recovery of copperas or acid, particularly the Kestner-Fakler, de Lattre Tinsley, and Swindin processes. He advocates the recovery of sulfuric acid and metallic iron, using a submerged flame for evaporation. For the present, copperas is a drug on the market, and must be reduced to acid and iron oxide, as in other recovery processes. Experiments dealing with the precipitation of copper from acid copper mine washes by means of metallic iron were reported by Wartman and Roberson (214).

Canning Wastes

At Fairmont, Minnesota, (102) canning wastes from peas, corn and lima beans were stored in a lagoon of 25.8 acres during the canning season. The lagoon was 6 ft. deep and capacity was 54.6 m.g. Flow of wastes was 3 to 25 m.g. per month. The lagoon was held over the winter, and B.O.D. samples of effluent in the spring were from 340 to 2,000 p.p.m. Odors were prevalent, and treatment with sodium nitrate may be necessary.

In California, Froelich (67) describes the troubles in disposing of wastes from canning of fruits and vegetables. A screen 10 ft. long and 5 ft. in diameter, with a small settling basin, appears to be the extent of the treatment, the effluent being delivered to the city sewage treatment plant. Only the coarsest solids are removed at the cannery.

Everts (62) of the Canners League of California, states that the canners in that region have not been forced to consider the disposal of soluble solids, and suggests that it would seem in the public interest to handle the wastes through sewage disposal plants, by the cities or districts in which the plants are located.

Citrus fruit wastes (80) at Corona, California, are flushed to screens of 0.05 in. mesh and screenings are fermented in silos for feed, with disposal of the liquid seepage on sand or gravel beds 2.5 ft. deep.

The production of bacterial proteinase from the juice of waste asparagus butts by Kline, MacDonnell and Lineweaver (112) gives added demonstration of the recovery of certain products from wastes.

Laundry Wastes

A very extensive study of laundry wastes has been made by Gehm (69). Such wastes are estimated at 5 to 10 per cent of the volume of dry weather sewage flow in normal communities. It is desirable to treat the wastes with sewage, if possible. For treatment alone, chemical precipitation is costly, filters or activated sludge require large areas or long aeration periods. Ferric chloride can be used best with acid to bring the pH to 6.0. From 2 to 15 per cent of sea water effects fairly satisfactory precipitation. With 1,200 p.p.m. lime, only 55 per cent of the B.O.D. was removed, but if 100 p.p.m. $MgSO_4$ was also added, the removal was 90 per cent. Zeolite residues were relatively ineffective. Waste iron pickling liquor, plus aeration, was quite effective. Use of 2 gallons pickling liquor per 1,000 gallons waste, plus aeration, reduced the B.O.D. 90 per cent. The solids were removed at the surface as scum at pH 3.0.

Miscellaneous Wastes

The effect of certain industrial solvents on sludge digestion was reported by Rudolfs (176). Small quantities influenced the rate and degree of digestion. Methyl, ethyl, butyl, and isoamyl alcohols and ethyl ether produced greater volumes of gas. Toluene and carbon tetrachloride in smaller quantities increased gas production while xylene was toxic to liquefying and gas producing organisms. Ethylene dichloride even in 1 to 2 p.p.m. concentrations retarded gasification while 10 p.p.m. reduced gas production by 50 per cent. Ortlieb (142) made studies to determine whether sewage and beer waste sludge could be digested. Gas production was lower than previously found by others. Variation in gas production was attributed to the changes in the character of organic matter added to the digester.

Künzel-Mehner (117) considered the chemical-mechanical treatment of strong tannery waste to be possible and economically sound. Batch treatment with $FeCl_3$ produced good clarification with complete removal of sulfur compounds. Dosage of $FeCl_3$ was 200 to 500 grams per cubic meter. The sludge produced could be vacuum filtered and burned.

Lime treatment of acid wastes derived from the manufacture of felt was found to give the best results by Scott (184). The sludge obtained was not amenable to pressing due to the fibers. The sludge from which the fibers were previously removed was disposed of by applying it to drying beds.

Wastes from a mercerizing, dyeing and finishing plant containing starch, chromates and dyes were treated after neutralization of the causticity by sedimentation and trickling filters (at the rate of 210 gal. per cubic yard per day) (184).

Coagulation of proteins in packinghouse waste by acid and a coagulant was patented by Sanders (179).

Industrial Waste Manuals

The Industrial Waste Manuals of the United States Public Health Service (209) refer to the following industries: brewery, canning, coal washing, coke, cotton, distilling, meat, milk, oil, paper and tanning. They are up-to-date and informative. The printed report also includes studies of acid mine drainage and epidemiological and biological studies.

STREAM POLLUTION

Abatement and Control

The data collected by the U. S. Public Health Service (210) on the discharge of raw sewage and inadequately treated effluents into our coastal and inland waters emphasizes the importance of the stream pollution abatement problem. An example of a home rule program in stream pollution abatement control is given by Allen (2) who described the organization of the Interstate Commission on the Delaware River Basin by the states of Delaware, New Jersey, New York and Pennsylvania. Rice (165) pointed out that Indiana's first stream pollution law, passed in 1901, which appropriated no money for investigation but required the State Board of Health to issue a permit for the discharge of wastes or close a factory until investigation was possible, was a failure. The Indiana Stream Pollution Control Board was established in 1935 and made considerable progress in improving stream conditions. This Board was abolished in 1941 and after vigorous effort was re-established in 1943. Indiana experience has shown that it costs as much to clean up a mile of river as to build a mile of concrete highway. Stream pollution conditions in the St. Joseph River basin, in which the three largest cities with a combined population of 163,000 or 80 per cent of the basin's total have no sewage treatment plants, were studied by the State Board of Health (84).

New Hampshire, according to Howard (90), lacks laws for pollution abatement of public waters already polluted and consequently takes recourse to charging the existence of a nuisance for control. Legislation to control the discharge of sewage into public waters that are already polluted is sorely needed in the state.

Koon (113) reports that Portland, Oregon, voted a 12 million dollar bond issue in May, 1944, to prepare plans and build a sewage plant which will improve the badly polluted Willamette River.

In Pennsylvania, Moses (133) states that the Sanitary Water Board created in 1923 was given specific jurisdiction over trade wastes and was enabled to proceed against such polluters in 1937; and is now embarking upon a comprehensive program of stream improvement. The Board is now apprising municipalities and industries that are now discharging waste, which can and should be treated, what will be expected of them in the postwar period. To the end that the public will be apprised, public hearings are to be held in the various parts of the state and matters relating to all streams within a specific area will be considered. After the hearings, specific orders will be issued to the municipalities and industries. It is estimated that 500 municipalities in Pennsylvania will be affected. Stromquist (198), discussing the stream pollution problems of the Tennessee Valley, pointed out that 50 per cent of the pollution load originates from a small number of pulp, paper and rayon plants, and that co-operation with the industry is being carried on for solving the problem. The treatment given the effluents from a rayon plant at Front Royal, Virginia, for controlling the pollution of the Shenandoah River was described by Roetman (168). The pulp, paper and paperboard industry has set up a corporation (12), to which all manufacturers of paper and allied products are eligible for membership, for carrying on a coordinated research and development program for the recovery and treatment of wastes from this industry. The new organization, which is known as the National Council for Stream Improvement, has already started some laboratory and survey work which should be a big factor in abating pollution from this large industry.

The history of proposed national water pollution abatement legislation as prepared for the Conference of State Sanitary Engineers (9) presents two approaches to pollution control. One approach is for the enlistment of Federal authority to prevent pollution; the other is for Federal aid to interstate, state and local authorities in the control of pollution. The second approach would provide legislation for Federal participation by establishment of a technical agency to promote and coordinate education, research and enforcement in pollution abatement. This type of approach is exemplified in the Barkley-Spence bills (S. 1989 and H. R. 4741) which are in their major aspects consistent with proposed water pollution control legislation that has received favorable consideration by Congress, but contains revisions designed to eliminate the objections to budgetary procedures outlined in the Presidential message on the veto of the Barkley-Vinson bill in 1938. Biery (28) also reviewed the provisions of the Barkley-Spence bills which provide an orderly plan for postwar sanitation projects; he states that enactment of the Barkley-Spence bills or completion of the Compact by the several states of the Ohio Valley will greatly stimulate the progress of stream sanitation in this basin.

In England, Clay (46) reviewed the importance of stream pollution prevention from the standpoint of its effect both on public health and on fish life. Clay stated that he was not convinced that legislation for the creation of comprehensive river boards was necessary in England and believed that the lack of progress on pollution problems was due to the apathy of county councils to exert the authority conferred upon them to deal with pollution. He maintained that what was most needed was propaganda which will result in the creation and direction of public opinion so as to demand effective protection from pollution for rivers. Such education or propaganda is apparently also badly needed in our country.

Bacteriology and Biology

Chu (44) studied the effect of mineral compositions on plankton growth and found that the most favorable concentrations of calcium, magnesium, potassium, sodium and silicon dioxide differed considerably for different algae. Of special interest to stream studies was the fact that with few exceptions the algae investigated grew equally well in media supplied with nitrate and in those supplied with ammonia salts as long as the N concentration was within the optimum range. In lower N concentrations, growth was generally better when nitrate was supplied. Pennington (148), studying mixed cultures of algae and bacteria, found that both ammonia and nitrate were utilized. In a second paper Chu (45) showed that for plankton algae in pure culture the optimum range for nitrate nitrogen was 0.9 to 3.5 p.p.m. and for P was 0.09 to 1.8 p.p.m. It will be noticed that these values are within the range frequently found in polluted streams. These algae can use directly nitrogen in the form of ammonia. The nature of the nitrogen supply affects the optimum range of P concentration. Limiting growth effects occur in N concentrations of 0.1 p.p.m. downwards and P concentrations of 0.009 p.p.m. downwards. Low N and P concentrations exert a selective limiting influence on the phytoplankton population. Lackey (118) reported that with increasing pollution the varieties and probably the numbers of plankton had increased in the south end of Lake Michigan.

Chemistry

Van Horn (211) studied the pollutional aspects on streams of antiseptics used in the pulp and paper industry to control slime growths. He concluded that on an average stream it seemed unlikely that concentrations of these antiseptics lethal to fish would exist in a river over a wide area. An important study of the physical and chemical aspects of the exchange of dissolved substances between mud and water in lakes was reported by Mortimer (134). An objective determination of odor for stream investigations was reported by Nachtigall and Grill (136). The test is based upon the fact that volatile organic constituents are at least partly responsible for odor, and depends upon the distillation of a small sample portion from a liter sample followed by an oxygen consumed determination on the small distillate.

Stream Sanitation

Professor Phelps (150) has contributed the first book on the manifold problems of stream sanitation, in which he develops and interprets the fundamental concepts of pollution and self purification. He has drawn upon the extensive publications of the U. S. Public Health Service Stream Pollution Investigations Station at Cincinnati and the work of many other scientists, and interpreted the data from the standpoint of his own experience. The book includes six chapters in which the following subjects are discussed: the life history of a stream, biology of growth and decay, aerobic decomposition, anaerobic decomposition, oxygen balance, and public health aspects. A final chapter on stream microbiology by James B. Lackey is included. A large part of the book is devoted to phenomena concerning self purification in streams and in sewage treatment. Applications of theory and mathematical formulas are presented and illustrated by examples which add value to the book as a teaching medium. Although the book does not pretend to be comprehensive, the interpretation and correlation of some of the later stream studies might have profitably been included. All students of stream sanitation and the related fields of sewage treatment and water purification should find this book of value and interest. Johnson (101) presented a nomograph for the integration of stream flow records designed to speed up the analysis of stream flow data.

Standards

The minimum standard for waste effluents adopted by the Passaic Valley Water Commission for discharge into streams of the watershed above its potable water supply were described by Bonyun (32). These standards required a pH within the range of 4.0 and 8.3 and freedom from acidity; free caustic alkalinity; toxic substances; noticeable floating scum, oil, grease and sleek; and from offensive odors. Color, turbidity, *Coli-aerogenes* group and B.O.D. requirements which did not seem too difficult to meet were also given. In discussing the above paper Mallalieu (32) pointed out that the Rockaway Valley sewage plant actually improved the lower Rockaway River into which it discharges, suggested standards much more rigid in many respects to the above and concluded that it seemed desirable to combine stream and effluent standards. Berg (26) presented a plan of fitting a plant effluent to a stream which required the reduction of suspended solids to a degree dependent upon the stream velocity, the increase in D.O. to a minimum of 2.0 p.p.m., the determination of how much effluent the river will take by calculation, and finally the sampling of the river for D.O. below the effluent.

Surveys

Surveys of the condition of the beaches of Santa Monica Bay were reported by Belt (25) and Gillespie (74). After an extensive bacteriological and sanitary survey, ten miles of beach which had been used by 20 million people per year was quarantined. The average sewage discharge on the beach in 1942 following fine screening was 143 m.g.d. with 160 tons of dry suspended solids and 8 to 10 tons of grease. A limiting standard of 10 *E. coli* per ml. was used and an excess above the standard 20 per cent of the time was allowed. *Paratyphoid A* and *B* were isolated 300 feet from the submerged outfall and in the surf and along the beach. *E. coli* were found in excess of 110 per ml. in the surf 9 miles from the outfall. Dunstan, (56) at the University of Alabama, described a comprehensive plan for a pollution survey of the Black Warrior River which indicates an awakening interest in stream pollution problems in the South. In connection with a study of paper mill wastes, Eldridge (58) studied the Kalamazoo River and its tributaries; collected samples at 16 points for suspended solids, D.O. and B.O.D. determinations; and on the basis of the results made recommendations for the improvement of existing conditions at each mill.

To determine whether the treatment of sewage is actually alleviating the conditions in streams to the extent for which the plants were designed, Kaltenbach and Wolman (103) studied the data on four Maryland streams before and after sewage treatment plants were provided and operated. The data indicated that in the case of the large, well operated plants (Hagerstown and Annapolis) the treatment plant performs the function for which it was designed and improvements in the streams (Antietam Creek and Severn River, respectively) were evident. The small plants at Belair and Chestertown also showed improvements in the streams, though there was not infrequent neglect which nullified the benefits from the projects.

A comprehensive study of a 68-mile section of the lower Columbia River that receives the sewage from a number of large cities and the wastes from paper companies with an aggregate capacity of about 1,400 tons of pulp per day was made by Lincoln and Foster (123). Physical, chemical and bacteriological data are presented in a series of 56 figures which indicate that the maximum pollutional conditions existed in Camas Slough below some paper plants and that the pollutants from each plant are largely restricted to small areas along the bank of the river below the point of discharge. The wastes are diluted rapidly but the river current prevents their being readily dispersed across the channel. The discharge of sulfite waste stimulated the growth of *Sphaerotilus natans* to produce a nuisance that handicapped fishing operations in certain areas. The main channel river water, well below all sources of pollution, has an average B.O.D. under 2.0 p.p.m. and a D.O. ranging from 8.1 to 12.3 p.p.m.; and the *Coli-aerogenes* indices in midstream were generally below 1,000 per 100 ml. No evidence was found that the pollution has decreased the salmon runs in the river. This excellent study of the Columbia suggests that the authorities in Oregon and Washington are well aware of the damage that results from overloading a stream and that they intend to prevent any further deterioration of the Columbia River. The condition of six British rivers with respect to pollution by zinc and lead was studied by Newton (139), who pointed out that mine detritus covering river beds prevents the mechanical establishment of macrophytes and reduces the microflora. Zinc was as serious a pollutant as lead. The toxicity of these elements to plants, mollusca and fishes was studied. Fish were killed by an adsorption complex of heavy metal on the gills which, with an excess secretion of mucus, causes suffocation. Settling tanks did not entirely prevent lead solutions greater than 0.1 p.p.m. and zinc solutions greater than 0.3 p.p.m. from reaching the river and so did not entirely solve the problem.

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THE RELATIONSHIP BETWEEN ACCUMULATION, BIOCHEMICAL AND BIOLOGICAL CHARACTERISTICS OF FILM AND PURIFICATION CAPACITY OF A BIOFILTER AND A STANDARD FILTER

II. Biochemical Characteristics of the Film *

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The performance of a biological filter depends on the quantity and quality of the film as well as quantity and characteristics of the sewage applied. The film is the vital seat of activity on which the removal of solids and B.O.D. depend and in which nitrification is accomplished. Despite the indispensability of the film, very little information is available on its biochemical characteristics, even in reported investigations dealing with standard filters. Certain general differences in the behavior of the film in standard filters have been recognized, and the filter has been divided vertically into zones depending on the basis of the nature of changes brought about in the liquid flowing in the bed rather than the chemical and biochemical characteristics of the film. Storage and oxidation of the materials removed from sewage have been computed on the basis of the solids applied and the quantity of the solids in the effluent. Considerable information is available on the animal and plant population of such filters. The effect of size and type of filter media, rates of application, and seasons on the over-all purification has been extensively studied.

The biochemical nature of the film of high-rate filters is still more obscure. It is not known whether there is a considerable oxidation of the material removed from sewage or whether the function of such filters is merely to convert the finely dispersed materials in the settled sewage to settleable forms by bioflocculation and "colloider" effect. That a part of the soluble material in sewage is oxidized by high-rate filters is presumed from the relatively high B.O.D. reductions. It is not known, however, whether the oxidation extends to the destruction of the film itself. If the ash content increases, and the B.O.D., nitrogen and grease decrease in the film vertically in the filter, then it might be taken that biological oxidation is proceeding. It might even play a part in reducing the quantity of the film. A comparison of such biochemical characteristics in the biofilter and in the standard filter might reveal quantitative differences in the extent of oxidation. This paper will deal with the vertical and seasonal differences in the ash, B.O.D., nitrogen and grease in the film of the two types of filters.

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Methods

The sampling of stones from the top two-foot level of the beds has been described in a previous paper of this series (1). An additional sample, representing the solids discharged from the beds, was collected from the secondary clarifier. The day previous to sampling the clarifiers, all sludge was removed and a sample of the sludge collected within less than twenty-four hours was taken. An additional sample was taken from the six-foot level of the standard filter by flooding the bottom of the bed and catching the effluent at the entrance of the secondary clarifier after the valve was opened.

The B.O.D. of the sludge was determined by dispersing and macerating a small quantity of the sample in a Waring blender. The five-day B.O.D. was determined by using sodium bicarbonate dilution water. Dissolved oxygen was determined by the modified azide method. The results are expressed as grams of B.O.D. per kilogram of total or volatile solids.

Grease was determined by precipitation with $FeCl_3$, filtration followed by acidification, drying, and extraction with petrolic ether. Nitrogen in the sludge was determined by the Kjeldahl method.

Results

A. Biofilter

The average results of the ash content of the film found at different levels of the biofilter and of the effluent sludge are given in Table I.

Table I.—*Ash Content of the Film of Biofilter*

Period	% Ash at Top	% Ash at 1-ft. Level	% Ash at 2-ft. Level	% Ash in Effl. Sludge	Average % Ash (3 Levels)	*% Increase
Entire period (Jan. 1943 to Feb. 1944)	22.7	26.3	28.1	27.1	25.7	23.8
Summer ave. (May to Nov. 1944)	22.9	27.9	30.3	27.2	27.0	32.2
Winter ave. (Winter of 1943 and 1944)	22.4	24.4	24.5	26.8	23.8	9.3
Winter ave. (Winter of 1943)	23.2	25.6	26.5	32.1	25.1	14.2
Winter ave. (Winter of 1944)	20.5	21.5	21.8	18.0	21.3	6.3

* The percentage increase at the two-foot level over the top level.

The results are averaged on the basis of the entire period studied (22 samples) and summer and winter periods. The summer average covers the period from May to November inclusive when the sewage temperature was in excess of 62° F. and averaged 70° F. The winter period extends from December to April inclusive when the sewage temperature was below 56° F. and averaged 54–55° F. The winters of 1943 and 1944 are averaged together and separately because, as was shown in the previous paper (1), the quantity of film during the first winter of operation was different from that of the second winter. The average results show that the ash content of the film increased progressively from the top down to the two-foot level. The ash content at various levels was higher in summer than in winter. The average ash content at the three levels was 25.7 per cent for the entire period, 27.0 per cent in summer, 25.1 per cent in the winter of 1943 and 21.3 per cent in the winter of 1944, whereas the increase in ash amounted to 23.8 per cent during the entire period, 32.3 per cent in the summer and 9.3 per cent during the winters of 1943 and 1944. The percentage increase in ash was higher in the winter of 1943 than in that of 1944. The actual ash contents at different levels were lower during the second winter than during the first. These results indicate that oxidation was somewhat higher during the first winter than during the second. The increase in ash was, however, over three times higher during the summer than during the two winters. Considerable quantities of organic matter in the film are destroyed by oxidation in the bed, especially during the summer.

The average ash content of the sludge discharged from the bed is at times slightly lower and at other times slightly higher than the ash content of the film from the two-foot depth in the bed.

The progressive changes in the ash content of the film in the top, one-foot, and two-foot levels are given in Figure 1. The values between

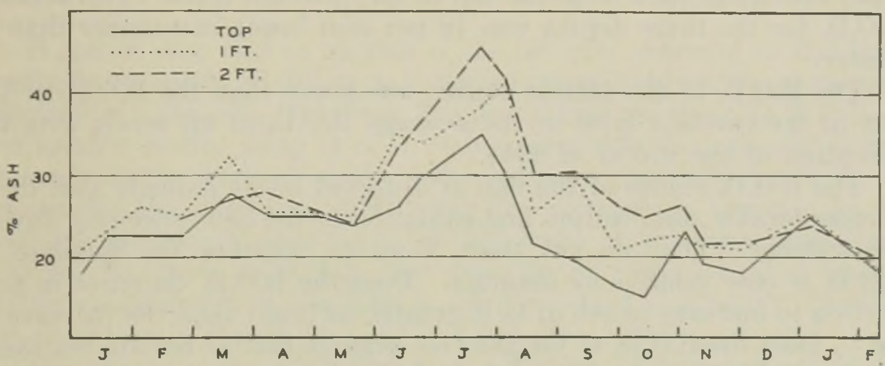

FIGURE 1.—The ash content of the biofilter film in the three different levels during the entire period of study.

January and May were fairly uniform and the difference between the various levels was small, indicating a state of equilibrium. The ash content at various levels increased after the middle of May, more sharply at first at the one-foot and two-foot levels. The peak was reached after the middle of July. The divergence in the ash content between the different levels was highest during this period. A maximum of 46.3 per cent ash was found at the two-foot level. The ash content decreased thereafter, at first sharply and then more gradually until November. During this period the divergence in the ash content at the different levels was also high. From November to February the fluctuations and divergences between the different levels were of smaller magnitude indicating another equilibrium.

The average B.O.D. of the film on the basis of solids at the different levels of the biofilter is given in Table II.

TABLE II.—*B.O.D. of the Film of Biofilter*
(*gm. per kg. dry solids*)

Period	Top	1 ft.	2 ft.	Effl. Sludge	Ave. of 3 Levels
Entire period (Jan. 1943 to Feb. 1944)	524	540	480	425	515
Summer ave. (May to Nov. 1944)	536	470	422	360	476
Winter ave. (Winter of 1943 and 1944)	509	625	580	501	571
Winter ave. (Winter of 1943)	473	638	605	416	572
Winter ave. (Winter of 1944)	594	594	546	631	578

For the entire period of study the values at the top and one-foot levels were nearly equal but there was some decrease at the two-foot level. The material containing the highest B.O.D. was at the top during the summer. The B.O.D. decreased progressively with depth. It was highest at the one-foot level during the winter. The reduction of B.O.D. from the top to the two-foot level was 21 per cent in the summer. The B.O.D. in the winter either increased as in 1943, or decreased only 8 per cent as in 1944 from the top to the two-foot level. The average B.O.D. for the three depths was 18 per cent lower in summer than in winter.

The B.O.D. of the effluent sludge was lower than the B.O.D. of the film at the two-foot level or the average B.O.D. of all levels with the exception of the winter of 1944.

The B.O.D. values of the film at different levels indicate that there is considerable stabilization and oxidation in the bed especially during the summer. They do not show, however, whether the decrease in B.O.D. is only relative or absolute. Does the B.O.D. decrease in proportion to increase in ash or is it greater or lower than the increase in ash? Does the B.O.D. of the ash-free organic matter remain the same, increase or decrease?

The results calculated on the basis of grams of B.O.D. per kilogram of volatile solids are presented in Table III. For the entire period the B.O.D. in the top two-foot zone decreased only slightly (2.5 per cent). The average during this period was higher at the one-foot level than

TABLE III.—*B.O.D. of the Film of Biofilter*
(*gm. per kg. dry volatile solids*)

Period	Top	1 ft.	2 ft.	Effl. Sludge	Ave. of 3 Levels
Entire period (Jan. 1943 to Feb. 1944)	680	725	663	572	691
Summer ave. (May to Nov. 1944)	702	644	644	490	663
Winter ave. (Winter of 1943 and 1944)	651	825	768	685	746
Winter ave. (Winter of 1943)	610	855	821	605	752
Winter ave. (Winter of 1944)	746	755	696	820	733

at either the top or the two-foot level. During the summer, the reduction in the top two-foot zone was somewhat more (8.2 per cent). The winter averages are either slightly lower or are actually higher at the two-foot level than at the top. Invariably, however, the values at the one-foot level are higher than at the top.

The effluent sludge had a lower B.O.D. for the entire period and during the summer than the film at the two-foot level. The average for the winter of 1944 is higher and for the winter of 1943 is lower than the corresponding values at the two-foot level.

The percentage increase of ash and decrease or increase in B.O.D., on solids and volatile matter basis, at the top two-foot zone were as follows:

	Entire Period	Summer	Winter of 1943 and 1944	Winter 1943	Winter 1944
Per cent increase in ash	23.8	32.3	9.3	14.2	6.3
Per cent decrease in B.O.D. on the basis of solids	8.4	21.2	+14.0	+28.0	8.1
Per cent decrease in B.O.D. on the basis of volatile solids	2.5	8.2	+18.0	+34.6	6.7

It can be seen that in no case is the per cent decrease in B.O.D. on the basis of solids of the same order of magnitude as the percentage increase in ash; and, therefore, the percentage decrease in B.O.D. on the volatile matter basis is of a lower magnitude than the percentage decrease on the basis of solids. The only exception appears to be the values for the winter of 1944 when the percentage increase in ash and the percentage decrease in B.O.D. were of the same magnitude. The results show, therefore, that the over-all destruction of organic matter as indicated by increase in ash proceeded at a faster rate than the reduction in B.O.D.

The average grease content of the film on the basis of solids and volatile matter are given in Table IV. On the basis of dry solids the average for the entire period varied from 9.4 to 11.6 per cent in the samples at various depths. The grease content was lower at the top than at the one-foot and two-foot levels and in the effluent sludge for

TABLE IV.—*Grease Content of Film of Biofilter*

	On % Dry Solids Basis				On % Dry Volatile Matter Basis			
	Top	1 ft.	2 ft.	Effl. Sl.	Top	1 ft.	2 ft.	Effl. Sl.
Ave. for entire period	9.4	11.2	10.3	11.6	12.2	15.1	14.2	15.4
Summer average	9.3	9.1	8.3	10.2	12.1	12.7	11.9	13.6
Winter of 1943 and 1944	9.5	13.6	13.6	13.8	12.3	20.0	18.0	17.8
Winter 1943	7.6	13.7	13.5	11.4	9.9	21.3	18.3	16.1
Winter 1944	13.4	13.4	13.7	17.0	17.0	17.2	17.6	20.1

the entire period. During the summer the grease content decreased somewhat at the two-foot level but was again higher in the effluent sludge than at the two-foot level. During the winter, the grease content remained either stationary or increased with depth. The results expressed on the basis of volatile solids indicate that only during the summer was the grease content lower at the two-foot level than at the top. The organic matter was relatively higher in grease content at the lower depths in the winter. The effluent sludge had more grease on the basis of solids or volatile matter than the film at the two-foot level. Only in the winter of 1943 was this relationship changed.

The nitrogen content of the film in the biofilter is given in Table V.

TABLE V.—*Nitrogen Content of Film of Biofilter*

	On % Dry Solids Basis				On % Dry Volatile Matter Basis			
	Top	1 ft.	2 ft.	Effl. Sl.	Top	1 ft.	2 ft.	Effl. Sl.
Ave. for entire period	8.3	7.8	7.5	7.1	10.6	10.5	10.3	9.6
Summer average	8.2	7.6	7.1	7.1	10.4	10.4	10.0	9.6
Winter ave. (1943 and 1944)	8.4	8.0	8.1	7.2	10.8	10.6	10.7	9.7
Winter ave. (1943)	8.9	8.2	8.6	6.3	11.6	11.0	11.6	9.4
Winter ave. (1944)	7.3	7.6	7.4	8.6	9.1	9.7	9.5	10.2

The variations in the nitrogen content of the various samples collected at the same level were small. On a dry solids basis the average nitrogen content for the entire period was 8.3 per cent at the top and decreased gradually to 7.1 per cent in the secondary clarifier sludge. In the summer the nitrogen content on the basis of dry solids was somewhat less than in winter, but on the basis of volatile matter there was little difference. The sludge from the secondary clarifier contained slightly less nitrogen on both the dry solids and the volatile matter bases than the samples collected from the bed itself.

The effect of applying the whole flow to one filter as a result of temporary shutdowns of one of the filters for repair, on the composition and characteristics of the film is shown in Table VI. The first shut-

TABLE VI.—*Effect of Temporary Shutdowns of One Filter on the Biochemical Characteristics of the Film in the Filter in Operation, Average of 0–2 Foot Levels*

	Filters in Operation	On Dry Solids Basis				On Volatile Matter Basis		
		B.O.D. gm. per kg.	Ash %	Grease %	Nitrogen %	B.O.D. gm. per kg.	Grease %	Nitrogen %
Sept. 29	two	515	21.4	7.5	8.1	650	9.5	10.3
Oct. 13	one	509	20.7	6.5	7.8	640	8.3	9.8
Oct. 15	two	579	17.8	10.0	7.2	700	12.2	8.8
Nov. 3	one	521	24.3	10.6	7.5	688	14.0	9.9
Nov. 12	one	608	20.8	10.0	8.0	807	12.8	10.1
Dec. 1	two	615	20.2	12.6	8.1	770	15.9	10.1

down occurred on October 12 and lasted for two days. The October 13 sample, therefore, illustrated the effect of one-day operation under these conditions. The September 29 sample is included as representative of the condition before the shutdown. The October 15 sample was taken just after the two filters were restored to operation and represents perhaps the full effect of the two-day shutdown. The filter was put out of operation again on October 25 and remained out of operation until November 12. The November 3 sample should represent the effect of nine days and the November 12 sample eighteen days of operation with a single filter. The December sample was taken nineteen days after both filters had been operating. The B.O.D. of the film increased somewhat during the two-day shutdown in October and reached the highest values after an eighteen-day shutdown period in November. After nineteen days of normal operation with both filters, the values were higher than those in September before the shutdown. The effect of low temperature in retarding the stabilization might contribute to the failure of recovery during this period. Although the flows during this period varied somewhat, the rate of application was nearly twice as high during the periods of shutdown as with normal operation with two filters. The percentage ash decreased from 21.4 per cent on September 29 to 17.8 per cent on October 15, indicating the effect of the short period of shutdown. On November 3, the ash content had increased to 24.3 per cent despite the fact that for nine days prior to this date one filter had been receiving the whole flow. Additional nine days of operation with one filter lowered the ash content to 20.8 per cent. The ash content was 20.2 per cent after nineteen days operation with both filters. The grease content increased during the two-day shutdown in October. It remained high during the November shutdown period and failed to recover after nineteen days operation with both filters. The nitrogen content of the film decreased during the first shutdown period and remained high thereafter, irrespective of whether one or two filters were in operation.

B. Standard Filter

The average ash content at the different depths of the standard filter is given in Table VII. The average percentage ash for the entire period increased progressively from the top to the six-foot level with a percentage increase of 71.7. During the summer the increase amounted to 72.9 per cent, whereas during the winter there was an increase of 71.1 per cent. Thus, the difference in the percentage increase of ash

TABLE VII.—*Ash in Film of Standard Filter*

	% Ash at Top	% Ash at 1-ft. Level	% Ash at 2-ft. Level	% Ash at 6-ft. Level	% Ash in Effl. Sludge	Ave. % Ash at 3 Top Levels
Average for entire period	22.6	31.3	34.8	38.8	31.0	29.2
Summer average	23.6	36.0	39.4	40.8	35.6	33.0
Winter average	21.5	26.5	26.4	36.8	33.7	24.8

between the summer and winter was not appreciable in the entire depth of the bed. The increase in the top two-foot zone was 54 per cent during the entire period, 67 per cent during the summer, and 22.8 per cent during the winter. The maximum increase in the ash content, therefore, took place in the upper two-foot depth in the summer with only a slight increase in the remaining four feet. The reverse was true in the winter. The ash content at the six-foot level in the winter was not so high as at the two-foot level in the summer. It is evident that the oxidation of the organic matter is retarded in the winter and, therefore, the full depth of the bed is required to produce results equivalent to summer conditions when the maximum oxidation takes place in the top two-foot depth.

The ash content of the sludge from the secondary clarifier was lower than that of the film from the six-foot level.

The progressive changes in the ash content of the film in the standard filter are given in Figure 2. The ash content of the film at the top of

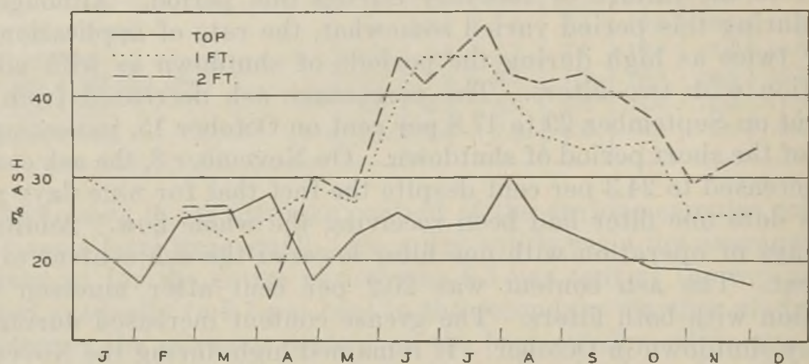

FIGURE 2.—The ash content of the standard filter film in the three different levels during the entire period of study.

the filter fluctuated between 17.5 and 25 per cent with only a few cases above the higher value. There was no appreciable summer increase. In contrast with this, the ash content increased from 25–30 per cent in the winter to 45 per cent in summer in the one- and two-foot levels. The high values in the summer extended over a longer period at the two-foot level than at the one-foot before declining to the low values of the winter period.

The average B.O.D. of the standard filter film is given in Table VIII

TABLE VIII.—*B.O.D. of Film of Standard Filter*
(gm. per kg. dry solids)

	Top	1 ft.	2 ft.	6 ft.	Effl. Sludge	Ave. Top 3 Depths
Average for entire period	454	385	355	188	222	400
Summer average	422	319	311	141	155	350
Winter average (1943 and 1944)	490	453	434	273	308	462

expressed as grams per kilogram of dry solids. The values are highest at the top and decrease progressively with depth. The average value for the entire period was 454 grams per kilogram of dry solids at the top and 188 at the six-foot level. The values were lower in summer than in winter at corresponding depths. The effluent sludge had a higher B.O.D. than the film at the six-foot level.

The B.O.D. values calculated on the basis of volatile matter are presented in Table IX. These data show the same tendency as those

TABLE IX.—*B.O.D. of Film of Standard Filter*
(gm. per kg. dry volatile solids)

	Top	1 ft.	2 ft.	6 ft.	Effl. Sludge	Ave. Top 3 Depths
Average for entire period	585	556	544	308	342	563
Summer average	552	498	515	238	249	522
Winter average	624	622	596	433	461	612

in Table VIII of decreasing B.O.D. with depth and lower values in summer than in winter. Unlike the biofilter values, however, the standard filter B.O.D. values, on the basis of volatile matter, failed to show increses at intermediate depths.

The percentage increase in ash and the decrease in B.O.D. on the basis of solids and of volatile matter are given below:

	Entire Period		Summer		Winter	
	0–2 ft.	0–6 ft.	0–2 ft.	0–6 ft.	0–2 ft.	0–6 ft.
Ash increase, per cent	54	72	67	73	23	71
Decrease in B.O.D. on solids basis, per cent	22	59	26	66	11	44
Decrease in B.O.D. on vol. matter basis, per cent	7	47	7	57	4	30

The ash increased 54 per cent in the top two-foot zone and 72 per cent within the full depth of the bed during the entire period. During the summer the increase was higher in the top two-foot depth with only a small additional increase in the lower levels. In the winter the increase in ash was low in the two-foot zone, but for the entire depth it was nearly equal to the increase in summer. The B.O.D. on the basis of solids decreased only 22 per cent in the two-foot zone as compared with 59 per cent in the entire bed during the year. The decrease was higher in the summer than in the winter in both the two-foot zone and the six-foot zone. The decrease in B.O.D. on the basis of volatile solids was small in the two-foot zone, but substantial for the entire depth of the bed.

The grease content of the film in the filter decreased progressively and markedly with increasing depth in the bed on both a dry solids and a volatile matter basis (Table X). The grease content on a dry solids basis was reduced greatly from the top to the six-foot level for the entire period. The grease content was lower during the summer than during the winter. The reductions within the six-foot level amounted to 50 per cent on a solids basis and to 40 per cent on a volatile matter basis during the entire period. There was little difference in the

TABLE X.—*Grease Content of Film of Standard Filter*

	On % Dry Solids Basis					On % Volatile Matter Basis				
	Top	1 ft.	2 ft.	6 ft.	Effl. Sl.	Top	1 ft.	2 ft.	6 ft.	Effl. Sl.
Average for entire period	9.9	7.1	5.3	4.9	7.6	13.4	10.2	8.1	8.1	11.5
Summer average	6.7	5.6	4.3	3.7	5.6	10.0	8.8	7.2	6.5	8.7
Winter average	13.2	9.0	7.0	7.0	10.1	17.0	12.1	9.5	11.1	15.2

percentage reduction of grease in the six-foot zone between the summer and winter, but it must be observed that the percentage grease in the film was only half as high in the summer as in the winter at the top level, indicating considerable decomposition at the top level during the summer. The grease content of the sludge from the secondary clarifier was higher than in the film taken from either the six- or the two-foot level.

In Table XI are given the average results of the Kjeldahl nitrogen content of the film on the dry solids and the volatile matter basis. The

TABLE XI.—*Kjeldahl Nitrogen Content of Standard Filter Film*

	On % Dry Solids Basis					On % Volatile Matter Basis				
	Top	1 ft.	2 ft.	6 ft.	Effl. Sl.	Top	1 ft.	2 ft.	6 ft.	Effl. Sl.
Average for entire period	7.6	7.1	6.4	5.0	5.2	9.9	10.2	9.9	8.2	7.9
Summer average	7.7	6.6	6.1	4.5	5.1	10.1	10.1	10.0	7.6	7.7
Winter average	7.5	7.6	7.0	5.7	5.4	9.5	10.2	9.7	9.0	6.9

nitrogen on the dry solids basis was highest at the top level and decreased progressively with increasing depth in the bed. The decrease was greater in summer than in winter. On the volatile matter basis the nitrogen content at the one- and two-foot levels was equal to or somewhat higher than that of the film at the top. At the six-foot level, however, there was an absolute decrease in the nitrogen content over the upper zones.

The percentage reduction in nitrogen at the two- and six-foot levels was as follows:

	Entire Period		Summer		Winter	
	0–2 ft.	0–6 ft.	0–2 ft.	0–6 ft.	0–2 ft.	0–6 ft.
Reduction in nitrogen on solids basis, per cent	16	34	21	42	7	24
Reduction in nitrogen on vol. matter basis, per cent	0	17	1	24	+2	5

The reduction on the basis of solids was over twice as great from the top to the six-foot level as from the top to the two-foot level. The reduction at the two-foot level was three times as high in the summer as in the winter, while at the six-foot level it was less than twice as high. On the volatile matter basis there was no reduction at the two-foot level, but at the six-foot level the reduction was 24 per cent in the summer and 5 per cent in the winter.

C. Protozoan Population

The preserved film samples were sent to Dr. J. B. Lackey, Senior Biologist of the Sanitary Engineering Division of the United States Public Health Service in Cincinnati, for microscopic examination. The results of this study will be published in greater detail. Here it is only necessary to report on the results briefly as they relate to differences in the characteristics of the film. The counts were grouped under three headings, namely: ciliates, flagellates, and rhizopods, expressed on the basis of dry solids and averaged for the entire period. In Table XII

TABLE XII.—*Numbers of Protozoa in Millions per Gram Solids*

	Top		1 ft.		2 ft.		6 ft.		Effl. Sludge	
	Bio-filter	Stand. filter	Bio-filter	Stand. filter	Bio-filter	Stand. filter	Bio-filter	Stand. filter	Bio-filter	Stand. filter
Ciliates	.92	2.67	3.08	1.83	1.57	1.36	—	.17	.97	0.10
Flagellates	41.90	12.00	18.47	22.30	20.74	21.20	—	19.00	21.33	1.30
Rhizopods	17.70	22.27	12.36	12.70	16.56	14.00	—	29.90	15.94	14.40

are given the results at the different levels of the biofilter and the standard filter. In the biofilter the ciliates were present in greatest numbers at the one-foot level whereas the flagellates and rhizopods were greatest in number at the top. In the standard filter the greatest number of ciliates and rhizopods were present at the top and flagellates at the one-foot level. The numbers of ciliates in the standard filter decreased gradually with increasing depth down to the six-foot level. The rhizopods on the other hand decreased in the intermediate levels, but increased at the six-foot level. The flagellates remained nearly constant at the one-, two-, and six-foot levels. There was a greater number of ciliates at the top of the standard filter than at the top of the biofilter. At the one- and two-foot levels this relationship was reversed. The flagellates were more abundant at the top of the biofilter. At the lower levels the numbers of flagellates in the two filters were nearly the same. Rhizopods were nearly the same in the two filters at equal depths. Of the three groups, flagellates were the most abundant organisms in both filters, followed by rhizopods and ciliates.

In the effluent sludge from the biofilter, the ciliates were fewer than at the different levels in the filter with the exception of the top layer. In the standard filter sludge, the ciliates were also very few in number in comparison with the film at the different levels of the bed, with the exception of the six-foot level. Flagellates and rhizopods in the sludge from the biofilter compared favorably with the numbers of organisms in the upper levels of the bed. In the standard filter sludge, the numbers of flagellates were decidedly smaller than at the upper levels. Comparison of the sludges from the two types of filters showed that the standard filter contained considerably fewer ciliates and flagellates than the biofilter, and a nearly equal number of rhizopods.

Of the ciliates one type, Vorticellidae, occurred in both filters most frequently and in greatest numbers. Ciliates were represented at the most by 4–5 species in the different levels of the biofilter, by a maximum of 11 species at the top of the standard filter and of 4–5 species at the one-, two- and six-foot levels and by only 2 species in the effluent sludge.

Colorless forms represented the most abundant and most frequently occurring types of the flagellates in both filters at all depths. The number of species at any time and at any level did not exceed 2–3 in either filter. Two rhizopods occurred most frequently and in greatest numbers at all the levels of both filters. These were *Diplophrys archeri* and *Hartmanella hyalina*. Other species occurring less regularly increased the number of species of rhizopods to 6–10, thus making it the group represented with the greatest number of species.

Discussion

1. *Comparison of the Chemical Characteristics of Biological Material from Biofilter, Standard Filter, and Activated Sludge*

The average composition of the film from the biofilter and the standard filter for the entire period of study is compared in Table XIII. The results represent the average of the top, one-foot, and two-foot levels

Table XIII.—*Comparison of Biochemical Characteristics of Biofilter and Standard Filter Films (Average for Entire Period of Three Top Levels)*

	Biofilter	Standard Filter
Ash in film, per cent	25.7	29.2
B.O.D., gm. per kg. solids	515	400
B.O.D., gm. per kg. volatile solids	690	563
Grease, per cent of total solids	10.3	7.4
Grease, per cent of volatile solids	13.8	10.6
N, per cent of total solids	7.9	7.0
N, per cent of volatile solids	10.5	10.0

of each filter. They represent the effect of the difference in the rate of application and strength of sewage on the biochemical characteristics of the film down to the two-foot level. Additional changes brought about by greater depth of the filter are excluded. It will be seen from the results that the film in the standard filter is characterized by a greater stability and a state of higher oxidation as indicated by higher ash content, lower B.O.D., and lower grease content. The nitrogen content of the film in the two-foot zone is only slightly lower in the standard filter than in the biofilter. It appears, therefore, that on account of a lower rate of application of sewage and consequent lower quantity of solids and B.O.D. applied, the stabilization of the film in the standard filter proceeded to greater magnitude than in the biofilter.

It is of interest to note that the percentage ash, grease, and protein (Kjeldahl N $\times$ 6.25) adds up to 85 per cent in the biofilter and to 80.5 per cent in the standard filter and that these three constituents account for the major portion of the solids. Proteins alone constitute 45–50 per cent of the solids. The organic nitrogen content of typical sewage averages from 15–20 p.p.m. with a total solids of 800–1,000 p.p.m. The organic nitrogen on the basis of total solids would amount to 2 per cent or 12.50 per cent protein. Thus the protein in the film could not be accounted for by the proteins in the sewage, even if they were completely adsorbed. The difference between the two values must be attributed to the protoplasmic growth of the flora and fauna made possible by the utilization and conversion of ammonia nitrogen in the sewage.

A comparison of the chemical composition of the film from biological filters with that of activated sludge reveals some interesting facts. Comparing the average values of the sludge from the secondary clarifier of the two types of filters with return activated sludge, we find:

	Biofilter	Standard Filter	Return Activated Sludge
Ash, per cent	27	31	25– 35
B.O.D., gm. per kg. total solids	425	222	220–300
Grease, per cent of total solids	11.6	7.6	5– 10
N, per cent of total solids	7.1	5.2	6– 6.5

The values for activated sludge are expressed within certain limits of variations as obtained from the available information in the literature. The majority of activated sludges will probably fall within the range of the values given. Depending on the nature of sewage and operation methods, some may be outside of these limits. The values given for the biofilter and the standard filter may not be generally representative, since they are based on one plant each. With these precautions, the figures show in general that the chemical characteristics of the film from the standard filter and activated sludge are more nearly alike than are those of the biofilter and activated sludge. The biofilter sludge has a higher B.O.D. per unit amount of solids than either the standard filter sludge or return activated sludge, indicating a lower degree of oxidation. This is in agreement with the conclusion drawn in the previous paper (1) that a greater amount of suspended solids is applied per unit amount of biological material in the biofilter than in the activated sludge process. It is further significant that the nitrogen content of the biofilter sludge is higher than that of return activated sludge. The nitrogen content of aerobic biological materials such as filter slime and activated sludge may be taken as an indication of the synthesis of microbial protoplasm from inorganic nitrogen. It is to be expected that the chemical nature of the sewage treated will affect the nitrogen content of the biological material formed. But in the absence of industrial waste, the carbon-nitrogen ratio of the sewage and the ratio of the organic to inorganic nitrogen in sewage do not vary materially. Hence the higher nitrogen content of the biofilter sludge may be taken to indicate that in this process the biological population is denser than in activated sludge. The higher amount of raw material applied per unit of biological material in the biofiltration process would give rise to a denser biological population. The average results of ciliates, flagellates, and rhizopods do not reveal material differences in numbers between the two filters with the possible exception of flagellates which are higher in the biofilter. But since no bacterial counts were made, because of the difficulty of dispersing the zoogleal masses, it is difficult to support the above statement from the actual counts of the biological population.

Another factor that may play a role in the nitrogen content of the film is nitrification. A part of the organic nitrogen may be lost as a result of transformation to ammonia nitrogen and oxidation to nitrites and nitrates. It may be significant that the biofilter sludge which had the highest nitrogen content did not produce appreciable amounts of nitrites and nitrates in the effluent from the plant. In the standard filter a high degree of nitrification was obtained and activated sludge plants produce intermediate and variable quantities of nitrates. The nitrification phase of the problem will be discussed further in a subsequent paper of this series.

It might be of interest to mention in this connection that the standard filter slime, which has chemical characteristics similar to the activated sludge, produced an effluent comparable to activated sludge (B.O.D. 10 p.p.m.).

2. *Oxidation of the Film in the Biofilter and in the Standard Filter*

Evidence of the extent of oxidation of the film in filters can be obtained from the changes in the stability of the film with increasing depth and from the differences between summer and winter results.

The differences in the ash, B.O.D., grease, and nitrogen content of the film with depth and seasons can serve as criteria of the extent of oxidation. The results obtained have already been presented and it is only necessary to summarize, compare, and interpret the evidence. The reductions or increases for the entire period from the top of the filters to the two-foot level and from the top to the six-foot level of the standard filters are given in Table XIV.

Oxidation as measured by ash increase was considerably higher than the reduction of B.O.D. on the basis of solids. It is to be expected that the increase in ash and the decrease in B.O.D. would be higher in the full depth of the bed than at the two-foot level. Biological stabilization is, therefore, of importance in the biofilter. Such filters are not mere "colloiders," converting the non-settleable solids into settleable form, and discharging it continuously. Unless the time lapse between the adsorption of the sewage materials and their discharge is extremely short, it would be impossible to prevent the utilization and stabilization of this material by the abundant flora and fauna in the

TABLE XIV.—*Comparison of Changes in the Stabilization of the Film in the Lower Levels of the Biofilter and the Standard Filter*

	Biofilter	Standard Filter
Ash increase in upper 2-ft. level, per cent	23.8	54.0
Ash increase in 6-ft. depth, per cent	—	71.7
B.O.D. reduction on the upper 2-ft. level on basis of solids, per cent	8.4	21.8
B.O.D. reduction in 6-ft. depth on basis of solids, per cent	—	58.6
B.O.D. reduction in upper 2-ft. level on basis of volatile matter, per cent	2.5	7.0
B.O.D. reduction in 6-ft. depth on basis of volatile matter, per cent	—	47.2
Decrease in grease in upper 2-ft. level on basis of solids, per cent	+9.6	46.5
Decrease in grease in 6-ft. depth on basis of solids, per cent	—	50.5
Decrease in grease in upper 2-ft. level on basis of volatile matter, per cent	+16.4	39.5
Decrease in grease in entire bed on basis of volatile matter, per cent	—	39.5
Decrease in nitrogen in upper 2-ft. level on basis of solids, per cent	9.6	15.8
Decrease in nitrogen in entire depth of beds on basis of solids, per cent	—	34.2
Decrease in nitrogen in upper 2-ft. level on basis of volatile matter, per cent	2.8	0
Decrease in nitrogen in entire depth of bed on basis of volatile matter per cent	—	17.2

film. That the material adsorbed is stored for some time is evident from the stabilization of the film. However, it does not appear that storage is as long as in the standard filter because the reductions obtained at equal depths are definitely higher in the standard filter.

Storage time is obviously not long enough in the biofilter to bring about material reduction in the grease content of the film at the two-foot level. The increase at this level over the top level is to be attributed to the relatively higher rate of adsorption. Since it does not seem likely that the decomposition of grease is slower at the two-foot level than at the top, the increase in the grease content at this level should be attributed to the higher rate of adsorption. Evidence has been produced in the previous paper (1) which tends to show that the velocity of flow of sewage at the top level may limit the quantity of film by reducing the contact time between the film and the materials to be adsorbed. If the grease is adsorbed more slowly than other ingredients in the sewage, a relatively greater proportion will be adsorbed at the lower levels where a greater contact time is available. In the standard filter with the lower rate of application, the percentage grease in the solids at the two-foot level does not increase, but is reduced by 46.5 per cent, indicating that adsorption of grease is greater at the top and storage is long enough to bring about substantial reduction. If the adsorption rate of grease in the standard filter is higher at the top, then less grease will reach the lower level. The percentage grease in the solids will therefore be lower and may not necessarily be a measure of greater destruction of grease. The criteria of ash and B.O.D., however, are not apt to be subject to such a criticism, unless it is assumed that there is also a differential adsorption of these materials at different levels, and they may, therefore, be taken as true measures of decomposition.

The decomposition as measured by the percentage ash increase is over twice as high in the standard filter as in the biofilter at equal depth. At the six-foot depth an overall increase of 71.7 per cent in ash was obtained in the standard filter, an increase as high as in anaerobic sludge digestion. The B.O.D. reduction also was 2.5 times higher in the standard filter than in the biofilter at the two-foot level. In the entire depth of the standard filter a total of 58.6 per cent reduction of B.O.D. on the solids basis was obtained. Since the percentage increase in ash was relatively higher than the decrease of B.O.D. on a dry solids basis, the reduction on the volatile matter basis was of a lower magnitude. The decrease in nitrogen on the dry solids basis was nearly twice as high in the standard filter as in the biofilter at a depth of two feet. At six feet the reduction in the standard filter was twice as high as at two feet.

The reductions or increases obtained at the two-foot level of the two types of filters during the summer and winter are compared in Table XV. The reductions are decidedly greater in the summer than

TABLE XV.—*Comparison of the Percentage Increase in Stabilization of the Film at the Two-Foot Level of the Two Filters During the Summer and Winter*

	Biofilter		Standard Filter	
	Summer	Winter	Summer	Winter
Ash increase, per cent	32.3	9.4	67.0	22.8
B.O.D. reduction on basis of solids, per cent	21.3	+14.0	26.3	11.4
B.O.D. reduction on basis of volatile matter, per cent	8.2	+18.0	6.7	4.5
Decrease in grease on basis of solids, per cent	10.8	+43.1	35.8	47.0
Decrease in grease on basis of volatile matter, per cent	1.6	+46.4	28.0	44.1
Decrease in nitrogen on basis of solids, per cent	13.4	3.6	20.8	6.6
Decrease in nitrogen on basis of vol. matter, per cent	3.8	0.9	1.0	+2.1

in the winter with the exception of the grease reduction in the standard filter. The grease content of the film at the top of this filter was nearly twice as high in the winter as in summer. Although at the two-foot level the material contained actually less grease in summer than in winter, a greater percentage reduction was obtained in the winter, because of the higher grease content at the top. The question arises whether the solids at the top of the filter can be considered identical in degree of oxidation with the raw sewage ingredients and whether at times, especially during the summer, considerable oxidation and reduction had not already taken place on the top. If this is so, then the calculations on this basis do not represent the maximum reductions, and the divergence between summer and winter reductions actually should be greater.

In the biofilter the B.O.D. and grease content in the winter at the two-foot level were higher than at the top. The greater rate of adsorption of grease at the lower level, due to the high rate of application accompanied by a lower rate of decomposition in the winter, would give rise to an increase in the grease content at the two-foot level over the top level.

The various values obtained pertaining to the percentage increase in ash and decrease in B.O.D., grease and nitrogen, with increasing depth, represent a magnitude of oxidation which is lower than actual because they are derived by using the material from the top of the filter as datum point. The film from the top of the bed is not equivalent to the raw material applied to the bed, but has undergone variable degrees of decomposition depending on the conditions. This can be best illustrated by reference to Figures 1 and 2, where it is shown that the percentage ash in the top film increases simultaneously with the ash content of the materials from the lower levels. The percentage increases calculated on this basis, therefore, represent minimum values, especially during the summer period.

Lower temperatures, according to these results, affect the process of decomposition and oxidation in the biofilter to a greater extent than in the standard filter at equal depths. In addition the latter has additional depth to make up for the retardation due to lower temperatures.

This demonstrated oxidation must, therefore, play an important role in the quantity of film in the filter. In the previous paper of this series (1) it was shown that the quantity of film in both filters was higher in the winter than in the summer. The rate of oxidation as indicated by the various criteria used is considerably retarded during the winter. It is, therefore, natural to conclude that oxidation of the film is an important factor in determinnig the quantity of the film. In the standard filter the spring sloughing reduced the quantity of film considerably, but thereafter film accumulation during the warmer months was kept in check by the stimulated biological activity. In the biofilter there was no indication of seasonal sloughing. The lower quantities of solids and B.O.D. applied in conjunction with the accelerated biological activities contributed to the low film accumulation during the summer in the biofilter. The fact that, despite the higher magnitude of oxidation in the standard filter, the quantity of film is not lower than in the biofilter must be attributed to the longer storage period in the former or, conversely, to the continuous unloading of solids in the latter.

3. *Relationship Between Various Chemical Characteristics of the Film*

The relationship between the various criteria used in determining the chemical characteristics of the film is illustrated graphically in Figures 3 and 4. The average of the values at the top, one- and two-foot

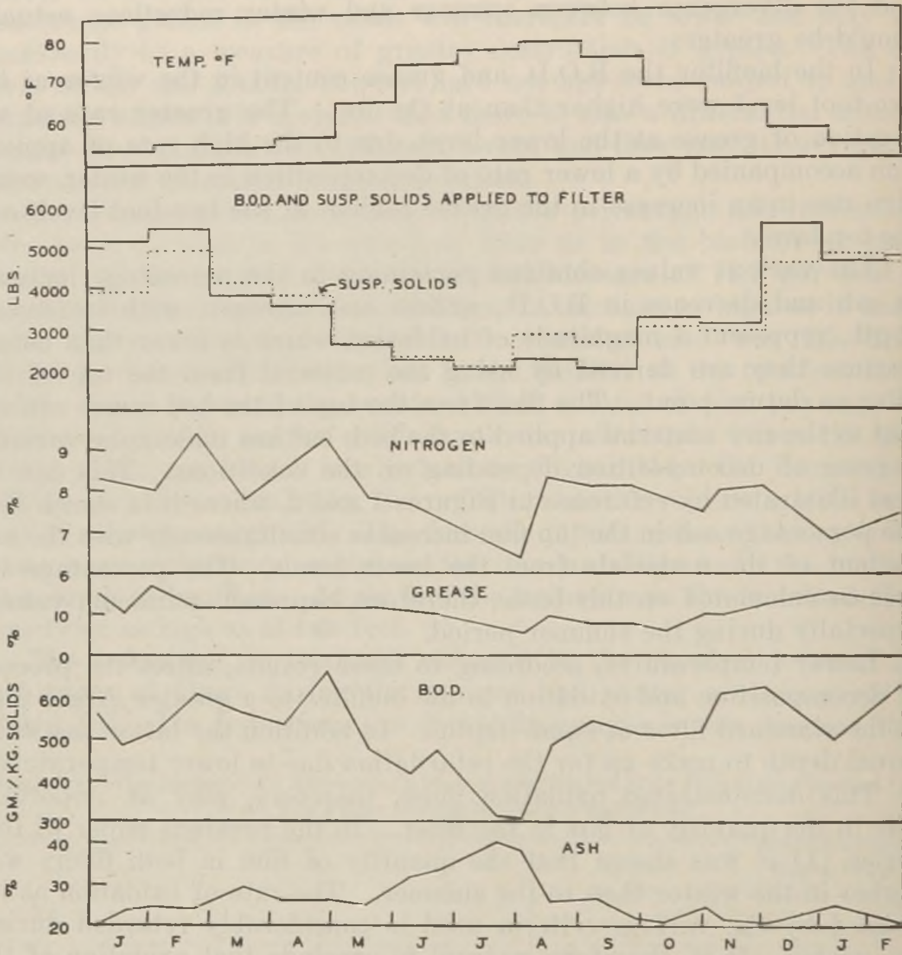

FIGURE 3.—The relationship of the nitrogen, grease, B.O.D., and ash contents of the film at the top two-foot level of the biofilter and the effect of temperature on the sewage and the B.O.D. and suspended solids loadings of the bed on the chemical characteristics of the film.

levels are compared in each case. In the biofilter the relationship between B.O.D. and ash is in general an inverse one. There are some individual variations in B.O.D. which are not reflected in the ash content. The grease content was high with high B.O.D. values and ash, but decreased when the B.O.D. decreased and the ash increased. The nitrogen content also varied directly with B.O.D. and indirectly with the ash content. Similar relationships existed in the ash, B.O.D., grease, and nitrogen contents of the film in the standard filter.

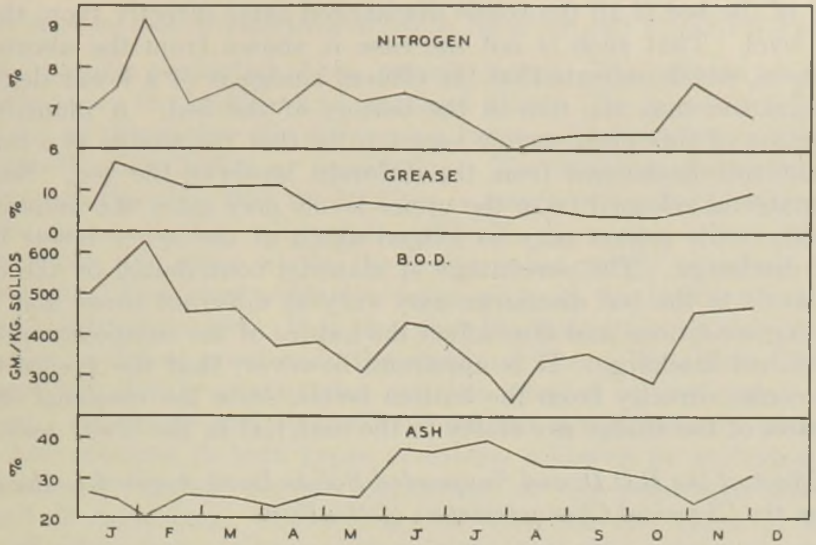

FIGURE 4.—Relationship between nitrogen, grease, B.O.D. and ash contents of the film at the top two-foot level of the standard filter.

4. *Comparison of the Chemical Characteristics of the Sludge Discharged from the Beds with the Films at the Lower Levels*

A comparison of the ash, B.O.D., grease, and nitrogen of the sludge obtained from the clarifier, which represents the discharge of the film from the bed, with the films at the lowest levels in the bed, is presented in Table XVI. These results represent the average for the entire

TABLE XVI.—*Comparison of the Chemical Characteristics of the Sludge from the Secondary Clarifier with the Film of the Lower Level*

	Biofilter		Standard Filter	
	2-ft. Level	Effl. Sludge	6-ft. Level	Effl. Sludge
Ash, per cent	28.1	27.1	38.8	31.0
B.O.D., gm. per kg. solids	425	480	188	222
Grease, per cent solids	10.3	11.6	4.9	7.6
Nitrogen, per cent solids	7.5	7.1	5.0	5.2

period. The effluent sludge is compared with the film at the two-foot level in the biofilter, and with the film at the six-foot level in the standard filter. The results show that the ash content of the sludge collected from the clarifier from both types of filters was lower than the film in the lowest level analyzed. The B.O.D. and the grease content on the other hand were higher in the effluent sludge than in the film in the lowest level of each filter. The difference in the nitrogen content was not material.

The chemical characteristics of the sludge collected from the secondary clarifier should be similar to those of the film from the lowest level of the bed if all the solids discharged came directly from the bottom level. That such is not the case is shown from the above comparisons, which indicate that the effluent sludge is of a lower degree of stabilization than the film in the bottom of the bed. A plausible explanation of this phenomenon seems to be that the sludge is a mixture of material discharged from the different levels in the bed. Some of the material released from the upper levels may enter the underdrains directly while a part may be lodged again at the lower levels before final discharge. The percentage of material contributed by the different levels to the bed discharge may vary at different times and under varying conditions and thus affect the nature of the composite obtained in the bed discharge. It is apparent, however, that the greatest portion comes directly from the bottom levels, since the chemical characteristics of the sludge are closer to the material in the lower zone.

5. *Effect of the B.O.D. and Suspended Solids Load Applied to the Filter on the Chemical Characteristics of the Film*

A complete record of the daily flows of sewage and volume of recirculated effluent and of B.O.D. and suspended solids determination from the different units of the biofilter plant was available. It is possible to estimate the pounds of B.O.D. and suspended solids applied to the filter, which include both the portion contributed by the primary tank effluent and that contributed by the recirculated final effluent. The results were averaged for each month and are presented in Figure 3 for comparison with the chemical characteristics of the film. No such complete records are available from the standard filter plant. Since the sewage is derived from a community without any industrial waste, the B.O.D. and suspended solids load would not be subject to the variations of an army embarkation camp.

The number of pounds of B.O.D. and suspended solids applied to the biofilter was high from January to May. During this period the ash content of the film was low and B.O.D., grease, and nitrogen contents were high. The B.O.D. and suspended solids load was low from May to October. During this period the ash content increased to a maximum and declined again before the load began to increase. Similarly, the B.O.D. of the film reached a minimum and then increased while the load applied was still at a low level. From October to February, the pounds of B.O.D. and suspended solids applied increased. During this period the ash content of the film was low, and the B.O.D. and grease contents were high. These results indicate that the volume and strength of the sewage and the temperature influence the chemical characteristics of the film. The highest degree of oxidation was obtained during the summer when the temperature was at an optimum for accelerated biological activity and at the same time the load was at an optimum. But the degree of stability of the film underwent a sharp change during August without an accompanying increase in load or a decrease in temperature.

6. *Differences and Similarities between Biofilter and Standard Filter*

The results presented above permit certain comparisons and analogies between the biofilter and standard filter. The question may now be posed as to whether the differences between the two types of filters are merely quantitative or qualitative. The evidence presented does not support the view that the biofilter is merely a "colloider" converting the non-settleable solids into settleable form and discharging it continuously. In other words, the action is not purely physical. That a substantial biological oxidation takes place in the biofilter has been definitely demonstrated. It is true that the magnitude of this biological action is not so great as in the standard filter. Therefore, the differences are merely quantitative and are affected by the higher loads applied. Straining and "colloider" actions are necessary prerequisites and common in both types of filters, followed by biological stabilization of varying degrees depending on the conditions and the method of operation. The analogy between the two types of filters and activated sludge is also evident in the fact that continued adsorption and purification of sewage impurities are dependent on the regeneration brought about by biological action. Just as in the activated sludge process, adsorption and clarification would come to a standstill in the absence of oxidation and regeneration of the occluded surfaces for further adsorption. Otherwise, biological filters would be in the same category as sand and magnetite straining devices and would require mechanical and physical cleaning facilities for continued operation. Sewage solids have little adsorptive power in themselves, but the zoogleal jelly which is produced from the utilization of the absorbed sewage solids by microorganisms has a great adsorptive power.

The factors that influence biological activity will therefore affect the stabilization of the film. The important factors that influence biological activity are temperature, food supply, and oxygen. Provided a bed does not become choked, there should be a definite relationship between the degree of stabilization brought about, the food supply (load) and temperature. When the food concentration exceeds a value which can be utilized at a given temperature, the degree of stabilization of the film will decrease and vice versa. Increasing the load to either the biofilter or the standard filter will have a similar effect on the degree of stability of the film. An overloaded standard filter may approach the chemical characteristics of the film from the biofilter, and biofilters operated under different load conditions will produce films of varying degrees of stability. A biofilter operated with relatively low load may have film characteristics and may produce purification results similar to the standard filter.

Time of storage, as affected by the rate of application and the depth of the bed, is also an important factor in the degree of stabilization of the film. But in the final analysis, the rate of application and the storage time are related and interdependent factors. With high rates of application and loading, the contact and the storage time is reduced, consequently, the chances for more or less complete oxidation are decreased. Continuous as contrasted with intermittent loading is also indirectly dependent upon the rate of application and loading.

Finally, the biological population as revealed by microscopic examination of the film does not show significant quantitative or qualitative differences between the biofilter and the standard filter.

Summary and Conclusions

The biochemical characteristics of the film at different levels of a biofilter and a standard filter were determined, the ash, B.O.D., grease, and nitrogen contents being employed as measuring devices. Microscopic examination of the biological population of the film were also made and are discussed in this paper insofar as they reveal similarities and differences between the two filters. The results obtained warrant the following conclusions:

1. There is a definite and significant increase in the stabilization of the film from both filters as revealed by increase in ash, decreases in B.O.D., and grease content in the lower levels of the bed and by the relatively greater increases in the summer than in the winter. The figures given below of the magnitude of biochemical oxidation are lower than actual, since they do not take into account the stabilization of the film at the top of the bed:

	Biofilter	Standard Filter
Increase in ash, per cent		
2 ft. level	23.8	54.0
6 ft. level	—	71.7
Decrease in B.O.D., per cent		
2 ft. level	8.4	21.8
6 ft. level	—	58.6
Decrease in grease, per cent		
2 ft. level	+9.6	46.5
6 ft. level	—	50.5
Decrease in total nitrogen, per cent		
2 ft. level	9.6	15.8
6 ft. level	—	34.2

2. The film from both filters is characterized by an unusually high nitrogen content, the proteins alone constituting 45–50 per cent of the solids, indicating a high photoplasmic material of the microflora and microfauna. The nitrogen content of the biofilter growth is higher than that of the standard filter and activated sludge. The B.O.D. of the film from the standard filter and that of activated sludge are approximately the same, but that of the biofilter film is higher than either of the others.

3. There was, in general, an inverse relationship between the ash content of the film and the B.O.D., grease, and nitrogen content. How-

ever, this relationship was not in direct proportion as the increase in ash was relatively at a higher rate than the decrease in the other criteria.

4. The rate of oxidation of the film was of such a magnitude as to be one of the important factors limiting the quantity of the film.

5. Temperature and the applied load (pounds of suspended solids and B.O.D.) play an important role in determining the biochemical characteristics of the film.

6. The chemical characteristics of the sludge collected from the secondary clarifier were not identical with the film collected from the lower levels of the bed. These characteristics showed a lower degree of stabilization, indicating that at least a part of the sludge collected came directly from the upper levels.

7. The numbers of ciliates, flagellates and rhizopods were practically the same in both types of filters. Flagellates were the most abundant organisms in both filters. Vorticellidae were the ciliates that occurred most frequently and in greatest numbers in both filters. Colorless flagellates presented the most abundant and frequently occurring type of flagellates in both filters. Two rhizopods, *Diplophrys archeri* and *Hartmanella hyalina,* occurred most frequently and in greater numbers in both filters.

8. The chemical and biological characteristics of the film revealed that the difference between a biofilter and a standard filter is only quantitative. Considerable oxidation of the film took place in the biofilter, which is, therefore, not a mere colloider.

References

1. Heukelekian, H., ''The Relationship Between Accumulation, Biochemical and Biological Characteristics of the Film and Purification of a Biofilter and Standard Filter. I. Film Accumulation.'' *This Journal,* 17, 23 (January, 1944).

Industrial Wastes

TREATMENT OF PACKINGHOUSE WASTES *

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The magnitude and importance of this subject is best illustrated by a few statistics relating to the meat packing industry. There are 68 markets in 32 states of this country where meat packing is a major industry, and there are many more meat packing plants than there are markets. The total annual kill of all animals under federal supervision in the United States has ranged from about 71,000,000 in 1929 to 98,000,000 in 1943 (see Table 1).

Table 1.—*Annual Kill of Animals in U. S. Under Federal Inspection*

Year	Total Number of Animals Killed
1929	70,791,993
1930	69,132,637
1931	70,950,690
1932	70,769,361
1933	*73,234,327
1934	†69,874,954
1935	53,367,407
1936	64,242,374
1937	58,981,830
1938	64,022,573
1939	68,055,165
1940	77,505,178
1941	75,590,194
1942	87,868,939
1943	98,511,369

* In 1933 the Government killed 6,410,866 pigs and sows not included in this total.
† In 1934 the Government killed 6,066,663 cattle, calves and sheep not included in this total.

In 1943 the total weight of all animals slaughtered in the United States under federal supervision amounted to 30,806,000,000 pounds.

The wastes produced from this slaughter would amount to about 50,000,000,000 gallons per year. Their population equivalent would be about 11,200,000 on a B.O.D. basis.

There is nothing static about the packing industry, either in its products or its production.

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New products are continually being developed and their sale promoted to a public which appears increasingly eager to buy ready-prepared foods.

To demonstrate the rate of growth of the industry, there are shown in Figure 1 the annual kills of all animals at three major packinghouses in the midwest. In the same figure is shown the annual kill of all animals in this country at plants under federal supervision.

The effect of this rapid rate of growth is of particular importance in cases where wastes from packinghouses are treated jointly with domestic sewage in a municipally owned and operated plant in a medium-sized community. Most municipal financing of sewage treatment plants is for a period of from 20 to 30 years. Except where construction costs are paid for by the proceeds from the sale of revenue

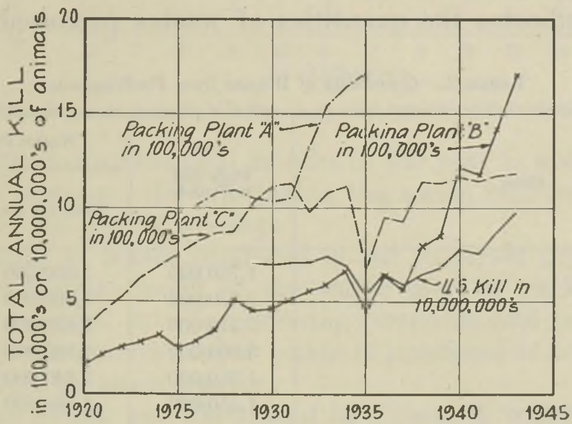

FIGURE 1.—Annual animal kill for three packinghouses and the entire United States.

bonds, which in turn are financed by service charges collected from users, general obligation bonds are voted and sold to pay construction costs. Frequent bond issues are not popular, nor is a large issue popular when it is large because of the need to provide capacity for an anticipated future increase in industrial load.

Difficulties Inherent in the Treatment of Packinghouse Wastes

The treatment of packinghouse wastes is not only a large problem but it is also a difficult one, due to many factors inherent in packing operations and in the characteristics of the wastes. Among these are:

1. The large quantities of the wastes.
2. The considerable variation in quantity of the wastes depending upon a varying seasonal kill.
3. The highly varying instantaneous rate of production of the wastes.
4. The strength of the wastes particularly as regards their content of B.O.D., suspended solids, grease and organic nitrogen, and their high temperature.

5. The high speed at which some of the organic solids go into solution.

6. The strong and disagreeable odor of the wastes.

7. The pre-treatment given the waste by the packer.

8. The degree of final treatment necessary to protect the receiving waterway.

Quantities of Packinghouse Wastes

The quantity of wastes produced per thousand pounds of animals killed varies for different packinghouses. Water uses are necessarily quite similar because of uniform regulations governing clean-up operations and the like. The quantity of wastes, however, appears to depend upon the measures taken within the plant to recover liquid wastes and to minimize the use of water.

Table 2 indicates the quantities of wastes produced per thousand pounds of kill at several packinghouses. Attention is called particularly to the low unit quantities of wastes produced at packinghouse "A" which are very low. During 1941 measures were taken within the plant to evaporate a large volume of the strongest wastes. The management at this plant has always stressed care in the use of water, and has also striven to reduce the quantity of waste by evaporating some of the stronger liquors.

TABLE 2.—*Quantities of Wastes from Packinghouses*

Plant	Daily Kill in Pounds	Wastes Produced—Gallons	
		Total per Day	Per Thousand Pounds of Animals Killed
Plant A (1941)	1,760,000	2,000,000	1,130
Plant A (1942)	2,150,000	1,960,000	916
Plant A (1943)	2,310,000	1,920,000	835
Plant B	3,000,000	4,800,000	1,600
Plant C	1,280,000	1,340,000	1,090
Plant D	1,550,000	2,480,000	1,600
Chicago			
Plant E	1,000,000	3,050,000	3,050
Plant F (1)	918,000	2,710,000	2,960
Plant G	658,000	1,460,000	2,210
Plant H (2)	434,000	930,000	2,150
Plant I (1)	1,424,000	1,810,000	1,270
Plant J	1,570,000	6,540,000	4,160

(1) Cattle only are killed. (2) Hogs only are killed.

Seasonal Variation in Kill and Quantity of Wastes

At most packinghouses there is a considerable seasonal variation in the quantity of wastes produced. The seasonal kills, expressed as percentages of the monthly average for the year, at a mid-western packinghouse, and for the entire country are shown in Figure 2. In

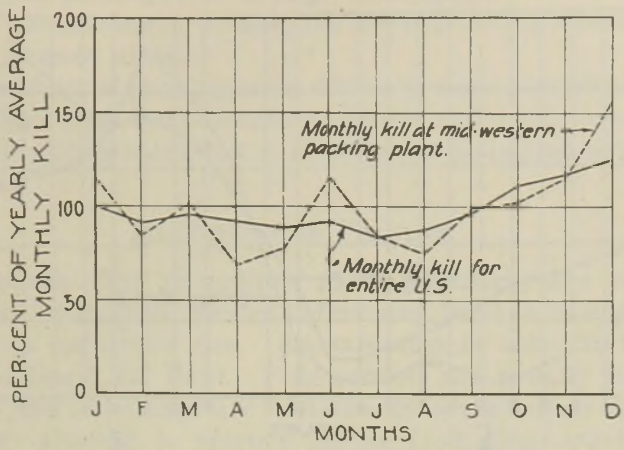

FIGURE 2.—Monthly variation in kill for U. S. and typical mid-western packing plant.

general the kill during the cold months of the year is about 120 per cent of the yearly average; the kill during the warm months of the year is 90 per cent of the yearly average.

The quantity of waste produced is not in direct proportion to the kill. This is because much of the water used in packing operations is used at a constant rate for cleaning purposes and is not dependent upon the kill. In general, more waste is produced in cold weather per unit of kill than in warm weather.

Both these points are illustrated in Figure 3, which is based upon one year's records at a large mid-western packinghouse.

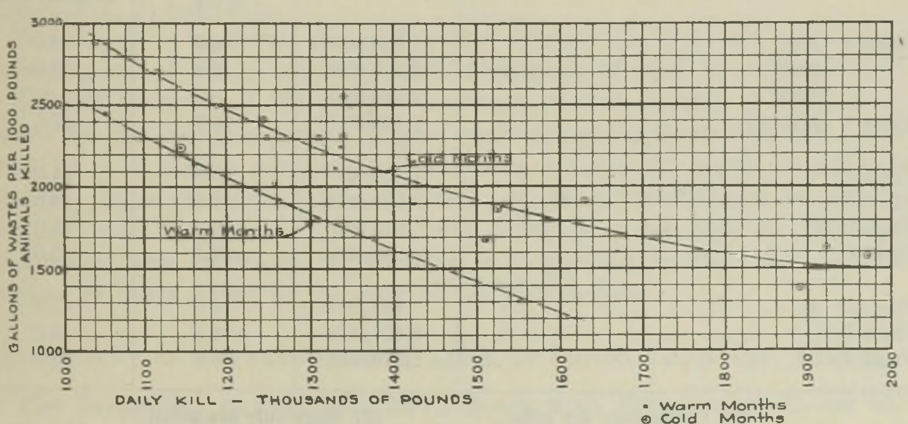

FIGURE 3.—Unit quantity of wastes.

Instantaneous Rates of Production of Wastes

Of considerable importance from the design standpoint are the highly varying instantaneous rates of production of the wastes. The curves shown in Figure 4 are typical of the rates of discharge at two midwestern packinghouses.

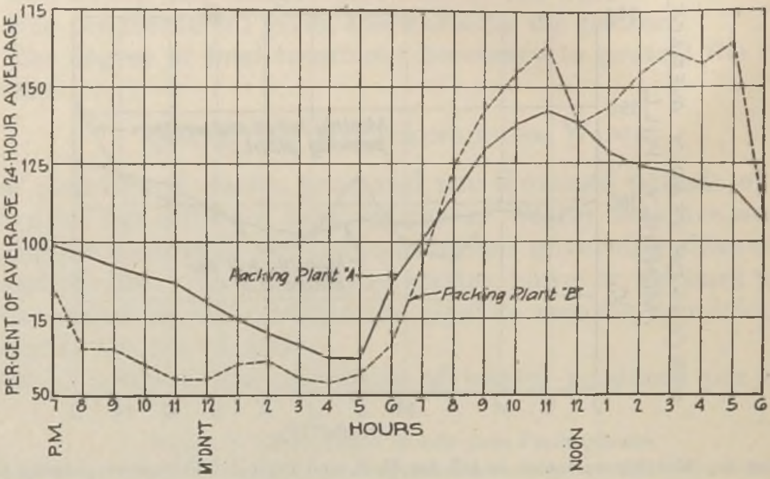

FIGURE 4.—Typical variations in discharge of packinghouse wastes.

COMPOSITION OF PACKINGHOUSE WASTES

Wastes from different packinghouses vary widely in composition as indicated by the data in Table 3 for nine packinghouses. These

TABLE 3.—*Composition of Wastes from Various Packinghouses*

Plant	Daily Kill in Pounds	Pounds per Thousand Pounds of Animals Killed	
		B.O.D.	Suspended Solids
Plant A (1941)	1,760,000	6.8	2.9
(1942)	2,150,000	7.8	3.0
(1943)	2,310,000	5.2	—
Plant B (1943–44)	2,100,000	16.7	17.5
Plant D	1,550,000	16.8	21.0
Plant E	1,000,000	14.0	12.0
Plant F (1)	918,000	9.9	11.0
Plant G	658,000	16.6	15.0
Plant H (2)	434,000	9.6	7.0
Plant I (1)	1,424,000	6.5	6.0
Plant J	1,570,000	18.9	22.0

(1) Cattle only are killed. (2) Hogs only are killed.

variations may be due to the kinds of animals killed, the amount and kinds of processing carried on, the practice within the plant to salvage inedible and edible by-products and, in some cases, the measures taken within the plant to reduce the load discharged to a wastes treatment plant.

Packinghouse wastes contain much organic nitrogen. This constituent is believed to exert a great influence upon the performance of certain biological processes of sewage treatment.

They also contain much grease, the average being about 7 pounds per thousand pounds of kill.

The temperature of packinghouse wastes is high, sometimes reaching 90 degrees. This high temperature promotes rapid solution of organic solids, which is detrimental, but it also favors biological sewage treatment processes.

Packinghouse Practice

With relatively few exceptions most packinghouses remove the paunch manure from their wastes before any further treatment at the packinghouse or anywhere else. An exception is noted in the case of the packers at South St. Paul. Fine screens are usually employed in the process. The screenings are customarily spread upon the land.

All packers attempt to remove grease from their wastes but the effectiveness of the removal processes varies greatly. In general, resort to improved methods of removal has been slow.

Recovery of blood is practiced, but here again, observation reveals a wide range in the effectiveness of the removal process.

Methods of Pretreatment

Pretreatment methods vary from none at all, or at the most the removal of paunch manure, in some of the large cities, where the ratio of domestic sewage to packinghouse waste is great, to pretreatment processes designed to reduce the strength of the packinghouse wastes to that of domestic sewage, as is the case at the Oscar Mayer Company at Madison, Wisconsin.

There seems to be no general policy among the packers regarding pretreatment of their wastes. Establishment of such a policy would be difficult because of the great variation in the degree of treatment needed in the various places where packinghouses have located. The industry is a highly competitive one and subject to much regulation already. It is probable that no general policy of pretreatment will be adopted until the industry as a whole develops some method of treatment which can be made to produce a by-product which will yield a revenue at least equal to the cost of its production.

Treatment of Packinghouse Wastes at Sioux Falls and Austin

The foregoing paragraphs have dealt with the subject in an exceedingly general way. The remainder of this paper deals with two specific cases of packinghouse waste treatment, namely, at Sioux Falls, South Dakota and Austin, Minnesota.

Some factors are common to both places. These are a rapidly growing packing plant which constitutes the main industry of the city, a receiving waterway which affords very little dilution for the effluent of a sewage treatment plant, a joint treatment plant owned and operated by the municipality treating about equal volumes of packinghouse waste and domestic sewage, and a wide range of climatic conditions.

At Sioux Falls the domestic sewage and packinghouse wastes may be treated separately or together. At Austin the domestic sewage and packinghouse waste must be treated together. Both plants utilize two stages of trickling filters.

At Sioux Falls pretreatment comprises plain sedimentation and grease skimming at the packinghouse, with the sludge removed being pumped directly to the sludge digestion tanks at the city sewage treatment plant. This pretreatment removes about 34 per cent of the B.O.D. and about 58 per cent of the suspended solids. Typical operating results are shown in Table 4.

TABLE 4.—*Pretreatment at Packing Plant at Sioux Falls (Plain Sedimentation and Grease Skimming)*

Period	Average Daily Flow	Settling Period in Hours	Influent P.P.M.		Effluent P.P.M.		Per Cent Removals	
			B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.
May '44	3.048	1.11	1620	1806	1119	687	31.0	62.0
June	2.651	1.30	1900	1730	1108	651	41.8	62.1
July	2.573	1.32	1433	1682	1018	833	29.0	50.1
Ave.	2.790	1.24	1651	1739	1081	724	33.9	58.1

At Austin the packinghouse wastes are first given plain sedimentation and then heavily dosed with chlorine and settled again. This process, inaugurated by Halvorson, has been described fully in the literature. Table 5 indicates results of the process. Some 3,500 to 4,500 pounds of chlorine per day are used to precipitate the proteins. The effect of this method of pretreatment is the removal of most of the organic matter subject to removal by sedimentation. This fact is illustrated by the low B.O.D. removals effected at the city sewage treatment plant with chemical flocculation and sedimentation, as shown in Table 6.

Dosages of alum ranging from 42 to 146 parts per million increased the B.O.D. removals only about 12 per cent over the amounts removed by plain sedimentation. The alum treatment effected an increased removal of suspended solids of about 19 per cent. The chief value of the treatment consisted in lessening the load of suspended solids on the preliminary filters.

Sioux Falls Sewage Treatment Plant

The sewage treatment plant at Sioux Falls comprises certain facilities allocated to the treatment of the packinghouse wastes. These

TABLE 5.—*Data on Pretreated Packinghouse Wastes at Austin, Minn.*

Date	Thous. Lbs. Kill per Day	Quantity of Waste		Lbs. Susp. Solids per Thous. Lbs. Kill	Lbs. B.O.D. per Thous. Lbs. Kill
		Total M.G.D.	Gallons per Thous. Lbs. of Kill		
1941					
Jan	1900	2.16	1140	1.92	5.36
Feb.	1840	1.90	1030	1.70	4.90
Mar.	2220	1.95	880	1.46	4.76
Apr.	1520	1.93	1270	2.15	6.10
May	1685	1.98	1170	2.16	5.41
June	1640	1.80	1100	3.50	7.20
July	1555	1.82	1170	3.00	7.55
Aug.	1380	1.92	1390	3.26	7.55
Sept.	1730	1.95	1130	2.74	6.60
Oct.	1510	1.95	1290	4.95	9.30
Nov.	1680	1.97	1180	4.76	9.95
Dec.	2410	2.06	850	3.90	7.50
1942					
Jan.	2140	2.06	965	6.22	12.50
Feb.	2260	1.90	840	3.24	8.00
Mar.	2650	1.92	725	2.36	5.70
Apr.	1850	1.91	1030	2.00	6.01
May	1870	1.80	960	2.70	6.61
June	2700	2.07	770	2.26	6.50
July	1910	1.95	1020	2.81	9.00
Aug.	1910	1.77	930	2.08	5.55
Sept.	1520	1.82	1200	2.92	8.41
Oct.	1880	1.84	980	3.06	8.22
Nov.	2020	1.94	960	2.30	6.60
Dec.	3140	1.93	620	3.90	10.00
1943					
Jan.	2220	1.92	860		6.32
Feb.	1960	1.92	980		7.60
Mar.	2180	2.12	960		5.80
Apr.	2060	1.93	940		4.00
May	2420	1.82	750		4.95
June	2780	1.76	630		4.44
July	2450	1.67	680		5.14
Aug.	2070	1.73	835		5.30
Sept.	2260	1.80	800		3.72
Oct.	1710	1.86	1090		5.72
Nov.	2180	2.04	940		6.10
Dec.	3460	1.99	575		3.82
1944					
Jan.	2580	1.94	750	2.52	6.08
Feb.	2980	1.92	640	2.18	6.90
Mar.	3410	1.92	560	1.12	3.70

TABLE 6.—*Performance of Preliminary Sedimentation Tanks at Austin, Minnesota*

1944	Alum Added P.P.M.	Settling Period Hours	Preliminary Sedimentation Tanks					
			Influent		Effluent		Per Cent Removals	
			B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.
Jan. 6	68	2.18	660		488		26	
11	64	2.27	760		552		27	
13	82	2.21	682		465		32	
18	46	2.06	748		522		30	
20	55	2.14	550	200	385	58	30	71
24	0	2.10	774	330	564	152	27	54
25	0	2.12	692	345	540	142	22	59
28	54	2.26	610	390	439	97	28	75
Feb. 1	55	2.06	670	362	449	101	33	72
3	53	2.21	640	289	442	72	31	75
8	67	2.13	614	177	442	46	28	74
10	61	2.27	1145	340	780	85	32	75
15	52	2.17	738	169	552	52	25	69
17	85	2.29	730	287	445	129	39	55
22	146	2.08	650	345	441	45	42	87
24	112	2.20	616	288	386	46	37	84
Mar. 2	87	2.17	482	304	323	61	33	80
7	100	2.29	640	266	404	51	37	81
9	62	2.21	551	193	441	77	20	60
14	69	2.09	548	179	371	32	32	82
16	100	2.23	500	200	340	46	32	77
21	102	2.27	590	240	382	43	35	82
23	50	2.23	470	163	348	54	26	67
28	55	2.29	486	255	311	110	36	57
30	0	2.32	372	244	241	126	35	48
Apr. 4	0	2.19	532	183	500	93	6	49
6	0	2.23	696	204	590	96	15	53
11	0	2.14	426	192	385	86	10	55
13	0	2.09	533	288	395	89	26	69
18	0	2.36	795	305	668	125	16	59
20	0	2.06	548	295	416	124	24	58
May 2	0	2.11	518	216	450	108	13	50
4	44	2.09	710	522	369	68	48	87
9	42	2.04	750	276	486	77	35	72
16	45	2.05	508	216	396	65	22	70
23	43	2.05	346	164	253	49	27	70
25	43	2.05	410	134	320	56	22	58

are an equalizing storage tank with capacity to hold about 15 per cent of the total 24-hour flow of packinghouse wastes, a rate controller to govern the rate at which the packinghouse wastes are put through the plant, a flocculating tank in which the presettled packinghouse wastes are flocculated with air and waste activated sludge before preliminary sedimentation, a preliminary sedimentation tank, four preliminary filters of the backwash type, an intermediate sedimentation tank and a pumping station to pump the effluent from the intermediate settling tank to the secondary trickling filters. These facilities are provided exclusively for the treatment of the packinghouse wastes.

The domestic sewage is screened, detrited and settled in separate facilities.

The settled domestic sewage may be combined with the packinghouse waste which has been flocculated, settled, filtered and settled, and the whole applied to a second stage conventional filter, the effluent of

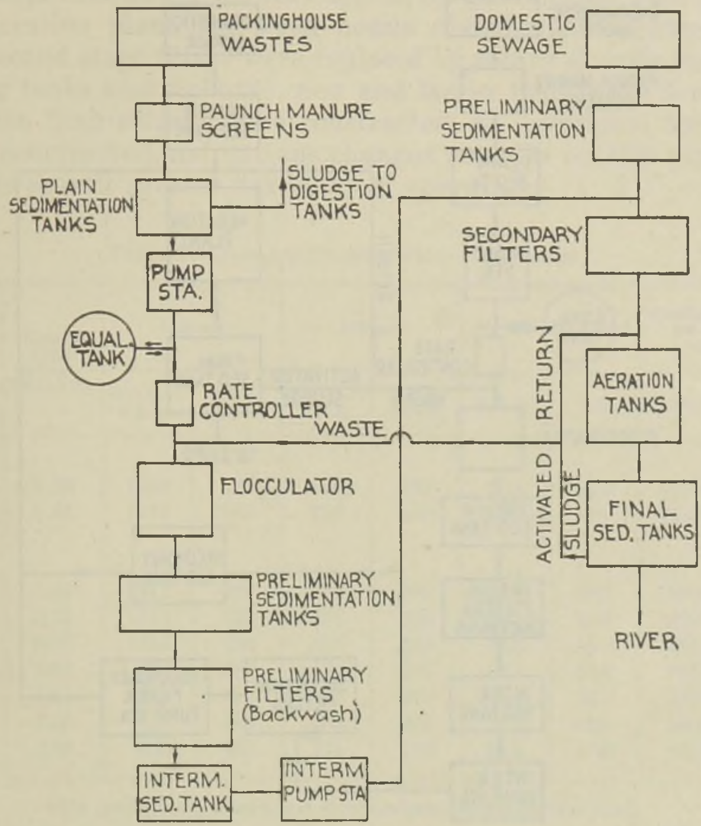

FIGURE 5.—Sioux Falls, So. Dakota, flow diagram of summer operation.

which is pumped to the activated sludge plant and then settled, or the settled domestic sewage may go directly to the activated sludge plant and only the packinghouse waste be applied to the second stage filter. In the latter case the packinghouse waste is recirculated through the filter before going to the activated sludge plant.

Figure 5 illustrates the first method of operation. This method is available for summer use when the load on the plant decreases (because of the light load from the packinghouse) and when it is necessary to avoid too complete purification of the sewage by the filters. At such times the aeration tanks can be operated without return of sludge to avoid difficulties from denitrification.

Figure 6 illustrates the second method of operation and is the method followed during the winter months (of heavy packinghouse load) when it is necessary to secure the maximum amount of purification from the filters before the sewage goes to the aeration tanks. Another reason for applying only the packinghouse sewage (with recirculation) to the secondary filters in the winter is to keep them warmer and promote greater biological activity.

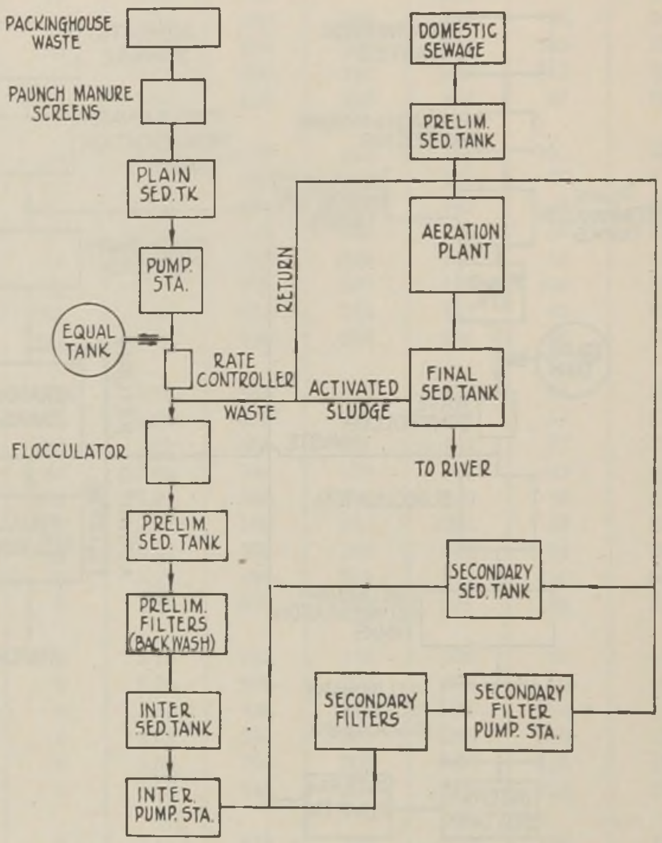

FIGURE 6.—Sioux Falls, So. Dakota, flow diagram of winter operation.

There have been three major construction projects by which the plant has achieved its present status. In 1927 the screen, detritor, preliminary sedimentation tanks, conventional trickling filters and three sludge digestion tanks were built. At that time the load on the plant was about 2.4 M.G.D. of domestic sewage and 1.0 M.G.D. of packinghouse waste. The annual kill at the packinghouse was about 500,000 animals.

By 1931 the plant was nearing its capacity. In 1937 additions comprising flocculating tank with equipment for adding ferric chloride to assist in the sedimentation of the packinghouse wastes and an activated sludge plant were constructed. The activated sludge plant was arranged either to precede or to follow the filters.

A sudden increase in the load of packinghouse wastes occasioned by the war again threatened to overload the plant. So in 1941, 1942 and 1943 further additions were made to the plant, comprising the four preliminary filters of the backwash type previously mentioned, an intermediate sedimentation tank to settle the effluent from these filters, an intermediate pumping station to pump the settled preliminary filter effluent to the second stage filter and a fourth digestion tank. Also during this period larger blowers driven by gas engines were installed for the aeration plant, the fixed nozzle distribution systems on the existing second stage filters were replaced by rotary distributors (without dosing tanks and siphons), new and larger final tanks for settling the aeration tank effluent were constructed, an additional flocculating tank was constructed and various changes made in outside piping and conduits to permit greater flexibility of operation.

TABLE 7.—*Primary Trickling Filter Performance*

Period	Rate of Application—M.G.A.D.	Influent		Effluent		Per cent Removals*		Loadings—Pounds per Acre Foot per Day	
		B.O.D.—P.P.M.	S.S.—P.P.M.	B.O.D.—P.P.M.	S.S.—P.P.M.	B.O.D.	S.S.	B.O.D.	S.S.
1943									
Nov.	6.29	1220	526	886	298	27.4	43.5	13758	5060
Dec.	6.38	1273	563	798	313	37.4	44.4	10400	5450
1944									
Jan.	6.42	1312	579	930	289	29.1	50.2	11600	5120
Feb.	6.73	1315	552	894	298	32.1	46.0	14106	4550
Mar.	6.79	1218	460	820	262	32.9	43.2	13354	4400
Apr.	5.63	878	384	480	221	45.5	42.6	7613	3000
May	6.31	591	392	271	218	54.0	44.4	5174	3420
June	5.56	738	400	368	204	50.2	49.0	5680	3080
July	5.03	668	402	231	210	65.6	47.6	4650	2800

* By preliminary filters and intermediate sedimentation tank.

Flocculating the packinghouse wastes with air and waste activated sludge has increased the removals of B.O.D., suspended solids, and grease by the preliminary sedimentation tanks and has been especially helpful in throwing out the grease as sludge rather than scum.

The preliminary filters were placed in operation in cold weather and their effectiveness was disappointing at first. However, since the filters have become seeded and also since the proper routine for backwashing has been established, these units have performed well. Warmer weather has probably been of help as well. Results of several months of operation are shown in Table 7.

These units are 87 feet in diameter and 5½ feet deep. The aggregate is crushed granite ranging in size from 2 to 3½ inches. The filters are backwashed at about two-week intervals with final effluent.

The second stage filters since being equipped with rotary distributors and operated with recirculation have done an astonishing job as will be noted from the data in Table 8. Prior to the installation of the preliminary filters and the rotary distributors and also prior to the procedure of recirculating continuously through the filters, they were subject to clogging and low efficiencies, especially in the colder months. Continuous dosing has kept the filters warmer during cold weather and has maintained an active bacterial flora throughout the entire depth of

TABLE 8.—*Secondary Trickling Filter Performance*

Period	(1) Rate of Application—M.G.A.D.	Influent		Effluent		(2) Per Cent Removals		Loadings—Pounds per Acre Foot per Day	
		B.O.D.—P.P.M.	S.S.—P.P.M.	B.O.D.—P.P.M.	S.S.—P.P.M.	B.O.D.	S.S.	B.O.D.	S.S.
1943									
Nov.	3.24	886	298	305	155	(3) 65.0	48.0	1383	466
Dec.	3.27	798	313	223	115	(3) 72.2	56.0	1358	530
1944									
Jan.	3.17	930	289	144	112	84.4	61.5	1367	425
Feb.	3.22	894	298	144	101	84.0	66.1	1404	465
Mar.	3.23	820	262	89	82	89.2	68.5	1075	345
Apr.	3.02	480	221	55	83	(3) 88.6	62.4	612	282
May	3.13	271	218	56	92	(4) 79.2	58.0	398	320
June	3.00	368	204	121	112	(4) 67.4	45.1	458	254

(1) Estimated.
(2) Including sedimentation following the filters.
(3) Filter began unloading about mid-month.
(4) Filters unloading.
(4) Filters unloading.

the units. Last winter there were dead psychoda in the effluent all winter long and the nitrate content of the effluent ranged from 3 to 10 parts per million.

Some difficulty is experienced, particularly in warm weather, with denitrification of the activated sludge in the final settling tank, which causes large amounts of sludge to rise in the tanks and go out with the effluent. Various experimental procedures have been tried over a period of several months to control this denitrification. The problem is now being studied jointly by representatives of the city and the State Board of Health of South Dakota.

Austin Sewage Treatment Plant

A detailed description of this plant may be found in the November, 1939, issue of *This Journal,* hence none will be given here. Figure 7 shows the flow of sewage through the plant.

The combined packinghouse waste and domestic sewage at Austin has quite different characteristics from those of the combined wastes at Sioux Falls, due to the different pretreatment given the packinghouse waste at Austin. At Sioux Falls 60 per cent of the total organic load of the domestic sewage and packinghouse waste is removed by preliminary sedimentation. At Austin only about 15 per cent of the total organic load is removed by flocculation (with exceedingly heavy doses of coagulant) and sedimentation (see Table 6).

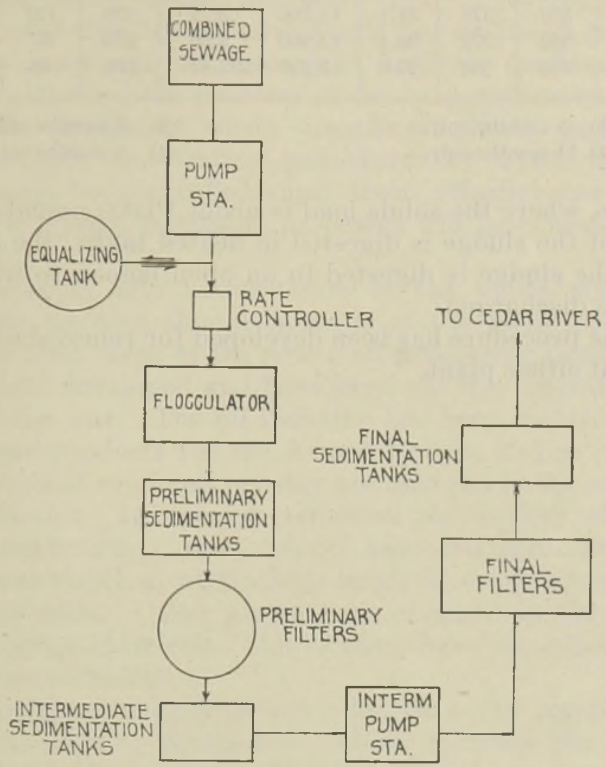

FIGURE 7.—Austin, Minn., flow diagram.

The preliminary filters have consistently removed from 30 to 40 per cent of the applied B.O.D. loadings ranging from 15,000 to 11,000 pounds per acre foot per day. The final filters, which have fixed nozzle distribution systems and which are also housed, have not performed as well as the second stage filters at Sioux Falls. Operating results are shown in Table 9 for both filters.

At neither plant has the problem of ultimate disposal of sludge been solved. At Sioux Falls, where the total daily dry solids load amounts to about 54,000 pounds, all sludge is digested. The sludge gas is collected and utilized to generate power and to operate the blowers and for heating purposes. The digested sludge and all supernatant liquor is lagooned and dried.

TABLE 9.—*Filter Performance at Austin, Minnesota*

Year	Preliminary Filters (Inc. Sed. Tk.)					Final Filters (Incl. Sed. Tk.)				
	Rate of Application—M.G.A.D.	5-Day B.O.D.—P.P.M.		Per Cent Removed	Loading—Lbs. per Ac. Ft. per Day	Rate of Application—M.G.A.D.	5-Day B.O.D.—P.P.M.		Per Cent Removed	Loading—Lbs. per Ac. Ft. per Day
		Applied Wastes	Effluent				Applied Wastes	Effluent		
(1) 1940	19.2	402	233	42.1	11,500	3.53	233	58	75	860
1941	20.5	425	266	37.5	12,100	3.79	266	83	69	1050
1942	20.2	550	379	31.1	15,400	3.74	379	122	68	1180
(2) 1943	21.2	392	273	30.4	11,850	3.86	273	67	75	1100
(4) 1944	21.7	456	342	25.0	18,230	(3) 3.81	370	91	75	1470

(1) 8 months only.
(2) 11 months only.
(3) 5 months only.
(4) 3 months only.

At Austin, where the solids load is about 10,000 pounds daily, about 75 per cent of the sludge is digested in heated tanks; the remaining 25 per cent of the sludge is digested in an open lagoon to which digested sludge is also discharged.

No routine procedure has been developed for removal of sludge from the lagoons at either plant.

TREATMENT OF OIL INDUSTRY WASTES *

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The wastes of the oil industry which at the time of publication could be regarded as potential water pollutants, were enumerated and discussed in an article by Weston and Hart (1941). As this publication is available in most files, these wastes will not be listed here. Indeed, the available space will be devoted to methods employed in the oil industry for attacking the problem of devising necessary waste treatment methods, designing waste treatment plants, and developing analytical methods and testing procedures by which the treatment operations may be controlled, and their effectiveness established. Finally, a few typical treatment processes will be considered in more detail.

Before entering into a discussion of the topics outlined above, however, some mention should be made of the waste products which have resulted from some of the newer oil processing procedures, those which have been developed and have been put into operation since the beginning of the war. The oil industry has been required to produce more and more products for the Armed Forces, and at present about 4,500,000 barrels of crude oil per day are charged to the various operations in refineries. In refining activities the variety of wastes has increased considerably. Many plants have put into operation processes for isomerization, alkylation, catalytic cracking and other oil processing methods. Other plants have engaged in the manufacture of various organic chemicals. All of these have introduced new problems in waste treatment.

The oil industry usually is regarded as being composed of four distinct divisions, *i.e.*, production, which includes the drilling and operation of the wells, and the collection and field storage of crude oil; refining, in which may be included all the various operations by which the crude oil is converted into the wide variety of products which are used in nearly every form of human activity; marketing, the division of distribution; and transportation, which includes the activities of the pipe lines, tankers, tank cars, and so forth.

Production wastes have always been of the same general nature. There always have been waste oils (or rather escaped oils, for no oil is a waste today), emulsions, and drilling muds. Waste oils are retained and used or burned, and emulsions are treated for oil recovery. Recently, as drilling techniques have been improved to provide for greater depths and higher pressures, different chemicals and other substances have been added to drilling muds to control weight,

* Presented at Seventeenth Annual Meeting, F.S.W.A., Pittsburgh, Pa., October 13, 1944.

viscosity, or other characteristics. Thus, drilling mnd can become a potential pollutant, perhaps toxic to aquatic or other life. But drilling muds so treated are expensive, and consequently they are handled carefully, and are not allowed to escape.

The most important waste of the production division is the brine that may be brought to the surface from the very start of production of oil from a well, or may appear only after the well has been operated for some time, particularly if the well is in a field subject to water encroachment, and has been drawn on too heavily. This waste has been one of the major problems of the oil industry, but return to the earth through injection wells is proving quite successful in several states.

The refining division of the industry presents a more diversified series of waste treatment problems than any other of the four major divisions. This will be entirely understandable if thought is given the wide variety of operations. From ordinary crude distillation the products may pass on through chemical treatment with acid, neutralization with caustic soda, washing for removal of sulfur compounds or other undesirable substances, solvent refining in one of the several possible processes which may employ nitrobenzol, phenol, furfural or other organics, cracking processes in which various pre- or post-treatments may be necessary, and other processes in which the gases from the stills and cracking units are utilized. Then, too, there are the further complications which arise because of the effect of charging different kinds of crude oils into some and perhaps most of these processes. For example, the waste caustic from the washing of a straight run naphtha which has been taken off of a low sulfur, paraffin base crude, and washed to remove still odor, may require only neutralization to eliminate its one objectional characteristic, in this case its causticity. On the other hand, the waste caustic from washing a high sulfur, napthenic crude may be objectionable because of taste and odor characteristics, toxicity and oxygen consumption, as well as causticity. Therefore, the number of wastes, as tabulated from the processes producing them, can be multiplied almost by the number of different crudes being run to obtain the number of significantly distinct degrees of treatment necessary for good practice in waste disposal. This should be borne in mind when the method of attacking a waste treatment problem is discussed.

The marketing and transportation divisions of the oil industry are much alike in so far as the wastes they produce are concerned. Largely there is but one, and that is the oil which escapes from lines or tanks as a result of leaks, spills or other accidents, and sometimes through careless or thoughtless handling. Again it should be repeated that this is not a waste product, but because regardless of its source, or the cause of its escape, it can cause pollution, it must be included in the category of wastes, for steps must be taken to prevent this pollution as far as practicable.

The Approach to the Problem

A little earlier an attempt was made to show just how many significantly different wastes are produced in the oil industry, largely, of course, in the refining division. With clear understanding of this great number, it will be obvious that each such significantly different waste cannot be regarded as requiring a treatment specific to its own individual obnoxious characteristics, nor to the degree to which these characteristics are present in that particular waste. Nor would this be desirable, for refineries in particular are constantly changing methods of processing, and also changing the kinds of crudes they run, so that a waste treatment process which has been designed for too narrow a range of applicability may be successful one month, but inadequate two months later. Consequently, with those having to do with devising waste treatment methods for the oil industry, it has become customary to divide the great number of individual wastes which are possible, as mentioned above, into groups based upon their particularly obnoxious characteristic, or perhaps characteristics, which they possess. Thus, one waste may be a matter of salt water disposal, another will require the "breaking" of an emulsion and the retention of the oil, a third may be a problem in the elimination of taste and odor, or oxygen demand, or toxicity, and so forth. Usually, a petroleum industry waste will fall into one of the following categories:

1. Oil-field brines.
2. Free (unemulsified) oil and water.
3. Oil-water emulsions.
4. Wastes which contribute odor and taste.
5. Wastes which consume dissolved (in water) oxygen.
6. Truly toxic or poisonous wastes.
7. Acid wastes.
8. Alkaline wastes.
9. Wastes which contribute color.

The above categories are not arranged in any order of importance, or usual quantity which results per unit of crude oil processed; they simply constitute a list. Any waste may have more than one of these characteristics, or may have only one. To determine just what characteristics we are concerned with, therefore, is the first step in the approach to the problem of how to treat the waste so as to conform with good practice in its disposal. With some wastes only a very casual examination is necessary, with others a rather complicated analysis may be required, and a bioassay using some acceptable aquatic living form as a test animal will have to be performed to establish the degree of toxicity. When the undesirable characteristics have been determined, an intelligent attack can be made on the problem of how to eliminate them, or at least minimize them to the necessary degree.

The treatment method which finally is devised should conform with good practice in waste disposal. This phrase "good practice in waste disposal'' describes a highly desirable practice, but there are several ramifications. As a primary requirement, the pollutional potentialities of the waste must be so reduced that the waste, after treatment, can be disposed of by discharge into the receiving waters without interfering unreasonably with the normal uses of these waters. At the same time, reasonable use of the characteristics of the receiving waters, and of the quantity of receiving water in relation to the quantity of waste (*i.e.*, dilution), is regarded as an available aid to the purpose of the treating process. But there must be understanding and judgment in the determination of just what characteristics of the receiving water should be considered as usable, and to what extent they should be used. For example, in devising a treatment method recently, it was desirable to discharge the treated waste in a slightly acid condition, at about pH 5.0 to 6.0. The receiving water carried a total alkalinity of about 90 p.p.m. as calcium carbonate, and in quantity amounted to perhaps 300 times the quantity of treated waste. Obviously, there was little danger of destroying all of the alkalinity, which is an extremely important factor in the receiving water. In fact, the receiving water is little affected by the discharge. Had the dilution ratio (*i.e.*, the ratio of the quantity of receiving water to the quantity of waste) been a great deal lower, or the acidity of the treated waste been higher, all the alkalinity might be destroyed. This would not be good practice. At no time should any characteristic of the receiving water be entirely destroyed, nor the stream, or other receiving water put into such condition that it cannot fully recover its normal cleanliness in a reasonably short length of flow or time.

There is another idea which should be regarded as a part of the complete definition of good practice. The waste treatment process devised should be the most inexpensive, from the standpoint of construction cost and operation expense, which can be developed. This does not mean that the treatment plant just should be thrown together. On the contrary, it should be designed in accordance with the best engineering practices and treatment procedures. But where material from the salvage yard, or second hand material which is in good, usable condition can be incorporated in the construction, it should be done. This should not be interpreted as advocating any disregard of the importance of proper waste treatment. Instead, it is a helpful factor in advancing the abatement of pollution. Only infrequently does a waste treatment process in the petroleum industry offer any opportunity for a profit. Such processes usually are an expense, and by some are regarded as an unnecessary expense. Therefore, the lower the cost of waste treatment, the wider will be its application. With these various fundamentals in mind, advance to the actual development of the waste treatment process can be made.

Devising the Treatment

There are various more or less standard methods, comparable to unit chemical engineering processes, which are known to be effective for the elimination of various undesirable characteristics of a waste to be discharged to some body of surface water. For example, free oils are separated and retained by gravity-type, oil-water separators. Segregated emulsions are "broken" by chemical treatment and the oil separated and retained. The most effective chemical can be ascertained in the laboratory by treating a small quantity of the emulsion with a drop of the treating agent and watching the effect under the low power of a microscope. A long glass slide with a series of recesses into which a drop of the emulsion can be placed for treatment, is very handy for this purpose. Oxygen consuming wastes can be aerated or treated chemically. Taste and odor producing compounds are chemically treated, or, as recently demonstrated, can be treated biologically. Acids and alkalies, of course, can be neutralized.

Sometimes a waste is encountered which requires a definite study to determine how best it can be treated for proper disposal. Then, experience and ingenuity must be called upon, and the value of a good waste control laboratory, where the necessary research can be carried on, will become apparent. In some instances of this kind, surprisingly simple and relatively inexpensive procedures have been devised. Some of these procedures, as well as some which are more standard in nature, will be referred to later.

The next step in devising the treatment is to transfer the findings of the laboratory to small scale equipment similar in material to that which will be used in the plant. Many wastes are rather complex mixtures of uncertain composition, and it cannot always be predicted just what will happen, for example, when a method developed in the laboratory, in glass, is transferred to steel or other metallic equipment. Therefore, unless there can be absolute assurance that the devised procedure will not be affected when used in metallic equipment, it should first be tried in a small scale plant, or, as sometimes expressed, on a semi-works scale. When it has been shown to be satisfactory in the semi-works model, which can be of a size that is operable in the laboratory, or at least close by where it can be carefully observed, it can be transferred to plant scale with confidence.

Finally, the design of the necessary equipment must be prepared. With the method of treatment established, the quantity of waste to be treated will be the important factor in the size of the plant. This quantity should be determined with care, and if actual measurement is possible, the flow of waste should be measured. Then comes another important consideration. Will the manufacturing operation which produces the waste be expanded? Will it soon experience reduced activity, or is it soon to be abandoned? If expansion is anticipated, the increase in waste should be taken into consideration in establishing the treatment plant size. If a reduction in activity is to occur later, the present waste flow only need be provided for, or perhaps a plant which will be fitted to the later reduced flow will provide sufficient treatment at the present rate of waste production to protect the receiving waters reasonably well. If the manufacturing operation soon is to be discontinued, the waste treatment plant should be constructed as cheaply as possible. For example, corrosion resistance should be included only to permit operation of the plant till the manufacturing operation is shut down. This principle will not hold, however, if the waste treatment plant can be used to serve some manufacturing operation which is to supersede the one to be closed down, or by modification can be adapted to some other use.

Where there has been decision as to the waste treatment plant capacity, in accordance with the consideration just noted, design data can be tabulated on the basis of the various requirements of the treatment method and quantity of waste to be handled, and turned over to the organization whose function it is to design details and prepare plans for construction. Design details and so forth do not have place in this general discussion.

Establishing Effectiveness

There have been instances in which the most carefully investigated and devised procedure has not functioned just as anticipated. This is true in fields other than waste treatment. Therefore, it is a part of good practice in waste disposal to be sure that the treatment is functioning effectively.

There are those who advocate that any check of the treatment process should be made upon the effluent of the treatment plant. When this is done, however, the results can be compared only with the predicted effectiveness of the plant, for the beneficial effects of dilution, natural alkalinity, and so forth, of the receiving waters will not have been included. Therefore, allowance must be made for this further treatment of the waste (*i.e.,* the further action upon any residual of the undesirable characteristic which will occur in the receiving waters) when it is discharged.

One of the difficulties which has been experienced in the waste disposal activities of the oil industry is the matter of testing methods. Standard analytical procedures frequently have had to be modified, and sometimes quite extensively, to overcome interferences and to obtain accurate results. At times methods which are practically new have had to be devised. But these obstacles have been overcome, and the effectiveness of waste treatment can be estimated with a reasonably good degree of accuracy. The methods used are chemical, physical, and by some laboratories, biological. Some of these will be discussed under the heading of recent developments.

The final and most conclusive proof of the effectiveness of the waste treatment is the condition of the stream after it has received the discharge, and there has been opportunity for admixture. This can be determined only by a stream survey, for which there are well established procedures. Usually such surveys are made by state or federal organizations, but sometimes have been made by the industry. When a stream survey indicates that the treatment of the waste has rendered it so completely innocuous that it has no effect upon the receiving waters, it can be concluded that the waste treatment method is effective, and there remains only to see that it is operated properly, is well maintained, and checked from time to time to assure that no change in waste quality has caused change in effectiveness.

Recent Developments and Current Investigations

The oil industry is made up of a large number of individual companies, and no one individual can be conversant with all the recent developments and the investigations currently being conducted. All the various companies do not have the same policies with regard to waste disposal, nor do they all carry on the work in the same way. Different types of organization, and differences in the allocation of responsibilities, contribute to some extent to this situation. Also, the industry has been pretty busy since December 7, 1941, contributing a lot to the present improved war situation.

The general activities of the oil industry in matters of waste disposal largely are centered in the committees of the American Petroleum Institute. The results of the work of these committees have been published in a series of manuals which are obtainable from the Institute in New York. The manuals are revised from time to time as new data and procedures are developed.

Some companies have entered into these activities more extensively than others. The Atlantic Refining Company is one of these and there can be rather intimate discussion of the investigations now under way at the Waste Control Laboratory which is operated at the Philadelphia refinery. All of these, of course, will be available to the entire oil industry, and may be regarded as contributions of the industry to the program of natural resource protection.

Several years ago the investigations on which the design of the so-called A.P.I. separator is based were carried out by the laboratory. An experimental separator was constructed and after certain modifications demonstrated its ability to separate free oil from water flowing through it. The design was published in an American Petroleum Institute manual and subsequently a number of such separators were placed in operation. Soon criticisms appeared, the gist of most of them being that too much oil carried through. This did not seem logical, and some of the separators were observed to try to learn the reasons for these difficulties. Conditions were found which explain, at least in some instances, the excess oil in the effluent.

In some cases stable emulsions are allowed to reach the separator. No gravity-type separator will break or retain the oil from any stable emulsion. Some emulsions of this type contain high concentrations of oil, and very small amounts will result in high oil in the separator effluent. This oil will be found by any testing methods using a solvent, or any other procedure by which the emulsion will be broken. There is only one remedy for this situation. Emulsions in even small amounts must be kept out of the separator. No amount of investigation, design or anything else will effect a cure.

Another criticism of the design concerns that part of the inlet end known as the film rupture chamber, which becomes clogged. This is a valid criticism, and yet this particular section of the separator serves a very useful purpose. It has been commented upon by authorities on fluid mechanics as being sound in principle.

To study this condition of clogging, a sub-committee of the Committee for the Disposal of Refinery Wastes now is active and it is hoped that there will be an early solution.

Intimately related to the problem just mentioned is the problem caused by the biological growths which sometimes form in cooling water systems, sewer systems, waste water ditches and in the separator itself. Frequently, it is sloughed off masses of such growths that clog the film rupture chambers and cause other difficulties. One of the worst of these difficulties is that as particles of the growths are carried along in the separator flow they take up oil, perhaps in very small amount, and they then pass out of the separator with the oil still attached. Out in the stream the oil usually is released to cause irridescence. Similar results follow septic action in bottom sludges when separators are not kept well cleaned.

Another sub-committee of the main committee for refinery waste disposal (American Petroleum Institute) has been charged with finding means for controlling biological growths. Much of this study will have to be carried on in the Waste Control Laboratory at Philadelphia for it is one of the few laboratories in the industry equipped for such studies.

Sometime ago, in an attempt to discover a suspected relation between suspended matter in separator flow and excessive oil in the effluent, a series of filtration experiments was started at Philadelphia. These experiments were interrupted by the war effort, but enough was learned to know as fact that the reduction of oil in the effluent is in practically straight line proportion to reduction of suspended matter in the separator flow. Since that time, in one refinery using a heavily silt-laden water, the bottom slurry of silt remaining after the separator has been drained, contains as much as 25 per cent, by volume, of oil. The investigation of the influence of suspended matter will be continued when time permits, which from the progress of the war seems to be coming soon. Another similar, and probably related research, is just being started by an eastern university under a financial arrangement with the Committee for Disposal of Refinery Wastes.

One of the most serious problems in refinery waste disposal is that presented by waste caustic. This is the spent sodium hydroxide solution after use to wash various naphthas, kerosenes, and sometimes crudes. This waste may range from perhaps 500 to 50,000,000 in threshold odor. The oxygen demand figures are relatively astronomical, 100,000 to 200,000 p.p.m. are not uncommon, and the solution is highly toxic. Just before the war started, research was initiated to see just what possibilities there were in biological treatment of this waste. This investigation also became a war casualty, but not before the practicability of the procedures was confirmed. There remains to develop the controls and proper feeding methods, and to devise the most efficient equipment. This part of the work can be taken up again at an early date, it is believed, and it then will be carried through to a conclusion.

Many state laws for the control of water pollution prohibit the discharge of any substance dangerous to public health or inimical to aquatic life, but no really scientific measure of what is inimical to aquatic life ever has been widely published. Making use of the rather prevalent idea that the presence of a varied and profuse fish fauna is an indication of an acceptable degree of water cleanliness, the laboratory at Philadelphia decided to explore the possibility of measuring toxicity of wastes by using fish as test animals. It was thought that it would not take very long, and that it would not require a very voluminous publication. That was about three and a half years ago. The conservation department biologists of several states were consulted, also fish culturists, ichthyologists and others were consulted, and their help solicited. That help was given in degree which deserves only the highest commendation. By about the end of this year a limited edition of this toxicity evaluation method, in pamphlet form, will be distributed to the various states and to others on a necessarily restricted list. This first edition is put out with the hope that the recommended procedures will be used and criticized, and that as a result of the criticisms the methods will be improved. Then, depending upon the reception accorded the issue just mentioned, it is planned to develop methods in which other aquatic forms can be used as test animals, and again to publish these methods for comment and criticism.

Other researches are on the agenda of the Laboratory at Philadelphia. Included are a study of methods for the treatment of polysulphides, various particular types of emulsions, and some of the wastes resulting from the newer refining procedures. However, the amount of work done so far does not warrant more than mere mention. Much time during the past year has been taken up by an exhaustive study of how slime in cooling systems using Schuylkill River water can be controlled. This has been an interesting problem and will be published when time permits.

Typical Waste Treatment Plants

Considerable space has been devoted to the practices by which waste treatment processes are developed in the oil industry, and to the various investigations related to water pollution prevention. Some applications of the principles used, in the form of typical installations, will serve to show the extent to which some companies which are a part of the industry have gone to protect our water resources.

Disposal by Controlled Discharge

This is another way of saying disposal by dilution, for it takes advantage of the dilution in the receiving water as the only treatment.

When the type of waste permits, several years of experience have shown this procedure to be effective.

The installation used here as an example produced a waste containing from 28,000 to 30,000 parts per million of dissolved solids, about 1.5 per cent of free sulfuric acid and having a pH value of about 0.5. The dissolved solids consisted largely of ferrous sulfate and aluminum sulfate. When the waste first was discharged into a stream flow of rather soft water and at low stage, it killed all life in the stream for miles.

Obviously, to correct this waste the dissolved solids had to be reduced to a range in which osmotic effects would not dehydrate fish, and the pH had to be raised to a reasonable degree. Several procedures were considered, but the economics of each one in turn were far from practicable. Then the possibilities of controlled discharge were studied. The stream varied widely in rate of flow, the variation being seasonable. Yet the total annual stream flow, when compared to the total annual waste flow, showed that an ample degree of dilution was present. A study of the soil on the plant property revealed a deep clay top layer that would retain the waste if impounded.

Using these data, a diversion box was designed by which a certain percentage of the current production would be allowed to go to the stream, and the remainder to large impounding reservoirs. The percentage of waste to be sent to the stream would be picked from a curve in which quantity of waste which the stream could take was related to stream flow, as indicated by a nearby stage gage. The curve was extended to show the amount of waste that could be withdrawn from the reservoirs, together with the current waste, at periods of high river stage. The equipment was installed and the procedure was placed in operation. The results were highly satisfactory. The pH of the stream came back practically to neutrality. The dissolved solids in the stream fell to around 250 parts per million and there was immediate improvement in the appearance of the stream. After allowing a few weeks for conditions to become stabilized, the stream again was surveyed. No dead fish were seen, but there was a normal evidence of live ones that had moved in. Other conditions were found to be satisfactory. Of course, there was some change in the general condition of the water, but there was no evidence that its normal conditions were affected.

About the only unusual feature in the design of this disposal system is the diversion box which consisted of a receiving chamber with 10 orifices as its outlets. Each orifice is designed to pass 10 per cent of the greatest anticipated rate of flow. By adjusting the sliding divider piece, all the waste, or any multiple of 5 per cent of the flow, can be diverted to either the stream or the reservoirs. The flow from the resrvoirs is measured by controlling the head on a large V-notch weir, by means of large ceramic plug-cocks.

Treating Oil Emulsions for Disposal

Advancing from the rather simple type of disposal by dilution (controlled-rate disposal is another term) to a more intricate procedure, a treatment plant for breaking emulsions can be used as an example. This plant was devised to treat emulsions from a barrel washing operation. The barrels and drums washed have contained oil, animal fats, soaps and other similar materials. They are cleaned by steaming, and the resultant waste waters are milky in appearance and consistency. The waste is a truly stable emulsion, with oils and fats in the dispersed phase and water as the continuous phase. Even a small amount of such an emulsion will mix with a large volume of water and will cause it to become turbid. If allowed to flow to a separator, it is inevitable that it will cause excessive oil in the separator effluent. Therefore, it must be treated to break out the oils, which are retained and put into so-called "slop-oil," and only the water is allowed to reach the separator.

Briefly the treatment plant consists of a large tank equipped with air for agitation, heating coils, a swing-line skimming device, the necessary pumps and lines and a rather ordinary type of sand filter.

The waste wash water is accumulated in a ground tank where any free oil accumulates as a top layer and is collected and discharged to the slop-oil tank. The milky emulsion is pumped to the treating tank. When the tank has been filled to the working level, agitation and heating with exhaust steam is started. The tank content is heated to about 160 deg. F. When this temperature is reached, the treating agent, usually lime, is added and the charge is agitated for about one hour after which both heating and agitation are stopped and the tank is allowed to settle, usually overnight.

The oils and fats, some as soaps, accumulate at the top of the tank and after the settling period they are skimmed off and sent to the slop-oil storage. Most of the charge remains in the tank as clear water. This is drawn off through the sand filter and a clear water, satisfactory in every way for discharge, leaves the filter and goes on into the plant sewer system.

Sometimes a stubborn emulsion is encountered and the treating chemical used will not bring about the clear "break" desired. Then it is necessary to go into the laboratory and find a chemical which will serve the purpose. Again the value of a laboratory for waste disposal studies will be demonstrated. In all cases to date, a satisfactory treatment has been found.

A small amount of sludge, usually consisting of undissolved treating agent, precipitated lime soaps, sand and silt, gradually builds in the bottom of the treating tank. After the separated oil has been skimmed the clear water is drawn off through the filter to the separator sewer system, with care that none of the sludge is drawn into the line. From time to time the sludge is removed from the tank to a dump where it can do no harm of any kind.

The water from this treatment has been examined on several occasions and found to be free of oil, suspended matter and objectionable odor. Other emulsions are handled in a similar manner using calcium chloride as a treating chemical.

Treatment to Break Emulsion and Remove Taste and Odor

As has been stated, the usual problems in marketing and transportation are the result of the escape of oil. Occasionally, however, other problems arise. A rather interesting one came about as the result of pollution of a small stream used as a water supply. It was in a rural district and the waste which caused the trouble came from a garage where tank trucks were washed with a special soap, and a small amount of oil which was incorporated when the soap solution was made up. The waste itself contained oils and soaps, had a rather high oxygen demand and a strong but not altogether unpleasant odor. The problem consisted of removing the oil and emulsion, reducing the oxygen demand and reducing the odor.

The investigation was conducted in the laboratory and led to the design of a continuous treating plant which produced an entirely satisfactory effluent. The plant consists of a grit chamber, an air mixing chamber, a flocculation chamber, and a sedimentation chamber, all built together as a single unit which discharged through a final clay filter (*i.e.,* waste decolorization clay which has been burned free of oil). As has been said, the plant is continuous and the trucks are washed the same as ever, without any loss of time. The wash water runs off to the plant which is operated only while the washing is being done, the same operators taking care of both the truck job and the treating plant.

There are, of course, the necessary pumps and lines and definite instructions for their care and for the plant operation. Waste sludge, like oils and tars, washed from the trucks and separated, is collected and burned in collection and burning equipment provided.

This plant even now is under some degree of study because of the extreme efficiency of removal. It has been thoroughly tested and each time has shown the same high results. It is possible that something may be learned later which will be useful in future design. A more detailed discussion will be published later. The percentage reduction of oil, turbidity and oxygen consumed is of the order of 98 to 99 per cent. Odor is reduced 80 to 90 per cent.

The neutralization of acid or alkaline wastes is a rather common procedure throughout various industries and the use of separators is generally the practice for retaining escaped oils in the oil industry. These operations are so well known that they will not be given space here. The examples of waste treatment to provide for good practice in waste disposal which have been presented are just a sample of some of the practices of the oil industry. Some plants have problems of rather great magnitude just in oil separation alone. One refinery, which uses about 135,000 to 150,000 gallons of water per minute, is confronted with the problem of removal of oil from tons of silt which settles out of the water in its separators. To take care of this condition a large master separator is to be installed and already a sizable silt washing plant is in operation. Eventually, instead of flushing this silt to the stream, it will be collected in the separator and picked up by a large dredge. The dredge will deliver the silt to a silt washing plant to be built, where, by air agitation, the oil will be removed and the silt used as fill. This is really a large operation and in cost is comparable to a sewage disposal plant for a fairly large town. But it is just another example of the increasingly greater interest that the oil industry is taking in the treatment of its wastes, so that its operations will not interfere with the water resources of the country.

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THE CITRUS CANNING WASTE DISPOSAL PROBLEM IN FLORIDA *

By Robert S. Ingols

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Problems arise with two distinct citrus canning wastes. The first waste, consisting of some solid material and a large proportion of wash water, is produced in the canning plant itself in maintaining sanitary conditions. The second waste is a press liquor which contains from 8 to 10 per cent solids. This liquor is rejected by a few of the plants that produce cattle feed from the solid wastes of the canning process, which include peel, rag and seeds. The problem presented by the sanitary waste of the canning plant is primarily one of disposal. The press liquor of the feed plants is a challenge for by-product development.

Several excellent methods of handling canning wastes have been developed (1, 4) for the short fruit and vegetable canning seasons of northern states. The citrus canning season generally lasts for six months, between November and July, and the volume and concentration of the wastes are such as to necessitate a year-round method of treatment. Earlier work was done on both of Florida's citrus waste problems by von Loesecke, Pulley, Nolte and Goresline (6) who showed that the sanitary wastes can be treated quite well on a trickling filter. Unfortunately this method of treatment is very expensive because of its high initial cost. Nolte, von Loesecke and Pulley (3) published methods for utilizing the press liquor with the development of feed yeast or alcohol as a by-product. Van Antwerpen (5) described the production of cattle feed and the concentration of the press liquor in multiple-effect vacuum evaporators. The concentrate is sold as citrus molasses for use in feeds. The status of citrus wastes disposal was reviewed recently by Hall (2). In October, 1943, Weber (7) published an article on the development of a plastic, "Weberite," which can be made from solid citrus wastes.

For the sake of clarity the two liquid wastes will be discussed separately hereafter under the headings: Canning Wastes, and Feed Plant Press Liquor.

Canning Wastes

The disposal of the diluted canning wastes presents no peculiar sanitary problem. Generally the concentration of organic matter is

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such that the oxygen consumed value is not more than 2,000 p.p.m. when cooling water is included with the waste. This figure is much higher than that for domestic sewage, but does not represent an especially concentrated industrial waste. The effluent is high in carbohydrate and low in nitrogen. This fact must be considered with regard to analysis, the means by which the effluent can be treated, and in some cases the nature of pollution which it causes.

An evaluation of the present methods for disposal of these wastes follows:

1. *Emptying Into Lakes.*—This is the common method of disposal for the canning plants.

The effect of adding canning wastes to lakes depends on the size of the lake and the presence and source of other wastes in the lake. The smaller the lake, the more serious the pollution becomes. One lake that we have studied was so heavily polluted with press liquor several years ago that large numbers of fish were killed from the lack of oxygen. This year, the water of the same lake is saturated with oxygen even though it shows a 60 p.p.m. oxygen consumed. Another lake shows a lower oxygen consumed value and almost no dissolved oxygen. This condition in the second lake is due to the presence of some local domestic sewage. In the first instance, the press liquor robbed the lake of both its oxygen and its nitrogen. If a situation arises where both sewage and canning wastes must be dumped into the same lake or river, the two should be treated together, if possible, before being discharged. Sewage contains an excess of nitrogen that even the most complete treatment of sewage does not remove. On the other hand, the canning wastes lack nitrogen, and if treated separately will require addition of nitrogen for complete microbiological stabilization. If the sewage and canning wastes are treated together in the same plant, a mutually beneficial adjustment will take place under controlled conditions. If allowed to enter into a lake separately, the water will be very heavily polluted and lose its oxygen rapidly.

2. *Trucking.*—The concentrated wastes are carted by tank truck to a suitable place of disposal. This is an excellent temporary method of reducing the nuisance, but necessitates the full time use of one or more trucks and drivers. The scarcity of material and labor, especially during wartime, would make it impractical except as an emergency method. In order to reduce the cost as far as possible, it is necessary to separate all cooling and condenser water from the waste to be trucked. This method is not suited to those plants which pack sections of grapefruit, because the volume of the most concentrated waste possible is still too high. The volume of the concentrated wastes at juicing plants is low, and this method can be used.

3. *Discharge Into the City Sewerage System.*—The use of a city's sanitary sewerage system for the treatment of any industrial waste should be conditioned upon whether the system has been properly designed to handle this extra load. The City of Lakeland, Florida, is receiving citrus cannery wastes, along with domestic wastes, at its

sewage-treatment plant. This plant was designed to take care of the seasonal industrial load. The treatment includes 3 steps: (*a*) primary sedimentation; (*b*) passage through a single-stage, high-capacity trickling filter (Lakeside Engineering Corp. Aero-filter); and (*c*) secondary sedimentation. The city is large in relation to the canning plant load. This means that no special change in operation is required; but there is some increase in the biochemical oxygen demand of the effluent during the increased load. If a constant high-quality effluent were required, a higher rate of recirculation could be employed, but even this would have to be considered in the original design, with regard to recirculating pumps, pipes, settling tanks, underdrains and filter ventilation. Where a canning plant uses more water per day than the city in which it is located, it is obvious that all factors will have to be properly taken care of in the original design. Fine screens should be included either at the cannery or at the sewage plant, or at both, to keep seeds and rag out of the pumps and sludge.

The addition of citrus cannery wastes to a sewage plant after only the customary primary treatment is unwise. The concentration of the cannery wastes will not be appreciably reduced by the short detention period and will tend to upset the sludge disposal operation.

4. *Lagooning.*—The disposal of dilute cannery wastes in lagoons depends upon the availability of waste lands where the odors and flies will not cause complaints. The odors may be somewhat controlled by the use of sodium nitrate, but flies will breed in the scum that forms on the lagoon unless it is removed regularly. Sludge generally collects and fills the lagoon so that another one must be available, or some means of removing the sludge must be provided.

5. *Sand Filtration.*—The sandy soil of the citrus belt of Florida is very tempting for use in the disposal of cannery wastes. The canning plant at Highland City is located so that the sandy soil near the plant can be dosed readily. The wastes are first collected in a pit where some sludge is deposited and can be removed regularly. The liquid is pumped from this pit to sandy areas. The bottom of the pit is 10 feet below the sandy disposal areas and still above the water table. This means that the sandy areas nearby have an excellent natural drainage with no normal tendency for flooding. Each of two areas of approximately one acre each is dosed for several days and then rested. When the area shows signs of clogging, the surface is disced during its resting period. This constitutes a highly desirable method of treatment. However, the high water table near most plants prevents the use of a natural sandy area near the plant. Artificially underdrained areas are expensive and require space, but they may be the solution for some plants.

6. *Disposal with Adequate Dilution.*—The disposal of cannery wastes into large bodies of water is largely limited to coastal areas of Florida. Even in the coastal areas, cities are beginning to lay plans for sewage treatment to protect shell-fish areas and the canning in-

dustries would be wise to determine whether they should be included in the city plans in order to avoid later trouble.

7. *Drainage Wells.*—Some plants are using drainage wells for the disposal of the canning wastes mixed with the other wastes, but not for canning wastes alone because they are not sufficiently concentrated to warrant the expense of such wells.

Feed Plant Press Liquor

The press liquor from the cattle feed plants has received considerable attention from several agencies. The industry is aware of the amount of material that it is discarding as press liquor; the Department of Agriculture and Florida Citrus Commission are anxious to see useful by-products developed from this waste as a means of aiding in the solution of a State Board of Health problem. At present it is being handled by the following methods:

1. *Drainage Wells.*—The discharge of the press liquor into drainage wells is still being practiced by some companies. Several who have tried this method have run into difficulty. In two cases the wells have contaminated city water supplies and new wells have had to be drilled to overcome the odors produced. One drainage well has contaminated the wells of the plant itself and is limiting development of new wells for that plant. Several wells have blown back. The water flowing down the well entraps some air and the micro-organisms present in the liquor use the food to generate more gas. Finally the pressure of the gas exceeds that of the water column and the well belches. When hydrogen or methane gas is present the gas may become ignited and burn for several days. Some other method of disposal is certainly desired.

2. *Emptying Into Lakes.*—Discharge of large quantities of press liquor into small lakes has been tried. The quantity of organic matter in the press liquor was so great that the oxygen in the water disappeared rapidly and the fish were killed. When this occurred in a lake where houses were built close to the lakefront, the situation was serious.

3. *Lagooning.*—Lagooning of the press liquor is about the only allowable sanitary method of disposal that is available to most plants discharging this waste. This method is not wholly desirable, because a sour alcoholic fermentation takes place in the open pits. The odor from this fermentation may be carried several miles and cause complaints. The liquor deposits a sludge which collects in the bottom of the lagoon and retards seriously the seepage of the liquor. Flies and other insects are attracted by the material and constitute a health hazard. Ortho-dichlorobenzene has been used to good advantage by one company to keep the flies at a minimum. Another company has partially overcome the difficulty of the sludge by using two pits alternately as primary tanks. The supernatant from one is withdrawn as the other one needs relief and is allowed to flow to a third pit in which there is less sludge and from which seepage is faster. At times

the supernatant from the third pit must be drawn into a fourth pit. After the pits have been drained for the season, the sludge must be removed in preparation for the next season. Very small quantities of the sludge may be placed on the soil of citrus fruit groves as a source of humus.

4. *Citrus Molasses.*—The most common by-product made from the press liquor is citrus molasses. The press liquor is concentrated in multiple-effect vacuum evaporators and sold as feed. The use of these vacuum evaporators prevents undue decomposition of carbohydrates and promotes efficiency. The by-product is very similar to the molasses that is obtained from cane sugar production, except that it has a slightly bitter taste. While this country is short of cane molasses, citrus molasses is enjoying a good market, but there is considerable concern as to whether there will be a postwar market for both kinds of molasses. If the feed plants are not able to get a good price for citrus molasses after the war, they may take what they can get and charge the difference between the price and cost of production against waste disposal. This situation would not be desirable and could not continue for long if a more profitable by-product were found.

5. *Alcohol Production.*—The production of alcohol from citrus wastes has been studied by Nolte, von Loesecke and Pulley (3). About 75 per cent of the solids in the press liquor are fermentable sugars. Yeast can be added to change the sugars to alcohol or the wild yeasts that are present in the crude press liquor can be depended on to bring about this change. In general, it is best to add the kind of yeast that will do the best job. Any fermentable sugar can yield about one-half its weight of alcohol. This means that the 6 to 8 per cent sugar solution of the press liquor will yield a 3 to 4 per cent alcohol solution. It is expensive to boil large amounts of water to drive off this small amount of alcohol. The original press liquor can be concentrated by evaporation before fermentation. This removes some of the volatile peel oils which interfere with fermentation. The total amount of alcohol produced would be the same, but the fermentation tanks could be smaller if the press liquor were partially concentrated before fermentation. Under wartime conditions alcohol is very much in demand, and this method of utilizing the press liquor could be used advantageously by more plants.

It is the author's belief that, even after the war, industrial alcohol may have an expanded market due to its many uses as a solvent and material for synthetic chemicals, especially those used in synthetic rubber manufacture. It is true that alcohol can be produced more cheaply from other materials which in the postwar period may be so cheap as to make this by-product of press liquor unprofitable.

When the alcohol has been distilled from the fermented liquor there is left in the still a liquid having a high content of organic matter. This distillery slop contains dead yeast cells plus any unfermentable material from the press liquor. The biochemical oxygen demand is very much lower than that of the original press liquor because of the fermentation and the removal of much organic matter as carbon dioxide and alcohol, but distillery slop will cause heavy pollution of any land area onto which, or of any body of water into which, it is discharged. Some large distilleries find it profitable to evaporate such material to dryness and sell the residue as cattle feed. Wet distillery slop has been used locally as hog feed when produced on a fairly small scale. The residual yeast is high in vitamin content and so could be recovered profitably for use in feeds. Thus, if alcohol production is used for the disposal of press liquor, it must be followed by disposal of the distillery slop.

6. *Yeast Production.*—The production of feed yeast is carried out under aerobic conditions. In the process just described yeast grows in the absence of air and produces alcohol. Theoretically, one-fifth of the energy of the sugar molecule is used by the yeast for growth; the other four-fifths of the energy is represented by the alcohol produced. The number of yeast cells that develop in the absence of air is limited by the amount of energy available for growth. The alcohol that has been produced from sugar is not available to the yeast cells for energy under anaerobic conditions. However, under aerobic conditions all of the energy originally in the sugar molecule is available for the growth of the yeast. The total quantity of yeast produced is, therefore, much higher under aerobic conditions, for the total amount of energy liberated from the sugar is much greater. Under the optimum conditions one can expect a yield of yeast that will be approximately 45 per cent of the weight of sugars originally present or added during the fermentation. During the fermentation some form of nitrogen must be added. Urea, ammonium sulfate and ammonia water are the most common forms used. Phosphoric acid, sulfuric acid and ammonium hydroxide are used to keep the pH in the desired range. During a fermentation an operator should check for pH, yeast cell count, approximate amount of bacterial contamination, presence of excess nitrogen, sugar remaining, dissolved oxygen and temperature.

After the aeration period, the yeast cells must be separated from the liquor. This may be done by a conventional settling tank, but it is better to do it rapidly by a centrifuge. The concentrated slurry may then be dried and the dried material sold as cattle feed. This process is simple, and most of it has been carried out successfully in the laboratory with press liquor on a small scale, but it has not been tried on a plant scale. There are still some problems to be solved. The press liquor causes foaming during aeration, and this foaming must be controlled. The yeast centrifuge will probably work better than any other device for obtaining a concentrated suspension of yeast, but this must be checked. Experimental work indicated that double drum dryers would be very satisfactory for drying the yeast, but other methods will be tried. The press liquor contains some chemicals, not found in the usual raw material sources for yeast culture, that may affect the drying technique somewhat.

As activated sludge plant operators know, air is expensive, when measured by the cost of satisfying the biochemical oxygen demand of organic matter. Some technique for measuring the dissolved oxygen in the yeast medium will be helpful in reducing the cost of the air used.

Since yeasts are not the only organisms that grow in the press liquor, the wild yeast, bacteria and molds that are present in the liquor originally must be inactivated. This is best done by heating the liquor to 90° C. After cooling, the liquor should be seeded with an added culture of the desired kind of yeast and aerated. The aeration vessel must be protected from chance contamination, and provision must be made for partially sterilizing the aeration vessel after it is used.

7. *Discharge Onto Groves.*—In at least two cases, the press liquor from feed plants has been placed on the ground around citrus trees—in one case at the request of the grove owner and in the other, by accident. In both cases the result has been the same. The trees were rapidly defoliated and had to be replaced. Dr. A. F. Camp, head of the Florida Citrus Experiment Station, believed that the killing of the trees was due to the loss of oxygen in the soil around the roots of the trees. There are other possible explanations, but the question of what is the true cause will make very little difference to the sanitary engineer. The orange tree lives in a loose sandy soil and must have plenty of oxygen for its roots at all times. The press liquor has a very high oxygen demand and can deoxygenate the soil about the tree's tiny feeding roots. This would kill the roots, and since the leaves cannot get moisture they would drop off rapidly.

Pilot Plant Study

The desire to find a cheap method of sewage treatment has controlled our research program this year. Some practical experience with lagooning of citrus canning wastes in Texas was previously obtained by one of the supervisors of the program. The lagoons, in effect huge reaction tanks intended to give 48 hours detention, were seeded with bakers' yeast. They operated rather satisfactorily while the canning plants were working, but developed odors during plant shut-downs. New lagoons were dug when the first ones became filled. The use of this treatment required that large areas of waste land be available.

It was planned to repeat these studies in a co-operative pilot plant operation at one of the citrus canning plants near Winter Haven. The plant of the Polk Company at Haines City was chosen for this work. All of the liquid wastes from this plant are discharged through a rotating fine screen. The screened liquid is collected in a shallow concrete pit under the screen and discharged directly into the nearby lake.

A wet well and an adjacent pump well were constructed near the screen pit. A two-inch, open-impeller, corrosion-resistant pump was used in a vertical position in the pump well. The liquid was pumped into a weir box and the excess was piped back to the wet well. A

45-degree, V-notch weir was used to measure the flow to the tanks. Three 1,200-gallon rectangular cypress tanks were operated in series with a 1-foot drop in head between them. The effluent from the last tank could be discharged to the lake, or part of it could be recirculated through the wet well.

The pump was connected in parallel with the screen motor and the screen was shut off when the canning plant was shut down. This arrangement prevented the pump from running dry when no liquid wastes were coming from the plant. The tanks were connected with troughs which were baffled to give some aeration of the liquid.

The tanks were dosed with enough liquid to give approximately 10 hours detention with 50 per cent recirculation. This meant 10 gallons per minute over the inlet weir. A heavy scum of micro-organisms soon developed on the walls of the weir box, tanks and troughs. The scum which developed daily on the surface of the liquid in the three tanks amounted to about ½-inch of scum in the first tank. When the scum on the tanks was not removed regularly it attracted flies and gave off an offensive odor. The scum was formed by heavy particles of organic matter which were raised to the surface by the gas bubbles formed in the sludge layer. A proper means of removing this sludge or scum should be included in any plant-scale reaction tank. A heavy layer of scum has been noticed in other canning plant wet wells having short detention periods.

During the first part of the season the screen pit received all of the liquid wastes. At the end of March the cooling water was removed from the screen pit line and discharged separately to the lake. When the waste included cooling water, the reduction in the concentration of the waste as the result of passing through the tanks amounted to approximately 50 per cent. When the cooling water was excluded, the final concentration of the waste was higher and the percentage of removal approached 67 per cent. It must be remembered that these results are at best approximations because of the difficulty caused by clogging of pump and valves.

A 24-hour survey was made of the canning plant wastes and pilot plant effluent while the cooling water was excluded from the liquid going to the screen. The plant operation consisted of juicing and sectionizing during the first day, juicing only at night, and sectionizing only during the second day. The volume of wastes was estimated by a 12-inch weir at each sampling. The samples were combined to form a composite which was preserved for analysis on the following day. The pilot plant effluent was sampled whenever a raw waste sample was taken. A day and a night composite were made.

The flow of wastes from the juicing operation amounted to 15 gallons per minute and showed 3,600 p.p.m. oxygen consumed. The waste from the sectionizing operation averaged 90 gallons per minute and showed 900 p.p.m. oxygen consumed. The juicing operation was conducted at full capacity. The sectionizing operation was not conducted at full capacity; therefore, a slightly higher volume of waste might be expected when running at full capacity. The night shift effluent showed 400 p.p.m. oxygen consumed whereas the day shift effluent showed 500 p.p.m.

Following this 24-hour survey, sectionizing of grapefruit was discontinued, and juicing was limited to one shift per day. The pump settings were not changed and, therefore, the waste was detained 20 hours in the tanks. The volume and concentration of juicing wastes were similar to those for the 24-hour survey. The effluent averaged only 300 p.p.m. oxygen consumed. Apparently, the juicing-room wastes are more concentrated, but easier to treat, than the sectionizing wastes. Visits to two other juicing plants have shown that their wastes are similar in volume and concentration to those reported here.

The results of these pilot plant studies will be helpful in designing the proper sized waste treating tank for a citrus juicing plant. It is not possible to predict how large a tank must be unless one studies the volume of the plant wastes and the degree of treatment required by the receiving area. Each is an individual problem, but some general comments are offered. When a plant can release its waste onto a sandy area with very little trouble, a low degree of pretreatment may be adequate. Thus, the tank should be large enough to provide a 10–12 hours detention period and to give a 50 per cent reduction in concentration. This degree of treatment should relieve the sandy area of the sludge that tends to clog the soil, cause odors, and breed flies. If there is a very high water table under the sandy area or if there is only a small body of water into which the wastes may be discharged, then a higher degree of treatment may be needed. A detention period of 24 hours should give a 75 per cent reduction in the concentration of the wastes. Most sandy areas, small lakes, and sewage disposal plants should find this 75 per cent degree of treatment an adequate reduction of concentration for easy handling of the remaining load.

The number of shifts operated by the canning plant must be taken into account when designing waste treating facilities for a canning plant. Other things being equal, a one shift plant needs a tank one-half the size of a two shift plant. In general, a plant with a larger overall capacity should have a larger factor of safety in the size of its waste treating facilities. Mechanical equipment of simple design should be included in a reaction tank to insure the removal of the solids that will collect in the tank if it does its job. These solids will have a high nitrogen content and if not removed regularly will cause very unpleasant odors and breed flies. It is suggested that the sludge be collected in large garbage cans and hauled away for disposal by burial.

The juicing plants handle large amounts of fruit and are very important to the industry. Several will go into operation after the war. It is fortunate that a reasonably inexpensive method of treating their wastes has been found.

Summary

This paper has discussed the question of what to do with the liquid citrus canning wastes in Florida. The liquid wastes from the canning plants are rather dilute and primarily a sanitary disposal problem. Descriptions have been given of the methods used and others that could be used. The liquid waste from the cattle-feed plants is a press liquor containing approximately 10 per cent solids. The various methods for disposing of this liquor and for manufacturing several proposed by-products from it have been reviewed.

Results of the pilot plant study of the citrus canning plant wastes showed that it should be possible to treat the concentrated wastes from juicing plants.

Acknowledgment

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THE TREATMENT OF SOME CHEMICAL INDUSTRY WASTES *

By Thomas Powers

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The Midland Plant of the Dow Chemical Company is one of the largest chemical plants in the country within one enclosure. Here the manufacture of over 400 products requires the use of some 250 million gallons of water per day which discharge to the Tittabawassee River having a minimum flow of 150 c.f.s. Pollutants in this river discharged from oil fields, municipalities, and industries are borne to the Saginaw River and thence to Saginaw Bay and Lake Huron (Figure 1). There

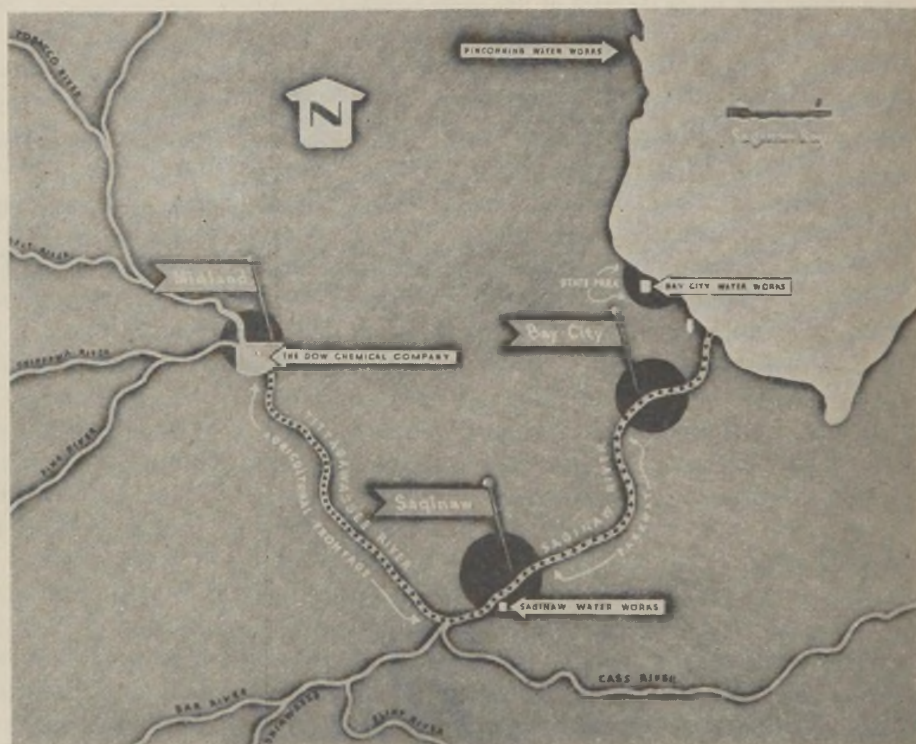

Figure 1.—Usage of Tittabawassee and Saginaw Rivers below The Dow Chemical Company plant at Midland, Michigan.

are many users of these receiving waters. The first use is agricultural for a 20-mile frontage. The city of Saginaw and many of its industries have the Saginaw River as a water source and also use it for wastes disposal. Almost the entire length of the Saginaw River between Saginaw and Bay City could be classed as recreational frontage

* Presented at Seventeenth Annual Meeting, F.S.W.A., Pittsburgh, Pa., October 13, 1944.

while the watercourse itself is open to lake boat commerce. Many of the industries in Bay City also use the river as a water source and for wastes disposal. The city of Bay City has its water source in Saginaw Bay some 4 miles from the mouth of the river. Saginaw Bay is a productive commercial fishing water and has miles of recreational frontage.

Waste waters from the Dow Midland plant requiring treatment total 75 m.g.d. Strong waste brines are stored in some 400 acres of ponds and released during periods of high flow by arrangement with downstream water users. The general plant wastes of 50 m.g.d. flow through some 40 acres of sedimentation ponds. Strong phenolic wastes require a 30-acre storage pond prior to treatment. A 50-acre pond is used to treat and cool a difficult waste resulting from the direct quench of cracked oil gases.

General Plant Wastes

The general plant wastes of 50 m.g.d. which are now settled in 40 acres of ponds before discharge to the river have a B.O.D. population equivalent of about 130,000. The wastes result from the manufacture of all products other than the phenolic type. The oxygen demand is created by such compounds as polysulfide, sulfites, alcohols, and many aliphatic combinations.

A treatment plant for these combined wastes is being studied. Experimentally it was found that activated sludge would do a creditable job of oxidizing this waste.

Specific Chemical Wastes

Too often investigators fail to evaluate the oxygen demand of certain chemical wastes. Polysulfide wastes resulting from the manufacture of a synthetic rubber and also from the treatment of cyanides have an immediate oxygen demand. Polysulfide rapidly oxidizes to thiosulfate as shown:

$$2Na_2S_x + 3O_2 = 2Na_2S_2O_3 + (x)S\downarrow$$

With the proper bacteria present the oxidation is completed:

$$2Na_2S_2O_3 + O_2 = 2Na_2SO_4 + 2S\downarrow$$

$$2S + 3O_2 + 2H_2O = 2H_2SO_4 + (282 \text{ calories})$$

These reactions should proceed in a two stage process since the oxidation of sulfur and thiosulfate results in an acid water which would release H_2S from the polysulfide if added, and the excess alkali contained in polysulfides would slow up the oxidation rates. It is believed that few activated sludge plants would be capable of receiving much polysulfide waste without seriously affecting the effluent because of the high oxygen demand.

The use of blowing-out towers has proved effective in removing certain low boiling organics such as styrene, ethyl benzene, chlorobenzol, alcohols and benzene.

Complete elimination of certain waste waters such as cracking process quench water has proved necessary.

The oxidation of organic matter, using bacteria as catalysts, is by far the cheapest method available. If an industry under severe pollution restrictions has gone as far as practical with biological treatment, what more can be done?

The oxidation of residual taste and odor pollutants can be accomplished chemically using chlorine, bromine or perhaps ozone. The control of oxidation by chlorine or bromine (Figure 2) must be exact or there is great danger of increasing the taste and odor.

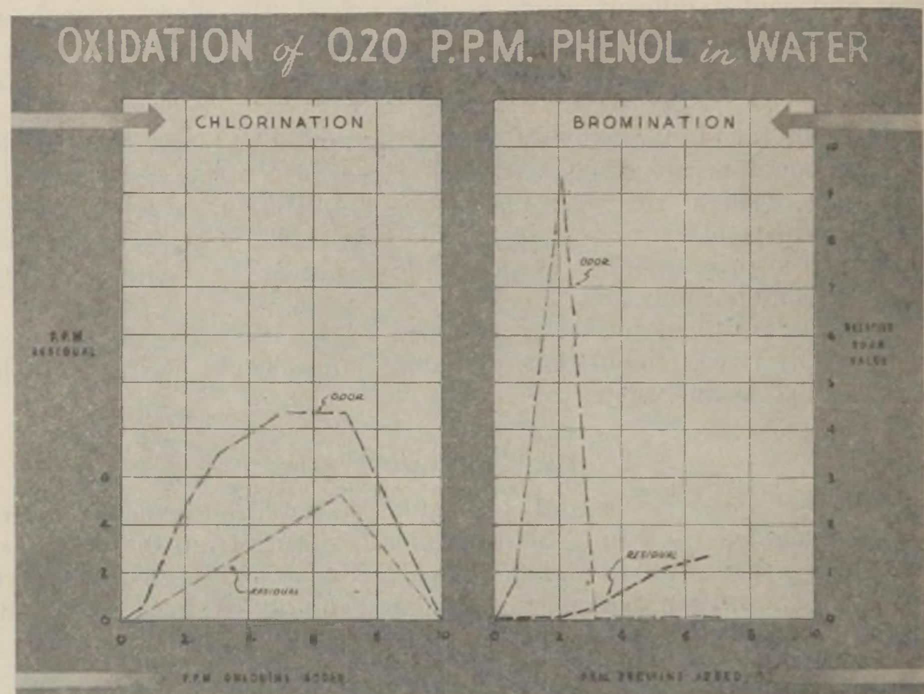

FIGURE 2.—Oxidation of 0.20 p.p.m. phenol in water by chlorine and bromine.

The adsorption of residual organics by activated carbon might also become feasible provided the biological or extraction process is carried to its practical limits.

The treatment of phenolic wastes has been the subject of many articles for the past twenty years. As Mohlman (1) pointed out years ago a pound of phenol requires 2.38 pounds of oxygen when completely oxidized to CO_2 and H_2O:

$$C_6H_5OH + 7O_2 \cdots 6CO_2 + 3H_2O$$

$$\frac{94}{1} :: \frac{224}{2.38}$$

Eldridge (2) concluded that inhibition of biological oxidation does not start until about 180 p.p.m. of phenol are present.

The cresols, aniline, salicylic acid and most of the lower substituted phenols are readily oxidized biologically. Within their range of solubility, the toxicity of phenolic compounds to bacteria (3) increases with the molecular weight (Figure 3). The fact that most of the higher substituted phenols are insoluble in acid solution should lead toward pretreatment of such wastes by acidification.

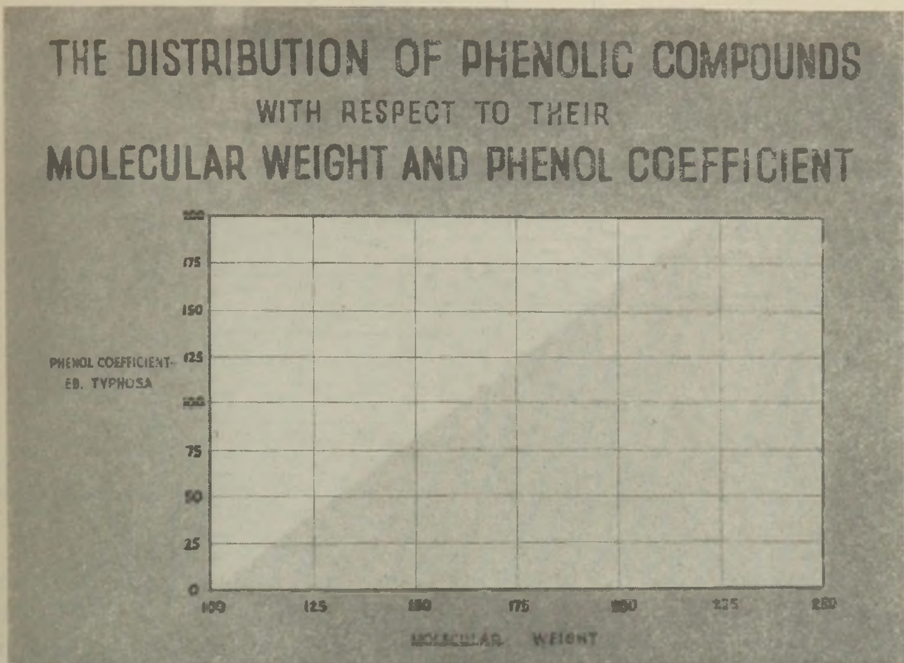

Figure 3.—The distribution of phenolic compounds with respect to their molecular weight and phenol coefficient.

Phenolic Waste Treatment

The units for treatment of the phenolic wastes of the Dow Chemical Company are (Figure 4): strong waste storage pond, Dorr clarifier, four trickling filters, and an activated sludge plant and 50 acres of effluent ponds.

Strong phenolic wastes are pumped to the storage pond by all bronze open-impeller centrifugal pumps and Saran discharge lines. The pond is a treatment unit which serves to equalize flows and waste concentrations besides precipitating substituted phenols which are insoluble in acid solution. The volume of strong waste averages about 1.25 m.g.d. with a concentration of phenolics of about 600 p.p.m. The pH might vary between 2 and 4 and contain an acidity of 270 parts per million as HC1. Storage capacity of 42 million gallons permits control of feed to treatment process.

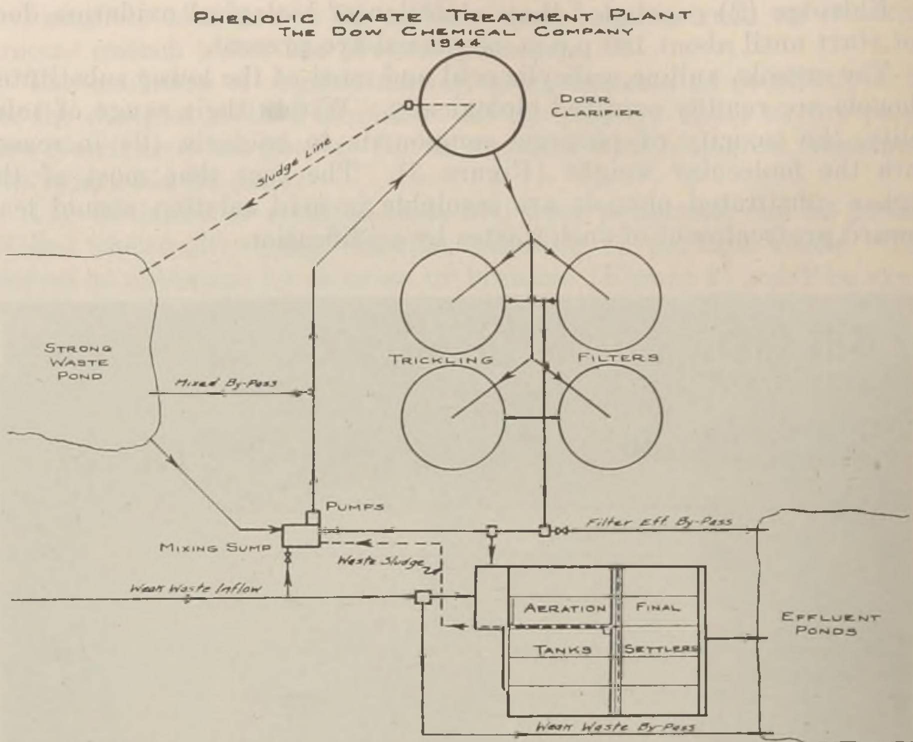

FIGURE 4.—Layout of phenolic waste treatment plant of The Dow Chemical Company at Midland, Michigan.

Weak waste flows of 12 m.g.d. in the winter and 20 m.g.d. in the summer contain from 5 to 1 p.p.m. of phenol. This waste is mixed with the strong wastes (and filter effluent recycle when necessary) and is pumped to the clarifier at a rate of 15 m.g.d. The clarifier at this plant serves to skim light oils and settle whatever heavy oils and precipitates are present. No phenol is removed in this unit (Figure 5).

It is possible to pump the mixed waste to the strong waste pond

FIGURE 5.—Trickling filters and sedimentation unit treating phenolic wastes.

when weak waste concentration of acid, caustic or phenolics might create overloaded or toxic conditions. The underflow from the Dorr clarifier is lagooned in a portion of the strong waste pond. Overflow from the clarifier flows by gravity to the four trickling filters which are 142 feet in diameter on top with the 2½–3½-inch blast furnace slag media forming the outside wall on a 45 degree slope, which makes the bottom diameters 162 feet. The center gallery and complete bottom coverage of ''Armcre'' tile were designed to give maximum aeration (Figure 6). Motor driven, two-arm distributors are of ten-inch pipe

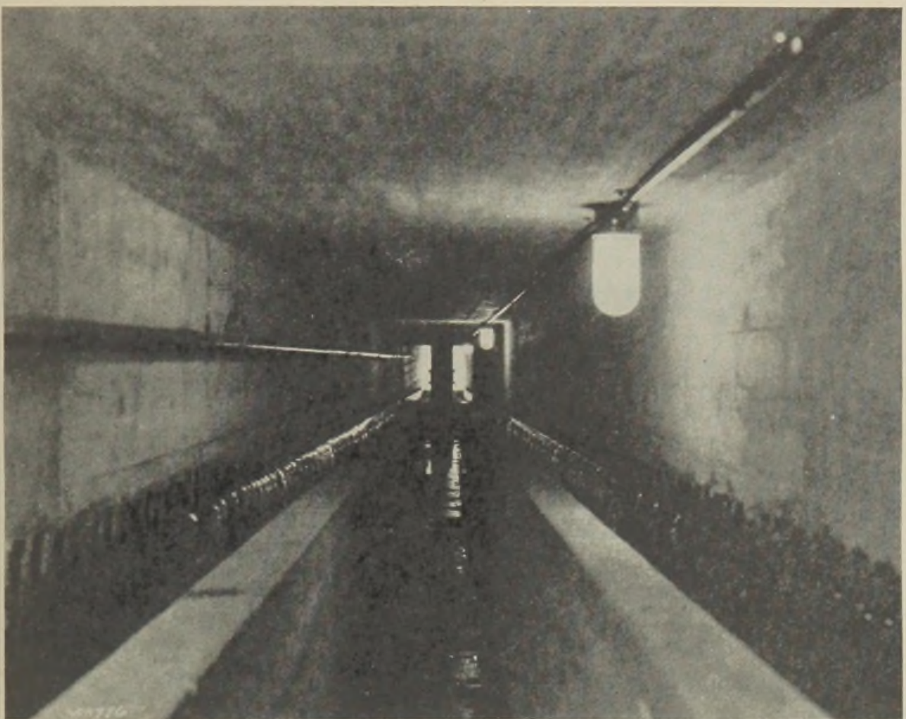

FIGURE 6.—Effluent gallery of trickling filters shown in Figure 5.

with eight-inch for the last ten feet. Water head on these units is sufficient to rotate them so that the motor serves as a speed regulator most of the time. The temperature of the mixed waste leaving these filters varies from 53 deg. F. to 95 deg. F. The pH of the mixed liquor is kept above 6.1 and below 8.0. The phenol concentration for normal feeds varies between 30–50 p.p.m. Concentrations higher than that are recirculated. The beds average 9.75 feet deep and obtain removals of phenol from 4.29 lbs. per 1000 cu. ft. at 56 deg. F. to 9.0 lbs per 1,000 cu. ft. at 83 deg. F. with a feed rate of 10.2 m.g.a.d. Removal of B.O.D. varies from 15.8 lbs. per 1,000 cu. ft. to 27 lbs. per 1,000 cu. ft. at the respective temperatures given.

The population equivalent of the B.O.D. load to this plant is about 125,000.

Activated Sludge Plant

The activated sludge plant (Figure 7) receives the filter effluent and excess weak wastes through a grit chamber. Return sludge is mixed with inflow at the effluent end of the grit chamber and the flow is directed to each of the 5 batteries. Three mechanical aerators in series in a 24-foot by 75-foot tank with a 15-foot depth, followed by a 24-foot width, 70-foot length and 10-foot depth settling tank, comprises one battery.

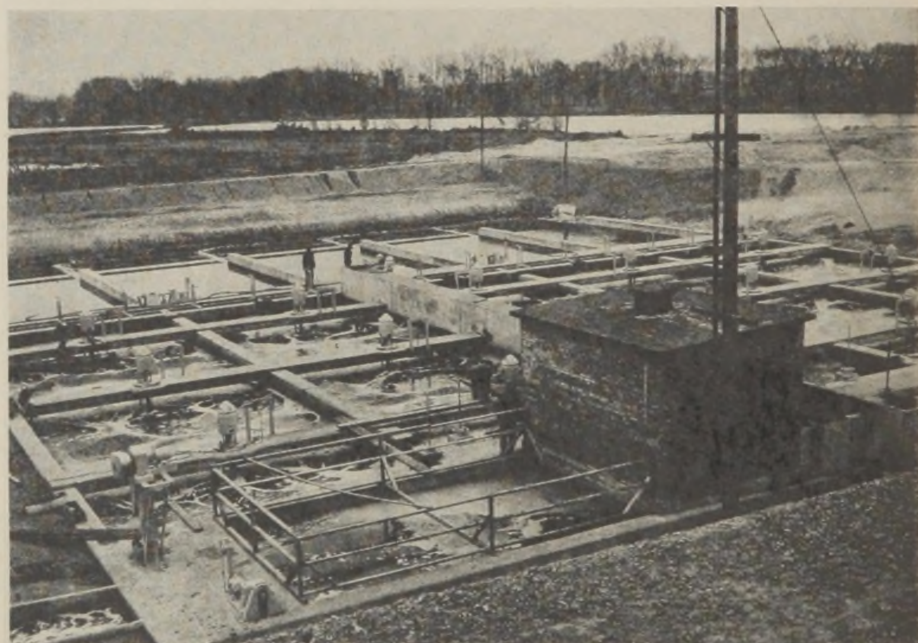

FIGURE 7.—Activated sludge plant treating phenolic wastes at Midland plant of The Dow Chemical Company.

Return sludge is delivered by slip pipes to a channel leading to screw pumps which lift the sludge to the channel set on top of the wall between No. 2 and No. 3 batteries.

The activated sludge plant has been found to be capable of oxidizing 1,300 lbs. per day of phenol or 3,300 lbs. per day of B.O.D.

The overall removal effected by various units is illustrated (Table 1). The final effluent to the river averages less than 0.4 p.p.m. of phenol.

The Dow Chemical Company has proceeded on the basis of eliminating or recovering wastes wherever possible and providing biological treatment where feasible. Each chemical plant must be

TABLE 1.—*Summary of Phenolic Waste Disposal—The Dow Chemical Company Midland, Michigan*
Removal of Phenol by Various Units

Month	Pounds of Phenol per Day				Over-all Per cent Removal
	Total Received	Removed by Filters	Removed by Activated	Removed by Ponds	
May '43	5152	3880	810	172	98.6
June	5745	4853	515	139	96.2
July	4775	3875	346	153	94.6
Aug.	4332	3184	523	299	95.8
Sept.	5703	4547	914	136	98.2
Oct.	3987	3217	590	73	97.1
Nov.	4063	2947	1011	55	98.9
Dec.	4040	2695	1316	55	98.0
Jan. '44	3999	2746	1188	32	99.3
Feb.	3892	2603	1193	60	98.8
March	4054	2655	1280	80	99.0
April	4496	3089	1234	117	98.8
May	5463	4805	540	61	98.9
June	4444	3996	334	43	98.4
July	4028	2651	294	41	98.9
Aug.	4499	3715	561	105	97.5

studied separately and every waste evaluated with respect to its pollutant characteristics.

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INDUSTRIAL WASTES IN CONNECTICUT AND THEIR TREATMENT *

By William S. Wise

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Industrial wastes of a polluting nature are discharged into the waterways of Connecticut at the rate of about 100,000,000 gallons per day. These wastes vary enormously in character and it is estimated that their total pollution load upon the waterways is equivalent to that which would result from the sewage discharged untreated by all the municipalities of the state.

These wastes are produced by many different types of industries. The three largest groups are: (1) metallurgical; brass and copper, iron and steel, (2) textile, (3) paper board and allied products. The smaller groups are hat, leather, chemical, rubber, distillery, dairy, laundry, machine tools and others.

The amount of materials discharged in these wastes is in some instances startling. In 1941 a survey was made of the brass and copper heavy industries in the state to determine the amount of metals lost primarily in the pickling processes. During that year it was estimated that 1,560 tons of copper and 1,150 tons of zinc were discharged in the liquid wastes. This amounted to 2,675 lbs. of copper and 1,950 lbs. of zinc per 500 tons of processed material shipped. The pickling operations required the use of 10,250 tons of sulfuric acid, 1,440 tons of sodium bichromate and water at the rate of about 8,000,000 gallons per day.

Paper board and allied industries in this state discharge about 23 tons of pulp per day with 18,000,000 gallons of water; one plant alone loses over 5 tons of pulp per day in this manner.

In addition to the tangible loss of certain recoverable products there is the intangible loss caused by gross pollution of public waterways. The latter represents a real loss of considerable magnitude, even though it cannot readily be evaluated on a monetary basis. The increase in cost of obtaining satisfactory water for domestic and industrial uses; destruction of fish and aquatic life; effect upon recreational uses; damage to structures and land values; formation of deposits in stream channels; public nuisances, such as unsightliness and foul odors; and the effect upon public health; are all conditions which directly and indirectly affect the lives and welfare of all the people.

Industrial waste treatment has a two fold purpose, the abatement of pollution and the recovery or re-use of materials used in the manufacturing processes. A very important aspect of the problem confronting those desiring to improve the condition of waterways and those charged with the duties of pollution abatement is the decision as to the

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degree of treatment necessary or justified. Nearly all industrial wastes can be treated by a process or combination of processes to a degree which will permit of their discharge into almost any watercourse. The limiting factor is the cost.

Because of the multiple uses made of watercourses, it is not practical to maintain all streams in a state of pristine purity, but to permit their use for indiscriminate disposal of wastes is unthinkable. The common law doctrine, whereby the riparian owner is entitled to the stream flow by or through his land undiminished in quantity and unpolluted in quality, has been modified in practice if not by law. There is an economic balance determining for what purpose a stream can or should be used.

The goal of an industrial waste treatment policy must be the restoration and maintenance of all watercourses in a reasonable condition of purity within the limits of physical possibility of attainment and that which is economically feasible. If this is to be done it is necessary to have in outline a comprehensive program for the guidance of administrative agencies and as a graphical picture showing how it affects each individual offender.

Program for Pollution Abatement

Pollution abatement programs on a watershed basis should be set up in accordance with certain fundamental considerations, among which are: conservation of water; stream size and characteristics; character and volume of wastes discharged; natural laws and self-purification; local conditions and needs; and multiplicity of uses made of the watercourse.

Conservation of Water

In certain industrial areas unsatisfactory conditions of surface waters for manufacturing purposes are a factor in the trend of industry toward developing ground water supplies to satisfy its needs. In some localities the draft on wells is critically taxing these limited supplies with the alternative of treating highly polluted river water or purchasing from utilities.

While not all waters can be conserved for only one type of use, it is obvious that the vital and limited water resources of a state or region are best conserved when rivers are so maintained and protected that they can meet, to the maximum extent possible, the varied demands of the area through which they flow.

Self-Purification of Streams (1) (2)

The natural factors of self-purification represent a tremendous economic asset, which should be used and not abused. The amount of organic matter thus stabilized is remarkable when the biochemical reactions are in equilibrium and allowed to proceed in an orderly sequence of stages of oxidation. However, when inorganic materials, acids, alkalies, toxic compounds, and excessive quantities of organic matter reach the waterway with limited dilution, the results are putrefaction, odors, unsightly appearance and depreciation of property values.

Classification of Streams and Standards of Quality (3) (4)

Classification of all streams in a state or region based on restoring them to the best condition which is economically feasible provides reasonable standards to aspire to and supplies a logical foundation upon which to develop a pollution abatement program. Obviously, standards cannot be used as a mechanical device by armchair theorists to solve the complex problem of pollution on a rational basis. There is the temptation, in setting up standards, to make them all-inclusive, rigid and with many details that later are found to be conflicting and impractical of enforcement. This should be avoided.

Recognition must be given to three fundamental limitations: first, the fact that it is impossible to control, by standards or otherwise, the quality of water to fit the specific requirements for all uses; second, the great difficulty in sampling the wastes and the receiving water to determine whether the degree of treatment is meeting the requirements set forth in the standards; third, the impossibility of developing foolproof treatment plants which will continuously produce a uniform effluent, because of the number of unpredictable factors involved, such as failure of mechanical equipment, varying character and volume of wastes, natural conditions and the exceedingly important human element.

No single standard can be set for an entire state, region or country. One, satisfactory for a drainage basin in Connecticut, might not be applicable to another watershed or in another state or even for the entire course of a stream.

Work on the classification of streams in New England was started before the war and discontinued for the duration (5). The object was to set up, through joint action of the states, a reasonable classification for interstate streams and to have each state classify all streams wholly within its borders, in accordance with the same general plan. This classification divides the streams into four classes, designated as A, B, C and D, depending upon their existing and potential highest use and the quality of effluent which might be expected from reasonable and practicable treatment processes.

This classification has considerable merit because of its simplicity, flexibility, reasonableness and comparative ease of administration, and is particularly applicable to sewage pollution. It is probably impracticable to set up any classification which would be applicable to all types of industrial wastes. Therefore, flexibility is necessary to permit of discretionary requirements by the administrative agencies.

Treatment of Industrial Wastes

It is neither feasible to treat all types of industrial wastes so as to produce the same high degree of purity, nor reasonable to require the same degree of treatment for similar wastes which are discharged into streams of different size and characteristics. The logical course lies in the adoption of methods to fit the quality of receiving waters contemplated in a rational classification program.

Some wastes contain products of value recoverable at a comparatively low cost and permit a profitable re-use of the water; others are not amenable to high degrees of purification except at a high cost and do not yield products of value.

Mixing and Equalization

The majority of industrial wastes contain intermittent slugs of high concentration discharged with the more dilute wastes and wash waters. One department of a plant may discharge acid wastes, another alkaline wastes.

Mixing and equalization of wastes of this nature is frequently necessary as a first step for further treatment and occasionally is the only treatment required, particularly if ample dilution is available.

Some wastes contain minute or colloidal particles which do not settle because they carry electric charges of the same sign. Mixing this solution with another, the molecules of which carry charges of opposite sign, may result in a partial clarification of both wastes if precipitation is permitted.

Industrial Wastes and Sewage Treatment

The desire of some industrial officials to discharge wastes into municipal sewerage systems is natural and logical. However, the majority of industrial wastes cannot thus be accepted in plants using biological treatment processes without satisfactory pretreatment of the wastes.

A considerable amount of research work has been carried out to determine the effect of copper upon sludge digestion (6). It was found that a sewage containing 0.5 p.p.m. of copper produced a sludge containing over 100 p.p.m. While this investigation has been interrupted by the war, it has tentatively been concluded that the chemical nature of the copper, the presence of certain sulfates in the sewage and the concentration of solids in the sludge all have an effect upon the toxicity of the copper and its inhibitory effect upon digestion. In general, a decrease in the efficiency of sludge digestion can be expected when the constant amount of copper in the sewage exceeds 1 p.p.m.

It has also been found that when 200 p.p.m. of precipitated chromium is present in sludge the rate of digestion is noticeably reduced and when the concentration of chromium in sewage constantly exceeds 1 p.p.m. its effect is similar to that of copper (6).

Other toxic materials in plating solutions, such as nickel, cyanides, etc., also have an inhibitory effect upon biological treatment.

Wastes from a textile plant discharging dyeing and finishing wastes through an equalization and controlled flow system are satisfactorily handled at a sewage treatment plant where the sewage is chlorinated during the bathing season (7). The wastes apparently have no serious effect upon sludge digestion and a detailed investigation disclosed the following reduction in chlorine demand of the wastes through its mixture with the sewage.

Sewage flow (average rate)	16 m.g.d.
Volume of wastes:	
Dilute	850,000 g.p.d.
Concentrated	50,000 g.p.d.
Chlorine demand of wastes:	
At mill	2,060 lbs.
At sewage treatment plant	1,300 lbs.

The chlorine demand of the various wastes at the mill ranged from 8 to 3,200 p.p.m.

At another plant it was found that textile wastes would probably not interfere with the operation of the sewage treatment plant if their discharge were controlled through an equalization system so that the volume at any time would not exceed 10 per cent of the volume of sewage (6). This method of disposal, however, cannot always be used because some textile wastes contain toxic and other components which may interfere with sewage treatment.

Metallurgical Wastes

A detailed investigation of the wastes from the pickling operations at one of the large brass and copper plants revealed the startling fact that the dilute wash waters carry away 88 per cent of the acid used and 90 per cent of the lost metals. The remainder is lost in the form of spent pickle liquor (8). The composition and enormous variation of the wastes discharged from each of the three main departments was found to be:

Source of Waste	Concentration in P.P.M.			
	Sulphuric Acid	Copper	Zinc	Total Chromium
Rolling Mill				
Hourly Maximum	2,000	90	115	85
Hourly Minimum	105	10	20	5
Average	590	35	55	30
Tube Mill				
Hourly Maximum	245	145	70	80
Hourly Minimum	10	35	20	5
Average	85	75	40	25
Rod and Wire Mill				
Hourly Maximum	4,940	1,580	4,300	1,110
Hourly Minimum	190	385	350	345
Average	1,390	890	1,465	690

A great deal of research has been undertaken in an attempt to find a satisfactory method for treating this type of waste and in 1935 a pilot plant was operated at a large brass manufacturing plant where the pickling wastes were mixed with cooling and other used water (9). The average composition of these combined wastes covering a period of about six months was found to be:

Sulfuric acid	105 p.p.m.
Copper	24 p.p.m.
Zinc	20 p.p.m.
Chromium (total)	20 p.p.m.
Chromium (as chromate)	9 p.p.m.

The purpose of this study was to recover the copper and zinc in a form that could be re-used in the furnaces and the chromium in a form satisfactory for re-use in pickling.

The results of this investigation indicated that a complete treatment plant to handle 3,000,000 gallons per day would cost approximately $200,000 to construct. The annual fixed and operating costs were estimated at $79,000 and the value of recovered products at $55,000.

The information obtained is valuable in indicating the difficulties and cost of treating the combined wastes and also in pointing the way to new lines of attack. After the war it is anticipated that research in the treatment of these wastes will proceed along the lines of concentrating the metals from the dilute wastes, and their recovery from the concentrated solution.

Treatment of wastes from iron and steel pickling operations has for some years been carried out at one plant by neutralization with lime, flocculation and precipitation, on a continuous flow basis. The effluent contains practically no iron, is nearly neutral and water clear. Sludge is disposed of in lagoons. Another plant has manufactured copperas from concentrated wastes for more than 20 years, with some of the more dilute wastes discharged to the sewerage system.

Paper Board Mill Wastes

The volume of these wastes in the different plants varies from 5,000 to 40,000 gallons per ton of product. They usually have a pH of from 5.0 to 7.0 and contain from 2 to 6 lbs. per 1,000 gallons of suspended solids with occasional surges of several times the high figure. The 5-day B.O.D. usually varies from 100 to 600 p.p.m.

Save-alls of various types are used primarily for reducing the fiber loss in the plant. However, from a pollution standpoint the revolving screen type in general use cannot ordinarily be expected to produce an effluent with a suspended solids content of much less than 2 lbs. per 1,000 gallons.

More effective treatment can be obtained either by sedimentation or flotation and the solids removed can generally be re-used. The following results may be obtained:

Treatment	Percentage of Fiber Removed
Sedimentation (approximately 2 hours)	75
Sedimentation plus flocculation without chemicals	85
Sedimentation plus flocculation with chemicals	95
Flotation with chemicals	95

Temperature is a factor affecting the sedimentation of these solids, not only in the difference between that of the wastes and the atmosphere but also between the wastes themselves.

In addition to the value of the recovered solids a substantial saving can accrue from the re-use of the clarified water, where the quantity is limited and particularly where the temperature must be raised.

Ordinary settling basins, without provision for sludge removal, are not practicable because of the large capacity necessary and the over-all inadequacy of sedimentation due to the constantly increasing sludge volume, together with the exposure of large surface areas to wind currents. The difficulty in eventually removing and disposing of the sludge which is not satisfactory for re-use, because of septic action, presents a serious problem. The sludge must be in a fresh condition for re-use.

Textile Wastes (10) (11)

The liquid wastes produced in dyeing and finishing operations on cotton, wool, rayon, silk and felt materials vary greatly in composition and volume, and do not lend themselves to the recovery of by-products. The exception to this is the recovery of caustic soda from mercerizing liquors by dialysis or by centrifuging and evaporation.

It is impossible to discuss, or even summarize in a few minutes, the whole problem of treating textile wastes because of the many different manufacturing processes involved, and the countless combinations of wastes which are produced and they usually are of a complex nature.

Chemical precipitation is the most widely used method of treatment which, naturally, has its limitations as far as the quality of effluent produced is concerned. In the smaller plants this is usually carried out in tanks on the fill and draw or batch method, because of the need for equalization and an opportunity for preliminary tests to determine the proper amount of chemicals necessary. Continuous flow tanks are generally more applicable for the large volumes produced in large plants.

The chemicals found to be most effective are lime and iron salts—either ferrous sulfate (copperas) or ferric sulfate. Combinations of lime and alum, ferric chloride, calcium chloride and soda ash are effective on certain wastes. Sulfuric acid, at times, is necessary for pH control, neutralization of strongly alkaline wastes, precipitation of certain dyes and to break up soap solutions.

The B.O.D. of composite wastes usually varies between 200 and 1,500 p.p.m. With the addition of proper amounts of chemicals and adequate mixing or flocculation preceding a sedimentation period of about 2 hours, 80 to 90 per cent of the oxygen consuming material can be removed when the B.O.D. is over 800 p.p.m. and 60 per cent removal can be obtained when the B.O.D. is from 200 to 300 p.p.m. The amount of chemicals necessary is usually 1 to 2 lbs. per 1,000 gallons for the weaker wastes and greater quantities for the more concentrated.

The cost of chemical treatment is of course dependent upon many factors. However, for plants discharging less than 500,000 gallons per day, the fixed and operating costs may run from 10 to 20 cents per 1,000 gallons. For plants treating over 1,000,000 gallons per day the costs may be less than 10 cents per 1,000 gallons.

The causticity of kier liquors can be reduced by exposure to air, thus permitting the absorption of carbon dioxide. Complete neutralization of the caustic alkalinity was found after 7 days exposure with an 8-inch depth of liquid. The greatest reduction in the oxidizable organic matter as measured by oxygen consumed was found by partial neutralization through exposure and completion of neutralization by sulfuric acid followed by sedimentation. Another method for treating these wastes has been developed whereby flue gases and calcium chloride are used with the possible recovery of calcium carbonate.

The disposal of sludge from the treatment of textile wastes presents a problem unless there is sufficient land available for lagoons, in which it is dried, removed and finally disposed of elsewhere.

The effluents from chemical treatment plants are rarely clear. They may be colored, turbid and contain dissolved organic matter. Where higher degrees of treatment are necessary this can be accomplished on biological filters.

Oil and Grease

For many reasons oil and grease are among the most objectionable elements of pollution and metallurgical industries usually discharge appreciable quantities of them. Their recovery is neither difficult nor expensive. One metallurgical plant has, for several years, recovered, by means of a simple oil separator, approximately 2,000 gallons per week for re-use at a substantial profit.

The American Petroleum Institute has made a distinct contribution to abatement of pollution due to oil, through its studies and development of equipment for removing oil from industrial wastes (12). The following tabulation is interesting as an indication of the thickness of an oil film according to its appearance and the amount present when uniformly distributed:

Approximate Thickness of Film (inches)	Appearance	Approximate Quantity of Oil for Film 1 Sq. Mi. in Area (gallons)
0.0000015	Barely visible under most favorable light conditions	25
0.0000030	Visible as silvery sheen on surface of water	50
0.0000060	First trace of color may be observed	100
0.0000120	Bright bands of color are visible	200
0.0000400	Colors begin to turn dull	666
0.0000800	Colors are much darker	1,332

It has been determined also that films up to 0.000003 inch in thickness do not persist on the average for more than 5 hours on an agitated water surface, and that appreciable quantities can be discharged under favorable conditions without becoming visible to the eye, provided the distribution is uniform.

Water soluble oils used for coolants in cutting and grinding operations on metals have caused increased pollution during the war. However, two methods have been developed for treating these compounds for re-use by removal of the small metal particles: (1) sedimentation and filtration through a spring filter, and (2) flotation of the metal particles by a process used in ore dressing. Three plants in Connecticut doing precision work have been using this equipment for a number of months and re-using, at a substantial profit, all of the treated coolant. The control of bacterial growths in a closed system is a problem requiring further study.

Spills and drippings, not re-usable, can be treated by combinations of sulfuric acid, alum, ferric sulfate and lime to produce a satisfactory effluent (13).

Plating Wastes (14)

These wastes contain chromium, copper, nickel, cadmium, other metals and cyanides all of which are toxic.

At one plant the composite wastes usually have a pH of from 2.0 to 5.0 and contain from 100 to 500 p.p.m. of chromium in a form that cannot be precipitated without the use of a reducing reagent. The most satisfactory reagent for these wastes was found to be barium sulfide. Copperas is satisfactory for some types of wastes.

The treatment consists of batch operation with preliminary tests for proper amounts of chemicals. Barium sulfide is added in solution form in required amounts (10 lbs. per 1,000 gallons for 400 p.p.m. of chromium); copperas at 0 to 3 lbs. per 1,000 gallons and lime from 3 to 5 lbs. per 1,000 gallons. Occasionally, sulfuric acid is added to the influent for proper pH control and liberation of the cyanide gas. The effluent is usually water clear, having a pH of about 8.5 with all metals removed and the cyanide content reduced about 60 per cent. Sulfide odor, if objectionable, can be corrected by the addition of small amounts of sodium or potassium permanganate.

Under certain conditions the cyanide remaining in the effluent may be objectionable. In another state the cyanide in the treated effluent is destroyed by chlorination, the end products being nitrogen and hydrochloric acid. There is a need for research work on the destruction of cyanide by chlorine to determine its applicability in the presence of the usual metals and under various conditions. Other methods for converting cyanides to non-toxic compounds have been developed elsewhere. Consideration should be given to the possibility of its reconversion to a toxic form under certain conditions.

The liberation of cyanide as a gas can be carried out in lagoons with a long period of exposure and a pH of about 3.0.

There are indications that the future may produce entirely new methods and new lines of attack for the treatment of industrial wastes. One method, which at present holds some promise, involves the principle of base-exchange or de-ionization by the use of synthetic resins. The element of cost will be an important determining factor in the adoption of any processes.

Conclusion

This discussion has included the treatment of but a few of the many types of industrial wastes produced. It does not pretend to be the final answer to the large and complicated problems of industrial waste treatment but rather an indication of the lines of attack based on present knowledge and experience.

The conclusion is justified that the treatment of industrial wastes can best be pursued by attempting to fit the processes to the conditions in accordance with a comprehensive program. Such a program should be carried out by those familiar with the fundamental local conditions and needs. Remote directives, based on many theoretical premises, are no substitutes for a program formulated "at home" and based on a balance between that which is physically possible of attainment and that which is economically feasible.

Acknowledgment

Note: All research work for the State Water Commission has been carried out cooperatively at Yale University, New Haven, Connecticut, and Wesleyan University, Middletown, Connecticut, under the direction of Dr. H. A. Curtis, succeeded by Dr. B. F. Dodge at Yale, and the late Dr. C. R. Hoover, succeeded by Dr. G. A. Hill at Wesleyan.

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THE OPERATOR'S CORNER

Safety in Sewage Works Operation

Early returns on the reception of Manual of Practice No. 1 of the Federation's Committee on Sewage Works Practice indicate that the committee chose well in selecting the subject of safety as demanding first attention. We shall be disappointed if the application of the safety principles referred to in the manual, by designers, manufacturers and operators, does not result in a marked reduction in accident rates and insurance premiums in the not too distant future.

The manual will not do the job alone, however. Operators will do well to study it in great detail and to check every part of existing plants for the hazards described, immediately correcting any condition which may be potentially dangerous. It will be worth while to become thoroughly acquainted with the characteristics of the gases which may be encountered, as described in Table III on pages 22-23 of the manual. The procedures recommended as safe practices should be made the rule and each employee should be requested to study, or better still, given instruction in the techniques of rescue and first aid.

Probably the greatest deficiency in safety practice at this time is in regard to accident prevention equipment and its use. Very few sewage works are properly equipped to prevent accidents and many of them have no equipment at all. The alert plant superintendent or chief operator will find the safety manual very useful in selling his department head or the city council on the need for such equipment. The lengthy list of accidents recorded in Appendix A of the manual will speak for itself, even to a layman.

Given adequate equipment, it is important to see that it is used when and how it should be used. The tendency to lay aside safety devices because they may be inconvenient or because their use may foolishly be deemed unmanly, must be overcome—by education, if possible, otherwise by enforcement of orders.

The manual should also bring about an increased consciousness of safety considerations on the part of sewage works designers and manufacturers of equipment employed in such works. The elimination of hazards during design and the "foolproofing" of equipment will relieve the burden on the human element in plant operation. There will be further emphasis given potential occupational hazards by state sanitary engineers and other agencies to which plans are submitted for review and approval.

Manual of Practice No. 1 paves the way for a great saving in life and property. Let us all make sure that it is used to fullest advantage!

W. H. W.

SEWER MAINTENANCE PLANNING—RECORDS AND METHODS *

By Reuben F. Brown

Superintendent of Sewer Maintenance, City of Los Angeles

"Blueprint Now" is a slogan being used for postwar planning. It is also significant in connection with a yearly sewer maintenance program, in that a planned program is vital and necessary to proper maintenance of a sewerage system.

Along with planning is the standardization of records, costs of work, and the methods of maintenance. Every sewer department has its own forms for keeping records and its own methods of arriving at the cost of various types of maintenance work. In order to have a comparison of work as performed in different communities, there should be a uniformity and standardization of records in the different parts of the country. Then, through Sewage Works Journal and other national periodicals, an exchange of ideas becomes of great benefit to every one connected with sewer maintenance. The unit cost of the different functions will average about the same if all items which enter into the completion of the work have been taken into consideration and not charged against some other function of work or hidden in a roundabout method in the accounting system.

Standard records are essential to sewer maintenance planning, practices and methods. From an analysis of daily and monthly records, the work is scheduled. Plans are made to make necessary yearly repairs so as to take first things first in their importance of benefit to the whole. Emergency breakdowns and repairs will change a yearly preventive maintenance schedule. By the use of charts and diagrams showing accumulative performance and comparison of work, maintenance crews can be transferred from an operation where they are ahead of schedule, to the emergency work requiring immediate consideration. This gives flexibility to maintenance personnel.

In Sewage Works Journal for May, 1944, is published a "Sewage Works Check Test for Postwar Planning." Every phase of maintenance operation has been taken into consideration from the disposal of waste at the house connection lateral to the final discharge from the treatment plant. This check list shows the close contact and coordination necessary between administration, design and maintenance, in a well planned program. Effectiveness of sewer design and field operation depend on maintenance reports and records to establish a basis for scientific control of a sewerage system.

An effort is made here to point out with illustrations of different maintenance problems, the need for such records and reports and their use in scheduling and planning.

* Presented at Seventeenth Annual Meeting, California Sewage Works Association, Fresno, June 22–25, 1944.

Equipment and material are of first importance in maintenance work. Trucks are tools in sewer work. At Los Angeles they are equipped with about $550 worth of essential tools for cleaning, flushing, and repairs (Figure 1). Work performance records of this equipment

FIGURE 1.—Typical sewer maintenance truck used at Los Angeles.

with cost of repairs and replacement will give a standard measurement of efficiency, or show a need for change of method or equipment. These records should show length of service, hours of operation, cost of repair and apply to portable tools, pumps, gas engines, motors, ventilating fans, measuring instruments, and special tools for different types of work.

Material used in repair work to overcome some difficult problem should have a record card. This card should be filled so periodic inspections can be recorded and should show type of materials, when installed, life of materials, cost and replacement. Improved service will result from such a record.

Records in pipe line maintenance apply to all sizes of pipe, from the eight-inch main line to the twelve-foot outfall. Reports show sewer or storm drain districts worked, manholes inspected, cleaned, flushed, feet of pipe rodded, amount of water used, partial or complete stoppages, cause of stoppage, and any type of work applying to pipe lines maintenance, and the time required for such work. In a preventive maintenance schedule, inspection of all pipe lines at least twice a year has been found essential. There should also be a list of bad locations where roots and grease, or industrial waste, is the problem and which require frequent cleaning. Field inspection reports will clearly indicate overtaxed sewer lines, obnoxious sewer gas odors, erosion of sewers and drains, both physical and chemical. From a study of these reports, action can be taken to eliminate the cause of such conditions.

FIGURE 2.—Cleaning machine clears a bad root stoppage. Root shown is 120 feet long.

FIGURE 3.—Flexible steel rods used for sewer cleaning. Small gasoline engine power unit increases efficiency of 3-man crew.

Cleaning of catch basins in a separate storm drain system is routine. Scheduled time of cleaning is necessary, with greater frequency given to bad locations. Record of material removed and cause of frequent cleaning should be studied. Where open channels or ditches empty into a storm drain, the record of channel maintenance is important to prevent serious storm drain stoppage caused by trash entrance during heavy storms. Maintenance of storm drain pipe is costly, due to size of pipe and amount of material removed. Records

FIGURE 4.—Nine tons of grease removed from a 30-inch sewer in which a complete stoppage had occurred. Sold for $350 to the industry believed to have discharged it to the sewer originally.

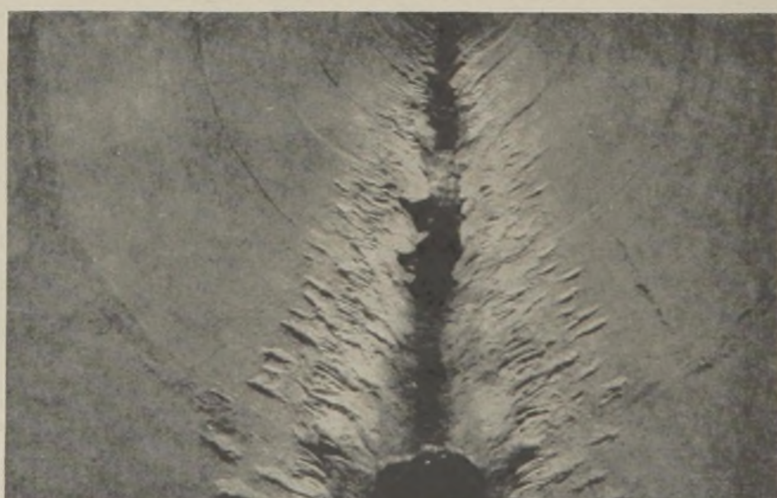

FIGURE 5.—Effect of corrosion and abrasion on a sewer line.

made of heavy cleaning, location, method of doing the work, tools used, and cost of such work, are part of a planned program. This also applies to culverts, both large and small.

From a well-kept system of pipe line records, locations requiring repair will be found in the sewerage system. Repair of underground pipe lines is a costly item of maintenance. They ordinarily consist of replacing broken pipe, relief of overtaxed sewer lines, locating lost house connection sewers, raising and lowering manholes, replacement of manhole steps, providing by-pass lines for emergency operation, repair of catch basins and culverts, all of which repairs should be made before a condition of emergency exists. During heavy storms emergency repairs increase and may demand use of the entire maintenance staff.

Sewage pumping plant maintenance also requires a planned program. A preventive maintenance schedule of inspection, adjustment and repair will make continuous operation practically a certainty. Standard records and reports should show the required work from which can be determined the man-hour demand.

Basic rules of procedure for the maintenance of all types of machinery and plant equipment are as follows:

1. Schedule the shutdown time of pumps and motors, or time equipment is, or will be, available for mechanical repair work.
2. Build up and maintain a reserve of units and parts so quick changes can be made.
3. Keep renewal parts clean, dry and in good order, with a periodic checkup of stock.
4. Keep a record of troubles and cures, as a means for running down chronic cases, and finding causes.
5. Carry out inspection as regularly as circumstances will permit. Check and report on the daily form, noises, heating, changes in surroundings, type of sewage, heavy grease or gas fumes.
6. Correct any indication of wear or breakage before equipment failure.

Automatic pumping stations, measuring stations, or special control structures are generally under the supervision of one operator or inspector who looks after a number of such stations. A small repair crew, supplemented with a pipe line maintenance crew when heavy repairs are necessary, makes an ideal flexible organization in a planned program.

"Equipment maintenance in Time of War" by Morris M. Cohn, as published in *Sewage Works Engineering and Municipal Sanitation* (1944), should be part of every operator's, foreman's, superintendent's and engineer's library on how to keep equipment rolling.

Similar rules and records necessary for sewage pumping plants apply to treatment and disposal plants. The failure of equipment performing this work is often due to lack of planning and may cause by-

FIGURE 6.—Maintenance crews should record damage to all structures such as this manhole at which corrosive gases have been active.

FIGURE 7.—Routine inspection is a fundamental of proper sewer maintenance. This sewer had been tested for toxic gases and oxygen deficiency to determine if it could be entered safely.

passing of raw sewage into watercourses, rivers, lakes and oceans with contamination of water supply and danger to the health of a community.

Industrial waste discharge into a sewerage system requires planning with adequate records and reports. A study of crew foremen's reports on pipe line repairs or locations in industrial areas requiring frequent maintenance, may disclose high acidity or alkalinity in the sewage, or heavy greases, oils and chemicals, which are a menace to maintenance operations and cause heavy repairs. Records of such investigations from field crews, pumping station records and treatment plant reports are necessary to arrive at a satisfactory solution of the effects of such waste discharges. It has been found that business firms are willing to co-operate, as there has generally been a benefit to them, either through preventive repair in their plants or salvage of by-products.

FIGURE 8.—By-passing sewage from overflowing manhole to storm water inlet while repairing broken line. Sand bags confine flow.

Safety measures are one of the most important phases of sewer maintenance planning. Gas hazards and danger from explosions in sewer lines and plants must be eliminated as part of preventive maintenance. Locations where occupational disease hazard from noxious and explosive gases and vapors, and oxygen deficiency will be found, should be well guarded and checked for dangerous conditions before entering. Regular inspection of manholes for explosive conditions with record and reports of such location, showing test results and final elimination of the danger, should be part of a planned schedule. Cross connections between the drinking water supply and sewage piping, equipment, and manhole structures, should be strictly forbidden. Records of such connections should be made and action instituted for their elimination.

FIGURE 9.—Survey truck used for investigating explosive gas conditions.

Sewer maintenance with its many problems and variety of skilled work, requires "in-service training" of personnel. This training should be part of a planned program. Time should be allowed, either full time or part time, for class instruction and discussion. These classes should be conducted by the administrative official in charge of maintenance operations and should be held for short periods of time once a year. Round table discussion and the "seeing, doing and hearing" method of instruction has been found effective. The course of instruction should be well planned, and cover all activities in sewer maintenance work. Instruction may be divided according to the following outline:

FIGURE 10.—In-service training of personnel prevents accidents.

1. The organization of the department, bureau and division.
2. Rules and regulations of Civil Service.
3. Sewer cleaning and storm drain cleaning.
4. Sewer and storm drain construction and repair.
5. Sewer records, time sheets and reports.
6. Use of sewer records and field maps.
7. Cost and operation of trucks.
8. Use of portable tools and equipment.
9. Operation of sewage pumps and ventilating plants.
10. Maintenance of electrical equipment.
11. Open channel maintenance.
12. The industrial waste problem.
13. Reducing maintenance through inspection.
14. Field measurements and observations.
15. Definitions and terms used in sewer maintenance.
16. Safety orders and instructions.
17. Costs of work.

Quiz questions, answered by student employees on subjects selected for them, will indicate the success of class instruction. By using illustrated work pictures along with blackboard diagrams, maintenance problems will be clarified.

The duties of the individual, the objectives of the work, the reasons for methods used, the general over all plan of maintenance for the sewerage system, when understood by sewer maintenance employees, make for a hard-hitting organization, both in emergency and daily routine assignments, that will make successful the planned schedule of the yearly program.

In conclusion, it is urged that sewer maintenance aims and standards should be of the highest. Standard methods of work, records and reports, with clear analysis of results showing comparison of each function, is necessary to yearly planning.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Conducted by LeRoy W. Van Kleeck

ANNUAL REPORT OF THE BUREAU OF SEWERS OF THE CITY OF WORCESTER FOR THE YEAR 1942 *

By John H. Brooks, Jr.

Superintendent, Bureau of Sewers

Sewers

It is interesting to note that in the last thirty years—1912 to 1942—the total mileage of the public sewer system has practically been

* This report was awarded first prize in the Annual Operation Report Contest of the New England Sewage Works Association for the year 1944, at the annual meeting of the Association on September 13, 1944. For previous extracts see: *This Journal,* 10, 1075 (1938); *This Journal,* 13, 1244 (1941).

doubled. In 1912 there were 213 miles of sewers while at the end of 1942 this total was 425.5 miles.

The cleaning of sewers together with the removal of debris from the catch basins represents the major expenditures in the maintenance account. A total of 3,512 catch basins were cleaned during the year with the removal of 7,475 cubic yards of material.

(Abs. note: A table in the report giving the cost per mile for the maintenance of the sewer system from the year 1884 to 1942 indicates an approximate average maintenance cost per year of $200 per mile of sewer in use.)

Description of Sewage Treatment Works

The sewage treatment works consists of 2 grit chambers; 2 mechanically raked bar screens; 12 Imhoff tanks, each 61 × 90 × 31 feet deep; 4 pairs of dosing tanks, each tank of 37,600 gallons capacity and operating at a head of 8 feet to 1 foot in the filter nozzles; 13.68 acres of trickling filters, 10 feet deep and 4 final settling tanks, each 60 × 120 × 15 feet deep.

The outfall sewer is 72 inches in diameter and about 2.1 miles long; its capacity is approximately 70 m.g.d.

All sludge produced at the plant is removed from the several drying areas by an ''overhead'' motor powered tractor loader, dumped into trucks and hauled to adjacent waste dumps. The present drying areas were originally used as sand filters during the period of sewage treatment by the intermittent sand filtration method.

There are three sections of the drying area so designated in respect to their respective size and use. Area No. 1 consists of 21 beds, each ¼ acre in area, having earth division dikes. Imhoff tank sludge drawn during the summer season is delivered by gravity flow to these beds. Area No. 2 consists of 32 beds, each 18 feet by 110 feet in area, having concrete division walls. Concentrated final settling tank sludge produced during the summer season is pumped to these beds. Area No. 3 consists of 42 one-acre beds, having earth division dikes. Imhoff and final settling tank sludges are pumped to these beds during the winter season.

The final settling tank sludge is concentrated during the summer months by pumping to two storage tanks, each of 38,352 gallons capacity, where it is held for a few days. Each morning, top water is drawn and the tanks again filled. Following the drawing of top water on Friday, the concentrated sludge is pumped to 4 of the 32 small drying beds.

Owing to the lack of help and the inadequacy of operating funds, no attempt was made during 1942 to use sections No. 1 and No. 2 and all of the sludge has been pumped to section No. 3, the so-called winter area.

The works were placed in operation, June 25, 1925, and were designed for an average daily flow of 28 m.g.d.; the average daily sewage flow during 1942 was 23.29 million gallons. The maximum daily sewage flow to the works in time of storm flow totalled 61.67 million gallons.

The works are in immediate charge of Supervising Chemist Roy S. Lanphaer of the Bureau of Sewers, Department of Public Works. The regular employees total 14; extra help throughout the year included only the operators of the loader and the bull-dozer during removal of dried sludge from the beds.

General Works Operation

An increased sewage flow definitely reflected an industrial pick up in the community. This circumstance carried with it a comparable increase in sludge production.

The problem of disposal of wet sludge remains the most serious part of works operation. Lagooning of sludge was resorted to for a six-weeks period. The decrease of total Imhoff tank sludge production from 22.7 to 18.9 million gallons was the vital factor in holding lagoon use to this short period of time.

Grease accumulation on the surface of the sewage in the sedimentation compartments of all of the Imhoff tanks has increased during this past year. If the quantity of grease accumulation continues to increase on tanks other than those where special gates are provided to facilitate grease removal, it may become advisable to install a system whereby the other tanks can be cleared of grease accumulation with a necessary minimum use of manual labor. The upper scum boards in the sedimentation compartments of two-thirds of the Imhoff tanks have been renewed.

The replacement of air piping in the dosing tanks, in a few instances, is a repetition of our previous experience where a few pipes developed pin-holes after six years use. The most of the original installation lasted ten years and it is possible that major replacement may not be necessary until 1945.

Owing to the intermittency of snow-fall and water run-off from melted snow last winter, considerable unfavorable operating conditions for trickling filters resulted. Growth on the top stone, which is a usual spring occurrence of short duration and causes pooling, was present practically all winter. During this past month, December, 1942, filter B developed an excessive amount of pooling, due to the presence of growth; filters A, C and D were not so badly affected.

There are two remedies; filter resting, permitting the growth to dry and pass away and treatment of the filter influent with chlorine. The former can not be done during the winter months since it would only result in solid ice formation on the surface of the filter. The use of chlorine will prove expensive owing to the presence of a high chlorine demand by organic and inorganic material contained in the Imhoff tank effluent. Punching the top stone with pointed bars helps to drain away the pooling water and is the most feasible method, but it uses an excessive amount of our available man-hours of labor. The growth tends to move with the water and to plug the holes soon after they are made.

Meteorological Data

The average mean temperature of the atmosphere during 1942 was 50.7° F. This temperature varies between 48° F. and 51° F. from year to year. Warm temperatures of the summer and fall months are helpful in trickling filter operation. The winter temperatures are of vital importance since both continued and extreme low temperatures result in excessive ice formation on the filters. During periods of extreme low temperature it is necessary to remove all end nozzles in order to prevent possible clogging and consequent freezing of the influent in the distribution systems. Both of these conditions result in marked deterioration of the quality of the filter effluents.

Sewage Flow

The total sewage flow was 8,500.88 million gallons, a daily average of 23.29 million gallons. With the exception of 1928, this quantity is the largest for any year since the present works were placed in operation, June 25, 1925.

Grit Chambers

Each grit chamber was cleaned eight times during the year. This is done by using sewage to flush the material to an old intermittent sand filter adjacent to the chambers, aided by shoveling by hand labor. A total quantity of 878.3 cubic yards of material were removed from the chambers; the average quantity per million gallons of sewage passed through them was 2.78 cubic feet. The cost of this work was $334.94, representing an average of 38.1 cents per cubic yard of material removed.

Screening of Sewage

The cost of labor for operation of the Evers-Sauvage mechanical rakes was $1,337.34, representing a daily average cost of $3.66; 8.9 cents per cubic foot of screenings; 15.6 cents per million gallons of sewage screened.

Imhoff Tanks

The increased quantity of sewage treated averaged 3.2 m.g.d., as compared with 1941 and resulted in the shortened detention period from 3.0 to 2.5 hours. The effect of the shorter detention period of the sewage is only slightly noticeable in the removal of suspended and settleable solids contained in the sewage.

The quantity of grease removed from the sedimentation compartments of the tanks totalled 5,019 cubic feet. This quantity was greater than that removed in any year since 1934. It was the grease removed from tanks Nos. 11 and 12, where gates are provided to aid its removal to diked areas where it is burned. The grease which accumulated in the first five tanks in each battery was hosed down with water and, until this year, this method has proven reasonably effective in preventing excessive accumulations on the surface of the sewage in the sedimentation compartments. Grease was not carried out with the tank effluent, but the appearance of so much grease in the sedimentation compartments was somewhat offensive.

The installation of gates and channels or pipe-lines, by means of which the grease can be removed from these ten tanks,'or the installation of any equipment or tank for effective grease removal from the sewage, will result in improved appearance of the Imhoff tanks throughout the entire year.

For the second time since the works were placed in operation, efforts were made to use the grease at the Worcester Rendering Works with the same unfavorable result. The presence of mineral oil and fecal matter mixed with the grease appeared to be the difficulty encountered. It does not appear practicable for the Bureau of Sewers to install and operate equipment for the refining of this grease.

Trickling Filters

The trickling filters treated 7,879.78 million gallons of Imhoff tank effluent, a daily average of 21.59 million gallons. This is an increase of 2.29 million gallons per day as compared with 1941. The average rate of filtration increased from 1.44 to 1.65 m.g.a.d.

The usual filter flooding for fly control was carried on from May to September. No complaints were received at any time.

The combination of a higher rate of treatment of the influent, together with unfavorable filter conditions above mentioned, resulted in a filter effluent containing less dissolved oxygen and nitrate and nitrite nitrogen than for a number of years. Its average stability was the poorest of any year of operation since the establishment of normal biological purification of the influent in 1928.

The stability of the filter effluent varied from 53 + to 70 + per cent during the first six months of the year; it improved rapidly during July to an average of 94 + per cent for the month. During the next three months the filter effluent was perfectly stable, an improved result as compared with 1941, when October was the only month during the year when this quality of effluent was obtained. During November and December, the latter month in particular, increasing quantities of growth again accumulated on the filters and the stability of the effluent dropped to 81 per cent in November and to 59 per cent in December.

It is quite evident that the efficiency of trickling filter treatment of Imhoff tank effluent during the winter and early spring months is seriously affected by the accumulation of growth on the filters.

Secondary Tanks

The average detention period of the trickling filter effluent in the secondary tanks was 1.9 hours; the maximum on any day was 2.7 hours and the minimum 1.3 hours.

The quality of the final effluent is dependent upon two factors;

maintenance of the secondary settling tanks in a clean condition and the quality of the trickling filter effluent which enters the tanks. Weekly pumping of sludge has kept the tanks reasonably clean of sludge.

Like the trickling filter effluent, the stability of the final effluent dropped, averaging 81 per cent as compared with 90 per cent in 1941 and was the lowest result obtained since 1928. The dissolved oxygen and the nitrogen as nitrates and nitrites were low. The suspended solids content of the final effluent averaged 56 p.p.m.; the biochemical oxygen demand averaged 21.6 p.p.m. Both of these results were close to the usual figures. The settleable solids content of the final effluent was high and was definitely due to the results obtained during those months when the trickling filter effluent, as well as the final effluent was of poor quality. Therefore, it is essential that efforts be made to control the accumulation of growth upon the trickling filters whenever it is necessary to do so.

Sludge Disposal

Dried sludge was removed from the winter sludge bed area from June 15 to July 23, 1942, using the overhead loader, a bull-dozer, and Bureau of Streets trucks. A total of 8,745 cubic yards of dried sludge were removed at a cost of $2,937.32, without foreman and overhead expense; this was an average of 33.6 cents per cubic yard.

More dried sludge was removed later in the year using the same equipment except hired trucks in place of Bureau of Streets trucks at an average cost of 33.2 cents per cubic yard.

Approximately $4,500 represented the minimum expense for removal of dried sludge from the winter sludge bed area during 1942. Attention is directed to the use of the lagoon for disposal of a part of the wet sludge. It is also directed to the method of cleaning the beds, one which is not applicable to a drying area which is to be used a number of times each year and year after year. In the near future, it will be necessary to remove a layer of mixed sand and sludge from the winter beds in order to regain a reasonable degree of filtration of the water from the solids of the sludges.

Cost of Sewage Treatment

The cost of sewage treatment is summarized as follows:

	Total	Per Million Gals.
Grit chambers	$ 524.26	$0.06
Screen	2,317.27	0.27
Imhoff tanks	9,951.23	1.17
Trickling filters	10,085.32	1.19
Secondary tanks	6,356.27	0.75
Sludge disposal	11,314.45	1.33
Laboratory	6,320.05	0.74
Total	$46,868.85	$5.51

The cost per capita served was approximately 24.7 cents per year or 2.1 cents per month. Inasmuch as the population served and the operating expense are not affected by variation of quantity or character of the sewage, these figures are of value.

It is a well established fact that the annual cost per capita for operation of a sewage treatment works of the Imhoff tank-trickling filter type varies from 33 to 36 cents, over a considerable range of population.

The difference of 8 cents per capita annual operation cost is of vital importance. First, the reduced cost represents efficient management of works operation; second, a great part of the difference is absolutely essential for solution of our sludge disposal problem in an orderly and efficient manner.

Summary of 1942 Operating Data, Worcester, Mass.

Item	Average
Sewage flow, m.g.d.	23.29
Grit removed, cu. ft. per m.g.	2.78
Screenings removed, cu. ft. per m.g.	1.75
Imhoff tanks	
Detention, hrs.	2.5
Grease removed, total for year, cu. ft.	5,019.0
Sludge removed, gals. per m.g. sewage	2,275.0
Digested sludge	
Volatile matter, per cent	46.62
Iron, per cent	3.88
pH	6.8
Trickling filters	
Sewage applied, m.g. per acre daily	1.65
Secondary tanks, detention hours	1.9
Suspended solids, p.p.m.	
Raw sewage	285.0
Imhoff tank effluent	102.0
Trickling filter effluent	114.0
Secondary tank effluent	56.0
5-Day B.O.D., p.p.m.	
Raw sewage	167.9
Imhoff tank effluent	103.7
Trickling filter effluent	28.1
Secondary tank effluent	21.6
Nitrates plus nitrites, plant effluent, p.p.m.	2.97
Dissolved oxygen, plant effluent, p.p.m.	4.0
Relative stability, plant effluent, per cent	81.0
Operation costs	
Per million gallons treated	$5.51
Per capita served per year	$0.25

REPORT OF OPERATION OF THE DISTRICT OF COLUMBIA SEWAGE TREATMENT PLANT FOR THE FISCAL YEAR 1944

By Ralph E. Fuhrman, *Supt.*

During 1944 (fiscal year ending June 30, 1944) the plant reached practically the design load of sewage flow, so that it may now be said that the plant is fully loaded with respect to quantity of sewage and is carrying approximately a fifty per cent overload on a population basis. Following is a summary of operating data for the last fiscal year. For previous extracts see: *This Journal,* **14**, 1102 (1942), and *This Journal,* **17**, 132 (1945).

Summary of 1944 Operating Data, District of Columbia

Item	Average
Treated sewage, m.g.d.	129.5
K.W.H. per m.g. sewage pumped	87.4
Grit removed	
Cu. yds. per day	5.4
Cu. ft. per m.g. sewage	1.1
Per cent solids	77.4
Per cent volatile solids	14.6
Primary settling tanks	
Suspended matter removed, dry lbs. approx.	85,000.0
pH raw sludge, approx.	5.7
Per cent solids in sludge, approx.	8.5
Per cent volatile matter in sludge, approx.	65.0
Scum removed daily, approx. gals.	11,000.0
Per cent solids in scum, approx.	15.0
Sludge digestion	
Volatile solids, daily additions, dry lbs.	74,044.0
pH digested sludge	7.3
Temperature digesting sludge, °F.	95.0
Per cent fats in digested sludge (chloroform)	7.7
Gas produced, thous. cu. ft. daily	849.9
Gas produced, cu. ft. per capita daily	0.88
Elutriated sludge	
Per cent solids	6.4
Per cent volatile matter	46.8
Ratio wash water to sludge volume	1.7
Alkalinity digested sludge, p.p.m.	3,122.0
Alkalinity elutriated sludge, p.p.m.	984.0
Sludge dewatering	
Days of filter dewatering, year total	218.0
Filter hours, average per month	416.2
Cake produced, wet tons, monthly	2,689.0
Solids in cake, per cent	26.9
Yield of filters, lbs. per sq. ft. per hr.	6.9
Per cent ferric chloride	3.58

Summary of 1944 Operating Data, District of Columbia.—Continued

Item	Average
Sewage analyses	
Suspended solids	
Raw, p.p.m.	174.0
Effluent, p.p.m.	91.0
Per cent removed	48.8
5-Day B.O.D.	
Raw, p.p.m.	181.0
Effluent, p.p.m.	143.0
Per cent removed	31.5
Cost of operation	
Dollars per million gallons	3.83

SEVENTH ANNUAL REPORT FOR THE SEWAGE TREATMENT WORKS AT RICHMOND, INDIANA, YEAR 1943

By W. E. Ross, *Supt.*

General Description of Plant

The Richmond sewage treatment works was put in operation on June 30, 1936. The sewage is brought to the plant through two interceptors, one 36 inches in diameter and the other 27 inches in diameter. These interceptors join at an overflow flume which allows storm flows in excess of the plant capacity to be by-passed.

The treatment works is of the activated sludge type. There are two grit channels followed by two bar screens and a grinder. These are followed by two primary clarifiers, having straight-line conveyors. Secondary treatment by the activated sludge process follows the primaries and is composed of three aeration batteries followed by three final clarifiers.

The aeration units are the most unique feature of the plant. They are constructed so as to make use of gravity for part of the aeration. There are three batteries, each of which consists of three units—each unit on an elevation of 11 feet below the one before it. The mixed liquor flows spirally through the upper unit and drops through three gravity aspirators to the unit below. In falling, the liquor pulls air into the pipe so that the liquor and air are discharged through a fish-tail nozzle into the lower unit. There are eighteen of these gravity aeration units and the flow through them can be regulated by a hand wheel on each unit. They add from 500 to 700 cubic feet of air per minute to the mixed liquor. Tests show that they are very effective and decrease materially the diffused air requirements. The aeration units can be operated as three separate batteries or as one large unit.

Each aeration battery is followed by a final clarifier. The sludge from the final clarifier is returned to the effluent of the primary clarifiers where it can all be mixed together or enter the separate aeration batteries without coming in contact with the sludge from the other clarifiers. This permits experimentation with secondary treatment since the aerators and final clarifiers can be operated as one large plant or as three separate plants.

The sludge from the primary clarifiers is drawn into a digester with a floating cover and then into one of two fixed covered digesters. The digested sludge is either run into four open sand drying beds or is disposed of in liquid form by tank truck.

The gas generated in the digesters during the decomposition of the sludge is collected and used in two gas-fired boilers and as fuel for a 120 horse-power engine furnishing air for the secondary treatment.

Special Operations

During this year all of the diffuser plates in the aeration tanks were removed, soaked in acid bath for 16 hours, then thoroughly washed with air and water before being replaced.

Four holes had to be drilled and tapped for each of the 684 plates. Old bolt heads were drilled and tapped for over three-quarters of the holes and the same number of stud bolts had to be made, as aluminum bolts could not be purchased. Wood clips had to be substituted for aluminum. The air pressure was reduced from 9.5 pounds to 6.75 pounds per square inch which will effect a very substantial reduction in the power required to produce the air. The entire operation of the aeration units has also been improved. Some of the plate holders were found to be in very bad condition and will require replacement in the near future. The total cost of cleaning and repairing the diffuser plates was $711.70.

The roof of the floating cover of the digester was so badly rotted that it was necessary to remove the old cover. A new partial cover was installed which will allow better maintenance of the steel cover plates and trusses.

The three-inch gas line into the primary digester sheared off inside the tank. To replace it would have meant draining the digester and purging it to remove explosive gases. In order to avoid this trouble, two 2-inch lines were run from the top of the gas dome of the floating cover over the side of the digester and into the control room where connection was made to the original main. The joints were so constructed that the tank cover can move in almost any manner without putting a strain on the pipes. Since the installation of this piping, no moisture trouble has been encountered such as previously existed.

Gas Engine Operation

The cost of repairs to the gas engine for the past year totalled $453.88. New connecting rod bearings were the biggest item. The value of compressed air produced by the engine-driven blower for 1943 was $3,760.50, representing a saving of $3,306.62 effected by the engine.

Summary of 1943 Operating Data, Richmond, Indiana

Item	Average
Connected population	33,700.
Sewage treated, m.g.	1,836.4
Air	
Produced, m.c.f.	692.0
Per gal. sewage, c.f.	0.386
Per lb. B.O.D., c.f.	427.0
Sludge gas	
Produced, m.c.f.	8.5
Per lb. volatile solids added, c.f.	7.35
Per capita daily, c.f.	0.631
Grit, c.f. per month	247.0
Grit, c.f. per m.g.	1.6
Screenings, c.f. per month	307.0
Screenings, c.f. per m.g.	2.0
B.O.D.	
Raw, p.p.m.	147.0
Primary effluent, p.p.m.	127.0
Final effluent, p.p.m.	8.0
Total removal, per cent	94.5
Suspended solids	
Raw, p.p.m.	213.0
Primary effluent, p.p.m.	98.0
Final effluent, p.p.m.	21.0
Total removal, per cent	89.1
Mixed liquor solids, p.p.m.	1,521.0
Sludge index	79.0
Costs	
Total operating expense, dollars	17,794.53
Operating cost per 100 lb. B.O.D. removed	8.36
Operating cost per m.g. sewage treated	9.72
Operating cost per capita per year*	0.529

* Based on connected population.

SEWAGE TREATMENT PRACTICES AT TONAWANDA, N. Y.*

By Channel Samson

Superintendent, Tonawanda, N. Y.

The Town of Tonawanda operates two separate sewage treatment plants which serve a total equivalent population of 65,000 persons. One of these plants serves 52,000 persons, giving primary treatment, and the other serves the balance of the town with primary and secondary treatment. Of the two plants, the larger, primary treatment works is the more interesting since it is newer, and this paper will be devoted to experiences connected with it.

The present plant layout and the current operating practices at the plant are, to a large extent, the outgrowth of information and ex-

* Presented at Spring Meeting of New York State Sewage Works Association, Syracuse, N. Y., June 16–17, 1944.

perience obtained from laboratory control during the time that it consisted only of Imhoff tanks. The other factors which regulated the design of the plant were a continuous and rapid growth of domestic population and a gradual increase in industrial activity. It was recognized that such problems as digester foaming, odor control, imperfect digestion and general inflexibility could not be solved without incorporating into the proposed new plant a number of features which might be considered novel in a works of this size. The primary object of this article is to point out those features which we consider essential and helpful, if not truly novel.

Having previously demonstrated that laboratory control is very desirable, it was decided, in planning our present plant, to set up a complete and well equipped laboratory. The facilities have since proven to be not only desirable, but actually essential in making studies of industrial wastes, such as dairy wastes, highly corrosive chemical wastes, digestion inhibitors, and occasional large quantities of floc-forming clays. Frequent analyses are made of the digester gas and it has been found that there is a very definite relationship between the composition of the gas and the tendency for digestion to go into the troublesome acid range which just precedes foaming. By careful examination of the gas we have been able to avoid foaming completely since the plant was put in operation and that, we believe, is an accomplishment. Another valuable control function of the laboratory is in analyzing the sludge from the bottom of the digesters so as to know when digestion is complete and how much of the digester contents may be removed to the sludge drying beds. Chlorine consumption has been effectively reduced by means of frequent residual chlorine determinations. Our laboratory data will also provide a basis for checking the adequacy of our present facilities.

Perhaps the most valuable feature of our digesters, of which there are four, is the equipment which makes it possible to sample the sludge at any point throughout the whole depth of the tank at one-foot intervals. Piping was built into each digester and carried down to varying depths. Each pipe was brought out to a trough and terminated with a quarter-turn Nordstrom valve. This arrangement was ridiculed no end when first suggested, but has since proven so valuable that we would not consider building any new digesters without sampling cocks at one foot intervals, at least in the zone in which sludge will be stored. In using sampling cocks it is necessary to provide a backwashing water line since the sludge left in the pipes after sampling will create gas pockets which prevent sludge withdrawal. It has also been found that continuous agitation in the digesters gives the best results since, without it, there is a tendency for scum to form to such a depth that large volumes of gas are trapped beneath the surface, which when suddenly liberated will blow the liquid gas seals. Actual measurements show that our digesters accumulate no more than four inches of scum. An Infilco lime injector provides a neat and positive means of adjusting pH when gas analyses indicate the necessity.

The digesters are maintained at 85°F. by means of hot water coils and the quantity of water circulated is measured by parallel water meters which have been in continuous use for four years.

The gas produced during digestion is used for heating the digesters and buildings. Collection and storage of the gas has been effected with relatively simple equipment and all gas, whether burned in the boilers or in the waste gas burner, is metered through two 4-inch Pittsburgh gas meters, thereby providing an accurate record of cubic feet of gas produced per pound of sludge in the digesters. Gas from our high-pressure storage tank is piped into the low-pressure system by means of diaphragm type reducing valves and provides a reserve of gas in case production falls below the consumption rate.

Following are monthly average data on gas analyses during 1943:

Month 1943	Per Cent Carbon Dioxide	Per Cent Methane	Per Cent Oxygen	Per Cent Nitrogen (By Difference)
Jan.	30.6	66.9	—	2.5
Feb.	30.4	65.6	—	4.0
Mar.	31.3	62.2	—	6.5
Apr.	31.8	64.6	—	3.6
May	31.6	64.8	0.6	3.0
June	31.2	65.4	0.4	3.0
July	30.6	66.0	0.3	3.1
Aug.	32.2	64.8	0.4	2.6
Sept.	31.0	64.5	0.2	4.3
Oct.	32.8	64.2	0.6	2.4
Nov.	31.5	64.8	0.5	3.2
Dec.	30.1	65.8	0.4	3.7

In a plant such as this, in which sludge must be pumped uphill, it is almost imperative that rags and solids of any size be kept out of the system. To accomplish this, we use two comminutors to shred all rags, so that they will not clog the sludge pumps. Without this device, it would be necessary to install bar screens of close spacing, which are bothersome and inefficient at best.

Digester Operation

All of our digester capacity is devoted to single stage, moderate temperature digestion. There has never been any apparent necessity for using two stage digestion and we have always felt that as long as digestion is carried on in the mesophilic range, there would be no particular advantage in two stage digestion. There appears to be an economy in time and power by using single stage digestion. Furthermore, if any one digester were to be in trouble, there would be a smaller proportionate loss of capacity with all four units operating in the same manner.

The four digesters are of the fixed cover type with power driven scum breaking and sludge stirring mechanisms.

Following are typical results of sludge analyses in the digesters starting with the one-foot level up to the sixteen-foot level:

Distance from Bottom (Feet)	Per Cent Water	Per Cent Dry Solids	Per Cent Volatile (Dry Basis)
1	88.2	11.8	39.8
2	86.7	13.3	39.5
4	89.0	11.0	39.4
6	88.3	11.7	39.0
8	89.2	10.8	38.2
10	89.7	10.3	38.4
14	92.4	7.6	38.0
16	Above 99	Less than 1	—

These data indicate that after a digester has been in operation for at least eighteen months the entire volume of sludge is uniformly digested, regardless of depth carried in tank.

Raw sludge is pumped from the clarifiers to the digesters every other day rather than every day. The object of this schedule is to thicken the sludge in the clarifiers and thereby pump less liquid and reduce the total pumping time. This practice is somewhat different than the ordinary method of operation, but it has caused us no trouble up to the present time.

When digested sludge is to be discharged from the bottom of digestion tanks, we can pump from the bottom or run by gravity to the sludge beds. Neither method of withdrawal has caused any trouble over a period of four years.

Withdrawal of sludge is not especially troublesome but extreme care must be taken to pump raw sludge into the digester at the same rate as digested sludge is drawn off. If the rate of delivery into the digester is too slow, air is likely to be drawn in through the liquid gas seals and result in an explosive mixture within the tank. In order to be sure that this does not happen we make it a point to have some supernatant overflow during the withdrawal operation. When sludge drying beds are filled, we always make sure that the digesters are filled and that supernatant is overflowing, so that the tank will be ready for operation the following day.

We just recently had a new experience in emptying the No. 1 digester which was done to determine the cause of the frequent shearing of pins at the stirring mechanism. The emptying of the digester to find the trouble was not very complicated. We pumped six feet of sludge from the bottom of digester No. 1 to digester No. 3. The balance of sludge in digester No. 1 was pumped to the drying beds. The supernatant and scum remaining was pumped into digester No. 2 which was the only possible way to get supernatant from the No. 1 tank back to the inlet of the plant. While the stirring mechanism was broken, there was an opportunity to find out just what results could be obtained in digestion of sludge without the use of the stirring mechanism, with the temperature kept at 85° F.

It was found that stirring brings very definite improvement in the digestion rate. Tests that were made on two tanks, with and without stirring, showed that we can reduce the volatile matter and get thicker sludge much more quickly by running the stirring mechanism eight hours per day.

After digester No. 1 was cleaned and aired thoroughly, tests were made for explosive mixtures and hydrogen sulphide. The tests proved the tank to be in safe condition for the inspection, which was made by two operators and the writer. We checked heating coils, bolts, arms, bearings, scum breakers, etc., and found everything very satisfactory, as there was little corrosion and no broken parts. After inspection of all metal, six pails of sand were found in the sump. The sand was hoisted out of the tank and dried for examination so as to determine if there was anything in it that could possibly cause the stirring mechanism to jam. The only thing found was one large stone which apparently wedged under the breaker arm in the sump, and this must have caused the trouble. Checking the bottom of sump, it was found possible for the stone to have embedded itself in a small hole in the concrete, causing the mechanism to stop. After the final interior inspection, the mechanism was started and no other cause for trouble has been discovered.

This being the fourth year that digesters No. 1 and 2 have been in operation, it is intended to clean out digester No. 2 and give it a general inspection, thus anticipating rather than waiting for trouble.

Digester Stirring Mechanisms

In 1943, the Carter Pump Company installed two stirring mechanisms in the new digesters, which equipment includes a complete alarm system. The alarm can be given by a bell or by lights and either choice will immediately notify the operator when trouble occurs. The alarm system will operate in case of electric trouble, a shear pin break or lack of forced lubrication. The reduction gears are fully enclosed and completely tight to any type of weather.

A new feature of the stirring mechanisms is that they have a high and low speed drive. The reducing gears can be operated at the rate of 50 r.p.m. or 100 r.p.m. During tests before the tanks were filled, it was found that at low speed the stirring arm would make one complete revolution in approximately 12 minutes and at high speed one revolution in 6 minutes. There is as yet no available data as to what results in digestion can be obtained by either high or low speed but it is our intention this fall to run the No. 3 digester at low speed and the No. 4 digester at high speed for a comparison of digestion rates and results. Every effort will be made to keep the sludge depths equal and temperature of both tanks at the same temperature throughout the winter. The stirring mechanisms will be operated 8 hours daily. The data collected over a period of six months will give something definite as a guide to the best speed for quick and complete digestion.

Application of Gas Analyses to Digester Operation.

Several years ago it was suggested to us by Mr. L. H. Enslow that the percentage of carbon dioxide in the digester gas was just as informative in operation control as the usual pH determinations. For the past three years we have checked both results and the findings have been interesting. On the average, the pH in the digesting sludge is about 6.9 and the carbon dioxide content of the gas about 30.6 per cent. When the carbon dioxide values exceed 30 per cent, the pH drops in proportion. At a digester pH of 6.6 the carbon dioxide content of the gas is about 33.4 per cent.

Practice at Tonowanda is to make one gas analysis per week and to make pH determinations three times weekly of the raw sludge from the clarifiers, digested sludge and supernatant liquor overflow.

BARK FROM THE DAILY LOG

By Walter A. Sperry

Superintendent, Aurora Sanitary District

January 1—Sunday. No rest for a superintendent—wicked or not! It's a twenty-four hour responsibility including Sundays and holidays. Yet none of us would swap our jobs for any other. We all love its variety and excitement to say nothing of the secret and satisfying feeling that we are rendering a worth while service to our community that likely no one else in town could do quite so well. It suggests the old Presbyterian doctrine of foreordination and predestination, and we like it. So we are cheerfully out today to do the routine checking of the records, weigh and calculate the sludges and read the Imhoff cones. All was in order and we went home to dinner.

Ruddy—the sample and errand man—slipped on the ice today and hurt his leg which kept him home for several days. Work schedule disrupted again!

January 3—Trouble on the gas line feeding the gas stove in the Secondary Pump House. The meter on this line usually registering 800–900 feet per day, yesterday showed 1,800 and today 2,700 feet with scarcely any gas at the stove. This painfully indicated a broken line which was finally found just outside the wall at the Administration Building where the line angled down an embankment. The earth had settled, breaking the line at a 45-degree elbow. It was repaired by applying a cast iron, split "Economy" clamp large enough to embrace the elbow and a part of the pipe. The ends were sealed with packing and the clamp poured full of lead through a hole drilled in the top.

January 6—The telephone rang today in the middle of a laboratory job as it so often does. Mrs. B—explained that she was attending a Red Cross class and had been asked to give a twenty-minute talk on the Sanitary District that afternoon. Asked whether she had ever visited the plant, she said, "No, but couldn't she be given a few notes over the phone?" This was an impossible situation. She would never remember. We urgently advised her to beg off till the time of the next class. We suspicioned that there would be more calls—and there were. We wrote up a neat little "speech," complete but short, and mimeographed a supply. Sure enough, nearly a dozen have been mailed out since and everyone is happy.

January 7—Called on Ruddy with the injured leg today. This takes time but shows a gracious interest in one's work family. The men appreciate it.

Started a general study of the chemical and physical characteristics of the digester supernatant liquor. Up to now only the suspended solids have been observed and recorded. Some time later will give some of the results of these tests in this Log.

The Board met all of this afternoon. This is always one of the most interesting days of the month. Today all records were assembled for the annual audit. In Illinois, the audit must be published within thirty days after the close of the year. If it is not, the County Treasurer is required by law to withhold all payment of District tax money. We are careful, therefore, about the audit.

January 11—Two men normally are busy all summer on the grounds about the plant and little inside housekeeping is done. In the winter, walls are cleaned and painted, furniture washed and cupboards cleaned. This year we decided to repaint and then varnish the laboratory walls. After the varnish job was completed, large areas of dull spots appeared and, on investigation, we found this phenomena was called a "bloom." It was caused by having digester gas burners lit while the varnishing was being done. The moisture formed by the burning gas caused the "bloom." Try sticking a cold chunk of iron into a gas flame and watch the water drip from it. One pound of methane gas burns to form about two and a quarter pounds of water vapor. One thousand cubic feet of 65 per cent methane digester gas produces about 95 pounds of water vapor. Did you know that? We've learned our lesson. Never have a gas burner lit while varnishing!

January 14—Just a routine day.

Four men working on sludge beds.
Cleaning in Switch Board Room.
Correspondence dictated.
Working on summaries of records for 1944.
Packing secondary sludge pump.
Pumping out clarifiers Nos. 3 and 4 to repair the "Aurora" baffles.
Two Trustees out to look over the books of the District preparatory to doing all the bookkeeping from now on at the District office.

January 17—Monday, the day to run last week's paper mill samples. This is Chapter Two of the Paper Mill Story. The mill superintendent is a pleasant fellow but harrassed. He has enough to do to keep a twenty-four hour schedule on time, to say nothing of the Sunday work necessary for cleanouts, repairs and change-overs. He always has a worried look. Any scheme of routine sampling would have to be made simple enough to require but little attention and time and be easily understood, to insure his co-operation. It had to be complete enough to give a fair representation of the quality of the mill waste and of the volume entering the District interceptor. The sampling arrangement consisted of two wooden trays with a carrying handle, into which would fit six 1-qt. milk bottles, labeled for each work day. A sampling cup was made with a long handle and of a size that four full cups, taken at six-hour intervals through the twenty-four hour day, would about fill the bottle for that day. A package of milk bottle caps was provided for bottle closure. The superintendent was co-operative enough to leave the previous week's samples at a fire engine house on Sunday and pick up the empty tray. On Monday the samples for the laboratory were picked up for the weekly test, thus saving unnecessary travel. (To be continued.)

January 21—Felt a real sense of triumph today. The men completed the rebuilding of the Tipping-Bucket Sludge Meter. It was planned and built in 1933 (**This Journal, 6,** 797 1934). It has given excellent service but despite repairs and replacements, like the "One-Hoss Shay" it had finally gone to pieces. War conditions prevented rebuilding until we learned that we could not only get No. 10-gage plate, but ball bearings and a zinc metalizing job as well. This was unanticipated luck. We salvaged the tank body by applying No. 70 Bitumastic. The feed hopper, bucket, sample tank and cover were completely zinc metalized (0.004 inches). The cover was completely redesigned to make it splash proof. All shaft and pipe openings were closed with felt washers. Finally, the old brass bushed bearings (always wearing egg-shaped) were replaced with ball bearings and a new counter was supplied. The whole was given a coat of aluminum paint. The meter now operates very smoothly and is easy to keep clean.

Some have cast doubt on the protective value of sprayed zinc as compared to a slow dipped job, claiming the sprayed zinc to be porous. Zinc is unaffected by sulphur and the tenure of protection will be watched with interest. It was an exciting and satisfying job of redesign.

January 27—Gas troubles again. The meter on Digester No. 2 refused to register. It was sent down to the meter department of the local utility. Thanks to our good neighbor policy, the utility's loss of the power account (when we installed gas engines) has never affected their willingness to help us out. The repairs were extensive and we are learning that it is good practice to tag all meters with the repair date. After replacement, the meter checking hand indicated a flow of 9,000 cubic feet but the register showed much less. This did not make sense since the register is continually geared. The utility man came out and replaced the register but with no different result. Then the trouble was found—an old difficulty.

The gas pressure at the digester was enough to blow the seals continuously. This caused some back pressure at the meter through the check valves, causing the meter to run backward. Periodically, wrought iron pipe gas lines develop a heavy deposit of iron sulphide, free sulphur and iron scale. These deposits collect particularly at elbows and once in about 2-3 years enough accumulates to cause obstruction of the gas flow. Sometimes it will wash out with strong water pressure. Sometimes the pipes must be taken down and the scale hammered loose. After about 10–12 years the gas lines develop pin-holes and must be replaced. This was the first scaling of the new pipe placed about three years ago and the scale readily washed out. The gas registration jumped up to normal and we made our explanations and apologies to the meter man.

January 26—Found the float system on the Dorr automatic screen in trouble today. The floats were pin-holed and water-logged. Copper seems to be the natural material of which to make floats—but not for sewage liquors. Our ever-present friend sulphur is again the "nigger in the wood-pile." A coat of No. 70 Bitumastic is a tempting try to extend the life of a repaired copper float. When available, floats are always replaced with stainless steel. Another successful stunt is have the floats made of tinned copper with the tinned side **out** and the joints well soldered.

January 28—Turned in a list of postwar projects today to a state officer. These projects plan for the following:

1. A new Northwest Interceptor, to give a sewage outlet to two factories and an extensive residential area not heretofore served. The engineering work on this project completed.

2. Preaeration units ahead of clarification and placed in one of the four existing clarifiers, to reduce odors further and to produce some flocculation of the raw sewage to improve clarification. Engineering work on this project completed.

3. An extension of the office and laboratory with shop facilities and an oil storage room beneath. This project to include rebuilding the roof and walls of the clarifier house, with glass brick in mind. Engineering work in progress.

4. Extensions to the Southeast Interceptor to reach new territory now unserved.

Total estimated cost of these projects about $240,000.

January 31—Monday, and the week off to a bad start. There was a heavy fall of greasy snow last night on hard ice. Car turned around twice in the street within four blocks of home and then ran out of gas in the middle of town. Kept fairly calm. Have had an order in for a new fuel gage for weeks but no gage yet. The two gallons of reserve fuel always kept in the trunk is a life saver.

Found the men at the plant had already hitched the patrol grader to the tractor to clear the plant drives and then the telephone rang. Our "irate tenant next door" with the odor complex called to ask "sweetly," this time, if the men would not run in over her driveway too, while the snow plow was out. Oh well, we did!

USE OF ALUM TO HASTEN SLUDGE DRYING AT STRATFORD, CONN.*

By Walter Thompson

Chief Operator, Sewage Treatment Plant, Stratford, Conn.

This brief report describes the successful use of alum in making possible the satisfactory operation of a small and greatly overloaded sewage treatment plant.

When the present plant was built at Stratford, Conn., in 1921, the population was 12,000. Since January, 1944, the plant has served an additional 14,000 employees of the Chance Vought plant of United Aircraft and a new federal housing project, bringing the present estimated population served to 32,000. The aircraft plant alone contributes approximately 400,000 gallons per day of sewage.

The treatment works comprises six Imhoff tanks and two sludge drying beds. When it was realized that the sludge drying area was overloaded, the problem was discussed with representatives of the Connecticut State Department of Health and the use of alum suggested. Reference was made to the work of Sperry at Aurora, Illinois (*This Journal* **13**, 855, September, 1941) for guidance in application of the alum.

A 10-inch pipe carries the sludge to the two sludge drying beds, each of which holds about 70,000 gallons. The alum must be added to the sludge just as it is discharged into the drying beds and to accomplish this a large horizontal concrete T was built at the discharge end of the pipe, so arranged that the sludge can be diverted into either of the beds by plank gates.

A 1-inch pipe was passed through the wooden gate and connected by an elbow to a vertical pipe of convenient length for adding the alum solution. To the inner end of the pipe through the gate was secured a 15-inch length of flexible rubber hose. The object was to mix thoroughly the alum solution with the sludge as it passed through the box and the movement of the flexible hose together with the turbulance in the box seems to accomplish this in a simple and thoroughly satisfactory manner. Previous to using the rubber hose, a rigid metal pipe was used but the mixing was not satisfactory. The streaked appearance of the sludge as deposited in the bed made it evident that the alum was not being used efficiently.

It is also important that the alum be entirely dissolved for good results. In the earlier experiments, the alum in granulated form was added in a dry state to the flowing sludge and this seemed to have very little beneficial effect, probably because the alum crystals settle to the bottom and were dissolved by the water draining out of the sludge.

The procedure at Stratford is to use 200 gallons of water to dissolve

* Presented at Fall Meeting, New England Sewage Works Association, Worcester, Mass., September 13, 1944.

400 pounds of alum. This amount of water is probably five times the volume actually required to effect complete solution but the excess is desirable in that the solution is accomplished more quickly and is more easily mixed with the sludge. It is believed that any more water would only add to the amount which must be drained away and that the mixing operation would not be improved.

It is well known that the time required for the dewatering of sludge in open beds depends upon the season, the temperature, the amount of rainfall, wind, humidity and other factors. The experience at Stratford proves definitely that there is a surprising advantage in the use of alum regardless of season or other conditions.

For the purpose of comparison between alum treated and untreated sludge, the following data may be considered average for non-freezing weather. If a 12-inch depth of alum-treated sludge is drawn to the drying bed, the depth will drop to about 7 inches in 24 hours, whereas the depth of untreated sludge will be 8½ to 9 inches at the end of the same period. The first cracks in the drying residue will appear in 4 days in treated sludge, whereas 8 to 9 days are required for cracks to appear in the untreated bed. In the treated bed the residue cracks more uniformly and with many more cracks and this, of course, speeds the drying and makes it possible to remove the dried residue sooner. The treated sludge will dry out so that it can be removed in about 8 days while the untreated sludge under the same conditions requires about 20 days.

It is also noticeable that the dried residue from the treated sludge is of less thickness and lighter in weight. Also, because of the more numerous cracks mentioned before, the residue is more easily broken up and can be removed more easily from the bed.

Another interesting and important advantage to the use of alum is the almost complete elimination of objectionable odor. As will be appreciated, this feature alone would make the use of alum desirable where the sludge beds are located near a residential section.

To summarize briefly, the Stratford experience indicates the following points are of interest regarding the use of alum:

1. A good working concentration of alum solution is about two pounds of alum to a gallon of water.
2. The alum must be completely dissolved.
3. The alum solution must be thoroughly mixed with the wet sludge just before it enters the drying bed.
4. The reduction in depth of sludge or, in other words, the reduction of water content in 24 hours is nearly twice as great for treated sludge as for untreated sludge. This is an important point in freezing weather.
5. The treated sludge dries in less than one half the time required for untreated sludge. This means that the beds can be used more efficiently and that a greater volume of sludge can be handled each month.

6. The dried residue is thinner and lighter in weight and, therefore, more easily removed.
7. Because the residue cracks more uniformly and completely, it can be easily broken up for removal.
8. Objectionable odor is almost entirely eliminated.
9. No elaborate equipment is required for the application of alum. Any operator can improvise a setup for adding the solution at a uniform rate and arrange for thorough mixing.
10. The cost of alum, about $8.00 per 70,000 gallons of sludge, is of little consequence when compared with the results in an overloaded plant.

TIPS AND QUIPS

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Tidbits from Toronto, where the Canadian Institute on Sewage and Sanitation held its largest meeting in history on November 2–3, 1944 . . . an attendance of 336, which was 66 per cent above the highest recorded at any previous meeting . . . an entertainment innovation in the form of a "Club Room," sponsored by the Canadian Sanitation Equipment Association, which contributed much to the social aspects of the annual banquet and luncheon . . . the "discussingest" gathering of individuals we have had the pleasure to meet, carrying overtime two hours on the open forum which concluded the program . . . and no wonder, since the Guided Discussions which are given so much emphasis in the programs of this organization are carefully outlined and distributed to all members before the meeting, permitting them to give advance thought to their remarks . . . a well founded and well presented paper on the industrial waste problem by G. E. Symons of *Water Works and Sewerage* . . . other commendable program contributions on postwar planning by J. F. MacLaren and Alderman Donald M. Fleming, both of Toronto . . . an obvious surplus of film and flashlight bulbs in Canada, the photographers laying down a continuous barrage during every session . . . a preview of the beautiful Hotel Royal York, headquarters for the 1945 Annual Meeting * of the Federation . . . and a Canadian hospitality that is determined to make the next Federation conference an unforgettable occasion!

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Walter Sperry, whose first "Daily Log" column appeared in the November, 1944, *Journal,* is already receiving "fan mail." One of these letters came from his old friend, C. T. Mudgett of Muskegon, Mich., who questioned the statement made that the Holbrook Avenue pumping station at Aurora had been out of service for 108 days because of the river elevation being above the elevation of the overflow

* Subject to issuance of permit by O.D.T.

at the station (page 1229, November, 1944, issue). Mudgett goes on to report that Muskegon has a similar problem in that the pumping stations along the Lake Michigan shore are also affected by the lake level, which reaches a high point every 14 years. The overflows at Muskegon are progressively raised and lowered to meet these variations in lake level so that the pumping stations may be kept in operation at all times.

In explaining the Aurora situation, Sperry advises that it was not nearly as serious as it may have sounded. The pumping station in question serves part of an island in the river and handles a maximum flow of only 0.25 m.g.d. When the flow in the river reaches 1060 c.f.s., the river is at flood stage and the station cannot be operated, but it is pointed out that, at such times, all the other overflows on the combined sewer system at Aurora are in operation and that liberal dilution is available in the river. The condition is evidently one of those which must be tolerated as an inherent disadvantage of combined sewers.

Mudgett also refers to a coincidence in that Muskegon, like Aurora, has a Holbrook pumping station. Who was this man Holbrook, to have so many sewage pumping stations named for him?

• • •

At last we have been exposed to the point of view of the fish in regard to this matter of stream pollution. It is unfortunate that every sewage works operator could not have heard the remarks of Dr. M. M. Ellis, Senior Aquatic Physiologist of the Fish and Wild Life Service of the U. S. Department of the Interior, who spoke at the Industrial Waste Utilization Conference held at Purdue University on November 29–30, 1944.

Dr. Ellis emphasized the fact that the fish are not interested in the *average* values in which we take so much pride in reporting effluent or stream conditions. Our piscatorial friends are more concerned with the extreme high or low values which represent conditions for a day or an hour. That is, a monthly report might show that the stream averaged 6 p.p.m. of dissolved oxygen for the month while a heavy loss of aquatic life might have taken place during one day of that month when the D. O. was only 1 p.p.m. This point might be kept in mind when considering use of the by-pass, even for a short time, when stream flows are low.

Dr. Ellis also pointed out that the fish is exposed to only 1/3000 to 1/7000 of the amount of oxygen in its "atmosphere," per pound of weight, as is man. Consequently, the quantity of oxygen in the water is of great importance and a safe minimum value of 5 p.p.m. was given as favorable to the life of fresh water fishes of the U. S. It was made clear, however, that oxygen content is only one factor and that pH, osmotic pressure, and toxic substances were also important environmental factors. pH is important in the assimilation of oxygen by fishes and critical limits of pH 5.5 to 8.0 were stated; a pH of 4.0 is lethal to all aquatic life. Increased osmotic pressures cause dehydration of the tissues of the fish, therefore, effluents high in mineral salts, even though not toxic in character, may take heavy toll.

Discussing toxic substances, Dr. Ellis advised that mineral and lactic acids were extremely lethal. He described one situation in which all life in a 40-mile length of stream was destroyed by a waste containing a small excess of zinc which was discharged from a plant manufacturing cellulose products.

• • •

Among the gadgets receiving Honorable (?) Mention in the Gadget Contest conducted by the New York State Sewage Works Association in 1944 was the device illustrated in Figure 1. Although not one of the regular prize winners, this entry garnered 31 votes in the balloting, much to the consternation of the Gadget Committee.

Authorship and sponsorship of the gadget was anonymous but rumor has it that the scheme originated among the staff of the sewage treatment works at Olean, N. Y.

Looks like a good source of cigarette money—if you can find a good source of cigarettes!

• • •

By the way, that Industrial Waste Conference at Purdue was really worth while. Credit for it must go to Prof. Don E. Bloodgood, who is making the wheels of sanitation revolve at accelerated speed at Purdue nowadays.

• • •

Uhl T. Mann of Syracuse, N. Y., formerly superintendent of the sewage treatment plant at Cortland, N. Y., was honored for the second time in the year 1944 when he was named joint winner of the Federation's Gascoigne Award with James T. Lynch, of Auburn, N. Y. Earlier in the year, Mr. Mann won the Annual Rating Award of the New York State Sewage Works Association in recognition of his work at Cortland.

Who said there was a Mann-power shortage!

• • •

Like a refreshing spring breeze from the direction of the trickling filter was the first issue of *Buckeye Sludge*, "The Voice of Sewage," which reached our desk on a frigid day last December. This effective news letter-bulletin, set up as a miniature newspaper, is "published once in a while" by the Ohio Conference on Sewage Treatment.

We have always been a staunch supporter of the news letter idea as a Member Association activity and the Ohio publication serves the purpose in fine fashion. The paper is full of personal items and notes on Conference activities—all presented in a breezy, homely style that does

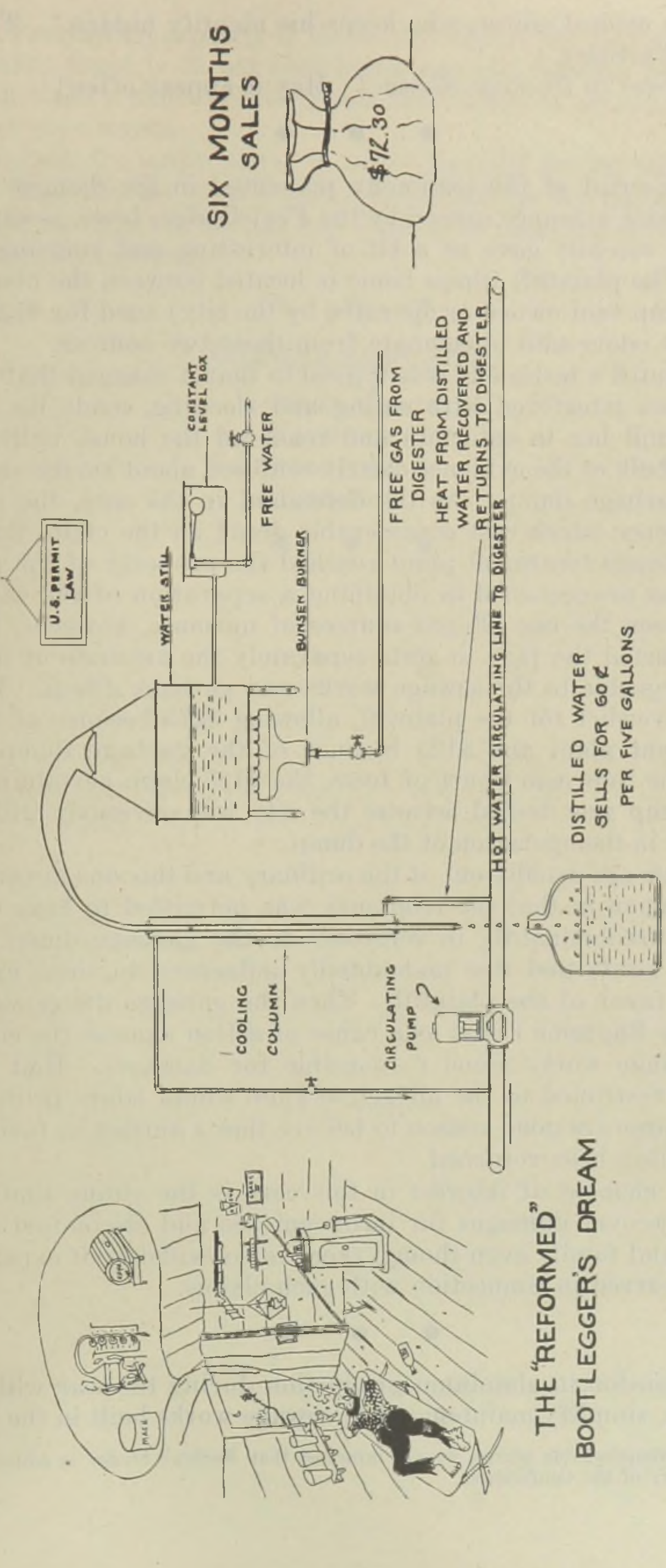

FIGURE 1.—Perpetual motion gadget.

credit to its modest editor, who keeps his identity hidden.* There are no technical articles.

More power to *Buckeye Sludge!* May it appear often!

● ● ●

The transcript of the testimony presented in the damage suit for an alleged odor nuisance caused by the Fort Dodge, Iowa, sewage treatment plant, recently gave us a bit of interesting and amusing outside reading. The plaintiff, whose home is located between the plant and a garbage dump (not owned or operated by the city) sued for $1,200 damages for the odors said to emanate from these two sources.

The plaintiff's testimony was typical in that it charged that the nauseating odors interfered with eating and sleeping, made his wife ill, did not permit her to entertain and rendered the house unlivable, although the bulk of the evidence clearly centered about smoke and fumes from the garbage dump. As the defendant in the case, the city presented evidence which cast considerable doubt on the claim that odors from the sewage treatment plant reached the property of the plaintiff. The city was unsuccessful in obtaining a separation of the charges of action between the two alleged sources of nuisance, however, the trial judge instructed the jury to state separately the amounts of damages, if any, chargeable to the sewage works and garbage dump. The jury returned a verdict for the plaintiff, allowing $275 because of the sewage treatment plant and $125 because of the garbage dump. Upon appeal to the Supreme Court of Iowa, the $125 claim pertaining to the garbage dump was denied because the city was obviously without responsibility in the operation of the dump.

Odor suits are usually out of the ordinary and this one appears to be most uncommon in that the trial jury was permitted to hear evidence which was predominantly in reference to the garbage dump (in our opinion, at least) and this undoubtedly influenced to some extent its decision in favor of the plaintiff. Then the garbage dump was eliminated by the Supreme Court as a cause of action against the city, leaving the sewage works alone responsible for damages. Had the evidence been restricted to the alleged sewage works odors in the beginning, there appears good reason to believe that a verdict in favor of the city might have been returned.

Another element of interest in this case is the ruling that a landowner can recover damages for inconvenience and discomfort suffered by himself and family even though there is no evidence of expense having been incurred in connection with such claims.

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The expansion in aluminum production during the war will, among other things, simplify maintenance of sewage works built in the postwar

* Via an unimpeachable source, we are informed that *Buckeye Sludge* is edited by L. B. Barnes, Secretary of the Conference.

period. Production capacity is thrice that before the war and the price of aluminum ingot is 25 per cent below pre-war levels. These factors will bring about a much greater peace time usage of aluminum, particularly in sewage works.

Aside from the many places in which its light weight will be advantageous, think of the trouble and work saved by having a rust-proof metal used for exposed fittings and fixtures in pumping stations, screen houses and pipe gallerys!

• • •

Shortage Short Story

Wartime shortage?
 Worst one yet!
Anyone got a
 Cigarette?

• • •

Editorial

FEDERAL AID IN SEWAGE WORKS PLANNING AND CONSTRUCTION

While it has been eminently successful in approaching its objectives, as evidenced by the $812,608,000 in sewage works and $401,373,000 in water works construction which was in or through the blueprint stage on February 1, 1945,* the Committee on Water and Sewage Works Development has been measurably handicapped in its task by the lack of definite information in regard to the possibility of federal subsidization of public works planning and construction in the postwar period. This problem is recognized in the following extract from the statement of policy of the Committee, as contained in Secretary Jordan's detailed report of November 30, 1944:

"5. Since this statement was issued, it has become evident that the laws in many states which prohibit the incurring of planning expenses until cash to pay for construction is in hand, make it necessary that the incentive of loans or grants for planning expense be made effective. This has been done to greater or less degree by state legislation in California, Maryland, Michigan, New Jersey and New York and is contemplated (but funds not yet authorized) through federal loans by the terms of the Reconversion Act.

"6. The Committee recognizes the merit of federal loans of reasonable magnitude to municipalities in order to permit them to develop plans for postwar public works and recommends that, if such loans become available and will make it possible for a community to plan public works which could not otherwise be planned, they should be negotiated.

"7. The Committee, however, still holds the opinion that needed water works and sewage works construction, *during the immediate postwar period, can* be financed by the great majority of cities, towns and districts which have need for them. It does not doubt that there are exceptions to this rule, but it does not accept the idea that the inability of a minority of cities should be the basis of grants-in-aid for other than such minority, and then should be based on proof of valid justification.

"8. At the end of 1944, the evidence is clear that, as soon as wartime restrictions are lifted, the demand for consumer goods, housing and the like will rise to great proportions. This will automatically encourage rehabilitation of water and sewage works facilities as well as additions to existing works to serve new housing and industry. But, there is danger that the desire to provide immediate postwar employment will lead some to overlook this great demand for consumer goods and to promote a program of federal grants-in-aid which will collide in timing with the great demand for consumer goods and services.

"9. To superimpose a program of federally aided public works upon the spontaneous demand for consumer goods and the capital investments related thereto is to plan the road to a depression of greater severity than any previous one experienced in America. This is a time for realistic thinking and realistic thinking will not force a depression by premature timing of federal aid.

"10. If, after the peace has come, the natural course of enterprise does not maintain a level of adequate employment and it becomes a matter of national policy for the federal government to engage in subsidization of public works, then this Committee agrees

* Report of A.S.C.E. Committee on Postwar Construction. Data furnished by *Engineering News-Record.*

that water works and sewage works have such immediate and permanent values in the scale of living that they should commend themselves to those in authority as enterprises to which the federal government can properly give support and aid."

These paragraphs brought forth several thought provoking comments from members of the Federation Board of Control, to whom the complete report was submitted for approval by letter ballot. The ballot, incidentally, was overwhelmingly in favor of such approval.

One commentator points out that the Committee policy may be inconsistent in that it "welcomes Federal aid for planning but not for construction," and proceeds to say:

"If municipalities will not even *plan* without Federal aid, how can we expect them to build? Also, I do not agree that since Federal aid is not needed for municipalities, no Federal aid is needed. There are smaller communities, boroughs, districts and settlements that should have better sanitation facilities and, of their own powers, are not able to provide them. A judicious use of Federal aid would materially assist in making such facilities available."

Another correspondent comments as follows:

"Paragraph 5 states that 'laws, in some states, prohibit incurring planning expenses until cash to pay for construction is in hand,' and apparently for that reason, it becomes necessary to provide a greater incentive for planning expense either by means of loans or grants. Clearly, if a law prohibits incurring an expense for planning, a municipality so restricted could not accept a loan, unless that loan is made wholly a risk of the loaning agency and collectible only if the borrower later raises construction funds. That means that no planning would be done, unless a 'grant' program is initiated. No municipality, particularly if a little reluctant about such a program, though unrestricted by law, will go ahead by itself if there is a chance for a grant from some source, as there must be in equity, if the 'restricted' municipality is to receive aid. It would appear more logical for the Committee to direct its efforts toward correcting such limiting statutes.

"Paragraph 7 appears to be a compromise between those advocating and those opposed to a program of Federal subsidy. I do not know how a program could be undertaken by which grants-in-aid could be made only to the 'minority' municipalities as cited. I have approved applications for aid in planning submitted to the State Planning Commission by municipalities for upwards of $115,000,000 of construction in the sanitary field. I know that just as soon as any indication is given that there is to be any further subsidy of any sort, right then our program is going to stop stock still until the officials of our communities find out what it is about. A subsidy program for a certain selected group will not work. . . . It seems to me we must either endorse or oppose a subsidy program and there can be no successful half-way measure."

A Director representing a southern Member Association commends the Committee policy and continues:

"We are in somewhat a stalemate because of the news which has been extended through various Governmental agencies that Congress will soon make an appropriation to cover postwar plans of public works improvements. An attempt was made to have the State Legislature provide the city with funds, but apparently nothing will come of it since it is the opinion of the State Legislature that 'home rule' cannot be exercised by the municipalities because of the fact that if the State Legislature grants money to the municipalities there must be necessary strings.

"In large, those municipalities that are in good financial shape are going ahead with their postwar plans in the water and sewerage fields and are taking the attitude that these postwar projects can be self-liquidating. This is certainly a healthy attitude and has been the line of promotion that we have used.

"However, there are a large number of smaller towns which are in financial straits and the matter of financing is going to be rather difficult. This is naturally more applicable to sewers and sewage treatment than to construction or improvements of water utilities. Probably the greatest asset at this time would be to get out of the minds of a great number of city officials that there is going to be a large Government subsidized public works program after the war."

A fourth commentary emphasizes the importance of timing of public works construction in the light of inflationary trends and experience in the depression of the 1930's:

"I am very much interested in programs for the promotion of public works, especially those in the field of sanitation, in order that there may be provided worth while projects for postwar employment. It would indeed be tragic were we to go into the postwar years without having learned a lesson from the 1930's with regard to the essential need for the timing of public work programs so that the planned projects will be available to meet depression demands.

"I feel that the committee may have overlooked a real opportunity to stress the importance of withholding public works construction during boom periods through such controls as may be necessary in order to provide more stabilization in the use of construction materials and labor. These commodities and not money are basic realities, and we should be ready and willing to use public works programs to secure employment stabilization. . . .

"The unchecked competitive bidding of one community against another for a limited supply of construction labor and material will of necessity force construction costs up, and may well contribute to an inflation spiral. Unless there is some retarding influence that will hold in check the unrestricted construction spending during periods of easy credit that frequently precede a financial depression, we may well anticipate a future W.P.A. with no worth while planned projects held in reserve.

"Federal aid should not be regarded solely as a source of 'pump priming' funds but rather as a national insurance against both over and under spending on public works. A national stabilization of employment may be more nearly achieved if we are willing to co-operate to that end, with the same spirit that is making possible our present war production. I completely agree with the committee and with the statement made by Mr. Holden that stimulated public works programs in a tight market may well increase the inflation threat. . . .

"I feel that Federal grants-in-aid offer a feasible way of securing a stabilization of construction activity, and that through Federal legislation, at least a start can be made in the direction of insuring the availability of worth while employment. Construction could be stimulated or retarded through a Federally coördinated program of construction credit control.

"I think that we as engineers have a duty and a responsibility to plan the timing of our public works programs so that they will serve not only as monuments to sound engineering practice but also as an insurance against less useful made work programs that may otherwise become necessary in the years to follow.

"The economic disaster of depression years can to a certain extent be avoided if we are willing to plan in the years of impending inflation for the control of this destructive force. It is but natural that we should long for the untrammeled freedom of the economic frontier and the release of all the controls that have been imposed to secure the coördination essential for our war effort. But before we throw these controls into the discard we need to be sure that our economic system can live without them."

It will be evident that the policy of the Committee is basically sound and well considered. At the same time, the points raised by those quoted above are worthy of profound consideration. Many of the doubts could be eliminated and much of the policy could be solidified if there was positive promise of what may or may not be forthcoming in the way of federal public works subsidization in the postwar scheme. There is a faint ray of hope in the statement of the President in his opening message to the 79th Congress, when he said, "I shall communicate further with the Congress on these subjects at a later date," after discussing such topics as public works, housing and social security. In his budget message to Congress, the President recommended that funds be appropriated to carry out the planning provisions of the Reconversion Act.

There is further encouragement in the fact that nearly a billion dollars in sewage works construction is being planned without the promise of federal aid. This is indeed a good sign in that it indicates a wholesome desire on the part of municipal officials to retain financial independence without sacrificing any rights or prerogatives of "home rule" such as may be inherent in federal subsidy. It is also significant that these municipalities look upon the loans and grants of depression days only as emergency remedies and not as a permanent source of funds for public works.

W. H. W.

Proceedings of Member Associations

FEDERAL SEWAGE RESEARCH ASSOCIATION

Fifteenth Annual Business Meeting

At the annual business meeting of the Federal Sewage Research Association the following officers were elected to serve for the calendar year of 1945:

President............F. E. DeMartini
Vice-President.......J. H. LeVan
Secretary-Treasurer..M. LeBosquet, Jr.

C. T. Wright and A. L. Dopmeyer were designated to serve on the Executive Committee of the association.

The following resolution was adopted in memory of the late John Blake Gordon:

Whereas, our beloved and esteemed colleague, John Blake Gordon, has passed from our midst, and

Whereas, Mr. Gordon, affectionately known as "J. B.," was an outstanding Sanitary Engineer and a recognized leader in public affairs in the District of Columbia, and

Whereas, his passing was a severe loss not only to the association and the engineering profession but to the District of Columbia, which he served so loyally and efficiently through the greater part of his professional life,

Therefore, Be It Resolved, that the Federal Sewage Research Association extend its sympathy to his family, and that this Resolution be spread upon its record and that copies thereof be sent to the family and to the Commissioners of the District of Columbia.

F. E. DeMartini, *Secretary-Treasurer*

NORTH CAROLINA SEWAGE WORKS ASSOCIATION

Business Meeting

Durham, North Carolina, November 14, 1944

The business meeting of the North Carolina Section of American Water Works Association and the North Carolina Sewage Works Association was held in the Council Committee Room in the City Hall at Durham on November 14, 1944. The meeting was called to order by Chairman J. R. Purser at 10 A.M. with all members of the Board of Directors present except Capt. W. M. Franklin, whose military duties at Camp Shelby prevented, together with various committee members. After explaining the holding of a business meeting instead of the usual conference, Chairman Purser appointed Fred Earp, J. E. Moses and Miss Anne Pope as a committee to count the election ballots.

Later in the meeting, this committee reported the election of E. M. Johnson, Superintendent of Water Department, Raleigh, Chairman; L. I. Lassiter, Sanitary Engineer, Consolidated Board of Health, Wilmington, Vice-Chairman; D. M. Williams, Director of Water and Sewage, Durham, Secretary-Treasurer; J. M. Jarrett, Director of Sanitary Engineering, N. C. State Board of Health, Raleigh, Trustee (2-year term); E. R. Thomas, Superintendent Municipal Water Department, Burlington (1-year term); and H. F. Davis, District Manager, Wallace & Tiernan Company, Incorporated, Charlotte, Chairman of the Nominating Committee.

Captain W. M. Franklin could not attend the F.S.W.A. meeting in Pittsburgh. His proxy was turned over to Mr. Piatt after his hotel and railroad reservations were made. The Director's meetings were scheduled before the opening of the conference and after its adjournment. His railroad reservation prohibited his attending either meeting.

Program Chairman L. I. Lassiter, reported that the following papers had been promised for publication in the *Journal*:

1. "Report to the North Carolina Section on the Activities and Reorganization of Division of Sanitary Engineering," by J. M. Jarrett.
2. "A Study of the Chlorine-Ammonic Nitrogen Reactions," by John N. Lesslie, Jr.
3. "A Preliminary Report on the Effect of Calgon on the Tooth and Bone Structure when used in Drinking Water for Hardness and Corrosion Control," by Lynn G. Maddry.
4. "The Control of Corrosion at Army Posts in North and South Carolina," by Capt. A. Lund.
5. "Some Experiences of an Old Timer that may be of Interest to the Younger Men in the Profession," by McKean Maffitt.
6. "Some Observations of Public Water Supply in Brazil," by Dr. H. G. Baity.
7. "History of the Hampton Roads Sanitation District Commission," by R. W. Digges.
8. "Ground Water Problems of North Carolina," by M. J. Mundorff.
9. "Using a Control Factor for Successful Chemical Precipitation of Textile Wastes," by H. D. Fesperman.

Some of the authors were unable to complete their papers by this meeting and the Publications Chairman extended the time of delivery until January.

Chairman Felix Doggett of the Membership Committee reported that his duties during the year were other than in the field where he could personally contact prospective members, but that a great number of letters had been written by himself and other members of the committee. He reported that Witty had obtained some members living in South Carolina who were assigned to the Southeastern Section. A number of members pay their dues at the convention and the membership will suffer by not having a meeting this year. Efforts will be made to persuade all to renew their membership before the deadline.

Chairman D. M. Williams of Publication stated that the *Journal* would like to publish a short sketch of each member of the section in military service, citations etc., permitted by military authority.

It is desired that each one at home appoint himself as a committee to obtain and send in this information concerning his friends, as the Publications Committee will not be able to collect the information.

Chairman Purser extended an invitation from the City of Charlotte for the 1945 meeting to be held in Charlotte. It was unanimously voted to accept the invitation.

Tentative plans have been made with the Hotel Charlotte for November 5, 6, and 7. Further information will be given as soon as date and arrangements are confirmed.

D. M. Williams, *Secretary-Treasurer*

SOUTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

Tenth Annual Meeting

Watertown, South Dakota, Nov. 14–15

The Tenth Annual Meeting of the South Dakota Water and Sewage Works Conference was held in Watertown, South Dakota, on November 14 and 15, with 89 members and guests attending. While more registrations have been recorded at previous meetings, a new high was established for the number of cities represented.

The first paper pertaining to the sewage treatment field was presented by Leonard Thompson of St. Paul, Minnesota, entitled, "The Advantages of Postwar Planning for Municipal Sanitary Facilities." In discussing the paper, K. C. Lauster, Director of the Division of Sanitary Engineering, North Dakota State Department of Health, enumerated the disadvantages of lack of planning and commented upon the progress of postwar planning in his state.

The paper, "Proposed Improvements to the Winner Sewage Disposal Plant," by Julian Staven, Consulting Engineer of Rapid City, South Dakota, described the design features of the proposed plant and cited the old plant as an example of design restricted by the city's unwillingness to spend enough money to provide the proper type of works.

K. V. Hill of Greeley and Hansen, Chicago, presented a paper on "Modern Design Trends for Sewage Treatment," which stressed the influences resulting from such factors as the war, research, governmental influence, industrial waste treatment, patented processses, and regional development of sewage treatment. Mr. Hill advised that patented processes should be used warily and with adequate performance guarantees and prophesied the increased use of mechanical equipment in future construction.

Paul Cerny, Sanitary Engineer, U.S.P.H.S., gave a discussion of "Pending Federal Legislation Relating to Stream Pollution." He advocated the type of legislation whereby a federal agency would be empowered to co-operate with and subsidize a state agency in the alleviation of local problems to the mutual betterment of state and federal interests. A resolution was passed endorsing in principle the Spence Bill (H.R. 4741), which is now under consideration in Congress.

At the business meeting of the Conference held at the conclusion of the technical meeting, the following officers were elected:

President. ....M. J. Hoy, Watertown
Vice-President. ....Harry Steckler, Yankton
Secretary-Treasurer. ....Glen J. Hopkins, Pierre

GLEN J. HOPKINS, *Secretary-Treasurer*

Federation Affairs

FEDERATION ENDORSES BARKLEY–SPENCE BILL

At the Board of Control meeting on October 14, 1944, consideration was given the provisions of the Barkley-Spence Bills (S. 1989 and H.R. 4741) which were companion measures introduced in the 78th Congress and which pertained to the control of stream pollution in the U. S. A tentative resolution on the bills was referred to the General Policy Committee for study and recommendation to the Board.

The following resolution was adopted by letter ballot of the Board on December 15, 1944:

> The Barkley-Spence Bill has been brought to the attention of the Board of Control of the Federation of Sewage Works Associations for review and endorsement.
>
> (1) The Board endorses the objectives of the Bill: *i.e.,* the elimination of stream pollution throughout the United States.
>
> (2) The Board endorses the principle of co-operation among the states and between the states and Federal Government.
>
> (3) The Board endorses the principle that the states shall have the right to pass upon and give final approval of plans of proposed sewage treatment works.
>
> (4) The Board recommends that the Bill as finally presented shall clearly set forth these principles.
>
> (5) The Board urges that all individuals and organizations interested in the elimination of stream pollution communicate their views to members of the Congress to the end that adequate implementing Federal laws may be enacted.
>
> (6) The Board is of the opinion that Federal participation in the cost of construction of works designed to carry out the objectives of the Bill is a matter of broad public policy to be determined by the Congress at the time the measure is enacted into law.

The 78th Congress adjourned without acting upon the Barkley-Spence Bills but copies of the resolution have been sent to members of the 79th Congress for their consideration in connection with similar legislation which may be introduced in that session.

W. H. Wisely, *Executive Secretary*

IMPORTANT NOTICE!

1945 Membership Contest

For the encouragement of membership activity in the Member Associations of the Federation, the Board of Control has authorized the issuance of two prizes to be awarded to individuals for such activity during the year ended September 30, 1945. Rules of the contest follow:

(1) All Active and Corporate Members of the Member Associations comprising the Federation shall be eligible to compete for the prizes, **except** the Executive Secretary of the Federation.

(2) The term of the contest shall be from October 1, 1944, to September 30, 1945.

(3) Two prizes are to be given as follows:

(**a**) To an Active or Corporate Member to be designated by the Member Association which records the highest **percentage increase** in membership for the period of the contest.

(**b**) To an Active or Corporate Member designated by the Member Association which records the greatest **numerical increase** in membership for the period of the contest.

(4) The Member Associations eligible to assign the prizes will be determined by the Executive Secretary of the Federation from his records on September 30, 1945. In tabulating the results, only those members receiving the publications of the Federation through affiliation with the Member Association will be credited to that Member Association.

(5) At the termination of the contest, the Executive Secretary of the Federation will notify the secretaries of each of the two Member Associations which are found eligible to assign the prizes and request the names of the individuals to whom the prizes are to be awarded. Any Member Association so notified may have the option of dividing the prize among two or more individuals if such division is desired.

(6) In the event that one Member Association shall record **both** the highest **percentage** increase and the greatest **numerical** increase during the period of the contest, such Association shall be eligible to assign only one of the prizes. The Member Association recording the **second highest numerical increase** in membership for the period of the contest will become eligible to assign the other prize, in this case.

(7) Each of the two prizes will be $100 denomination, Series "E" U. S. War Bonds.

BRITISH JOURNAL NOW AVAILABLE TO FEDERATION MEMBERS

In a preliminary move to bring about a closer collaboration between the British Institute of Sewage Purification and the Federation, the Institute has provided for the distribution of its *Journal* to individuals affiliated with the Federation who may wish to subscribe. The annual subscription fee is $3.65 and orders may be placed through the headquarters of the Federation, 325 Illinois Building, Champaign, Illinois. Payment of the annual fee must accompany all orders.

The official *Journal* of the Institute is ordinarily published in four issues per year but, owing to war conditions, the 1944 volume will comprise a single issue. The 1944 *Journal* will be available late this year and orders for it can be accepted to July 1, 1945. The 1945 *Journal* of the Institute will consist of two issues and thereafter the original four-issue per year schedule will be restored.

In his communication regarding this matter, Secretary W. F. Freeborn of the Institute extends the following cordial invitation:

> "The Institute would also like to accord to all members of the Federation who may be visiting this country all the services of the Institute available to members in Great Britain. For this purpose the Institute would be glad if you would through your publications invite any of your members who may be visiting Britain to communicate with me immediately on their arrival in this country."

This is indeed a gracious action on the part of our friends in England and it is hoped that Americans having occasion to visit the British Isles will avail themselves of the hospitality which has been offered. Federation affiliates in the armed services of the U. S. now stationed in England may also wish to take advantage of this opportunity.

It is urged that all of those desiring to subscribe to the *Journal* of the Institute of Purification will place their orders immediately. Remember that orders for the 1944 volume cannot be accepted after next July 1.

W. H. Wisely, *Executive Secretary*

Reviews and Abstracts*

Conducted by

Gladys Swope

Mellon Institute of Industrial Research,
Pittsburgh 13, Pennsylvania

STRAW-SLUDGE MANURE

By F. H. Ransome

Inst. Sewage Purification (Great Britain), October (1944)
The Surveyor, 103, 525 (1944)

Recently in England Ransome has utilized surplus straw and sewage sludge to make compost. He recommends complete soaking of the straw, adding adequate nitrogenous matter and aeration of the heaps. An underdrained area is prepared with tile every 2 ft. 6 in. On these areas, heaps are built, generally 9 ft. wide, of suitable length, to a height of 6 ft. With dried sludge, an 18-inch layer of straw is covered with 2 inches of dried sludge, then repeated. Such a heap should heat to 160° F. in five days. The straw is well rotted in three months. Four tons of straw and eight tons of dried sludge are said to produce 24 tons of manure. With liquid sludge, layers were built up with 18 inches of straw and then settled primary sludge contains about 6 per cent solids. About 1,200 Imp. gal. (1,500 U. S. gal.) can be applied to a ton of straw. The heaps should be built rapidly. The wet sludge may be sprayed on with a hose.

The resulting product resembles well-rotted farmyard manure, with a somewhat higher nitrogen content, but lower potash content.

Langdon Pearse

THE MANURIAL VALUE OF SEWAGE SLUDGE (Part 2)

By E. M. Crowther and A. H. Bunting

Inst. Sewage Purification (Dec. 6–7, 1944)

This article supplements Part I (*Inst. Sewage Purif.*, 1942) by detailing some of the results of use of sludge as manure. For the past two years more experiments have been made on potatoes than any other single crop, comparing sludges and farmyard manure, with the full range from no fertilizer to full NPK dressings. Obviously, sewage sludges contain less potash than farmyard manure.

The sewage sludges tested were Sludge A from industrial sewage, digested, air-dried, shed-dried, and pulverized; Sludge B from domestic sewage, containing activated sludge, air-dried.

The average analyses used at the Rothamsted experiments over three seasons were:

Sludge	Per Cent Moisture	Per Cent of Dry Matter				
		Org.	N.	P_2O_5	$CaCO_3$	N as NH_4
A	28	37	2.13	2.58	7.7	0.12
B	52	48	2.51	2.50	3.7	0.09

Comparable tests were made at Rothamsted and St. Albans.

* It will be appreciated if Miss Swope is placed on the mailing lists for all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in this *Journal*. Publications of health departments, stream pollution control agencies, research organizations and educational institutions are particularly desired.

At Rothamsted, a potato experiment was conducted on a fresh site in each of the years 1941–1943, and each experiment was continued for a second year on barley, with no further manurial treatment beyond a dressing of 100 lb. of sulfate of ammonia per acre. At Oaklands, the 1941 tests were on mangolds applying organic manure at the rate of three tons per acre of sludge A and six tons per acre of sludge B. The Oaklands 1943 potato tests were on a new site. In all five tests, the main plots were quartered to tests of different fertilizer combinations.

The actual rates for the potato tests were:

Year	Sludges Tons per Acre	Farmyard Manure Fresh Weight Tons per Acre
1941	4 and 8 (fresh wt.)	8 and 16
1942	5 and 10 (dry wt.)	8 and 16
1943	5 and 10 (dry wt.)	8 and 16

Fertilizers were given to the respective plots at the rates of 60 lb. of N (as about 300 lb. of sulfate of ammonia) per acre; 60 lb. of P_2O_5 (as about 300 lb. superphosphate) per acre; 100 lb. K_2O (as 170 lb. muriate of potash) per acre.

The extreme range in yield was from 4.6 tons per acre on unmanured plots to 12 tons per acre with both farmyard manure and full NPK fertilizer. Manure or fertilizers alone each gave a little over nine tons per acre. The outstanding increases in yield were from either muriate of potash or farmyard manure.

Sludge A failed to increase yields for any combination of presence or absence of fertilizers. It reduced the yield on plots receiving both N and K.

Sludge B increased yields in amount 1.1 to 2.7 tons per acre, according to the fertilizers used. On plots with potash but no phosphate Sludge B increased the yield by about two tons per acre, as compared with three tons per acre of farmyard manure. On plots with both phosphate and potash, Sludge B increased the yields by only one ton per acre, as compared with nearly three tons from farmyard manure.

Farmyard manure gave the highest yields for all combinations of fertilizer.

The averages on potatoes at Rothamsted are as follows:

Mean Yields in Individual Experiments on Potatoes Followed by Barley at Rothamsted, 1941–4

	No Organic Manure	Sludge A	Sludge B	F.Y.M. Normal	F.Y.M. Strawy	S.E.
Potaotes						
Tons per acre:						
1941	4.8	6.2	6.4	9.1	9.2	±0.28
1942	11.6	12.1	12.8	13.4	13.2	±0.42
1943	4.4	3.2	5.5	8.2	7.8	±0.32
Mean	6.9	7.2	8.2	10.2	10.1	—
Barley						
Grain, Cwt. per acre:						
1942	24.4	29.2	25.6	29.2	28.9	±1.07
1943	20.6	24.2	27.4	23.2	24.3	±0.91
1944	21.6	22.5	24.0	25.8	23.6	±0.90
Mean	22.2	25.3	25.7	26.1	25.6	—
Straw, cwt. per acre:						
1942	23.7	27.0	24.6	26.9	27.0	±0.85
1943	24.1	27.2	30.4	26.4	28.6	—
1944	22.7	23.4	24.7	27.0	24.6	±0.75
Mean	23.5	25.9	26.1	26.8	26.7	

The authors offer no satisfactory explanation for failure of Sludge A.

The analyses of other sludges are given:

Analyses of Sewage Sludges from Drying Beds, 1942–3

	No. of Materials	Dry Matter Per Cent of Fresh	Organic Matter	Ash	N	P_2O_5	$CaCO_3$	N as NH_4	N as NO_3
	Per Cent of Dry Matter								
Sewage Sludges									
Raw	15	39.5	50.5	49.5	2.37	1.31	2.0	0.12	0.01
Digested	9	42.8	44.3	55.7	2.63	2.05	3.7	0.08	0.04
Digested (+ Act.)	17	52.0	43.7	56.3	2.59	2.17	3.2	0.10	0.05
Shed-dried	6	80.2	39.3	60.7	2.45	2.61	4.7	0.29	0.04
Farmyard Manure	58	26.7	65.8	34.2	2.23	1.60	—	0.23	Nil
	Per Cent of Organic Matter								
Sewage Sludges									
Raw	15	—	—	—	4.71	2.62	4.2	0.21	0.02
Digested	9	—	—	—	5.99	4.68	8.9	0.18	0.10
Digested (+ Act.)	17	—	—	—	5.97	5.18	7.8	0.22	0.12
Shed-dried	6	—	—	—	6.22	6.92	12.9	0.76	0.15
Farmyard Manure	58	—	—	—	3.42	2.51	—	0.35	Nil

Apparently American practice leads to a greater loss of organic matter and nitrogen on digestion.

The authors hold that the nitrogen in digested sludge is certainly no less available than that in raw sludges and some of it, in fact, is more readily available. In this they differ with deTurk.

Pot experiments on the availability of the P_2O_5 in sludges showed wide differences, ranging from 3 to 50 per cent.

The authors stress the importance of determining what sludges have most agricultural promise, by suitable laboratory nitrification and fermentation tests and pot cultures to determine the availability of the nitrogen and phosphate, and the presence of toxic substances. Field tests should also be made.

Composting with straw and liquid sludge, as well as dried sludge, is considered promising.

Langdon Pearse

SEWAGE DISPOSAL AT CHICHESTER

By F. R. Dennis

The Surveyor, **103,** 546 (Nov. 10, 1944)

The particular interest of this article to American sanitarians will be the disposal of raw sludge by open air drying.

The original sewage works were constructed in 1893 and comprised primary settling tanks, land irrigation areas, and a tidal storage tank. In the early 1900's a 200-foot diameter trickling filter and secondary sedimentation tank were added.

Sludge is treated with milk of lime and dewatered in filter presses. All cake produced is readily sold to farmers. This process is costly and it has been decided to construct sludge drying beds which will be used now to dry raw sludge but which, after construction of sludge digestion tanks, will dry digested sludge. Full scale experiments during the last five years with the drying of raw sludge on an old irrigation area indicate that raw sludge dries quite well during the summer with production of very little odor. The newly constructed sludge drying beds will provide an area of one square yard for seven persons for a total population of 22,000.

The effluent from the plant is discharged into a tidal channel much used by bathers and also for shell fish culture. The effluent is chlorinated at the rate of 5 p.p.m. before entering the tidal storage tank.

K. V. Hill

EFFECT OF TREATMENT IN PERCOLATING FILTERS ON BACTERIAL COUNTS

By L. A. Allen, T. G. Tomilson and Irene L. Norton

The Surveyor, 103, 585–87 (Dec. 1, 1944)

The authors have attempted to learn what reductions in bacterial counts were affected by treatment on two stages of trickling filters operated at high rates and upon a single stage filter operated at conventional rates. They point out that whereas a great deal of information is available on the chemical changes which take place in sewage filters, there is a scarcity of information on the bacterial changes which take place.

A bacteriological and chemical study extending over a period of 12 months was made of settled sewage and the effluent obtained by treatment of the settled sewage in the trickling filters of an experimental plant at Minworth, Birmingham.

Sewage was applied to the single-stage filter at an average rate of approximately 60 gallons per cubic yard of filtering medium per diem. The same sewage was applied to the two-stage filters by alternating double filtration with a daily alternation in the order of the filters at an average rate of approximately 240 gallons per cubic yard per diem of filtering medium in the two filters together.

Weekly samples of the applied sewage and of the filter effluent were collected with aseptic precautions and examined for bacterial counts and B.O.D. Bacteriological and chemical results for the warm weather period and cold weather period were approximately as follows:

	Total 37° Count per ml.	Presumptive Count *Coliform B.* per ml.	B.O.D. p.p.m.
Warm Weather Period			
Settled Sewage	563,000	35,500	215
Primary Filter Eff.	582,000	18,400	62
Secondary Filter Eff.	344,000	2,250	31.5
Single Stage Filter	59,000	425	27.5
Cold Weather Period			
Settled Sewage	255,000	4,000	215
Primary Filter Eff.	605,000	4,000	56
Secondary Filter Eff.	254,000	500	17.5
Single Stage Filter	74,000	300	17.5

Bacterial counts at 20° C. and 30° C. were much higher in all stages than the counts at 37° C.

Samples of sewage were taken from 1, 2, and 4 feet depths of the single-stage filter which was 6½ feet deep and examined for total bacterial count. These samples indicated a variable bacterial count in the first two feet of filter. There was sometimes an increase and sometimes a decrease in the number. Between depths of 2 feet and 4 feet there was usually a decrease. Samples from lower depths in the filter consistently showed only a small fraction of the bacteria in the applied sewage.

The authors conclude that the chemical quality of a sewage effluent is no criterion of its bacterial count. In the alternating double filtration plant the B.O.D. was reduced appreciably in the primary filter and to a satisfactory low value in the secondary filter. The bacterial count of the primary effluent was usually high and the count of the secondary effluent was, on the average, considerably higher than that of the effluent from a single filter. Bacterial counts of settled sewage were in general considerably higher in the warmer than in the colder months of the year.

K. V. Hill

FUTURE OF SEWAGE DISPOSAL

By James H. Edmondson

The Surveyor, 103, 609–610 (Dec. 15, 1944)

The following excerpts are taken from the inaugural address of the writer to the annual meeting of the Institute of Sewage Purification. The address was a review of postwar problems and new developments.

The writer commends the proposed regionalization method of developing sewage treatment projects within well defined water sheds and drainage areas.

The author feels that members of the Institute will be more concerned with individual postwar problems rather than with national policies. Among these problems are:

(1) The consideration and possible adoption of the Public Health (Drainage of Trade Premises) Act, 1937.

(2) The effect of the proposed housing development and redistribution of the population upon sewage treatment plants.

(3) Repair and overhaul of a plant which has been unavoidably neglected due to the urgency of war.

(4) Extension and additions to a plant which were necessary prior to the war, or have developed during the war.

The Public Health Act will probably affect the majority of sewage undertakings. There appears to be general agreement that the provisions of the Act should be drastically reviewed. The acceptance of trade effluent under agreement has been advocated as an alternative to the adoption of the Act. Although such agreements are subject to the provisions of the Act, they do give the local authority the opportunity of fixing permissible limits to harmful substances and in this respect the proposal has appeal.

The proposed housing development must take precedence over all other postwar developments because of the extreme shortage of houses. The effect this will have upon sewage treatment must receive the same urgent consideration. In the majority of cases rehousing will probably be within the same drainage area and thus will not affect sewage disposal arrangement. In other cases new housing will be planned as small satellite towns, extending into rural districts and new watersheds. In such cases it may be necessary to provide two sewage treatment plants.

Design of additions to existing plants and new plants will probably include greater attention to the development of power from sludge digestion gas. New developments in the use of filters will probably also be extensively used. These include:

1. High rate primary or "Colloidal" filter.
2. Double filtration with periodic change in order of operation.
3. The enclosed filter with forced aeration.
4. Recirculation or bio-filtration.
5. Dilution with nitrated effluent prior to filtration.

The last-mentioned process is about to be tried out on full plant scale lines.

A more intensified method of dewatering sludge and one unaffected by climatic conditions is highly desirable. Disposal of liquid sludge on land is worthy of consideration where sufficient land is available near the sewage works site because of the high manurial value of the liquid portion of the sludge. The provision of a limited area of drying beds along with an area of agriculturally worked land appears to be an attractive combination. Composting sewage sludge with straw which has found favor during the war period should be further investigated. Further investigations should be made of the economics of producing dried powder sludge for fertilizer.

The pursuit of fundamental research concerning the mechanism of various sewage treatment processes is still highly desirable. Pure scientific investigation, however, is not all that is required. Improved methods of caring for some of the nuisance operations at a sewage treatment plant are also indicated.

Greater attention to the aesthetics of design and maintenance of sewage works cannot be overlooked. The public still associates a sewage treatment plant with other unpleasant things in life.

K. V. Hill

REPORT ON INVESTIGATION OF POLLUTION IN THE LOWER COLUMBIA RIVER

By J. F. Lincoln and R. F. Foster

Washington State Pollution Commission and Oregon State Sanitary Authority, 143 pp. (1943)

This report discusses the pollution of the Lower Columbia River and the injury to the fisheries. The survey (December, 1940 to April, 1942) covered the lower river from the Bonneville Dam to Puget Island, a distance of 90 nautical miles (103.6395 miles). The drainage area above the dam is 241,700 sq. mi. In 1941 the discharge varied from 70,000 to 270,000 c.f.s. For the first 25 miles the 5-day B.O.D. varies from 0.4 to 1.9 p.p.m. The principal source of industrial waste pollution in the lower river is sulfite paper mills at Camas, Vancouver, and Longview, Washington. In 1941 the sulfite pulp production of the three large mills reached 760 tons per day. Domestic sewage also enters from Vancouver (10,000 pop.) and Longview (8,000 pop.), Washington, and Portland, Oregon (305,394), and several small towns. In 1940 the total population above the Bonneville Dam was 1,322,000 (on 202,700 sq. mi.). Below the dam is a population of 822,000 (on 17,500 sq. mi.). On an average, this gives 6.8 persons per sq. mi. above the dam and 46.3 persons per sq. mi. below.

The high concentrations of the various pollutants are restricted to six areas where the wastes hug the river bank below the source of pollution and disperse slowly into the main flow. Thus pulp mill wastes equivalent to 100 p.p.m. to 500 p.p.m. of sulfite digester liquor containing around 10 per cent total solids hug the river bank for at least three miles below one mill. The B.O.D. on one side of the river may be 4 to 6 p.p.m. as compared with 1 p.p.m. on the relatively unpolluted side. The oxygen demand of the waste liquor reduces the dissolved oxygen in certain stretches below 5 p.p.m. The entrance of the Willamette River flow also reduces the dissolved oxygen.

At Lady Island (22 miles from Bonneville), above the mill pollution, the 5-day B.O.D. ranged from 0.6 to 2.0 p.p.m. and the D. O. from 10 to 15 p.p.m.

At Puget Island (89.8 miles from Bonneville), the pulp mill wastes are well mixed in the entire river flow. The 5-day B.O.D. ranged from 0.4 to 1.8 p.p.m. and the D.O. from 8.0 to 12.3 p.p.m.

In certain areas of the lower river growths of *Sphaerotilus* handicap fishing. These growths are most luxuriant below the pulp mill outfalls where the concentration of waste sulfite liquor is 50 p.p.m. or greater. The carbohydrates in the waste liquor are the specific cause of the growths which break loose and float downstream, catching on nets. The growth stops during the winter months.

In the ten years (1932–1941) the average annual catch of salmon was 19,600,000 pounds. So far there is no evidence that pollution of the Main Columbia River has decreased the runs of salmon. However, precautions are required to prevent the pollution from damaging the valuable fisheries. The Columbia River is not at present grossly polluted by sewage, but nowhere should the water be used for drinking unless adequately treated by filtration and chlorination. However, the bacterial pollution in most of the river renders swimming dangerous.

The recommendation is that the waste sulfite liquor be properly dispersed so the concentration when diluted is below 50 p.p.m.

The report contains an extended discussion of *Sphaerotilus* and its habits; the effect of paper wastes on fish life; and the sewage pollution in its relation to public health. A bibliography is given, principally related to local data.

LANGDON PEARSE

SEWAGE TREATMENT IN A TROPICAL CITY

BY L. LLOYD

Nature, 151, 646–647 (1943)

This report gives an account of the Presidential address of the Section on Engineering and Metallurgy of the 30th Indian Science Congress, Calcutta, in 1943, by N. V. Modak. It describes the operation of the Dadar, Bombay works, the first city in India to operate a plant under skilled technical and scientific personnel.

The plant was constructed in 1934 for a capacity of 10 m.g.d. Five m.g.d. receive complete treatment and 5 m.g.d. only plain settling after which it is discharged into storm channels.

The complete treatment consists of Simplex aeration units, an inclosed bacteria bed with forced aeration, and separate sludge digestion.

There are special difficulties due to the tropical climate. Septicity develops very rapidly in the primary tanks. Surface grit is only prevalent after storms but the habit of scouring pans with ashes and dust introduces a steady quantity of grit into the domestic sewage.

Due to faulty design, the screens are down flow from the grit chambers, the inorganic matter becomes mixed with rags, faecal material and cellulose waste to the extent of 40 per cent. The grit in the most septic state has to be removed 4–6 times a day instead of following a storm as is the general practice in moderate or cold climates. The material removed is offensive and is a source of fly breeding and must be transported far from the city as no washing or incineration facilities are available.

Due to the septicity the detention period in the Dortmund settling tanks must be limited to 1½ hours whereas usual practice gives a minimum of 8 hours. Sludge must be removed every two hours in dry weather and four hours in wet weather. English practice for the same tanks would remove sludge once a week. A radical flow circular tank gave somewhat better results but the scraper had to be used continually to prevent septic solids from adhering to the sides.

The volume of surplus sludge was enormous—2 m.g.d. being produced from 4 m.g.d. flow. This difficulty was overcome by devoting 6 tanks (out of 18) to consolidation for a 6-hour period so that the sludge was reduced to one-half of its volume.

The fauna of typical high-quality activated sludge developed only during the monsoon, though the system gave fair results when local conditions were mastered, but it was hypersensitive.

The inclosed percolating filter with forced draft is better than the activated sludge process for tropical climates as odors and fly escape are reduced and (1) it requires 15–18 h.p. per m.g. whereas activated sludge requires 28–35 h.p., (2) the mechanical attention required is much less, (3) skilled supervision is not constantly required, (4) less manual labor is required for its up-keep, and (5) about one-half the area is required.

The filter was 78½ ft. in diameter, 12 ft. deep and 7,000–12,000 c.f.m. of free air was driven through the cone-shaped roof. Nitrates were never formed. The filter was expected to treat 2 m.g.d. but only treated 1 m.g.d. satisfactorily.

GLADYS SWOPE

FLOCCULATION OF BACTERIA BY PROTOZOA

By Garrett Hardin

Nature, 151, 642 (1943)

It was found that the fresh water and soil flagellate *Oikomonas termo* Kent, when grown in two-membered culture with various bacteria, caused a very marked flocculation of certain species, particularly *Erwinea cartovora, Erw. phytophthora, Proteus vulgaris, Phytomonas tumefaciens* and one strain of *Escherichia coli.*

The medium used for these mixed cultures was 0.2 per cent glycerol, 0.1 per cent Difco proteose peptone, and 0.02 per cent each of calcium chloride and magnesium chloride. In tubes containing 10 ml. of this medium, flocculation usually occurred within three or four days after introduction of small inocula of the bacteria and the protozoa.

Both the bacterial and protozoan cultures used for the inoculations were pure cultures and since bacteria grown alone in this medium flocculated very slightly, and then only in old cultures, there can be little doubt of the casual significance of the protozoan.

Gladys Swope

EFFECT OF SOLVENTS ON SLUDGE DIGESTION

By Willem Rudolfs

Industrial and Engineering Chemistry, 36, 742–3 (Aug., 1944)

Various types and differing amounts of solvents are used in industrial processes from which small quantities of solvents escape or are discharged regularly or intermittently. Some solvents have been used for a considerable time, whereas others are relatively new or are replacing those which have been in use. The effect of various solvents on biological sewage treatment processes and particularly on sludge digestion has not been studied in detail.

During a study of the effect of different types of wastes (acids, alkalies, poisons) on a sewage plant receiving industrial wastes, suspicion was aroused concerning certain solvents present in small quantities. Sludge digestion was unaccountably retarded and gas production reduced at intervals. The decrease in gas production, amounting to 10–80 per cent, lasted for several days or even weeks, in spite of the fact that there were no appreciable changes in the wastes. Laboratory studies on the portion of the work dealing with certain solvents are reported.

Fresh solids and ripe sludge collected from plants receiving only domestic sewage were combined in a ratio of 2 : 1 on a volatile matter basis and incubated at 70° F. with various quantities of acetone, ethyl, methyl, butyl, and isoamyl alcohols, benzene, ethyl ether, ethylene dichloride, carbon tetrachloride, toluene, and xylene. Percentages of volatile matter reduction and total gas production were chosen as indices of the effect of solvents on digestion.

The total solids concentrations used for the mixtures varied from 6.62–6.63 per cent and the ash content from 39.1–40.0 per cent. The volatile matter reduction of the control mixtures after 36 days digestion averaged 32.0 per cent. The average amount of gas produced by the control mixtures was 515 cc. per gram volatile matter added. The experimental results are tabulated and presented graphically in three figures.

Relatively small quantities of solvents used in industrial processes influence the rate and degree of sludge digestion. In general, the depressing or retarding effect of the solvents was more uniform on volatile matter destruction than on gasification. The different solvents have various effects on volatile matter destruction and gas production. Small quantities of methyl, ethyl, butyl, and isoamyl alcohols produce greater volumes of gas but slightly retard volatile matter destruction. Ethyl ether stimulates gas production but has no effect on volatile matter reduction. Acetone increases liquefaction of volatile matter without affecting gas production. Toluene and carbon tetrachloride, in small quantities, aid gas production but do not materially affect volatile matter destruction. Larger quantities retard or inhibit digestion. Xylene is toxic to liquefying and gas producing organisms. Ethylene dichloride is extremely toxic. Even 1 to 2 p.p.m. of this compound in the sludge liquor retards gasification, whereas 10 p.p.m. reduces gas production over 50 per cent. Plant experience indicates that small batches of spent solvent cause fluctuation in gas production and repeated discharges retard greatly or may inhibit the sludge digestion process.

RICHARD D. HOAK

RECOVERY OF PROTEINS FROM WHEAT MASHES WITH SULFITE WASTE LIQUORS

BY JAMES S. WALLERSTEIN, EDUARD FARBER, GERTRUDE D. MAENGWYN-DAVIES AND ARTHUR L. SCHADE

Ind. and Eng. Chem., 36, 772 (Aug., 1944)

Sulfite waste liquors have been used successfully to precipitate proteins from waste mash of the fermentation industries. Up to 90 per cent of the protein content of the mash has been recovered. The development has possibilities of serving a dual role from the standpoint of stream pollution prevention, in that some sulfite waste liquor of the paper industry and protein waste of the fermentation industry could be kept from the stream.

Details of the process are discussed in the article.

E. HURWITZ

THE CORROSION OF CEMENT AND CONCRETE

BY C. HAMMERTON

The Institute of Sewage Purification (British) 16 pages. (Oct. 21, 1944)

Cement almost invariably refers to Portland cement and is liable to attack by water containing carbon dioxide, acid soils, soils with high acid exchange properties, waters containing high concentrations of inorganic salts, acids, many organic compounds, and the products of the activities of certain microorganisms. Deterioration occurs in different ways. Soft waters may leach out part of the cement of the structure, while under other conditions the cement may be softened to a paste, exposing the aggregate. Loss of strength may be the first sign of attack.

The latest investigations appear to have established that the compounds formed in the burning of the raw materials during the manufacture of cement are tricalcium silicate, $3CaO \cdot SiO_2$; dicalcium silicate $2CaO \cdot SiO_2$; tricalcium aluminate $3CaO \cdot Al_2O_3$; with possibly a small quantity of less basic aluminate $2CaO \cdot Al_2O_3$; terta-calcium aluminoferrite $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$; and a little uncombined magnesia and lime. The various compounds react with water during the setting process and considerable heat is evolved. The presence of free lime in the set product is of importance from the point of view of chemical attack.

The attack of cement by water is reduced if the water is hard. Carbon dioxide renders water aggressive to cement. A rough guide suggested is that waters having a carbonate hardness of from 10 to 20 p.p.m. will not be aggressive unless the free CO_2 content is more than 10 p.p.m.; but with lower carbonate hardness, corrosion can be marked even though the free CO_2 is negligible. If the pH is above 6.5, natural waters are likely to produce marked effects only when the carbonate hardness is less than 50 p.p.m. If the temporary hardness is negligible, waters with a pH as high as 7.5 can have a solvent action.

The sulfates are the most troublesome of the inorganic substances which attack cement. The most vulnerable constituent is tricalcium aluminate. When Portland cement is left in contact with a sulfate solution, calcium sulfate is first formed by interaction with the calcium hydroxide liberated during setting. This calcium sulfate reacts further with the hydrated calcium aluminate to form calcium-aluminate which crystallizes with 31 molecules of water thus causing a significant volume increase. In crystallizing this compound exerts a thrust causing damage to the structure. Concrete corroded by sodium or calcium sulfate becomes soft and mushy but where the attack is by magnesium sulfate hard granules are found in the pores and though this delays final disruption somewhat, magnesium sulfate attack is quite serious.

The following classification of sites has been suggested:

(1) Sites with low risk of sulfate attack: ground water containing less than 300 p.p.m. sulfate as SO_3.

(2) Sites with moderate risk: ground water containing 300 to 1,000 p.p.m. sulfate as SO_3.

(3) Sites with high risk: more than 1,000 p.p.m. sulfate as SO_3.

French experience with aluminous cement, a product not containing the higher calcium silicates but consisting chiefly of the less basic calcium aluminates, has indicated a high resistance to the action of sea water. Aluminous cement (high aluminous cement) is manufactured by melting a mixture of bauxite and lime then grinding the fused product. Where severe conditions are to be met the use of high aluminous cement to produce a 1:2:4 mix is recommended, with a water content of not more than 60 per cent by weight of the cement used. Prolonged mixing is harmful. It is important that the curing temperature be below 25° C. (77° F.).

The addition of siliceous material (pozzolana) to combine with the excess lime is another method of approach. Ground blast furnace slag added to Portland cement improves its resistance to corrosion. Supersulfate cements have been developed which contain around 7.4 per cent sulfate (as SO_3) by weight. In this type of cement the previously discussed sulfate reaction is allowed to occur during setting so that the finished product is immune to further reaction.

Concrete is not normally affected by sewage unless the latter has become septic in which case it is the hydrogen sulfide gas evolved which is the destructive agent. Corrosion occurs above the water line as indicated by the following:

	Condition of Concrete	
	Below Water Level	Above Water Level
Appearance	gray	white
Texture	hard	soft
Ratio cement:sand	1:2	3:2
Calcium sulfate in cement	trace	66%

It has been suggested that the corrosion reaction may be brought about by combination of hydrogen sulfide with the lime in the concrete forming calcium sulfide, which is then oxidized to calcium sulfate by oxygen from the air. To avoid difficulty with hydrogen sulfide the sewage must be prevented from turning septic which is not always possible or a conduit must be constructed that is unaffected by the gas. High temperatures favor the formation of hydrogen sulfide. However temperature control is out of the question so either the length of the collector must be reduced or early chlorination of the sewage carried out at suitable points. In building sewer systems in warm climates, much study should be given to the planning so that the minimum length of trunk sewer or main collector is obtained.

Two investigators have recently reported that the formation of hydrogen sulfide by sulfate reducing bacteria may be prevented by means of a dyestuff of the 3, 6-diamino-acridine group, *e.g.*, acriflavine, proflavine, or 2, 7-dimethyl 3, 6-diamino-acridinium hydrochloride. Concentrations between 1 in 50,000 and 1 in 150,000 are sufficient to prevent corrosion. This is equivalent to about 7–20 p.p.m.

When hydrogen sulfide and air are in contact with a moist concrete surface, the hydrogen sulfide is either absorbed on the surface and oxidized to sulfuric acid which then decomposes the concrete with the formation of calcium sulfate or the hydrogen sulfide is absorbed by the free lime forming calcium sulfide which is later oxidized to the sulfate. Probably both reactions occur.

Many surface coatings have been tried but the author is not aware of any that have proved entirely successful, the coating tending to delay corrosion rather than prevent it. Furthermore to coat a large concrete sewer internally is quite difficult since in order for the coating to adhere it is essential that the surface be dry, a condition difficult to realize in practice. The author's opinion is that large outfall sewers should be lined with acid-proof brick and jointed with a high-silica acid-proof mortar.

Ventilation has been advocated as a means of minimizing sulfide corrosion but this can rarely be effective except in cases of very short stretches of conduit and it may give the reverse of the desired effect. Total elimination of air from the sewer would stop attack but engineering difficulties are such that this is usually impracticable.

The action of trade wastes on various types of cement concrete is fairly well established. Reference is made to Lea and Desch's book "The Chemistry of Cement and Concrete" from which the following are quoted:

Mineral acids are corrosive to concrete.

Lactic acid (dairies, creameries, cheese plants) is quite destructive.

Acetic acid is destructive.

Oxalic acid has no action on aluminous cement and slight action on Portland cement. (Film of calcium oxalate protects.)

Oleic, stearic, palmitic acids and other aliphatic acids all exert a marked action on concrete.

Alkali hydroxides have no effect on Portland cement concrete but seriously decrease the strength of aluminous cement concrete.

Ammonium hydroxide (10 per cent). No action.

Ammonium salts are corrosive to Portland cement concrete. Aluminous cement appears to be resistant.

Sulfur compounds. All sulfur compounds are destructive, particularly photographic chemicals.

Aluminum sulfate (over 1 per cent) attacks Portland but aluminous cement concrete is more or less immune.

Sugar solutions are corrosive to Portland cement concrete.

Stoneware is far more resistant to chemical attack than concrete. The only chemical which is more corrosive to stoneware than to concrete is strong alkali.

Jointing material should be chosen with care and in most cases ordinary cement grout would be ruled out but aluminous cement grout should be satisfactory in many instances with sulfur cement or bituminous jointing compounds as an alternative. The author gives a detailed discussion regarding sulfur cements.

Seventeen references are given. Three photographs show the influence of cottonseed oil, magnesium sulfate and sodium sulfate on Portland cement and high aluminous cement concrete.

PAUL D. HANEY

SLIME-PRODUCING COLIFORM AND COLIFORM-LIKE BACTERIA

BY J. R. SANBORN

Journal of Bacteriology, 48, 211–217 (1944)

In pulp, paper and paperboard mills coliform bacteria and certain closely related species are the chief slime forming flora. Ordinary coliform bacteria of the pollutional type are effectively eliminated in a majority of plants by chlorine and chloramine treatments. The eradication of mucoid growths is more difficult due to the gelatinous gums in which the cells are embedded. Analyses of slime growths from 340 mills show that in 52.6 per cent of the plants coliform bacteria are either prevalent or among the principal members of the slime flora. Ninety-four per cent of the coliform organisms found were *Aerobacter* varieties. *Aerobacter cloacae* was more prevalent than *Aerobacter aerogenes.* The mucoid species of *Aerobacter* that develop slimes in pulp and paper mills are usually considered coliform organisms that have become acclimitized to this habitat. They have a close resemblance to members of *Klebsiella* and *Eriwinia.*

Difficulties are encountered in eradicating slimes caused by coliform organisms and the mucoid variants belonging to the genera *Alcaligenes, Flavobacterium* and *Achromobacter.* Mills find that members of the coliform group vary in their susceptibility to chlorine. Certain raw water pollutional types as *Esch. coli* and "intermediates" such as *Alcaligenes faecalis, Pseudomonas fluorescens* and *Pseudomonas viscosa* are readily controlled with chlorine residuals of 0.4 to 0.8 p.p.m. Under certain conditions mucoid-variants such *Aerobacter aerogenes* and *Aerobacter cloacae* may be killed with residuals in excess of 1.0 p.p.m. In order to eradicate the types resistant to chlorine 125 different compounds were tested. The chemicals giving good results against slime forming bacteria were as follows: trichlorophinate fractions, metallic salts of chlorinated phenols, chlorinated isopropyl phenols and various alkyl derivatives of halogenated phenols. These products in aqueous dilutions ranging from 1:10,000 to 1:100,000 are capable of controlling slimy coliform organisms studied. Some of these materials were investigated under conditions of mill operation where coliform growths were present. The treatments not only removed coliform groups promptly but also penetrated to the deeper layers of fungus slime exerting a killing action which no chemical previously employed had been able to accomplish.

H. Heukelekian

THE EFFICIENCY AND CALCULATIONS FOR HIGH RATE FILTERS

By F. Pöpel

Ges. Ing., Special Number Series 2, No. 21., 40 pages, 1943, R.M. 7.50

Pöpel has brought together results of 34 publications on high rate filters. He calls such filters "washing trickling filters," because they are subject to high surface loading and a rapid movement of water through the filter ("washing"). The surface loading is usually 5–10 times higher than on standard filters. "Washing" should not be considered as mechanical action only, but the biological action should be considered. Pöpel found that the efficiency of the trickling filters depends upon the following characteristics and actions:

1. B.O.D., also putrescibility of the sewage. Up to a B.O.D. of about 500 p.p.m. of the settled sewage the purification is about 80 per cent without recirculation.

2. Utilization of surface area, namely: (*a*) form and type of media. The influence is small. Media with rough surfaces produce quicker results, but with strong sewage has the disadvantage of clogging and interferring with aeration. (*b*) Size of media. The influence of size is not very great. Media which have a surface area between 74 and 1500 m^2 per m^3 (22.6 and 457 sq. ft. per cu. ft.) showed only a small increase in efficiency with increasing surface area. Stones of 3 and 8 cm. (1³⁄₁₆ and 3³⁄₃₂ in.) dia. appeared to be equally effective.

3. Height of filter. With equal loadings and the same temperature a 6 m. (19.7 ft.) high filter is about twice as efficient as a filter 1 m. (3.3 ft.) high.

4. Volume and surface loading. Recirculation acts as though the height of the filter was increased. Recirculation is similar to dilution with rain water. One part recirculated water added to each part of sewage is double filtration, because the water runs twice through the filter. Recirculation 1:1 has the same value as increasing the height of the filter from 1 to 6 meters (3.3 to 19.7 ft.). With recirculation 2:1 the efficiency is similar to a filter 15 times higher.

5. Oxygen excess in air. This is the relation between the amount of oxygen in the air passing through the filter and the amount of oxygen dissolved in the water. With weak American sewages excess of oxygen from 50 to 200 times has been found; with strong milk waste from 2 to 10 times and in clogged filters (like Beuthen) 40 to 45 times.

6. Temperature. (*a*) Sewage temperature—efficiency is higher in summer than in the winter. Between 10° C. and 20° C. the efficiency increases from 0.8 to 1.3. (*b*) Temperature drop is the difference between sewage temperature and air temperature, since natural aeration depends upon this difference.

The various factors are evaluated and expressed in a formula. The formula can be used to calculate the quantities of oxygen supplied to the sewage. With oxygen supply is meant the quantity of oxygen removed from the air and dissolved in the sewage while passing through the filter. It is the difference between the B.O.D. of influent and effluent. Since this quantity of oxygen is used for stabilization and oxidation, the oxygen supply is a measure of efficiency of the filter.

WILLEM RUDOLFS

THE AGRICULTRAL VALUE OF SEWAGE SLUDGE

BY E. STECHER

Ges. Ing., 66 (13), 119 (1943)

Utilization of undigested sewage sludge is not recommended, despite the greater manurial value. Well digested sludge has also considerable value. The whole problem cannot be regulated, but should be considered locally.

WILLEM RUDOLFS

INCREASED EFFICIENCY IN TRICKLING FILTERS

BY R. PONNINGER

Ges. Ing., 66 (14), 141 (1943)

The purpose of the stone media in trickling filters is to provide surface area for the biological film. The colloids and soluble materials in the sewage are absorbed and destroyed by the organisms of the film. The insoluble material is washed out or held as sludge. Part of the sludge is liquified; soluble materials may be precipitated and form sludge. Most of the sludge is gasified. Maximum loading is determined by the rate of absorption and the degree of decomposition. If more material (food) is added the degree of purification is reduced. The limit of loading depends on: strength of sewage, quantity of film and air supply.

The limit of loading is best expressed as volume loading (m^3 sewage/m^3 stone/day).* The principle of "limit loading" may be shown by an example: The old Wilmersdorf trickling filter efficiency is 0.5:1. From these values can be calculated, with 2 min. spraying and 12 min. "aeration resting," the limit loading $= (12 + 2)/2 \times 0.5 = 3.5:1$. This is the volume loading without aeration resting, or in other words, volume loading with continuous application. Rest periods are required to prevent clogging. In the struggle against clogging the following were tried: (1) dilution of sewage with higher application to filter, so that sludge is washed out; (2) artificial aeration to aid oxidation and make sludge porous.

Each drop of sewage applied exerts a washing effect, which increases with the volume and velocity of the water. This washing effect keeps the stones clean. This principle has been used by intermittent sewage application, instead of uniform application over 24 hours. The measure of the flushing power is the surface loading, expressed as m/h (ft./hr.). To obtain proper flushing the minimum quantity is 0.5–0.8 m/h (1.6–2.6 ft./hr.) This high loading can be reached only when the sewage is weak, or

* *Editor's note:* In English or American practice we would express this as gallons/cu. ft. or cu. yd. of stone per day.

TABLE I

Place	B.O.D. of Influent		Limit of Loading	Length of Filter		Surface Loading	
	gram/m³	Lb./Cu. Ft.		Meters	Feet	m/h	Ft./Hr.
Stuttgart	140	.0088	9:1	1.65	5.42	0.62	2.03
Berlin (Halverson)	111	.0069	10:1	2.50	8.20	1.42	4.66
Beuthen	450	.0281	3.5:1	3.70	12.14	0.54	1.77
Soest	222	.0139	3.4:1	3.50	11.48	0.45	1.48
Wilmersdorf	±400	.0250	4:1	2.50	8.20	0.42	1.38

diluted, or with very high filters. Comparison of the surface loading (Table I) shows only a little difference between Stuttgart and Beuthen, but the Beuthen filter retained considerable quantities of suspended solids, while all suspended matter was unloaded at Stuttgart. Other old filters, like Wilmersdorf, cannot be operated unless time is allowed for aeration or artificial aeration is applied. For high rate filters without artificial aeration or operated continuously and receiving high loadings, two conditions are necessary: (1) low B.O.D. of influent (100–150 g/m^3) (.006–.009 lb./cu. ft.) and (2) high surface loading.

Instead of the flushing effect another factor may be considered, namely: biological activity. With weak sewage insufficient growth of flora and fauna may result. The reducing power of the filter should be aided but not fought. About 50 per cent of the total oxygen demand is ascribed to the sludge and reduction of air supply affects only the destruction of the sludge, without affecting the purification of the sewage. The aeration time (between doses) of filters receiving low loadings, can be displaced by artificial aeration, allowing continuous application and reducing sludge retained. A naturally aerated filter clogged after 5 months with a loading of only 2:1, whereas no clogging occurred with artificial aeration in a filter of the same height and size of stone. The same happened in filters with larger stones, as well as with more shallow filters. Similar results were obtained with a strong sewage.

Since with weak or recirculated sewage no suspended solids are retained in the filter and no sludge is formed, large increases of Psychoda flies are impossible. With very weak sewage or sewage diluted with effluent containing dissolved oxygen no odors are produced. Strong sewage produces increased sludge, hence more food for fly larvae. When the flies are numerous they should be left alone, because the larvae destroy the sludge. Complete covering of the filter and forced aeration prevents escape of the flies. Incidentally, the odor problem is solved, because the air is purified by passage through the filter.

Viehl (*Ges. Ing.*, 64 (26), 269 (1941)) states that nitrates are formed primarily from ammonia originally present in soluble form. With unnecessary long aeration a part of the nitrogen in the sludge may become available. In weak sewage low nitrate formation can be expected; hence when the effluent is recirculated (thereby reducing the strength of the sewage) few if any nitrates will be found, but if the recirculated effluent is compared with raw sewage of the same strength, more nitrates will be found in the recirculated water, or the quantity of ammonia will be greater. The Berlin results show high nitrates corresponding with low ammonia and *vice-versa*. When high nitrates are present the B.O.D. will be low and *vice-versa*. As far as fertilization of the receiving water is concerned it makes no difference whether nitrates or ammonia contents are high; the total nitrogen is the same. The nitrification in the filters is so erratic that the production of nitrates cannot be correlated with nitrification of the sludge. Nitrates can be formed in filters "completely free of sludge."

Properly constructed filters receive the limit of loading discharge sludge long before it can be nitrified. It is still putrefactive, is reduced (50 per cent) to carbon dioxide and nitrogen gas. When the sludge is not discharged, it is destroyed in the bed (low loadings) and high nitrification will result.

The most important basis for measuring the efficiency of a filter is the strength of sewage expressed as B.O.D.:

$$B.O.D. = 35/Kg.m^3 \,*$$

where: 35 = grams B.O.D./cap.

K = water consumption/cap. in m^3/day.

In design, only the maximum volume loading of the filter and the limit loading are of importance. These are dependent upon the height of the filter as well as the type and size of media.

WILLEM RUDOLFS

SIMPLE CALCULATION FOR BIOLOGICAL TREATMENT WORKS

BY K. IMHOFF

Ges. Ing., 66 (15), 164 (1943)

Volume measurement has little value because of the great variation in water consumption. The best measuring stick for impurities in sewage is B.O.D. Usable averages are for instance: activated sludge, 500 gr. B.O.D./day per 1 m^3 (0.031 lb. B.O.D./day/cu. ft.) aeration tank capacity; high rate filters 700 gr. B.O.D./m^3 (0.033 lb. B.O.D./cu. ft.) stone; low rate filters B.O.D./m^3 (0.011 lb. B.O.D./cu.ft.) stone/day. It is assumed that the B.O.D. per cap./day averages 35 gm. (.077 lb.). This needs more study. The calculation of allowable loadings of biological treatment works on the basis of population is simple and clear. This method should be used when no B.O.D. determinations made over extended periods are available. When B.O.D. results are available the population equivalents can be calculated.

WILLEM RUDOLFS

MECHANICAL FLOCCULATION OF SUSPENDED SOLIDS IN MUNICIPAL AND INDUSTRIAL WASTES

BY F. PÖPEL

Ges. Ing., 66 (17), 213 (1943)

Laboratory experiments lead to the following conclusions:

1. Mechanical flocculation aids the adsorption of finely divided materials and reduces the time of self-flocculation to 20–30 minutes.
2. The effect of mechanical flocculation increases with increasing quantities of suspended and semi-soluble substances capable of flocculation.
3. The action of mechanical flocculation is increased by mixing different types of wastes or by artifically increasing the suspended solids by return of sludge.
4. Mechanical flocculation causes an increase in the rate of settling.
5. Mechanical flocculation has no economic value in settling good activated sludge.
6. It increases the rate of settling of suspended solids from trickling filters by 50 per cent.
7. The flocs formed are very fragile and disintegrate when the velocity of the water is more than 0.4 m/sec. (13.1 ft./sec.).

Plant experimentation with a flocculator-settling tank "showed several times that the effluent had 15 to 20 per cent lower oxygen consumed values than quiescently settled raw sewage retained in cylinders for the same time as the detention period in the tanks" (about 5 hours).

WILLEM RUDOLFS

* *Editor's note:* 453 grams = 1 lb.
1 M^3 = 1 cu. meter = 35.31 cu. ft.

TECHNIC OF RECIRCULATION ON TRICKLING FILTERS

By K. Imhoff

Ges. Ing., 66 (17), 220 (1943)

Recirculation may be compared with dilution by rain. With recirculation a heavier sewage can be treated on shallower beds. The recirculated effluent adds oxygen, nitrates organisms and enzymes to the sewage, makes sewage fresher, reduces odor and flies, helps purification. Usually recirculation is practiced at a ratio of 1:1. A disadvantage is increased power costs. Ponniger claims that artificial aeration is important. By resting the filters time is allowed for the organisms to eat the film.

Willem Rudolfs

ANAEROBIC DECOMPOSITION OF ACTIVATED SLUDGE WITH PARTICULAR REFERENCE TO GAS PRODUCTION

By W. Ortlieb

Ges. Ing., 66 (18), 231 (1944)

A description of a special bulletin with the title by H. Teichgrater. Studies were made to determine whether sewage and beer waste sludge at Weida could be digested. Gas production was lower than previously found by others. Temperature and pH value were important. Variation in gas production is caused by changes in character of organic matter added to the digester. Author stresses "specific quantities of gas," by which term he means the quantity of gas produced from one gram organic matter completely destroyed.

Willem Rudolfs

THE DESIRABLE DEGREE OF SEWAGE TREATMENT

By W. Müller

Ges. Ing., 66 (18), 242 (1944)

From a health standpoint sewage and industrial wastes must be disposed of, and from an economical standpoint, as much water and ingredients saved as possible. For disposal one can use: rivers and water courses, irrigation, subsurface discharge, reuse, or evaporation. The degree of treatment varies greatly in Germany and is in most cases insufficient, with resulting pollution. Extent of dilution required when discharged into a pure stream: biological treatment 1:20, settling 1:40, chemical treatment 1:20–1:40. In practice conditions are different. Critical conditions in a stream arise 3 days after sewage is discharged. In 10 days 90 per cent of putrescrible materials are decomposed. Using average flow velocities in 12 streams in Germany, the author finds that the critical point is 155.5 KM (97 miles) below the outfall. The influence of many outfalls is superimposed. Calculations show that the relation between sewage produced and total runoff is 1:24, so that settling alone is insufficient. Since insufficient land is available for filters, sewage should be treated biologically before discharge.

Willem Rudolfs

OPERATION DIFFICULTIES IN SEWAGE PUMPING STATIONS

By W. Husmann

Ges. Ing., 66 (20), 298 (1943)

In the Emscher district large volumes of sulfate containing ground waters are carried in the combined sewer systems. In addition to domestic sewage there are appreciable amounts of pickling liquors and chemical wastes (principally barium chloride) from industries. The pumps operate and rest alternately about 20 minutes. Sludge is formed rapidly by the interaction of the barium compounds and sulfates in the ground water. The sludge settles rapidly and interferes with efficiency. Special sump pumps were installed.

WILLEM RUDOLFS

DISTRIBUTION OF LIQUID DIGESTED SEWAGE SLUDGE

BY W. KUNZE

Ges. Ing., 66 (20), 300 (1943)

Lack of labor prevented drying and removal of sludge from sand filters at the Zwickan treatment plant serving 80,000 people. Farmers, who used the air dried sludge, were induced to take the liquid material carted in tanks. A tank was erected on the crest of the digester allowing the sludge to be discharged into vehicles. About 2,800,000 gallons (78.4 per cent of the total) liquid sludge a year were handled. Application to soil; sludge from 40 people per acre. Good crops; no difficulties.

WILLEM RUDOLFS

THE AGRICULTURAL ASPECTS OF SEWAGE TREATMENT

BY K. P. KELIS

Ges. Ing., 66 (21), 312 (1943)

Formerly, the city of Groningen in Holland applied sewage sludge to poor soil, which improved the soil and produced good crops. Later, the sewerage system was extended to suburban towns and sewage discharged into the Zuider Sea with attendant loss to agriculture. Modern sewage treatment processes cannot remove all suspended and soluble substances, hence a loss. Since collection and treatment of sewage of extended districts rather than of separate cities and towns is foreshadowed after the war in Holland, results of experiments made in Amsterdam with partial activated sludge and dewatering of sludge are of importance for the entire country, particularly from an agricultural standpoint.

WILLEM RUDOLFS

AGRICULTURAL UTILIZATION OF SEWAGE

BY M. BIMANIS

Ges. Ing., 67 (1), 10 (1944)

Settled sewage is best for agricultural purposes. The settled sludge can be digested and used as fertilizer. Settled sewage should not come in contact with the plant grown, hence the system of spraying sewage (artificial rain) cannot be used for vegetables or root crops.

WILLEM RUDOLFS

SEWERAGE AND SEWAGE TREATMENT IN PARIS

BY F. REINHOLD

Ges. Ing., 67 (1), 12 (1944)

The city of Paris had in 1940 about 2,800,000 inhabitants; the sewers serve surrounding suburban territories as well, amounting to 6 million people. The density of population varies from 19 to 344 per acre. Since 1856, the law requires connections of houses with sewers. All outfalls discharge to the Seine, resulting in considerable pollution. Since 1896 all street wash and storm water runs into the sewers, refuse on the streets is also flushed into the sewers. The outfalls are connected into a large interceptor. The total length of sewers is about 1,200 miles. Several pumping stations force the sewage to various points outside Paris. At the Clinchy pumping station settling basins receive about 260 m.g.d.; a small part is pumped to Genevilliers and treated on farms; but most of the sewage is forced to Colombes and passes through mechanical clarifiers (at present bypassed to the treatment works at Achère) and thence pumped 14 miles to sewage farms and the Seine. Of the present total dry weather flow of about 315 m.g.d. an average of about 54 per cent is discharged into the Seine with only mechanical settling or no treatment at all. The farms, mostly northwest of Paris, cover about 12,750 acres, of which 4,500 are owned by the city, the rest privately owned. The city farms are rented and the farmers must comply with certain rules and regulations regarding treatment. The private farmers can do as they please. Applications to the field is restricted by law to 166 inches a year, although 5 times the amount could be filtered through the calcereous soil. The treatment works at Achère consist of Dorr clarifiers with 1½ hr. detention, activated sludge with 6 hr. aeration, final settling tanks with 1½ hr. detention, and sludge digestion at 30° C. Pumps and air blowers are run with digester gas stored in two 1,600 cubic meter (56,500 cu. ft.) capacity holders. One plant treating 52 m.g.d. sewage produces 350,000 cubic feet of gas or nearly 10 cubic feet per kilogram (2.2 lb.) solids retained.

WILLEM RUDOLFS

TREATMENT OF TANNERY WASTE WITH FERRIC CHLORIDE

BY A. KÜNZEL-MEHNER

Ges. Ing., 67 (3), 73 (1944)

Chemical-mechanical treatment of strong tannery waste is possible and economically sound. Batch treatment with ferric chloride is preferred and produces good clarification with complete removal of sulfur compounds with additions of 200–500 grams $FeCl_3$ per cubic meter (12–27 grains per gallon). Best results are obtained at pH 4.5, although good results can be obtained at a pH range of 5 to 7. Sludge produced can be vacuum filtered and burned.

WILLEM RUDOLFS

Federation of Sewage Works Associations

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FEDERATION OF SEWAGE WORKS ASSOCIATIONS, INC.

325 Illinois Building, Champaign, Ill.

1944–45 OFFICERS

President: Albert E. Berry

Vice-President: John K. Hoskins

Treasurer: W. W. DeBerard

Executive Secretary-Editor: W. H. Wisely

Advisory Editor: F. W. Mohlman

PAST PRESIDENTS

Name	*Period Served*
Charles A. Emerson	1928–41
Arthur S. Bedell	1941–42
George J. Schroepfer	1942–43
A. M. Rawn	1943–44

HONORS AND AWARDS

Honorary Members

The qualifications for Honorary membership in the Federation are set forth in Article II, Section 4 of the By-Laws. Honorary Members are elected upon recommendation by a committee comprising the President and four latest Past Presidents, the senior Past President as chairman, in accordance with a policy adopted by the Board of Control on October 23, 1943. Honoray Members elected to date are as follows:

Charles Alvin Emerson	1941
Arthur S. Bedell	1942
Julius W. Bugbee	1942
Langdon Pearse	1942
Charles Gilman Hyde	1943
Howard Eugene Moses	1943
Floyd William Mohlman	1944

The Harrison Prescott Eddy Medal

The Harrison Prescott Eddy Medal is awarded annually to a member of any Member Association of the Federation "for outstanding research contributing in important degree to the existing knowledge of the fundamental principles or processes of sewage treatment, as comprehensively described and published during any stated year in SEWAGE WORKS JOURNAL." The award commemorates Harrison Prescott Eddy, a famous engineer and a pioneer in the art of sewage treatment.

Past recipients of the award are:

Harry Willard Gehm	1943
John Raymond Snell	1944

The George Bradley Gascoigne Medal

The George Bradley Gascoigne Medal is awarded annually to a member of any Member Association of the Federation "for outstanding contribution to the art of sewage treatment works operation through the successful solution of important and complicated operational problems, as comprehensively described and published during any stated year in SEWAGE WORKS JOURNAL." This award is in memory of George Bradley Gascoigne, a prominent consultant from 1922 to 1940, who demonstrated an unusual interest in matters of sewage works operation.

Past recipients of this award are:

Kerwin L. Mick	1943
James T. Lynch and Uhl T. Mann	1944

The Charles Alvin Emerson Medal

The Charles Alvin Emerson Medal is awarded annually to a member of any Member Association of the Federation "for outstanding service in the sewerage and sewage treatment works field, as related particularly to the problems and activities of the Federation of Sewage Works Associations in such terms as the stimulation of membership, improving standards of operational accomplishments, fostering fundamental research, etc." This award honors Charles Alvin Emerson, who served as President of the Federation from 1928 to 1941 and holds the distinction of being its first Honorary Member.

Past recipients are:

Floyd William Mohlman	1943
Willem Rudolfs	1944

The Kenneth Allen Award

Each Member Association of the Federation is privileged once in each three years to designate one of its members to receive the Kenneth Allen Award "for outstanding service in the sewerage and sewage treatment works field, as related particularly to the problems and activities of any Member Association." The award commemorates Kenneth Allen, an eminent engineer who made notable contributions to the creation of the Federation and the New York State Sewage Works Association.

Recipients of this award have been:

1943

Name	*Member Association*
Harry Thornton Calvert	I. S. P. (England)
Edward F. Eldridge	Michigan
John Kurtz Hoskins	Federal
Fred Merryfield	Pacific Northwest
Edward P. Molitor	New Jersey
Robert S. Phillips	North Carolina
Alfred Henry Weiters	Iowa
William Homer Wisely	Central States

1944

Name	*Member Association*
Alfred Edward Berry	Canadian
Van Porter Enloe	Georgia
Albert Legrand Genter	Maryland-Delaware
F. Wellington Gilcreas	New England
Charles A. Holmquist	New York
Dana Ewart Kepner	Rocky Mountain
Leon Benedict Reynolds	California
Wilson Waldo Towne	Dakota

Convention Attendance Award

The Convention Attendance Award is in the form of a trophy which is presented annually to the Member Association which is credited with having aggregated the greatest number of man-miles in attending each Annual Meeting of the Federation. Permanent possession of the first trophy was won by the Central States Sewage Works Association in 1943, that organization having won the award for three consecutive years.

Central States Sewage Works Association 1941
Central States Sewage Works Association 1942
Central States Sewage Works Association 1943
Central States Sewage Works Association 1944

Membership Prizes

Prizes for membership activity in its various Member Associations have been sponsored by the Federation since 1943. Recipients of these prizes to date have been:

Name	*Association*	*Year*
Frank E. DeMartini	Federal	1943
George L. Loelkes	Missouri	1944
Martin A. Milling, Douglas E. Dreier, John C. Mackin and Maurice L. Robins (jointly)	Central States	1944

Quarter Century Operators Club

The Quarter Century Operators Club is an informal group comprising Active or Corporate Members of any Member Association who had been engaged in sewage treatment works operation, on a full-time resident basis, twenty-five years prior to the date of their admission into the Club. The Club was created in 1941 under the sponsorship of Frank Woodbury Jones, who serves as its registrar.

Reuben A. Anderson
Harry M. Beaumont
George C. Behnke
Julius W. Bugbee
Stuart E. Coburn
John R. Downes
Almon L. Fales
Wm. C. Hamm
Charles C. Hommon
Frank W. Jones
Roy S. Lanphear
John V. Lewis
C. D. McGuire
Paul Molitor, Sr. (Dec.)
Wm. M. Piatt
Theodore C. Schaetzle
Glenn Searls
John S. Simmerman
H. W. Streeter
S. L. Tolman

ANNUAL MEETINGS AND CONVENTIONS

Annual Meeting Number	*Location*	*Date*
1	Chicago, Illinois *	October 16, 1928
2	New York, New York *	January 18, 1929
3	New York, New York *	January 14, 1930
4	New York, New York *	January 22, 1931
5	New York, New York *	January 22, 1932
6	New York, New York *	January 19, 1933
7	New York, New York *	January 18, 1934
8	New York, New York *	January 18, 1935
9	New York, New York *	January 16, 1936
10	New York, New York *	January 22, 1937
11	New York, New York *	January 21, 1938
12	New York, New York *	January 20, 1939
13	New York, New York *	January 18, 1940
	Chicago, Illinois †	October 3–5, 1940
14	New York, New York *	January 15, 1941
	New York, New York †	October 9–11, 1941
15	Cleveland, Ohio ‡	October 22–24, 1942
16	Chicago, Illinois ‡	October 21–23, 1943
17	Pittsburgh, Pa. ‡	October 12–14, 1944

DIRECTORY OF COMMITTEES

1944–45

Constitutional Committees

(*See Article VI of By-Laws*)

Executive Committee of the Board of Control

A. E. Berry, *Chairman*

W. B. Marshall
F. S. Friel
Dana E. Kepner
Charles A. Emerson

General Policy Committee

The General Policy Committee studies and recommends to the Board of Control upon all matters of policy affecting the well-being and usefulness of the Federation and its Member Associations; matters of public relations; the advancement of and the professional and social status of members, and such other matters of similar nature as may be referred to it by the Board.

A. M. Rawn, *Chairman*

S. R. Probasco
J. H. Brooks
A. S. Bedell
M. S. Campbell
M. LeBosquet
D. E. Bloodgood

* Annual business meeting of Board of Control.
† Convention of membership-at-large.
‡ Annual business meeting of Board of Control and convention of membership-at-large.

Publications Committee

The Publications Committee arranges the technical programs for the annual conventions of the Federation and has general supervision of all publications of the Federation.

F. W. Gilcreas, *Chairman*

Rolf Eliassen
Carl M. Green
C. C. Larson
F. W. Mohlman
F. M. Veatch
W. H. Wisely

Organization Committee

The Organization Committee examines and reports to the Board on applications for membership in the Federation and endeavors to encourage the formation of new regional associations or conferences eligible for membership.

Earnest Boyce, *Chairman*

C. R. Compton
R. H. Suttie

Sewage Works Practice Committee

The Sewage Works Practice Committee reviews and directs for publication any resolution, report or publication which establishes professional or technical standards in the name of the Federation.

Morris M. Cohn, *Chairman*

J. H. Brooks, Jr.
J. R. Downes
G. P. Edwards
F. W. Gilcreas
H. F. Gray
C. E. Keefer
L. W. Van Kleeck
F. W. Mohlman
A. H. Niles
Langdon Pearse
W. H. Wisely
J. J. Wirts
Willem Rudolfs

Sub-Committee on Use of Sludge for Fertilizer

This sub-committee of the Sewage Works Practice Committee has the duty of compiling a Manual of Practice on "The Use of Sewage Sludge for Fertilizing Purposes." The manual is in a late stage of preparation and may be published in 1945.

A. H. Niles, *Chairman*

F. W. Gilcreas
Langdon Pearse
W. Rudolfs
T. C. Schaetzle
L. W. Van Kleeck

Sub-Committee on Occupational Hazards

This sub-committee of the Sewage Works Practice Committee has been assigned to compile a Manual of Practice on "Occupational Hazards in the Operation of Sewage Works." The manual has been completed and was distributed to the membership in December, 1944.

L. W. Van Kleeck, *Chairman*

S. H. Ash
Reuben F. Brown
Joseph Doman
Fred R. Ingram
L. L. Langford
L. E. West

Sub-Committee on Air Diffusion

This sub-committee of the Sewage Works Practice Committee has been charged with the duty of producing a Manual of Practice on "Air Diffusion in Sewage Treatment." The manual is in an early stage of preparation.

John J. Wirts, *Chairman*

W. A. Allen
A. J. Beck
A. A. Birger
H. A. Faber
C. T. Mickle
P. E. Morgan
F. C. Roe

Sub-Committee on Sewer Maintenance

This sub-committee of the Sewage Works Practice Committee has been directed to develop a Manual of Practice on "Maintenance of Sewers and Appurtenant Structures." The manual is in an early stage of preparation.

John H. Brooks, Jr., *Chairman*

C. G. Andersen
W. H. Brown, Jr.
G. E. Fink
Grant Olewiler
R. L. Patterson
C. W. Phillips
Roy E. Phillips
Richard Pomeroy
Robert P. Shea

Sub-Committee on Chlorination of Sewage

This sub-committee of the Sewage Works Practice Committee has been assigned the development of a Manual of Practice on "The Use of Chlorine in Sewage Treatment." The committee is in the process of organization.

F. W. Gilcreas, *Chairman*

Sub-Committee on Standardization of Units

This sub-committee of the Sewage Works Practice Committee has been assigned to develop an approved schedule of units to be used in the reporting of plant operation and laboratory data. The committee is in the process of organization.

Willem Rudolfs, *Chairman*

Research Committee

The Research Committee has the function of stimulating research work among the various Member Associations, and of co-operating with other organizations in the promotion of research.

H. Heukelekian, *Chairman*

H. E. Babbitt
D. E. Bloodgood
G. P. Edwards
H. A. Faber
A. J. Fischer
A. L. Genter
H. J. Miles
F. W. Mohlman
C. C. Ruchhoft
L. R. Setter
L. W. Van Kleeck

Special Committees

Committee on Awards

The Committee on Awards was created by the Board of Control on October 11, 1941. Functions of the committee are to advise the Board on matters of award procedures and to make recommendations as to the annual winners of the Eddy, Gascoigne and Emerson Awards.

G. P. Edwards, *Chairman*

E. S. Chase
G. M. Ridenour
L. F. Warrick

Honorary Membership Committee

Authorized by the Board of Control on October 24, 1942, this committee comprises the President and four latest, living Past Presidents with the senior Past President as chairman. The committee reviews nominations for election to the grade of Honorary Member and makes recommendations to the Board on such nominations.*

Charles A. Emerson, *Chairman*

A. S. Bedell — A. M. Rawn
G. J. Schroepfer — A. E. Berry

Finance Advisory Committee

The Finance Advisory Committee was created by the Board of Control on October 11, 1941, and has the duty of advising the Board and officers of the Federation in financial matters.

W. J. Orchard, *Chairman*

A. E. Berry — A. M. Rawn

Operation Reports Committee

The Operation Reports Committee was created by the Board of Control on October 11, 1941, to provide for Federation recognition of outstanding operation reports. The committee is now engaged in developing the mechanics of an annual award for such outstanding reports.

H. E. Babbitt, *Chairman*

Wm. A. Allen — W. F. Shepherd

Operator's Qualifications Committee

Authorized by the Board of Control on October 11, 1941, the Operator's Qualifications Committee is assigned to "establish minimal qualifications for operators of various classes of treatment works." The committee also has the duty of collecting and compiling data on present procedures in the licensing and certification of operators, for reference to Member Associations.

L. W. Van Kleeck, *Chairman*

Wm. A. Allen — E. P. Molitor

Industrial Wastes Committee

The Industrial Wastes Committee was created by the Board of Control on October 23, 1943, for the purpose of developing interest in this important field and to direct a program whereby the Federation may be of service in industrial waste problems.

F. W. Mohlman, *Chairman*

D. E. Bloodgood — L. F. Oeming
H. W. Gehm

Joint Committees With Other Associations

Committee on Standard Methods of Sewage Analysis

Created by the Board of Control on January 22, 1931, the Committee on Standard Methods of Sewage Analysis has functioned with committees of the American Water Works Association and American Public Health Association in the production of the Eighth Edition of the volume *Standard Methods of Water and Sewage Analysis.* The section on sewage analysis for the Ninth Edition was completed by the committee in 1943 and is now being edited for publication.

* See *This Journal,* 16, 1, 196 (January, 1944).

W. D. Hatfield, *Chairman*

G. E. Symons
S. E. Coburn
D. E. Bloodgood
F. W. Gilcreas
E. F. Hurwitz
Keeno Fraschino
W. S. Mahlie
H. Heukelekian
G. P. Edwards
E. W. Moore
M. Starr Nichols
Richard Pomeroy
C. C. Ruchhoft
Willem Rudolfs
H. W. Gehm

Committee on Sewage Works Nomenclature

The Committee on Sewage Works Nomenclature was created by the Board of Control on January 22, 1937, to function with similar committees of the American Society of Civil Engineers and American Public Health Association. This Joint Committee on Definition of Terms Used in Sewerage and Sewage Disposal Practice is now engaged in the compilation of a "Glossary of Water and Sewage Control Engineering," in conjunction with the Joint Committee on Definition of Terms Used in Water Works Practice, which comprises the American Society of Civil Engineers, American Public Health Association and American Water Works Association.

C. J. Velz, *Chairman*

C. E. Keefer
C. A. Emerson

Committee on Water and Sewage Works Development

The Committee on Water and Sewage Works Development was organized in 1943 to promote the planning of water and sewage works and to encourage the inclusion of such projects in postwar planning programs. The committee comprises representatives of the Water and Sewage Works Manufacturers Association, American Water Works Association, New England Water Works Association and the Federation of Sewage Works Associations. Federation representatives are:

C. A. Emerson
G. J. Schroepfer

Special Convention Committees

Convention Management Committee

The function of this committee is to supervise details of the management of the Annual Meetings of the Federation.

A. E. Berry, *Chairman*

Stanley Shupe
W. H. Wisely
W. J. Orchard
A. T. Clark

Meeting Place Committee

This committee reviews invitations received for the Annual Meetings of the Federation and makes recommendations to the Board of Control in regard to the time and place of such meetings.

A. E. Berry, *Chairman*

J. K. Hoskins
A. M. Rawn
W. H. Wisely
E. M. Jones
L. H. Enslow
A. T. Clark

Publicity and Attendance Committee

The function of this committee is to prepare publicity releases in connection with the Annual Meetings of the Federation and to direct the distribution of such material.

L. H. Enslow, *Chairman*

E. J. Cleary
M. M. Cohn
W. S. Foster
A. Prescott Folwell
J. P. Russell
J. A. Daly

SUMMARY OF MEMBERSHIP

(As at December 31, 1944)

Federation Members

Honorary Members	7
Associate Members	73
Member Associations	27
Active Members	2979
Alternate Active Members	32
Corporate Members	16

Net Membership of Member Associations *

Member Association	Honorary	Active	Alternate Active	Corporate	Total
Arizona	—	10	—	—	10
Canadian	—	162	—	—	162
California	1	289	12	—	302
Central States	2	529	—	12	543
Dakota	—	41	—	—	41
Federal	—	102	—	—	102
Florida	—	63	—	—	63
Georgia	—	53	—	—	53
I.S.E. (England)	—	32	—	—	32
I.S.P. (England)	—	98	—	—	98
Iowa	—	43	—	—	43
Kansas	—	19	—	—	19
Maryland-Del.	—	27	—	—	27
Michigan	—	106	15	—	121
Missouri	—	37	—	—	37
Montana†	—	—	—	—	—
New England	1	158	1	—	160
New Jersey	—	84	—	—	84
New York	1	490	4	1	496
North Carolina	—	58	—	—	58
Ohio	—	105	—	—	105
Oklahoma	—	5	—	—	5
Pacific Northwest	—	100	—	—	100
Pennsylvania	2	219	—	3	224
Rocky Mountain	—	71	—	—	71
San. Eng. Div. (Arg.)	—	10	—	—	10
Texas	—	68	—	—	68
Totals	7	2979	32	16	3034

* Not including Dual Members.

† New affiliate in October, 1944.

Directory of Members

December 31, 1944

MEMBER ASSOCIATIONS

Arizona Sewage and Water Works Association (Affiliated 1928).

Territory: State of Arizona.
President: H. H. Idle; *First Vice-President:* E. S. Borquist; *Second Vice-President:* Geo. W. Marx; *Director:* Geo. W. Marx; *Secretary-Treasurer:* Geo. W. Marx, Arizona State Dept. of Health, Phoenix, Arizona.

California Sewage Works Association (Affiliated 1928).

Territory: State of California.
President: Frank S. Currie; *First Vice-President:* Keeno Fraschino; *Second Vice-President:* G. A. Parkes; *Director:* Clyde C. Kennedy; *Secretary-Treasurer:* Harold H. Jeffrey, 112 City Hall, Sacramento, California.

Canadian Institute on Sewage and Sanitation (Affiliated 1933).

Territory: Dominion of Canada.
President: R. J. Desmarais; *Vice-President:* N. S. Nicklin; *Director:* Stanley Shupe; *Secretary-Treasurer:* A. E. Berry, Ontario Department of Health, Parliament Buildings, Toronto, Ontario.

Central States Sewage Works Association (Affiliated 1928).

Territory: States of Illinois, Indiana, Wisconsin and Minnesota.
President: W. D. Hatfield; *First Vice-President:* Capt. E. J. Beatty; *Second Vice-President:* P. W. Riedesel; *Third Vice-President:* Carl B. Carpenter; *Director:* Major B. A. Poole; *Secretary-Treasurer:* J. C. Mackin, Nine Springs Sewage Treatment Plant, Route 4, Madison 5, Wisconsin.

Dakota Water and Sewage Works Conference (Affiliated 1936).

North Dakota Section.

Territory: State of North Dakota.
President: F. W. Pinney; *Vice-President:* S. K. Svenkeson; *Director:* K. C. Lauster; *Secretary-Treasurer:* K. C. Lauster, State Department of Health, Bismarck, North Dakota.

South Dakota Section.

Territory: State of South Dakota.
President: M. J. Hoy; *Vice-President:* Harry Steckler; *Director:* K. C. Lauster; *Secretary-Treasurer:* Glen J. Hopkins, Division of Sanitary Engineering, State Board of Health, Pierre, South Dakota.

Federal Sewage Research Association (Affiliated 1930).

Territory: Federal employees wherever stationed.
President: F. E. DeMartini; *Vice-President:* J. H. LeVan; *Director:* M. LeBosquet, Jr.; *Secretary-Treasurer:* M. LeBosquet, Jr., U.S.P.H.S., East Third and Kilgour Sts., Cincinnati 2, Ohio.

Florida Sewage Works Association (Affiliated 1941).

Territory: State of Florida.
President: J. B. Miller; *Vice-President:* George W. Reid; *Director:* Fred A. Eidsness; *Secretary-Treasurer:* J. R. Hoy, 404 Hildebrandt Building, Jacksonville, Florida.

Georgia Water and Sewage Association (Affiliated 1936).

Territory: State of Georgia.

President: H. G. Wylds; *Vice-President:* W. G. Bryant; *Second Vice-President:* Comer Turley; *Director:* H. A. Wyckoff; *Secretary-Treasurer:* V. P. Enloe, R.F.D. No. 5, Box 363, Atlanta, Ga.

Iowa Wastes Disposal Association (Affiliated 1928).

Territory: State of Iowa.

President: T. R. Lovell; *Vice-President:* Paul Winfrey; *Director:* John W. Pray; *Secretary-Treasurer:* L. O. Stewart, Iowa State College, Ames, Iowa.

Institute of Sewage Purification (Affiliated 1932).

Territory: British Empire.

President: James H. Edmondson; *Director:* John H. Garner; *Secretary:* W. F. Freeborn, 34 Cardinal's Walk, Hampton-on-Thames, Middlesex, England.

Institution of Sanitary Engineers (Affiliated 1932).

Territory: British Empire.

President: Guy Howard Humphreys; *Director:* Guy Howard Humphreys; *Acting Secretary:* Mrs. E. M. Kerry, 118 Victoria St., Westminster, S.W. 1, London, England.

Kansas Water and Sewage Works Association (Affiliated 1935).

Territory: State of Kansas.

President: R. H. Hess; *First Vice-President:* Herman Weigand; *Second Vice-President:* F. D. Elliott; *Third Vice-President:* H. H. Huffman; *Fourth Vice-President:* Rex Reynolds; *Director:* Paul D. Haney; *Secretary-Treasurer:* Paul D. Haney, 1745 Louisiana St., Lawrence, Kansas.

Maryland-Delaware Water and Sewage Association (Affiliated 1928).

Territory: States of Maryland and Delaware.

President: J. W. Alden; *First Vice-President:* Clarke Gardner; *Second Vice-President:* J. W. Engle; *Director:* A. L. Genter; *Secretary-Treasurer:* Miss E. V. Gipe, State Department of Health, 2411 N. Charles St., Baltimore, Md.

Michigan Sewage Works Association (Affiliated 1930).

Territory: State of Michigan.

President: Paul Stegeman; *Vice-President:* B. A. DeHooghe; *Director:* W. F. Shepard; *Secretary-Treasurer:* R. J. Smith, Michigan Department of Health, State Office Building, Lansing, Michigan.

Missouri Water and Sewerage Conference (Affiliated 1929).

Territory: State of Missouri.

Chairman: John F. Sanders; *Vice-Chairman:* Roscoe R. Howard; *Director:* George S. Russell; *Secretary-Treasurer:* Warren A. Kramer, State Board of Health, 200 Monroe St., Jefferson City, Missouri.

Montana Sewage Works Association (Affiliated 1944)

Territory: State of Montana.

Chairman: J. M. Schmit; *Vice-Chairman:* W. M. Cobleigh; *Director:* H. B. Foote; *Secretary-Treasurer:* H. B. Foote, Division of Sanitary Engineering, State Board of Health, Helena, Montana.

New England Sewage Works Association (Affiliated 1929).

Territory: States of Maine, New Hampshire, Vermont, Massachusetts, Connecticut and Rhode Island.

President: Frank L. Flood; *First Vice-President:* George H. Craemer; *Second Vice-President:* Thomas R. Camp; *Director:* John W. Brooks; *Secretary-Treasurer:* L. W. Van Kleeck, State Department of Health, State Office Building, Hartford, Conn.

New Jersey Sewage Works Association (Affiliated 1942).

Territory: State of New Jersey.

President: John Simmerman; *First Vice-President:* L. J. Fontenelli; *Second Vice-President:* Edward P. Decker; *Treasurer:* Edward P. Molitor; *Director:* Edward P. Molitor; *Secretary:* John R. Downes, P.O. Box 11, Dunellen, N. J.

New York State Sewage Works Association (Affiliated 1930).

Territory: State of New York.

President: G. E. Symons; *Vice-President:* Uhl T. Mann; *Director:* C. G. Andersen; *Secretary-Treasurer:* A. S. Bedell, State Department of Health, Albany, New York; *Assistant Secretary:* A. W. Eustance; *Assistant Treasurer:* J. C. Brigham.

North Carolina Sewage Works Association (Affiliated 1929).

Territory: State of North Carolina.

Chairman: E. M. Johnson; *Vice-Chairman:* L. I. Lassiter; *Director:* W. M. Franklin; *Secretary-Treasurer:* D. M. Williams, P.O. Box 1170, Durham, North Carolina.

Ohio Sewage Works Conference (Affiliated 1932).

Territory: State of Ohio.

Chairman: J. R. Turner; *Vice-Chairman:* D. D. Heffelfinger; *Director:* C. D. McGuire; *Secretary-Treasurer:* L. B. Barnes, 127 Meeker St., Bowling Green, Ohio.

Oklahoma Water and Sewage Conference (Affiliated 1929).

Territory: State of Oklahoma.

President: Frank Taylor; *Vice-President:* Cecil Harrison; *Director:* Frank S. Taylor; *Secretary-Treasurer:* H. J. Darcey; Chief Engineer, Oklahoma State Department of Health, Oklahoma City, Okla.

Pacific Northwest Sewage Works Association (Affiliated 1933).

Territory: States of Washington, Oregon and Idaho.

President: C. V. Signor; *First Vice-President:* C. M. Howard; *Second Vice-President:* H. C. Clare; *Director:* M. S. Campbell; *Secretary-Treasurer:* W. P. Hughes, Lewistown, Idaho.

Pennsylvania Sewage Works Association (Affiliated 1928).

Territory: State of Pennsylvania.

President: L. D. Matter; *First Vice-President:* William J. Murdoch; *Second Vice-President:* Norman G. Young; *Director:* F. S. Friel; *Secretary-Treasurer:* Bernard S. Bush, District Engineer, Pennsylvania Dept. of Health, Kirby Health Center, Wilkes-Barre, Pennsylvania.

Rocky Mountain Sewage Works Association (Affiliated 1936).

Territory: States of Wyoming, Colorado and New Mexico.

President: Dana E. Kepner; *Vice-President:* Mike Leonard; *Director:* Dana E. Kepner; *Secretary-Treasurer:* Carroll H. Coberly, 1411 Welton St., Denver, Colorado.

Sanitary Engineering Division, Argentina Society of Engineers (Affiliated 1936).

Territory: Republic of Argentina.

President: Roberto J. Perazzo; *Director:* E. B. Besselievre *; *Secretary:* Julio Cavicchia, Division de Ingenieria Sanitaria, Centro Argentino de Ingenieros, Buenos Aires, Republica Argentina, South America.

Texas Sewage Works Section (Affiliated 1928).

Territory: State of Texas.

Chairman: E. J. M. Berg; *Vice-Chairman:* Capt. R. M. Dixon; *Director:* W. S. Mahlie; *Secretary-Treasurer:* V. M. Ehlers, State Department of Health, Austin, Texas; *Assistant Secretary-Treasurer:* Mrs. E. H. Goodwin.

* Term expired October, 1943. Successor not yet appointed.

HONORARY MEMBERS

Bedell, Arthur S. (1942), Div. of Sanitation, State Dept. of Health, Albany, N. Y.

Bugbee, Julius W. (1942), Supt., Sew. Disp. Wks., 25 New York Ave., Providence, R. I.

Emerson, Charles A. (1941), Havens & Emerson, Woolworth Bldg., New York, N. Y.

Hyde, Prof. Charles Gilman (1943), Rm. 11, Engr. Bldg., Univ. of Calif., Berkeley, Calif.

Mohlman, Dr. Floyd W. (1944), 910 S. Michigan Ave., Chicago 5, Ill.

Moses, Howard E. (1943), 1522 N. Second St., Harrisburg, Pa.

Pearse, Langdon (1942), Chicago San. Dist., 910 S. Michigan Ave., Chicago 5, Ill.

ASSOCIATE MEMBERS

Aluminum Co. of America, 2100 Gulf Building, Pittsburgh, Pa., Rep. C. E. Magill.

American Brass Co., Waterbury, Conn.

American Cast Iron Pipe Co., Birmingham, Ala., Rep. E. L. Gilder.

American City Magazine, 470 Fourth Avenue, New York, N. Y., Rep. Edgar J. Buttenheim, Pres. & Mgr.

American Well Works, Aurora, Ill., Rep. J. D. Walker, Sanitary Div.

Ampco Metal, Inc., 1745 South 38th St., Milwaukee 4, Wis., Rep. B. J. Bickel, General Sales Mgr.

Armco Drainage Products Assn., Middletown, Ohio, Rep. W. H. Spindler, Publicity Mgr.

Automatic Control Co., 1005 University Ave., St. Paul 4, Minn., Rep. J. S. Williams.

Builders-Providence, Inc., Div. of Builders Iron Foundry, P. O. Box 1342, Providence, R. I., Rep. C. G. Richardson.

Cambridge Instrument Co., 3732 Grand Central Terminal, New York, N. Y., Rep. F. G. Paully.

Carter, Ralph B., Co., 192 Atlantic St., Hackensack, N. J., Rep. J. W. Van Atta.

Chain Belt Company, Milwaukee, Wis., Rep. W. B. Marshall, Sales Promotion Mgr.

Chapman Valve Manufacturing Co., 203 Hampshire St., Indian Orchard, Mass.

Chicago Pump Company, 2300 Wolfram St., Chicago, Ill., Rep. Milton Spiegel, Vice-Pres. & Gen. Mgr.

Clay Products Ass'n, 111 W. Washington St., Chicago 2, Ill. Rep. J. D. Cook, Secy.

Crane Company, 836 S. Michigan Ave., Chicago 5, Ill., Rep. G. W. Hauck, Mgr., Eng. Sales Section.

Dickey, Clay Mfg. Co., W. S., 607 Commerce Trust Bldg, Kansas City, Mo., Rep. A. G. Frerking, Vice Pres.-Sales Mgr.

Dorr Co., Inc., 570 Lexington Ave., New York, N. Y.

Dow Chemical Co., Midland, Mich., Rep. Ralph B. Ehlers, Industrial Sales.

Eimco Corporation, 111 W. Washington St., Chicago 2, Ill., Rep. Paul O. Richter, Mgr. Central Div.

Electro Rust-Proofing Co., 1026 Wayne St., Dayton 10, Ohio, Rep. E. H. Ingle, Gen. Mgr.

Engineering News-Record, 330 W. 42nd St., New York, N. Y.

Everson Manufacturing Co., 214 W. Huron St., Chicago 10, Ill. Rep. R. B. Everson, Pres.

Fairbanks, Morse & Co., 80 Broad St., New York 4, N. Y., Rep. Charles J. Prestler, Manager Pump Sales.

Flexible Sewer-Rod Equipment Co., 9059 Venice Blvd., Los Angeles, Calif., Rep. Peter L. Ciacco, Mgr.

Foxboro Company, Neponset Avenue, Foxboro, Mass.

Gale Oil Separator Co., Inc., 52 Vanderbilt Ave., New York City, Rep. Wm. A. Gehle, Pres.

General Chemical Co., 3357 W. 47th Place, Chicago 32, Ill., Rep. L. I. Birdsall, Technical Service Div.

Glamorgan Pipe & Foundry Co., Lynchburg, Va., Rep. John D. Capron.

General Electric Co., 1 River Road, Schenectady, N. Y., Rep. H. V. Crawford.

Graver Tank & Mfg. Co., Inc., 4809 Tod Ave., E. Chicago, Ind., Rep. G. V. Malmgren, Vice-Pres.

Green Bay Fdy. & Machine Wks., 401 S. Broadway, Green Bay, Wis., Rep. James P. North, Pres.

Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo., Rep. Wm. P. Gruendler, Secy-Treas.

Hardinge Company, York, Pa., Rep. M. C. Fleming.

Hersey Manufacturing Co., Corner of E and Second Sts., South Boston 27, Mass. Rep. Wm. C. Sherwood.

Homelite Corporation, Port Chester, N. J., Rep. Nelson Thompson.

Infilco, Inc., 325 W. 25th Place, Chicago, Ill., Rep. H. W. Gillard.

Iowa Valve Co., 812 Hubbell Bldg., Des Moines, Iowa, Rep. C. S. Howard, Vice-Pres. & Gen. Mgr.

Jeffrey Manufacturing Co., Columbus, Ohio, Rep. J. X. Farrar, Adv. Mgr.

Johns-Manville Corporation, 22 E. 40th St., New York City, Rep. C. A. McGinnis, Mgr. Transite Pipe Dept.

Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill., Rep. R. O. Friend.

Limestone Products Corp. of America, Newton, N. J., Rep. Peter J. Kelley, Service Representative.

Link-Belt Company, 2045 W. Hunting Park Ave., Philadelphia, Pa., Rep. Geo. M. Sharer.

Ludlow Valve Mfg. Co., P. O. Drawer 388, Troy, N. Y., Rep. Robert Bischoff.

Lynchburg Foundry Company, Lynchburg, Va., Rep. W. Ray Odor.

Mathieson Alkali Works, Inc., 60 E. 42nd St., New York 17, N. Y.

Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa., Rep. N. R. Chillingworth, Sales Statistical Dept.

Monsanto Chemical Company, Merrimac Div., Everett Station, Boston, Mass., Rep. J. J. McCarthy.

Mueller Company, 512 W. Cerro Gordo St., Decatur, Ill.

Munroe, James A. & Sons, 160 N. Washington St., North Attleboro, Mass., Rep. James E. Munroe.

National Water Main Cleaning Co., 30 Church St., New York, N. Y., Rep. Clinton Inglee, Pres. & Gen. Mgr.

Nichols Engineering & Research Corp., 60 Wall Tower, New York, N. Y., Rep. R. W. Rowen, Vice-Pres.

Omega Machine Company, 9 Codding St., Providence, R. I.

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill., Rep. L. E. Rein, Pres.

Pennsylvania Salt Mfg. Co., 1000 Widener Building, Philadelphia, 7, Pa., Rep. L. L. Hedgepeth, Mgr.

Pittsburgh-Des Moines Co., Neville Island Branch, Pittsburgh, Pa., Rep. J. E. O'Leary.

Pittsburgh Equitable Meter Co., 400 N. Lexington Ave., Pittsburgh, Pa., Rep. R. S. Reed, Jr., Advtg. Mgr.

Proportioneers, Inc., P. O. Box 1442, Providence, R. I., Rep. H. E. Hollberg, Vice-Pres.

Public Works Magazine, 310 E. 45th St., New York, N. Y.

Quigley Company, Inc., 527 Fifth Ave., New York City 17, N. Y., Rep. H. L. Stedfeld.

Royer Foundry & Machine Co., 158 Pringle St., Kingston, Pa., Rep. S. B. Davies, Pres. & Gen. Mgr.

Sewage Works Engineering, 24 W. 40th St., New York, N. Y., Rep. Karl M. Mann.

Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa., Rep. Everett M. Jones, Sales Mgr.

Smith Manufacturing Co., A. P., 545 N. Arlington Ave., East Orange, N. J., Rep. W. P. Baerenrodt, Treas.

Stuart-Brumley Corp., 516 N. Charles St., Baltimore, Md., Rep. Fred E. Stuart.

United States Pipe & Foundry Co., Burlington, N. J.

Vapor Recovery Systems Co., 30 Church St., New York City, Rep. C. T. Stanhope, Eastern Sales Mgr.

Wailes Dove-Hermiston Corp., Westfield, N. J., Rep. W. H. T. Thornhill, Vice-Pres.

Wallace & Tiernan Co., Inc., 11 Mill St., Belleville, N. J., Rep. B. M. Lindsay.

Water Works & Sewerage, 155 E. 44th St., New York, N. Y.

Wood, R. D., Co., 400 Chestnut Street, Philadelphia, Pa., Rep. Chas. Becker, Sales Mgr.

Worthington Pump & Machinery Corp., Harrison, N. J.

Yeomans Bros. Co., 1343 Dayton St., Chicago, Ill., Rep. Chas. Yeomans, Pres. & Treas.

MEMBERSHIP OF MEMBER ASSOCIATIONS

Arizona Sewage and Water Works Association

Mr. Geo. W. Marx, *Secretary-Treasurer*, Sanitary Engineering Division, Arizona State Department of Health, Capitol Building, Phoenix, Arizona.

Bejcek, Otto, P.O. Box 1486, Coolidge, Ariz.

Borquist, E. S., Prof., Head Dept. of Civil Engr., University of Arizona, Tucson, Ariz.

Cushing, Robert, 948 Ash Ave., Tempe, Ariz.

Johannessen & Girand, Consulting Engineers, Ellis Bldg., Phoenix, Ariz.

King, Ed. E., Supt., Upper Verde Public Utilities Co., Clarkdale, Ariz.

Ladlow, John, Box 1784, Phoenix, Ariz.

Luthin, John C., Sanitary Engineering Div., State Dept. of Health, Phoenix, Ariz.

Marx, Geo. W., State San. Engr., State Bd. of Health, Phoenix, Ariz.

Miller, Alden W., 1833 N. 13th Ave., Phoenix, Ariz.

Travaini, Dario, 69 W. Wilshire Dr., Phoenix, Ariz.

California Sewage Works Association

Mr. Harold H. Jeffrey, *Secretary-Treasurer*, 112 City Hall, Sacramento, Calif.

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Burgess, Harold, New York
Burley, Fred H., Michigan
Burn, G. A. H., Canada
Burnett, A. H., Canada
Burnson, Blair I., California
Burr, R. S., New England
Burrell, Robert, New England
Burrin, Thomas J., Central States
Burt, Gordon L., Central States
Bush, A. F., California
Bush, Archie E., New York
Bush, Bernard S., Pennsylvania
Bushee, Ralph J., Central States
Butrico, Frank, New York
Butterfield, C. T., Federal
Butterworth, C. C., Missouri
Byxbee, J. F., California

Cadwell, Ivan W., New York
Cahill, Wm. J., Jr., New York
Caird, James M., New York
Calder, Charles L., California
Calderara, O. J., Federal
Caldwell, David H., California
Caldwell, H. L., Central States
Callen, Loy A., Central States
Callon, Harry A., Central States
Calvert, A., England (I.S.P.)
Calvert, C. K., Central States
Cambridge Instrument Co., Associate
Cameron, A. B., Michigan
Cameron, Geo., New Jersey
Camp, Cecil S., North Carolina
Camp, Thomas R., New England
Campbell, A. S., South Dakota
Campbell, John, Pennsylvania
Campbell, J. L., England (I.S.P.)
Campbell, M. S., Pacific Northwest
Capano, Sam J., New Jersey
Capen, Charles H., Jr., New Jersey
Capone, Domenic, Federal
Capraro, Paul E., Central States
Capwell, Water, New England
Caracausa, Albert C., New England
Cardillo, Wm. V., California
Cardwell, Edw. C., Central States
Carey, Wm. N., Central States
Carl, Charles E., Missouri
Carlson, A. J., Canada
Carlson, H. R., Federal
Carlson, Paul R., Central States
Carmichael, Davis W., New Jersey
Carnahan, Chas. T., Federal
Carolina Aluminum Co., North Carolina
Carothers, Chas. H., Florida
Carpenter, Carl B., Central States
Carpenter, Geo. D., New York
Carpenter, Harry C., New York
Carpenter, Howard F., New England
Carpenter, J. D., Pennsylvania
Carpenter, Wm. T., New York
Carrique, Carlos S., Argentina
Carroll, Geo. B., New York
Carson, R. G., Central States
Carter, Alton B., California
Carter, Bruce F., New York
Carter, Earl, Central States
Carter, Co., Ralph B., Associate, Att'n., J. W. Van Atta
Cary, F. Arthur, New York
Cary, Glen, Rocky Mountain
Cary, W. H., Jr., Federal
Cary, Willis E., New England
Casad, C. C., Pacific Northwest
Case, Raymond G., New Jersey
Casey, Albert E., New England
Casey, John J., California
Cash, Kenneth, Texas
Castello, W. O., California
Caster, Arthur, Central States
Caulwell, Wilson S., Pennsylvania
Cederberg, C. R., Rocky Mountain
Cenicola, Samuel, New Jersey
Ceriat, Eugene, California
Cerny, Paul J., New York (Dual—New England)
Chain Belt Co., Associate, Att'n: W. B. Marshall
Chamberlain, L. H., New York
Chamberlain, Wm. T., New York
Chamberlin, Noel S., New Jersey
Chambers, Grover, Pacific Northwest
Chamier, A. U., Michigan
Chanlett, Emil T., California
Chapman, Howard W., Federal
Chapman Valve Mfg. Co., Associate
Charlton, David B., Pacific Northwest
Chase, E. Sherman, New England (Dual—New York, and Pennsylvania)
Chasick, Abraham H., New York
Cheadle, Wilford G., Central States
Chesney, C. T., Canada
Chester, Burke, Florida
Chicago Pump Co., Associate, Att'n: Milton Spiegel
Chisholm, Colin B., New York
Chisholm, D. M., Canada
Chisholm, Henry, New England
Christensen, Gordon R., Central States
Christian, J. A., England (I.S.P.)
Christianson, A. C., Michigan
Church, Dean F., Central States
Chutter, H. W., California
Cipriano, Anthony G., New York
City of Webster City, Iowa, Att'n: Leo Holtkamp, Supt., Iowa
City Water Dept. (Statesville, N. C.), North Carolina
Claffey, Walter H., New England
Clare, H. C., Pacific Northwest
Clark, Alfred, Kansas
Clark, Arthur T., Central States (New York—Comp.)
Clark, Boyd H., New York
Clark, H. W., England (I.S.E.)
Clark, J. C., California
Clark, Joseph R., Michigan
Clark, Kenneth M., Central States
Clark, Lloyd K., North Dakota
Clark, M. S., Michigan
Clark, Robert N., New York
Clarke, Samuel M., Central States
Clarke, V. B., New England
Clarkson, G. H., Canada
Classen, Ashley G., Texas
Clawson, Earl M., Florida
Clay, H., England (I.S.P.)
Clay Products Assoc., Associate, Att'n: J. D. Cook
Clear Lake, City of, Iowa
Cleary, Edw. J., New Jersey
Cleland, R. R., Pennsylvania
Clem, Curtis B., Central States
Clements, G. S., England (I.S.P.)
Cleveland, E. A., Canada
Clifford, Gilbert W., Florida
Clifford, W., England (I.S.P.)
Clore, L. B., Central States
Clouser, L. H., Pennsylvania
Cloyes, W. J., Pacific Northwest
Clubb, William C., Pacific Northwest
Coates, John J., New York
Cobb, Edwin B., New England
Coberly, Carroll H., Rocky Mountain
Coburn, S. E., New England
Cochrane, John C., New York
Cochrane, W. F., South Dakota
Cockroft, T. N., England (I.S.P.)
Coffey, Michael J., New York
Cohn, Morris M., New York (Dual—New England)
Cole, Arthur F. W., Canada
Cole, Chas. W., Central States
Cole, E. Shaw, New York
Cole, H. B., Texas
Cole, Harvey M., Jr., California
Coleman, Dwight B., New York
Collard, A. E., England (I.S.E.)

Collier, James, Ohio
Collings, Wm. E., New Jersey
Collins, A. J., England (I.S.E.)
Collins, A. Preston, California
Collins, John T., New York
Collins, W. H., Canada
Collison, Okla C., Missouri
Collyer, Joseph C., New York
Colquhoun, Colin, New York
Colsen, Justin, North Dakota
Coltart, Rodney F., New England & Pennsylvania
Compton, C. R., California
Conant, F. M., Canada
Condrey, Lawrence M., Central States
Connell, C. J., Texas
Connell, Maurice H., Florida
Consoer, Arthur W., Central States
Cook, Lawrence H., California
Cook, Max E., California
Cook, Rodney E., New York
Cook, S. J., Canada
Cooley, E. C., California
Cooley, Henry A., New York
Coombs, E. P., England (I.S.E.)
Coope, Albert, Ohio
Cooper, G. F., England (I.S.P.)
Copeland, Kern Hadley, California
Copeland, Wm. R., New England (Dual—New York)
Coplen, Warren W., Rocky Mountain
Copley, Chas. H., New England
Corbett, Walter E., New England
Corcoran, J. D., Canada
Corddry, W. H., Pennsylvania
Corey, R. H., Pacific Northwest
Cornell, R. M., Central States
Cornilson, C. K., Central States
Corson, B. I., New Jersey
Corrington, C. E., Central States
Cortelyou, H. P., California
Costello, John J., New York
Cotta, Maurice L., Pacific Northwest (Dual—Federal)
Cotterell, G. T., England (I.S.E.)
Cotton, Edwin R., New York
Cottrell, H. S., New York
Couch, L. I., Central States
Coulson, C. L., Canada
Cousineau, A., Canada
Covert, Henry Rew., Central States
Covill, R. W., England (I.S.P.)
Cowles, M. W., New Jersey (Dual—New York)
Cox, Clifford B., Central States
Cox, C. R., New York
Coy, Burgis, Rocky Mountain
Craemer, George H., New England
Craig, Clifford, Central States
Craig, J. D., Georgia
Craig, Robt. H., Pennsylvania
Cranch, Eugene T., New York
Crane Company, Associate, Att'n: G. W. Hauck
Crane, H. R., California
Crane, Harlan B., New York
Craun, J. M., Ohio
Crawford, H. V., New York
Creears, T. H., California
Creedmoor, Town of, North Carolina
Crockett, Vernon P., Federal
Crocker, Harold S., New England
Croft, H. P., New Jersey
Crooks, Howard, Michigan
Cropsey, W. H., Central States
Crosnoe, G. C., Central States
Cross, Russell, Central States
Crow, Harry B., Pacific Northwest
Crundall, S. F. W., England (I.S.P.)
Culley, Walter M., New York
Culli, George O., Jr., Texas
Cullison, Eugene F., New York
Cunningham, John W., Pacific Northwest
Cunningham, M. B., Oklahoma
Currie, Frank S., California
Cushing, Robert, Arizona
Cushman, S. P., Central States
Cutting, O. S., Pacific Northwest
Cyr, Rene, Canada
Czerepinski, Henry Peter, Central States

Dagg, Ralph G., Iowa
Dagger, G. E., Rocky Mountain
Dahl, Arve H., Federal
Daireaux, Carlos F., Argentina
D'Aleo, A. R., New York
Daley, Stanley J., Central States
Daly, James A., Canada
Damon, Nelson A., New England
Damon, Wayne F., New England
Damoose, N. G., Michigan
Daniels, F. E., Pennsylvania
Daniels, P. N., New Jersey
Darby, George M., New England
Darby, W. A., Pennsylvania (Dual—New York)
Darling, E. H., Canada
Dashiell, Walter N., Federal
Davenport, Llewellyn D., California
Davey, H. W., California
Davids, E. M., California
Davidson, J. F., California
Davis, Charles A., Rocky Mountain
Davis, Clarence A., New York
Davis, D. A., Central States
Davis, Edward T., Pennsylvania
Davis, Frederick E., Central States
Davis, G., Jr., Pacific Northwest
Davis, Howard A., Central States
Davis, H. F., North Carolina
Davis, P. D., North Carolina
Davis, T. J., Georgia
Dawson, Arthur, New York
Dawson, F. M., Iowa
Dawson, Norman, Central States
Dawson, Thomas T., Pennsylvania
Day, L. A., Central States
Dayton, Alfred E. (Alt.), New York
DeBerard, W. W., Central States
DeBrito, F. Saturnino, Jr., New York
Debrun, John W., Jr., Central States
Decker, C. D., Ohio
Decker, Edward P., New Jersey
Decker, Herbert M., Federal
Decker, Walter G., Central States
Deckert, Christ, Central States
DeGroat, Frank N., New York
DeHaas, Nicholas, New England
DeHooghe, Bernard A., Michigan
de Jarnette, N. M., Georgia
DeLano, Huntley, Michigan
DeLeuw, C. E., Central States
Dellasala, John J., New York
DeMartini, Frank E., California (Dual—Federal)
Deming, P. H., California
Demorest, S. L., Michigan
DeMoss, Samuel, Pacific Northwest
DeMunn, E. M., New York
Denise, Wm. D., New York
Dennis, Carl E., Michigan
Dent, Harry, New York
DePoy, A. G., Central States
Depp, David, Central States
Derby, Ray L., California
Dermitt, Chas. W., Pennsylvania
Deslauriers, A. J., Canada
Desmarais, R. J., Canada
Des Moines, City of, Iowa
Deuchler, Walter E., Central States
DeVal, Eric, Rocky Mountain
Devendorf, Earl, New York
Dewante, Randolph H., California
Dewart, Donald M., New York
DeWolf, A. B., Florida
Dick, Robert, Jr., Central States
Dickey Clay Mfg. Co., W. S., Associate, Att'n: A. G. Frerking
Dickson, D. B., Texas
Dickson, W. K., North Carolina
Diefendorf, Fred G., Pennsylvania
Dietz, Jess C., Central States
Dietz, John, Central States
DiIorio, Anthony F., New Jersey
Diller, Walter W., Central States
Dimmitt, Bruce S., Central States
Dion, Clarence K., New England
Disario, G. M., New England
Dixon, F. S., South Dakota
Dixon, G. Gale, New York
Dixon, R. M., Texas
Doane, C. C., California
Dobstaff, Robert, Jr., New York
Dobstaff Robert W., Sr., New York
Dodd, C. K. S., Florida
Dodge, H. P., Michigan
Dodson, Roy E., Jr., Pacific Northwest
Dodson, Wm. T., New York
Doman, Joseph, New England (Dual—New York)
Domke, L. C., Central States
Domogalla, Bernhard, Central States
Donaldson, Wellington, New York
Donnell, Geo. M., Rocky Mountain
Donnelly, Robert M., New England
Donnini, Frank L., New England
Dopmeyer, A. L., Federal (Dual—California)
Dore, Stanley M., New England
Dorr Co., Inc., Associate
Dorr, Fred, Michigan
Douthitt, Merton J., Michigan
Dow Chemical Co., Associate, Att'n: Ralph B. Ehlers
Dowd, Ira, Michigan
Downer, Wm. J., Central States
Downes, John R., New Jersey
Downing, Francis J., New York
Doyle, Thomas J., Michigan
Doyle, Wm. H., Central States
Dozier, B. C., Texas
Drake, James A., Central States
Dreier, D. E., Central States
Drew, Samuel T., New England
Drexel, Frederick, New York
Driscoll, Timothy J., New York
Drummond, A. H., England (I.S.P.)
Dudley, D. E., Central States
Dudley, Richard E., New England
Duell, Garth H., California
Dufficy, Frank J., New York
Duffy, Ora, Kansas
Dufresne, Paul Ed., Canada
Duncan, Roland, California
Dundas, Wm. A., Central States
Dunmire, E. H., Central States
Dunn, Town of, (North Carolina) North Carolina
Dunstan, Gilbert H., California
Durand, Edwin M., Michigan
Durham Water Dept. (North Carolina), North Carolina
Durr, John J., Jr., Pennsylvania
Durrant, W. K. F., Canada
Dust, Joseph V., Central States
Duvall, Arndt J., Central States
Dyckman, Warren W., New York
Dyer, Samuel, New England

Eager, Vernon, New York
Earl, Ralph, Georgia
Early, Fred J., Jr., California
Early, Mart, Pacific Northwest
Easdale, W. C., England (I.S.E.)
Easley, G. E., California
Eastburn, W. H., Pennsylvania
Easter, Charles W., New England
Easterday, Conrad G., Florida
Eckbert, Chester A., Pennsylvania
Ecusta Paper Corp., North Carolina, Att'n: Herbert F. Finck
Eddy, Harrison P., Jr., New England
Edgecombe, G. H., Canada
Edgerley, Edward, Pennsylvania
Edighoffer, Albert, New York
Edmond, H. P., Georgia
Edmondson, J. H., England (I.S.P.)
Edwards, G. H., Pacific Northwest
Edwards, Gail P., New York
Edwards, Harlan H., Pacific Northwest
Edwards, William L., New York
Egan, J. H., California
Egger, Oscar O., Central States
Eglof, Warren K., New York
Ehle, Virgil, New York
Eich, Henry F., New York
Eidsness, Fred A., Florida
Eimco Corporation, Associate, Att'n: Paul O. Richter
Elder, Leiton J., California
Eldora, City of, (Iowa), Iowa
Electro Rust-Proofing Co., Associate Att'n: E. H. Ingle
Eldridge, E. F., Michigan
Elias, Geo. A., Pennsylvania
Eliassen, Rolf, New York
Elkland Leather Co., Inc., Pennsylvania
Elmendorf, C. E., New York
Ell, Henry T., New Jersey
Ellms, J. W., Ohio

Ellsworth, Samuel M., New England
Elmore, Howard, Central States
Elnor, Geo. E., Canada
Elsdon, G. D., England (I.S.P.)
Ely, E. H., England (I.S.E.)
Emerson, C. A., Pennsylvania
Emigh, Wm. C., Pennsylvania
Engineering News-Record, Associate
English, Joseph, Jr., Pennsylvania
English, Leslie B., Canada
Enloe, V. P., Georgia
Enoch Pratt Free Library, Maryland-Delaware
Enslow, L. H., New York
Epler, J. E., Central States
Erichson, Roy H., Central States
Erickson, Carl V., Central States
Erickson, John E., Iowa
Erickson, F. K., Federal
Erickson, W. J., New York
Escritt, L. B., England (I.S.P.)
Estrada, Alfred A., Pennsylvania
Ettinger, M. B., Federal
Eustance, Arthur W., New York
Eustance, Harry W., New York
Evans, Byron B., New York
Evans, David A., Pennsylvania
Evans, F. M., New Jersey
Evans, James, Pennsylvania
Evans, R. W., Central States
Evans, S. C., England (I.S.P.)
Everest, Howard, New York
Everson Manufacturing Co., Associate, Att'n: R. B. Everson
Everson, R. B., Central States

Faber, Harry A., New York (Dual—Pennsylvania)
Faget, Walter H., Central States
Fair, Gordon M., New England (Dual—New York)
Fairbanks, Morse & Co., Associate, Att'n: Charles J. Prestler
Fales, Almon L., New England
Falls, O. M., Canada
Fanning, Harold R., New York
Farnsworth, George L., Jr., Central States
Farrant, James, New Jersey
Farrar, J. H., California
Farrell, Michael, New York
Fassnacht, Geo. G., Central States
Faulkner, T. G., England (I.S.E.)
Fawls, James F., New York
Feierstein, Jacob L., New York
Feldhake, C. J., Federal
Feltz, Fred C., Central States
Fenger, J. W., New York
Fenn, Ernest G., New England
Fenton, John V., New York
Ferebee, James L., Central States
Ferguson, G. H., Canada
Ferguson, Gerald W., Federal
Ferris, James E., New England (Dual—New York)
Field, Emerson & Morgan, Inc., New York
Figeley, Paul, Central States
Filby, E. L., Missouri
Filkins, D. A., (Alt.) Michigan
Finch, J., England (I.S.P.)
Finch, Lewis S., Central States
Finch, R. M., Central States
Finch, G. E., Maryland-Delaware
Findlay, Arthur, New York
Finkbeiner, Carleton S., Ohio
Finley, Dexter L., California
Finley, T. R., Florida
Fischer, Anthony J., New York
Fischer, F. P., Ohio
Fiscus, A. E., California
Fish, R. S., California
Fishbeck, Kenneth, Michigan
Fisher, Lawrence M., Federal
Fiskett, F. J., Central States
Fitch, T. A., California
Fittro, Louis L., Federal
Fitzgerald, Edw. P., Central States
Fitzgerald, J. A., New York
Fitzgerald, Joseph, New England
Five, Helge, New York
Fiveash, Charles E., Florida
Flanagan, Joseph E., Jr., Pennsylvania
Flanagan, Pat, Florida
Flannery, Harold J., California
Flatt, Truman L., Central States
Fleet, Gerald A., New York
Fleming, M. C., Pennsylvania
Fleming, Paul V., New England
Flexible Sewer-Rod Equipmen Co., Associate, Att'n: Peter L. Ciacco
Flood, Frank L., New England
Flood, T. S., Pacific Northwest
Flower, G. E., Ohio
Flowers, E., England (I.S.P.)
Foncannon, Gareld, Texas
Fontenelli, Louis, New Jersey
Foote, Kenneth E., New England
Forbes, Albert F., New York
Ford, J. R., Central States
Fore, Clifford, Central States
Foreman, Merle S., (Alt.) California
Forest City, City of (Iowa), Iowa
Forrest, Thos. K., Central States
Fort, Edwing J., New York
Fort Dodge, City Of (Iowa), Iowa
Fortenbaugh, J. Warren, New York
Fortman, John A., Central States
Foster, Chas., Central States
Foster, Herbert, Jr., California
Foster, Norman, Pennsylvania
Foster, Richard G., Michigan
Foster, Robert F., Rocky Mountain
Foster, William Floyd, California
Foth, Herbert S., Central States
Fowler, G. J., England (I.S.P.)
Fowler, H. D., Pacific Northwest
Fowler, James D., Texas
Foxboro Company, Associate
Francis, Geo. W., Michigan
Francis Hankin & Co., Ltd., Canada
Franklin, W. M., North Carolina
Franks, John T., Rocky Mountain
Fraschino, Keeno, California
Fraser, Charles E., Canada
Fraters, E. W., California
Frazier, Ernest, Central States
Frazier, Leonard H., New York
Frazier, Royall C., Georgia
Frazier, R. W., Central States
Frazier, W. H., Central States
Frederich, Hoyt A., Central States
Frederickson, LeRoy, California
Freeborn, W. F., England (I.S.P.)
Freeland, B. H., Central States
Freeburn, H. M., Pennsylvania
Freeman, A. B., Federal
Freeman, W. B., Rocky Mountain
Freer, Paul H., California
French, R. Del., Canada
Freund, J. P., Pennsylvania
Frick, A. L., Jr., California
Frickstad, Walter N., California
Fricker, Augustus E., Pennsylvania
Friedman, S. N., New Jersey
Friedman, Wm. M., Jr., New York
Friel, F. S., Pennsylvania
Friendly, Hugo H., New York
Frith, Gilbert R., Georgia
Froehde, F. C., California
Frye, Jacob E., New Jersey
Fuchs, Abraham W., Federal
Fuehrer, Carl W., Pennsylvania
Fuhrman, Ralph E., Federal
Fuller, H. L., Missouri
Fuller, N. M., New York
Fuller, Raymond H., Ohio
Fulmer, Frank E., Central States
Funk, John B., Maryland-Delaware
Funk, John T., Jr., Pennsylvania
Fynn, Geo. F., New York

Gade, A. H., New York
Gadomski, Albert J., New Jersey
Gail, A. L., Central States
Gale Oil Separator Co., Associate Att'n: Wm. A. Gehle
Gard, Chas. M., New York
Gardner, Clarke, Maryland-Delaware
Gardner, Geo. W., New York
Gardner, R. T., California
Garland, C. F., Florida
Garlock, Samuel C., New York
Garner, J. H., England (I.S.P.)
Garrett, R. W., Canada
Garthe, E. C., Federal
Garvelink, Frank, (Alt.) Michigan
Garwood, Kirk, Iowa
Gass, George M., Canada
Gatley, H. K., New Jersey
Gaudin, E. L., Ohio
Gauntt, W. C., Texas
Gause, Frank R., Central States
Gavett, Weston, New York
Gearhart, J. N., Pacific Northwest
Gehm, Harry Willard, Jr., New Jersey
Gelbke, Arthur W., New York
Gellon, Edmundo R., Argentina
Gelston, W. R., Central States
General Chemical Co., Associate, Att'n: L. I. Birdsall
General Electric Co., Associate, Att'n: H. V. Crawford
Genter, Albert L., Maryland-Delaware
Gentsch, Edward, Michigan
George, J. E., Missouri
George, J. W., California
Gerard, F. A., Central States
Gerdel, W. E., Ohio
Gere, William S., New York
Gerhart, Edgar, Pennsylvania
Getz, Murray A., Central States (Dual—Federal)
Gibeau, H. A., Canada
Gibbons, E. V., Canada
Gibbons, M. M., New Jersey
Gibbs, Frederick S., New England
Gibbs, R. C., England (I.S.P.)
Gidley, H. K., Pennsylvania
Giesey, J. K., Central States
Gietz, Carlos E., Argentina
Gifford, J. B., Central States
Gifft, H. M., New York
Gilbert, J. J., Pennsylvania
Gilbert, J. Miles, Florida
Gilcreas, F. Wellington, New England (Dual—New York)
Giles, J. Henry L., New England
Gilkey, A. E., California
Gill, John B., California
Gill, Paul, Pennsylvania
Gillard, J. E., England (I.S.P.)
Gillespie, C. G., California
Gillespie, E. A., Texas
Gillespie, Wylie W., Florida
Gilman, Floyd, New York
Gilman, Harry I., Georgia
Gilman, N. A., Pacific Northwest
Gisborne, Frank R., (Alt.) New England
Glace, I. M., Pennsylvania (Dual—New York)
Gladding, Charles, California
Gladue, Donat J., New England
Glamorgan Pipe & Foundry Co., Associate
Glines, Robert A., New England
Glynn, William J., New York
Gmeiner, Frank, Central States
Godfroy, J. I., Michigan
Goeke, R. H., Federal
Goff, James S., New England
Goff, Wm. A., Pennsylvania
Goicoechea, Leandro de, Florida
Golbert, George M., Rocky Mountain
Goldsmith, Philip, New York
Goldthorpe, H. H., England (I.S.P.)
Gooch, E. W., Pacific Northwest
Goodman, Arnold H., Central States
Goodnight, V. L., Pacific Northwest
Goodridge, Harry E., California
Goodwin, S. E., Canada
Gordon, Arthur, Central States
Gordon, Charles W., Central States
Gordon, J. B., Federal
Gorman, Richard C., Jr., New York
Gorman, Wm. A., Pennsylvania
Goslau, Richard, New Jersey
Gotaas, Harold B., North Carolina
Goudey, R. F., California
Gould, Richard H., New York
Grabbe Construction Co., H. A., Central States
Graber, Ralph Carl, Federal
Gracenin, Sylvester, Pennsylvania
Graden, Paul W., Central States
Graemiger, Joseph A., New England
Graf, Edward G., New York
Graham, Edward J., New York
Graham, E. H., California
Graham, James E., Michigan
Gran, John E., Georgia
Granger, George M., New England
Grant, A. J., (Alt.) California

Grant, Howard L., Texas
Grantham, Geo. R., Central States
Graul, Leroy H., New Jersey
Graver Tank & Mfg. Co., Inc., Associate, Att'n: G. V. Malmgren
Gray, Earl G., Michigan
Gray, Harold F., California
Greeley, Richard F., New England
Greeley, Samuel A., Central States
Green, Alvin W., Pacific Northwest
Green Bay Fdy. & Machine Wks., Associate, Att'n: James P. North
Green, Carl E., Pacific Northwest
Green, Howard R., Iowa
Green, Roy F., Central States
Green, Wingate, Florida
Greene, J. F., Rocky Mountain
Greene, R. A., Michigan
Greenfield, H. C., New Jersey
Greenleaf, John W., Jr., New England
Gregory, The John H., Stationary & Municipal Reference Library, California
Gregory, L. L., England (I.S.E.)
Gregory, Ted R., California
Greig, John M. M., New York
Grelick, David, New York
Gresham, Paul J., Texas
Grieff, Victor C., New York
Griffin, A. E., New Jersey
Griffin, F. T., New York
Griffin, Guy E., New England
Griffin, H. P., Texas
Griffith, Charles R., Central States
Griffith, L. B., Texas
Grimes, Ben. L., Jr., Texas
Grimsley, J. T., Federal
Grinnell Company, Inc., North Carolina
Grinnell, Russell, Michigan
Groen, Michael A., Michigan
Gromada, Stanley, Georgia
Gross, Carl D., Central States
Gross, Dwight D., Rocky Mountain
Grossart, L. J. H., Pennsylvania
Grosshans, Edw. W., Central States
Grover, Robert H., New York
Gruendler Crusher & Pulverizer Co., Associate, Att'n: Wm. P. Gruendler
Gruss, A. W., California
Gruss, John G., Pennsylvania
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Hamlin, F. M., Texas
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Johnson, Milan, Federal
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Keefer, R. K., Pennsylvania
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Kershaw, Arnold, England (I.S.P.)
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Kingsbury, H. N., Central States
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Kingston, T. M. S., Canada
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Kinney, E. F., Central States
Kinney, J. B., Canada
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Marshall, Leslie S., New York
Marshall, W. B., New York, Also see Chain-Belt Co.
Marston, Frank A., New England
Martens, Myron M., Central States
Martin, A. E., New York
Martin, Alexander G., New York
Martin, Charles P., California
Martin, Edw. J., Jr., New York
Martin, George W., Pennsylvania

Martin, Geo. W., Central States
Martin, Stanley F., California
Martin, Sylvan C., Central States
Marx, Frank, New York
Maryland State Dept. of Health, (Maryland) Maryland-Delaware
Marx, Geo. W., Arizona
Mather, Edw. K., South Dakota
Mathers, Geo., New York
Mathews, E. R., South Dakota
Mathews, Frank E., Pacific Northwest
Mathews, W. W., Central States
Mathieson Alkali Works, Inc., Associate
Matter, L. D., Pennsylvania
Mattox, Leon, Central States
May, D. C., Michigan
May, Harold L., California
Mebus, Geo. B., Pennsylvania
Meckler, Wm. G., Federal
Medbery, H. Christopher, California
Megaw, Evelyn, Pennsylvania
Meeker, Herbert J., New York
Melander, William E., Sr., New York
Melburg, Fred, Rocky Mountain
Menefee, James H., Georgia
Mendelsohn, I. W., New York
Menzenhauer, F. C., New Jersey
Menzies, D. B., Canada
Menzies, J. Ross, Canada
Meredith, L. A., Central States
Merkel, Paul P., Pennsylvania
Merlo, Louis A., Jr., Canada
Merrick, Ray, Central States
Merrill, Walter E., New England
Merryfield, Fred, Pacific Northwest
Merz, H. Spencer, Central States
Merz, R. C., Central States
Meserva, Charles, (Alt.) Michigan
Mesner, Elmer C., New York
Metzger, Ambrose B., Pennsylvania
Metyko, Frank J., Michigan
Meyer, Carle, New England
Meyer, H. L., Michigan
Meyer, Louis P. H., California
Meyers, Harry L., Central States
Michaels, A. P., Florida
Mick, K. L., Central States
Mickle, Chas. T., Central States
Micklethwaite, W. E., Canada
Middleton, Francis M., Federal
Miick, Fred E., California
Miles, Henry J., California
Miller, Alden W., Arizona
Miller, A. P., Federal
Miller, A. S., England (I.S.P.)
Miller, Basil, Central States
Miller, Charles W., New York
Miller, David R., Central States
Miller, Fred M., New York
Miller, John B., Florida
Miller, J. John, Pennsylvania
Miller, L. A., Central States
Miller, Lewis B., Pennsylvania
Miller, Maurice L., Central States
Miller, Noble, Central States
Miller, Norman A., Michigan
Miller, Olly G., Canada
Miller, Robert G., Iowa
Miller, W. C., Canada
Miller, Wallace T., Rocky Mountain
Milligan, Francis B., Pennsylvania
Milling, Martin A., Central States
Mills, J. Ralph, California
Mills, S. W., Canada
Mine Safety Appliances Co., Associate
Minneapolis-St. Paul San. Dist., (Corporate) Central States
Mirgain, F. C., New Jersey
Mitchell, Burton F., New England
Mitchell, Louis, New York
Mitzel, Robert W., Pennsylvania
Modak, N. V., England (I.S.P.)
Moehr, Louis, Michigan
Moeller, Carl, Central States
Mogelnicki, Stanley, Michigan
Moggio, Wm. A., North Carolina
Mohlman, F. W., Central States
Molitor, Edward P., New Jersey
Monk, H. E., England (I.S.P.)
Monroe, City of, (North Carolina) North Carolina
Monroe, S. G., Ohio
Monsanto Chemical Company, Associate, Att'n: J. J. McCarthy
Monsell, Harry M., New York
Montreat, City of, Canada
Moon, James N., Pennsylvania
Moon, Robert, Central States
Mooney, Earl E., New York
Moor, Alex, (Alt.) New York
Moor, W. C., Texas
Moore, Charles A., Pennsylvania
Moore, Edward W., New England
Moore, F. Owen, England (I.S.E.)
Moore, Geo. S., North Carolina
Moore, George W., New York
Moore, Lee S., Central States
Moore, R. B., Central States
Moore, R. L., England (I.S.P.)
Moore, W. A., Federal
Moran, Alton B., Rocky Mountain
Morehouse, W. W., Ohio
Morey, Burrows, New York
Morgan, Edward F., Jr., New England
Morgan, Geo., Canada
Morgan, L. S., Pennsylvania
Morgan, Philip F., Central States
Morgenroth, Fritz, New England
Morin, A., Canada
Morkert, Kenneth, Central States
Morrill, Arthur B., Michigan
Morrill, Leigh W., New Jersey
Morris, Arval, (Alt.) California
Morris, D. K., Central States
Morris, Lee, South Dakota
Morris, Paul J., Pennsylvania
Morrisey, Richard A., Pennsylvania
Morrison, James E., Pacific Northwest
Morrow, Ben S., Pacific Northwest
Mortenson, E. N., Central States
Moses, H. E., Pennsylvania
Moss, F. J., Federal
Mott, C. A., Canada
Moudy, R. B., Rocky Mountain
Mount Airy, Town of, (North Carolina) North Carolina
Mountfort, L. F., England (I.S.P.)
Mowbray, Geo. A., New York
Mowrey, J. Hase, Pennsylvania
Mowry, R. B., New Jersey (Dual—Pennsylvania)
Moya, ING. Victor Jose, Pennsylvania
Moyar, Jesse, Ohio
Mudgett, C. T., Michigan
Muegee, O. J., Central States
Mueller Company, Associate
Muldoon, Joseph A., New England
Mulholland, R. A., Texas
Mulvihill, F. J., Pennsylvania
Munding, Miss Germaine G., New York
Munroe, E. H., Canada
Munroe, James A., & Sons, Associate
Munroe, W. C., Maryland-Delaware
Munson, Laura A. (Mrs.), California
Murphy, John A., Central States
Murdock, Wm., Pennsylvania
Murphy, Lindon J., Iowa
Murphy, Reginald A., New York
Murray, A. E. Scott, England (I.S.E.)
Murray, K. A., England (I.S.P.)
Murschel, Jacob, South Dakota
Musgrove, Robt., Michigan
Mutzberg, F. A., North Carolina
Myatt, H., England (I.S.P.)

Naehr, Harry F., Georgia
Nangle, B. A., South Dakota
Nasi, Kaarlo W., California (Dual—Federal)
National Council for Stream Improvement, (New York City) (Corporate) New York, Att'n: Harry W. Gehm
National Water Main Cleaning Co., Associate, Att'n: Clinton Inglee
Naylor, William, New England
Nauer, Louis A., Jr., Central States
Neffendorf, Alfred, Texas
Neiman, W. T., Central States
Nelle, Richard S., Central States
Nelson, Ben O., Pacific Northwest
Nelson, Casper I., North Dakota
Nelson, D. H., Central States
Nelson, Frederick G., Ohio
Nelson, H. Lloyd, Pennsylvania
Nemmers, W. P., Iowa
Nesheim, Arnold, Federal
Neumann, George B., Central States
Neves, Lourenco Baeta, New York
Nevitt, I. H., New York
Newell, M. A., Rocky Mountain
Newell, Town of, (Iowa) Iowa
Newlands, James A., New England
Newland, Stewart H., Texas
Newman, Alfred C., Florida
Newsom, Reeves, New York
Newton, City of, (Iowa), Iowa
Newton, Donald, Central States
Nicholas, Forrest A., Central States
Nichols, Arthur E., New York
Nichols Engineering & Research Corp., Associate, Att'n: R. W. Rowen
Nichols, F. E., Ohio
Nichols, M. Starr, Central States
Nicholson, C. P., New York
Nickel, Jack B., Georgia
Nicklin, H. S., Canada
Niebergall, Herbert J., New York
Nielsen, N. P., Rocky Mountain
Niemi, Arthur G., Central States
Niles, A. H., Ohio
Niles, Chas. A., New York
Niles, Thomas M., Central States
Nixon, J., England (I.S.P.)
Nixon, M. B., Georgia
Nixon, Ray, Kansas
Noel, Carl F., California
Nold, Vern, Central States
Nordell, Carl H., Central States
Norfleet, Clark T., (Alt.) California
Norgaard, John, Michigan
Norman, G. A., Central States
Norris, Francis I., Federal
Nugent, Franklin J., Pennsylvania
Nugent, Harold F., New York
Nugent, Lee M., California
Nussbaumer, Newell L., New York
Nussberger, Fred, New York
Nutter, Frank H., Central States

Obma, Chester A., Central States
O'Brien, Earl F., New York
Ocean City Sewer Service Co., New Jersey, Att'n: E. S. Steelman
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O'Connell, Wm. J., Jr., California
O'Connor, Wm. F., New York
Odbert, Eugene, Jr., Central States
Odell, Lester, Central States
O'Dell, W. H., New York
O'Donnell, Charles F., New York
O'Donnell, R., Pennsylvania
Oeffler, W. A., Central States
Oeming, L. F., Michigan
O'Flaherty, Fred, Ohio
Ogden, Henry N., New York
O'Hara, John, Pennsylvania
O'Hara, Franklin, New York
Ohr, Milo F., Michigan
Oke, Ernest E. W., Canada
Okun, Abraham H., New York
Old, H. N., Federal
Olewiler, Grant M., Pennsylvania
Oliver, Warren D., Rocky Mountain
Olsen, W. C., North Carolina
Olson, Frank W., Central States
Olson, Herbert A., Michigan
Olson, Jack, Rocky Mountain
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Oplinger, Lester, Pennsylvania
Orchard, W. J., New York
Ordway, E. S., New Jersey
O'Rourke, John J., New York
Orr, George M., Central States
Orr, Wm. S., Canada
Orton, J. W., Michigan
Osage, City of (Iowa), Iowa
Osborn, L. C., Rocky Mountain
Osterhoudt, William C., New York
Osthoff, Richard H. L., New Jersey
Ousterhout, Alfred, New York
Overall, W. G., Central States
Ozelsel, A. M., Central States

Pacheco, Leo, California
Pacific Flush Tank Co., Associate (Corporate), Central States & Ohio
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Page, C. A., Georgia
Painter, Carl E., California

Palange, Ralph C., Federal
Pallo, Peter E., New York
Palmer, Benjamin M., New England
Palmer, C. L., Michigan
Palmer, Harold K., California
Palmer, John R., Central States
Palocsay, Frank S., Ohio
Pardew, W. Holmes, Pennsylvania
Parker, H. C., California
Parker, J. C., North Carolina
Parker, L. K., New England
Parks, C. A., Pacific Northwest
Parkes, G. A., California
Parrish, Clifford, Texas
Parrish, L. S., Michigan
Parrish, Miles A., California
Parrish, Rial T., Ohio
Parsons, R. H., Canada
Patrick, Dale F., Central States
Patterson, J. R., Florida
Patterson, Orville W., Central States
Patterson, Roy K., New York
Paul, Lewis C., New York
Pawlak, John S., New York
Pay, R. H., England (I.S.P.)
Payrow, Harry G., Pennsylvania
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Pealer, Thomas, Pennsylvania
Pearl, Emanuel H., Texas
Pearsall, Ted, Central States
Pearse, Langdon, Central States
Pease, Maxfield, Ohio
Peaslee, Geo. A., Central States
Peck, Lawrence J., New York
Pecker, Joseph S., New York & Pennsylvania
Peightal, Wm. H., California
Peirson, Nat D., North Carolina
Pelz, Wm. J., Canada
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Peterson, Ivan C., Central States
Peterson, J. H., California
Peterson, Myhren C., Central States
Peterson, Ralph W., Central States
Petrie, Wm. P., New England
Pett, K. M., Central States
Pfeifer, John C., Pacific Northwest
Phelps, B. D., California
Phelps, E. B., New York
Phelps, Ellis K., Florida
Phelps, Geo., Canada
Philips, H. S., Canada
Phillips, H. N., New York
Phillips, Roy L., Pennsylvania
Phillips, R. S., North Carolina
Phillips, R. W., Texas
Phoenix, Edward A., New York
Piatt, Wm. M., North Carolina
Pickett, Arthur G., California
Pierce, C. L., California
Pierce, George O., Central States
Pierce, H. M., South Dakota
Pierce, W. E., (Alt.) Michigan
Pierron, Wm., Sr., Pacific Northwest
Pincus, Sol, New York
Pine, E. T., Central States
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Pinney, F. W., North Dakota
Piper, K., North Dakota
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Pitkin, Ward H., New York
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Pittsburgh Equitable Meter Co., Associate, Att'n: R. S. Reed, Jr.
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Plamondon, Sarto, Canada
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Pohl, C. A., New York
Pollex, Elmer, Ohio
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Pomeroy, Clarence, (Alt.) Michigan
Pomeroy, Donald W., California
Pomeroy, Richard, California
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Poole, S. B., England (I.S.P.)
Poole, Wm. A., California
Pope, Lester, New Jersey
Porges, Ralph, Federal
Porter, H., California
Porter, Thomas H., Canada
Porter, William, New York
Porteous, W. K., England (I.S.E.)
Posey, James, Maryland-Delaware
Post, Fred W., California
Poston, R. F., Rocky Mountain
Potter, H. M., Maryland-Delaware
Potts, Clyde, New York
Potts, Harry G., Michigan
Powell, A. R., New York
Powell, Otto, Central States
Powell, Reuben R., Florida
Powell, S. T., Maryland-Delaware
Powell, W. L., Texas
Powers, E. C., Ohio
Powers, R. W., California
Powers, Thomas J., Michigan
Pratt, Gilbert H., New England
Pratt, Jack W., California
Preston, A. M., Texas
Prestrude, Peter, Rocky Mountain
Price, Charles R., South Dakota
Price, D. H. A., England (I.S.P.)
Prichard, Robert L., Federal
Pringle, H. L., Canada
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Prodanovich, Danilo, Georgia
Proportioneers, Inc., Associate, Att'n: H. E. Hollberg
Proudman, Chester F., New England
Provost, Andrew J., New York
Public Works Magazine, Associate
Puckhaber, Fred H., Texas
Puffer, Stephen P., New England
Purdie, David J., New York
Purser, John R., North Carolina

Quaely, Martin F., New York
Quartly, Eric V., California
Quigley Company, Inc., Associate
Quinn, Joseph L., Jr., Central States

Racek, L., Jr., Central States
Racely, Wilbur A., California
Radcliffe, Jack C., New Jersey
Raisch, Wm., New York & New England
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Ramseier, Roy E., Sr., California
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Randolph, R. R., Rocky Mountain
Rankin, R. S., Central States
Raneri, Ray, Federal
Rantsma, W. Frank, (Alt.) California
Ratcliffe, Robert C., Rocky Mountain
Rath, Henry M., New York
Rawlins, George S., North Carolina
Rawn, A. M., California
Rawson, E. Otto, Canada
Ray, Clayton B., Georgia
Raymond, Nelson I., Michigan
Raymond, R. P., New Jersey
Read, Homer V., Central States
Read, Jack E., Canada
Reames, H. S., (Alt.) Michigan
Reardon, Joseph F., New York
Reardon, Wm. R., Central States
Reaves, S. H., Georgia
Rector, K. E., Kansas
Redding, Harry P., North Carolina
Redfern, W. B., Canada
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Redmon, Polk, Central States
Reed, Leon H., New England
Reedy, Timothy D., Michigan
Reeve, Lester G., Pennsylvania
Reeves, C. F., California
Rehler, Joseph E., New York
Rehmann, Earl J., Pennsylvania
Reid, G. Graham, Canada
Reid, Geo. W., Florida
Reidell, Alfred G., California
Reiman, F. J., Michigan
Rein, L. E., Central States
Reiners, A. H., New Jersey
Reinhardt, Arthur W., California
Reinke, E. A., California
Reisert, Michael J., New York
Remsburg, W. N., Kansas
Remsen, John, New York
Rendell, Theodore, England (I.S.P.)
Rennels, Willard T., Central States
Requardt, G. J., New York
Reuning, Howard T., Pennsylvania
Reuschel, Earl R., Missouri
Rew, Myron E., California
Reybold, E. C., Rocky Mountain
Reynolds, Leon B., California
Reynolds, M. W., Michigan
Reynoldson, C. G., Central States
Reynoldson, T. H., England (I.S.P.)
Rhoads, Edward J., Pennsylvania
Ribal, Raymond Robt., California
Ribner, Morris, New York
Ribreau, Gilbert E., New York
Rice, Archie H., Pacific Northwest
Rice, Clyde, California
Rice, John E., Federal
Rice, John M., Pennsylvania
Rice, Lawrence G., New York
Richards, G. H., Canada
Richardson, C. G., Associate (Dual—New England) Also see Builders-Providence, Inc.
Richheimer, Chas. E., Florida
Richgruber, Martin, Central States
Richman, W. F., Central States
Richter, James B., Central States
Richter, Paul O., Central States
Rickard, Grover E., New York
Ridenour, G. M., Michigan
Riedel, John C., New York
Riedesel, Henry A., Central States
Riedesel, P. W., Central States
Riehl, W. H., Canada
Riffe, Norman T., California
Riis-Cartensen, Erik, New York
Riker, I. R., New Jersey
Rinehart, Clidus, Central States
Ritter, Bruce, (Alt.) Michigan
Ritter, Roy H., Maryland-Delaware
Roach, Vincent, Iowa
Roach, W. H., North Dakota
Roahrig, Henry L., Central States
Robbins, George T., Florida
Roberton, L. T., Canada
Roberts, C. R., New York
Roberts, F. C., Jr., Federal (Dual—California)
Roberts, Jack, New York
Roberts, J. B., New Jersey
Roberts, W. C., California
Robertson, Geo. E., New York
Robertson, John, California
Robinson, B., Canada
Robins, Maurice L., Central States
Robinson, Carl H., New York
Robinson, Fred M., Central States
Robinson, G. G., Canada
Robinson, I. F., Canada
Robinson, Philip L., Georgia
Robinson, W. S., California
Rocco, John, New York
Rock, Harold F., New York
Rockstraw, F. W., Pennsylvania
Rodwell, Robert D., Central States
Roe, Frank C., Central States
Roeller, R. S., Pennsylvania
Roetman, Edmond T., Pennsylvania
Rogers, Allan H., New York
Rogers, D. Paul., Pennsylvania
Rogers, Harvey G., Central States
Rogers, Jack C., Federal
Rogers, John A., New England
Rogers, Milford E., Kansas
Rogers, M. W., Canada
Rogers, W. H., Central States
Rohlich, Gerard A., Central States
Rojas, Luis Pachon, Texas
Roll, A. H., Central States
Romaine, Burr, Central States
Romeiser, C. H., Central States
Roney, L. R., North Dakota
Roob, F. H., Central States
Rosemeyer, Alfred, Central States
Rosen, Milton, Central States
Rosengarten, W. E., Pennsylvania
Ross, Hermann M., Central States
Ross, W. E., Central States
Roth, R. F., Ohio
Rowen, R. W., Central States
Rowntree, Bernard, California
Royer Foundry & Machine Co., Associate, Att'n: S. B. Davies
Rubin, Arthur L., Ohio

Rubincam, James L., Pennsylvania
Ruchhoft, C. C., Central States (Dual —Federal)
Ruck, Franklin, Ohio
Ruckel, Paul J., Sr., Rocky Mountain
Rudgal, H. T., Central States
Rudolph, R., California
Rudolfs, Willem, New Jersey
Rue, Robert, Ohio
Ruge, J. Herman, Florida
Ruhmann, Ovid G., Central States
Rumble, G. B., Canada
Rumsey, James R., Michigan
Ruppert, E. L., Pacific Northwest
Rupp, Daniel H., Ohio
Ruscica, Samuel, Canada
Russell, George, Missouri
Russell, George S., Missouri
Russell, J. P., Canada
Ryan, Alfred J., Rocky Mountain
Ryan, J. Samuel, New York
Ryan, Wm. A., New York
Ryckman, Seymour J., New England
Rymer, Mary E. (Mrs.), Rocky Mountain

Saetre, Leif, New York
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St. John, Conrad H., Florida
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Sampson, George A., New England
Samson, Channel, New York
Samson, R. A., Rocky Mountain
Sanborn, J. F., New York
Sanchis, Joseph M., California
Sander, Irwin P., New York
Sanderson, W. W., New England (Dual—New York)
Sandler, Theodore T., Florida
Sanitary District of Elgin (Illinois) (Corporate), Central States
Sargent, Edward C., Ohio
Sauer, Victor W., California
Savage, Edward, New York
Saville, Thorndike, New York
Sawyer, C. N., Central States
Sawyer, Robt., W., Jr., New England
Scales, E. P., Georgia
Schaefer, Edw. J., New York
Schaetzle, T. C., Ohio
Schatz, Robert J., Pennsylvania
Schaut, Geo. G., Pennsylvania
Scheak, H. M., Canada
Scheffer, Louis K., Pennsylvania
Scheidt, Burton A., Central States
Schenk, E. F., Iowa
Schick, V. R., Ohio
Schier, Lester C., Central States
Schilling, Keith, (Alt.) Michigan
Schirk, J. M., Rocky Mountain
Schlenz, Harry E., Central States
Schliekelman, R. J., Iowa
Schloss, Chas. M., Rocky Mountain
Schmick, Mark F., Pennsylvania
Schmit, J. M., Rocky Mountain
Schneller, M. P., Central States
Schoepfle, O. F., Ohio
Schott, Edgar C., California
Schouten, Ernest W., Oklahoma
Schreiner, W. R., New York
Schriner, P. J., Central States
Schroeder, Arthur W., Central States
Schroeder, C. A., Central States
Schroeder, Harry, Pennsylvania
Schroepfer, George J., Central States
Schubert, Frank J., Central States
Schuck, H. W., California
Schulhoff, Henry B., New York
Schureman, A. L., California
Schuyler, Howard L., Pennsylvania
Schwartz, Charles F., New York
Schwartz, H. L., Pennsylvania
Schwartz, Louis, New York
Schwartz, Oswald, Central States
Schwieterman, E. F., Ohio
Schwob, Carl E., Federal
Sciver, A., England (I.S.E.)
Scott, Cliffton A., Central States
Scott, Guy R., Federal
Scott, Ralph H., Central States
Scott, Roger J., Central States
Scott, Rossiter S., New York
Scott, W., England (I.S.P.)
Scott, W. M., Canada
Scott, Walter M., New York
Scott, Warren J., New England
Scovill, John R., New York
Seaman, Henry, North Carolina
Searight, Geo. P., Pennsylvania
Searls, Glenn, New York
Seaver, Wist D., Missouri
Segel, A., (Alt.) California
Seid, Sol, New Jersey
Seifert, Wm. P., New York
Seitel, G. C., California
Sellers, A. E., England (I.S.P.)
Seltzer, J. M., Pennsylvania
Semino, Carlos L., Argentina
Sencey, Joe, Central States
Senseman, Wm. B., California
Setter, Lloyd R., New York
Sewage Works Engineering, Associate Att'n: Karl M. Mann
Shank, John J., Pennsylvania
Shannon, R. C., Michigan
Shapiro, Maurice A., Florida
Shapiro, Robert, New York
Shapley, William H., Iowa
Shard, R. H., England (I.S.P.)
Sharon, H. H., California
Sharp, Perry C., Federal
Shaw, Frank R., Federal
Shaw, Morton, Central States
Shaw, Paul A., California
Shaw, Robert S., New Jersey
Shaykin, Jerome D., Central States
Shea, Walter J., New England
Shearer, A. B., California
Sheen, Robt. T., Pennsylvania
Sheets, W. D., Ohio
Shelley, Harry, Pennsylvania
Shephard, W. F., Michigan
Shepperd, Frederick, New York (Dual —New England)
Shera, Brian L., Pacific Northwest
Sherman, Leslie K., New England
Sherratt, Gayle F., Pennsylvania
Shertzer, J. H., Pennsylvania
Shiffer, Russell R., Pennsylvania
Shipman, H. R., Central States
Shirley, Donald L., Pacific Northwest
Shivers, Clifford H., Pennsylvania
Shockley, C. A., Missouri
Shockley, Homer G., New York
Shoebotham, T. B., Central States
Shook, H. E., California
Shook, H. R., Canada
Showalter, Charles M., Pennsylvania
Shupe, S., Canada
Sickler, Archie H., New York
Sidle, R. S., England (I.S.P.)
Sieber, John D., Pennsylvania
Siebert, Christian L., Pennsylvania
Siegel, John A., California
Signor, C. V., Pacific Northwest
Sigworth, E. A., New York
Silberbauer, Walter R., California
Silverts, S. A., California
Simmerman, John S., New Jersey
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Simon, Samuel S., New York
Simonton, Lewis R., Georgia
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Simpson, Maynard, Central States
Simpson, R. W., New York
Simson, George, Jr., Rocky Mountain
Singer, Oscar C., Ohio
Singleton, M. T., Georgia
Siple, H. M., Pennsylvania
Sisler, H. H., Pacific Northwest
Skinner, J. F., California (Dual—New York)
Sklarevsky, Rimma, Maryland-Delaware
Slagle, Elmer C., Central States
Slee, Angus E., Rocky Mountain
Slinger, J. F., Missouri
Sloan, Garrett, Federal
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Slough, John, New York
Smallwood, Charles, Michigan
Smith, A. H., Ohio
Smith, Benjamin L., New York
Smith, C. A., California
Smith, E. E., Ohio
Smith, E. A., Cappelen, New York
Smith, Earl T., Michigan
Smith, Edward J., New York
Smith, F. L., Canada
Smith, Frank Edward, California
Smith, Frank J., New York
Smith, G. C., England (I.S.P.)
Smith, Gilbert M., Central States
Smith, Harold, New York
Smith, Harold L., Michigan
Smith, Harvey J., Pacific Northwest
Smith, H. G., California
Smith, J. F., California
Smith, J. Irwin, Central States
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Smith, Marvin L., Pennsylvania
Smith, Neal D., California
Smith, Paul L., Maryland-Delaware
Smith, Ralph A., Central States
Smith, R. C., New Jersey
Smith, Robt. J., Michigan
Smith, R. L., Central States
Smith, Russell S., Federal
Smith, R. Trumbull, Pacific Northwest
Smith, S. H., Michigan
Smith, W. Austin, Georgia
Smith, Walter E., Michigan
Smith, Willard R., New York
Smithson, Thomas, Pacific Northwest
Snedeker, L. LaVerne, Michigan
Snelsire, Wm., Pennsylvania
Snell, J. R., New England
Snook, W. F. A., England (I.S.P.)
Snow, Donald L., Central States
Snow, Willis J., New England
Snyder, John A., California
Snyder, M. K., Pacific Northwest
Snyder, N. S., New York
Snyder, R. F., Ohio
Sohler, George W., California
Solander, Arvo A., Federal
Solomon, G. R., New York
Sommerfeldt, Everett L., New York
Somers, Verne, Central States
Souther, Fred L., California
Sowden, Howard J., Central States
Sowdon, Wm. K., New York
Spaeder, Harold J., Central States
Spaeth, Julius, Kansas
Sparr, A. E., New York
Spaulding, L. H., Pacific Northwest
Spear, James J., California
Spear, Wm. B., Pennsylvania
Speiden, H. W., Pennsylvania
Spencer, C. C., Federal
Spencer, City of (Iowa), Iowa
Sperling, Elmer J., Florida
Sperry, John R., Central States
Sperry, Walter A., Central States
Spiegel, Milton, Central States
Spieker, Roy G., South Dakota
Spier, Daniel R., New York
Spies, Kenneth H., Pacific Northwest
Spitzer, Elroy F., Central States
Sporseen, Stanley E., Pacific Northwest
Spragg, H. J., Iowa
Spry, Fred J., New York
Spurgeon, Ralph, Central States
Staley, H. H., Kansas
Stanbridge, H. H., England (I.S.P.)
Standley, J. B., Texas
Stanhope, Clifford T., New York
Stankewich, M. J., New York
Stanley, C. M., Iowa
Stanley, Joe A., Jr., Texas
Stanley, Wm. E., New York
Stapf, R. J., South Dakota
Stapley, Edward R., Oklahoma
Stark, Louis, Michigan
Stauff, Paul V., Central States
Staynes, E. H., England (I.S.P.)
Steacy, John J., New York
Steffen, A. J., Central States
Steffensen, S. W., New York
Steffes, Arnold M., Central States
Stegeman, Paul, Michigan
Steindorf, R. T., Central States
Steiner, S. K., New York
Stepanek, Charles H. B., New York
Stepleton, Harold A., Ohio
Sterling, City of (Colorado), Rocky Mountain

Sterns, Edw. A., New York
Stevens, Donald B., Federal
Stevens, Harry, Maryland-Delaware
Stevenson, Albert H., New York (Dual—Federal)
Stevenson, Ralph A., California
Stewart, Clyde L., Oklahoma
Stewart, Earl, Canada
Stewart, H. M., Pennsylvania
Stewart, Jesse A., California
Stewart, Morgan E., California
Stewart, R. E., California
Stewart, W. H., New York
Stickels, Russell, Central States
Stiemke, Robt. E., North Carolina
Stigall, J. C., Texas
Stilson, Alden E., New York
Stipe, George J., Rocky Mountain
Stites, H. L., California
Stock, Mitchell B., New England
Stockman, L. R., Pacific Northwest
Stone, A. R., England (I.S.P.)
Stone, Ralph, Florida
Storey, Benjamin M., Central States
Storrie, Wm., Canada
Straker, M. L., Ohio
Strandburg, Charles J., New York
Strang, J. A., Kansas (Dual—California)
Strangard, Edward L., (Alt.) California
Stratton, Charles H., New York
Straub, Conrad P., New York (Dual—Federal)
Street, H. R., Texas
Street, John Z., Pennsylvania
Streeter, H. W., Federal
Streeter, Robert L., Rocky Mountain
Streeter, S. H., England (I.S.E.)
Strelow, J. L., Iowa
Strickland, G. H., Canada
Strickland, Raymond, Central States
Stringer, R. M., Georgia
Strockbine, Walter, Pennsylvania
Stroessenreuther, G. A., Central States
Strong, Bruce F., New York
Strowbridge, John C., New York
Stuart-Brumley Corp., Associate
Studebaker, Leo, New York
Studinski, C. R., Rocky Mountain
Sturgeon, R. G., Canada
Stutz, C. N., Central States
Sulentic, S. A., Kansas
Sullivan, R. H., Georgia
Summers, M. W., England (I.S.E.)
Sund, Gutorm, Central States
Susa, Stephen A., Pennsylvania
Sutcliffe, H. W., Canada
Suter, Max., Central States
Sutherland, Henry M., New York
Suttie, R. H., New England
Sutton, R. W., England (I.S.P.)
Svenkeson, S. K., North Dakota
Svenson, Sven H., New York
Svore, Jerome H., North Dakota
Swab, Bernal H., North Carolina & Pennsylvania
Swanz, Howard G., New York
Swartz, Martin, North Carolina
Sweeney, J. Stanley, Florida
Sweeney, R. C., New York
Sweeney, William, New England
Sweet, Theodore T., Florida
Swender, Harvey P., Iowa
Swenholt, John, New York
Swenson, John P., Georgia
Swinehart, Eugene B., Pennsylvania
Swope, Gladys, Central States
Sylliassen, M. O., Pacific Northwest
Sylvester, Wm. L., New York
Symons, G. E., New York
Szymanski, John R., New England
Szymanski, Walter C., California

Taggart, Robt. S., New York
Tallamy, Bertram Dalley, New York
Tallent, Lee H., Rocky Mountain
Tamer, Paul, New York
Tanksley, Noble, Central States
Tapleshay, John A., Central States
Tapping, C. H., Central States
Tarbell, W. P., North Dakota
Tarbett, R. E., Federal
Tark, M. B., Pennsylvania
Tarlton, Ellis A., New England
Tarman, John E., Pennsylvania
Taylor, Arthur, California
Taylor, D. R., Florida
Taylor, Frank S., Oklahoma
Taylor, F. W., Georgia
Taylor, Godfrey M. C., England (I.S.E.)
Taylor, H., England (I.S.P.)
Taylor, Henry W., New York
Taylor, Homer, California
Taylor, J., England (I.S.P.)
Taylor, Warren G., New York
Tempest, W. F., Central States
Tennant, H. V., Central States
Terhoeven, G. E., New York
Ternent, Andrew, Canada
Terrill, James G., Jr., California (Dual—Federal)
Terry, Frank, New York
Tetzlaff, Frank, New York (Dual—Federal)
Thalheimer, Marce, Central States
Thamasett, Otto E., New York
Thatcher, E. F., Missouri
Thatcher, Fred A., New York
Thatcher, H. D., England (I.S.P.)
Thayer, Paul M., Central States
Thayer, Reginald H., New York
Theriault, E. J., Federal
Theroux, Frank R., Michigan
Thews, Vernon W., California
Thiel, James A., Pacific Northwest
Thoits, Edw. D., California
Tholin, A. L., Central States
Thomas, A., England (I.S.P.)
Thomas, Ariel A., Central States
Thomas, A. H. R., Canada
Thomas, E. C., Canada
Thomas, E. R., North Carolina
Thompson, H. Loren, Central States
Thompson, J. T., England (I.S.P.)
Thompson, N. J., Rocky Mountain
Thompson, Robert B., New England
Thompson, Thomas C., New York
Thompson, Walter E., New England
Thomson, F. N., New York
Thomson, J. B. F., New York
Thorn, William J., Pennsylvania
Tier, J. V., Florida
Tierney, Lawrence J. J., New England
Timmons, Cyrus L., Florida
Tims, Wm. C., Florida
Tinniswood, William W., Pacific Northwest
Todd, Lee O., Texas
Todd, Stanley B., New York
Toledo, City of (Iowa), Iowa
Tolles, Frank C., Ohio
Tolman, S. L., New York
Tomek, Arthur O., Central States
Tomkins, Lloyd, Michigan
Tomm, LaVern M., New York
Toomer, G., England (I.S.P.)
Tovey, C. A., Florida
Town of Forest City Water Wks. (North Carolina), North Carolina
Towne, W. W., South Dakota
Townend, C. B., England (I.S.P.)
Townsend, Darwin W., Central States
Townsend, Theodore, (Alt.) Michigan
Tracy, Edward L., New England
Travaini, Dario, Arizona
Trebler, H. A., Pennsylvania
Trimble, Earle J., New York
Troemper, Paul A., Central States
Trotter, Roy M., California
Troutman, LeRoy, Federal
Trubnick, Eugene H., New Jersey
True, Albert O., North Carolina
Trulander, Wm. M., Central States
Tschida, Ed., North Dakota
Tuhus, Kenneth, Central States
Turner, E. S., England (I.S.P.)
Turner, Homer G., Pennsylvania
Turner, J. R., Ohio
Turner, Wm. S., Pacific Northwest
Turpin, U. F., Central States
Tuttle, Leon E., New England
Twin City Testing & Engr. Lag., (Corporate) Central States
Tygert, C. B., Pennsylvania
Tykosky, Frank, Michigan
Tyler, R. G., Pacific Northwest

Udell, Harold, Federal
Uhlmann, Paul A., Ohio
Umbenhauer, E. J., Pennsylvania
Underwood, J. E., Canada
United States Pipe & Foundry Co., Associate
University of California Library, California
University of Southern California General Library, California
Updegraff, W. R., California
Upton, Frank W., New York
Urban, Robert C., New York
Urick, R. H., Iowa
Urquhart, M. B., Rocky Mountain

Vaaler, Adrian W., Pacific Northwest
Van Atta, J. W., New York (Dual—New England & Pennsylvania). Also see Ralph B. Carter Co.
Van Camp, Paul M., North Carolina
Van Campen, Alden, Pacific Northwest
Van Denburg, J. W., New York
Vanderlip, Arthur N., New York
Van Der Vliet, Henry, New Jersey
Van Derwerker, Ralph J., Federal
Van Deusen, E. J., New York
Van Deventer, M. S., Missouri
Van Horn, R. B., Pacific Northwest
Van Kleeck, LeRoy W., New England
Van Ness, Joseph A., Rocky Mountain
Van Norman, James H., California
Van Praag, Alex, Jr., Central States
Van Wyck, George W., New York
Vapor Recovery Systems Co., Associate, Att'n: C. T. Stanhope
Vaseen, V. A., Rocky Mountain
Vaughan, E. A., California
Veale, J. C., England (I.S.P.)
Veatch, F. M., Rocky Mountain
Veatch, F. M., Jr., Central States
Veitch, Wm. M., Canada
Velz, C. J., New York
Velzy, C. R., New York
Venn, Frank, (Alt.) Michigan
Vensano, H. C., California
Venzano Botet, Carlos F., Argentina
VerDow, William H., (Alt.) New York
Verhoek, Benjamin J., Central States
Vest, W. E., North Carolina
Vickery, John U., Florida
Victoria, John, New York
Vincent, G. G., Canada
Vinson, A. T., Florida
Vivier, Harvey, New England
Vogelbein, Charles J., Missouri
Vognild, R. O., Pacific Northwest
Voigt, Richard C., New York
Volonte, August F., Maryland-Delaware (Dual—Federal)
Volpp, A. G., Pacific Northwest
Von Pelt, Richard, California
Vosicky, Frank E., Pennsylvania
Vredenburg, Edward L., New York
Vrooman, Morrell, New York

Waddell, W. H., Canada
Wade, W. J., Central States
Wadhams, S. H., New England
Wagenhals, H. H., New York
Waggoner, E. R., California
Wagner, Edward P., New York
Wagner, Edwin B., Pennsylvania
Wagner, Vincent, Pennsylvania
Wahlstrom, Carl A., Central States
Wahmhoff, John J., Ohio
Wailes Dove-Hermiston Corp., Associate, Att'n: W. H. T. Thornhill
Walbridge, Thornton, Central States
Walker, C. C., Ohio
Walker, Chas. L., New York
Walker, Edward A., Pennsylvania
Walker, J. Donald, Central States
Walker, Elton D., Pennsylvania
Walker, W. P., Jr., Texas
Walker, William W., Federal
Wallace & Tiernan Co., Inc., Associate Att'n: B. M. Lindsay
Wallach, Arthur, Federal
Waller, L. E., Georgia
Walters, F. Y., Canada
Walters, Grover L., California

Walton, Graham, Central States (Dual—Federal)
Ward, A. R., England (I.S.P.)
Ward, C. N., Central States
Ward, Oscar, Central States
Warden, Lotus A., Central States
Wardwell, T. M., Central States
Wardle, J. McClure, New York
Ware, Howard, New York
Warner, E. L., Pacific Northwest
Warner, Richard G., North Dakota
Warren, George D., New York
Warrick, L. F., Central States
Washburn, Howard C., New York
Washburn, James J., Rocky Mountain
Washington State Pollution Comm., Pacific Northwest
Wasmund, Roy J., Rocky Mountain
Water Department, (Hillsboro, N. C.) North Carolina
Water Dept., (Lenoir, N. C.) North Carolina
Waterman, Earle L., Iowa
Water Works & Sewerage, Associate
Waters, Geo. E., Central States
Watmough, W. W., Canada
Watson, Carl H., New York
Watson, David M., England (I.S.E.)
Watson, Henry G., Rocky Mountain
Watson, Lester L., Pennsylvania
Watson, W., England (I.S.P.)
Watters, T. C., Central States
Watts, M. R., Pennsylvania
Weachter, Horace, Pennsylvania
Weasner, Leo, Central States
Weatherby, Charles H., New York
Weaver, W. H., Georgia
Webber, R. H., Canada
Weber, Robert R., Ohio
Webster, Roy W., Pacific Northwest
Wechter, Wm. H., New York
Wedeman, John D., New York
Weeber, Earl R., Michigan
Weeber, Wm. Keith, Central States
Weed, Sam A., California
Weibel, S. R., Federal
Weil, Harold M., California
Weiner, Daniel J., Federal
Weir, E. McG., England (I.S.P.)
Weir, H. McLean, Canada
Weir, Paul, Georgia
Weisel, W. O., Pennsylvania
Weiss, Federico F., Argentina
Weiss, R. H., Texas
Welch, W. H., Texas
Welker, Leland A., New York
Wells, E. Roy, Central States
Wells, S. W., Florida
Welsch, W. Frederick, New York
Welsh, William J., New England
Wencelblat, Nicolas R., Argentina
Wenger, J. H., Ohio
Wentworth, John P., New England
Wertz, C. F., Pennsylvania
Wertz, Leroy F., Ohio
Wesby, Vernon L., Central States
West, A. W., Central States
West, L. E., New Jersey
Westergaard, Viggo, New York
Westfall, Milton, Central States
Weston, Arthur D., New England
Weston, Roy F., Pennsylvania
Westwood, H. W. D., England (I.S.E.)
Wheeler, C. E., Jr., Central States
Wheeler, Robert C., New York
Whelchel, H. E., Georgia
Whipple, Melville C., New England
Whitby, Stephen S., Pennsylvania
Whitcomb, Leon R., Pennsylvania
White, Clyde, Texas
White, F. L., Pennsylvania
White, Geo. C., California
White, H. H., California
White, Paul R., Central States
White, R. E., California
White, R. H., England (I.S.E.)
White, W. W., California
Whitehead, F. E., New Jersey
Whitlock, Ernest W., New York
Whitlock, Henry C., New England
Whitney, Alfred C., Central States
Whittaker, H. A., Central States
Wiegert, Lester O., Central States
Wiest, Gordon J., Pennsylvania
Wieters, A. H., Iowa
Wigley, Chester G., New York
Wild, Harry E., Florida
Wiley, Averill J., Central States
Wiley, John S., Federal
Wilkes, F. Dean, Canada
Wilkins, George F., California
Willett, C. K., Central States
Williams, A. C., Pennsylvania
Williams, C. C., Central States
Williams, Chas. H., Pacific Northwest
Williams, Chas. W., Central States
Williams, Clyde E., Central States
Williams, G. Bransby, England (I.S.E.)
Williams, J. E., Texas
Williams, J. F., Texas
Williams, Leon G., Central States
Williams, W. B., Michigan
Williams, William D., Federal
Williamson, A. E., Florida
Williamson, Joe, Jr., Florida
Williamson, Martin F., Central States
Wilmot, W. G., Pacific Northwest
Wilson, C. T., Iowa
Wilson, Harry L., Central States
Wilson, J. Preston, Rocky Mountain
Wilson, Murray A., Kansas
Wilson, Robert A., Central States
Wilson, R. D., Central States
Wilson, R. H., Ohio
Wilson, William B., Canada
Winch, Norman M., New England
Windridge, M. E. D., England (I.S.P.)
Winfield, Wilmer M., New York
Wing, Frederick K., New York
Winne, Geo., New York
Winslow, William H., Pennsylvania
Winsor, C. E., England (I.S.P.)
Winter, Orvan V., Central States
Wintersgill, A. T., California
Wirt, R. M., Pennsylvania
Wirts, J. J., Ohio
Wise, William S., New England
Wisely, F. E., Central States
Wisely, W. H., Central States
Wishart, J. M., England (I.S.P.)
Wisniewski, Theo., Central States
Witcher, C. Preston, Michigan
Withington, C., Canada
Wittmer, Earl F., Ohio
Wittwer, N. C., New Jersey
Witty, T. E., North Carolina
Woese, Carl F., New York
Wolf, Wm. E., Central States
Wolfteich, John, New York
Wolman, Abel, Maryland-Delaware
Woltmann, J. J., Central States
Wontner-Smith, H., England (I.S.P.)
Woo, Francis H., California
Wood, Alan H., Pennsylvania
Wood, George L., California
Wood, Herbert M., New York
Wood, J. R., Canada
Wood, R. D., Co., Associate, Att'n: Chas. Becker
Woodhouse, Herbert M., Canada
Woodruff, F. L., Ohio
Woodrum, Logan, Central States
Woodward, John D., Pennsylvania
Woodward, R. D., (Alt.) California
Woodward, R. L., Federal
Wooten, M. Frank, Jr., North Carolina
Wormuth, W. H., New York
Worrest, Howard A., Pennsylvania
Worthington, Erastus, New England
Worthington Pump & Machy. Corp., Associate
Wright, A. L., Rocky Mountain
Wright, Arthur, Pennsylvania
Wright, Arthur, New Jersey
Wright, Charles T., Federal
Wright, Chilton A., New York
Wright, Edw., New England
Wright, L. R., California
Wright, Scott, Texas
Wurtenberger, Helen, Central States
Wyant, Clifford, Pennsylvania
Wyatt, Bradley W., California
Wyatt, Wendell C., Kansas
Wyckoff, Charles R., New York
Wyllie, Geo. F., Michigan
Wymore, Allan H., Missouri

Yaeck, Arthur W., Canada
Yaeger, Oscar G., California
Yaffee, C. D., Federal
Yeager, Bert T., Central States
Yenchko, John, Pennsylvania
Yeomans Brothers Co., Associate (Corporate), Central States
Yerkes, Milton R., Pennsylvania
Yoder, M. Carlton, California
Young, Alden W., New York
Young, C. H., Pennsylvania
Young, Norman C., Pennsylvania
Yow, W. E., North Carolina

Zack, Samuel I., New York
Zele, Alexander S., New York
Zeller, P. J. A., Texas
Zetterberg, Edw., Central States
Ziegler, C. H., Pennsylvania
Zimmer, W. E., Michigan
Zoglmann, Martin, Central States
Zorn, Ray H., Ohio
Zuckweiler, G. C., (Alt.) California

CONSTITUTION AND BY-LAWS
OF THE
FEDERATION OF SEWAGE WORKS ASSOCIATIONS

Adopted January 15, 1941. Amended August 25, 1941 and May 15, 1942.

CONSTITUTION

ARTICLE I

NAME

The name of this organization shall be the Federation of Sewage Works Associations, hereinafter designated as the Federation.

ARTICLE II

OBJECTIVES

The objects of this Federation shall be: The advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes; the design, construction, operation and management of treatment works; the study, promotion and encouragement of improved sanitation of waterways; the correlation and strengthening of regional and state sewage works associations or conferences within or without the United States of America; the publication of a journal; and other relevant activities.

ARTICLE III

MEMBERSHIP

The membership of the Federation shall consist of regional or state associations or conferences, either within or without the territory of the United States of America, hereinafter designated as Member Associations, whose objectives and constitutions are in harmony with the purposes of this Federation, and of individuals or corporations as specified in the By-Laws, subject to the conditions and limitations prescribed in the Constitution and By-Laws of the Federation.

ARTICLE IV

ORGANIZATION

SECTION 1. The affairs of the Federation shall be conducted by a Board of Control (hereinafter designated as the Board), under such rules as the Board may determine, subject to the specific conditions of this Constitution and By-Laws.

SECTION 2. The officers of the Federation shall be a President, a Vice-President, a Secretary, a Treasurer, and an Editor.

SECTION 3. The Board shall consist of:

- (a) The President of the Federation.
- (b) The Vice-President of the Federation.
- (c) The Treasurer of the Federation.
- (d) One Director to be appointed by and to represent each Member Association.
- (e) Six Directors-at-Large, of whom three are to be elected by the Executive Committee of the Sewage Works Division of the Water and Sewage Works Manufacturers' Association, and three by the Directors representing the Member Associations.

(f) The latest living Past President of the Federation.
(g) The Chairman of the Organization Committee.
(h) The Chairman of the Publications Committee.
(i) The Chairman of the Sewage Works Practice Committee.
(j) The Chairman of the Research Committee.

SECTION 4. After the Annual Meeting of October, 1941, the terms of office of the President, Vice-President, and Treasurer shall be one year, and the Directors three years, which terms shall start at the beginning of the last session of the Annual Meeting of the Board at which they are elected and continue until a successor qualifies. The Secretary and the Editor shall be appointed by the Board for the terms of office stated in the By-Laws. In the case of a vacancy in the office of President, the Vice-President shall act in his place for the unexpired term. In case the Vice-President cannot act, the latest living Past President shall do so. In the case of a vacancy in the office of Treasurer or of any Director-at-Large, the Executive Committee shall appoint an Active Member to fill such office for the unexpired term.

SECTION 5. The President, the Vice-President, and the Directors of the Federation will not be eligible for reelection for consecutive terms.

SECTION 6. The President of the Federation shall be the Presiding Officer of the Board.

SECTION 7. A quorum of the Board shall consist of a majority of its members. Absent members may vote by proxy, all such proxies being counted in determining a quorum.

ARTICLE V

NOMINATION AND ELECTION OF OFFICERS AND DIRECTORS

SECTION 1. The annual meeting of the Board in 1941 shall be held in January. Thereafter, it shall be held on the first Saturday of October in each year, or such other day in October as may mark the closing of the Annual Convention of the Federation.

At the annual meeting the Directors representing the Member Associations shall meet under the Chairmanship of the President of the Federation and shall by a majority vote of all such Directors, elect a President, Vice-President, Treasurer, and one Director-at-Large. Absent Directors may vote by proxy. Any candidate so elected shall be an Active Member of some Member Association and shall signify willingness to serve. Any candidate elected as President or Vice-President shall at some time previous to such election have been a member of the Board of Control.

The President, Vice-President and Treasurer, elected at the meeting of the Board in January, 1941, shall hold office until the beginning of the last session of the meeting held in October, 1941. Thereafter, the terms of office shall be as provided in Article IV, Section 4, of this Constitution.

SECTION 2. One Director on the Board of Control to represent each Member Association shall be elected by each Member Association. Each Director so elected shall be an Active Member of the respective Member Association and in good standing at the time of his election.

After the annual meeting of October, 1941, the term of each Director so elected shall be for three (3) years beginning with the last session of the Board immediately following his election.

In the case of any Director, representing a Member Association, retiring for any cause before his term is completed, the governing board of the Member Association shall designate his successor, who shall serve for the unexpired portion of his term.

ARTICLE VI

Except as specifically mentioned herein, this Constitution shall take effect immediately upon its adoption by the Board of Control.

ARTICLE VII

AMENDMENTS

Amendments to this Constitution may be made by a two-thirds vote of the total membership of the Board, notice of the proposed amendment having been given to each member of the Board and to the Secretary of each Member Association not less than sixty days in advance of the meeting, at which the said amendments are to be voted upon.

BY-LAWS

ARTICLE I

MEMBER ASSOCIATIONS

SECTION 1. Any regional or state sewage works association or conference, or other organization whose objectives and constitution are in harmony with those of the Federation, may be granted membership in the Federation by a majority vote of the Board; provided, that the constitution of the applicant association or conference has been examined and certified by the Board as being in accord with Article III of the Constitution of this Federation; and provided further, that certification shall be made by the association seeking admission to membership that the Constitution and By-Laws of the Federation are accepted by it.

SECTION 2. Any Member Association may withdraw from the Federation at the end of any fiscal year by giving three months' notice of such intention, provided that the dues of such Member Association in the Federation are fully paid up to time of withdrawal.

SECTION 3. Any Member Association may be excluded from this Federation, at the pleasure of the Board, for non-payment of dues, as hereinafter provided, or for any change in its constitution that may bring it into conflict with the Constitution or By-Laws of the Federation.

SECTION 4. Any change in the existing constitution or by-laws of a Member Association shall be reported in full to the Secretary of the Federation within thirty days after its adoption by said Member Association.

ARTICLE II

CLASSIFICATION OF MEMBERS

SECTION 1. Membership of the Federation shall be composed of Member Associations, Honorary Members, Associate Members, and Sustaining Members. Membership of the Member Associations shall consist of Active Members and Corporate Members only.

SECTION 2. An Active Member shall be a superintendent, manager, operator, or employee of a sewage or industrial wastes system or treatment works; a professional engineer; a chemist, bacteriologist, biologist, or any qualified person professionally engaged or interested in the advancement of knowledge relating to the disposal or treatment of sewage and industrial wastes or improved sanitation of waterways. Present membership in any Member Association is to be taken as sufficient evidence that the individual is so qualified for as long as he continues to be a member in good standing.

SECTION 3. A Corporate Member shall be a Sewerage Board, Department or Commission; Sanitary District; Department of Public Works handling sewerage; National, State, District or Municipal Board or Department of Health; or other body, corporation or organization engaged or interested in at least one of the stated objectives of the Federation, and shall be entitled to one representative whose name shall appear on the roll of members and who shall have all the rights and privileges of an Active Member. This representative may be changed at the convenience and pleasure of the Corporate Member on written notice to the Secretary of the Member Association to which the Corporate Member is accredited.

SECTION 4. An Honorary Member shall be a person of acknowledged eminence in one or more fields of activity within the scope of the stated objectives of the Federation.

Candidates may be nominated by any Member Association but can be elected only by a majority vote of the Board. There shall not be more than ten living Honorary Members at any time. No candidate for Honorary Membership shall be an elective or appointive member of the Board at the time of his nomination. Honorary Members shall be elected for life and shall receive, without cost, all the publications of the Federation that are distributed to its members.

SECTION 5. An Associate Member shall be a person, firm, or corporation engaged in the manufacturing or furnishing of supplies, materials, or equipment for the construction, operation or maintenance of sewerage works and shall be elected by affirmative vote of a majority of the Board after consideration of written application duly made to the Secretary.

SECTION 6. A Sustaining Member shall be an individual or a corporation interested in the general objectives of the Federation.

ARTICLE III

DUES

SECTION 1. The status and dues of the different classes of members established by Member Associations, as applied to their members, shall be as determined by the Member Association.

SECTION 2. (a) For each Active Member the annual dues shall be Three Dollars, payable in advance by the Member Associations to the Secretary of the Federation on December 31, excepting that on specific request and with the approval of the governing body or specifically designated officers of any Member Association, the dues of Active Members may, for acceptable reasons, be reduced temporarily to One Dollar and Fifty Cents a year up to a limit not exceeding fifty per cent of the total Active membership of the respective Member Association.

(b) For each Corporate Member the annual dues shall be Ten Dollars, payable to the Secretary of the Federation by February 1 of each year.

(c) For each Sustaining Member the annual dues shall be not less than Twenty-five Dollars, payable to the Secretary of the Federation by February 1 of each year.

(d) For each Associate Member the annual dues shall be Twenty Dollars, payable to the Secretary of the Federation by February 1 of each year.

(e) Corporate Members, Sustaining Members, or Associate Members whose dues remain unpaid on March 1 of any year may be dropped from membership on action of the Executive Committee.

(f) The dues for Member Associations outside the United States of America and its territorial possessions shall be greater than the amounts hereinbefore specified by an amount to be fixed annually by the Board as equivalent to the added cost for mailing the Journal to such associations as compared with the average cost for mailing to members residing within these limits.

(g) Active members, paying full dues and Corporate members of Member Associations, and Associate and Sustaining Members of the Federation, in good standing, shall be entitled to one copy each of all publications that are distributed by the Federation to its members. Active members paying partial dues shall be entitled to alternate issues of the Journal and to such other publications that are distributed by the Federation to its members as may be determined by the Board of Control.

SECTION 3. The fiscal year of the Federation shall begin on January first, and annual dues shall be collectible on that date and shall have been paid before February first.

If the dues of any Member Association shall not have been paid by February first, fifteen days' notice of the dues in arrears shall be given to that association, after which time, if the dues remain unpaid, that association may be dropped from the rolls of the Federation on action by the Board, as provided in Article I, Section 3, of these By-Laws.

SECTION 4. Any member, newly elected before June 30, shall pay full dues and shall be entitled to all of the publications of the Federation that are distributed to its members during the year. Members elected after June 30 shall pay one-half the regular dues for that year, and shall be entitled to all of the publications distributed during the half year beginning July 1.

SECTION 5. In transmitting dues to the Federation, each Member Association shall forward with them a certified list of the names and correct mailing addresses of all members of all classes of the said association who are in good standing and are entitled to receive the Journal or other distributed publications of the Federation during the ensuing year.

ARTICLE IV

DUTIES OF OFFICERS AND DIRECTORS

SECTION 1. The President shall have general supervision of the affairs of the Federation, and shall preside at all conventions of the Federation and meetings of the Board. In his absence, he shall designate a Presiding Officer to act in his stead at such conventions or meetings. The President shall be, ex-officio, a member of all committees.

SECTION 2. The Vice-President shall assist the President in the performance of his duties, and act in his stead when required.

SECTION 3. The Board of Control shall be the legal representative of the Federation, and as such shall manage its affairs subject to the conditions and limitations prescribed in the Constitution and By-Laws; direct the investment and care of funds of the Federation; make appropriations for specific purposes; appoint employees and fix their compensation; take measures to advance the interests of the Federation; and generally direct its business. The Board shall not incur indebtedness beyond the funds in the hands of the Treasurer and the Secretary. The Board shall hold a meeting during the Annual Convention. Other meetings shall be held at the call of the President, or on petition addressed to the Secretary and signed by ten or more members of the Board representing not less than seven Member Associations. Notice of all meetings shall be issued by the Secretary at least fifteen days in advance of such meetings to all members of the Board and to the Secretary of each Member Association.

At the Annual Meeting the Board shall appoint a Secretary to serve for a term of two years, and an Editor to serve for a term of three years, unless removed for cause by the Board.

Except as otherwise provided in the Constitution and By-Laws, all questions before the Board shall be decided by a majority vote.

SECTION 4. The Treasurer shall have charge of the funds of the Federation and custody of its investments, if any. He shall pay bills against the Federation when certified by himself and the Secretary. He shall make a report for each calendar year at the Annual Meeting of the Board, showing receipts from the Secretary and other sources, the expenditures, the investments and other assets, and the liabilities of the Federation. He shall make such other reports as may be required by the Board.

He shall be bonded at the expense of the Federation, and to an amount to be determined by the Board.

He shall perform such other duties as may be assigned to him by the Board.

SECTION 5. The Secretary shall be an Active Member and, under the direction of the President and the Board of Control, shall be the executive officer of the Federation. It shall be his duty to attend all conventions and meetings of the Board, prepare the business and duly record the proceedings thereof. He shall see that all monies due the Federation are carefully collected and without loss transferred to the custody of the Treasurer. He shall scrutinize all expenditures, shall certify to the accuracy of all bills and vouchers on which money is to be paid, and shall countersign checks drawn by the Treasurer against the funds of the Federation when such drafts are known by him to be proper and duly authorized by the Board. Once every three months he shall forward to each member of the Board a financial summary of receipts and disbursements, and at the annual meeting of the Board shall present a balance sheet of his books as of the 31st of December and as of the 30th of September preceding the meeting, together with a report of the activities of his office.

He shall have charge of the books and records of the Federation, including lists of members of the Federation and subscribers to the Journal. He shall have charge of the mechanical production and distribution of the Journal and other publications of the Federation, and shall handle all financial matters connected therewith.

He shall be bonded at the expense of the Federation, and to an amount to be determined by the Board.

He shall perform such other duties as shall be assigned to him by the Board.

The books of the Federation shall be audited annually at the expense of the Federation by public accountants to be appointed by the Board.

In the event that the Secretary or Treasurer shall be unable to sign checks against the funds of the Federation, the President or Vice-President shall be authorized to countersign such drafts in his stead.

Section 6. The Editor shall be the literary agent of the Board and shall receive all manuscript copy and prepare it for publication. He shall have the authority to return to the author for correction, or to reject entirely, any manuscript which may be in bad condition, illegible, or clearly deficient in respect to composition, subject matter or supporting data, or otherwise conspicuously deficient or unfit for publication. He also shall have the authority to reject any manuscript which is designed to promote commercial interests. He shall be a member of the Publications Committee and of the Committee on Sewage Works Practice. Decisions of the Editor relative to rejection of manuscripts shall be subject to appeal to the Publications Committee.

ARTICLE V

CONVENTIONS OF THE FEDERATION

The Annual Convention of the Federation shall be held at a time and place to be selected by the Board, preferably in the month of October. All conventions and meetings shall be conducted according to "Roberts Rules of Order."

Each member and guest present at any of the conventions of the Federation shall pay a registration fee of such amount as may be determined by the Executive Committee.

ARTICLE VI

COMMITTEES

Section 1. There shall be an Executive Committee of five members consisting of the President and four Directors. This committee shall be chosen by the Board at its annual meeting. The President of the Federation shall be Chairman, and the Secretary of the Federation shall act as Secretary of the committee. In the absence of the President, the committee shall choose a temporary Chairman from its members. The duties of this committee shall be to direct the administrative work of the Federation and carry out the policies of the Board between meetings of the latter. The Executive Committee shall present at the annual meeting of the Board a budget of estimated expenses of the Federation, including publications, for the ensuing year. On the adoption of the budget by a majority vote of the Board, the expenses of the Federation shall be limited, as far as may be practicable, within the amounts prescribed in said budget. A quorum of the committee shall be three members.

Section 2. A General Policy Committee of seven members consisting of the latest living Past President, who shall serve as Chairman, three Directors and three Members-at-Large, appointed at the outset for terms of one, two, and three years, and thereafter for three-year terms, shall be appointed by the Board at its annual meeting. Three of the seven members of the committee shall be operators of sewerage systems or sewage or industrial wastes treatment plants.

The committee shall study and recommend to the Board upon matters of general policy affecting the well-being and usefulness of the Federation and its Member Associations; matters of public relations; the advancement of the professional and social status of members, and such other matters of similar nature as shall be referred to it by the Board.

SECTION 3. A Publications Committee shall be appointed by the Board at its annual meeting. It shall consist of the Editor and at least four additional Members-at-Large. Its Chairman shall be, ex-officio, a member of the Board. The Publications Committee shall arrange the technical programs for the annual convention of the Federation and shall have general supervision of the publications of the Federation and of the performance of contracts and expenditures connected therewith. The committee shall prepare general rules which, after approval by the Board, shall control the preparation, presentation, acceptance and publication of papers and shall have general supervision of such other matters of similar nature as the best interests of the Federation may require.

SECTION 4. An Organization Committee of at least three Members-at-Large shall be appointed by the Board at the annual meeting, and its Chairman shall be, ex-officio, a member of the Board. The Organization Committee shall examine and report to the Board on application for membership in the Federation and also shall serve in the encouragement of the formation of new regional or state associations or conferences eligible for membership, as well as serving in an advisory capacity in other matters of a similar nature as the best interests of the Federation may require.

SECTION 5. A Sewage Works Practice Committee consisting of the Editor and at least four Members-at-Large shall be appointed by the Board at the annual meeting, and its Chairman shall be, ex-officio, a member of the Board.

Any resolution, report or publication which undertakes to establish in the name of the Federation, professional or technical standards shall be submitted to this committee, and it shall direct such matters on behalf of the Federation.

It shall give notice by publication to the membership of all such proposed standards and report its approval or disapproval of such to the Board.

It shall appoint such sub-committees as it may deem necessary properly to carry on its work.

SECTION 6. There shall be a Research Committee of at least five Members-at-Large. The Chairman shall be appointed by the Board, and the other members of the Committee may be appointed by the Chairman, by and with the consent of the President of the Federation. The Chairman shall be, ex-officio, a member of the Board.

The Research Committee shall be charged with the duty of stimulating and co-ordinating research work among the various Member Associations, and of co-operating with other organizations in the promotion of research work.

SECTION 7. The Board shall appoint such other committees as may be necessary to carry on the work of the Federation.

SECTION 8. The reports and recommendations of all committees of the Federation shall be subject to approval by the Board.

SECTION 9. Members-at-Large are Active Members who are not members of the Board.

ARTICLE VII

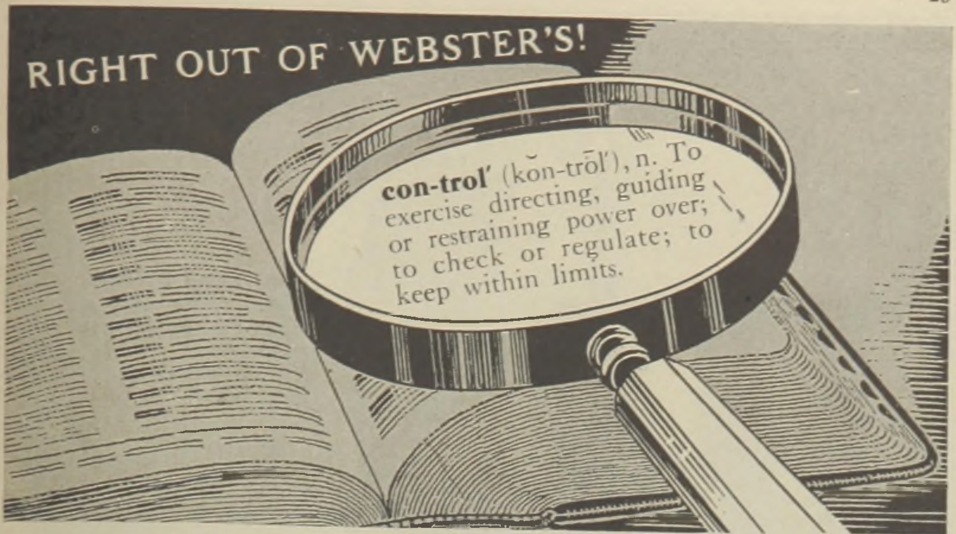
PUBLICATIONS

All publications of the Federation shall be issued under the direction of the Board and shall be copyrighted as far as is practicable and proper.

ARTICLE VIII

AMENDMENTS

The Board of Control may amend these By-Laws in any manner not inconsistent with the Constitution by the two-thirds vote of those voting at any meeting of the Board or by sealed letter ballot, providing that a copy of such proposed amendment has been mailed by the Secretary to each member of the Board and to the Secretary of each Member Association at least thirty days prior to such meeting or letter ballot.



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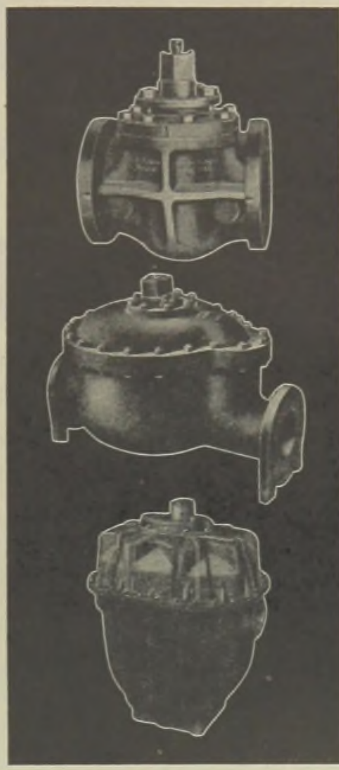

Efficient sewage plant operation depends upon absolute knowledge and control of the fluids being handled. Accurate measurement is a necessary part of the control in any process. Hence, metering of sludge gas produced, consumed or wasted provides valuable records that prove economies and guide operating procedures. Cost control, too, depends upon the knowledge that meter records produce and in this sense the water consumed, both hot or cold, should be accurately measured. Pittsburgh Equitable has furnished many gas and water meters for these purposes.

Nordstrom Valves are in a class by themselves for controlling the flow of sludge, gas and water. They are lubricated both for ease of operation and as a protection against corrosion and erosion. They are inherently leak-resistant and open or shut with a quarter turn. Nordstrom Valves are nationally recognized as providing superior pipe line control.

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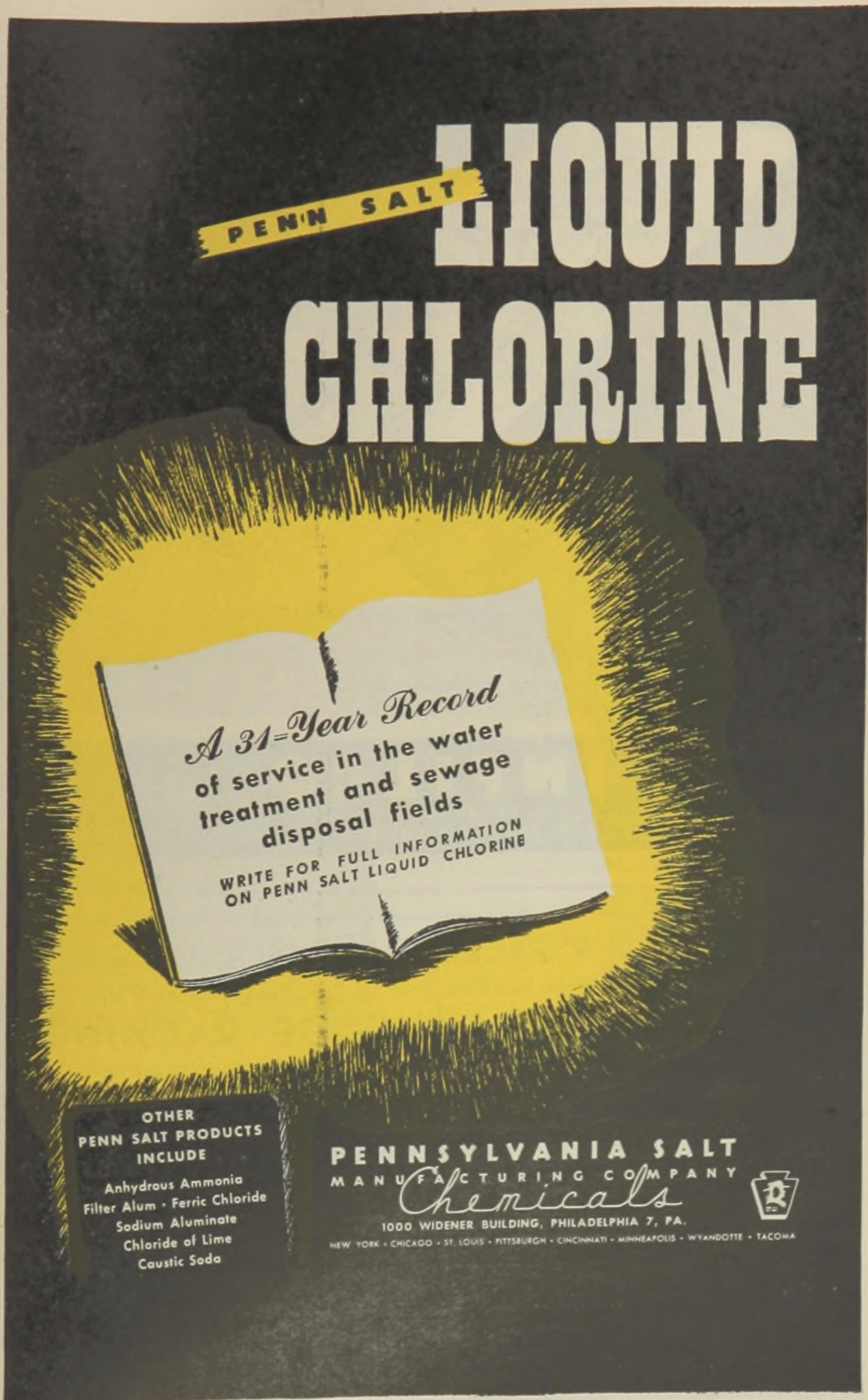
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