SEWAGE WORKS JOURNAL

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Special Features

Grease Determination—Hatfield and Symons

Activated Sludge Settling Tank Design—Anderson

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1944 Committee Reports

OFFICIAL PUBLICATION OF THE

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

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FEDERATION OF SEWAGE WORKS ASSOCIATIONS

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FEDERATION OF SEWAGE WORKS ASSOCIATIONS

SEWAGE WORKS JOURNAL

REG. U. S. PAT. OFF.

A Bimonthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of sewage works.

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Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879.

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Excerpts from Mr. Dorr's "annual letter" advertisement published in full in Water Works & Sewerage and Sewage Works Engineering for January.

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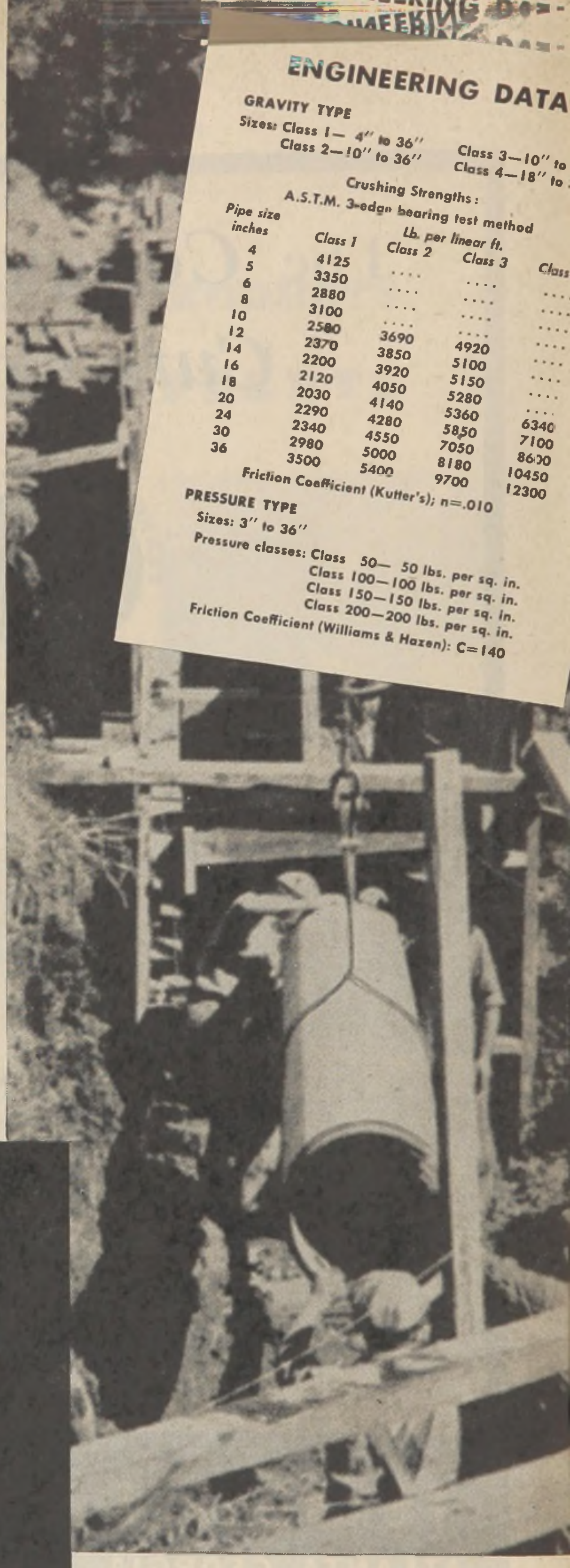

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Class 3—10" to
Class 4—18" to

Crushing Strengths:
A.S.T.M. 3-edge bearing test method
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5	3350	....	....	....
6	2880	....	....	....
8	3100	....	....	....
10	2580	3690	4920	....
12	2370	3850	5100	....
14	2200	3920	5150	....
16	2120	4050	5280	....
18	2030	4140	5360	6340
20	2290	4280	5850	7100
24	2340	4550	7050	8600
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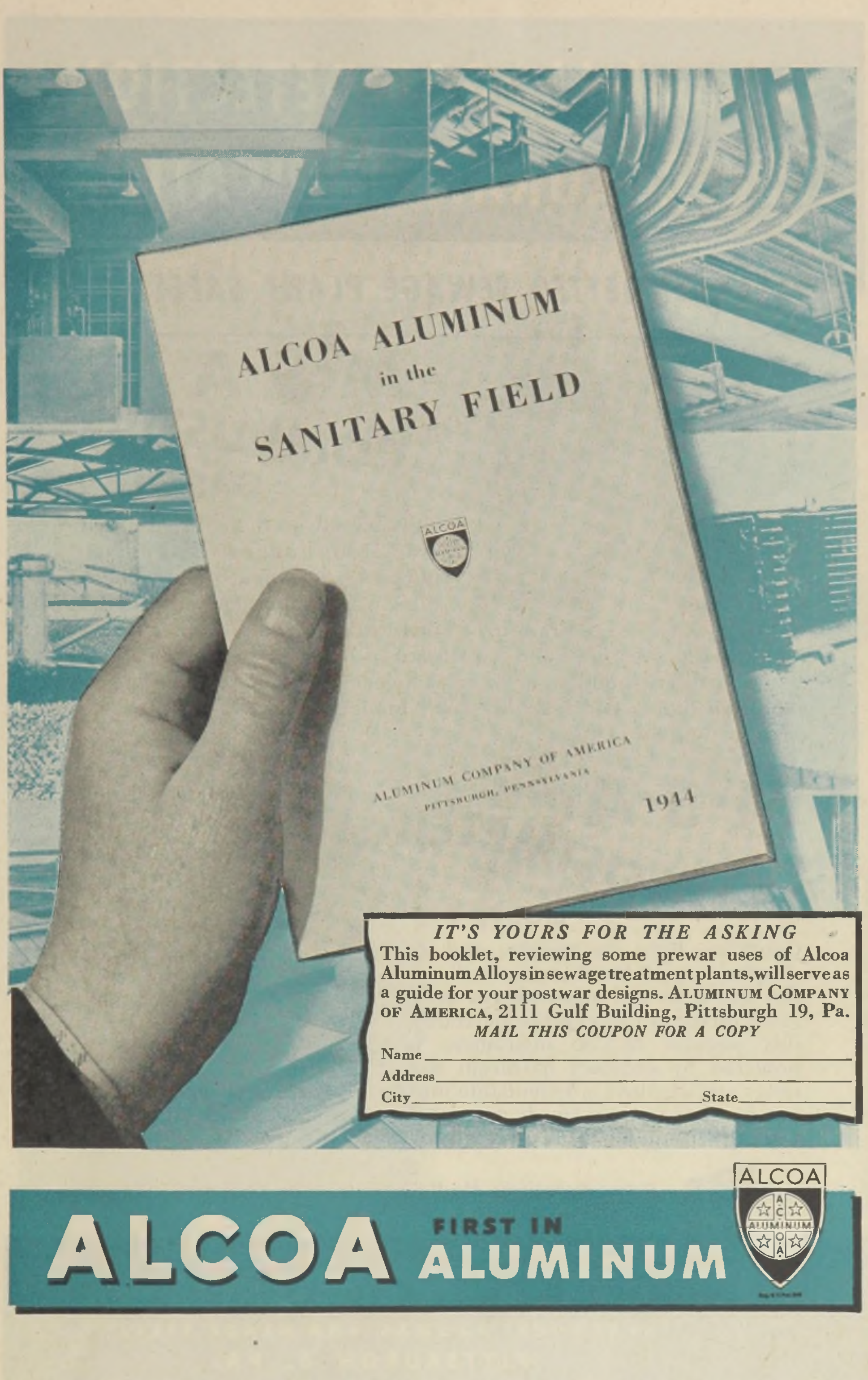
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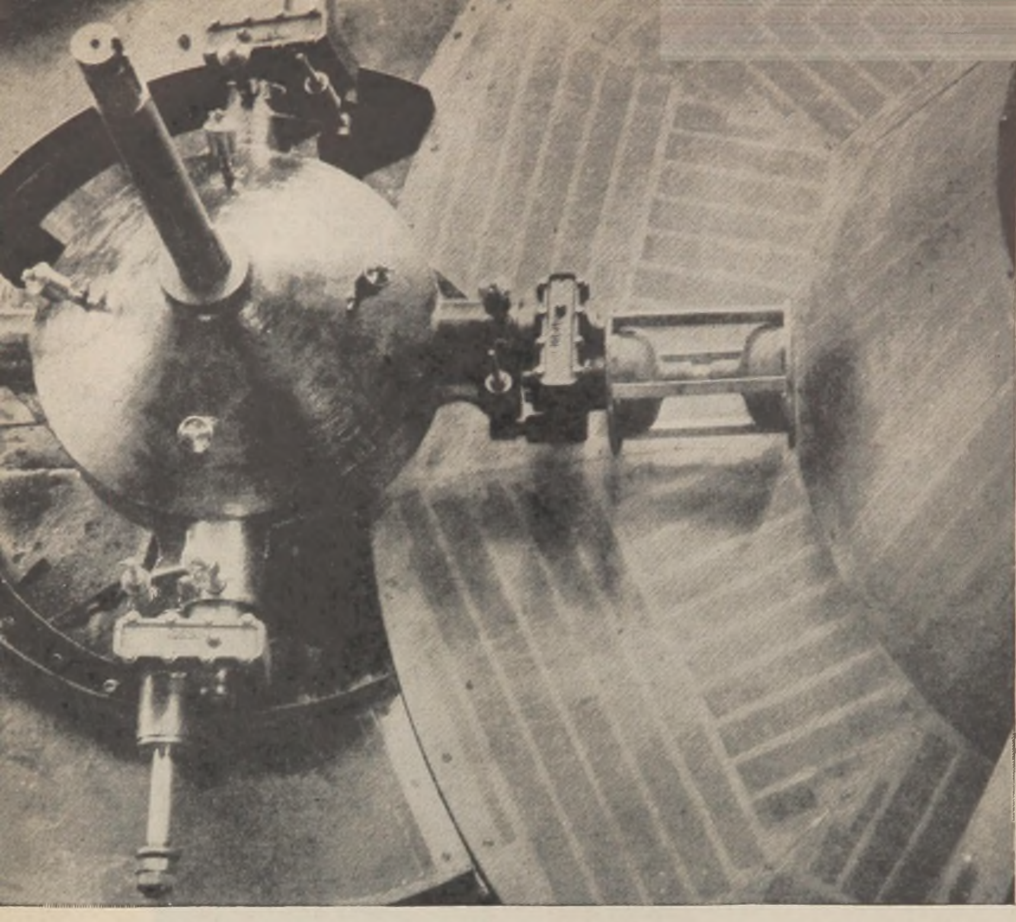

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Plant Operation

A MODIFIED INDEX FOR SEDIMENTATION EFFICIENCY *

By Joseph Doman

Sanitary Engineer, Public Works Dept., Greenwich, Conn.

In judging the performance of sedimentation plants, reliance is usually placed on suspended solids tests to indicate plant efficiency on the basis of percentage removal and also to indicate the quality of the effluent from the p.p.m. of suspended solids remaining. Using the percentage removal as a criterion of plant performance, an attempt is sometimes made to establish some specific percentage as a standard

Table 1.—*Data on Plant Performance*

Grass Island Sewage Disposal Plant, Greenwich, Conn.

Sampling Periods (1943)	Sewage Flow (m.g.d.)	Estimated Settling Period * (hrs.)	Suspended Solids †			Sedimentation Index
			Inf. (p.p.m.)	Eff. (p.p.m.)	Per Cent Removal	
1/18– 1/23	3.040	2.9	80	38	52	86
2/15– 2/20	2.830	3.0	62	34	45	89
3/15– 3/20	3.820	2.3	40	28	30	98
4/12– 4/17	1.734	5.0	88	34	61	73
5/10– 5/15	2.198	3.9	100	26	74	52
6/ 7– 6/12	2.940	2.9	78	30	62	68
7/ 5– 7/10	1.760	4.9	130	31	76	55
8/ 2– 8/ 7	1.592	5.4	151	38	75	63
8/30– 9/ 4	1.448	6.0	162	30	82	48
9/27–10/ 2	1.515	5.7	162	38	77	61
10/25–10/30	2.840	3.0	81	28	65	63
11/22–11/27	2.240	3.7	74	26	65	61
12/20–12/24	1.730	5.0	128	34	73	61
Average	2.280	4.1	103	32	69	63
Maximum	3.820	6.0	162	38	82	98
Minimum	1.448	2.3	40	26	30	48

* Taken as 100 per cent of theoretical as tanks are equipped with sludge collectors and sludge is removed daily. Sludge hoppers not included in settling tank capacity.

† Determined from 8 A.M. to 2 P.M. composites for influent and 10 A.M. to 4 P.M. composites for effluent during the sampling period.

* Presented at Fall Meeting, New England Sewage Works Assn., Worcester, Mass., September 13, 1944.

which the plant should meet in order to be judged as functioning properly.

The effective use of percentage removal as a criterion for establishing standards obviously depends upon a reasonable correlation between such percentages and the p.p.m. remaining in the effluent, in which there will be less solids in the effluent as the percentage removal increases. This correlation, which is a natural one to expect, really does not exist at some plants because of the considerable variation in sewage strength and flow and the occasional interference by industrial wastes. In these circumstances, very little value is obtained from the use of percentage removal as a criterion of sedimentation efficiency or as a performance standard.

TABLE 2.—*Data on Plant Performance*

Old Greenwich Sewage Disposal Plant, Greenwich, Conn.

Sampling Periods (1943)	Sewage Flow (m.g.d.)	Estimated Settling Period * (hrs.)	Suspended Solids †			Sedimentation Index
			Inf. (p.p.m.)	Eff. (p.p.m.)	Per Cent Removal	
1/18– 1/23	0.770	3.0	84	29	65	64
2/15– 2/20	1.071	2.1	61	34	44	90
3/15– 3/20	1.723	1.3	40	23	42	81
4/12– 4/17	0.798	2.9	79	34	57	77
5/10– 5/15	0.726	3.1	68	22	68	54
6/ 7– 6/12	1.056	2.2	64	28	56	72
7/ 5– 7/10	0.639	3.6	167	41	75	66
8/ 2– 8/ 7	0.588	3.9	120	47	61	86
8/30– 9/ 4	0.508	4.5	113	42	63	79
9/27–10/ 2	0.666	3.4	104	46	56	90
10/25–10/30	1.646	1.4	63	34	46	88
11/22–11/27	0.864	2.6	68	33	52	81
12/20–12/24	0.586	3.9	93	40	57	83
Average	0.895	2.9	87	35	60	75
Maximum	1.723	4.5	167	47	75	90
Minimum	0.508	1.3	40	22	42	54

* Taken as 95 per cent of theoretical as tanks are equipped with sludge collectors and sludge is removed three times a week. Sludge hoppers not included in settling tank capacity.

† Determined in same manner as for Grass Island Plant.

There can be no doubt that a practical criterion and standard of some sort would be of benefit to plant operators as well as to administrative agencies in the judgment of sedimentation efficiency. With this idea in mind, a study was made of the records of the four plants at Greenwich and some rather encouraging results were obtained by combining the percentage phase with the p.p.m. phase into one number, hereafter called the "sedimentation index." This index is obtained by adding the percentage solids *remaining* in the effluent to the p.p.m. of solids also remaining in the effluent.

The following six tables illustrate the application of the index to the four plants at Greenwich. Tables 1 to 4 inclusive, give pertinent data for each of the plants in 1943. Table 5 combines these data and reclassifies the certain values to show the relationship between percentage removal and effluent p.p.m. while Table 6 is another reclassification to show the relationship between sedimentation index and effluent p.p.m.

TABLE 3.—*Data on Plant Performance*

Cos Cob Sewage Disposal Plant, Greenwich, Conn.

Sampling Periods (1943)	Sewage Flow (m.g.d.)	Estimated Settling Period * (hrs.)	Suspended Solids †			Sedimentation Index
			Inf. (p.p.m.)	Eff. (p.p.m.)	Per Cent Removal	
1/18– 1/23	0.914	2.8	42	28	33	95
2/15– 2/20	0.930	2.7	46	31	33	98
3/15– 3/20	1.520	1.7	18	15	17	98
4/12– 4/17	0.764	3.3	54	32	41	91
5/10– 5/15	0.771	3.3	52	30	42	88
6/ 7– 6/12	0.965	2.6	24	15	38	77
7/ 5– 7/10	0.575	4.4	108	40	63	77
8/ 2– 8/ 7	0.449	5.8	142	71	50	121
8/30– 9/ 4	0.399	6.4	140	59	58	101
9/27–10/ 2	0.405	6.3	174	56	68	88
10/25–10/30	1.056	2.4	60	40	33	107
11/22–11/27	0.858	3.0	70	32	54	78
12/20–12/24	0.615	4.1	126	40	68	72
Average	0.787	3.8	81	38	53	85
Maximum	1.520	6.4	174	71	68	121
Minimum	0.399	1.7	18	15	17	72

* Taken as 80 per cent of theoretical as tanks were originally designed as septic tanks but are now operated for a four-month run during which time solids are allowed to accumulate. Tanks are thoroughly cleaned prior to starting each run. Sludge hoppers not included in settling tank capacity.

† Determined in same manner as for Grass Island Plant.

As can be seen from Table 5 the effluent suspended solids content in p.p.m. actually increases instead of decreases as the per cent removal increases, thus nullifying the use of per cent removal as a criterion for judging the functioning of the plants. Table 6, on the other hand, shows a fairly good correspondence between effluent p.p.m. and sedimentation index, the p.p.m., as expected, increasing fairly regularly with the index. For the Greenwich plants, at least, the sedimentation

TABLE 4.—*Data on Plant Performance*

East Port Chester Sewage Disposal Plant, Greenwich. Conn.

Sampling Period (1943)	Sewage Flow (m.g.d.)	Estimated Settling Period * (hrs.)	Suspended Solids †			Sedimentation Index
			Inf. (p.p.m.)	Eff. (p.p.m.)	Per Cent Removal	
1/18– 1/23	0.274	3.9	182	38	79	59
2/15– 2/20	0.277	3.9	195	48	75	73
3/15– 3/20	0.347	3.1	216	40	82	58
4/12– 4/17	0.210	5.1	255	76	70	106
5/10– 5/15	0.191	5.6	257	44	83	61
6/ 7– 6/12	0.277	3.9	188	48	74	74
7/ 5– 7/10	0.209	5.1	254	58	77	81
8/ 2– 8/ 7	0.200	5.3	394	46	88	58
8/30– 9/ 4	0.198	5.4	290	47	84	63
9/27–10/ 2	0.193	5.5	289	50	83	67
10/25–10/30	0.360	3.0	176	36	80	56
11/22–11/27	0.252	4.2	214	48	78	70
12/20–12/24	0.208	5.1	232	51	78	73
Average	0.246	4.5	242	49	80	69
Maximum	0.360	5.6	394	76	88	106
Minimum	0.191	3.0	176	36	70	56

* Taken as 80 per cent of theoretical as tanks were originally designed as septic tanks but are now operated for a three-month run during which time solids are allowed to accumulate. Tanks are thoroughly cleaned prior to starting each run. Sludge hoppers not included in settling tank capacity.

† Determined in same manner as for Grass Island Plant.

TABLE 5.—*Correlation of Per Cent Removal with Effluent Suspended Solids*

Per Cent Removal	No. of Samples	Effluent Suspended Solids (p.p.m.)	Average p.p.m.
0 to 30	2	15, 28	22
31 to 40	4	15, 28, 31, 40	26
41 to 50	7	23, 30, 32, 34, 34, 34, 71	37
51 to 60	8	28, 32, 33, 34, 38, 40, 46, 59	39
61 to 70	12	22, 26, 28, 29, 30, 34, 40, 40, 42, 47, 56, 76	39
71 to 80	13	26, 31, 34, 36, 38, 38, 38, 41, 48, 48, 48, 51, 58	41
81 to 90	6	30, 40, 44, 46, 47, 50	43
		Average of all 52 samples	38

index provides a reasonably satisfactory criterion for plant efficiency.

Investigation was therefore made to determine if this criterion could be used for establishing a standard for plant performance. The best procedure seemed to be to arrive at an average figure for the dry weather flow, as uninfluenced by excessive infiltration or storm water, and to require a reasonable removal of suspended solids for sewage of this strength, then compute the sedimentation index from these figures and establish it as a standard.

Table 6.—*Correlation of Sedimentation Index with Effluent Suspended Solids*

Sedimentation Index	No. of Samples	Effluent Suspended Solids (p.p.m.)	Average p.p.m.
0 to 50	1	30	30
51 to 60	7	22, 26, 31, 36, 38, 40, 46	34
61 to 70	12	26, 28, 29, 30, 34, 38, 38, 41, 44, 47, 48, 50	38
71 to 80	11	15, 28, 32, 34, 34, 40, 40, 42, 48, 48, 51	37
81 to 90	12	23, 30, 33, 34, 34, 34, 38, 40, 46, 47, 56, 58	39
91 to 100	5	15, 28, 28, 31, 32	27
101 to 110	3	40, 59, 76	58
111 to 120	0		
121 to 130	1	71	71
		Average of all 52 samples	38

Averaging the suspended solids for the four plants during the five periods of dry weather flow, the influent sewage showed an average content of 175 p.p.m. Applying a 60 per cent removal to this figure yields a 40 per cent remainder, which amounts to 70 p.p.m. in the effluent. Adding these last two figures gives a sedimentation index of 110 as the general standard. Regardless of variations in sewage flow or strength, indices below this figure should indicate good plant performance and those above this figure should indicate poor performance, if this standard is to be of practical value.

Table 6 shows that 51 of the 52 samples complied with this standard and the effluents were actually satisfactory, ranging from 15 to 76 p.p.m. and averaging 38 p.p.m. The one sample which failed to meet this standard was at the Cos Cob Plant during a period when the sewage was noticeably soapy in character, due no doubt to comparatively large amounts of laundry wastes. At this time the influent sewage showed 142 p.p.m. and the effluent 71 p.p.m. a removal of only 50 per cent. For average strength domestic sewage this would really be poor performance by the plant and the high sedimentation index points this out. On the other hand, one of the satisfactory effluents showed 76 p.p.m. suspended solids, which, at first glance, would seem to reflect poorer plant performance than that yielding the 71 p.p.m. effluent. The influent sewage for the 76 p.p.m. effluent, however, showed 255 p.p.m. suspended solids and the removal was 70 per cent, which indicated satisfactory plant performance for that strength sewage. The sedimentation index in this case was 106, which also indicated satisfactory plant performance.

In general, it is the writer's opinion that the use of the sedimentation index as a criterion and standard reflects actual plant sedimentation performance in the Greenwich plants in a reasonably satisfactory manner.

In establishing the sedimentation index standard, a removal of 60 per cent suspended solids from the average dry weather sewage was taken as a reasonable figure. If this figure is used as a general standard a very interesting condition is indicated by Table 5. Here it is found that 21 of the 52 samples, or 40 per cent, failed to meet this standard but showed an average of 35 p.p.m. suspended solids in the effluent, whereas the other 31 samples which did meet this standard showed an average of 41 p.p.m. Actually, the samples which met the 60 per cent removal standard were of poorer quality than those which failed to meet this criterion. Although 60 per cent removal of suspended solids should readily be provided by plants treating domestic sewage not excessively diluted by infiltration or storm water, the general use of this or any other percentage removal for actual conditions at a plant where considerable variation occurs in sewage flow and strength is of very doubtful value.

It is suggested that the sedimentation index affords promise as a reasonably correct criterion of the efficiency of sedimentation units and that appropriate standards of plant performance may be derived from it. For very dilute sewages and very small percentage removals, a high index will be obtained which will reflect plant performance in a reasonably correct manner but which may unnecessarily condemn an effluent of good quality. This is brought out by the following example:

Two influent analyses showed 40 p.p.m. suspended solids. If the corresponding effluents had shown 35 p.p.m. (actually they were lower) this would have shown a removal of only 12.5 per cent and a sedimentation index of 123, thus correctly indicating poor plant performance. Yet, a primary sedimentation effluent of only 35 p.p.m. suspended solids is actually a very good one. Here it is believed that the quality of effluent should take precedence over percent removal or sedimentation index. Conditions of this sort, therefore, should be given consideration in establishing any standard for performance of sedimentation plants.

As a general standard for the Greenwich plants it is considered that all effluents of 35 p.p.m. or less of suspended solids should be regarded as satisfactory; above this figure a sedimentation index of 110 or less should be regarded as indicating satisfactory plant performance and a greater index as indicating unsatisfactory performance, requiring investigation of its cause as a prerequisite for possible remedial measures.

It is to be noted that the foregoing discussion of results at the Greenwich plants is based on analyses of samples of the day flow only. If full 24 hour samples had been taken, no doubt the suspended solids in influent and effluent would have been less than those recorded; the percentage removals would probably have been less than those noted and the sedimentation index greater. In the establishment and use of standards, therefore, it is important that the period of sampling and method of compositing be definitely stated in order to avoid misleading conclusions. While a 60 per cent removal of suspended solids from the dry weather *day* flow may seem reasonable for the conditions and sampling methods at Greenwich, this figure may not apply at all to conditions and sampling methods at other places. Standards would, therefore, have to be worked out independently for each locality, with perhaps, some sort of limiting standard for an entire region or drainage area. Whether or not practical standards for entire drainage areas can be developed from the sedimentation index will require further investigation, but from the data at Greenwich it offers more promise than a percentage removal standard.

OPERATING STAFFS FOR SEWAGE TREATMENT PLANTS *

By N. S. Holroyd

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Everywhere today is heard the cry of "manpower shortage." If a piece of equipment is ordered from a manufacturer, the first thing he asks is, "What is your priority? In other words, are your requirements important enough for us to remove men from another job or must we hold your order for fulfillment until some time in the future?" The operators of most sewage treatment plants have been hearing the cry of manpower shortages for many years before the time "priority" became such an important word in our vocabulary. Sewage treatment plant personnel should enjoy a high priority in any municipality inasmuch as the disposal of sewage is such an important and essential utility to the good health of its citizens.

The success of any project depends upon the interest shown by all who are a part of that program. The successful operation of a sewage treatment plant is no different from any other undertaking. A definite administration policy must be adopted which provides all participants with a feeling that the desired results can be obtained. If an impossible program is laid out the spirit is lost and the project is due for failure before it starts. The results obtained after the right policy has been adopted largely depend upon the operating personnel placed in charge of the plant.

Many plants have a fine policy prepared for them and a competent superintendent or chief operator found and placed in charge. This man is in complete agreement on the schedule selected but when he begins his work he finds that he cannot accomplish his goal due to the lack of co-operation in the obtaining of supplies and accessories needed to make the plant function smoothly or due to inadequate or incompetent help or possibly both. As soon as he realizes that the policy outlined cannot be followed, he should not hesitate to discuss the situation with his superior. First, however, he should study his own job and those of the other plant personnel to see if each man on his staff is being used to the best of his ability. If he thinks changes should be made among his men he should not hesitate to make them. The chief operator should use his own initiative to see that the desired results are obtained; that is the first responsibility and duty of his position. If the operator fails to get the results required after really trying, he should then make up a detailed list of the items that are giving him trouble. Each item should be followed by a statement showing what he has tried to do to correct the difficulty and the results. After this should follow his plan, outlining what he thinks is needed to rectify the

* Presented at Fall Meeting, New England Sewage Works Association, Worcester, Mass., September 13, 1944.

situation. The supervisor cannot help but listen to a concise report which has been made after considerable thought and detailed study. Many operators are continually annoying their supervisor with items of such trivial nature that when something important arises, it is not recognized as such and considered only as another minor complaint that will be overcome in time.

The chief operator should be given the full support of the supervisor in the handling of the men placed under him. Without this support, it is almost impossible for an operator to secure efficient and economical operation and meet the requirements of the State Department of Health. If a man comes from the plant to the supervisor with petty complaints, they should be heard before the chief operator or the answer given through him. Due to various reasons it is sometimes, we might say, impossible to discharge certain employees for failure to do the work assigned to them. In some municipalities the supervisor, through the chief operator, has given the uncooperative employee an immediate vacation from one to two weeks without pay. This has been most effective. The employee and all the operating force then realize that the chief operator has authority and that they must do the work assigned.

It is not difficult for the designing engineer to make definite recommendations as to the number of employees and the qualifications required by each, for a plant which he has built. He has made a study of the type of sewage which is to be treated, designed the plant accordingly, and knows what is required in the way of staff for proper operation. It is well known that the quantity of screenings, grit, scum, etc. received and handled, vary with every plant. Some small plants receive much larger quantities of grit than other plants several times their size. This means additional labor at the small plant to remove and dispose of the grit. The amount of screenings and grease obtained from some systems provide a major problem while they are no cause for concern at others. Operating personnel must be picked according to the requirements of the plant and not by the number of men employed in the treatment works of a neighboring community.

At a certain plant which handles the sewage from a population of only about 3,000 people, the flow and screenings were exceedingly heavy due to the location within the village of a large factory which processes leather. This company receives hides in carload lots direct from slaughterhouses throughout the country. All the hair must be removed from the skin together with uneven pieces of the hide known as fleshings. Considerable quantities of water are used in the process and when the vats are emptied, hair and fleshings enter the sewer and flow to the sewage treatment plant. For many years some of the fleshings were removed on the hand-raked bar screen but practically all of the smaller pieces and the hair went through to the tanks, causing tremendous layers of scum. The number of men required to operate this plant far exceeded that normally expected for a community of this size. After considerable discussion, the leather company agreed to install a fine screen to remove the hair and fleshings from their most offending sewer. This at once lightened the load at the sewage treatment plant and better results were obtained. This screen was installed several years ago and today you could not make the leather company remove it as they have found a ready market for the hair. The sale of this hair has not only paid for the screen but is a continual money maker for the company. Sometime after this screen had been in service a comminutor was installed at the sewage treatment plant which cut up the remaining fleshings together with the other large solids received from the village sanitary system. These improvements reduced the operating force, thereby saving money for the community, made money for the leather company by the sale of the hair salvaged, and also pleased the State Health Department by the discharge of a much more desirable effluent from the plant. This incident has been brought into this discussion as an example of one of the many things which affect the number of men needed to operate a sewage treatment plant and the results which can be obtained when a detailed study is made, followed by a definite plan of action.

The amount of equipment also has a decided bearing on the number of men required. The type of equipment is another important factor, not only in deciding the number of men, but also their qualifications. In the case of a new plant, or the remodeling of an old one, the engineer should make positive recommendations to the owner regarding the number of men required to operate the plant. He should also designate the types of men needed and the amount of training required by each to handle the job properly.

A great deal is heard today about creating public interest in sanitation. The operating staff can do far more to stimulate interest in the municipal sewage treatment plant than any others connected with the program. One of the first requirements is to insist on a clean plant. Good results cannot otherwise be obtained for long and it is impossible to interest people in visiting a plant which is dirty. Care should be exercised by the operator to continually keep it clean because one poor report overshadows many good ones and the uninformed public expects the place to be filthy due to the nature of material being handled. A clean plant gives standing to the operator and his staff and their work is considered on an equal basis with others in industry. Personnel at a dirty plant are often considered far from this equal.

Provision should also be made in staffing the plant to provide for the upkeep of the buildings and grounds around the units. A few dollars spent for paint, shrubs and seed pays big dividends in public respect. This is extremely important and is becoming more so each year with the trend to locate plants closer to the area being served. With the combining of the municipal incinerator and the sewage treatment plant at one site this is especially true. A nicely kept lawn, some well placed shrubs and a few flowers command the attention of every passerby, thereby creating the interest and good-will of the public. A tally of the names found in the guest book of a clean, well kept plant over that of a poorly kept one will show this to be very true. It is difficult to think of the Garden Club of a good sized city listing the city sewage treatment plant and incinerator as one of their garden spots but this, however, is just what has been done for the last few years at New London, Connecticut. The operating staff has taken such an interest in its plant by the planting of flowers, shrubs, and the upkeep of its lawns that it is one of the show places in the city. People who otherwise would never think of visiting the site become interested in the plant due to the pleasing appearance of the grounds and ask to be taken on a complete tour of inspection.

The certifying or licensing of sewage treatment plant superintendents and operators by the State Departments of Health has done much to improve the caliber of operating personnel. While the classifications differ in various states, the advantages are there and the general standing has been raised. There has been considerable discussion whether more than one man should be certified at a single plant. It is natural for a conscientious and able employee to desire to improve himself in position as well as financially. If he knows that by applying himself he can obtain a certificate which will then permit advancement or the opportunity of becoming chief operator at another plant, it will be an incentive to do good work. It appears that capable operators should be given every consideration.

As mentioned before, it is not difficult for the engineer to recommend operating personnel for the plant he has designed. It would not only be difficult but very unwise to state that a definite number of operators are required based only on the population served or the average sewage flow. Each plant should be considered as an individual problem and manned according to the work involved. This can be very readily shown by reviewing the records of many plants from all sections of the country with sewage flows from 0.3 million gallons per day to 98.6 million gallons per day. These records show operating costs which vary from $2.48 per million gallons to $40.75 per million gallons and from $0.11 per capita yearly to $1.60 per capita yearly. The great variation in cost is due to many features such as character of sewage, type of plant, design, arrangement of plant units, age of plant, size, degree of treatment, and so forth. The administration policy also has a great bearing on the cost of operation. Political or non-political control of municipal plants is of major importance as well as the degree of civic interest shown. Large plants are usually able to show lower costs per million gallons treated and per capita yearly than are small plants, although the large plants are more liberal in the number of operating personnel and their salaries.

Many small plants are limited to one operator regardless of the number of plant units and of his assignment to other part time services. He is to give the plant the attention he thinks it needs. There is no set schedule and if the operator is not conscientious and interested in the results obtained or the appearance of the plant, it soon takes on a run-down look. After a time, it is necessary to furnish additional help for a good clean up and general repair after which the cycle starts over again. Few plants can get along on part time, hit or miss attention. Definite instructions should be given to the operator outlining his duties, and periodical inspection should be made to see that the instructions are being carried out. If it is a new installation, the engineer should properly instruct the superintendent when he takes over the plant in the operation of the different units. If it is an existing plant that has become run down and the designing engineer is not available, the State Department of Health will be found most co-operative and helpful if sincere assistance is requested. Adequate additional help should be promptly given to a good operator when needed for the removing of sludge, making repairs, or other emergencies.

While it has been pointed out that it would be very unwise to select the staff required for a sewage treatment plant without knowing the character of the sewage and other operating conditions, we will select several hypothetical plants for the purpose of this discussion, make certain assumptions, and man the plants accordingly. All plants will be located in cities of about 20,000 population, receiving sewage from a sanitary system only and with the volume of industrial wastes small in comparison with the total received. The plants will be moved from one section to another and the treatment changed as required to meet conditions. Working time will be on the basis of a forty-four hour week with shifts staggered for complete coverage. All plants will be attractively landscaped.

The first plant will be located along the coast or on a large river. Due to the dilution obtained by the effluent in the adjoining large body of water primary treatment only is required. This plant will consist of grit collector, bar screen, plain sedimentation, separate sludge digestion, gas utilization, chlorination, and sludge drying beds.

The staff at this plant would consist of one superintendent or chief operator, one operator skilled in mechanical and electrical maintenance, and two general operators. Operation is on the basis of one shift per day. Operators in a plant of this size are expected to do all types of work and their duties are not limited to taking samples and pumping sludge.

Now let us move the plant inland and place it so that the effluent enters a small river or stream. Under these conditions additional treatment is required so trickling filters and final sedimentation are added. One additional operator is now needed who is particularly skilled in chemistry. One laborer should also be employed. The staff would then consist of one superintendent or chief operator, one operator skilled in electrical and mechanical maintenance, one operator trained in chemistry, two general operators and one laborer. This plant would normally operate on a one-shift schedule although it might be necessary during the summer months to work the two general operators on a two-shift arrangement.

The third plant to be considered will remain on the same small river or stream as the second but will be located nearer to the center of town and will be modernized by the installation of vacuum filters in place of sludge drying beds. The operating schedule and number of men would remain the same as for plant number two.

The next plant will remain the same as number three, which included trickling filters and separate sludge digestion, except that after vacuum filtration the sludge cake will be dried and burned. The same operating force will be employed provided that the equipment is of a type that can be operated during only one shift. In the event that the incinerator requires twenty-four hour operation, two additional men would be needed for each of the two night shifts. These would be required only during the periods that the filtering and burning was in progress.

Let us now revise the type of treatment and make it an activated sludge plant. It is still located inland and includes grit collector, bar screen, settling tanks, aeration tanks, final settling tanks, separate sludge digestion, gas utilization, chlorination, and sludge drying beds. The operating staff would remain the same on the day shift as plant number two except that the operator previously referred to as skilled in chemistry should be a chemist. There would also be one operator for each of the two night shifts. Personnel would be as follows: one superintendent or chief operator, one chemist, one operator skilled in electrical and mechanical maintenance, four general operators and one laborer. No change would be made in the number if vacuum filters were used. If the sludge is to be burned on a twenty-four hour schedule, two additional men would be required during the period that the incinerator was in operation.

This discussion has now indicated the number of operators for several hypothetical plants. Actual conditions may change the number materially. It has also pointed out some of the more important requirements to be considered in the staffing of any plant. Sewage treatment plants must be designed to meet existing conditions. Personnel for operating them must also be picked according to the amount of work to be done. To insure good results, it is imperative that management and operators co-operate to the fullest extent. The operating staff must consist of men who are not only capable, willing and interested in their work, but in an adequate number to keep the plant well groomed and functioning properly at all times so that it serves the purpose intended, that is, to safeguard the public health.

ERRATUM

Donaldson, Wellington. ''Utilization of Sewage Grease.'' *This Journal,* 16, 495 (May, 1944).

Disregard data given for ''average month'' and ''average day'' in last column of Table 1 on page 496. By direction of the author.

Sewage Research

THE DETERMINATION OF GREASE IN SEWAGE *

By W. D. Hatfield and George E. Symons

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The determination of grease in sewage, like much of the history of sewage treatment in America, dates back to the early work of Allen Hazen (1) at the Lawrence Experiment Station.

Throughout the first seven editions of *Standard Methods for the Examination of Water and Sewage,* Hazen's historic method served its purpose and because there seemed to be no demand for more accurate methods, it persisted. The method consisted of evaporating 500 ml. of sewage to 50 ml., neutralizing the alkalinity with normal H_2SO_4, evaporating to dryness and extracting the residue with boiling ethyl ether three times. The ether was filtered and evaporated, and the greasy residue was dried for 30 minutes at 100° C., weighed and reported as fats or ether solubles.

In 1934, Knechtges, Peterson, and Strong (2) reported a study of "lipids in sewage" in which the method of determinations was as follows: Neutralize the sample with hydrochloric acid; evaporate in a dish containing about 15 mg. of asbestos to facilitate removing the residue; transfer the residue to a thimble where it was extracted in a Soxhlet extractor for 12 to 16 hours with ethyl ether, petroleum ether or chloroform. Chloroform gave the highest results and was preferred by the authors.

The Committee on Standard Methods appointed in May, 1935, by the Federation of Sewage Works Associations was not quite ready to recommend chloroform as the exclusive extractant and did the deplorable thing of recommending all three extractants until further work was done. The method as recommended by the Committee was published in the 8th edition of *Standard Methods* in 1936.

Since that time, there has been an increased interest in the determination of "grease" and several new methods have been evolved and proposed. These new methods might be classified or designated according to certain distinguishing characteristics as follows:

1. Alum coagulation with diatomaceous earth as a filter aid, drying and sixteen hour extraction with petroleum ether (Gehm (3))
2. Acidification and refrigeration; filtration through cotton, extraction of filtrate, drying and extraction with petroleum ether for four hours (Hurwitz (4)-Ludwig (5))

* Sub-committee Report Presented at 16th Annual Meeting, New York State Sewage Works Assn., New York City, Jan. 21, 1944.

3. Direct wet extraction of acidified sewage with mixed hexanes in separatory funnel, filtrations of hexane, evaporation and weighing of grease (Pomeroy-Wakeman (6))

4. Lime coagulation and filtration on asbestos, acidification and fluffing, extraction with petroleum ether for 3 to 4 hours (Eliassen and Schulhoff (7))

5. Oil extraction of sewage solids or sludge and ether extraction of the oil (Gehm (8))

Grease Referee Committee

In 1941, the Chairman of the Committee on Standard Methods of the Federation (the senior author), appointed a referee committee on the grease determination to be headed by the junior author. Fifteen persons with laboratory facilities were asked to serve on this referee committee, each to carry out certain comparative experiments. Because of the war or for other reasons the response was not unanimous. In fact, only three laboratories actually undertook and carried out the tests as prescribed. These were the laboratory of the New York State Dept. of Health at Albany, N. Y., under the direction of F. Wellington Gilcreas, Asst. Director; the laboratory of the Buffalo Sewer Authority, Buffalo, N. Y., under the direction of Dr. George E. Symons, Chief Chemist; and the laboratory of the Indianapolis sewage treatment plant, Indianapolis, Ind., under the direction of Don E. Bloodgood, Supt.

The work on investigation of the methods for grease determination was started before the last two above named methods had been suggested and hence the comparative studies were confined to the first three methods. In the comparative studies, each laboratory was to determine grease on ten samples of sewage, the determination being

Table A.—*Comparison of Procedures for Grease Determination*

Gehm	Hurwitz-Ludwig	Pomeroy-Wakeman
1. 1–4 liters sewage	1 liter sewage	1 liter sewage
2. See (5) below	Acidify (HCl) to pH 1.0, boil 2 min., chill 2 hrs.	5 ml. 1 : 1 H_2SO_4 (pH not given)
3. 40 ml. (300 g. per 1,000) alum, stir 5 minutes, settle		
4. Filter on Dicalite etc.	Filter on cotton disc	
5. Acidify residue with 10 ml. 1 : 10 HCl		
6. Dry at 60° C., this takes 2–4 hrs.	Dry residue 103° C. 30–45 minutes	
7. Extract in Soxhlet 12 hrs.	Extract in Soxhlet 3–5 hrs.	Extract in sep. funnel about 5 times
8. Petroleum ether 30–60° C.	Petroleum ether 40–60° C.	Hexane (60–62° C.) not specified.
9. Dry 60° with vacuum 1 hr.	Dry 103° C., 15 minutes with vacuum	Dry 103° C., 15 minutes air jet
10. Weigh	Desiccate 1 hr. and weigh	Weigh

TABLE B.—*Results of Comparative Tests for Grease*

Sample No.	New York State Dept. of Health Lab.									Indianapolis, Ind. Sanitary District									Buffalo Sewer Authority								
	Coagulation			Refrigeration			Wet Extraction			Coagulation			Refrigeration			Wet Extraction			Coagulation			Refrigeration			Wet Extraction		
	p.p.m.	Ave.	Dev.	p.p.m.	Ave.	Dev.	p.p.m.	Ave.	Dev.	p.p.m.	Ave.	Dev.	p.p.m.	Ave.	Dev.	p.p.m.	Ave.	Dev.	p.p.m.	Ave.	Dev.	p.p.m.	Ave.	Dev.	p.p.m.	Ave.	Dev.
1	209.2		1.0	165.9		16.1	122.0		10.9	88.3		3.8	72.9		.2	65.7		1.6	30.5		.7	40.6		5.0	33.8		1.0
	208.9		.7	143.5		6.3	138.2		5.3	96.9		4.8	72.5		.2	63.5		.6	35.3		4.1	37.2		1.6	39.9		7.1
	206.4	208.2	1.8	140.1	149.8	9.7	138.5	132.9	5.6	91.2	92.1	.9	72.8	72.7	.1	63.1	64.1	1.0	27.7	31.2	3.5	28.9	35.6	6.7	24.7	32.8	8.1
2	89.9		2.6	65.6		5.8	55.0		.7	24.5		.6	22.4		1.5	18.8		.1	27.5		.5	37.4		2.5	21.8		2.1
	96.0		3.5	67.9		3.5	54.2		.1	24.9		.2	19.9		1.0	19.3		.4	28.2		1.2	32.3		2.6	26.3		2.4
	91.5	92.5	1.0	80.6	71.4	9.2	53.8	54.3	.5	25.9	25.1	.8	20.5	20.9	.4	18.7	18.9	.2	25.3	27.0	1.7	35.0	34.9	.1	23.6	23.9	.3
3	300.5		.8	241.1		8.8	183.3		6.2	75.4		2.1	50.8		3.0	56.9		2.4	15.9		.2	27.1		.5	21.6		1.0
	299.9		.2	215.5		16.8	182.0		7.5	72.4		.9	53.3		.5	52.2		2.3	9.1		7.0	26.8		.2	21.3		.7
	298.6	299.7	1.1	240.2	232.4	9.9	203.3	189.5	13.8	72.0	73.3	1.3	57.4	53.8	3.6	54.5	54.5	.0	23.4	16.1	7.3	26.0	26.6	.6	18.9	20.6	1.7
4	120.0		2.1	106.7		2.5	72.7		5.0	58.4		.6	40.3		5.3	48.1		.2	12.2		3.8	33.4		1.1	22.1		1.7
	123.8		1.7	111.7		2.5	90.3		12.6	59.4		1.6	52.3		6.7	46.4		1.5	23.9		7.9	37.2		2.7	21.7		2.1
	122.6	122.1	.5	—	109.2	—	70.2	77.7	7.5	55.5	57.8	2.3	44.2	45.6	1.4	49.2	47.9	1.3	12.0	16.0	4.0	32.9	34.5	1.6	27.7	23.8	3.9
5	99.6		4.2	59.3		9.2	60.9		1.1	97.8		1.5	58.7		0	64.3		.8	17.8		.2	30.4		.8	17.2		1.8
	95.2		.2	75.2		6.7	64.8		5.0	99.6		.3	57.0		1.7	64.0		.5	18.7		1.1	29.3		1.9	19.6		.6
	91.3	95.4	4.1	71.1	68.5	2.6	53.7	59.8	6.1	100.4	99.3	1.1	60.4	58.7	1.7	62.3	63.5	1.2	16.3	17.6	1.3	34.0	31.2	2.8	20.1	19.0	1.1
6	50.2		2.3	46.9		2.7	29.9		1.2	108.7		.4	94.7		.9	81.7		3.3	15.1		1.1	20.5		1.2	17.4		2.0
	54.9		2.4	42.0		2.2	35.3		4.2	107.5		.8	92.7		1.1	86.0		1.0	11.7		2.3	17.9		1.4	21.4	19.4	2.0
	—	52.5	—	43.6	44.2	.6	28.1	31.1	3.0	108.6	108.3	.3	94.0	93.8	.2	87.4	85.0	2.4	15.1	14.0	1.1	19.4	19.3	.1	—		—
7	72.1		2.6	69.6		5.7	40.9	1	4.3	74.2		3.1	50.6		2.8	58.1		.8	27.8		.7	28.5		3.4	21.8		1.6
	77.4		2.7	55.9		8.0	46.1		.9	64.7		5.4	51.4		2.0	52.5		6.4	25.1		2.0	35.0		3.1	24.9		1.5
	74.6	74.7	.1	66.3	63.9	2.4	48.7	45.2	6.5	71.5	70.1	1.4	58.2	53.4	4.8	66.0	58.9	7.1	28.4	27.1	1.3	32.3	31.9	.4	23.6	23.4	.2
8	51.6		.3	39.0		2.8	29.0		.6	51.7		.1	37.9		1.8	40.2		2.6	14.4		.9	24.5		3.2	26.2		1.7
	53.3		1.4	44.0		2.2	32.4		2.8	53.5		1.9	38.8		.9	44.1		1.3	16.9		1.6	23.0		1.7	24.0		.5
	50.8	51.9	1.1	42.5	41.8	.7	27.5	29.6	2.1	49.6	51.6	2.0	42.4	39.7	2.7	44.0	42.8	1.2	14.6	15.3	.7	16.5	21.3	4.8	23.4	24.5	1.1
9	93.8		.5	64.3		3.9	42.1		.7	70.7		2.8	48.8		.9	45.3		.1	24.5		2.1	19.5		.6	14.4		1.0
	95.3		2.0	62.3		.9	42.7		.1	64.4		3.5	53.8		4.1	45.1		.1	20.9		1.6	19.0		1.1	13.5		.1
	90.9	93.3	2.4	54.6	60.4	5.0	43.7	42.8	.9	68.5	67.9	.6	46.6	49.7	3.1	45.2	45.2	0	21.7	22.4	.7	21.9	20.1	1.8	12.2	13.4	1.2
10	164.9		3.6	167.5		15.0	131.9		7.6	81.4		.1	51.0		.5	60.5		1.5	16.8		.3	20.3		.1	15.3		.8
	165.4		3.1	170.3		12.2	136.6		12.3	78.8		2.7	49.8		.7	62.7		.7	14.7		1.8	21.4		1.2	13.6		.9
	175.1	168.5	6.6	209.6	182.5	27.1	104.3	124.3	20.0	84.4	81.5	2.9	50.7	50.5	.2	62.8	62.0	.8	17.9	16.5	1.4	18.9	20.2	1.3	14.7	14.5	.2
Average	125.9		1.9	102.4		6.9	78.7		5.4	72.7		1.7	53.9		1.8	54.3		1.5	20.3		2.1	27.6		1.9	21.6		1.7
Maximum			6.6			27.1			20.0			5.4			6.7			7.1			7.9			6.7			8.1

made by each of the three methods and each method being determined in triplicate. In all, this meant ninety determinations of grease to be made in each laboratory. At Indianapolis and Buffalo the determinations were made on different samples of sewage from the same plant, but at Albany the determinations were made on samples of ten different sewages.

As to the technique of each method used it should be noted here that the actual techniques were not those as published by the authors of the methods but were the latest revisions (at the time) as obtained from those authors. Before the tests were undertaken each of the originators of the methods was supplied with the step by step procedures proposed for the committee to follow. After considerable correspondence all of the authors were agreed on the size of the sample, drying time, and temperature, and other details. The details of these techniques as they vary from the original published methods are not important enough to reproduce here. It is sufficient to say that standard techniques approved by the method originators were used in each of the three laboratories and Table A shows the general features of the tests. The studies were begun in late 1941 and completed in 1943.

Results of Comparative Tests

The analytical data of all tests are shown in Table B from which, together with comments by the workers, it has been possible to see certain advantages and disadvantages of the three methods of determining grease.

In general, the first method, alum coagulation with Dicalite as an aid was found to be tedious because the diatomaceous earth holds the grease so firmly that 12 to 16 hours extraction are required to remove the grease. This long extraction period tends to dissolve soluble material other than grease. In short, it may be said that good results were obtained with the method although the results seem to be somewhat high.

The second method, that of refrigeration and acidification of the sewage, appeared to give a grease that was quickly soluble in petroleum ether, although it has the disadvantage of requiring extraction (wet) of the liquid to obtain dissolved grease and emulsified grease that had not solidified on chilling.

The third method, that of wet extraction with hexanes, has several advantages, particularly for field work. It is also very applicable to sewages low in suspended solids. With high suspended solids, activated sludges, digested sludge, or mixed liquors, the results would appear to be low when determined by the wet extraction method. Whether hexanes as a solvent have any advantage was not observable from the studies made, but it seems that the more readily obtainable and standard solvent should continue to be the more desirable.

In order to arrive at the tendencies shown in the tests it is helpful to summarize in brief the data from Table B and this may best be done as follows:

Laboratory	Average Grease Content in p.p.m.		
	Coagulation	Refrigeration	Wet Extr.
N. Y. State—10 different sewages, range 50–300 p.p.m.	126	102	79
Indianapolis—10 samples same sewage, range 25–110 p.p.m.	73	54	54
Buffalo—10 samples same sewage, range 14–43 p.p.m.	20	28	22

It will be observed that at the New York State Lab. there was no agreement in any of the three methods, but the coagulation method gave the highest results and the wet extraction the lowest. At Indianapolis the coagulation method gave the higher results while the refrigeration and wet extraction methods gave lower but relatively equal results. At Buffalo the refrigeration method gave the highest results while the coagulation and wet extraction method gave lower but relatively equivalent results.

In spite of this seeming inconsistence, a study of the main table will indicate that reproducibility of results is quite feasible in the determination of grease regardless of the method. The average deviation from mean values ranged only from 1.7 to 2.1 p.p.m. for all of the 270 tests.

Committee Decisions

There has been an insistent demand from the sewerage field to do two things; (1) to define "grease" for the purposes of sewage analysis and plant operation and (2) to present a standard procedure which would have the legal backing of the A.P.H.A. Standard Methods even though other methods seemed to be just as good or were receiving further study by the committee.

At the Fourth Annual Meeting of the Federation of Sewage Works Associations in Chicago in October, 1943, members of the referee committee and of the Standard Methods Committee of F.S.W.A. met and discussed these results in an effort to arrive at answers to both of the above points. By that time there were, in the literature, two other methods for grease determination and the members of the committee had to weigh these also. (These are Nos. 4 and 5 as listed earlier in this report.)

It was the consensus that the analytical data were inconclusive and did not justify the selection of any one of the three methods. Other observations and comments of these committeemen were: Each observer appeared to obtain the best results with the method with which he was most familiar; the oil extraction method of Gehm appears to be more in the nature of an approximate and rapid test than one which could be chosen as a standard method; personnel time and elapsed time for the determination are important factors, as is equipment;

the long time of the coagulation and filter aid treatment method of Gehm rules against this method, while the newer method of lime coagulation of Eliassen and Schulhoff has distinct advantages both as to time and equipment required, but it unfortunately lacked confirmation in other laboratories.

Definition of Grease

By unanimous agreement grease was defined as "that material which is extracted from an acidified sample of sewage by petroleum ether (b.p. 40–60° C.) when using the standard procedure as outlined by the committee." While this is an arbitrary definition, it has two advantages. From a practical point of view it determines grease that causes "trouble" in sewage treatment plants and it is not concerned with small amounts of grease fats or lipoids contained in seeds or otherwise bound in sewage solids. The definition is also practical in that should the committee find another method to be more exact, easier of technique or generally more applicable, the definition will still hold good.

Determination of Grease in Sewage and Industrial Wastes

The standard procedure as agreed on by the Committee consists of the refrigeration method combined with a wet extraction of the filtrate to remove any emulsified grease which may not be removed by the chilling and filtration process. In many cases the wet extraction of the filtrate will be found unnecessary. The standard procedure is as follows:

1. *Reagents*

1.1 Hydrochloric acid, conc.
1.2 Petroleum ether, B.P. 40° – 60° C.
1.3 Cotton discs, washed with solvent and dried.
1.4 Filter paper—No. 1 Whatman 9 cm.

2. *Procedure*

2.1 Strongly acidify (pH 1.0) a liter sample with conc. HCl. Bring to boil and boil for two minutes. Cool and chill in refrigerator (50° F. or lower) for at least two hours.
2.2 Prepare a 9 cm. filter paper overlaid with grease-free cotton disc (cut from absorbent cotton to fit filter) extracted with petroleum ether and dried.
2.3 Filter the chilled sample through the cotton disc. Wipe the sides and bottom of the beaker carefully with a pad of grease-free cotton taking care to collect all solid material, add to filter.
2.4 Dry the filter paper and cotton pad in an evaporating dish in a hot air oven at 103° C for 30 to 40 minutes.
2.5 Roll filter paper and cotton pad to fit in a suitable extraction thimble and insert the thimble.

2.6 Transfer filtrate to a separatory funnel. Shake with 50 ml. or more of solvent. Run off the water layer and filter the ether layer through the Soxhlet thimble into a weighed extraction flask.
2.7 Extract in Soxhlet apparatus at rate of 8 to 10 cycles per hour for 3 to 5 hours.
2.8 Drive off ether from extraction flask on water bath and dry in oven at 103° C. for 15 minutes.
2.9 Draw off last traces of ether vapor by inserting a tube connected with vacuum pump into flask while still warm.
2.10 Cool in desiccator for one hour and weigh.
2.11 Gain in weight of flask in gms. × 1,000 = p.p.m. total grease.

Determination of Grease in Liquid Sludge

Procedure

2.1 Weigh sample large enough to yield about 50 mg. grease.
2.2 – 2.10 Proceed as for sewage, omitting step 2.6.
2.11 Determine per cent of dry solids on separate sample.
2.12 $\dfrac{\text{Gain in wt. of flask in gm.}}{\text{Dry wt. of sample in gm.}} \times 100 = \text{per cent total grease.}$

Comment

Although the committee members agreed on the above technique as standard, they also recommended that further studies be made in some of the available laboratories, of the lime coagulation method of Eliassen and Schulhoff. This recommendation was made with the idea in mind that this method and the wet extraction method might be included in the next edition of *Standard Methods* as a provisional method.

In choosing one method in preference to the others, the committee members did not intend to criticize the techniques of the other methods, but by and large they agreed that the chosen method best fitted the needs of the field as regards equipment, personnel time involved, elapsed time, and simplicity of technique.

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

I. Film Accumulation *

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A number of excellent studies pertaining to the biology and biochemistry of conventional or standard filters are available. The performance of such filters is well established. Features of design, loadings, and operation results of biofilters and other high-rate filters are becoming available of recent years, especially from army camp installations. Very little information, however, is available to parallel the studies in respect to the biochemistry and biology of standard filters. The following are some of the fundamental questions that remain to be answered:

1. Is the mechanism of purification of sewage in biological filters changed by increasing the load? In other words, is the difference between a high-rate and standard filter qualitative or merely quantitative?
2. Is the quantity of film in a high-rate filter different from that in the standard filter? What are the factors which govern the rate of accumulation and the rate of discharge of the film in a high-rate filter?
3. Are there essential differences in the biochemical characteristics of the film from the two types of filters? Is the degree of stability of the film in a high-rate filter different from that of the standard filter film? Is it true, as has been claimed, that a high-rate filter is merely a colloider and, therefore, the biological oxidation is of secondary importance?
4. Is the fact that high-rate filters generally do not produce appreciable quantities of nitrates due to the failure of nitrifying organisms in getting established, or is it due merely to the inability of the organisms to nitrify during the short time of contact with high rates of application?
5. Are the flora and fauna of the two types of filters different, and if so which type supports the greater number and types of organisms?
6. Is the performance of the filter affected by the quantity and characteristics of the film?
7. Do variations in environmental factors such as temperature affect both types of filters to a similar degree?

* Journal Series Paper, New Jersey Agricultural Experiment Station, Rutgers University, Dept. Water & Sewage Research, New Brunswick, N. J.

8. What is the importance of surface and what is the relationship between surface and purification?

The objective of this study was to answer, if possible, these main questions and a number of others that are interrelated with them.

The results of the study will be published as a series of papers, each dealing with a different phase of the problem:

1. Film Accumulation
2. Biochemical Characteristics of the Film
3. Nitrification and Nitrifying Capacity of the Film
4. Biology of the Film
5. Purification Capacity of the Treatment Plants
6. Correlation Between the Accumulation, Biochemical and Biological Characteristics and Purification Capacity
7. Correlation of Various Types of Filters.

The helpful co-operation of Major R. Eliassen, Mr. C. Shephard, and Mr. M. Kachorsky in making such a study possible, by furnishing help in obtaining the stone samples and in making available the operating records of the plants studied, is gratefully acknowledged. Acknowledgment is also made of the work done in the enumeration of the biological population of the film by Dr. J. P. Lackey, Senior Biologist of the United States Public Health Service Water and Sewage Investigations.

Description of the Plants

The biofilters studied are a part of the sewage treatment plant located in an army embarkation camp, consisting essentially of grit chambers, primary and secondary clarifiers, filters, separate sludge digestion tanks, and sludge drying beds. The plant was designed for a population of 35,000, but the population is variable. The sewage is distributed to the filters by two-arm rotary distributors. Recirculation is practiced from the effluent of the filters to the primary clarifier and also from the secondary clarifiers to a diversion chamber ahead of the filters. The plant was put in operation in October, 1942. The standard filter studied is a part of the Manville, New Jersey, sewage treatment plant. It treats only domestic sewage. The distribution to the filter is by two-arm rotary distributor. The plant has been in operation since 1938. Some of the pertinent basic design data of the two plants are shown at top of opposite page.

Methods and Procedure

The sampling on both filters was started in January, 1943. Samples were taken once or twice a month. Sampling in the biofilter plant was extended to February, 1944. It was discontinued at the standard filter plant in December, 1943, when 22 sets of samples had been collected.

Stone samples were collected from the top, one-foot, and two-foot

	Biofilter	Standard Filter
Sewage flow, average m.g.d.	3.5	0.83
Clarifiers		
Number	2	1
Detention period, ave. hours	2	4
Filters		
Number	2	1
Diameter each, ft.	125	110
Depth of stone, ft.	3	6½
Size of stone, inches	2½	1½ to 2
Total surface area, acres	0.56	0.22
Total stone, cu. yd.	2734	2285
Raw sewage application, m.g.a.d.	6.3	3.8
Raw sewage loading, lbs. B.O.D. per cu. yd. per day	1.5	0.3 to 0.4*
Recirculation ratio	1.5	none
Final settling tanks		
Number	2	1
Detention period, hours	2	1

* On the basis of assumed values of 100 and 150 p.p.m. of B.O.D. in raw sewage. The average suspended solids during the year for the eight-hour day flow was 170 p.p.m.

levels. The surface layer of stone was removed before the samples were taken from the top. A hole was dug each time at a different part of the filter for sampling from the different depths. In the biofilter, the same filter was sampled each time, except when that filter was out of service.

The stone samples from each level, amounting to 20-25 pounds, were scraped with a brush into tap water immediately after they were brought to the laboratory. The weight of the stone and the volume of sludge obtained were determined and the quantity of film per kilogram of stone was calculated from the amount of dry solids in the material removed from the stone.

Results

The average quantity of the film in three levels of the biofilter during the period covered by this study is shown in Fig. 1. The quantity of dry film fluctuated from 1.4 to 2.8 grams per kilogram of stone from January to October. There was a sharp increase thereafter, reaching a maximum of 4.4 grams per kilogram in January. The results indicate that the quantity of film during the first winter was lower than that during the second winter.

The yearly, summer and winter averages of the film at different levels are given in Table I. The summer average covers the period from May to November inclusive, when the temperature of the sewage was in excess of 62 deg. F. and averaged 70 deg. F. The winter period covered from December to April, inclusive, when the temperature of the sewage was below 56 deg. F. with an average of 54 deg. F. The averages for the 1942-43 and 1943-44 winters together and separately are given in the table. The results indicate that the quantity of film at all levels was lower in the winter of 1942-43 than in 1943-44.

The pounds of B.O.D. and suspended solids applied to the filter are shown in Fig. 1. They represent the load applied to the filter and include the B. O. D. and suspended solids contributed by the primary clarifier effluent and the recirculation from the secondary clarifier.

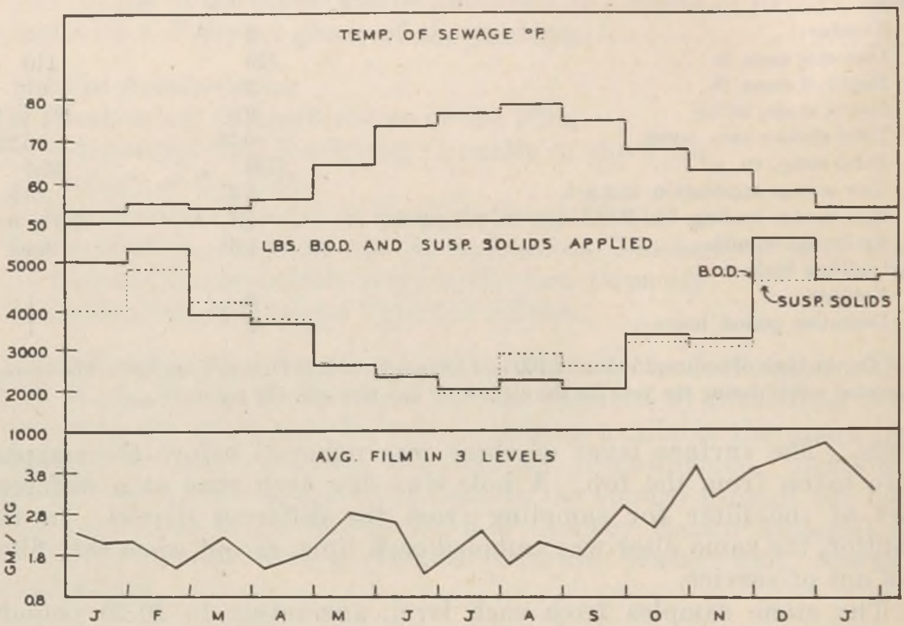

FIG. 1.—Comparison of the film content (gm. dry solids per kilogram stone, average of three levels) in the biofilter with the B.O.D. and suspended solids load applied to the filter and the temperature of sewage.

TABLE I.—*Quantity of Film in Biofilter in Grams Dry Solids per Kg. Stone*

	Period	No. of Samples	Temp. °F	Top	1-foot	2-foot	Ave. of 3 Levels
Yearly Ave.	Jan. 1943–Feb. 1944	22	62	2.12	2.80	2.71	2.52
Summer Ave.	May to Nov. 1944	12	70	2.33	2.72	2.47	2.51
Winter Ave.	Winter of 1943 and 1944	10	55	1.87	2.90	3.12	2.63
Winter Ave.	Winter 1943	7	54	1.30	2.39	2.09	2.26
Winter Ave.	Winter 1944	3	54	3.21	4.10	4.49	3.90

The differences in film accumulation during the two winters are not due to the load variations, because the pounds B.O.D. and suspended solids applied to the filter during the winter of 1942-43 were as high as in 1943-44. It should, therefore, be concluded that the quantity of film in the bed in the winter of 1942-43 is not typical of winter conditions. Film accumulation was retarded by the onset of cold weather soon after the plant was put in operation in October, 1942. Since the film failed to accumulate, despite the high loadings, the removals of suspended material by the bed during this period should be low.

Actually, such was the case, as will be shown in the section dealing with the purification capacity of the filter.

The quantity of film in the biofilter, with the exclusion of the initial working-in period, varies directly with the pounds B.O.D. and suspended solids applied and indirectly with the temperature (Fig. 1). When the rate of biological destruction of the film was high in the summer, the loading was low and the conjunction of these two factors resulted in low film accumulation. When the ability of the bed to destroy the film was retarded by the lower temperature, high loads were applied, which resulted in larger film accumulation. If the loadings applied had been higher in the summer than in the winter, it is possible that the quantity of the film would have been greater, but probably not at the same level as in the winter.

When May and October are selected for comparison, the following results are obtained:

	May	October
Temperature, deg. F.	64	67
Load, lbs. B.O.D. applied	2,600	3,300
Film dry solids, gm. per kg. stone	2.8	2.5

The average temperature of the sewage was 3 deg. F. higher, the B.O.D. loading was 700 pounds or 27 per cent higher, and the quantity of film was 0.3 gm. per kg. stone lower in October than in May. The results on film accumulation are on the basis of one sample during each month and may not represent accurately the actual quantities during the month. With nearly equal loadings on the basis of pounds B.O.D. and suspended solids and with temperature above 70 deg. F. during June, July, August, and September there were some minor fluctuations in the average quantities of film. The discrepancy in the quantities of film in December and February, with nearly equal B.O.D. and suspended solids loadings and temperature, is due to the failure of the bed to mature fully in the cold months after the plant was placed in operation.

The average quantities and the progressive changes in the film at the top, one-foot, and two-foot levels are given in Table I and Fig. 2. With only a few exceptions, the top level of the bed contained the least film. The average values are considerably lower at the top than at the lower levels. The difference in the average film content between the one and two-foot levels is not appreciable. The individual values at these two levels are close to each other, with a few exceptions when the quantity of the film was considerably higher at one level than the other. The fluctuations in the quantity of film at different levels follow one another fairly closely. An increase in the quantity of the film at one level is reflected in the other levels. In other words, the factor or factors that influence the film accumulation are effective throughout the top two-foot zone. This also indicates that the sampling methods were adequate and reliable.

The vertical distribution of the film in the bed is shown in Fig. 3. During the summer the quantity of film in the bed was low and was uniform from the top to the two-foot level. During the winter of

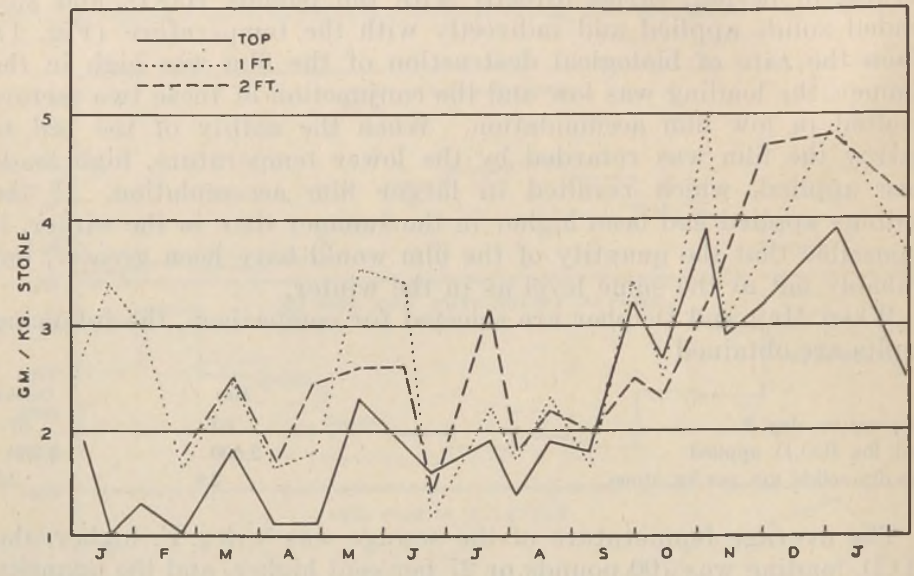

FIG. 2.—Comparison of the quantity of film at the different levels of the biofilter (gm. dry solids per kilogram stone).

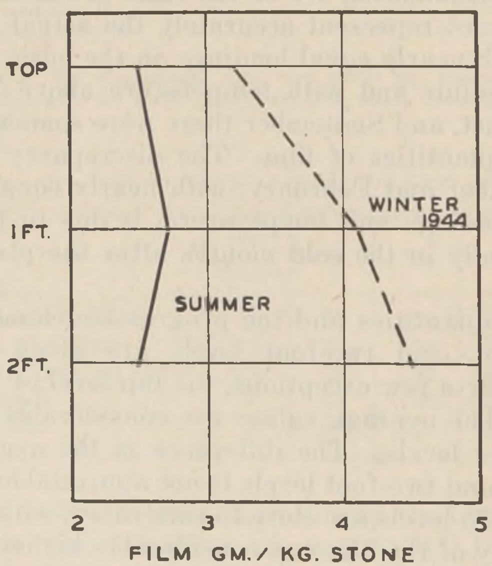

FIG. 3.—Vertical distribution of film in the biofilter during the summer and winter (gm. dry solids per kilogram of stone).

1943–44, the solids content in the bed was high and increased from the top to the two-foot level.

In an effort to account for the low film accumulation on the top of the filter, the volume of total flow applied to the filter is compared with the film accumulation on the top of the filter in Fig. 4. The total flow figures include the recirculation. After the middle of March, there is a direct positive relationship between the quantity of film at the top level and the total flow through the filter. It appears from these results that the low film accumulation on the top of the filter is not due to

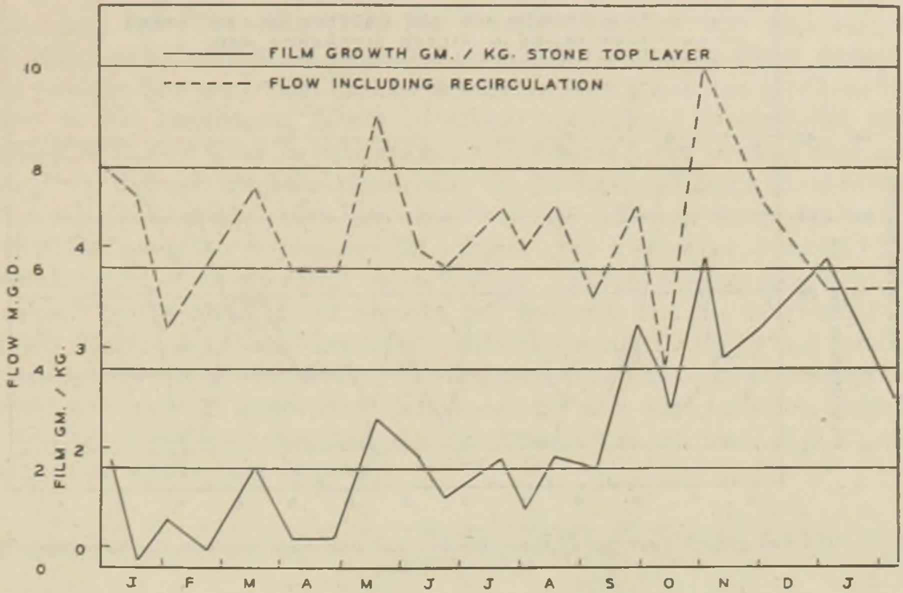

FIG. 4.—The quantity of film at the top layer of the biofilter and the flow applied to the filter including the recirculation

the flushing action of the higher flows striking the surface, because a positive correlation was obtained instead of a negative correlation. The range in the flows varied from a minimum of 4 to a maximum of 10 m.g.d. or from 7 to 18 m.g.a.d. Within this range of flows, scouring of the film does not seem to be an important factor.

Since the quantity of film in the bed is the resultant between the rate of accumulation and the unloading of solids, the periods of high accumulation should coincide with periods of low discharge of suspended solids and vice versa, provided unloading is an important factor in determining the quantity of film remaining in the bed. Such a comparison is made in Fig. 5, where the p.p.m. suspended solids in the effluent from the filter is compared with the average quantity of film at the three levels. The results show that at certain times the relation between suspended solids in the filter discharge varies indirectly with the film growth, as would be expected if unloading was the only factor in the quantity of film present in the bed, but at other times the relationship is direct. The negative correlation between suspended solids in the filter effluent and the quantity of film is more apparent during the winter when biological growth is limited. The suspended solids in the filter discharge was at a minimum during the period from May to July.

During this period the suspended solids and B.O.D. load applied to the filter were also at a minimum. The solids in the effluent increased, however, before the load increased appreciably.

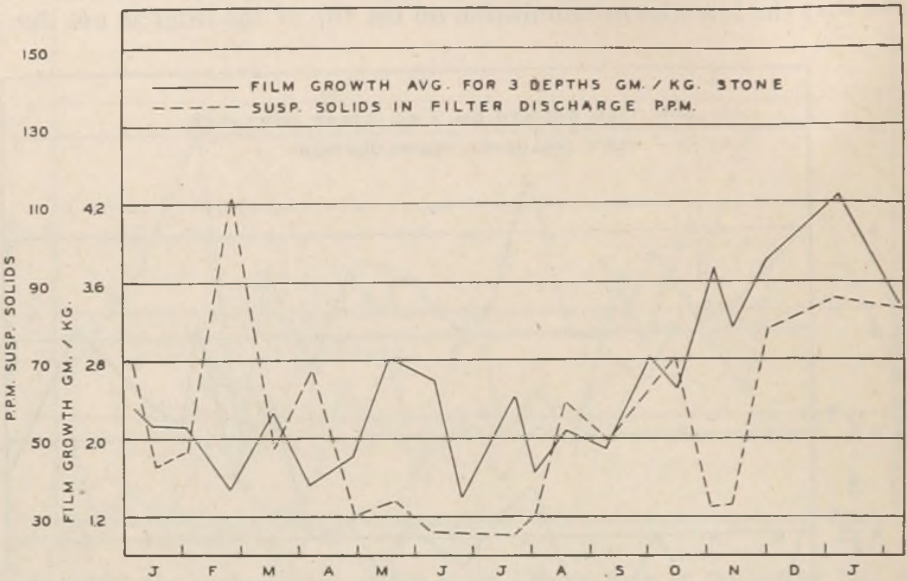

FIG. 5.—The film growth (average of three depths) and suspended solids in the filter discharge in the biofilter.

The effect of applying the whole flow on one of the filters, necessary for temporary repairs of the distributors, on the quantity of film is presented in Table II. On October 12, one of the filters was shut down for two days. The bed was sampled on October 13 and again on

TABLE II.—*Effect of Temporary Shutdown of One Filter on the Quantity of Film in the Filter in Operation*

Date	Filters in Operation	Sewage Flow M.G.A.D.	Total Flow M.G.A.D.	Film Growth Dry Solids gm./kg.			
				Top	1-ft.	2-ft.	Ave.
September 29	two	4.4	12.8	3.26	3.43	2.52	3.07
October 13	one	5.8	14.5	2.66	2.55	2.34	2.51
October 15	two	6.4	15.6	2.41	2.57	2.38	2.45
November 3	one	9.8	17.6	3.90	4.97	3.19	4.00
November 12	one	6.6	16.4	2.92	3.03	3.44	3.13
December 1	two	4.6	13.2	3.19	3.71	4.72	3.87

October 15 when the two filters had been put in service. The sample taken on September 29 when both filters were in operation is included for comparison with the October 13 and 15 samples. From October 25 to November 12 the whole flow was again passed through one filter. Two samples were taken during this period, one on November 3 and one on November 12, just before the two filters were put in service again. The December 1 sample, representing a period of operation of over two weeks when both filters were in service, is included for comparison. The method of operation during the periods when one of the filters was out of service was modified to the extent of eliminating the recirculation of the secondary clarifier effluent to the biofilter, although the recirculation from the filter effluent to the primary clarifier was maintained. The total sewage flow was treated on one filter during these periods. The sewage flow and total flow to the filters in m.g.a.d. are given on the basis of the number of filters in actual operation. During the first period, with one filter in operation on October 13, the sewage flow and total flow did not increase materially on the basis of m.g.a.d. of actual filter area in service. The film growth at the different levels decreased somewhat over the September 29 values. On November 3 and 12 the actual rates of application were higher. There was a considerable increase in the quantity of film on November 3, but the November 12 values were lower than December 1 values when both filters had been in operation for over two weeks. It appears from these results that the volumetric rate of application influences the film accumulation only to a limited extent and that the important factor is the total B.O.D. and suspended solids load applied.

TABLE III.—*Film Accumulation in Standard Filter (gm. dry solids per kg. stone)*

	No. of Samples	Top	1-foot	2-foot	Ave.
Yearly Ave.	17	3.98	2.64	2.77	3.31
Summer Ave.	9	2.53	1.99	1.83	3.17
Winter Ave.	8	5.60	3.44	4.47	4.50

The quantity of film in the standard filter is given in Table III. In contrast with the biofilter, the highest film accumulation in the standard filter was at the top. At the one-foot level the values were higher in the summer and lower in the winter than at the two-foot level. As in the biofilter, the film was lower at all levels during the summer than in winter. The average film content in the standard filter was 30 per cent higher than in the biofilter, practically all due to the greater film content at the top, since the quantities of film at the other two levels were nearly the same in the two types of filters. As in the biofilter, the vertical distribution of the film in the standard filter was more uniform in the summer than in winter (Fig. 6). The seasonal fluctuations in the quantity of film at the three levels is presented in Fig. 7. The quantity of film in the filter reached a peak in April and decreased sharply until the middle of June. Plant records show that spring sloughing started in the middle of May and continued until the end of June. Flooding for fly control was resorted to only twice during the summer and, therefore, exerted only minor influence on the quantity of film. The increase of film in the filter after the spring sloughing started at the top of the filter, was followed by increases at each succeeding level. By December, the top level had accumulated a copious film, but at the one and two-foot levels it was only moderate.

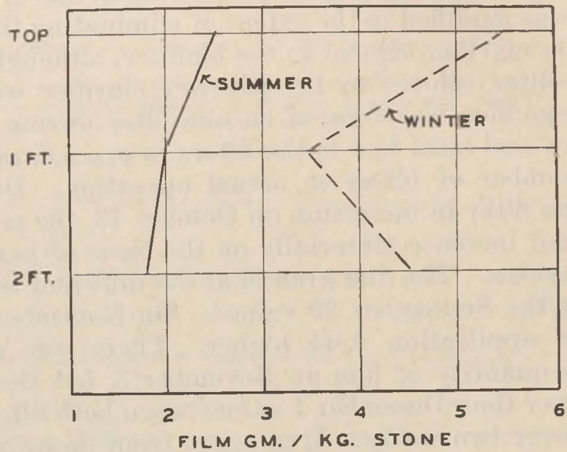

FIG. 6.—Vertical distribution of film in the standard filter during the summer and winter (gm. dry solids per kilogram stone).

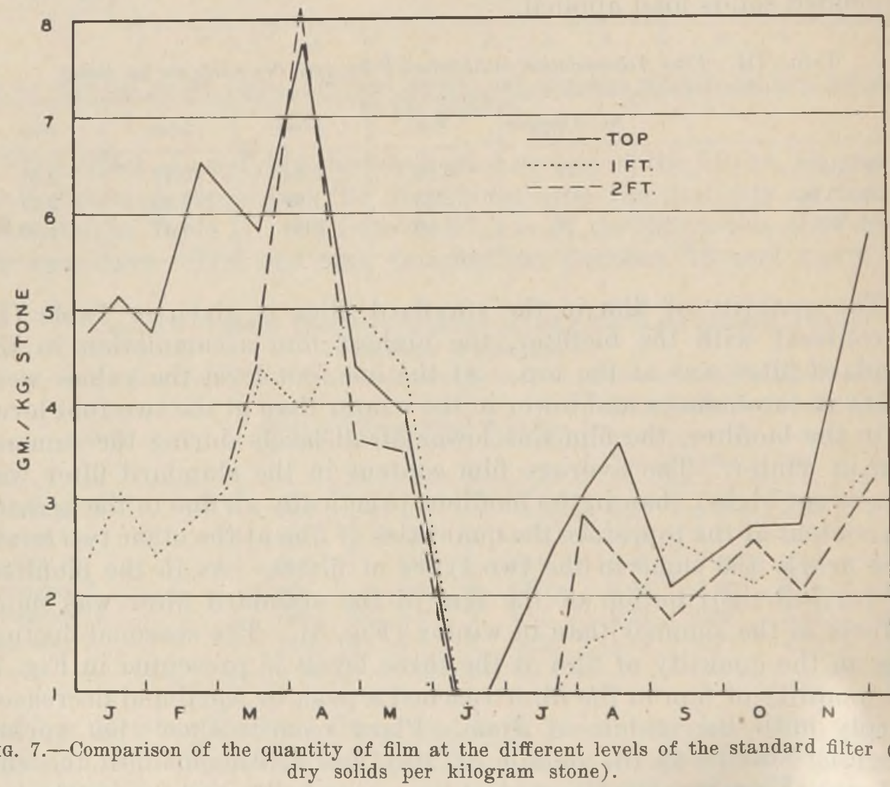

FIG. 7.—Comparison of the quantity of film at the different levels of the standard filter (gm. dry solids per kilogram stone).

It appears that, in the standard filter, first and greatest accumulation takes place at the top, the growth moving downward as the top accumulation becomes heavy.

Discussion

The quantity of film in a filter bed is determined by the net effect of two opposing factors, (1) accumulation and (2) unloading and oxidation. The accumulation is the result of removal of solids from the sewage applied and the growth of the flora and fauna. The film consists of (1) living and dead cells of the biological population, (2) organic matter retained from sewage at different stages of decomposition, and (3) digested and undigestible organic residues. The quantity of film is influenced directly by the B.O.D. and the suspended solids load applied. In general, the greater the load applied the higher is the removal of solids and B.O.D. and the greater is the resultant increase in the biological population. The film thus grows directly by the solids removed and indirectly by the biological growth which feeds on the materials removed. Under certain conditions, however, the removals of applied solids may not take place and the quantity of film may not respond to the greater load applied. Such was the case in the biofilter during its initial operation period in the cold weather. Despite the high loadings, the quantity of film in the bed remained low during this period. It follows that it is not the total suspended solids and B.O.D. load applied as much as the portion that is removed and adsorbed which builds up the film either directly or indirectly by increased biological population. With equal percentage removals the greater load applied will result in greater film accumulation.

The removal of the applied load is in turn dependent on a number of factors. Temperature is an important factor influencing the percentage removal of applied solids both in high-rate and standard filters. According to results published from other sources and the data that will be furnished in a subsequent paper in this series, temperature exerts a great influence on the removals in high-rate and standard filters. It is to be expected that with equal loads, the removal by the bed will be lower in winter than in summer and should therefore result in a lower quantity of film. But temperature acts also in the opposite direction. A greater percentage of the solids removed from sewage will be destroyed during the summer than in winter, resulting in a lower net increase in film, despite higher percentage of removals. If, in addition, the B.O.D. and suspended solids load applied decreases in summer, as it did in the biofilter studied, the net effect of all these factors will be a considerably lower quantity of film in the summer. It appears, then, that variations in the quantity of film caused by normal decrease in the efficiency of removals in winter are not so important as the load applied and the greater destruction of the film induced by higher temperature. The importance of the latter factor will be discussed in the next paper of this series.

In evaluating the relative importance of the load and of temperature, the data obtained from the biofilter plant under study are insufficient to warrant generalization because the suspended solids and B.O.D. load to the filter decreased simultaneously with an increase in temperature. The decrease in the load to the filter was not caused so much by a decrease in the flow and concentration of incoming sewage as by the greater efficiency of the primary clarifier, as will be shown in a subsequent paper. It is conceivable, however, that if the amount of suspended solids and B.O.D. applied to the filter was considerably higher in the summer, a greater quantity of film might be obtained despite the greater rate of destruction of the film.

The retention of the applied load by the filter is also affected by the rate of application and the contact time. The percentage of applied load removed is lower but the total quantity of material removed per unit volume of filter medium is greater in the high-rate than in the standard filter. In spite of this, the quantity of film in the high-rate filter is actually lower. Aside from the differences in the unloading rates in the two types of filters, which is discussed below, a part of this effect is due to the shorter contact time between the applied load and the film in the biofilter as compared with the standard filter. It has been shown that the quantity of film is lowest at the top of the biofilter and highest at the top of the standard filter. It is to be expected that the greatest removals would take place at the top where the largest quantity of removable material comes in contact with the film. In the standard filter, where longer contact time is available, the removal and consequent film accumulation is greatest at the top. In the high-rate filter, sufficient adsorption and retention of the applied load does not take place at the top because of the high velocity and short contact time. As the sewage passes into the filter, the velocity is reduced and greater removal becomes possible with resultant larger film accumulation.

The important factors tending to increase the quantity of film in a bed are, therefore, (1) load, (2) temperature, and (3) retention of the applied load. Biological growth, which constitutes a considerable portion of the film, is affected by the load and the temperature. The load is derived not only from the non-settled portion of the sewage flow but also from the unremoved portion of the filter effluent recirculated to the primary clarifier and the load contributed by the recirculation of final effluent to the filter. At certain times, these last two components of the load applied to the filter increase the load contributed by sewage to a considerable degree. The removal of the load applied is influenced, in turn, by temperature and the rate of application.

The forces tending to reduce the quantity of film in the filter work simultaneously with the forces tending to increase the quantity of film. Unloading and destruction of the film by biological action are the two most important forces tending to reduce the quantity of film, temperature being a contributory factor to both unloading and biological destruction. The influence of oxidation in reducing the quantity of film has been referred to above. The magnitude of this factor will be discussed in greater detail in connection with the biochemical characteristics of the film. For the present, it is sufficient to say that it is an important item and is influenced by the temperature.

Factors contributing to the unloading of a standard filter have been previously studied in detail. The standard filter studied did not vary materially from the recognized pattern in this respect. The large quantities of film accumulated in the bed during the winter were unloaded in the spring. The amount of film decreased sharply during the sloughing period and remained low during the summer months. There was no indication of a natural fall sloughing. The filter is underloaded even as a standard filter and the increase in the quantity of film and the destruction of the film during favorable summer temperatures kept pace with the accumulation, resulting in maintenance of an equilibrium. In the absence of excessive accumulation of film, the fall sloughing was not noticeable.

Insect larvae play an important role in destroying and dislodging the film. The average numbers of insect larvae per gram of dry solids in the different levels of the standard filter are given in Table IV.

TABLE IV.—*Average Number of Insect Larvae in the Standard Filter (per gm. dry solids)*

	Top	1-foot	2-foot	6-foot	Effl. Sl.
Yearly Ave.	1,380	2,930	2,400	436	152
Summer Ave.	2,245	4,580	3,075	580	230
Winter Ave.	230	1,050	900	145	58

The numbers are relatively low at the top, increase to a maximum at the one-foot level, drop somewhat at the two-foot level, and are low at the six-foot level and in the sludge from the secondary clarifier. The numbers are decidedly higher in the summer than in the winter at all levels, as was to be expected. In addition, the activities of the larvae are greater in summer than in winter. These facts correspond to the low film accumulation in the summer and indicate that the larvae play an important role in keeping down the growth either by direct consumption or by the dislodging of the film.

There is no evidence of seasonal unloading in the biofilter. The quantity of film in the biofilter is low in the summer, but this is not due to a spring unloading, because the suspended solids in the filter effluent do not show an increase during this period. Only once were the suspended solids in the effluent high enough (110 p.p.m.) to be indicative of unloading. This occurred in February and can be readily attributed to the failure of the bed to remove the large concentration of suspended solids applied. The suspended solids in the filter discharge varied considerably and were generally higher in the winter. The suspended solids also fluctuated directly with the quantity of film. These facts indicate that the solids in the discharge are influenced not only by the unloading, but also by the efficiency of removals and cannot be taken as a safe index of the extent of unloading. Unloading appears to be continuous but at no time severe enough to affect the quantity of film in the bed appreciably.

In regard to unloading induced by variations in flow, the evidence presented seems to indicate that within a range of flow from 7 to 18 m. g. a. d. including recirculation, the quantity of film at the top of the filter varies directly with the flow. It does not seem that, within this range of flow, flushing velocities are effective in removing the film from the top of the bed. It has already been shown that the relatively lower quantities of film at the top of the filter in comparison with the lower levels could be attributed to the failure of adsorption to take place with the high surface velocities.

TABLE V.—*Average Numbers of Insect Larvae in the Biofilter (per gm. dry solids)*

	Top	1-foot	2-foot	Effl. Sl.
Yearly Ave.	625	1,270	1,740	355
Summer Ave.	621	1,120	1,730	435
Winter Ave.	628	1,450	1,765	270

The average numbers of insect larvae per gram of dry solids in the different levels of the biofilter are given in Table V. The results show that at the top level the numbers are low, as in the standard filter. The maximum numbers in the biofilter, however, occur at the two-foot level instead of at the one-foot level as in the standard filter. It is noteworthy that the numbers of insect larvae in the biofilter are considerably lower than in the standard filter. Furthermore, the numbers in the summer and in the winter are nearly the same. These facts indicate that larvae play a more restricted role in the biofilter than in the standard filter.

On the basis of a minimum of 2 and a maximum of 4 grams of dry film per kilogram of stone (see Table I) the total quantity of dry film in the biofilter would vary from 15,100 to 30,200 pounds or 5.5 to 11.0 pounds per cubic yard of stone. Similar calculations for the standard filter, using the basic figure of 3 and 4.5 grams of dry film per kilogram of stone, give values of 8.1 and 12.2 pounds of dry film per cubic yard of stone.

The suspended solids load applied to the biofilter including that contributed by the effluent from the primary clarifier and the recirculation directly to the filter varied from 3970 to 1660 pounds per day. On the basis of 15,100 pounds of solids in the bed, the ratio of film to suspended solids applied would vary from 4:1 to 9:1. On the basis of twice as much solids in the bed, the ratios would be 8:1 and 18:1. In the activated sludge process the returned sludge suspended solids ratio has been placed between 10:1 and 20:1 (2). Heukelekian (1), from laboratory investigations, arrived at a value of 13:1 as the optimum for activated sludge. In comparison with activated sludge, the load applied per unit quantity of biological material is greater in the biofilter than in activated sludge, and hence the degree of purification is less. Since the rate of application and the strength of sewage on the standard filter were less than in the biofilter, and at the same time the quantity of film was higher, the load applied and the work done per unit amount of film were lower than in the biofilter.

Summary and Conclusions

The quantities of film at the top, one-foot, and two-foot levels in a biofilter and in a standard filter were determined at intervals for a period of over a year. The results warrant the following conclusions:

1. There was an extended maturing period in the biofilter due to the cold weather at the start of the operation. Consequently, the film accumulation during the first winter was lower than that during the second winter. The quantities of film were considerably lower during the summer than during the second winter.
2. The variations in quantity of film in the biofilter, with the exclusion of results obtained during the maturing period, follow directly the load applied to the filter expressed as pounds of B.O.D. and suspended solids. Both the load applied and the quantity of film accumulated were low in the summer and increased during the winter.
3. The quantity of film in the standard filter was also high in the winter and decreased to a low level during spring sloughing. There was only a moderate quantity of film during the summer.
4. The vertical distribution of film in both filters was uniform during the summer period when the quantities of film were generally lower. In the winter, however, the maximum quantity of film in the biofilter was found below the top level, whereas in the standard filter it was found at the top.
5. Within a range of flows varying from 7 to 18 m.g.a.d. the film quantity varied directly with the flow in the biofilter. It does not appear that within this range of flow, which includes recirculation, a presumed flushing action is effective in dislodging the film.
6. The difference in the quantity of film at the top of the biofilter and standard filter is attributed to incomplete adsorption and removal of the load by the biofilter at the surface because of inadequate contact time.
7. The quantity of film in the standard filter was 8–12 pounds per cubic yard of stone in comparison with 5.5–11 pounds per cubic yard of stone in the biofilter.
8. Calculations show that the suspended solids load applied per unit amount of biological material was higher in the biofilter than is common in the activated sludge process.
9. The important factors determining the quantity of film in the biofilter are: (*a*) B.O.D. and suspended solids applied and removed. With higher applied loads and greater removals the quantity of film increases by the retention of the solids and the resultant increase in biological population, which uses as food the materials removed from

sewage. (*b*) Higher temperatures increase the removals, but the net effect, on the basis of equal loadings, is to decrease the quantity of film because of a higher rate of biological oxidation of the film. (*c*) Unloading in the biofilter is continuous and not seasonal, and does not deplete the quantity of film markedly. The suspended solids in the filter effluent vary considerably but do not necessarily indicate unloading, since with high suspended solids in the filter effluent the film may increase. The high suspended solids in the filter effluent seem to be due to failure of removal when passing through the bed.

10. The application of the whole flow on one filter during periods of repair on the distributor arms varying from two days to over two weeks did not increase the quantity of film materially beyond some of the values obtained during periods when both filters were in operation.

11. Numbers of insect larvae both in the biofilter and in the standard filter are low at the top. The maximum numbers occur at the one-foot level in the standard filter and at the two-foot level in the biofilter. The numbers in the biofilter are lower than in the standard filter and, unlike the latter, do not show an increase in the summer. It is concluded that larvae play a restricted role in the biofilter.

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Industrial Wastes

INDUSTRIAL COFFEE WASTES IN EL SALVADOR

By Captain Paul C. Ward, Sn. C., A.U.S.

Sanitary Engineer, Institute of Inter-American Affairs

The chief industry of the Republic of El Salvador is the growing and processing of coffee. The average yearly production for the period 1936–1941 was in the order of 120 million lbs. The present war has stimulated coffee production in this country and new ground is now being converted to coffee cultivation.

Approximately 70 per cent of the coffee produced is "washed," that is, the ripe coffee cherry is picked and milled in a process which requires the use of water. This process is differentiated from that of "dry" coffee, in that the dry cherry is picked from the tree and the hull is removed by dry milling.

Washed coffee of good quality receives the highest price in the United States where it is blended and roasted before the ultimate consumption in the American home. Washed coffee generally brings a price of $1.20 per 100 lbs. more than dry coffee, and thus this process is a profitable one.

The best quality of coffee is grown at the higher altitudes (2,000–3,000 ft.), and because of this fact and the necessity of adequate clean water, many small mills are located near spring outcroppings or on the headwaters of small creeks. The larger mills, however, are located at the lower elevations near railroads and highways where the coffee cherries may be easily transported from several producing areas.

The ultimate discharge of the liquid wastes from the coffee mills has become an important problem to solve. Water is a scarce commodity and streams are being subjected to a damage from which they cannot recover. Wastes are discharged into dry channels where decomposition occurs, and an odor nuisance develops affecting those in the immediate vicinity. Fortunately, during the rainy season these channels are flushed.

The ground water in El Salvador is limited to certain areas, and the inhabitants of many localities are dependent upon small streams as the only sources of water. The dangers of surface water for drinking purposes are well recognized, but the chemical and physical properties of these streams must be protected so that subsequent treatment, even simple boiling, will yield a palatable and safe product.

The scarcity of water is also reflected in the operation of mills and the quality of the coffee produced. Many plants must collect and store rain water for use during the milling season as no other water is available.

The greatest single factor that limits the capacity of the coffee mills is the quantity of water which a mill has available. Thus, in many plants, water is recirculated and reused to the point where further use would damage the quality of the product.

The water requirement is in the order of 260 gallons per 100 lbs. (quintal) of finished coffee, in those plants where it is only used once. This quantity is reduced to 100 gallons per 100 lbs. (quintal) of finished coffee in those plants which recirculate as much water as is possible.

Description of Process

The coffee cherry is dumped into a receiving vat from which it is conveyed to the pulpers by water. During this conveyance, stones, etc. are separated by traps, and "floaters," the unsound cherries, are di-

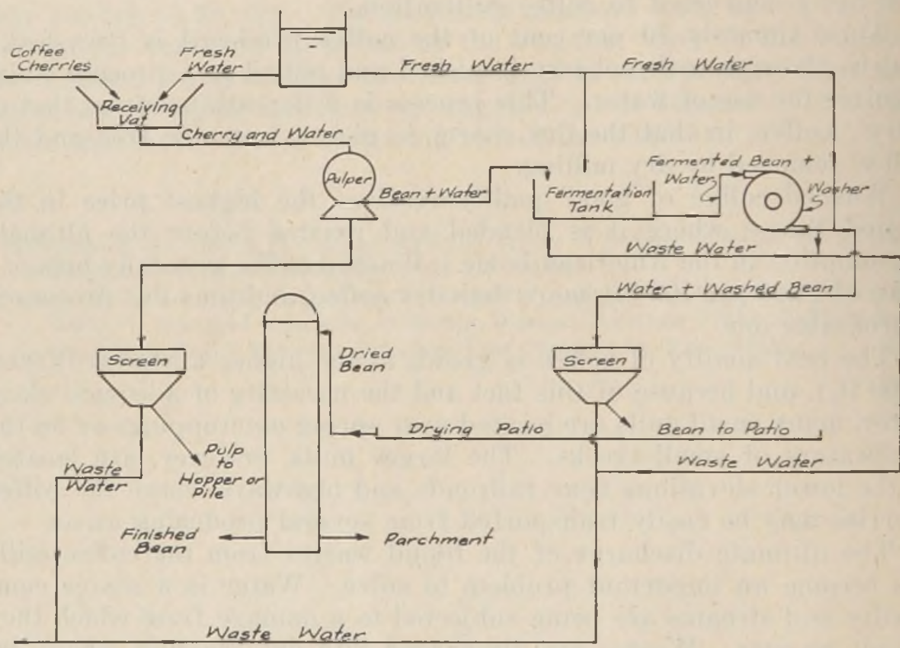

FIG. 1.—Flow sheet of typical coffee washing mill.

verted to separate pulpers. The pulper removes the skin and a large proportion of the flesh from the coffee bean. The hulled bean is then transported by water to a fermentation vat where it is allowed to remain and ferment in a moist state, the excess water being drained off after conveyance and reused if necessary. The period of fermentation may be as little as 12 hours or as much as 2 days, depending on fermentation conditions.

Fermentation of the bean is required before all the flesh of the cherry can be satisfactorily removed from the parchment which immediately surrounds the silver skin of the coffee bean. The protopectine in the flesh is insoluble and cannot be washed or scrubbed off the parchment, and no machine has been yet developed that can satisfactorily remove the unfermented flesh and undried parchment from the bean. The bean cannot be satisfactorily dried before damaging fermentation of the bean itself occurs as long as the protopectine adheres to the tough parchment. The fermentation process enables the bean to be dried in a clean parchment which guarantees its quality.

Fig. 2.—Coffee drying patio. Photo by courtesy of Public Roads Administration.

The theory of the fermentation process is as follows: protopectine in the presence of the enzyme protopectinase is converted to pectine. The pectine is converted by pectase into pectic acid and methyl alcohol or is converted to pectinase, galactoronic acid and methyl alcohol. In the presence of calcium, which is always present in small amounts, the pectic acid is converted to a soluble gel of calcium pectate. These products, some of which are soluble, are readily removed from the parchment of the coffee bean by washing.

The fermented bean is then washed and conveyed to the drying patios, again by water. The beans are screened from the water and spread out to dry in the sun for several days. Some plants are equipped with mechanical driers which are used subsequent to sun drying.

When the coffee has dried sufficiently to insure color and flavor it is milled to remove the parchment. The coffee bean is then graded, sacked, and shipped to the markets.

Therefore, the principal uses of water in the coffee mills are as follows;

1. To transport the coffee to the pulpers.
2. To transport the pulp to a hopper or pile.
3. To transport the beans to the fermentation vats.
4. To wash the fermented bean.
5. To transport the fermented bean to the drying patio.
6. Miscellaneous operations:
    a. Traps for stones, etc.
    b. Separation of "floaters."
    c. Hydraulic classification of beans.
    d. Boiler water.

Character of Wastes

The wastes from coffee mills may be listed as follows:

1. Pulp.
2. Pulping water.
3. Fermentation wash water.
4. Parchment.

These result from the processing of the coffee cherry, which has the following composition:*

	Minimum (per cent)	Maximum (per cent)	Average (per cent)
Water	6	16	9–12
Ash	3	4.5	4
Nitrogen	8	14	12
Cellulose	10	35	24
Sugars	6	11	9
Dextrine	—	—	1–1.5
Fat	10	14	12
Cafetannic Acid	6	10	8–9
Cafeine	0.6	2.25	0.7–1.3
Nitrogen-free Extract	12	33	18
Essential Oil	—	—	0.7
Water Soluble Material	20	36	25.30
Theophylline	Trace	—	—
Theobromine	Trace	—	—

The pulp is the most potentially damaging waste from the mills, but it is generally recovered and used for fuel or fertilizer. When the fresh pulp is stored in open piles its sugar is attractive to flies and a bad nuisance develops. When the pulp begins to ferment, a foul, repulsive odor is emanated. There is no fly breeding in the pulp, probably because of the acid nature of its decomposition.

The pulping water contains a relatively high amount of settleable solids, and as it contains sugars and other soluble materials, it is a large contributor to stream pollution.

* Data by Asociacion Cafetalera de El Salvador.

The fermentation wastes are very bulky with colloidal gels of pectine and the other products made removable from the coffee parchment by fermentation. The strength of this waste is small when compared with that of the pulping water, and its products of decomposition are relatively stable and inoffensive.

The parchment from the dry milling of the dried bean has no sanitary significance. It is nearly pure cellulose, and is generally used for fuel in the steam boilers that power the mills.

Samples were taken of the wastes at three plants and as each plant used different proportions of water, the results of the examinations varied considerably. The extreme values of the analyses are as follows:

	5-Day, 20° B.O.D. (p.p.m.)	Settleable Solids (ml. per liter)	Total Solids (p.p.m.)	Suspended Solids (p.p.m.)
Pulp	47,000	—	—	—
Fermentation Wastes	1,250– 2,220	660–700	4,260.	2,060
Pulping Wastes	1,800– 2,920	60–127	4,960	848
Combined Pulp and Fermentation Wastes	6,150–134,000	160	3,220	—

These analyses were made at the end of the milling season, and the plants were not operating at capacity. The above figures will, therefore, be low compared to what may be expected when the peak of the processing is reached, and more cherries are milled per volume of water.

The results are more significant and consistent when calculated on a unit basis. They will also more nearly approach the strengths expected when the mills are operating at capacity.

Lbs. of 5-day, 20° B.O.D. per Quintal (100 lbs) of Coffee Cherry Milled

Plant	Pulping Water	Fermentation Water
Ateos	0.51	0.10
El Jabali	0.61	0.06
Average	0.56	0.08

Disregarding the pulp which is usually removed, the expected 5-day 20° B.O.D. load per quintal of coffee cherry milled would be the sum of the two other components of the waste or a total of 0.64 pounds. This represents a population equivalent of 4 persons per quintal of coffee cherries processed per day. Thus a coffee plant that mills 1,000 quintals of coffee cherry per day, would contribute the same B.O.D. load to a stream as would a city of 4,000 people.

Present Disposal Methods

Many plants are now practicing methods that minimize the extent of the damage and nuisance created by their wastes. In a few mills these methods are sufficient and satisfactory.

Pulp is valuable as a fuel or fertilizer, and after removal from the conveying water by screens it may be handled in one of the following ways:

1. Stored in a pile. The fresh pulp, because of its sugar content, creates a fly nuisance. Also, if it is allowed to remain in a moist condition, fermentation occurs which yields foul odors. Flies and odors are sometimes partially controlled by sprinkling lime over the pile. After the milling season the pulp is usually taken to the farms where it is used as fertilizer.
2. Immediately hauled by trucks or carts to the farms where it is put into the ground and covered.
3. Immediately dried upon patios and used for fuel. Filter presses have been used very satisfactorily to yield a cake that may be burned after a few hours drying. Dried pulp is also used for fertilizer.

Most mills discharge their liquid wastes directly into the nearest water course, but in a few instances, the wastes may be subjected to sedimentation or lagooning. The wastes are held in the lagoons until the rainy season. They are then discharged into the flooded streams. Odor nuisance at lagoons cannot be avoided, but are lessened by the use of lime. Sedimentation, using a series of small basins or baffles in a dry water course, has been practiced with good results.

Recommended Methods of Disposal

In most coffee mills, screening and primary sedimentation of the wastes is justified. This will not only reduce the amount of oxygen required to stabilize the effluent, but will increase the yield of pulp which in itself is valuable to the industry. One analysis * of dried pulp is as follows:

	Content (per cent)
Protein	1.30
Fiber	19.7
Nitrogen-free Extract	50.1
Ash	9.0

The value of pulp for fuel and fertilizer is well established, and these two products, fuel and fertilizer, have become increasingly scarce in this country. In every plant visited which has had complaints made of it, improper pulp disposal was observed.

As mentioned before, the storage of moist pulp in piles results in a serious odor and fly nuisance. If it is not practicable to dry or remove pulp immediately, or to add sufficient lime to the pile to control these nuisances, the pulp should be put in pits and covered. This disposal would be similar to the land fill method of garbage disposal. Trenches or cells could be dug, and the pulp discharged into them.

* University of California, Experimental Station, Davis, California.

After each day's milling, the resulting pulp could be completely covered with earth. Pulp will then decompose without nuisance, and will yield a rich humus that can be later used on the farms.

It is interesting to note that pulp silage has been suggested for animal feed. Controlled feeding experiments are now being conducted at a dairy farm owned by Sr. Carlos Alvarez, Santa Ana, with the co-operation of the Institute Technologico de El Salvador.

The use of liquid wastes for irrigation has been overlooked. Observations of dry stream channels which conduct wastes that have had reasonable sedimentation, show no evidence that the waste is toxic to plant life. Damage has only been observed where plant life is subjected to wastes, high in solids, that have been ponded. This method of disposal would be practicable and beneficial in those areas where contour irrigation ditches could be utilized. Lime could be added if needed for pH control, and its application would enhance the value of the waste for land use.

Lagooning of the liquid wastes is an easy solution of the problem in those instances where the mills are in isolated areas. The liquid wastes can be later discharged during the rainy season when streams are flooded.

Should the nature of the area and receiving stream be such as to require other and further treatment, liming, biological treatment, and possibly slow sand filtration is suggested. Reductions in the five-day B.O.D. averaging 26 per cent were obtained by doses of 2 to 10 grains of lime per gallon of waste. Chemical precipitation, using lime and alum as a coagulant, did not materially reduce the B.O.D. of the waste to a greater extent than did the use of lime alone.

A pilot treatment plant is to be built before the next milling season at a mill of de Sola and Hijos of San Salvador. A study will be made of the possibility of treating the liquid wastes so that they can be reused in the milling processes. In addition to screening and sedimentation, the plant will have trickling filters that can be operated at various rates, final sedimentation, and slow sand filtration. It will be possible to add lime to wastes at any stage of treatment. Results of this plant's operation will be of interest to the coffee industry and the public health officials of El Salvador.

This investigation was carried on by the writer under the immediate supervision of Lieutenant Colonel Henry W. Van Hovenberg, Chief of the United States Health and Sanitation Field Party of the Institute of Inter-American Affairs, and Director of the Servicio Cooperativo Interamericano de Salud Publica in El Salvador, C. A. The Institute field party is operating under the general direction of the Division of Health & Sanitation of the office of the Co-ordinator of Inter-American Affairs, of which Lieutenant Colonel H. B. Gotaas Sn. C., is Director.

Sewage Works Design

PREAERATION, GRIT CHAMBERS AND SKIMMING TANKS *

By Frank S. Currie

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In January, 1941, the Bureau of Sanitary Engineering of the California State Board of Health presented a complete list of sewage disposal works for all political subdivisions of the state. This list includes sewage disposal installations for communities ranging in population from 200 to 1,500,000, with degrees and types of treatment varying from the old sewer farm, and ocean disposal of raw sewage, to complete treatment. The first of these installations was made in 1906.

Of these nearly 400 various disposal works, seven are provided with grit chambers or detritors, and two have facilities for grease or scum removal other than that provided in the ordinary sedimentation tanks. No record was made of the use of aeration preceding primary settling.

During the past 30 years I have been directly connected with the design of at least 50 sewage treatment plants. Nearly all of these plants were designed for the treatment of sewage from separate sanitary sewer systems. Not one of them provided separate skimming tanks, or any method for grease and scum removal other than the manual or mechanical skimming of the settling tanks. The detritor for the plant at San Diego and the small manually cleaned grit chamber for the City of Las Vegas are the only plants where any provision (other than primary settling) was used for the removal of grit.

We have used preaeration at Seal Beach and San Bernardino. Preaeration has also been used at Whittier and we are planning to retain it in the revamped Whittier plant.

It is evident from the foregoing that few of us are interested in the actual operation of grit chambers and separate skimming tanks. Personally, I believe the percentage of plants requiring either grit chambers or separate skimming tanks is typical of the California installations, which is less than 2 per cent for grit chambers and 1 per cent for separate scum removal.

However, without question, grit chambers are indicated for some installations, especially where the collection system is used for combined storm and sanitary sewage. Many operators have undoubtedly had trouble with sludge lines clogging because of excessive grit, and the life of many pump impellers has been shortened for the same reason.

* Presented at 17th Annual Meeting, California Sewage Works Association, Fresno, June 22–25, 1944.

Recently in some of the larger plants, "flash drying" of the sludge has been used. In these installations considerable wear has been experienced in the drying units because of the presence of grit in the sludge. However, the presence of large amounts of grit in a well designed and constructed separate sanitary sewerage system is highly improbable and, though some difficulty may occasionally arise because of the presence of sand and grit, less trouble, and certainly less odors and nuisance, will be experienced in the occasional cleaning of lines and tanks than in the continuous operation of a grit chamber or detritor. It is suggested that the operator who thinks he might want one first ask the man who has one.

While few of us have separate skimming tanks, practically all of us are familiar with the problems of skimming settling tanks. Most rectangular clarifiers move the scum to the outlet end of the tank, and most circular clarifiers collect scum at some point near the outer periphery. The slight disturbance caused by the skimming mechanism usually causes part of the scum to pass under the baffle and over the weir into the tank effluent. At the San Bernardino plant, where the overflow of the circular clarifier is split with one-half of the flow going to the north trickling filter and one-half to the south trickling filter, the skimming trough is so located that any scum passing under the baffle is carried to the south filter. Practically no nozzle cleaning is required in the north filter, but the south filter nozzles cause considerable trouble. The collection of skimmings at the inlet end of rectangular clarifiers and the center of circular clarifiers would certainly go a long way toward better effluents.

Since the outbreak of the war and the construction of a large number of sewage treatment plants for military camps, grease removal has become a major problem. Analyses of army sewage indicate a grease content varying from 25 to 250 parts per million. Such amounts are, of course, far in excess of normal municipal sewage, but they are responsible for several reports on grease removal, the most comprehensive of which is "Grease Removal at Army Sewage Treatment Plants" by Rolf Eliassen and H. B. Schulhoff, *This Journal,* **16**, 296 (March, 1944). As this article is available and has undoubtedly been read by all, it is not necessary to discuss it here. However, the authors' conclusions, which discuss the various methods of grease removal, consider that "plain settling is one of the most effective means of removing grease from raw sewage."

Where grease and scum removal beyond that obtained in the ordinary clarifier is advantageous, the Vacuator, which has been developed by the Dorr Company, seems to have considerable merit. This equipment consists of a covered tank equipped with a skimming device and designed with an overflow rate of 10,000 gallons per square foot per day. A vacuum of 9 inches of mercury holds the surface of the sewage at an elevation of approximately 10 ft. above the normal flow line. Sewage which has been aerated by a mechanical aerator for a very short period is allowed to flow through this tank, where the increased volume of the air bubbles floats a large proportion of the finer light materials to the surface, where they are removed by skimming.

It is claimed that the Vacuator also serves as a grit chamber, although the problem of cleaning and disposing of the grit is still to be solved.

In *This Journal,* 3, 621 (October, 1931), W. D. Hatfield discusses the operation of a preaeration unit at Decatur, Ill. As this was during the days when about all a sanitary engineer had to do was read, the writer spent considerable time on this article, and felt that while the advantages of preaeration as a method of odor control (especially spray odors in trickling filters) had not been stressed by the author, it might be considerably better and cheaper than prechlorination. The results of two years of study and testing by Hatfield indicated that 2.5 hours aeration could reduce the B.O.D. from 30 to 40 per cent, and that the settled, aerated effluent could be successfully applied to sprinkling filters at three times the rate of unaerated sewage. The writer also felt that the principal reason the activated sludge process was at that time replacing the standard trickling filter as a method of secondary treatment was because of the excessive odors from the fixed nozzle sprays. In fact, the trickling filter was probably saved as a method of treatment only by the use of the revolving distributor which minimized spray odors. It will be remembered that they came into extensive use immediately following this period.

The preaeration units at the Decatur plant provided 2.5 hours aeration. These tanks are immediately followed by clarifiers providing overflow rates of 800 gallons per square foot per day. At this plant, considerable activated sludge was developed; in fact, reaeration of this sludge was provided. It can be seen that this is actually a short-period activated sludge plant, inserted between the Imhoff tanks and the trickling filter, and should provide a high total B.O.D. removal preceding the trickling filter, as approximately 20 per cent B.O.D. removal is accomplished in the Imhoff tanks.

Preaeration, as we have used it, provides for the aeration of the raw sewage immediately preceding the primary clarifiers, only as a means of introducing dissolved oxygen into the sewage. It definitely cannot be considered as activated sludge in any sense. At no time has any activated sludge ever developed in the preaerators at San Bernardino, although sludge from the secondary clarifier is returned to the inlet of the aeration tank.

In 1934 at Seal Beach, where an especially septic sewage was encountered, preaeration was provided. However, the agitation caused large quantities of hydrogen sulphide to be released in the building which housed the aeration tanks, clarifier, and filter, so that while the spray odors might have been decreased, it could not be noticed. There is no question but that sedimentation efficiency was greatly increased by this preaeration.

At the old San Bernardino plant, previous to the depression, from 300 to 400 pounds of chlorine were used daily to control odors. With the beginning of the depression and continuing until the construction of the recent plant enlargement, the amounts of chlorine for odor control were greatly reduced and odors were very noticeable all around the plant. The problem was to double the capacity of the existing plant, which was done by providing a 2-hour preaeration period, followed by primary clarification at 800 gallons per square foot per day, the use of the existing trickling filter, and secondary clarification at the primary rates.

After the experience at Seal Beach where considerable hydrogen sulfide was released by the preaeration, there was some concern that preaeration at San Bernardino would release considerable odors, especially in the first aeration tank. However, this has not been the case. It is probably due to comparatively low amounts of hydrogen sulfide at the start of aeration, although all tests preceding aeration show no oxygen. Dissolved oxygen at the outlet of the aerators, when the supernatant is not returned to the incoming sewage, has varied from 3.0 to 6.3 p.p.m. Dissolved oxygen at the outlet of the primary clarifier has varied from 0 to 1.7 p.p.m. This, together with the return of from 10 to 20 per cent of the flow from the outlet of the secondary clarifier to the dosing chambers, has practically entirely eliminated all spray odors.

Operation to date at San Bernardino indicates that during the warm weather months better than 0.5 cubic foot of air per gallon will be necessary to produce dissolved oxygen in the dosing chambers.

So far our experiences have been thoroughly convincing in that preaeration materially increases solids removal in the primary clarifier, and by providing some dissolved oxygen in the trickling filter influent greatly increases their efficiency and capacity. However, if this were not the case, the cost of preaeration is fully justified in the elimination of spray odors alone, and should be worthy of consideration, both in the design of new plants and the rehabilitation and enlargement of old ones.

DESIGN OF FINAL SETTLING TANKS FOR ACTIVATED SLUDGE *

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This discussion is limited to settling tanks used in the activated sludge process because the mixed liquor from aeration tanks, when introduced into a settling tank, produces the phenomenon of "density currents," which is not present in other sewage settling tanks. These density currents have an important effect on the performance of a settling tank, and a design which does not take them into account may give poor results.

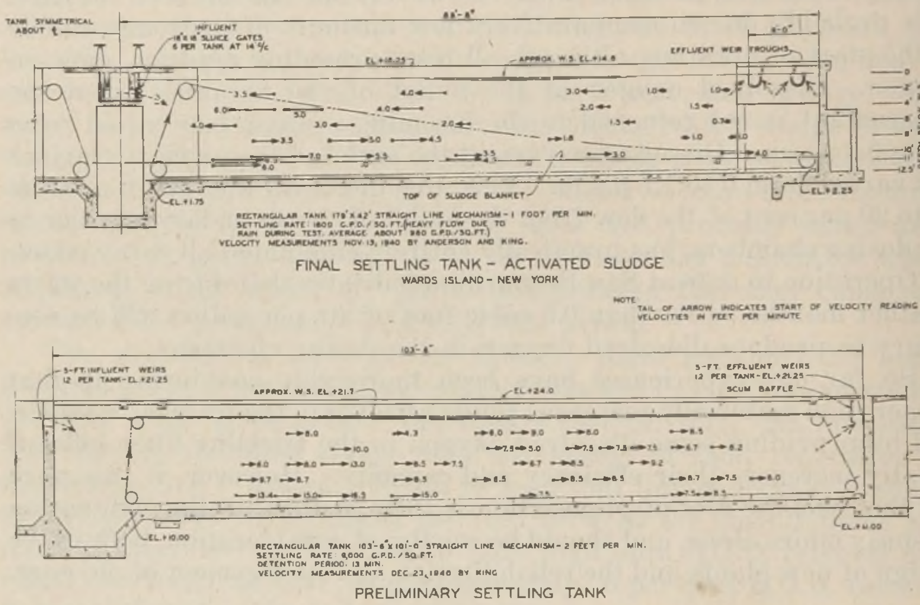


Fig. 1.—Velocity measurements in settling tanks.

Density Currents

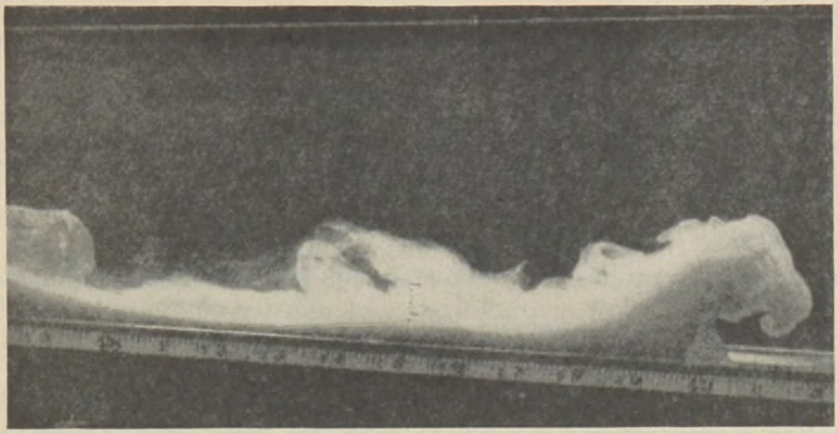
A density current is a gravity flow produced in one fluid by another fluid of slightly greater density seeking the lower level. This happens when the mixed liquor of an activated sludge plant enters the final settling tanks. Apparently, the mixed liquor is such an intimate suspension of flocculent solids that it acts as a liquid of greater density than water. This causes the mixed liquor influent to plunge to the bottom of the tank and flow along the bottom until deflected upward by some obstruction, usually the side of the tank, thereby inducing a counter-current in the upper levels back toward the influent.

This is shown by Fig. 1, which gives actual velocity measurements in two different tanks of approximately the same length and depth.

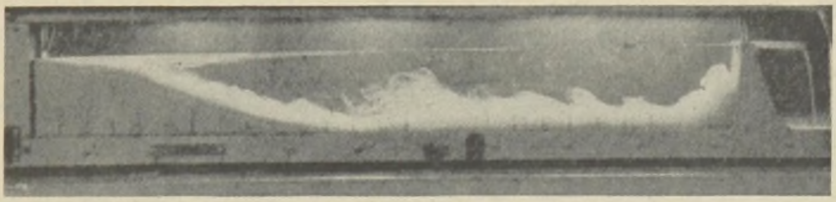
* Presented at Sixteenth Annual Meeting, Federation of Sewage Works Associations, Pittsburgh, Pennsylvania, Oct. 12–14, 1944.

On these longitudinal sections of the tanks, the direction and magnitude of the velocities are shown by arrows. The length of the arrows are in proportion to the velocity. The figures at the arrowheads show the observed velocities in feet per minute.

The upper illustration shows a final settling tank for activated sludge at the Wards Island plant in New York. This may look familiar since Mr. Gould used the illustration in a paper (2) presented



A turbid underflow leaping over a submerged weir.



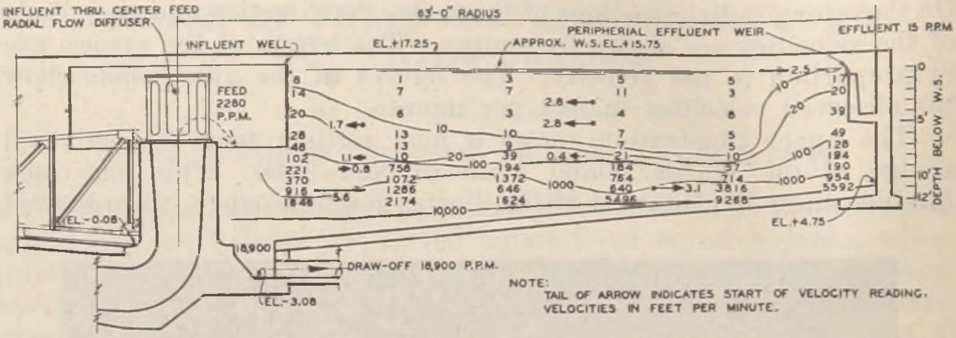
When a flow reaches the dam it rises against the face.

FIG. 2.—Model tests of density currents.

before the Federation and in subsequent published articles (3) (4). Note that only in the lower four feet of liquid above the sludge blanket is the flow toward the effluent end of the tank, with velocities up to 7 ft. per min. In the upper six feet, the flow returns toward the influent end, with velocities up to 6 ft. per min. There was no measurable velocity in the sludge blanket which was about 2 ft. deep at the time.

For contrast, the lower illustration shows a preliminary settling tank handling raw sewage at the Southwest Sewage Treatment Works, Chicago. In this case the flow is always toward the effluent end in all parts of the tank, density currents being practically absent.

It is interesting to find examples of density currents in other fields. There is a practical application in the control of water reservoirs, as presented in a publication (1) of the Department of Agriculture, issued in 1942, on "Stratified Flow in Reservoirs." This study is based on soundings in reservoirs and model tests. Figure 2



Final Settling Tank—Activated Sludge. Southwest—Chicago. Circular Tank 126′–0″ Dia. Revolving Type Mechanism, 1.0 R.P.Hr.; Settling Rate: 1200 Gal./Sq. Ft.; Velocity Measurements and Soundings Oct. 11, 1940 by Hillman; Rate of Sludge Draw-off 25% (15 M.G.D. Inflow, 3 M.G.D. Return); Solids Sludge Draw-off 1.89%; Sludge Index 53; Solids Concentration Figures in P.P.M. (Suspended Solids).

Fig. 3.—Velocities and solids concentrations.

shows two photographs of model tests taken from the above publication, and illustrates the flow characteristics of density currents better than words could describe. Velocity measurements indicate that the mixed liquor influent to a final settling tank acts in a similar manner.

Figure 3 gives the results of velocity measurements and soundings for solids concentrations in a 126-ft. diameter final settling tank made at Chicago's Southwest plant. The velocities are shown in feet per minute, and the solids in parts per million. Lines of equal density are interpolated for 10, 20, 100, 1,000 and 10,000 p.p.m. These lines form a

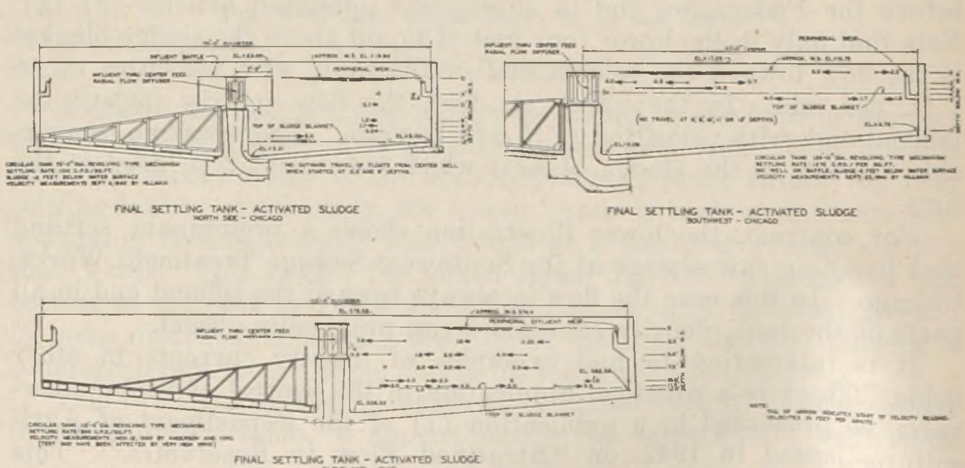


Fig. 4.—Velocity measurements in final settling tanks.

pattern similar to the turbid underflow of the models shown in Fig. 2. Note again, the outward current is only in the lower third of the tank, while in the upper two-thirds the flow is back toward the influent.

Figure 4 gives the results of velocity measurements in final settling tanks of other activated sludge plants. The upper illustration presents the 153 by 60-ft. rectangular tanks at Columbus, Ohio, which have a grid pattern of effluent weirs with no weir at the effluent end. The lower one shows the 112-ft. diameter tanks at the Cleveland Easterly Plant, which have peripheral effluent weirs. The middle left is a 75-ft. diameter tank at the Chicago North Side Plant. The middle right shows the currents found when the sludge blanket was maintained within 4 ft. of the water surface in one of the 126-ft. diameter tanks at the Chicago Southwest Plant. In all cases there is the characteristic outward flow just above the sludge blanket, and a return flow in a broader band above.

The velocity of the density current appears to be affected by the tank proportions and the inlet velocity.

How Density Currents Were Discovered

The discovery of density currents in final settling tanks resulted from a series of tests started at the Southwest Sewage Treatment Works of The Sanitary District of Chicago in June, 1940. The object of the tests was to improve the performance of the tanks, which were

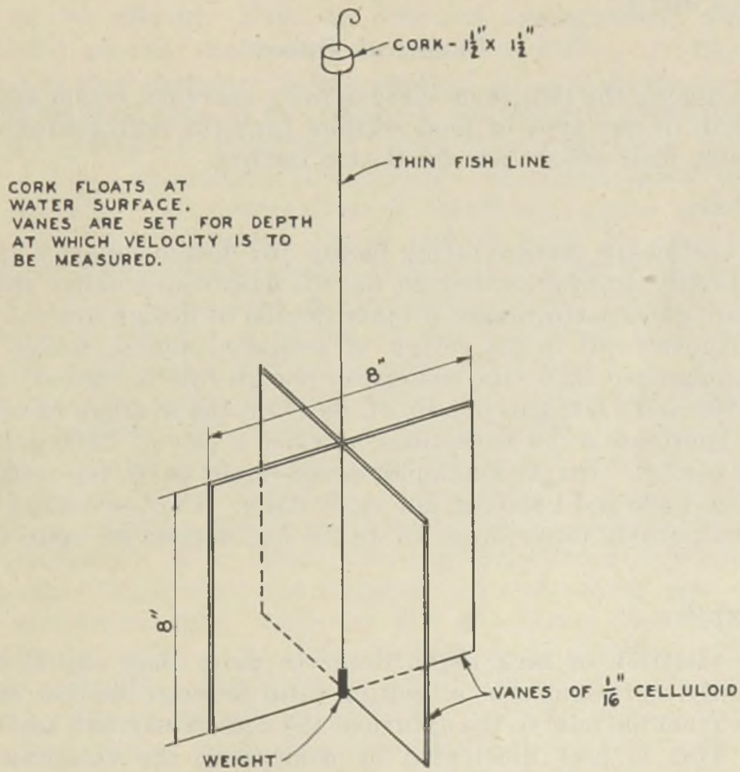


Fig. 5.—Special float used for observing currents in settling tanks.

not giving results equal to the District's North Side and Calumet plants. The Dorr Company engineering staff co-operated in these tests, one of its junior engineers, Arthur Hillman, being assigned full time to work with the sanitary district engineers for about four months.

In the course of investigating many types of influent diffusers and baffles, the currents in the tanks were measured by timing the travel of floats, such as shown in Fig. 5. The length of the line between the vanes and the cork is adjustable, and the area of the vanes is so much larger than the area of the cork that the travel of the cork at the surface represents approximately the current at the elevation of the vanes. This device was suggested by George Darby, of The Dorr Company.

The inability of any type of baffle to stop the plunge of the influent to the bottom of the tank led W. C. Weber, of The Dorr Company, in August, 1940, to suggest the possibility of a density current. Subsequent tests confirmed the belief that such was the case at the Southwest Plant.

In November, 1940, the author and his assistant, H. R. King, made similar current measurements in final settling tanks at Columbus, Cleveland Easterly Plant, and New York Wards Island Plant, with the co-operation of the staffs at the respective plants. The same characteristic currents were found, regardless of the type of tank, as shown in Figures 1 and 4.

Effect on Design

Recognizing the nature of these density currents, which apparently will obtain in any type of final settling tank for activated sludge, let us examine their effect upon the design factors.

Tank Rate

The customary surface rating factors for design capacity appear to be satisfactory insofar as they go, but the most conservative rating will not assure good performance if other details of design are not correct. R. T. Regester (6) in his review of activated sludge design data in 1941, summarized that "the customary design rate is between approximately 900 and 1,000 gal. per sq. ft. daily on the average mixed-liquor basis. There are a few exceptions in which a rate of 1,200 gal. per sq. ft. daily is used. On the maximum mixed-liquor basis, the settling rate is between 1,600 and 1,800 gal. per sq. ft. daily. Corresponding average detention periods range from 1.7 to 2.6 hr., depending upon the tank depths."

Tank Depth

This question of tank depth deserves more than casual mention. Apparently there should be a limiting ratio between the flow length, or distance from the inlet to the upturn of the density current, and the tank depth. This is best illustrated by comparing the velocities in the Southwest final tanks in Figs. 3 and 4, identical tanks, operating at approximately the same rate. Figure 3 shows a tank operating with the sludge blanket about 10 ft. below the surface; the maximum bottom velocity is 5.6 ft. per min. and the maximum return velocity is 2.8. In Fig. 4, with the sludge blanket held up to within 4 ft. of the surface, giving the effect of a tank only 4 ft. deep, the maximum bottom velocity is 14.6 and the maximum return velocity 5.0 ft. per min. The velocities are in approximately inverse ratio to the flow depth. This tendency toward higher velocities was found in the rectangular final tanks at Columbus (Fig. 4) and Wards Island, New York (Fig. 1), where the ratio of length to depth is relatively large.

There are insufficient data to fix this limiting ratio, and probably other elements of design modify the limit. However, the author would hazard an opinion that, in general:

(*a*) for circular tanks with center inlet, the radius should not exceed about 5 times the side water depth;
(*b*) for rectangular tanks, where there is a better opportunity to reduce the inlet velocity, the flow length should not exceed about 7 times the depth;
(*c*) the depth below the effluent weirs should not be less than about 10 ft. in order to avoid any disturbance caused by the mechanism and density current, nor less than 12 ft. if the weirs are located at the upturn of the density current.

Influent Arrangement

Regarding the inlet arrangement, it appears from the experiments at the Southwest Plant that no type of baffle has much effect on the quality of the effluent. Some 25 different arrangements were tried on the 126-ft. circular tanks, such as cylindrical baffles, or influent wells 20 ft. and 40 ft. in diameter, with a depth of 3, 7, and 12 ft.; an inverted conical baffle with apex at the center of the influent; horizontal baffles at various elevations; directional vanes around the inlet to give the influent a rotating motion; and multiple horizontal plates with concentric orifices. The combination of directional vanes and multiple plates was found by Hubbell (5) at Detroit to be the most effective, from the hydraulic displacement standpoint, for 200-ft. diameter preliminary settling tanks, as a result of model tests. However, neither device appeared to be of benefit in the Southwest final tanks, due apparently to the density effect of activated sludge.

Inlet locations away from the center also were tried at Southwest, including tangential inlets 22 ft. from the center by means of pipes carried on the rake arms; inlets along the bottom and side of a radial conduit; 8 inlet ports within 25 ft. at the side of a tank with vanes to direct the current in a spiral; and inlet ports spaced uniformly around the circumference of a tank. These arrangements produced more solids in the effluent than was obtained with the center inlet.

The Southwest tests indicated that the mixed liquor should be introduced as gently, or at as low a velocity as possible, without dependence on baffles. For a center feed, this means a velocity in the riser just sufficient to prevent settling, probably one ft. per sec. at average flow, and as much area as practical in the diffuser to get the least horizontal velocity. However, general observation indicated the benefit of a baffle extending above the water surface and about 3 ft. below for the purpose of submerging light solids which would otherwise float across the tank surface to the effluent weir. Also, in the case of large circular tanks, such a center baffle may be beneficial in retarding currents induced by high winds.

Regarding these wind currents, it has been observed in the 126-ft. diameter tanks that a high wind seems to produce an overturning current, which raises more floc on the windward side, but causes more flow over the effluent weirs on the leeward side with less floc, so that the final effluent was apparently little affected.

Effluent Weirs

Two factors are involved in the design of the effluent weirs, the location and the length, or weir rate, and these are interrelated. A higher rate may be used for weirs located away from the upturn of the density current than for weirs located at or near the upturn.

It should be noted that there were early experiments with effluent weirs which indicated the benefits of increased lengths and locations away from the effluent end of the tank before the reason was known. Among these were tests on rectangular tanks at the Des Plaines River Works of The Sanitary District of Chicago in 1931, and on rectangular and square tanks at Springfield, Illinois, in 1932. Also, in early designs at Milwaukee and Chicago North Side, ample weir lengths in the middle of the tanks were provided and gave good results. However, this experience was not fully appreciated in some of the more recent

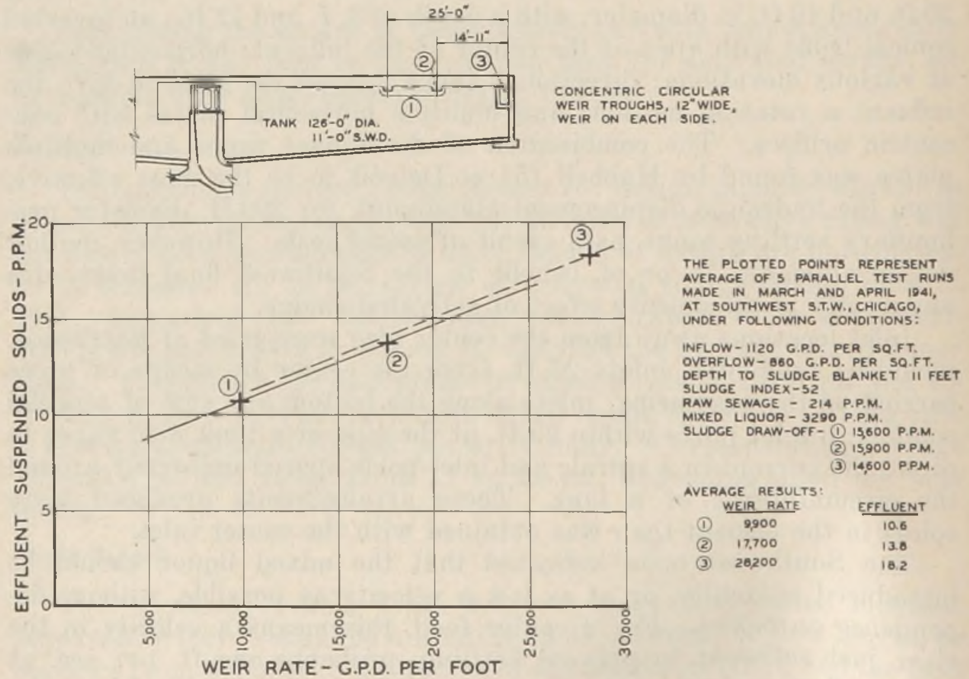
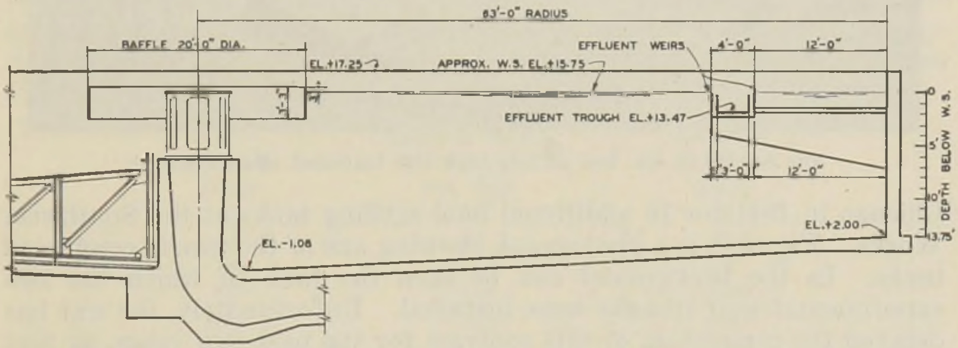


FIG. 6.—Weir-rate effect.

designs, including our own, because the reason back of it had not been apparent.

Plotting the effluent suspended solids against the weir rate for various plants gives an erratic pattern. A better indication of the weir-rate effect is shown by Fig. 6. This gives the results of parallel tests at the Chicago Southwest plant on 126-ft. diameter tanks, identical except for the weirs, and operated under identical conditions with close test control. From left to right: The first point represents a tank equipped with two concentric weir troughs, 15 ft. and 25 ft., respectively, from the outside wall, giving an overflow rate of 9,900 g.p.d. per ft., and an effluent with 10.6 p.p.m. suspended solids. The second point represents a tank with one concentric weir trough, 15 ft. from the outside wall, giving an overflow rate of 17,700 g.p.d. per ft. and 13.8 p.p.m. suspended solids. The third point represents a tank with a peripheral weir, giving an overflow rate of 28,200 g.p.d. per ft. and



The Sanitary District of Chicago. West-Southwest Sewage Treatment Works. Design Data: Sewage Flow Per Tank—12.5 M.G.D.; Gross Tank Area—12,500 Sq. Ft.; Net Water Volume—180,000 Cu. Ft.; Effluent Weir Length—614 Ft.; Weir Ratio—20.4 Ft. of Per Sq. Ft. of Tank; Surface Rating—1200 G.P.D. Per Sq. Ft. Inflow With 20% Return; Detention Period—1.85 Hrs. With 20% Return; Effluent Weir Overflow Rate—20,400 G.P.D. Per Ft.

FIG. 7.—Additional final settling tanks—1941.

18.2 p.p.m. suspended solids in the effluent. The lower line is drawn through the first two points, which represent weirs away from the upturn zone of the density current. The upper line is drawn parallel to the first and through the third point which represents a weir within the upturn zone. During this test the sludge index averaged 52. With a less favorable sludge the distance between the two lines would have been greater.

It is the author's present opinion that for effluent weirs located away from the upturn of the density current, the overflow rate should not exceed 20,000 g.p.d. per ft. of weir; and for weirs located within the upturn zone the rate should not exceed 15,000 g.p.d. per ft.

This would limit circular tanks with center feed and peripheral effluent weir to a maximum diameter of about 80 ft. at customary surface ratings. However, the inherent economy of the circular tank design may be carried into larger sizes by providing effluent weir troughs carried on cantilever brackets from the walls, as shown in Fig. 7. This is the design developed by The Sanitary District of

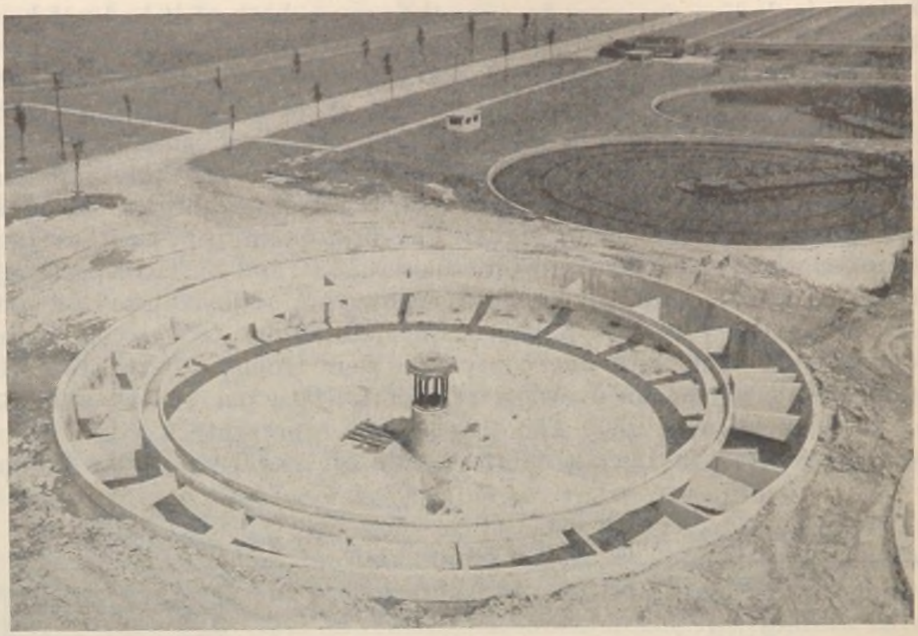


FIG. 8.—126-ft. dia. final settling tank with bracketed effluent through.

Chicago in 1941 for 16 additional final settling tanks at the Southwest Works. Figure 8 is a photograph showing one of the nearly completed tanks. In the background can be seen the tank in which the two experimental weir troughs were installed. Unfortunately, the war has delayed the completion of this contract for the past two years, so that no performance data are available on the new design.

Regarding the location of effluent weirs there seems to be a great deal of latitude. As previously noted, it is desirable to avoid the upturn of the density current. Also, effluent weirs located directly above the influent gave poor results in experiments at Chicago Southwest, due to wind or other disturbances causing clouds of light floc to rise over the weirs occasionally. However, experimental set-ups, with the inlets at one side, on the 77-ft. square tanks at North Side Chicago, in 1931, showed good results with effluent weirs only 7 ft. out from the influent. Between these extremes there seems to be little if any choice as far as available data indicate.

Sludge Draw-off

Design of the sludge draw-off involves chiefly the problem of moving the settled solids from the entire tank bottom to one or more draw-off pipes. The two desired results are (1) quick removal to keep the return sludge as fresh as possible, and (2) as much concentration as possible to reduce the cost of return sludge pumping and the size of aeration tanks required. Unfortunately, most of the things that can be done toward accomplishing either objective work against the other, so it seems the best that can be expected is a compromise.

Apparently, the greatest factor affecting sludge freshness is the sludge depth or sludge detention period. For example, if 5 ft. of sludge were carried in a tank 12 ft. deep operating at 2 hrs. gross detention period and 25 per cent sludge return, the average detention period of the sludge would be 3.3 hrs. While if the sludge were carried only 1 ft. deep, the average detention period would be only 40 minutes. This general idea has been recognized for many years, to the extent that most plant operators carry as little sludge as practical in the final tanks.

Ridenour and Henderson (7) made some investigation of the value of freshness, and determined for the particular plant investigated that concentrating the return sludge 2.5 to 3 times the mixed liquor gave best results. However, at Chicago North Side and at Milwaukee efficient operation is obtained with concentration ratios of 4.5 to 5.5.

Zack, (8) in connection with experiments on a 20-ft. dia. final settling tank equipped with a Laughlin filter, determined the relation between per cent return, concentration of return sludge, and sludge detention period. Plotting average curves from his tabulated figures (Table VI) gives the following average results:

Per Cent Return	Solids in Return Sludge Per Cent	Detention of Sludge Hours
20	1.8	2.5
40	1.0	1.2
60	0.7	0.8
80	0.55	0.65
100	0.5	0.6

The figures would vary with different tank characteristics and with different sludges. However, it should be kept in mind that this general relationship does exist and affects the design of the sludge handling facilities as well as the general plant operation.

A tank mechanism is one device that aids both quick removal and sludge concentration. The most popular types scrape and agitate the sludge on the tank bottom, causing the sludge to flow along the bottom to a central draw-off point. It has been recognized for some time that the greater part of the sludge movement is a hydraulic flow induced largely by the density of the sludge, and that the chief function of the flights or blades of a mechanism is to prevent adherence of the sludge to the bottom. Probably only the heaviest particles are actually conveyed or moved in the mechanical sense. The tendency of activated sludge to adhere to tank bottoms is demonstrated by the experience with small hopper-bottom tanks, where sludge builds up in clinging masses, even on slopes as steep as 2 on 1, so that some sort of mechanism seems justified even on very small tanks.

Another type of mechanism acts like a vacuum cleaner, picking up sludge from the tank bottom by a system of nozzles traversing the tank bottom periodically. Theoretically, any reasonable degree of freshness could be obtained with such a device if the bottom were traversed frequently enough and no depth of sludge allowed to accumulate. However, there must be some sludge depth in order to give a reasonable concentration, and this depth represents an appreciable detention period.

Location of Draw-off

In the New York Bowery Bay final settling tanks, Gould placed the sludge draw-off at the effluent end of the tanks in order to utilize the current along the tank bottom to help move the sludge to the point of draw-off. He reports (3) favorable results and that "tests of dissolved oxygen in the outgoing sludge have shown positive values on numerous occasions." However, the general applicability of this scheme appears to be doubtful, on the basis of the available data regarding three factors involved:

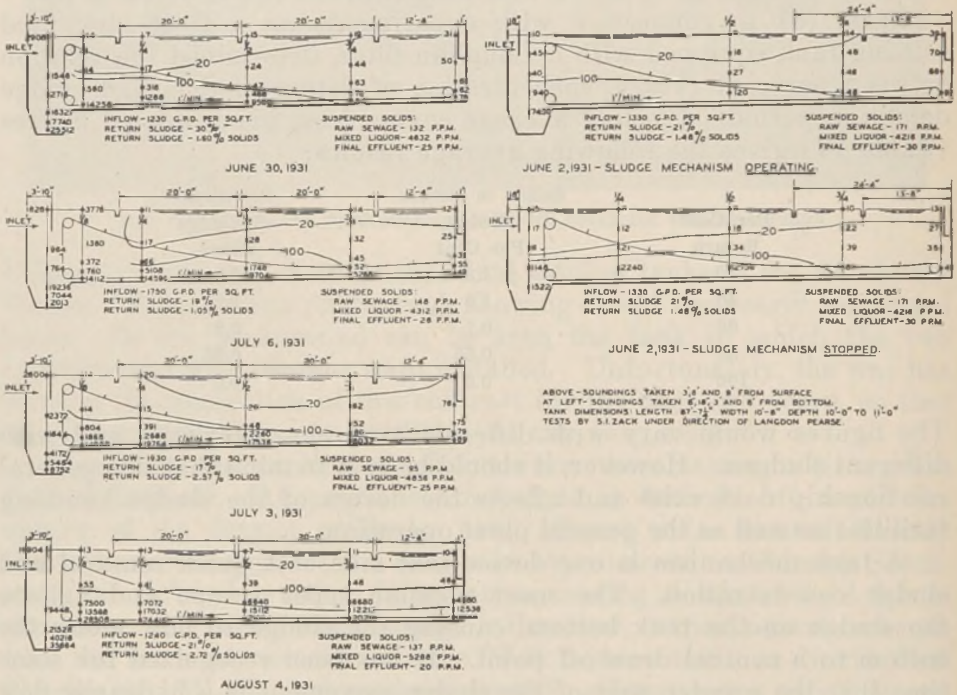


FIG. 9.—Final settling tank studies—1931 at Des Plaines river sewage treatment works.

First, activated sludge settles so quickly that, in general, practically all solids are deposited in the first two-thirds of the tank from the inlet. Figure 9 illustrates this point. These diagrams show the results of soundings for solids concentrations, made at the Des Plaines River Works of The Sanitary District of Chicago, in 1931. Dense sludge is found at the influent end, while at the effluent end, only light material, in concentrations of less than 100 p.p.m., is generally present, except when the sludge blanket is high, as shown on the diagram for August 4, 1931. It would seem desirable to move the settled sludge the least distance on the tank bottom, which is toward the inlet.

The second factor is that the density current seems to have little effect in moving sludge after it has settled to a concentration greater than that of the mixed liquor. This was found in measuring the bottom density currents as previously described. When the vanes were lowered, even a few inches, into the sludge below a relatively high velocity current, there would be practically no movement.

Third, recent experiments indicate that a fresh return sludge, containing dissolved oxygen as found at Bowery Bay, can be obtained with a tank of conventional design when operated on a similar basis; namely, a 45 per cent sludge return containing only 3,980 p.p.m. suspended solids, as shown by Gould (3) (4).

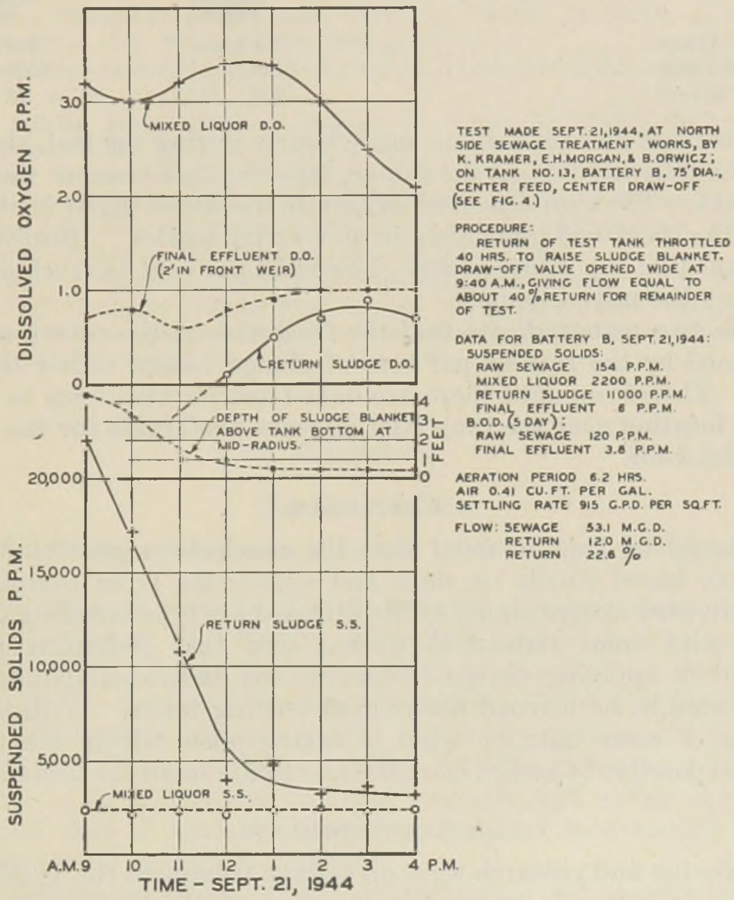


Fig. 10.—Rate of draw-off effect.

Figure 10 gives an indication of the effect of this high rate of draw-off on the freshness of sludge. This represents a 7-hr. test at the North Side, Chicago. The sludge return was first throttled for about 40 hrs. to build up the sludge blanket to a depth of 4 to 5 feet. The draw-off valve was opened wide at 9:40 A.M. to give a flow equivalent to 40 per cent return at average flow. Hourly determinations of dissolved oxygen and suspended solids were made from 9 A.M.

to 4 P.M. Within three hours, 0.1 p.p.m. dissolved oxygen appeared in the return sludge, when the sludge blanket had been drawn down to a depth of 1 ft. and the sludge return suspended solids reduced to about 6,000 p.p.m.

Another test of the effect of the rate of sludge return on the freshness of the return sludge was made on one of the 126-ft. diameter final tanks at the Southwest Plant. In this case an entire battery of tanks was operated at 40 per cent sludge return for three days before and during the test run. Hourly samples, taken from 10:15 A.M. to 3:15 P.M. on Monday, October 2, 1944, gave the following average results:

	Dissolved Oxygen	Suspended Solids
Mixed Liquor	8.1 p.p.m.	1248 p.p.m.
Return Sludge	5.9	3506
Final Effluent	6.0	13

Sludge blanket determinations, made hourly during the test, showed an average depth of 1.5 ft. at the center, tapering to a trace at the outside of the tank. The high dissolved oxygen in the mixed liquor is abnormal, due to the week-end reduction in industrial wastes. However, it is significant that the return sludge showed 73 per cent as much dissolved oxygen as the mixed liquor.

These two tests indicate that the freshness of the return sludge is determined by the rate or per cent of sludge return rather than tank design. Therefore, until there are data from parallel tests to the contrary, a location near the tank inlet appears preferable for the point of sludge draw-off.

Conclusion

It should be kept in mind that the conclusions presented in this paper are based chiefly on data and experience from comparatively large activated sludge plants of the diffused air type handling domestic sewage with some industrial wastes, and that judgment must be exercised in applying design factors to any individual plant. There is still much to be learned about final settling tanks. With the accumulation of more data on what is taking place within the tanks, it should be possible to assign more definite limits to all the design factors.

Acknowledgments

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Discussion

By R. H. Gould

Director, Division of Engineering, Department of Public Works, New York City

Mr. Anderson's paper is of great interest and importance in emphasizing the existence of "density currents" in final settling tanks for activated sludge. I had the opportunity to discuss this same phenomena before the Sanitary Engineering Section of the American Society of Civil Engineers in January, 1943, under the caption of "Improved Final Settling Tanks at Bowery Bay." * We seem to be in close agreement as to the nature of these currents and differ only in the application that is made in adapting the final tank design to take advantage of the principles disclosed.

It so happens that we in New York apparently became concerned about the effect of these density currents at about the same time that the matter was under discussion and investigation in Chicago. At the same time Mr. Anderson came on to conduct the current tests at the Wards Island plant I was able to show him a preliminary print of the contract drawing of the Bowery Bay final tanks substantially as described in the paper above referred to. The results of his findings at Wards Island and at several other locations, which he most generously

* *Civil Engineering,* Vol. 13, No. 6, June 1943, page 279.

made available, were of great help in assuring us that we were on the right track.

Mr. Anderson in discussing the location of sludge draw-off refers to the Bowery Bay final settling tanks and reaches the conclusion that "until there are data from parallel tests to the contrary, a location near the tank inlet appears preferable for the point of sludge draw-off." This conclusion is apparently based on three factors. The first was that "activated sludge settles so quickly that in general practically all solids are deposited in the first two-thirds of the tank from the inlet." This is illustrated by diagrams showing the results of soundings for sludge concentration made at the Des Plaines River Works in 1931 where dense sludge was found at the inlet end while at the effluent end only light material was generally present. The second factor was "that the density current seems to have little effect in moving sludge after it has settled to a concentration greater than that of mixed liquor." Both these conclusions seem to have been based on tests in tanks where the sludge draw-off was at the inlet end.

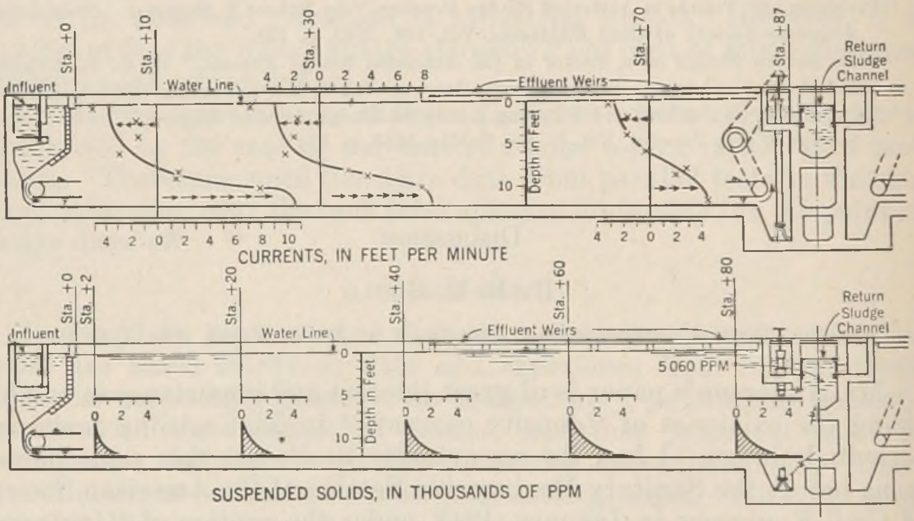

FIG. 1.—Flow characteristics of Bowery Bay final settling tanks.

One of the illustrations (Fig. 1) included in the writer's paper on the Bowery Bay tanks, referred to above, shows velocity currents and sludge densities found in actual operation of a tank with the sludge draw-off at the effluent end. It will be noted therefrom that the activated sludge flows along the bottom of the tank, most of it in the first two feet of depth, with the velocities near the inlet end of the tank at the rate of over ten feet per minute, and overruns the flights of the sludge collecting mechanism which are moving in the same direction but at a velocity of only three feet per minute. The velocity of the flow along the bottom apparently diminishes with increasing density of the blanket so that near the effluent end it is running only a little over four feet per minute. There seems to have been a progressive increase in the density of the bottom sludge from about 2,500 p.p.m. near the influent end to a little over 5,000 p.p.m. at the effluent end and this maximum density found here appears to coincide with that of the sludge withdrawn from the tank. These conditions are exactly reversed from those on which Mr. Anderson based his conclusions.

The third factor cited by Mr. Anderson is a somewhat negative one where he demonstrates that dissolved oxygen may be found in the sludge removed from the tank provided the rate of sludge pumping is high enough. This, of course, should be self-evident, for if the pumping rate is in excess of that at which sludge will flow to the pump suction, supernatant water in the tank containing dissolved oxygen will be drawn in with the sludge and the mixture may well contain dissolved oxygen. The scraper flights at Bowery Bay traveling at three feet per minute will move the heaviest sludge that may adhere to the tank bottom from the influent to the effluent end in something like thirty minutes. The flow of sludge along the bottom under the influence of the "density currents" and the sludge pumping moves the bulk of the sludge faster than the collector flights so that most of it would remain in the tank only about fifteen minutes. Under these conditions, all the sludge of necessity must be fresh. This can by no means be assured where the sludge is moved to the influent end by mechanical and hydraulic means counter to the flow of the "density current."

The problem, of course, in rectangular tanks and circular radial flow tanks is quite different. We feel that we are working toward adequate solutions for rectangular tanks. Mr. Anderson's solution for circular tanks appears to be about the best that can be done with a difficult situation. There is no question that excellent results have been secured with both rectangular and circular tanks of a more conventional type but I feel that these results have been based more on the securing of sludge with good settling qualities rather than in the outstanding excellence of the final settling tank design.

It is of first importance that basic principles be clarified and for this reason Mr. Anderson has made a distinct contribution in publishing the important test data and results from his numerous experiments. The application of these principles, of course, must be made by the designing engineer as he sees fit, based on all of the elements involved.

SAFETY CONSIDERATIONS IN THE DESIGN OF GAS UTILIZATION FACILITIES *

By Leonard L. Langford

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While it is generally known that one is subject to the greatest danger when in his own home, many of the same type of accidents such as slipping or exposure to electric shock, which prove fatal at home, are possible in sewage works, and means for their prevention should be instituted. In this connection, valuable information will be found in the recent report on "Occupational Hazards in the Operation of Sewage Works," made available recently by the Sewage Works Practice Committee of F.S.W.A. as Manual of Practice No. 1.

Of greater and more specific danger in sewage works is the handling of digester gas, involving the possible danger from explosion, burning, toxicity, and respiratory difficulties resulting from oxygen deficiency. The adaptation of separate sludge digestion in the past and its anticipated universal application in the future, warrants our most careful consideration of the hazards inherent in the production, use and waste of digester gas. Considered thought respecting the design of structures and equipment, from the standpoint of safety of men and materials, as well as from the more usual economic considerations, will in the long run, result in economy of life and property; without in any way sacrificing efficiency of operation.

In the field of American commercial gas practice involving the distribution and utilization of manufactured or natural gas, constant attention is paid to the fundamental detail of maintaining a *constantly positive pressure* at all times (6). This same fundamental is likewise of paramount importance in the safe handling of digester gas.

As so aptly expressed by Morrill (1), "any explosion is the result of four factors; the presence of an inflammable gas, oxygen, a proper mixture of the two, and a source of ignition. Eliminate any one of these and there can be no explosion. At the sewage plant, gas and atmospheric oxygen are, of course, always present, but the gas will not burn or explode unless diluted with oxygen supplying air. Because sources of ignition are so numerous and to a large extent unpredictable, it is accepted practice to consider them as uncontrollable, within limits of absolute safety. *Fortunately one can control the formation of explosive mixtures of gas and air by the simple expedient of keeping them separated.*"

Van Kleeck (2) has pointed out that "In considering burning we must remember that when the percentage of gas as compared with air, is high, at, or above the limit of the explosive range, a burning mixture is encountered."

* Presented at Spring Meeting of New York State Sewage Works Association, Syracuse, June 16–17, 1944.

In considering the minor constituents of digester gas, with reference to toxicity, we find hydrogen sulphide as the most important, for concentrations higher than 0.2 per cent can cause almost immediate cessation of breathing, this gas having about the same lethal power, as hydrogen cyanide (HCN), always considered the most deadly of gases.

In the consideration of "noxious gases," it is suggested that reference be made to a volume bearing that title in which the authors (3) point out that even educated and thoughtful people are generally oblivious to respiration and gaseous substances which are taken into the body through the lungs—"the reaction between a living man and the atmosphere about him are so immediate, so continual and so much a matter of course, that the normal individual passes days, even years, without a thought of breathing." "Yet the way most people die is by a cessation of respiration."

It will thus be seen, how important is the matter of adequate ventilation under all atmospheric conditions.

Ventilation

Ventilation is a science that treats of air in relation to human comfort, health and efficiency. The test of good ventilation is the measure of health, comfort and efficiency derived from it. The object of ventilation at sewage treatment works is to provide and maintain air purity, primarily with reference to its freedom from toxic gases. Proper ventilation depends primarily upon air volume, air temperature, relative humidity and air motion.

While injurious substances such as gases and fumes are usually handled by mechanical exhaust ventilation with effective distribution of inlets to the exhaust ducts, the writer is of the opinion that this type of ventilation should be used with discretion in connection with certain locations at sewage treatment works; particularly where gas consuming devices require an adequate supply of oxygen for their efficient operation and for safety to operating personnel.

From the practical standpoint, the one item which is the basis of all calculations and layouts is the quantity of air to be handled by the ventilating system to produce the results desired. It must be remembered that a supply of air which proves to be adequate for maintaining effective conditions in the winter, may prove inadequate for the same purpose in hot weather.

Ventilating systems may be roughly classified as natural, gravity and mechanical, and frequently various combinations of these systems may properly be used. With respect to natural ventilating systems utilizing the wind and temperature difference between the inside and outside air of the building, the openings utilized should provide for a sufficient air flow with wind forces of slight intensity. It is important, however, that control of such ventilation always be provided.

Windows, of course, are usually used to provide ventilating area in addition to their use for the transmission of light. Reliance upon the use of windows only as ventilating areas in those parts of sewage works which are listed as most critical, is not believed to be good practice.

Roof outlets concern mechanical as well as natural ventilating systems. Such outlets function as outflow or exhaust openings only, and, therefore, attention must be given to the provision of openings for inflow or supply, as it is evident that such ventilators could not function even in the strongest wind, and with the maximum temperature difference, without inlet openings. Inlet openings of about twice the area of the roof ventilators should be provided where natural ventilation is used. Dampers should be installed in ventilators, with adequate and accessible operating mechanism.

The discharge openings for all systems of ventilation must be arranged so that they shall not be influenced by wind or other atmospheric conditions.

Gravity ventilating systems are those which use openings especially provided for air flow, with ducts and flues, and which depend on the difference in weight caused by heat to compel the movement of air. Gravity systems obtain the necessary pressure difference by using chimneys or vent flues which become more and more effective as the difference between the outside and inside temperature increases. As long as a temperature difference of not less than 40 degrees between indoors and outdoors exists, these systems can be depended upon for a definite result. With slight temperature differences, the effectiveness of gravity systems decreases rapidly.

Exhaust systems of mechanical ventilation may be used in connection with any system of air supply. They will always be more effective if used to supplement controlled equipment for replacing with new air the exhausted air and its objectionable tenantry of gas or dust. Outlets from buildings for discharged air from exhaust systems of ventilation must be given careful attention. No dependence can be placed upon outlets which look out horizontally even though they come from powerful fans. A cold gale of wind against such an outlet can stop the egress of exhaust.

While there is no particular rule for locating inlets or outlets which can be laid down, it seems reasonably safe to suggest that, with horizontally discharging diffusers on the side of the room looking toward the windows and symetrically located, best results will be obtained.

In many cases in sewage treatment works both inlets and outlets, well designed, may properly be placed at or near the ceiling and near the floor, thus giving consideration to gases such as hydrogen sulphide which may be near the bottom of the structure, methane normally near the top but sometimes increasing to an uncertain depth, carbon dioxide normally found at the bottom but when heated may be stratified at points above the floor, hydrogen and carbon monoxide at or near the top, and chlorine at the bottom.

Chimneys

Concomitant with the subject of ventilation we must give some consideration to chimneys, the purpose of which is to produce the required draft as well as to carry off the products of combustion and to discharge them so that they will not be harmful or annoying. Chimneys of inadequate area and height are a general hazard; at sewage treatment works, chimneys which do not meet these requirements have proven to be extremely hazardous. In most cases natural draft is employed and this should be sufficient to overcome the friction and produce the velocity of the air required at the entrance to the furnace, to force air through the fuel bed, if any, to produce the velocity and to overcome the friction of the products of combustion in their passage through the heat absorbing surfaces, breeching and the chimney itself. In addition, adequate area is of equal importance especially where fuels other than gas are used.

Bear in mind that the burning of gas differs from the burning of coal or oil. In order to prevent incomplete combustion from excessive draft, all gas-fired boilers and furnaces should have a back-draft diverter in the flue connection to the chimney. While the use of such a diverter will cause the combustion products to come out into the boiler room in the event of a stoppage of the chimney, there will at least be no interference with the complete combustion of the gas. Also, of course, down draft from the chimney will have practically no effect upon the combustion of the gas, due to the baffles deflecting the draft into boiler room.

As is the case with the complete combustion of almost all fuels, the products of combustion of gas are carbon dioxide (CO_2) with water vapor, nitrogen (N_2), and a trace of sulphur trioxide (SO_3). Sulphur usually burns to the trioxide in the presence of an iron oxide catalyst. The volume of water vapor in the flue product is about twice the volume of the carbon dioxide when coke-oven or natural gas is burned. Because of the large quantity of water vapor which is formed by the burning of gas, it is quite important that all gas-fired units be connected to a chimney having adequate draft. Lack of chimney draft causes stagnation of the products of combustion in the chimney and results in the condensation of a large amount of the water vapor. A good chimney draft draws air into the chimney through the openings in the back-draft diverter, lowers dew-point of the mixture and reduces the tendency of the water vapor to condense.

A chimney for a gas-fired boiler or furnace should be constructed in accordance with the principles applicable to other boilers. Whether round or rectangular, all chimneys should preferably have a tile lining, although flue linings may be omitted in brick chimneys, provided the walls of the chimneys are not less than 8 inches, and the inner course be laid up with a refractory clay brick.

Flue connections from a gas-fired boiler or furnace to the chimney should be of a non-corrosive material. It should be resistant not only to the corrosion of water, but also to the corrosion of dilute solutions of sulphuric trioxide in water. Sheet aluminum is reported as serving this purpose very well.

It is important that there be separate chimneys and flue connections for each boiler or furnace where each is to burn a different kind of fuel. It is not desirable to serve devices using the same fuels—as for example, a gas boiler and a gas water heater with the same chimney flue, especially for low chimneys. Doors left open on one device while it is unfired will tend to annul the draft on another device. Gas burning devices, with their draft hoods and lack of draft dampers, are especially bad in this respect.

Boilers

With respect to boilers at sewage disposal works, these are usually for steam or hot water heating, of cast iron or steel construction. Boilers of all types, whether coal, oil or gas fired, may constitute a hazard from several standpoints. Their use involves a chimney for providing means of draft of adequate capacity. Fuel used should be of a heat content comparable to the basis on which the boiler was selected. The amount of attention required and the frequency of firing must equal that contemplated at the time of boiler selection. The proper design of the piping and heat-emitting surfaces connected to the boiler is necessary and it must function properly to obtain desired efficiency; the water in the system must be kept in favorable condition, free from grease and other foreign matter. We should add also that where hot water heating systems are used, there must be adequate water supply and *adequate pressure relief!*

Boilers are often placed in quarters which are too cramped for convenient operation, maintenance and repair. A space of at least 3 feet should be allowed on the back and two sides of every boiler for convenience of erection and for accessibility to the various dampers, cleanouts, pilots, controls and trimmings. Six feet in front of such boilers should be allowed for the purposes mentioned and so-called specialty equipment. Boiler room height should be sufficient for location of boiler accessories and for proper installation of all piping and breeching. The general ceiling height for small boilers should be at least 3 feet 6 inches above normal boiler water line.

For the protection of boilers there should be provided proper and convenient drainage connections. Strains on the boiler due to movement of piping during expansion should be prevented by suitable anchoring of piping and by proper provision for pipe expansion and contraction. Direct impingement of too intense local heat upon any part of the boiler surface, as with oil burners, should be avoided by protecting the surface with fire brick or other insulating material. Proper sizing of combustion chambers in proportion to the oil delivery rate is also important on oil-fired boilers. Condensation must flow back to the boiler as rapidly and uniformly as possible, and return connections should prevent the water from backing out of the boiler. Methods used for preventing water from backing out of steam boilers include check valves or the Hartford return connection. The Hartford return connection is to be preferred over the check valve because the latter is apt to stick or not close tightly and, furthermore, because the check valve offers additional resistance to the condensate coming back to the boiler, which in gravity systems would raise the water line several inches in the far end of the wet return.

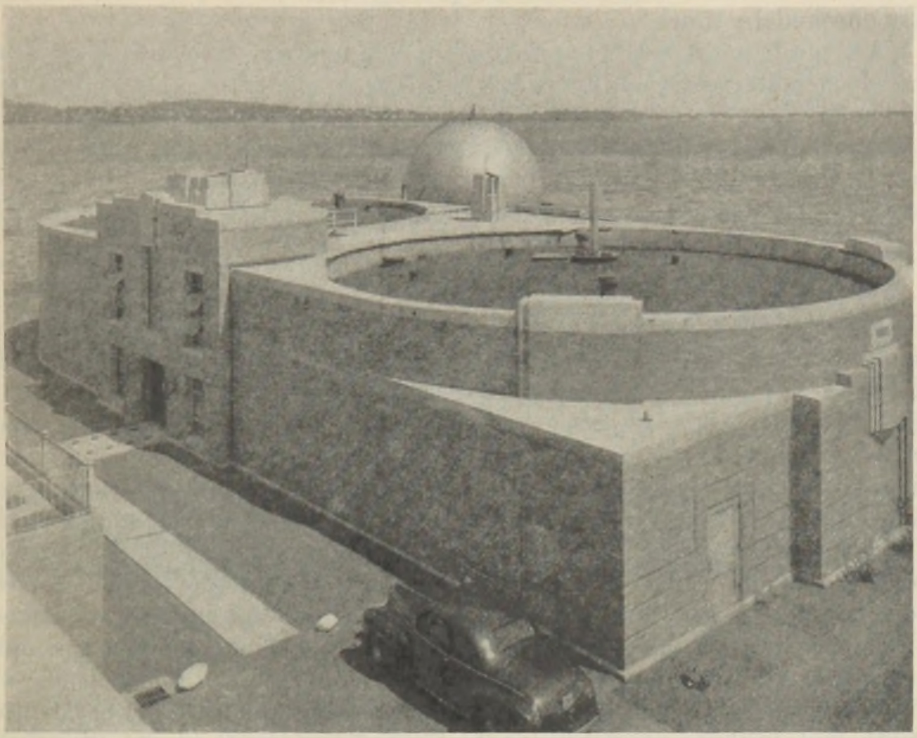

FIG. 1.—Attractive and well ventilated structure with safe provision for waste gas disposal at New Haven, Conn., digesters. Gascoigne and Associates, Consulting Engineers.

Safety and limit controls include the low water cutoff for steam boilers, used to shut off the burner if water drops below a safe level and the aquastat on water boilers to prevent water temperature from rising above a safe or desired degree. With water boilers, reverse acting aquastats are also used to control and prevent circulation of too low temperature water through the system, until the burner has been able to bring the temperature up to the desired degree.

Connection from the boiler smoke outlet to the chimney should be of adequate size, air-tight and as short and direct as possible, preference being given to long radius and 45-degree, instead of 90-degree bends.

Corrosion lodging between sections of gas-fired boilers will in time cause a strain to be set up which may crack a section which, of course, should be avoided. Corrosion lodging between boiler sections, if allowed to build up sufficiently, may cause the gas flame to damage the front of the boiler and its controls with hazard resulting from products of incomplete combustion or products of combustion, finding their way into the boiler room, to say nothing of possible damage to the gas control valve itself. To those operators who are inherently good housekeepers, this statement may seem far fetched, but the writer has seen just such conditions, unfortunately, at more than one plant. Corrosion of breeching will create pitting and set up a hazard if it is not checked in time.

An inadequate draft condition in connection with the use of a gas-fired boiler can readily prove fatal to an operator, particularly if the boiler is located in a room which is inadequately ventilated.

Gas boilers should be elevated above the floor by being placed on a concrete pedestal at least 15 inches high, thus permitting safe operation and servicing of pilots and main burners, etc.

Gas Piping

Where several connecting tanks and buildings are in close proximity to each other, the advantage of short gas lines can be obtained. Adequate support of gas piping is essential and lines outside of buildings are frequently improperly designed in this respect. Pipes laid in or supported by fill are frequently subject to severe strain, particularly where they run under permanent or temporary roadways. Such lines, properly referred to as mains, should be laid at sufficient depth to avoid frost penetration and protection from damage from roadway traffic. They should not come within the danger zone of tree root damage, generally understood to be six times the number of inches of the diameter of the trunk at a height of 4 feet 6 inches above ground, according to Codding (4). Deuber (5) reports that slow leaks of manufactured gas stimulate trees but excessive amounts bring certain death and, with increased beautification of treatment plants, this is a minor point to be considered. The subject of joints for mains is important, particularly in connection with pipe 3 inches in diameter or larger. Screw couplings for pipes up to 2 inches in diameter are used almost exclusively and, of course, screw joints are also used in connection with cast iron piping sizes up to 6 inches in diameter. In these larger sizes cast iron pipe is most widely used, despite the fact that, due to its brittleness, it is subject to rupture by an outside cause, such as frost, or the settling of the ground.

Corrosion of gas mains and services is something that can always be expected to occur to a greater or less extent. Corrosion of gas piping generally takes the form of pitting and, of course, gives rise to leaks. While special means can be taken to protect gas pipe, it must be considered whether it is more economical to replace the pipes or to pay for the additional cost of protection against corrosion, which, in general, is caused by electrolysis, self-corrosion or soil corrosion.

With respect to the various branch or service lines, care should be exercised in locating the various pieces of gas equipment. They should be reasonably accessible, adequately supported and so located as to afford reasonable protection against being accidentally knocked or struck. Control equipment which is subject to adjustment should be conveniently placed with respect to both light and position. Provision for flexibility and expansion, adequate drainage and the ready collection of moisture by providing safety type, manually operated drip traps at all low points in the system is important.

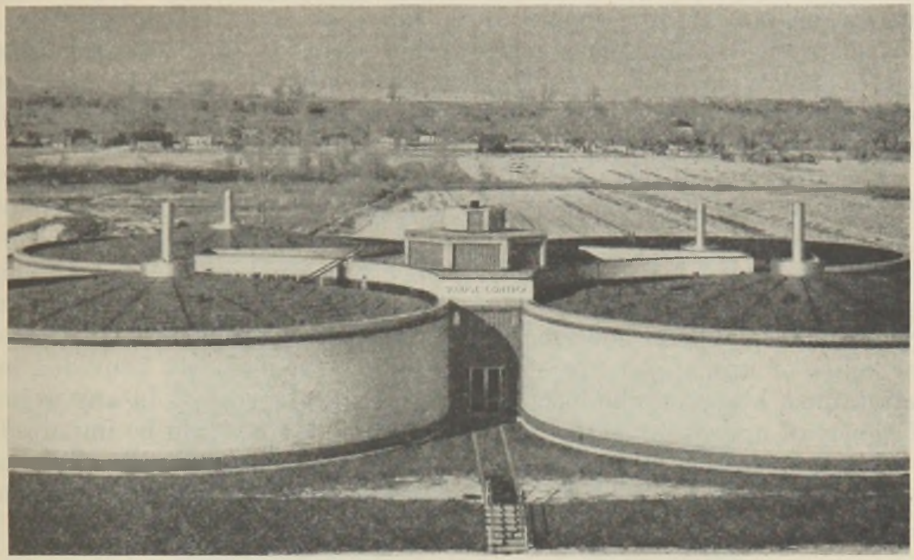

FIG. 2.—Digesters at Denver, Colo., with well lighted and ventilated control chamber. Black and Veatch, Consulting Engineers.

Gas lines of adequate size and capacity for handling peaks of gas production of at least three times the anticipated average flow, contribute to safe practice.

To facilitate periodic checking, gas lines may be painted a significant color or they may be marked every few yards; a combination of both schemes may well be considered.

Gas piping systems should, of course, be provided with means for determining gas pressures at a suitable number of proper points throughout the system.

Gas Meters

Gas meters used in sewage works are of two general classes, designated as volume or displacement meters and velocity meters. Under the first classification, we have the dry meter of the integrating type. Such meters, in a cast iron case and specially constructed for sludge gas, are available up to a rated capacity of 3,800 cubic feet per hour of 0.6 specific gravity gas at 2-inch adsorption. Larger meters of the same class and type, in pressed steel cases, and rated up to 10,000 cubic feet per hour, are also available. In this same classification is the positive or rotary displacement meter, which may be of the indicating or recording type. The advantages claimed for the latter are accuracy and dependability because the various parts are made of iron and steel and the design makes the meter self-cleaning, thereby reducing the liability of stoppage from impurities in the gas. Such meters are available in capacities up to 500,000 cubic feet per hour. Those of smaller capacity operate on a differential pressure of ½ inch water column while meters having ratings of 200,000 cubic feet per hour and larger, operate at 1 inch differential.

Under the second classification there are various velocity type meters employing the flat plate orifice, the Venturi tube, the flow nozzle, and the Pitot tube principles of metering. These have close precision and are available in integrating, indicating and recording types.

Moisture will often accumulate in gas meters which, of course, should be provided with a by-pass of adequate capacity. By the use of such by-pass and determination of pressure loss through each meter, as indicated by pressure gauges properly located in the gas piping system, meters can be drained when required. Lack of attention to this detail should not contribute to a hazardous condition. If means for relief of undue gas pressure have not been properly provided or maintained, however, the hazard might be developed and in any event efficiency of operation of the gas utilization system would be impaired.

Gas meters should always be placed on the protected side of flame traps and should be designed to withstand the same pressures as other portions of the gas system.

Condensate Traps

Designs of any system must include condensate traps or "drips," as they are known in connection with the distribution and utilization of city gas, at all low points in main lines. Drips on low pressure systems, such as we are considering, are of even greater importance. Their location must be determined almost entirely by the condition which makes them necessary. Mains should be provided with shut-off valves and the design of the system will influence the placing of such valves. It is generally desirable to have one on the line from and adjacent to each digester. On 4-inch mains or larger, a low pressure cast iron drip pot of 32 qt. capacity may properly be installed if provided with suction pipe and curb box.

Drip traps should be inspected periodically and if upon test any leaks are discovered, prompt correction of the cause of such leaks should be instituted. The rotary valve is self-aligning against the ring gaskets around the two ports, and seals positively since spring pressure is exerted through a spherical washer at the center of the valve. The only adjustment necessary is to keep adequate pressure between the face of the rotary valve and the ring gaskets around the inlet and outlet ports. To make this adjustment, turn the handle so that the outlet port is open and the inlet port from the gas line is closed. Remove the reservoir casting and clean out any sediment that may have collected. Tighten up on the spring with the nut provided until adequate pressure is exerted on the ring gaskets. Lock in this position with the lock nut, replace the reservoir and resume normal operation.

Pressure Regulators

With respect to the relief or waste gas branch of the system, such lines are of importance and should be of sufficient size to pass the maximum rate of production which has been used for determining the proper size of mains. At the junction of the waste line and the main or service to which it may be connected, there is required a pressure

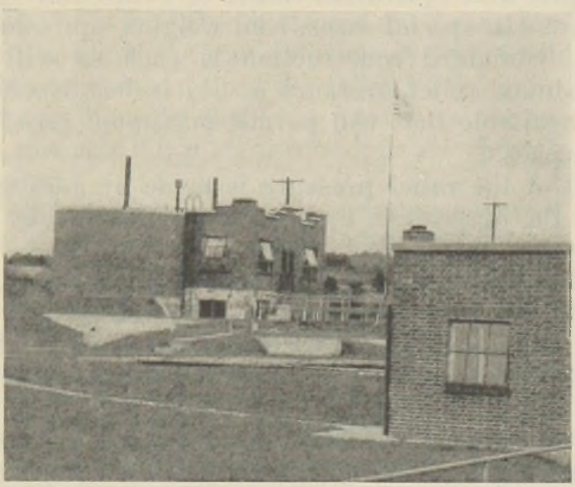

Fig. 3.—Compact design at Levy Court Plant, Wilmington, Delaware. Note provision for lighting, ventilation and entrance to both floor levels from grade. John W. Alden, County and Designing Engineer.

regulator or relief trap, adequate both as to capacity and ease of ready adjustment throughout the full range of operating pressures.

Pressure regulators are used to provide individual pressure control adjacent to each of a group of sludge digestion tanks or to give pressure control adjacent to sludge digestion tank where the waste gas burner must be located at a considerable distance from the point of pressure control. In these instances a separate flame trap must be used near the waste gas burner.

Another application of the pressure regulator is for booster control where a gas booster is used to increase the pressure in the gas supply lines following the sludge digestion tanks. The pressure regulator in this instance serves to limit the supply to the booster to the actual rate of gas production and prevents the booster from drawing a vacuum at the sludge digestion tank at times when the rate of gas flow is less than the capacity of the booster.

The pressure regulator consists of a relief valve of the weighted diaphragm type. The pressure control tube connected to the underside of the diaphragm serves to allow the gas pressure in the supply line to act on the diaphragm to open or close the valve.

The diaphragm housing should be vented to the outside to prevent escape of gas through the control tube into the room in the event of a diaphragm failure.

The valve seat and the valve plate should be made of aluminum to reduce the corrosive effect of the sludge gas. The valve stem should be of stainless iron, passing through an aluminum bushing to reduce the binding effect of impurities carried along with the sludge gas.

The weight of the diaphragm casting, valve plate and stem are equivalent to a relief pressure of 2 inches measured in water column. Cast iron weights with equivalent values of 1 inch and ½ inch are normally furnished. In special cases, lead weights equivalent to 4 inches are available. Standard construction is such as will permit establishing a maximum relief pressure of 8½ inches. Special diaphragm housings are available that will permit maximum relief pressures as high as 14½ inches.

Adjustment of the relief pressure is made by adding or removing weights above the diaphragm and access is obtained by removing the diaphragm cover.

When used to allow gas to go automatically to waste, the pressure regulator should be set to open at a pressure of ½ inch water column below the maximum operating pressure at the digester after deducting the pressure loss at maximum gas flow between the digester and the control point.

In installations where the pressure regulator is used for control ahead of a centrifugal gas booster, it will be necessary to have in mind the characteristics of the booster in determining the correct setting of the pressure regulator. It will be necessary to make adjustments by trial because the characteristics of the booster affect the adjustment of the valve.

Where regulators are used, they should normally be placed as close to the point of gas collection as possible.

Combination Pressure and Waste Gas Reliefs

The pressure relief waste gas flame traps are, as the name implies, a combination of pressure regulator and flame trap units, and the construction is similar to that described for them. If a combination relief and waste gas burner flame trap is used, such a device should be located within 25 ft. of the waste burner; it is none the less desirable that its location be such as to permit ready inspection and adjustment.

The pressure relief waste gas flame trap installed on the sludge gas supply line from the sludge digestion tank is intended to allow excess gas beyond demand to pass automatically to the waste gas burner where it is disposed of by burning to eliminate odor. The flame trap portion of the unit affords protection of the gas collection and distribution systems against entrance of flame from the waste gas burner.

The pressure relief waste gas flame trap contains a pressure relief valve of the weighted diaphragm type. The waste gas escaping through the relief valve passes through a flame trap element of alternately corrugated and smooth aluminum strips with openings of size sufficiently small to prevent passage of flame. The vertical direction of the passages is intended to insure drainage and reduce the tendency for clogging. The thermal plug serves to protect the flame trap element against continued burning gas mixtures. When subjected to excess heat, the solder in the bottom of the thermal plug will melt, allowing the link to pull out, releasing the spring and closing the relief valve, preventing the continued flow of gas that would maintain the flame.

The pressure control tube connected to the underside of the diaphragm serves to allow the gas pressure in the supply line to act on the diaphragm and open or close the relief valve.

The diaphragm housing should be vented to the outside to prevent escape of gas through the control tube into the room in the event of a diaphragm failure.

As in the case of pressure regulators the weight of the diaphragm casting, valve plate and stem of the combination pressure and waste gas relief is equivalent to an initial relief pressure of 2 inches measured in water column. Cast iron weights with equivalent values of 1 inch and ½ inch are normally furnished.

Adjustment of the relief pressure is made by adding or removing weights above the diaphragm. Access is obtained by removing the diaphragm cover. It is usually desirable also to remove the cotter pin at the thermal plug. When this has been done, the entire top assembly can be lifted off.

The pressure relief valve should be set to open at a pressure of ½ inch water column below the maximum operating pressure at the digester, after deducting the pressure loss at maximum gas flow between the digester and control point.

The leather diaphragm of the relief unit, although out of the stream of gas flow, will be in contact with saturated gas on the underside, and the life of the diaphragm will be materially prolonged if it is kept treated with neatsfoot oil. The gas produced at the digester, particularly during its initial operation, may be of such quality that the seat and plate of the relief valve will become coated with slime. Application of a very light grade of machine oil will keep the valve stem free. The valve parts should be inspected occasionally and kept clear.

Flame Traps

It is of importance to understand the essentials of an adequate flame trap. Flame traps should be installed in all supply lines to the various gas burning appliances and should be located in horizontal positions within 25 ft. of the respective appliance. The flame trap affords protection of the gas collection and gas distribution systems against entrance of flame from points of gas use.

Flame traps of the so-called dry seal type consist of a readily replaceable flame trap element, preferably of alternately corrugated and smooth aluminum strips, with openings of size sufficiently small to prevent passage of flame. Vertical direction of the passage insures drainage and reduces the tendency for clogging. Supported in a cast iron case is a spring operated, quick-closing valve actuated by a thermal link located above the flame trap element. This thermal plug serves to protect the flame trap element against continued flame from burning of mixtures of gas in the event of a flash-back. When subjected to excess heat, the solder in the bottom of the thermal plug will melt, allowing the link to pull out, thus releasing the spring and closing the valve on the inlet side and preventing the continued flow of gas through the unit. This action provides visual evidence of a closed valve and such action can also be registered by means of a bell or signal light located at any point in the plant.

There are no adjustments to make in the flame trap assembly. If losses through the trap are found to be excessive, the cover should be removed and the inside of the unit inspected to make sure that the passages of the flame trap element are open and permitting the free flow of gas.

Flame Cells

While flame cells, also referred to as flame arresters, are available, their use is not to be recommended for lines over 1 inch in diameter, or where the maximum flow will amount to more than 100 cu. ft. per hour. The device consists of a replaceable flame cell element, consisting of a series of ducts of proper design, enclosed in a cast iron housing. No thermal shut-off is provided for in this type of service and in this it is distinctly different from a flame trap. Such cells are reasonably self-cleaning if correctly installed in a vertical run of pipe.

Low Pressure Check Valves

There are no adjustments to make with respect to low pressure check valves. If losses through the valves are found to be excessive, the drain plugs should be removed after shutting off the section of piping in which the valve is located. Except to keep the leather diaphragm treated with neatsfoot oil as required, no other maintenance is necessary.

Pressure Gauges

It is again time to be reminded of our primary aim with respect to safeguarding against explosion hazards, that being the maintenance of a constantly positive gas pressure in all parts of the sludge gas distribution system. For the determination of gas pressures in low pressure systems of this order, a U-gauge or its equivalent is normally used where very accurate measurements are desired.

Such pressure gauges have scales calibrated for direct reading in inches of water, although gauges should use an oil of light grade with a viscosity rating of S.A.E. 10, thus minimizing the possibility of loss of gas through the device due to evaporation of the liquid used in the gauge column.

For safety's sake, not to mention convenience in plant operation, suitably designed pressure gauges permitting for a maximum pressure of at least 8 inches equivalent water column should be available at several points within the gas piping system, as well as at one or more convenient points about the plant such as the digester operating gallery, gas meter room, boiler room or other locations. This will enable a quick but accurate observation to be made by the operator on duty while attending to his routine chores.

All such pressure indicating gauges should be provided with means for venting pressure columns safely, and they should likewise be provided with means for gas-tight connection to vents which must be connected to a point outside the building. Such vents should neither terminate into the room or chamber in which the gauge is located nor be run into the breeching or chimney from a gas-fired or other type of boiler.

Waste Gas Burners

Waste gas burners are used for burning excess sludge gas which is not required for use, thereby eliminating one of the sources of odor nuisance. Such burners should be supported by a pedestal of adequate height, through which passes the main supply and pilot line, which piping should be insulated for the purpose of minimizing the tendency for accumulation of frost inside these lines.

Such burners, usually equipped with a flame retention nozzle and fire clay briquets, or their equivalent, surrounded by a burner pot adequately ventilated, are suitable for handling quantities of gas up to approximately 6,000 cu. ft. per hour per burner.

Properly located, this type of burner offers no particular hazard. There is, however, a tendency for the gas to burn away from the burner, particularly under high wind conditions.

The location of waste gas burners is, therefore, of considerable importance, and while the best location is possibly debatable and will to no little degree be influenced by plant layout, there are, however, two fundamentals which cannot be ignored. The location of any open flame must be such as to afford protection to persons and animals, and to insure against any possibility of igniting any combustibles under all wind conditions. Location should be such as to provide for safe access to the burner by qualified operators only.

If it is necessary to run horizontal lines to waste gas burners, their design should receive the same consideration as referred to in connection with gas mains.

Pilot lines to waste gas burners should be adequate in size, properly dripped and provided with convenient shut-off valves. Both main and pilot lines to waste burners are particularly susceptible to freezing of any moisture which may collect in them, therefore, particular care should be paid to the design and installation of them to prevent the possibility of such a condition.

Explosion Reliefs

Explosion reliefs have no place in the sewage gas utilization system. Any explosion relief must be so placed that it will release gas to outside atmosphere and, therefore, must in most cases be located at some distance from the source of the explosion. Hence, it is questionable whether the operation of any relief so located would be effective. This is because the speed of the explosion would undoubtedly carry the explosion pressures through the system, before the relief valve could function. The source of an explosion hazard can and should be eliminated by the proper location of adequate flame trap protective devices.

Mixed Gas Utilization

Where the use of a blend of manufactured or natural gas and sewage gas is to be used, there is generally required a pressure reducing valve and gas meter (both usually supplied by the local gas company), a low pressure check valve and a weighted regulator on the utilities side of the system. A low pressure check valve is used in addition to the other usual equipment on the sludge gas line. Such a mixture of gases together with the simple controls indicated can equally well be used in connection with hot water or steam boilers, or gas engines, without introducing any additional danger.

Gas Holders

There are three types of holders developed for commercial gas practice which have been successfully used for the storage of sludge gas. Two are classified as low pressure holders, and include the water sealed and the waterless or piston type of gravity holder. The third type of holder for high pressure storage involves either the bullet or cylindrical type or the spherical tank frequently referred to as the Hortonsphere.

Water sealed holders for sludge gas are generally limited to the single lift type, capable of developing pressures of from 4 to 5 inches. By far the greatest volume of sewage gas is stored in high pressure tanks which have the advantage of no moving parts and no sealing liquids. Also, on account of their relatively smaller size, therefore less space occupancy, they can more easily be made to harmonize with the attractive surroundings of our modern sewage works. Also, their cost is more nearly proportional to their capacity than is the case with the low pressure holders, and they have the further advantage of requiring only moderate foundations.

Placing a holder into operation should be carried out in the most cautious and businesslike manner. The American Gas Association, through a special committee, has established a recommended procedure for purging and placing gas holders into service or removing them from service. This applies to water-sealed holders and also various types of waterless and pressure holders. Preliminary inspection should determine that everything is in working order and, of course, the important thing is to guard against the formation of an explosive mixture of air and gas under conditions which would permit of its becoming ignited. In a water-sealed holder, even with the bell of the holder all the way down, there is always some space between the level of the water and the crown. As the holder is filled with air during construction, the problem is to dispose of this air in proper manner. This involves purging holder crown and all connecting lines with an inert gas. The inert gas is then displaced with the combustible gas or, in the event of removing the holder from service, with air.

Inert gas includes nitrogen, carbon dioxide and combustion products which are substantially free from oxygen and combustible components. Proper and approved connection arrangements for purging should be carried out and such connections should provide for test cocks for taking samples of gas at the proper time. Purging should be under the control of an experienced and competent gas analyst equipped with suitable gas analysis apparatus. Purging is generally considered complete when the purged gas from the vent and test cocks shows by analysis an oxygen content of less than 5 per cent by volume. After purging and closing of all vents, the holder should be inflated with inert gas to a height of at least 2 feet.

With respect to maintenance of water-sealed holders, some of the most important items include regular inspection of guide frames and carriages and proper lubrication and adjustment of these parts. Corrosion which might cause binding of rollers or corrosion of holder cups should not be permitted. Proper water level should be maintained. The holder crown should be kept as free as possible from snow during the winter and it should be kept clean at all times. Holder water should be tested periodically for acidity and harmful concentration of salts.

The importance of adequate painting as protection against corrosion should hardly need special mention.

Heating the holder water, special inspection of metal parts after several years' service, which may include ''plugging'' and repairs of gas leaks in plates and seams of crown and sides, are important details to consider as time goes on.

Purging of high pressure holders should be done with equal care, but as there are no moving parts or sealing liquid to complicate this procedure, it can be more easily carried out.

Pressure-Vacuum Reliefs

In connection with the maintenance of proper pressure range within the gas utilization system, the pressure-vacuum relief assembly, with which the digester should be equipped, must not be overlooked. If this piece of equipment suffers from lack of maintenance or inadequate adjustment, it may be the cause of sufficiently reduced gas pressure within the system as to incline toward a hazardous condition.

The pressure-vacuum relief assembly is intended to act as an emergency relief only against excessive pressures, and also against possible vacuums which might cause structural damage. The unit contains a pressure relief valve of the weighted diaphragm type and a vacuum relief assembly of the liquid seal or other type. Such an assembly should be so designed that escaping gas passes through a flame cell of adequate design. Where the vacuum relief assembly is of the liquid seal type, it is, of course, important that the seal be maintained, preferably using kerosene or oil as the sealing liquid so as to prevent excessive evaporation and to mitigate freezing.

It is not uncommon to observe an accumulation of mineral deposit upon the face of the pressure relief valve. This should be removed carefully so as not to score the seat of the valve and in this way prevent gas leakage at this point. The writer has observed the loss of gas in varying amounts due to this cause in a large number of assemblies, which periodic maintenance would have eliminated. Also, if gas is thus allowed to waste at this point, there may during winter months be a tendency for the formation of hoar frost, a substantial accumulation of which would nullify the action of the device.

Continuous wasting of gas through the assembly, if properly adjusted, of itself would normally indicate incorrect adjustment of the pressure regulator or combination relief located elsewhere.

Lightning Hazards

While damage suffered as the result of the stroke of lightning is popularly referred to as an "act of God," sewage works operators should be protected against this hazard insofar as possible. Such protection is possible, as witnessed by the operator at Lincoln, Nebraska, who had an interesting experience in connection with his vacuum-pressure relief assembly. Lightning struck and ignited the gas being released through the assembly on one of the digesters, but the gas only burned on the surface of the flame trap element, until it was extinguished by the operator. The flame trap element on this unit was adequate and prevented what otherwise might have become a very serious accident.

Lightning also struck the sewage works at an Army airport, jumping about fifty feet from a pole transformer to the end of a metal chimney pipe of a small gas-fired boiler located between two floating covered digesters. The bolt traveled down to the boiler, damaging the altitude gauge and thermometer and the gas control valve, to the extent that these units had to be replaced. Fortunately, no other damage resulted.

As an immediate reaction, the thought was to erect an arrester from the top of the gas pipe housing of one of the covers. It was pointed out, however, that, while possibly satisfactory as long as the tank was full enough to float the cover, a very poor ground condition would exist whenever the digester was less full. This brings out the importance of considering the adequacy of any lightning arrester system or means which may be established, either in the original design or subsequently, as an aid to the prevention of this universal hazard.

Digestion Tanks

Construction of sludge digestion tanks should be of the best and any leakage at walls or construction joints, particularly into adjoining control rooms, should not be tolerated. In conjunction with lack of ventilation, such a condition, involving leakage of liquor from active sludge placed into a new digester for seed purposes, produced a most hazardous condition in one instance which jeopardized the lives of two men.

It might be well to repeat for emphasis a statement previously made that, "One can control the formation of explosion mixtures of gas and air by the simple expedient of keeping them separated."

The simplest method of keeping air out of a digestion tank is by keeping the gas within the tank, under the classification of a water-seal gas holder. In normal operation, this condition is assured in the case of floating cover installations, since the unit floats upon the liquid in the tank and lowers when the liquid is lowered by removal of sludge or liquor, thereby eliminating any space which must be filled up by air or liquid.

In the operation of fixed-cover tanks, not connected to a gas holder filled to ample capacity, it is necessary to add liquid to the tank whenever sludge or liquor is withdrawn whether mechanically, or, as the result of barometric change, so that the liquid level in the digester is not lowered to a point where the gas is no longer under pressure (1) (8).

Pressure-vacuum reliefs on digestion tanks, installed to safeguard the structure, have already been described.

Piping, particularly gas and hot water piping, may be the indirect cause of an increased and unusually hazardous condition, resulting from the necessity of entering a digester for the purpose of inspection, cleaning, repair, or replacement of such piping. Adequate support, together with provision for expansion and contraction of heating coils, are of great importance.

It is of interest and no little importance to note in passing, the possibility of severe burns resulting from the opening up of digestion tanks and exposure to atmosphere of iron sulphide deposits. This may be found wherever steel has been attacked by hydrogen sulphide. In addition to burns of parts coming in contact with such deposits, formation of sufficient spontaneous heat may cause ignition followed by fire or explosion.

Digesters equipped with floating covers or gasometers should also be provided with tell-tale gauges of adequate size and properly placed. These will enable the operator to determine the elevation of the movable cover at all times. Such gauges should also be designed and constructed as to notify by electric bell and/or light, *before* such cover comes to rest upon the stops and after which point, a vacuum could be established within the digester with its concomitant possible gas air mixture.

Wherever digesters are designed in such a fashion as not to provide for emptying the tanks completely by gravity, or mechanically, there is a potential hazard whenever such tank might have to be entered for maintenance or repair purposes.

The removal of fuel oil from sludge digestion tanks, as is regular practice at the Main Plant at Springfield, Massachusetts, could well be considered as introducing a supplemental fire hazard, in addition to those more usually thought of in connection with such tanks. Proper means should be taken to safeguard against possible fire where such practice is employed.

Of course, in placing digestion tanks into operation, or removing them from service, the same precautions should be observed as has been referred to under the section "Gas Holders" with reference to purging.

Gas Control Room

Let the gas control room be separate, having an outside entrance and equipped with electrical equipment of explosion-proof type. This is not to say that means should not be provided for readily looking into this room from the control chamber, or gallery, to observe that the gas system is functioning properly with respect to meter operation and particularly the gas pressures at suitable points.

Adequate ventilation, lighting and working temperatures, are prerequisite.

Boiler Room

It is, of course, vitally important that boilers, whether of the gas-fired, oil-fired or coal burning type, be located in a room where ample oxygen is available. Too frequently, boilers are placed in small, inadequately ventilated rooms with too little thought given to adequate lighting. All too often the gas boiler indicated on the drawings as being a front burning type is actually, when delivered on the job, provided with burners front and back, and the boiler room, therefore, does not provide those requisites which have been set forth as being essential for adequate boiler operation and maintenance. That is to say, that there is not available the 6 feet required for the front of the boiler since the boiler in this case would actually have two fronts.

Boiler rooms should have ceilings of adequate height and should preferably have an outside entrance. As in the case of gas control rooms, means should be provided for observing boiler temperatures, pressures, etc., from the control chamber or gallery. For safety's sake, gas pressure gauges suitably located in the boiler room should indicate pressures on the inlet and outlet sides of flame traps.

As this room is the one most likely wherein an explosion might take place, complete reliance must not be placed upon a mechanical ventilating system. Conceivably there could be a power failure at the very time when removal of toxic gas or products of combustion was of the utmost importance from the standpoint of operating safety. The electrical system within such a room might well be of the explosion-proof type, for when the boilers are out of service conditions are most favorable for the creation of explosive mixtures which could be ignited by an electrical spark. The switch for the lighting system in the boiler room might well be placed outside of and near the entrance to such room.

Windows in boiler rooms might well be of liberal glass area and so hung that they will readily swing out in case of an explosion. Gas and oil burners should be installed and used in accordance with local ordinances or codes and the National Board of Fire Underwriters' Code relating to such equipment.

This is one room where the desirability of having a handily located fire extinguisher is definitely indicated.

Boiler rooms should be provided with adequate floor drainage.

Sludge Pumping Facilities

While sludge pumps need not be in a separate room, such design has its advantages, provided again that ample ventilation is secured, together with adequate floor drainage and ready means for washing down.

It would not be out of order to consider sludge pump connections as hazardous points, for the sludge does under certain conditions, represent actual as well as potential gas. It is believed, therefore, that whether separately positioned or not, sludge pumps should always be located at or very close to grade and within ready reach of an outside door at grade. As such location allows for the further operating advantage of a nominal suction lift on these pumps (usually of the reciprocating type) there seems to be no legitimate reason for subjecting sewage works operators to a hazard of the type which conduced to the loss of three lives at a West Virginia plant as well as the deaths of three other men in a similar accident at a nearby plant, as reported by Brandt (9).

It is recommended that sludge lines on a closed system of piping be treated with all of the respect that should be accorded to gas lines, and at the very least, they should be provided with adequate vents. Centrifugal sludge pumps should likewise be suitably vented, as well as gate valve bonnets and plugs of lubricated valves of that type. This does not mean fitting such parts with pet-cocks free to discharge into the operating room or building!

Electrical Systems

In the opinion of Keefer (7) "the use of electric power at sewage plants presents a hazard that should not be minimized." He points out, however, that while contact with even low voltages has proven fatal, when electrical equipment has been properly installed there should be little danger.

Rubber mats on the floor in front of switchboards mounting "alive" equipment has already been mentioned. Grounding of all electrical equipment in accordance with requirements of the National Electric Code is of the utmost importance, and all electrical materials and workmanship should conform to current standard rules, regulations and specifications of the American Institute of Electrical Engineers, the National Board of Fire Underwriters, and the National Electrical Manufacturers Association.

Electrical equipment of explosion-proof type only, should be incorporated in any room, building, gallery or chamber where there might be the possibility of explosive liquids or vapors. All power ventilating equipment must, of course, be equipped with approved explosion-proof motors.

Control Chambers

Control chambers, as referred to here, are intended to include all confined spaces wherein are located means for control of flow of liquid or gaseous substances. Or, simply, pipe galleries or rooms where the operation of valves or their equivalent control the flow of sewage, sludge, supernatant liquor or gas. Operating galleries between Imhoff tanks, or a valve and pipe chamber at the sludge-hopper end of one or more clarifiers, are likewise typical examples, in addition to chambers of greater cubage such as central control rooms between three or more digesters.

First must be provided adequate ventilation under the most severe emergency conditions likely to occur; for of what value is consideration of such matters under normal conditions, when lives are generally lost at times of modifying circumstances?

Certainly, safe means of ingress and egress are essential and this does not mean step-irons or ladders. Then comes the important detail of adequate lighting at all times. There is seldom justification for not providing reasonable headroom.

Out-of-reach valves should always be provided with chain pulls or the equivalent. A slip, while attempting to manipulate a handwheel from a precarious position some distance above the floor, could result in a serious accident.

Means for adequate drainage for all such chambers is essential.

Pipe Tunnels

Control chambers are frequently connected by so-called pipe tunnels, to which the above safety considerations are likewise applicable in design. In addition, attention is called to the possible "flue" conditions which, under certain atmospheric situations, may be set up in such tunnels. To mitigate against such draft conditions which might carry odorous or toxic compounds from one point to another, to the injury of operating personnel or to cause damage to structures or equipment, means to prevent such a situation should be instituted. Sometimes a division wall and door is sufficient; possibly more attention to design or rearrangement of roof outlets for the ventilation system of the control rooms, or tunnel itself, is required, as for example, the use of positional downdraft and updraft roof outlets.

It will be observed that no reference has been made to sludge pumping, gas metering or boiler operation in defining control chambers. It is the opinion of the writer that the stage has been reached in the evolution of sewage works design where separate rooms should be provided for these operations. Design practice has passed beyond the one-room igloo of the Eskimo type to a point where these functions and services should be given the privacy befitting them. This redounds to the good of the plant as a whole and of the operating personnel in particular.

Air Pollution Abatement

In addition to the removal of toxic fumes, ventilation is important from the standpoint of dust removal at certain points at sewage works such as chemical storage rooms and open sludge grinding and/or sacking chambers. If such dust is of sufficient quality and quantity as to become a secondary nuisance, after dissipation into the atmosphere as the result of adequate ventilation of such buildings, then suitable flue gas traps should be provided.

Under certain conditions, fortunately not common to any except sewage treatment works in very large municipalities, ventilation is called upon to include chemical treatment of vitiated air from all of the tanks (except digesters), chambers, operating galleries and buildings. Ozone may be used with limited success for the destruction of micro-organisms and as a deodorant. Activated carbon is also used to adsorb organic vapors from air in connection with air conditioning.

Conclusion

In terminating this discussion, it is emphasized that primary reliance should be placed on the *fundamentals* of safe practice during the design of gas utilization facilities and appurtenances. A common expression, "Rely on your brakes instead of your horn," finds application to this suggestion. There may be some accusations of heresy in the omission heretofore of reference to "No Smoking" and other warning signs at locations in sewage works most subject to fire and explosion hazards. Reminders of this character are, of course, highly desirable, but it is the writer's firm conviction that those concerned with the design, construction and operation of sewage works should aspire to the incorporation of every possible safety fundamental in gas collection and utilization facilities, thus minimizing the need for such warnings.

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Sewage Works Planning

PROPOSED IMPROVEMENTS IN SEWAGE DISPOSAL AND TREATMENT IN THE BOSTON METROPOLITAN DISTRICT *

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The agitation for improvement of conditions in connection with sewage disposal in the Metropolitan area has been going on for a number of years and many reports on the subject have been made to the legislature. The most noteworthy and most recent of these are the report of the Special Commission on the Investigation of the Sewage into Boston Harbor and its Tributaries, published as House Document 1600 of the year 1937, the report of the Special Commission Investigating Systems of Sewerage and Sewage Disposal in the North and South Metropolitan Sewerage Districts and the City of Boston, published as House Document 2465 of the year 1939, and the special report of the Metropolitan District Commission and the Department of Public Health Relative to Sewage Pollution of the Charles River, published as House Document 1961 of the year 1939. Most sanitary engineers are familiar with many of the problems involved through the publication of data and maps in these and previous reports.

Boston Harbor is a natural recreational area for Metropolitan Boston and it is polluted by over 250 million gallons of raw sewage which are discharged into it every 24 hours. There are three sewerage systems tributary to Boston Harbor, namely, the Boston Main Drainage District, the North Metropolitan Sewerage District and the South Metropolitan Sewerage District. The population tributary to these three outlets is as follows:

	Boston Main Drainage System	North Metropolitan System	South Metropolitan System
Present population served	500,000	700,000+	850,000+
Future population considered in the estimates (1955)	400,000	790,000	980,000
Probable percentage contributing	100	95	92
Population used for design	400,000	750,000	900,000

Figure 1 shows the location of all important bathing beaches in Boston Harbor and their relation to these outlets. The outlet nearest the most important of these beaches from the standpoint of their

* Presented at Fall Meeting of the New England Sewage Works Association, Worcester, Mass., September 14, 1944.

crowded attendance is the Moon Island outlet of the Boston Main Drainage System. Conditions are somewhat ameliorated at this important outlet by the fact that raw sewage is discharged only on the outgoing tide. Next in importance and nearness to the beaches is the Nut Island outlet of the South Metropolitan System. The Deer Island outlet of the North Metropolitan System is more fortunately located in the deep main channel known as President Roads, a much greater distance from most of the beaches.

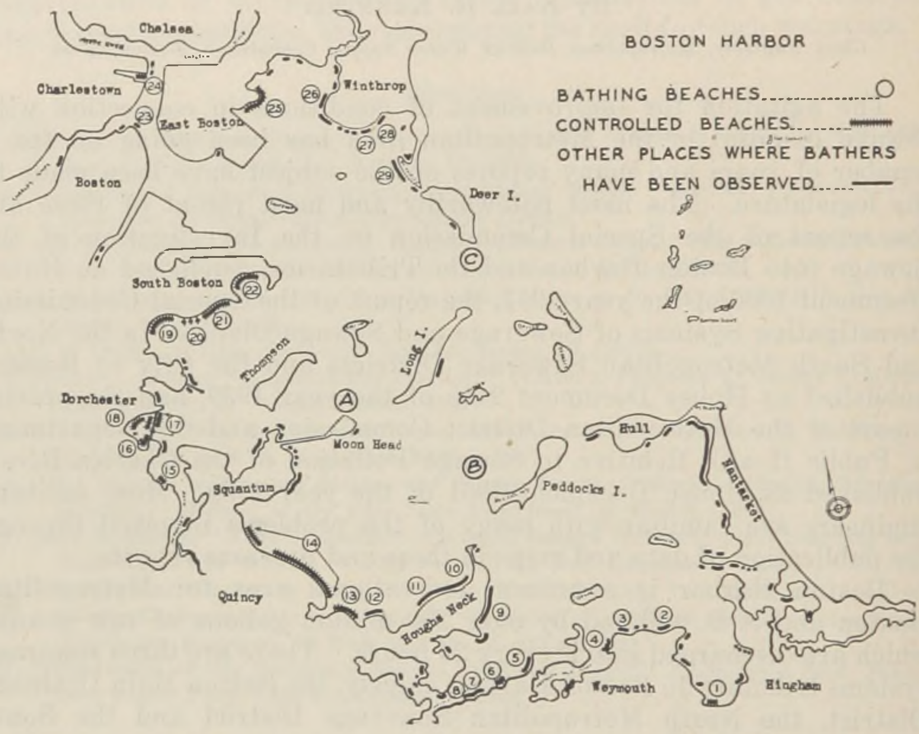

Fig. 1.—Relative location of bathing areas and sewer outlets in Boston Harbor. (A) Moon Island outlet of Boston Main Drainage System, (B) Nut Island outlet of South Metropolitan System and (C) Deer Island outlet of North Metropolitan System.

In addition to the recreational use of the beaches, the investigators have also stressed the deterioration of aesthetic values. The harbor is used by many yacht clubs whose members report that present conditions are a definite detriment to the advancement of the harbor as a recreational area.

In spite of the rather dark picture which has been painted the reports indicate that the most objectionable conditions are confined to the immediate vicinity of the three main sewer outlets, although, under certain tide and weather conditions, grease and other floating matters characteristic of sewage do reach the shores used for bathing. In House 1600 the Department of Health concluded that Boston Harbor has not, except in Fort Point Channel, contained oxygen in less than 57 per cent saturation. Therefore, the great dilution possible in

Boston Harbor which permits natural purification by oxidation of the organic matter makes a high degree of purification unnecessary, although some form of pretreatment for the removal of grease and floating matter may be necessary. This conclusion is supported by the unanimous opinion of the later special commission reporting in House 2465 that, for the present, only partial treatment is necessary for the sewage discharged into Boston Harbor and this is the basis of the designs.

House 2465 included results of investigations by Greeley & Hansen and Metcalf & Eddy, and the legislature in 1939 authorized the continuation of the studies and the preparation of preliminary plans. These engineers then undertook a program of subsurface investigations by borings covering many of the sites involved and prepared outline plans and a comprehensive report. As a result, the legislature in 1941 conditionally appropriated $15,000,000 for the construction of five specific projects. Various conditions with respect to the commencement of the work on any project and the securing of Federal aid mean that, as a practical matter, they are all in the class of postwar projects and there will undoubtedly be delays in the case of some of them. The importance of cleaning up the situation in the Boston Main Drainage outlet cannot be stressed too strongly. However, this is a matter which is being handled by the city of Boston independent of the metropolitan districts. As to the relative importance of conditions at the South Metropolitan and North Metropolitan outlets, the legislature has concluded to proceed first with the treatment works at the South Metropolitan outlet, where the expenditures can be most effective in early results. The North Metropolitan Outlet discharge into the main deep channel appears to give less trouble, as above noted, but the importance of cleaning up this situation also in the near future is not to be forgotten.

At about the time this legislation was passed the Metropolitan District Water Supply Commission was completing a program of heavy construction for additions to the system of water supply of the Metropolitan Water District. These consisted of the 415 billion-gallon Quabbin Reservoir, the 24.6-mile Quabbin Aqueduct tunnel, the Ware River Diversion Works, the new 18-mile Pressure Aqueduct, Norumbega Distributing Reservoir and other works, for which $65,000,000 was appropriated in 1926, which sum has been increased by Federal aid to about $72,700,000. The water supply commission was purely a designing and constructing commission created for the purpose of carrying out this huge program and distinct from the regular permanent maintenance departments. Its work would now be completed if the expenditure of the last $5,000,000 for the extension of the Pressure Aqueduct by tunnel to Chestnut Hill had not been interrupted by the war. The Legislature of 1941, however, gave to this construction organization the work of designing and building the sewerage projects above referred to. This accounts for the apparent misnomer and explains why the Metropolitan District Water Supply Commission is engaged in sewerage activities.

The Metropolitan District Water Supply Commission as originally organized consists of three members, two appointed by the Governor and a third who is chairman by virtue of his appointment by the Governor as chairman of the Metropolitan District Commission, the permanent organization for maintenance. As enlarged for the purpose of designing and constructing the sewerage projects, the commission includes two others, ex-officio, namely the chief engineer of the Sewerage Division of the Metropolitan District Commission and the chief sanitary engineer of the Department of Public Health.

The five projects referred to above, which are specified in Chapter 720 of the Acts of 1941, are as follows:

Project 1—A sewage treatment and sludge disposal plant and appurtenant works at the Nut Island outlet of the trunk sewer of the South Metropolitan Sewerage District.

Project 2—Extension from East Boston to Deer Island of the North Metropolitan relief sewer recently completed to East Boston by the Sewerage Division of the Metropolitan District Commission.

Project 3—A conduit to carry storm overflows in the Alewife Brook valley to the North Metropolitan relief sewer above referred to.

Project 4—A storm overflow relief conduit along the southerly side of the Charles River and the Charles River Basin.

Project 5—A similar storm overflow relief conduit on the northerly side of this river and basin.

Of the total appropriated $15,000,000, $3,800,000 was specifically allocated by the Act to the Nut Island treatment works, and the balance lacks approximately $800,000 of covering the aggregate estimates that have been made by the consulting engineers. Moreover, all the construction was made contingent upon the receipt of 25 per cent Federal aid. The only present authorization to proceed covers the matter of design of approved projects; the necessary approval has been obtained and progress is being made in the preparation of construction plans for Project No. 1, the Nut Island sewage treatment works.

In addition to the five projects named, the comprehensive plan envisages other future works to which these are not only directly related but to which the plan definitely points as necessary. These additional projects comprise principally the following:

1—A deep rock tunnel from the Back Bay to the East Boston pumping station to relieve the South Metropolitan trunk sewer by a partial diversion to the North Metropolitan trunk sewer.

2—Sewage treatment at the Deer Island outlet of the North Metropolitan Sewer.

3—Although not a District project there should also be listed with these postwar projects one which the city of Boston will some day have to undertake, namely a sewage treatment plant at the Moon Island outlet of the Boston Main Drainage System.

Proposed Sewage Treatment Plant at the Outlet of the South Metropolitan Trunk Sewer (Nut Island, Hough's Neck, Quincy)

At the present time the sewage is untreated except at the so-called screen house on Nut Island where it passes through racks of the cage-elevator type, from which it is discharged continuously through two 60-inch pipes to a point about 6,000 feet from the shore. A third 60-inch pipe to a point 1,400 feet off-shore is available at times of high flow. In the new design these pipes will be used to carry off the sewage effluent. Regardless of the improvement in the character of the sewage discharged through these outfalls, it is considered important to improve also the condition of diffusion at the submerged outlets.

Table 1.—*Design Data for Proposed Nut Island Sewage Treatment Plant, Boston, Mass.*

	Present Conditions		Design Conditions	
	Normal Dry Weather	Average	Average	Maximum
Sewage flow—m.g.d.	70[1]	87[2]	112	300
Population served	—	700,000	900,000	—
Suspended solids—lbs. per day (At 0.2 lb. per cap. daily)	—	140,000	180,000	—
Grit channel velocities—f.p.s.				
Two channels	0.8–0.9	—	—	—
Three channels	—	0.72–0.82	0.85–0.95	—
Six channels	—	—	—	0.95–1.05
Pumping lift—feet	8.4	8.6	8.9	10.75
Aeration channel detention—min.	32	26	20	7.5
Sedimentation period—hrs.	2.35	1.9	1.5	0.55
Suspended matter removal—per cent	65	58	50	—
Raw sludge—gallons per day (At 95 per cent moisture)	—	191,000	213,000	—
Digested sludge solids[3]—lbs. daily	—	51,000	56,500	—
Digested sludge—gallons per day (At 92 per cent moisture)	—	75,000	82,500	—
Supernatant liquor—gal. per day	—	114,000	126,000	—
Gas production—c.f. per day (At 0.75 c.f. per cap. daily)	—	525,000	675,000	—

[1] Occasional hourly minimum about 45 m.g.d.

[2] Does not include occasional storm flows.

[3] Assuming 60 to 65 per cent of solids removed by sedimentation.

It is expected that some form of baffles can be constructed at the outlet ends of these three pipes which will mix the effluent with sea water more thoroughly than is now the case with raw sewage.

The plant is being designed to remove floating solids and grease, and to reduce the amount of suspended solids by plain sedimentation. The minimum period of detention in sedimentation tanks that has been considered is about one hour at the design rate and the maximum about one and one-half hours. Provision will be made for chlorination of the effluent during the recreational season to prevent bacterial pollution of harbor and shore waters. Plans are being made to digest the sludge, and the approval of the State and Federal authorities is being sought to discharge the innocuous residue from the digestion tanks through an outfall pipe about 4 miles long to deep tide water.

The following table presents miscellaneous data being used in the design of the sewage treatment plant.

The proposed treatment works will include the following major units:

Two medium screen racks of about 2-inch net openings, in parallel channels 6 ft. wide by 6.5 ft. deep.

Six parallel grit channels.

Five screen racks of about 0.7-inch net openings, following three of the grit channels.

Six 36-inch comminutors following three of the grit channels, two in each channel.

Three 150 m.g.d. pumps, one of which is a standby unit.

Five parallel aeration channels.

Six sedimentation tanks.

Nine 150 g.p.m. sludge and grease pumps, three in each of three stations, one in each station to be used normally for grease and scum only.

Four digestion tanks, 110 ft. in diameter and 30 ft. deep, working capacity of 2,332,000 gallons each.

Miscellaneous basic data being used in the design are given in Table 1.

Variations in Rate of Sewage Flow

The variations in flow follow a definite pattern and there is a considerable equalizing effect in the long trunk sewer approaching the site. The minimum flows occur between 7:00 and 8:00 A.M. and the maximum between 5:00 and 6:00 P.M.; the difference between daily minimum and maximum appears to be about 26 m.g.d., regardless of whether the daily average is 65 or 165.

Results of Recent Analyses of Samples

For the past year or more composite 24-hour samples have been taken, with the following results, from analyses made by the Department of Public Health as shown on opposite page.

An average of the above, weighted for the flows measured on the days the composite samples were taken, gives the total suspended solids at a little less than 160 parts per million.

Plan of Construction

The layout is designed to take advantage of the fact that the trunk sewer for a length of about 270 feet approaching the existing screen house is divided into two parallel conduits, one of which can be used to maintain uninterrupted flow during the construction of the new works. The old cage racks in the so-called screen house will be removed as soon as their usefulness has ceased and the building will be used to house chlorine storage rooms and chlorinating plant.

Date	Parts per Million				
	Suspended Solids			B.O.D.	Dissolved Oxygen
	Total	Volatile	Fixed		
1943					
July 8–9	179	134	45	162	0.7
				327 Max.	2.4
				80 Min.	0.0
Aug. 1–2	94	72	22	128	1.5
				170 Max.	2.9
				85 Min.	0.2
Sept. 21–22	300	235	65	234	0.6
				407 Max.	2.2
				125 Min.	0.0
Oct. 21–22	153	119	34	315	0.8
				670 Max.	2.4
				170 Min.	0.0
Nov. 19–20	205	158	47	240	0.6
				450 Max.	1.6
				53 Min.	0.0
Dec. 8–9	138	108	30		
Dec. 14–15	182	140	42		
Dec. 20–21	231	169	62		
Dec. 27–28	178	121	57		
1944					
Jan. 4–5	82	65	17		
Jan. 12–13	126	98	28		
Jan. 20–21	166	130	36		
Jan. 28–29	88	68	20		
Feb. 7–8	230	177	53		
Feb. 15–16	156	106	50		
Feb. 23–24	160	124	36		
Mar. 2–3	113	88	25		
Mar. 10–11	179	136	43		
Mar. 20–21	120	86	34		
Mar. 28–29	113	75	38		
April 5–6	113	103	10		
April 13–14	154	122	32		
April 21–22	114	91	23		
May 1–2	107	79	28		
May 9–10	133	100	33		
May 17–18	205	145	60		
May 25–26	194	150	44		
June 2–3	194	164	30		
June 12–13	169	133	36		
June 20–21	223	156	67		
June 28–29	290	229	61		
July 6–7	173	153	20		
July 14–15	180	138	42		
July 24–25	164	116	48		
Aug. 1–2	230	174	56		
Aug. 9–10	268	209	59		

Main Emergency Spillway

The break into the existing sewer will be confined to a short length and the effluent will be returned close to the point of diversion. This permits the convenient installation at this point of an emergency spillway automatically bypassing the entire plant. Such a spillway must be provided with tide gates on the crest to cover the contingency of an extreme rise in level in the effluent conduit resulting from the maximum rate of sewage flow at the time of extreme high tide. The extent to which the spillway crest can be raised is limited by the surcharging of the trunk sewer itself. There is also an economical limit to the height to which the sedimentation basins and their overflows can be raised. On that account extreme conditions must be cared for by another emergency spillway which under the most critical conditions will permit a small quantity of sewage effluent to spill over to an offshore outlet instead of through the existing outfall pipes.

Coarse Racks and Grit Removal

The entering sewage will first pass through mechanically cleaned, coarse racks designed to be free from any tendency to jam the material at the bottom of the racks or at the top of the waterway opening. These racks might better be called medium rather than coarse because they are designed to eliminate as far as practicable the passage of rags and similar material which would tend to ball up and clog the subsequent grit removal mechanisms. The two coarse racks are in the approaches to a channel from which six parallel grit chambers are supplied through sluice gate control. These chambers are 80 feet long by 10½ feet wide with collectors that scrape the material from the downstream to the upstream end, elevate it through the incoming sewage and discharge it on a cross-belt supplying washers of the jig type. The velocities in the grit chamber vary from 0.8 to 1.0 f.p.s.

Comminutors and Fine Racks

Beyond the grit chambers, the design provides for the installation of comminutors or fine racks or both; for example, the plan shows a design which in ordinary operation will use two or three of the grit chambers depending upon the rate of flow, and these three chambers will feed six comminutors, two 36-inch units below each chamber. The other three channels, which ordinarily will be used only for infrequent high flows, feed fine racks of the same type as the coarse racks above referred to. Both comminutors and fine racks will discharge into the pump suction well but the discharge from the fine racks will have to be throttled to give the same conditions of hydraulic loss as occur through the comminutors. With such a design, all screenings would be fed to the comminutors, screenings from the coarse rack being first manually sorted for the removal of material that cannot be comminuted so that the other screenings can be sluiced directly to the comminutors through channels which bypass the grit chambers. Screenings from the fine racks when in use will be sluiced directly to the adjoining comminutors. Another possibility with such a design is that in any emergency requiring the pumps and sedimentation basins to be out of service, the plant can still be operated up to and including the fine racks which can bypass directly into the effluent conduit.

Low-Lift Pumps

Next come low-lift pumps capable of handling the entire capacity of the main trunk sewer, 300 m.g.d., with standby provisions. An investigation is being made of the possibility of reducing the number of units to three and using constant speed, direct-connected pumps with adjustable-blade impellers in which a wide range of capacities at high efficiency is obtained by automatically changing the angle of inclination of the impeller blades. The discharge from the pumps will unite to pass through a Venturi meter.

Preaeration Channels

We are investigating the extent to which preaeration should be employed to improve the removal of solids in the sedimentation tanks. The plans show five main channels about 180 feet long, 13½ feet deep and 17 feet wide in which it is proposed to aerate through headers that can be raised above the sewage level for servicing. The plans show a detention period of approximately 20 minutes at the design rate corresponding to about 30 minutes during the more important period of low flows in the summer recreational period.

Sedimentation Basins

The influent and effluent conduits extend along the two ends of the sedimentation basins, the conduit wall being the basin end wall in each case. The plans show 6 basins about 185 feet long, 64 feet wide, each partitioned into four 16-foot channels in which scum and sludge collectors of standard design will operate. It is planned to operate the basins in pairs, the cross scum collectors from two basins feeding one narrow conveyor designed to return the grease and scum along the side of one of the basins to the head end where the sludge and grease pump houses are located, one house for each two basins. The plans show the sludge sump constructed as an extension beyond the side wall of the basin in such a way as to permit the cross sludge collector to extend above the sewage level on its return course. In this way, all the conveyors are accessible for replacement and repair.

Sludge and Grease Pumps

It is planned to have three sludge and grease pumps in each of the three houses and to have them more or less interchangeable, although ordinarily it will be more convenient for one pump to handle the grease. The sludge pumps will pump directly from the basin sumps and the grease pump from a grease collecting and decanting tank fed by means of a controlled weir which will draw the grease and scum directly from the return conveyor above referred to. It is planned to have this weir discharge through a rack to remove any sticks or rags that may get by the comminutors or into the subsequent channels. These will then be sluiced back into the main trunk sewer ahead of the plant, using decant liquor from the grease collecting tank to assist the sluicing.

Sludge Digestion Tanks

The plans show four digestion tanks, 110 feet in diameter. Studies are being made of the practicability of having two tanks for primary digestion, possibly with fixed covers, and two for final digestion with floating covers combined with a gas storage tank. The large diameter of the tanks insures ample room in the central control building which will have two stories, an upper or mezzanine floor beneath which most of the piping will be located and a lower floor for pumps and other equipment. It is proposed to utilize the cooling water from the gas engines to maintain the temperature in the digestion tanks at the desired point, about 85 deg. F. Three 300 g.p.m. pumps are planned for this closed system of water circulation. During cold weather additional heat will be obtained from steam using the existing boilers in the screen house. These are fairly new, coal burning, in good condition and the fire boxes will be reconstructed to burn gas from the digestion tanks, or oil as a reserve. During hot summer weather, the digesters will not remove sufficient heat from the system and a cooler will have to be cut into the circuit, using sewage effluent for cooling water.

It is anticipated that sufficient gas will be generated in the digesters to develop the power required at all times; also that during the winter it will be necessary to heat the office building independently and the main building by steam generated in the existing re-equipped boilers.

Power Plant Installation

It is proposed to install:

Two—500 Kw. gas-engine electric generators
One—500 Kw. Diesel electric generator
Two—200 H.P. 5000 c.f.p.m. blowers

One gas-engine generator will carry the normal load and two will operate at higher loads. The diesel will serve as a spare unit and it will also be operated as necessary whenever sufficient gas is not available, and also during the period in which the digesters are put into service.

Fertilizer Possibilities

Preliminary estimates indicate that it will not pay to dry the digested sludge for the manufacture of low-grade fertilizer. However, there is space available so that experiments can be conducted on a small scale on the dewatering of a portion of the sludge to make it available as humus. It is impossible at this time to see how even this can be made to pay for itself.

THE OPERATOR'S CORNER

ANNUAL OPERATION REPORTS

As the new year brings its timorous hope and promise of peace and good will to this troubled sphere, how many sewage works supervisors will actually complete last year's job by compiling a useful summary record into an annual report? It is our positive opinion that the preparation of such a report is a definite responsibility—an essential duty to the municipality served.

Volumes have been written and spoken about the value of operation records with never a dissenting voice. Operators religiously begin each day with a round of all the meters and gauges, painstakingly recording the various readings. Diary entries are made and laboratory results recorded. Monthly summaries of these data are assembled in most plants but it is feared that even this practice might be much less general if it were not that state health departments and other pollution control agencies require them. But when it comes to annual reports, the picture changes materially; we hazard the guess that yearly summaries are prepared in less than ten per cent of all treatment works in existence!

It is true that plant superintendents have many other pressing duties and responsibilities; that they are often loath to leave more interesting tasks to undertake desk chores; that there is sometimes a discouraging lack of interest on the part of the municipal officials to whom such reports are submitted; that some expense is involved in reproducing the report for distribution; that the report is beyond the comprehension of the average citizen if it is made sufficiently technical to be of practical value as a plant record. Yet it is also true that the busy plant superintendent can waste much time in sifting through daily, weekly or monthly reports for what may be located quickly in the annual and that he will get an over all picture from the annual summary that is not possible in data representing shorter periods. Preparation of the annual report need not be an onerous chore if one is alert to the lessons and practical conclusions which so frequently may be found and used in meeting problems of the future.

Municipal officials who may not seem to appreciate the report when it is submitted must, however, respect the force given the superintendent's recommendations and arguments as substantiated by the data which are contained in such reports. It would be an ill-fated industrial corporation indeed, if its board of directors paid no attention to production records and costs. Our attention has been directed to one instance in which a city councilman has actually opposed the preparation of an annual report at the sewage treatment plant on the vague grounds "that it was unnecessary," but this is certainly a rare exception. Many municipal administrative bodies insist on annual reports and most of those remaining would place a higher value on the plant superintendent who, of his own volition, submitted annual reports for their information and guidance.

It is not essential that the annual report be presented as an elaborate printed brochure, replete with photographs and illustrations, such as is distributed from plants serving very large cities. These are too luxurious for the smaller municipalities and are usually not justified in such cases. A neatly mimeographed report will answer the purpose admirably and the reproduction cost is almost negligible, particularly if a machine is available in the municipal offices. Produced in this fashion, excessive cost is not a legitimate argument against their preparation; it is obvious that the modest investment involved may be offset many times by the savings made possible in operation, engineering and future construction costs.

The report need not be produced in sufficient numbers to supply each taxpayer with a copy. Local and state government officials should certainly be on the mailing list, as should the local newspapers. It is through the newspapers that the superintendent may achieve the dual functions of the transformation of his technical report into a story that the average citizen will understand and the actual distribution of the popularized version to the public. The superintendent will do well to offer personal assistance to the reporter in enlarging upon such items as may have particular news and public relations value. Finally, the mailing list should include the names of superintendents of other sewage treatment works in the state or region so that there is an interchange of information which will result in benefit to all.

The make-up and content of annual reports will differ somewhat due to the varied responsibilities of the superintendent and due to the varied character of facilities operated. Nevertheless, a complete report should contain the following essential elements:

1. A review of administrative activities including reference to personnel matters, official inspections, complaints, extension of facilities and similar developments pertinent to the administration of the department.

2. A summary of general information on rainfall, sewage and stream flows, population changes, etc., as will portray the general conditions and requirements imposed upon the facilities.

3. A resume of the operation of each part of the sewage collection and treatment works, setting forth loadings, efficiencies, difficulties experienced, quantities of materials involved and unusual occurrences.

4. Detailed tabulations of operating and analytical data, including coverage of the outlet watercourse.

5. A chronological maintenance schedule stating when and what maintenance work was performed on buildings, structures, equipment and grounds—a most useful reference item.

6. A breakdown and summary of costs, with comparison to those of preceding recent years.
7. A statement of conclusions and recommendations.

If annual reports are worth while in large sewage treatment plants—and they certainly are—they are just as much justified in the smaller ones. Why not put your plant in the "big time" by preparing your first annual report to cover the year 1944?

W. H. W.

SUMMARY OF EXPERIENCE IN MECHANICAL ACTIVATED SLUDGE PLANT OPERATION

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Continuing the program of "The Operator's Corner" in presenting studies of actual operation procedures in fundamental sewage treatment processes, this article reviews control practices in mechanical activated sludge plants. It is largely based upon data and comments obtained from 27 superintendents, engineers, chemists or operators of 29 representative plants through detailed questionnaires and through supplementary correspondence. An effort was made to obtain an even distribution of returns from plants utilizing the three most common types of mechanical aerators and, while complete success in that regard was not achieved, it is believed that adequate distribution was obtained. It is not the purpose of this review to discuss and compare the relative merits of mechanical aeration equipment of the several types. Grateful acknowledgment is given the complete co-operation of the following contributors:

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Dick, Robert, Supt., Elmhurst, Illinois
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Somers, Verne, Supt., Stevens Point, Wisconsin
Tanari, Myron, Operator, Ladd, Illinois
Todd, L. J., Supt., Milton Junction, Wisconsin
Tompkins, L. B., Operator, Michigan State Home and Training School, Coldwater, Michigan
Wolf, E. H., Operator, Waterloo, Illinois

A wide variation in capacity, loading and design is indicated in the general data for the plants contributing, as tabulated in Table I. The loading data tabulated in the ninth column of the table were calculated from the information submitted. While the data in that column are of general interest in indicating the relative degree of loading at the various plants, they should not be interpreted too broadly for the reason that some of the B.O.D. data utilized in the calculations may have been obtained from grab samples while other data were obtained from composite samples.

Before going into the detailed operation control procedures, it might be well to discuss first the general method of placing a plant in operation. In building up a healthy, well conditioned activated sludge it is important that certain fundamental factors be considered and followed. The organisms which go into the building of an activated sludge are all present in the sewage, but in order that those organisms may become acclimated and cultivated it is important that the aeration mixture contain dissolved oxygen and that the organisms be fed at a proper rate. In starting a plant, allow the aeration tanks to fill with settled sewage and start the aerators, setting them to operate continuously. Allow 30 to 50 per cent of the design flow to pass into the aeration tanks, by-passing the remainder of the settled sewage. The Chicago Pump Company, in its Operation Bulletin No. 1165, suggests by-passing all settled sewage for 24 hours after starting the aerators and before allowing additional sewage to pass through the aeration tanks. After the final settling tanks are full, start the collecting mechanism and return sludge pumps (or open valve on automatic sludge return line *). The return of these previously aerated sewage solids will cause a

* In the case of plants using American aerators.

TABLE I.—*General Information Regarding Contributing Plants*

Plant	Connected Population	Type Sewers	Average Flow (M.G.D.)	Average Primary Sedimentation Period (Hr.)	Aeration Units				Average 5-day B.O.D. (P.P.M.)			Final Tank Collector Speed (Ft. per Min.)
					Type Aerators	Number	Average Aeration Period (Hr.)	Cu. ft. Aeration Tank Capacity per Lb. Primary Effl. B.O.D.	Raw Sewage	Primary Effluent	Final Effluent	
Batavia, Illinois	4,700	Combined	0.895	0.45	American	7	4.62	57	287	70	9	1.0
Belvidere, Illinois	9,000	Separate	1.202	0.99	Chicago	9	7.00	49	223	126	5	0.75
Birmingham, Michigan	12,500	Combined	2.60	0.68	American	8	4.05	78	81	52	9.7	—
Bryan, Ohio	5,000	Combined	0.682	2.00	Chicago	6	9.26	109	102	67	10	2.0
Buchanan, Michigan	4,500	Separate	0.787	—	Chicago	3	3.10	46	96	56	21	2.0
Bucyrus, Ohio	9,600	—	1.066	1.5	American	6	6.00	45	263	126	4	—
Carlstrom Field	Restricted	Separate	0.067	1.5–3.0	Chicago (1)	2	10–20	99	181	138	3.6	—
Coldwater, Michigan	1,200	Separate	0.154	3.1	American	3	10.40	126	165	82	4	1.5
Crystal Lake, Ill.	5,000	Separate	0.30	—	Chicago	4	9.90	87	240	125	6	11.8
Dorr Field	Restricted	Separate	0.053	3.75	Chicago (1)	2	25.06	131	190	131	13	—
East Lansing, Mich.	13,500	Combined	1.838	1.20	American	9	4.80	107	79	40	4	10.0
Elmhurst, Illinois	16,000	Combined	1.50	1.60	Chicago	12	6.90	57	123	103	13	—
Ferguson, Mo.	12,000	Separate	0.80	2.0	Chicago	5	5.70	95	110	50	6	1.5
Geneva, Illinois	5,500	Separate	0.90	1.4	Yeomans	9	6.00	29	325	170	11	1.0
Great Lakes, Ill.	Restricted	Separate	Restricted	2.0	Chicago	12	10.00	—	375	225	19	2.0
Greece, New York	10,060	Separate	0.599	1.95	American	8	8.80	39	231	170	17	4.2
Illinois Ordnance	Restricted	Separate	0.100	5.32	Yeomans	3	22.00	163	150	130	1.5–3.0	1.0
Kewanee, Illinois	8,000	Separate	0.860	2.2	Yeomans	12	7.40	55	289	119	11	1.5
Knightstown, Ind.	500	Separate	0.060	—	Chicago (1)	2	—	—	—	—	—	—
Ladd, Illinois	1,200	Combined	0.070	1.75	Chicago (1)	2	17.00	37	—	—	—	—
Lambert Field	Restricted	Separate	0.250	1.2	Chicago	3	7.50	35	200	175	20	—
Laurens, S. Car.	5,700	Separate	0.480	0.50	Chicago	4	9.20	—	900	—	40	2.0
Milton Junction, Wisc.	2,000	Separate	0.080	12.0	Yeomans	2	25.00	87	800	300	20	1.0
Radnor—Haverford, Pa.	10,400	—	0.80	1.0	Yeomans	8	10.00	91	172	104	7	—
Riddle Field	Restricted	Separate	0.015	6.4	Chicago (1)	1	42.00	330	165	92	7	—
Rochelle, Illinois	4,400	Separate	0.416	2.5	American	6	9.90	72	249	148	12	4.0
Stevens Point, Wisc.	14,000	Separate	1.41 (2)	2.0	American	6	7.60	25	270	180	10	4.0
Waterloo, Illinois	1,300	Separate	0.098	—	Chicago	2	15.00	150	232	89	26	0.5
Willow Run	Restricted	Separate	1.49	3.0	Chicago	16	12.00	76	155	129	18	1.0

(1) Combintion Aerator—Clarifier. (2) 60 per cent given complete treatment.

gradual increase in the mixed liquor solids concentration. Walker, of the American Well Works, in notes for a lecture on activated sludge plant operation presented before the 1944 Illinois Sewage Works Operators Short Course, stated:

"The quantity of sewage added to the aerated mixture is gradually increased from day to day. The return to the incoming sewage of the settled solids (taken from the final settling tank) from the previously aerated sewage will gradually increase the solids concentration of the aerated mixture. The addition of more sewage has to be done very carefully so as not to supply more organic food to the organisms than they can consume. Overfeeding of the organisms will have a very detrimental effect upon their existence because there will then be more organic matter being absorbed by the young activated sludge than it can digest. In a like manner, underfeeding has a very detrimental effect and it can be easily imagined that starved organisms do not thrive.

"Operate the plant at ⅓ to ½ rated (design) load and do not try to force the early activated sludge development. As the activated sludge starts to develop (recognized first by much white foaming and characteristic strong, spicy odor), increase the sewage load slowly.

"Stop applying the sewage load at once if the activated sludge seems to be reverting back to the air flocculated solids phase." (Note: Walker divides activated sludge development into two phases: first, the air flocculated solids phase, and, second, the true activated sludge phase.)

The mixed liquor solids concentration will gradually build up to a point where sufficient solids are present to permit turning the entire sewage flow into the aeration tanks. Operation Bulletin No. 1165, of the Chicago Pump Co., suggests that this can be done when the suspended solids in the mixed liquor reach 400 p.p.m., and that careful wasting of activated sludge can be started when the suspended solids reach 600 to 800 p.p.m.

When starting a new activated sludge plant to serve a new sewer system it is nearly always found that the sewage flow is well below the design flow, which makes it advisable to begin operations, as described above, utilizing only a portion of the total aeration tank capacity of the plant. Similarly, if the plant is designed with more than one primary tank and final settling tank, it would appear desirable to start operations with only a portion of the settling capacity to avoid difficulties from overlong detention periods. Obviously, in the smaller plants this flexibility of operation of plant units is not common.

After the activated sludge has been developed, the operator finds that there are several variables over which he can and must exercise control in the operation of his plant. Those variables are:

1. Mixed liquor solids concentration.
2. Rate of returning sludge.
3. Application of air (amount of aeration).
4. Aeration period.
5. Condition of the activated sludge.

Those operation variables must be controlled by the operator to keep the plant in balance so that it can accommodate the normal loading received, and the same variables must also be regulated to accommodate fluctuations in loading, whether seasonal or otherwise. The comparison of control practices at the various plants contributing to this review clearly indicates the effect of local conditions upon control procedures.

Mixed Liquor Solids Concentration

The operation variable which usually receives first attention, and which is often considered the most important in activated sludge plant operation, is the mixed liquor solids concentration. The concentration of solids carried in the aeration tanks is adjusted by apportioning the activated sludge removed from the final settling tank between return and waste, this apportionment being accomplished in one of several ways, depending upon the plant design. In plants equipped for automatic sludge return (utilizing American aerators), wasting of activated sludge is usually controlled by a telescoping valve installed on the end of a sludge line branching off the return line and located in a waste sludge well. In plants employing pumps for returning sludge, the sludge is commonly pumped to a division box which can be manually adjusted to apportion the activated sludge between return and waste. In the case of the Chicago combination aerator-clarifier plant, a special waste activated sludge hopper is provided through which there is a circulation of mixed liquor at a controllable rate. Settling of waste activated sludge takes place in this hopper.

Data including the average and range of mixed liquor solids carried in the aeration tanks of 29 plants, together with the average sludge index and 30 minute mixed liquor settleable solids, are tabulated in Table II. These data indicate that fourteen of the plants carry average solids of 600 to 1,000 p.p.m., five plants carry average solids of 300 to 500 p.p.m., and one plant carries an average of only 200 p.p.m. Six of the plants carry average solids of over 1,000 p.p.m., two of which (Birmingham, Mich. and the Michigan State Home at Coldwater) carry averages of 2,000 and 1,876 p.p.m., respectively.

Grinnell (Birmingham, Michigan) states that his plant is normally operating at nearly 100 per cent overload, which makes it necessary to carry as high a mixed liquor solids concentration and index as possible in order to obtain good treatment at the short aeration period. At concentrations above 2,600 p.p.m. difficulty is experienced with floc carrying over the weirs of the final settling tanks, and this problem is accentuated when the volatile solids in the mixed liquor exceed 75 per cent. Grinnell further states that he attempts to maintain a sludge as high in per cent volatile solids and as slow in settling as the plant flow loading will allow without carrying floc over the weirs. The sludge high in volatile content is, of course, more active. This is important in an overloaded plant in which it is necessary to obtain the most from the sludge concentration which can be carried. Grinnell states that two intercepting sewers lead to his plant, one of which carries very dilute sewage following rains. It is usually necessary to by-pass this sewage, which is high in ash content (fixed solids) due to the silt washed off the gravel streets in the contributing area. If the volatile content of the mixed liquor is high when a rain occurs, the high ash content sewage is carried into the plant for a time to reduce these high volatile solids, thus to make the sludge more dense so that it will

TABLE II.—*Mixed Liquor and Return Sludge Data*

Plant	Mixed Liquor Suspended Solids (P.P.M.)		Return Sludge			Average Sludge Index	Average Mixed Liquor Settleable Solids (% in 30 min.)
	Average	Range	Average Return Rate (%)	Return Rate Range	Average Suspended Solids (P.P.M.)		
Batavia, Illinois	824	806– 851	30	25–45	1,519	56	4.6
Belvidere, Illinois	557	416– 903	17	16–19	—	643	36
Birmingham, Michigan	2,000	1,500–2,600	28	22–34	10,700	70	11
Bryan, Ohio	711	557– 780	30	25–45	2,037	603	57
Buchanan, Michigan	676	530– 882	25	—	—	266	18
Bucyrus, Ohio	1,000	—	25	25–50	4,800	150	20
Carlstrom Field	840	260–1,400	—	—	—	631	53
Coldwater, Michigan	1,876	1,550–2,080	50	42–78	4,583	122	23
Crystal Lake, Ill.	550	—	25	—	—	85	4–10
Dorr Field	744	467– 910	—	—	—	483	36
East Lansing, Mich.	1,100	500–1,790	33	23–44	2,700	53	12
Elmhurst, Illinois	433	315– 655	27.5	16–41	—	530	22
Ferguson, Mo.	300	200– 600	25	20–30	—	360	13
Geneva, Illinois	621	443– 778	14	13–17	2,518	110	5
Great Lakes, Ill.	750	700–1,000	50	40–55	2,500	280	10
Greece, New York	1,036	669–1,470	17	7–39	4,170	173	19
Illinois Ordnance	900	500–1,400	46	—	2,250	48	7
Kewanee, Illinois	1,062	200–2,800	30	—	3,453	309	30
Knightstown, Ind.	800	—	—	—	—	800	50
Ladd, Illinois	600	300–1,000	—	—	—	167	10
Lambert Field	500	—	25	—	900	700	35
Laurens, S. Car.	600	500– 700	20	—	700	350	36
Milton Junction, Wisc.	200	—	50	—	—	1,000	20
Radnor—Haverford, Pa.	900	800–1,000	40	35–45	2,000	155	18
Riddle Field	786	—	—	—	—	114	9
Rochelle, Illinois	445	310– 534	61	—	1,248	405	18
Stevens Point, Wisc.	600	500– 900	50	40–60	1,800	135	10
Waterloo, Illinois	641	—	33	—	758	410	27
Willow Run	1,100	650–1,550	28	16–56	3,400	237	40

settle in the final tanks at the increased rate of flow. If loading of the sludge with the silt-bearing sewage is carried to a point where the mixed liquor solids are lowered to 50 per cent volatile, or less, Grinnell states that an insufficiently active sludge results, as might be expected.

Tompkins (Michigan State Home, Coldwater) indicates that best results are obtained at his plant with an average mixed liquor solids concentration of 1800–1900 p.p.m. Decker (Bryan, Ohio) indicates that best results are obtained there when the mixed liquor solids are carried at 800 p.p.m. He indicates that about 100 p.p.m. higher mixed liquor solids are usually carried on Monday, the local washday, to compensate for the additional load.

Lamb (Belvidere, Illinois) carries an average of 557 p.p.m. of mixed liquor solids. He prefers to operate with mixed liquor solids as low as possible since it has been his experience that, while the plant might be somewhat more sensitive to upset at the lower solids concentrations, it will recover from an upset much faster than at higher solids values. Patriarche (East Lansing, Michigan) indicates that best results are obtained there at concentrations of 1,100 p.p.m., but states that the concentrations vary over a rather wide range in spite of efforts to control them. That this difficulty is similarly experienced in many plants is indicated by the rather wide range of mixed liquor solids reported from nearly every plant.

Denise (Greece, New York) states that 800 p.p.m. of solids are carried during the summer months and about 1,100 p.p.m. during the winter months. It was not indicated whether a higher volatile solids content during the summer months enables lowering the mixed liquor solids, or whether there might be a drop in the load during the summer, which would appear rather unlikely. Carothers (Riddle Aeronautical Institute) indicates that his rule for mixed liquor solids is "the higher the better, commensurate with the oxygen supply." Freeman (Geneva, Illinois) maintains approximately 620 p.p.m. of mixed liquor solids, but due to other duties which make it impossible to maintain as complete laboratory data as desired, mixed liquor solids are controlled on the basis of the settleable solids test, an effort being made to maintain between 5 and 8 per cent after 30 minutes. Lt Comdr. Klay (Lambert Field, St. Louis) indicates that the settleable solids test on the mixed liquor is used to control the concentration, as does Bradley (Buchanan, Michigan) and Longley at Radnor-Haverford, Pennsylvania. Fischer (Kewanee, Illinois) attempts to maintain 800 to 1,000 p.p.m. of mixed liquor solids, and utilizes both suspended and settleable solids as a control basis for determining return sludge and wastage.

In general, the amount of mixed liquor solids which can be carried in a plant is limited only by the air supply and by certain hydraulic capacity factors. It is noteworthy here that mixed liquor solids concentrations as high as 2,600 p.p.m. are carried in one plant utilizing mechanical aerators, apparently without difficulty in supplying adequate aeration. The 2,600 p.p.m. of solids are carried at Birmingham, Michigan, with operation of the aerators only 50 per cent of the time, and a dissolved oxygen content of 4.0 p.p.m. is maintained in the final aerator. It should be noted that the sewage at Birmingham is quite weak, however, an average aeration period of only 4.05 hours is available. It appears that the solids concentration which can be carried in some mechanical activated sludge plants overlaps well into the range of solids usually associated with diffused air operation.

It is logical, from the standpoint of economic considerations, that no more mixed liquor solids be carried than necessary to meet the conditions under which a plant must operate and to permit obtaining the required effluent quality. Where the strength of sewage is widely variable, care must be exercised to maintain sufficient solids to handle the peak load. Most operators, particularly those operating plants treating widely variable sewages, must determine by intelligent trial and error methods the mixed liquor solids concentration which gives the best and most economical results, first emphasis being placed upon obtaining an effluent fitted to the outlet stream requirements.

The Chicago Pump Company, in Operation Bulletin No. 1165, states that the operation of many plants utilizing Chicago mechanical aerators has indicated that for best results the mixed liquor solids should be from 600 to 1,000 p.p.m. Likewise, experience with their combination aerator-clarifier has indicated that best results are obtained in the 500 to 800 p.p.m. solids range. Yeomans Brothers suggests a range of mixed liquor solids from 300 to 1,000 p.p.m., with an average taken at about 500 p.p.m. They further point out the need for experimentation to determine the optimum concentration for any given plant.

Walker of the American Well Works, in lecture notes previously referred to, stated with regard to mixed liquor solids concentrations:

"Experimentation and study of a great number of plants operating under normal conditions discloses that it requires about 2 pounds of activated sludge present in the aeration tanks for each pound of 5-day B.O.D. per day in the primary effluent. This figure is conservative and does not take into consideration any sludge that is present in parts of the aeration tank which do not show a residual of D.O.

"Presumably, this amount of activated sludge can be carried as a high concentration in a relatively small aeration volume, or in a lesser concentration in a relatively greater aeration volume. This means that the currently popular concentration of 1,200 p.p.m. of activated sludge requires a filling period (aeration tank capacity) of about 6 hours, assuming a fresh primary effluent relatively free of settleable solids and having a strength of about 150 p.p.m. 5-day B.O.D. (Author's note: On this same basis, 900 p.p.m. would require a filling period of 8 hours.)

"This is figured without consideration to the return activated sludge flow because the activated sludge aeration period is not affected by the return activated sludge rate. The shorter flowing through period caused by the amount of return activated sludge flow only affects the contact period between the sewage and the activated sludge. The aeration period of the activated sludge is a matter of days and is a function of the pounds of sludge carried and the sludge wasted, gained by growth, etc. (Gould's formula).

"When substantially less than 2 pounds of effective activated sludge is carried, the floc is no longer a true activated sludge. In such a case, the operation amounts to air flocculation of organic matter in the presence of a like substance acting as a nucleus. Such operation may give good clarification and reasonably good 5-day B.O.D. removal, but no nitrification or real stability."

At most of the mechanical activated sludge plants covered in this review, the suspended solids test is used as the basis for controlling the mixed liquor solids, however, at five of the plants it was indicated that the settleable solids determination is used for that purpose. Most of the plants reporting indicated that settleable solids in the mixed liquor is utilized largely as an indication of the general condition of the sludge and for computing the sludge index, and several operators referred to the difficulty in controlling a plant on the basis of settleable solids alone because of the variable settling characteristics of the sludge. Cortner (Indiana Children's Home, Knightstown) utilizes a centrifuge in controlling mixed liquor solids, in lieu of suspended or settleable solids, as does Lovejoy at Laurens, South Carolina. In that

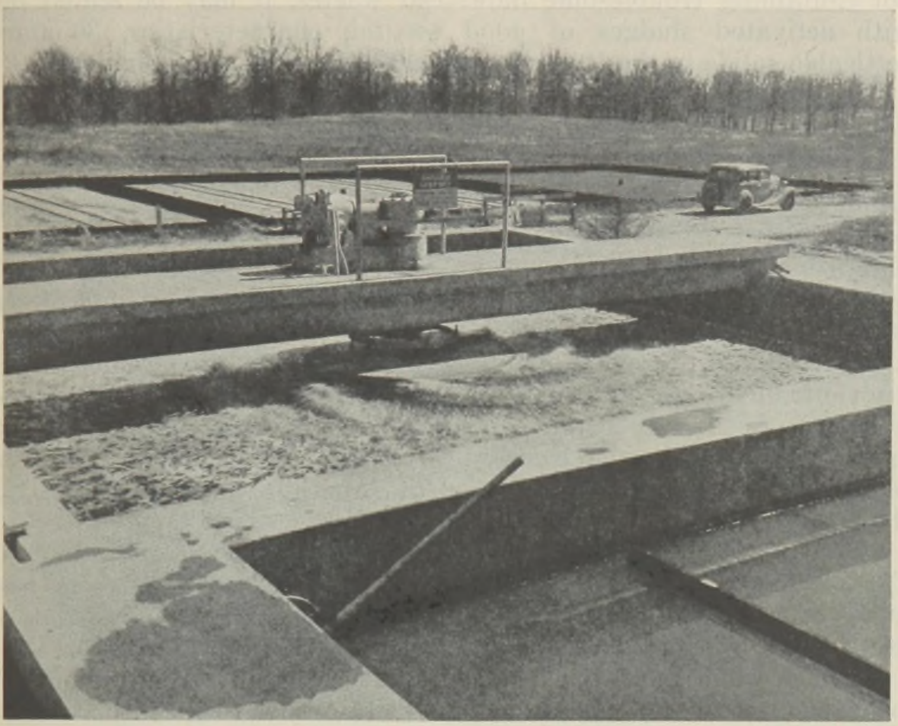


FIG. 1.—Yeomans-Simplex mechanical aerator in operation at sewage works of Illinois Ordnance Plant, Carbondale, Illinois.

regard, it should be stated that there are many plants utilizing centrifuge results on mixed liquor as a control test. The bulletin on "The Operation of a Chicago Combination Aerator-Clarifier Plant" states:

"It has been found that a centrifuge, either hand operated or electric, is a big help in controlling the concentration of solids in the mixed liquor. If the character of the sludge changes, the settling tests may vary greatly without any great change in the weight of the solids present or vice versa. The centrifuge readings vary only slightly, regardless of the character of the sludge, being nearly directly proportional to the weight of solids present. The centrifuge cannot replace the balance for accuracy, but is close enough for control of the mixed liquor solids and is far more accurate than the settling test alone.

"A centrifuge comes with two 15 c.c. graduated tubes. Fill these to the mark with a well mixed sample from the aerator and insert in the holders. Spin for 3 minutes at 1,800 r.p.m. (2 revolutions per second with the commonly used hand centrifuge). Let the centrifuge die down without braking and read the sludge volume in the bottom. A reading of 0.25 to 0.40 c.c. gives the proper amount of solids. This is approximately the same as 500 to 800 p.p.m. suspended solids."

A study of the average mixed liquor settleable solids data for the various plants, as tabulated in Table II , indicates a wide variation in per cent settleable solids for sludges of approximately the same suspended solids concentration, which is further verification of the need for intelligent and careful use of settleable solids if it is to be depended upon as the sole basis for controlling mixed liquor solids concentration. As a general average, in plants treating normal domestic sewages not containing troublesome industrial wastes, it may be stated that with activated sludges of good settling characteristics, 30-minute settleable solids in the 10 to 20 per cent range are most common.

Summarizing briefly, the following comments regarding mixed liquor solids control are offered:

1. Concentrations of 600 to 1,100 p.p.m. appear to be most common, although some plants operate below that range, and local conditions require that some plants operate above it. It is noteworthy that two plants included in this review are carrying concentrations normally associated only with diffused air operation, and without difficulty in supplying adequate aeration.

2. At all but five of the plants here represented, mixed liquor solids are controlled by use of suspended solids or centrifuge results, those five making use of settleable solids. It is recognized that many plants operate entirely on the basis of settleable solids, which procedure requires alertness on the part of the operator in interpreting the changes which occur in sludge settleability.

3. As stated by Wisely in his review of diffused air operation (see *This Journal,* **15,** 5, Sept., 1943), it is suggested that there be no hesitancy in varying the mixed liquor solids to meet seasonal variations in load and temperature.

4. There does not appear to be evidence of any trend among the mechanical activated sludge plant operators to utilize the volatile content of the mixed liquor solids as a control basis in lieu of the total suspended solids, only one operator having an overloaded plant serving a combined sewer system indicating the use of volatile solids as a control.

Rate of Returning Sludge

The return of settled activated sludge from the final settling tanks to the aeration tanks serves to maintain the necessary solids concentration in the mixed liquor, and keeps the activated sludge in a usable condition. Sludge which remains in the final tanks too long will become septic and, upon its return to the aeration tanks, will exert a high oxygen demand, will not perform its purification functions effectively, and may readily cause a complete plant upset. Too low a rate of return may result in a septic return sludge; conversely, too high a rate of return may presumably cause difficulty in disposing of the excess sludge, due to the larger volume which would have to be wasted of the resulting dilute sludge in order to maintain the mixed liquor solids at the desired concentration.

Walker (American Well Works), in the lecture notes previously quoted, listed the following causes of a septic return sludge:

"1. The return pumping rate is not great enough and a blanket forms on the floor of the final tank, causing the activated sludge to be out of aeration too long.

2. Faulty, slow or inefficient sludge conveying mechanisms in the final tanks.

3. Bad draw-off hydraulics causing 'holes' to be pulled in the hoppers and leaving the sludge behind.

4. Final tank units too large, making expeditious movement of settled sludge impossible.

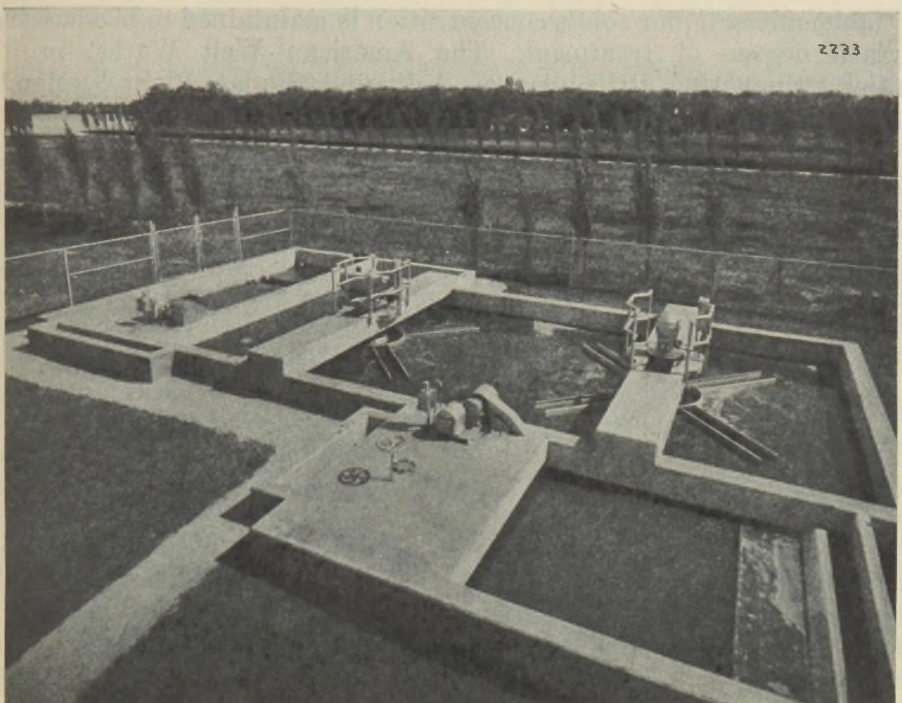


Fig. 2.—American mechanical aerator installation at McHenry, Illinois. Primary settling tank in foreground.

5. Not enough activated sludge available to treat the organic matter fed to it.

6. Too much dense primary solid matter enmeshed in the activated sludge.

"Where return activated sludge is septic and reaeration is impossible, either increasing the aeration at the head end, or returning sludge at a number of points along the line of flow may prove helpful."

The rates of return sludge practiced in the plants contributing to this summary, together with the return sludge suspended solids data, are tabulated in Table II. Of the 24 plants indicating their return sludge rate, 12 employ rates between 20 and 30 per cent, 8 employ rates between 30 and 50 per cent, one employes a rate of 61 per cent, and only 3 employ rates under 20 per cent. The data on the range of the return sludge rate indicate a considerable variation in the return sludge rate at a number of plants. Sludge return rates for the combination aerator-clarifier plants are not given, as the automatic return of sludge is a feature of that design.

The operation bulletin of the Chicago Pump Company suggests that the rate of returning sludge should be at 20 to 25 per cent of the sewage flow, and warning is given against allowing the sludge to become septic at any point. Yeomans Brothers suggests a return sludge rate of 15 to 20 per cent, indicating it may be less than that, but they do not recommend a rate in excess of 20 per cent. Yeomans further suggests that the best rate of sludge return be determined by test so that the optimum mixed liquor solids concentration is maintained to produce the highest degree of treatment. The American Well Works, in its leaflet "Suggested Principles of Activated Sludge Plant Design," states with regard to return sludge rates:

> "Activated sludge should be kept in the aeration tanks where it belongs. Most plants require a return sludge capacity of 50 per cent or over of the average flow, and some as high as 200 per cent. Generally, the smaller the plant, the greater the per cent of return activated sludge. We recommend 50 per cent to 75 per cent at large plants and 100 per cent *or greater* for smaller plants. Return activated sludge pumpage requires energy, but usually a greater return will result in a saving of aeration energy required to aerate a partially stale return sludge. Therefore, an overall saving in 'power' will be effected and the plant will run more smoothly."

A study of the return sludge suspended solids data does not reveal any definite relationship between the concentration of return sludge and the rate of sludge return. Variations in sampling methods may explain this seeming inconsistency. It is generally expected that lower solids concentrations will result from higher return sludge rates.

Of the plants commenting upon the maintenance of a sludge blanket in the final settling tanks, 14 plants do not maintain a blanket, but 7 plants indicated that a sludge blanket is maintained. In the latter cases, the depth of sludge blanket maintained was not indicated. The general tendency is to minimize the accumulation of a sludge blanket as much as possible, and it may also be stated that limitations in the sludge return facilities at some plants make it necessary to maintain a blanket. Some plants do maintain some sludge blanket so that this sludge will be available for shock loads, however, that practice was not referred to specifically by any of the plants contributing to this summary.

Application of Air

In diffused air activated sludge plant operation, the air must serve both as a mixing agent and to maintain the aerobic conditions required for effective operation. In a mechanical activated sludge plant, the air serves to satisfy the oxygen requirements of the activated sludge-sewage mixture and to maintain aerobic conditions, the mixing being accomplished by the mechanical aerator as it circulates the contents of the aeration tank. It is by means of this mechanical circulation that the conditions requisite to the entrainment of air in the mixed liquor are obtained. In a mechanical activated sludge plant the total quantity of air available is governed by the number of aerators in use and by the basic oxygenation capacity of the aerators, which is somewhat variable by means of adjustment of the equipment. Certain of the Yeomans Brothers-Simplex aerators are equipped so that the amount of air applied can be varied by a simple adjustment of the speed of rotation of the aerator cone. Speed regulation from 30 per cent below to 30 per cent above normal speed is commonly provided. The aerators of the Chicago Pump Company are rated at about 6 p.p.m. of oxygen supplied to the entire tank contents per tank turnover, the number of tank turnovers per hour determining the basic oxygenation capacity

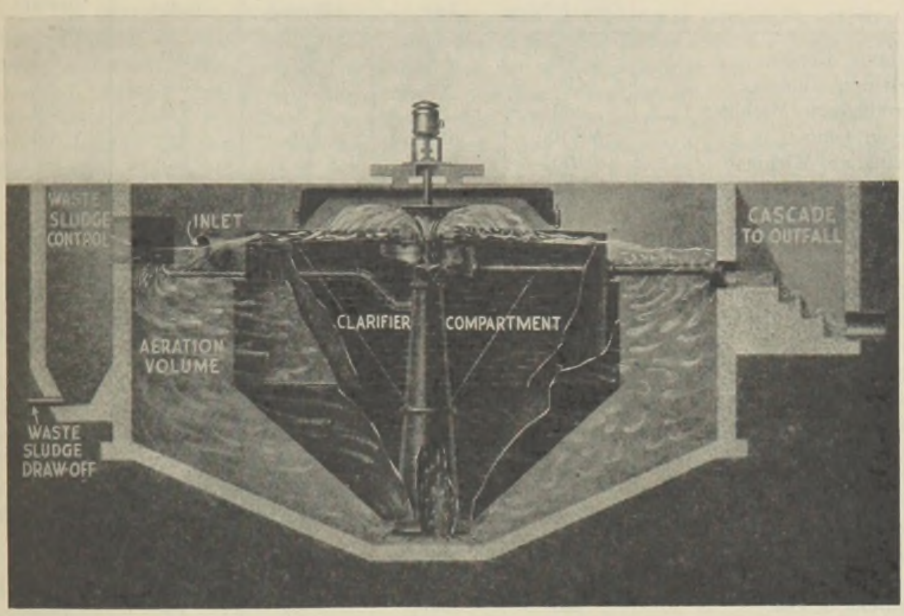


FIG. 3.—Sectional view of Chicago Combination Aerator-Clarifier.

rating. In an existing installation, the oxygenation capacity of Chicago aerators can be increased about 25 per cent by increasing the aeration propeller size, and about 150 per cent by increasing both propeller and motor sizes, according to their Bulletin 128-L. The American Well Works aerators are of the injector plate and mixing well type, or of the type equipped solely with air intake tubes. In the well type, the water level in the well can be regulated by adjusting the openings in the injector plate, which also regulates the air input. In the air tube type, the quantity of air applied can be readily adjusted by opening or closing the orifice unit on the air intake tubes.

For flexibility and economy of operation, the majority of mechanical activated sludge plants are equipped with time-clock control for the aerators which, by means of a simple adjustment, allows any desired operation-rest cycle during each cycle of the clock. The clock cycle is usually 15 or 20 minutes. The sewage strength at the majority of plants varies considerably, and for that reason it would not be economical to operate the aerators continuously at the same rate required for strong sewage at those times when a dilute sewage is received for treatment. In adjusting the time-clock control for the aerators the operator is nearly always guided by the dissolved oxygen content of the mixed liquor, most operators attempting to maintain a definite oxygen threshold before resorting to time-clock control.

TABLE III.—*Aerator Operation and Dissolved Oxygen Control*

Plant	Average Operation of Aerators, Per Cent of Time	Mixed Liquor D.O. (P.P.M.)			Final Effluent D.O. (P.P.M.)
		Inlet	Midpoint	Outlet	
Batavia, Illinois	76	1.0	2.5	5.0	3.2
Belvidere, Illinois	(1)	—	—	3.4	5.1
Birmingham, Michigan	50	—	—	4.0	2.0
Bryan, Ohio	50–100	0.1	2.0	3+	1.3
Buchanan, Michigan	100	—	—	5.5	—
Bucyrus, Ohio	85	—	—	—	5.6
Carlstrom Field	90	2.1	2.1	2.1	3.7
Coldwater, Michigan	90	—	—	6.0	5.0
Crystal Lake, Ill.	85	—	—	—	3.0
Dorr Field	90	2.7	—	—	2.9
East Lansing, Mich.	50–100	2.2	3.5	5.2	4.6
Elmhurst, Illinois	100	—	—	3.0	6.0
Ferguson, Mo.	65	—	—	4.5	5.0
Geneva, Illinois	100	0.2	2.2	3.0	4.6
Great Lakes, Ill.	80	2.0	—	1.5	0.2
Greece, New York	100	—	—	4.4	2.6
Illinois Ordnance	40	2.0	3–4	4–5	6.0
Kewanee, Illinois	77	—	—	—	2.7
Knightstown, Ind.	100	—	—	—	6.0
Ladd, Illinois	50	4.0	4–5	6.2	6.0
Lambert Field	62	—	—	3.0	2.0
Laurens, S. Car.	100	3.5	—	4.0	2.5
Milton Junction, Wisc.	75	—	—	2.0	0.4–1.0
Radnor—Haverford, Pa.	100	1.7	2.8	5.0	4.6
Riddle Field	70	—	1.8	—	4.4
Rochelle, Illinois	100	1.8	4.0	6.6	4.1
Stevens Point, Wisc.	66	—	—	0.3	0.8
Waterloo, Illinois	95	3–4	4.1	4.9	4.7
Willow Run	100	2.7	2.3	3.7	1.7

(1) Operated according to oxygen demand curve.

Table III indicates the average per cent of time that the aerators are in operation at the various plants, and also indicates average dissolved oxygen values in the mixed liquor at the inlet, mid-point and outlet of the aeration tank battery.

Decker (Bryan, Ohio) attempts to maintain 0.5 to 1.0 p.p.m. as a minimum dissolved oxygen concentration in regulating his time-clock control of aeration. Olson (Batavia, Illinois) has the last four of his six operating aerators on time-clock control, and he attempts to maintain a D.O. of 4.0 p.p.m. in the final aerator to meet shock loads of milk wastes. Grinnell (Birmingham, Michigan) operates his aerators to maintain a minimum D.O. of about 2.0 p.p.m. in the final effluent, which gives an average of 4.0 p.p.m. in the final aerator. The sewage at Birmingham is quite weak, and although 2,600 p.p.m. of mixed liquor suspended solids are carried at times, the operation of the aerators 50 per cent of the time has proved adequate.

Lamb, at Belvidere, Illinois, made some rather extensive oxygen demand studies by means of the Odeeometer and determined a typical oxygen demand curve for the conditions encountered at Belvidere. He states:

"The curve shows that at Belvidere large amounts of air are needed to satisfy the demand during the first 15 minutes of aeration period, and that at least a 7-hour aeration period is needed. By operating aeration units in accordance with this curve, we have obtained excellent operation with economy. Before operating in accordance with this curve, tests showed that there was considerable variation in the oxygen demand of the return sludge. On many occasions this demand was considerably higher than could be furnished by the aeration units.

"Tests taken after operating in accordance with the oxygen demand curve show that operation by this method eliminates excessive oxygen demand of the return sludge, and keeps the demand down where the aerators can meet it.

"The economy of operation is attested by the fact that power consumption has been reduced from a previous figure of 0.371 kw. hrs. per lb. B.O.D. removed in 1938 to 0.293 in 1939, 0.281 in 1940, and 0.257 in 1941.

"Aerators are cut in and out of service and time-clock operation used in order to meet the changing oxygen demand brought about by changes in either the volume or strength of the sewage." (Note: A complete description of the experimental work done by Lamb, and its interpretation in plant operation, is given in his thesis, "The Operation of an Activated Sludge Sewage Treatment Works With Special Reference to the Treatment of Cannery Wastes and the Oxygen Demand of Sewage and Activated Sludge Mixtures," University of Illinois Graduate School, 1940.)

Lamb further states that dissolved oxygen tests are made twice daily on the mixed liquor in the final aerators in each of the three batteries, and a low D.O. in the evening followed by a substantial recovery the next morning indicates economical operation in accordance with the oxygen demand curve.

Howe (Illinois Ordnance Plant) operates the aerators a sufficient time to produce an effluent in which the dissolved oxygen content is as great or greater than the B.O.D. of the same effluent. The Illinois Ordnance Plant is operating considerably below the design flow, and as a result the lift stations operate at irregular intervals causing the sewage flow to be received more or less as shock loads. Due to the long aeration period available, however, operation of the aerators during 40 per cent of a time-clock cycle has proved adequate to maintain a high degree of treatment. Patriarche (East Lansing) finds that as long as a slight amount of dissolved oxygen can be maintained in the return sludge, his plant is operating satisfactorily. A dilute sewage during the spring months makes 50 per cent time-clock operation of the aerators adequate, but nearly 100 per cent operation is considered necessary during the summer. An average D.O. of 5.2 p.p.m. is maintained in the final aerator. Patriarche states that a tapered aeration schedule has been tried, but that better results are obtained by operating all aerators the same percentage of time.

Denise (Greece, New York) indicates that about 2.2 hours preaeration of the primary effluent is standard operation, the sewage leaving the preaerator having a D.O. of 1.5 to 3.0 p.p.m. One hundred per cent operation of the aerators maintains a minimum of 4.0 p.p.m. D. O. in the final aerator. Tanari (Ladd, Illinois) indicates that from 4.0 to 6.0 p.p.m. D.O. seems to be necessary to prevent bulking, which is probably caused by milk wastes. Wolf (Waterloo, Illinois) attempts to maintain at least 3.0 p.p.m. of dissolved oxygen before resorting to time-clock control, as does Tompkins at the Michigan State Home. Tompkins has one time-clock for controlling the last two of the three aerators, the first aerator being run 100 per cent of the time. Lt. Comdr. Klay (Lambert Field) indicates that an average D.O. of 3.0 p.p.m. is maintained in the final aerator. Fischer (Kewanee, Illinois) has operated on a tapered aeration schedule, operating 4 aerators 100 per cent, 4 at 75 per cent, and 4 at 50 per cent of the time. Lovejoy (Laurens, S. Car.) indicates that his plant was designed for tapered aeration, consequently all aerators are run continuously.

Miller, at Great Lakes, operates the mechanical aerators 80 per cent of each clock cycle. Due to the exceptionally strong sewage at Great Lakes it was found necessary to supplement the mechanical aeration with diffused air at approximately 1 cu. ft. per gallon, equivalent to about 490 cu. ft. per pound of B.O.D. removed. The supplemental diffused air system was designed for tapered aeration. Dulmage (Willow Run Bomber Plant) indicates that 100 per cent operation of the aerators has been necessary to maintain sufficient dissolved oxygen in the aeration tanks.

Operation Bulletin No. 1165, of the Chicago Pump Co., suggests that there should be at least 3.0 p.p.m. of dissolved oxygen in the mixed liquor in each aerator that is placed on time control. Walker (American Well Works) suggests that, under normal plant operation, a positive trace of dissolved oxygen in all parts of the aeration tanks at all times is sufficient to maintain aerobic conditions. He indicates that in some plants it is necessary normally to carry 1 to 3 p.p.m. so as to assure the return of a fresh sludge to the aeration tanks.

Several operators referred to the need for building up dissolved oxygen in the mixed liquor to meet shock loads.

Aeration Period

Stronger sewages require longer aeration periods in order to obtain a high degree of treatment, although some adjustment can be made by varying the mixed liquor solids within the limits of the air supply. Adjustments in the aeration period are made by placing aeration tanks in or out of service.

Table I lists the average aeration periods for the contributing plants. A wide variation in available plant capacity is indicated. In studying the aeration periods and sewage strengths indicated, it is not surprising that a considerable variation in operation control practices exists.

At six of the plants reporting, aeration periods between 3 and 6 hours are indicated; at six plants, aeration periods in the 6 to 9 hour range are reported; at six plants, aeration periods are in the 9 to 12 hour range. The remaining plants have aeration periods in excess of 12 hours. One plant, which is a combination aerator-clarifier plant

FIG. 4.—A complete laboratory in the mechanical aeration activated sludge plant at Geneva, Illinois.

operating far below capacity, actually has a 42-hour aeration period. Carothers, at that plant (Riddle Field, Clewiston, Fla.), indicates some difficulty with rising sludge in the final tank due to overaeration.

Few of the plants included in this review indicated that the aeration period is used as an operation control. Lamb (Belvidere) does place aeration tanks in and out of service as required by the sewage flow and strength, as does Freeman (Geneva). Denise (Greece) used 4 or 5 of the available 8 aeration tanks during 1943 to maintain an average aeration period of 8.8 hours.

None of the plants indicated that reaeration of return sludge is practiced, although Decker (Bryan) suggested that some aeration of return sludge is effected in his plant by the unusual design, which provides a seven foot fall from the return sludge draw-off pipe, and two additional cataracts of five feet from the sludge division box.

Normally, plants having adequate aeration periods have less difficulty maintaining a well conditioned activated sludge and, therefore, are less affected by shock loads than plants which must operate with a low aeration period, low to the extent that it must be compensated for by carrying higher mixed liquor solids.

Condition of the Sludge

The operator is constantly guided by the condition of the activated sludge in controlling the operation variables, and the maintenance of a well conditioned sludge reflects the success of the operation procedures, although at times the activated sludge assumes characteristics which can be controlled with extreme difficulty if at all. In determining the condition of the activated sludge, the operator is most commonly guided by some or all of the following observations:

1. Physical appearance, both in the aeration tank and in the laboratory, and odor.
2. Settling characteristics, and sludge index.
3. Microscopic examination.
4. Sludge activity, often referred to as oxygen demand, as determined by the Odeeometer or by direct chemical methods.

Appearance and Odor.—A well conditioned activated sludge is usually golden to moderate brown in color, has a pronounced, spicy (sometimes described as earthy) odor, and, upon becoming septic, assumes a sour odor and a gray to black color. A sample of a well conditioned activated sludge, when allowed to settle in a graduate, will usually become gas lifted to the surface in a few hours.

A well conditioned activated sludge, when placed in a glass cylinder, will quickly form itself into clearly defined flocs and then settle readily. As the sludge mass begins to settle, an upward movement of some flocs within the settling sludge mass is usually apparent as other flocs subside.

An experienced operator can usually determine from the appearance of the mixed liquor in the aeration tanks, to some extent at least, whether a well conditioned sludge is being maintained. In that regard, the Operation Bulletin of the American Well Works suggests:

> "Another way of judging the condition of the aeration tank is to notice if the tank has a lively, active look while the air diffusion unit is running. Foam should be plentiful and white, and an active bubble pattern should form. When the machine is stopped, the sludge should rapidly crease and form furls. These furls should keep constantly changing and moving. If the sludge is in poor condition, the tank will have a dead look while the machine is running. There will be little or no foam present and the color of the sludge will change from brown to a pasty gray. When the machine is stopped the sludge will lay with an even surface and there will be no immediate creasing and furling."

Settling Characteristics and Sludge Index.—The success of activated sludge plant operation depends largely upon maintaining the settleability of the activated sludge since the ready separation of the liquid and the sludge in the final sedimentation units is the final prerequisite to the production of a good effluent. Disregarding activated sludges affected by industrial wastes, thirty-minute settleable solids in the 10 to 20 per cent range are most common. Values above and below that range are also quite common, as the data in Table II would indicate.

The sludge index (Mohlman), commonly defined as the volume in milliliters occupied by one gram of sludge after thirty minutes settling, is an expression of the density of the activated sludge and is found to be a helpful guide in plant operation. A rising sludge index may indicate underaeration, an overload, or a bulking tendency. The wide variation in average sludge index among the plants contributing to this summary, as listed in Table II, is most interesting and indicates the importance of determining the optimum operating range for any given plant. An index attendant to normal operation at one plant may only occur during impending or actual bulking at another plant.

Microscopic Examination.—The use of the microscope in observing activated sludge condition is reported by five plants. Longley (Radnor-Haverford) reports weekly observations to check for *Sphaerotilus natans.* Miller (Great Lakes) makes daily microscopic examinations of mixed liquor and return sludge to check for *Sphaerotilus* and to observe the activity and types of organisms. Dulmage (Willow Run Bomber Plant) uses the microscope to check the general appearance of the sludge as a parameter of sludge condition. Occasional observations are made at Kewanee, Illinois, and at least weekly at Michigan State Home.

Sludge Activity.—The oxygen utilization rate of the sludge in p.p.m. per hour, commonly referred to as sludge activity or oxygen demand, as determined by the Odeeometer or by direct chemical methods, is not utilized in most mechanical activated sludge plants. Of the plants included in this review, only Lamb at Belvidere has made use of extensive oxygen demand studies in plant operation, as previously recounted in this review.

Operation Problems

Bulking of Activated Sludge.—Nearly every activated sludge plant has at some time experienced a bulking condition of the activated sludge which is characterized by the loss of sludge settleability to such an extent that natural tank currents carry the sludge over the weirs. Bulking tendencies naturally occur with varying severity, and bulking may follow any condition from a mild expansion of the activated sludge to one in which there is little or no settlement of the sludge. Whether or not bulking will occur with any given degree of loss of sludge settleability will depend upon final settling tank flow velocities. At some plants, overloaded as to flow rate, a loss of solids occurs which is the direct result of excessive overflow rates in final sedimentation units. This condition simulates bulking but is not related to activated sludge condition.

Of the plants represented here, eight reported little or no trouble, two gave no reply, and the remainder indicated bulking difficulties with summarized causes as follows:

1. Shock loads from industrial wastes reportedly account for bulking at eight plants. Milk wastes and wastes containing excessive grease content were the major reported causes of bulking attributed to industrial wastes. The plant at Laurens, S. Car., reports bulking due to shock loads of starch and dye wastes from a textile industry. An unusual cause is that at Bryan, Ohio, reported by Decker as due to fine cork particles from a bottle cap salvage plant. The cork reduces activated sludge settleability, at times resulting in a sludge which contains 96 per cent settleable solids after thirty minutes. The sludge appears normal in every other way. Although not reported by any of the plants represented here, it is known that bulking can also be caused by toxic wastes from the metal industry or other sources, and by wastes high in organic content, such as those from packinghouses, breweries, canneries, and a host of others.

2. Septic sewage was listed as a cause of bulking at five plants, three of which indicated this difficulty usually follows a rain which flushes accumulated septic sewage solids from combined sewers. Difficulty with the carryover of waste activated sludge back to the aeration tanks was listed as a cause of bulking at several plants. Bulking sometimes follows the discharge of heavy supernatant liquor to the raw sewage at a number of plants.

3. The loss of operation balance was referred to by Bradley (Buchanan) and Patriarche (East Lansing) as basic causes of bulking. Patriarche specifically referred to bulking as resulting from too high or too low mixed liquor solids. Inadequate aeration might also be a cause.

4. It is common for overloaded plants to experience chronic bulking which defies the usual remedies. In cases of consistent organic overloading, unless the cause lends itself to ready reduction through pretreatment or other practices, plant expansion is usually indicated for chronic bulking elimination.

5. High pH in the mixed liquor was attributed by Carothers (Riddle Aeronautical Institute) as a cause of bulking at a plant serving a military camp having a lime-softened water supply.

Continuous, careful attention to the operation variables will prevent many cases of bulking, as will the exercise of careful and intelligent control over industrial wastes discharged to the sewers. Requiring industry to provide pretreatment of troublesome wastes, removal of toxic wastes, and/or flow equilization equipment to assure more uniform rates of discharge to the sewers often will minimize industrial wastes influences. If shock loads are a known cause of bulking, and if the loads are of such intensity that compensation or adjustment of operation variables may prevent or minimize some such cases of bulking, then it is obviously advantageous to learn to recognize promptly the receipt of a shock load so that preventive adjustments in operation may be made immediately. Air application and return sludge rate are commonly increased to meet shock loads. Either or both visual observations and analytical determinations may serve to indicate receipt of shock loads, depending upon the nature of the wastes involved.

A common practice among operators upon the first evidence of bulking is to increase the application of air and the return sludge rate. If possible, reducing the load applied to the aeration tanks is a helpful adjunct since the intensity of loading is normally closely associated with bulking tendencies. Dick (Elmhurst, Ill.) indicates bulking control by increasing rate of return sludge and sludge wastage (probably applied after bulking is in progress).

Chlorination of the return sludge is utilized at Great Lakes, Batavia, Bucyrus, and Radnor-Haverford as a remedy for bulking. Miller (Great Lakes) begins chlorination of the return sludge at the first evidence of impending bulking, a dosage of about 4 p.p.m., based on raw sewage flow, being utilized. Longley (Radnor-Haverford) indicates that bulking occurs frequently, but reports excellent control by chlorination of the return sludge at a dosage of 10 p.p.m., based on the return sludge flow.

Olson (Batavia) reports varied success in bulking control with the use of copper sulfate, and Todd (Milton Junction, Wisc.) reports some success with the use of lime. Patriarche (East Lansing) controls bulking by the careful discharge of heavy supernatant liquor (20,000 to 40,000 p.p.m. suspended solids) direct to the aerators, at the same time increasing the application of air, if possible. This method is used at the first signs of bulking as a preventive measure rather than a cure, and Patriarche reports that, if done carefully, it has always been very effective. A well conditioned activated sludge is usually restored, at East Lansing, by this method in about two days. Patriarche cautions that the mixed liquor solids concentration must be carefully watched.

Denise (Greece, N. Y.) reports that no bulking has occurred there since the practice of aerating the primary effluent prior to adding the return activated sludge was established. An average aeration period of 2.2 hours is utilized for that purpose, and the primary effluent contains 1.5 to 3 p.p.m. of dissolved oxygen when the return activated sludge is added. This procedure freshens the sewage and reduces its oxygen demand, and is most helpful in cases where a septic sewage is received. Preaeration before primary sedimentation of a septic sewage would probably be of greater overall benefit, however, few plants are so equipped.

Carothers (Riddle Aeronautical Institute) indicates that bulking was attributed to too high a pH in the sewage at a military camp in Florida. He indicates that this pH is lowered in the primary tanks from 9.5 to 7.8–8.1 by merely stopping sludge pumping from those tanks, the drop in pH being attributed to the bubbling of the CO_2 gas, formed in the settled sludge, through the sewage flowing through the primary tanks. He indicates a content of 15 to 20 p.p.m. free carbon dioxide in the primary effluent. The sludge is skimmed off and pumped to the digester as soon as it is gas-lifted to the surface. The problem at this plant is an unusual one, and the operation procedures indicated by Carothers are unusual and certainly unorthodox. An unusual combination of circumstances must exist to permit the successful use of the practices described by him, and high prevailing temperatures may be a factor. Primary tank efficiencies at Dorr and Carlstrom Fields are low, as would be expected as the result of the practices described by Carothers, however, it should be observed that available aeration periods are very long.

To restore the condition of a bulked activated sludge, common practice is to waste all or part of the bulky sludge, the amount wasted usually depending upon whether or not sludge wasting and disposal facilities are limited. Denise (Greece) reports that prior to the utilization of preaeration of the primary effluent, when bulking occurred it was controlled by wasting down to 400 p.p.m. suspended solids in the mixed liquor and building up again to the normal concentration.

Rising Sludge in Final Clarifiers.—Rising sludge, a condition in which large masses or clouds of sludge rise to the surface of the final settling tanks, is attributed to a number of causes by the operators contributing to this summary.

Rising sludge attributed to overaeration occurs at Waterloo, Dorr Field, Riddle Field, Laurens and Rochelle. At the latter two plants the rising sludge condition follows a drop in the industrial wastes load, and Lovejoy, at Laurens, wastes sludge as a control measure. This condition is rather common at plants handling fluctuating industrial wastes loads, and it may occur at any plant when the load falls off considerably. Decreasing air application and reducing mixed liquor solids may prove helpful, however, when reducing mixed liquor solids it should be borne in mind that the heavier loadings can be anticipated to return. It is difficult, and often impracticable, to adjust mixed liquor solids to load variations closely enough to prevent some degree of rising sludge from developing. The rising sludge condition which sometimes occurs when nitrification is high is commonly attributed to the reduction of nitrates in the sludge, the liberated nitrogen bubbles buoying the sludge masses to the surface. High nitrification commonly accompanies overaeration of the sludge, as does the presence of pin point floc in the plant effluent.

A condition, termed as rising sludge by the operators, occurs during the peak flows at Bryan, Batavia, Birmingham, Belvidere and Willow Run. This condition is probably closely associated with overflow rates and final settling tank velocities. Decker (Bryan) controls this condition by checking the sewage flow and backing up sewage in the outfall sewer during the peak flow. Lamb (Belvidere) indicates some success by increasing the return sludge rate. Dulmage, at Willow Run, has had some success in controlling this condition by discharging filtrate from the sludge filter into the inlet channel of the final settling tanks.

Septic conditions in the final settling tank sludge blanket will often result in the rising of masses of sludge to the surface. This was specifically referred to by Todd (Milton Junction), and is a basic reason why the majority of plants do not maintain a sludge blanket. This condition might occur if the final tank sludge collection mechanism was improperly installed or has been damaged.

Grease and Oil.—The receipt of undue quantities of grease or oil can seriously affect activated sludge plant operation. Six of the plants contributing to this review indicated some operation difficulty from oil or grease.

Grease may affect operation by acting as an organic overload, or by directly damaging the activated sludge into which it is readily absorbed. Impregnation with grease seems to reduce the oxygen absorbing powers of activated sludge, thus limiting the oxidizing capacity of the sludge which is reflected in the final effluent quality. This effect may be more pronounced when oil is received in quantity.

In lecture notes previously referred to, Walker (American Well Works) stated with reference to grease:

> "Grease passing into the aeration tanks will be readily adsorbed by activated sludge. This adsorption is accumulative since the activated sludge cannot rapidly convert the grease adsorbed. Very soon (depending on the amount of grease and the amount of activated sludge) the activated sludge becomes composed of one-half or more of grease, and goes septic and useless, even though completely aerobic conditions surround the floc. This is a case of putrefaction going on internally in the sludge floc even while a residual of dissolved oxygen exists in the surrounding liquor.
>
> "When the activated sludge has adsorbed too much grease, it loses its spicy odor and other activated sludge characteristics. It will turn to a light gray or black color and will refuse to settle well in the final settling tank. The effluent will develop a suspended turbidity which will be obvious in the clarity test. This increase in turbidity (diminishing final clarity) generally precedes the poor settling condition and is nearly always a good danger flag to the operator that all is not well."

Primary sludges or activated sludges high in grease content usually do not concentrate well, resulting in a digester operation problem at some plants. In addition to other effects, the pumping of a thin sludge to the digester results in a correspondingly larger quantity of supernatant liquor, which often creates a difficult disposal problem.

Waste Activated Sludge Disposal.—Of the plants contributing to this summary, eleven reported difficulty with waste activated sludge disposal, nine reported no difficulty, and the remainder indicated the method of disposal without further comment.

The most common method of handling waste activated sludge is to discharge it to the raw sewage so that the waste solids can be removed to the digester, along with the primary solids, after concentration in the primary settling tanks. That the method is not always satisfactory, however, is attested by the fact that of twenty plants utilizing it, eleven indicated that difficulties are encountered, and several others indicated that it must be practiced with care.

Failure of the waste activated sludge to settle out in the primary tanks during peak flows, thus imposing a recirculating load on the aeration tanks, was indicated at East Lansing, Lambert Field and Radnor-Haverford. Olson (Batavia) indicates that difficulty is most pronounced at times when a septic raw sewage is received. Browne (Bucyrus) indicates the waste sludge does not settle readily in the primary tanks when it contains appreciable grease and during the dry weather months (probably associated with the high volatile solids commonly prevalent during such periods). Dulmage (Willow Run) wastes activated sludge continuously to the primary tanks, and adds milk of lime to the waste sludge at times to prevent its carryover into the aeration tanks. Enough lime is added to raise the pH of the waste sludge to a maximum of 9.0, and the method has met with some success. Wolf (Waterloo) and Krueger (Ferguson) refer to the necessity for frequent pumping of the raw-waste sludge mixture from the primary tanks. Failure to do so often results in septicity of the sludge mixture, accompanied by rising sludge masses in the primary tanks. Several operators referred to the importance of wasting activated sludge at a low, uniform rate, particularly if primary sedimentation periods are low. Lamb (Belvidere) wastes sludge during the night when the sewage flow rate is low. Decker (Bryan) wastes sludge to the primary tanks continuously at a low rate and he indicates that, although a rather dilute mixed sludge results, less difficulty is encountered than when a concentration box was used for the waste sludge. Denise (Greece) indicates that the raw-waste sludge mixture is usually not well concentrated when pumped to storage or thickener tanks prior to vacuum filtration and incineration. Howe (Illinois Ordnance) indicates that waste activated sludge is pumped to a concentration well and thence to the digester. This practice is unusually successful at that plant, as indicated by the 3 to 4 per cent sludges reported to obtain. Activated sludge wasting through primary settling tanks is often a problem when the sludge indicates a bulking tendency, or is actively bulking, as the waste sludge may not settle, thus imposing a recirculating load on the aeration tanks. This condition may greatly hamper efforts to restore activated sludge condition, since common practice is to increase greatly activated sludge wasting when bulking is out of control. Difficulties arise with nearly all methods of waste activated sludge disposal when bulking occurs.

Chironomus Larvae.—Although most of the plants contributing to this summary indicated that the *chironomus* fly larvae, more commonly called the bloodworm, have not been a problem, three of the plants reported that the larvae have caused interference with operation. At Michigan State Home, Tompkins reports the blood worms constitute his most troublesome operation problem, and on occasion they have completely halted plant operation.

The larvae of the *chironomus* fly are bright red worms, commonly reaching lengths of one-half to one inch. The average life cycle of the fly is reportedly about five weeks, and under favorable conditions they multiply rapidly. The larvae surround themselves with sheltering cocoons of whatever material is available, and when activated sludge plants are infested the cocoon is formed of the activated sludge. The cocoons of sludge commonly adhere to tank walls for a while, then break loose and float on the final settling tank surface. The cocoons may break up and result in the formation of a thin layer of sludge on the tank surface. The heavy infestation of a plant may result in a serious loss of activated sludge, and in some plants the sludge has virtually disappeared overnight.

Tompkins (Mich. State Home) indicates screens have been placed over channels and quiescent portions of the final settling tanks to keep the flies out. He also indicates some benefit by maintaining a film of oil wherever possible. Denise (Greece) reported that difficulty with *chironomus* larvae was experienced during initial operation, and the only successful control was to clean out the entire plant and start over.

Pyrethrum, copper sulfate, and chlorine have been tried as control measures, usually with indifferent results. It is commonly conceded that dewatering and scrubbing infested tanks is the most effective control.

The *chironomus* larvae may be present in limited numbers without detrimentally affecting operation, however, they may readily develop into a major problem and their presence is always cause for concern.

Supernatant Liquor Disposal.—Probably the most common method of disposing of supernatant liquor is to return it to the raw sewage. This method of disposal is utilized at thirteen plants contributing to this review, with several of those plants indicating that alternate methods of disposal are available. Olson (Batavia) reports this method as ''a nasty practice and one difficult to control.'' Howe (Ill. Ordnance Plant) reports no difficulty when supernatant liquor is drawn slowly and carefully to the raw sewage. The supernatant liquor at Illinois Ordnance averages 800 to 1000 p.p.m. B.O.D., and only 110 p.p.m. suspended solids—a good supernatant at any plant. Tompkins (Mich. State Home) discharges a supernatant having an average of 619 p.p.m. suspended solids to the raw sewage without difficulty. A supernatant containing 661 p.p.m. suspended solids is similarly disposed of without difficulty by Dulmage at Willow Run. Freeman (Geneva) reports that a supernatant having an average B.O.D. of 610 p.p.m. and suspended solids of 1,730 p.p.m. is disposed of satisfactorily to the raw sewage if drawn slowly. Bulking results at Geneva if the supernatant liquor is drawn to the raw sewage at too high a rate.

Four plants reported disposal of supernatant liquor direct to the aeration tanks. Patriarche (East Lansing) refers to the necessity for carefully watching the mixed liquor solids concentration when utilizing that method of supernatant disposal. Considerable use is made of supernatant liquor at East Lansing to regulate and control the mixed liquor. This is interesting, particularly when considering that the supernatant liquor suspended solids average 25,000 p.p.m. Alternate disposal to the sludge drying beds is available. Fischer (Kewanee) draws supernatant liquor into an idle aeration tank for storage and then discharges it to an operating aeration unit at a controlled rate. He states that this method has not proved too satisfactory. Dulmage (Willow Run) draws supernatant either to the aeration tanks or to the raw sewage. He cautions that supernatant liquor disposal to the aeration tanks must be done with care. Browne (Bucyrus) indicates that when disposing of supernatant liquor to the aeration tanks, it is discharged at a low, continuous rate near the middle of an aeration tank battery. When supernatant liquor quality indicates it cannot be discharged direct to the aeration tanks at Bucyrus, it is discharged to a supernatant treatment tank equipped with an American Well aerator, this tank being operated on a fill-and-draw basis. The supernatant liquor is aerated, and coagulants and chlorine may be added if necessary. After this treatment, the settled sludge is returned to the digester and the clarified supernatant is withdrawn to the raw sewage. Browne reports very successful use of that treatment method.

A Pacific Flush Tank "atomizing" aeration-settling unit has been installed at Great Lakes for supernatant liquor treatment. Operating results were not yet available, as the installation was just completed and was undergoing minor adjustments when the questionnaires for this summary were distributed. Similar units at other plants have performed well, according to published data. Decker (Bryan) found it possible, through valve manipulations, to draw supernatant liquor into an idle flash mixing tank, where it is aerated and then discharged to the raw sewage during the night and low flow period. The supernatant liquor is drawn to the flash mixing tank at a slow rate.

At Belvidere, Indiana Soldiers and Sailors Children's Home, Dorr Field, Carlstrom Field, and Ferguson, supernatant liquor is disposed of by discharge to sludge drying beds. Lamb (Belvidere) reports this method of disposal proves satisfactory, but that the supernatant liquor dries slowly. Bradley (Buchanan) disposes of supernatant liquor to a lagoon, as does Russell at Rochelle. Lovejoy (Laurens) discharges supernatant liquor to the river.

Supernatant liquor disposal constitutes one of the most common operation problems, particularly in plants practicing its disposal to the raw sewage. At plants utilizing this method of disposal, it is a helpful precaution to provide an alternate method, such as a lagoon or drying bed, to be utilized when a poor quality supernatant is present. A poor quality supernatant liquor, if discharged to the raw sewage or to the aeration tanks, may result in a poorly settling activated sludge, which results in larger volumes of sludge for transfer to the digester, and thus in larger volumes of supernatant liquor for disposal. Whether a plant can handle supernatant liquor in the aeration tanks without pretreatment depends upon the degree of loading of those units, and upon the quality of the supernatant liquor.

OPERATION OF A MECHANICAL AERATION ACTIVATED SLUDGE PLANT *

By William D. Denise

Superintendent, Water and Sewer Departments, Greece, N. Y.

The Town of Greece is a residential community bordering on Lake Ontario northwest of the city of Rochester and adjacent thereto. The Town has a population of 15,000. The treatment plant serves the thickly populated suburban area and at the present time is treating the sewage from a population of 10,100. The plant was constructed in 1937 and placed in operation in July, 1938, serving a population of about 2,000 the first year. Gradually connections have been made until at the present time about 60 per cent of the houses are connected to the sewer system.

The system is composed of separate sewers and, as there are no industries in the district, the sewage is entirely domestic. The flows for the period of operation have ranged from 100,000 to 1,900,000 g.p.d. The average for 1943 was 599,000, maximum 1,300,000 and minimum 377,000 g.p.d. The average flow per capita is 66, maximum 118 and minimum 38 gallons per day.

The plant includes the following equipment and treatment devices: Two grit chambers; two primary sedimentation tanks of 26,600 gallons each, with sludge collecting mechanism; eight aeration tanks, each 27 feet square and 10 feet 4 inches below the water line and equipped with down draft mechanical aerators manufactured by the American Well Works; two circular final tanks 35 feet in diameter and 9 feet average depth; and two W. & T. chlorinators followed by a contact chamber and outfall line to the creek. Both of the final settling tanks (Fig. 1) were originally equipped with magnetite filter beds, but one of the beds has since been removed. The sludge disposal equipment consists of two thickener tanks, two 100 square foot rotary vacuum filters and a 15-ton per day incinerator.

Plant Operation

The grit chambers are cleaned on the average of once a month and last year the average grit removal was 8.4 cubic feet per million gallons. During 1943 both primary tanks were in operation; there are two reasons for this: first, because we have found that the equipment in the tank is kept in better condition while in operation, secondly, it gives a longer retention period for settling out the waste activated sludge. The average retention period was 1.95 hours, which is much too long, but we feel that under our conditions it gives better operation. The sewage entering the plant in the summer months is stale and septic regardless, so little damage is done in this respect.

* Presented at Spring Meeting of New York State Sewage Works Association, Syracuse, June 16–17, 1944.

After several years of operation and having had considerable trouble from bulking, it was thought that benefit might be derived from aerating the primary tank effluent before the addition of the return sludge, thereby freshening the aerator influent. This was started in July of 1942 and since then there has not been a single case of bulking as compared to 3 or 4 upsets yearly before. However, there were some other faults of design, construction and operation that were corrected

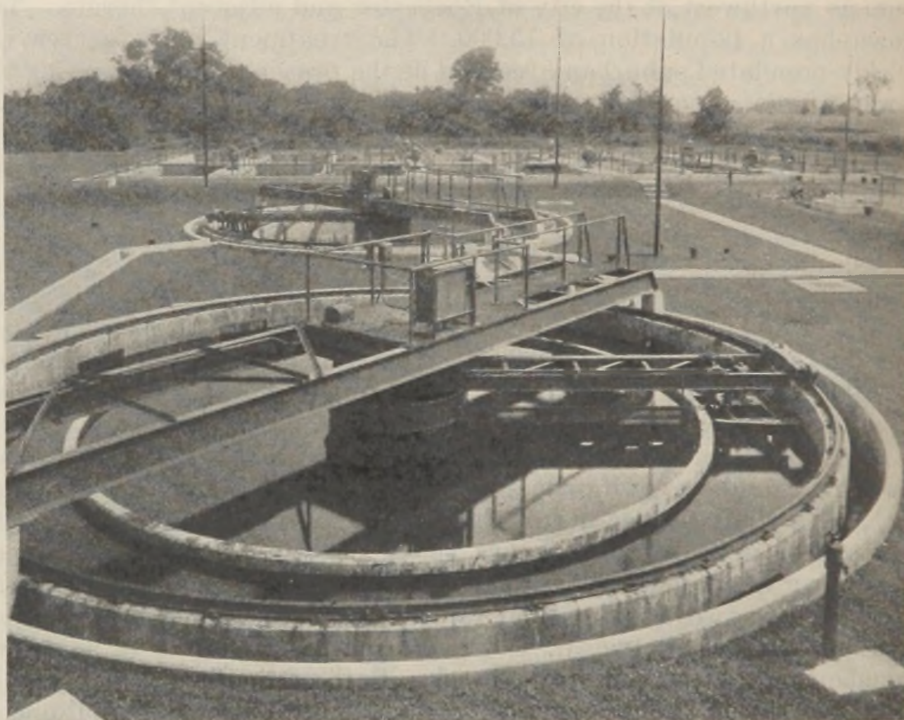


FIG. 1.—View of sewage treatment works at Greece, N. Y. Final sedimentation tanks (equipped with magnetite filters) in foreground. Mechanical aeration units at rear.

about the same time, some of which will be mentioned later, and probably these also have had something to do with the correction of former troubles. The aerating of settled sewage was continued until April of this year when it was discontinued so as to determine whether or not it is necessary. The return sludge is now being reaerated before its addition to the first aeration tank to ascertain if operation can be improved. If it does not considerably improve conditions, it will be discontinued; in other words, it is strictly an experiment.

About 1,100 p.p.m. solids are carried in the mixed liquor during the winter and about 900 p.p.m. during the summer months. Sludge that settles in a 1,000 ml. cylinder to around 20 per cent seems to be most desirable. None or a very little sludge blanket is carried in the final tanks, for it is believed that the place for the activated sludge is in the aeration tanks. Experimental blankets of various depths and concentrations have been tried but no benefit was obtained. When a heavy blanket is carried the sludge becomes septic and after being returned to the aeration tanks it requires considerable aeration to restore it to good condition. An average dissolved oxygen content of 4 p.p.m. in the mixed liquor is very desirable and appears quite necessary to good operation in this plant. The average aeration period during 1943 was 8.8 hours with 5 aeration tanks in service and the average B.O.D. of the final effluent was 17 p.p.m.

A word about the magnetite filters. The filters were of the up-flow type built in the final tanks. They were constructed in such a manner that the inner wall of the filter bed projected below the surface of the final tank to a depth of four feet. This left a tank depth below the filter bed wall of 5 feet, thereby cutting the effective volume of the tank by about 45 per cent, due to the fact that all of the tank effluent to be filtered was drawn from a point 4 feet below the surface. The filters, therefore, drew or swept the settled activated sludge from the lower portion of the tank, producing a much poorer effluent than if it had been taken from the surface. Permission for the removal of one of the filters was granted by the New York State Department of Health and the job was completed in June, 1942.

Following is a comparison of results for the years preceding and following removal of the filter. The average effluent B.O.D. after removal was 7 per cent lower, the maximum 47 per cent lower, the minimum 50 per cent higher. The average suspended solids after removal 39 per cent lower, the maximum 57 per cent lower and the minimum 30 per cent higher. This shows that at times the filters were effecting considerable removal. It was concluded that it is better to have a consistently good effluent than to have it excellent part of the time and then very poor at other times. The filters were installed as a protection to the stream during times of bulking but it has been proven that during these times the effluent was considerably worse than if it had been taken from the surface of the tanks. It is known that when activated sludge is settling properly a filter is unnecessary and it is the writer's contention that when bulking is taking place, no mechanical filter will satisfactorily remove the solids. Another objection to the installation is that considerable quantities of activated sludge became lodged under the filter beds and eventually returned to the aerators; it is believed that this condition had something to do with the bulking.

In conclusion, the experience in this plant proves that cleanliness in the treatment works is very essential, particularly in the activated sludge process. The channels, tank walls, and all other places where solids can lodge and become septic, should be flushed down. A practice is made of doing this job every day in the year. Sludge is drawn from the primary tanks twice daily in the warm months and daily in cold weather. All of these small items of operation, plus sound laboratory control, tend to make the plant operate satisfactorily.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Conducted by LeRoy W. Van Kleeck

ELEVENTH ANNUAL REPORT OF THE GREEN BAY METROPOLITAN SEWERAGE DISTRICT COMMISSION, GREEN BAY, WISCONSIN *

By George Martin, Superintendent

Sludge Prices

On March 18, the following schedule of prices for digested sewage sludge was adopted:

Lump sludge, 75 cents per cu. yd. (by truck or trailer).
Ground sludge, $1.50 per cu. yd. (by truck or trailer).
Ground sludge, 10 cents per cu. ft. (small containers furnished by customer).
Ground sludge, delivered, $2.75 per cu. yd. (1 yd. load).
Ground sludge, delivered, $2.25 per cu. yd. (2 or 3 yd. load).

Plant Heating

Again this year the entire treatment plant, including the digesters, was heated almost entirely by the gas engine cooling water. There were, however, a few times when it became necessary to draw on the auxiliary heating equipment which consumed 890,000 cu. ft. of gas (about 4 per cent of gas produced) and 46 tons of coal valued at $310.

Electric Power Generated by the Utilization of Sewage Sludge Gas

In the six years that the District's two Worthington sludge gas engine driven electric generators have been in operation, they have generated 3,596,437 kw. hr. of power that was used in the operation of the sewage treatment plant. This represents a value or gross saving of $71,928; however, in producing this power, there were expenses or operating costs as follows: Interest on gas engine units and power house of $4,365; insurance of $300; repairs and maintenance of $2,100; and lubricating oil of $1,535; all totaling $8,300. This leaves a net profit or saving of $63,628 on an investment of approximately $29,000. In figuring these profits, no labor was charged against the operation of these units—the reason being that the same number of men would be required whether gas engines were operated or not.

Realizing that the above method of computing net returns might be questioned, another set of accounts were kept wherein net returns were figured on the same basis as on those units owned by a private utility. (In the report a complete break-down by this method is pre-

* Report for 1939–40 extracted in *This Journal*, 13, 587 (May, 1941).

sented.) On the latter computation the net profit from June 1, 1937, to March 31, 1943, has been $34,395.67 or, based on a 55 per cent original cost to the District (the plant construction was a P.W.A. project), the net profit for this period has been $45,129.55. This shows that, based on the District's investment, the units had paid for themselves by March 31, 1942, at which time the depreciated value of the units was $35,015 whereas the total net return amounted to $36,058. Based on the total cost of the units they should be paid for during the fiscal year ending March 31, 1946.

Cost of Operation

The operating expense of the treatment plant for the fiscal year ending March 31, 1943, was $36,624.67. Following is a summary of operating data for the year:

Summary of Operating Data at Green Bay, Wisconsin, April 1, 1942–March 31, 1943

Item	Average
Sewage flow, ave. daily, m.g.	7.76
Kw. hrs. produced, ave. daily	1,907.0
Kw. hrs. consumed, ave. daily *	2,293.0
Chlorine, p.p.m., ave. daily	9.2
Chlorine, p.p.m., max. daily	15.1
Screenings	
Ave. daily, cu. ft.	14.1
Max. daily, cu. ft.	139.0
Ave. daily, cu. ft. per m.g.	2.0
Max. daily, cu. ft. per m.g.	3.7
Grit	
Ave. daily, cu. ft.	51.8
Max. daily, cu. ft.	339.0
Ave. daily, cu. ft. per m.g.	7.1
Max. daily, cu. ft. per m.g.	10.8
Max. per cent moisture	87.6
Min. per cent moisture	25.9
Max. per cent volatile matter	61.5
Min. per cent volatile matter	13.7
Raw sludge	
Lbs. dry solids, ave. daily	8,750.0
Lbs. volatile dry solids, ave. daily	5,670.0
Per cent dry solids, min. ave. daily	3.9
Per cent dry solids, max. ave. daily	5.8
Digestor heating water	
1,000 g.p.d., ave. daily per digester	10.5
Sludge temperatures, F. deg.	
Max. daily ave. all digesters	99.0
Min. daily ave. all digesters	73.0
Sludge gas	
Per cent methane, max.	68.6
Per cent methane, min.	64.4
Cu. ft., ave. daily, total all tanks	57,794.0
Cu. ft., per m.g.	8,348.0
Cu. ft., per lb. volatile solids added	10.2
Cu. ft. consumed per kw. hr., ave.	29.8

Summary of Operating Data at Green Bay, Wisconsin, April 1, 1942–March 31, 1943—Continued

Item	Average
Digested sludge	
Cu. yds. removed from digesters per month	14,454.0
Per cent moisture, max.	99.6
Per cent moisture, min.	86.1
Per cent volatile solids, max.	52.8
Per cent volatile solids, min.	38.5
Ground sludge, cu. yds. per month	4,107.0
pH	
Raw sewage, max.	9.7
Raw sewage, min.	6.7
Effluent, max.	8.5
Effluent, min.	6.8
Raw sludge, max.	8.0
Raw sludge, min.	5.0
Digested sludge, max.	7.2
Digested sludge, min.	6.5
Suspended solids, p.p.m.	
Raw sewage, daily ave.	226.0
Effluent, daily ave.	91.0
Average per cent removal	60.0
5-day B.O.D., p.p.m.	
Raw sewage, daily ave.	283.0
Final effluent, daily ave.	208.0
Per cent removal, ave.	26.5

* Surplus over produced was purchased.

REPORT OF OPERATION OF THE DISTRICT OF COLUMBIA SEWAGE TREATMENT PLANT FOR THE FISCAL YEAR 1943 *

By Ralph E. Fuhrman, *Superintendent*

Sewage Pumping

For the entire year, more than forty-four billion gallons of sewage were pumped and treated by the plant. The increase over the previous year was more than four billion gallons, or an increase of eleven per cent.

Grit Chambers

As in previous years, the operation of the grit collectors and conveyors was continued on an intermittent basis to minimize wear of this equipment. In addition to saving mechanical wear, about half of the electrical energy formerly used is saved.

Sludge Treatment

All solids removed from the sewage, whether they were removed as scum or sludge, were treated by digestion, elutriation, and de-

* Report for 1940–41 extracted in *This Journal*, 14, 1102 (September, 1942).

watering. The eight sludge digestion tanks were operated as single stage digesters.

The dewatering of digested and elutriated sludge was necessary at a high rate throughout the year because of the increased load. Reduced filter production early in the fiscal year indicated that it was largely due to the clogging of the vacuum filter screens, which support the filter cloth. Cleaning in place was not effective, so removal of the screens and sand blasting were finally necessary. This process restored the screens to their new condition and restored the filters to normal effective service. However, to regain the production lost through this period, it was necessary to operate this portion of the plant on a 6-day week instead of the usual 5 during the last three months of the fiscal year.

Of the total sludge cake production of 31,222.7 tons, 24,150 tons or 75.0 per cent were shipped by rail to the District of Columbia Penal Institutions at Lorton, Virginia. The remainder was hauled and used by others for miscellaneous soil conditioning uses. The largest user in this class was the U. S. Army at a nearby airport.

Power Plant

Operation of the 1200-horsepower sludge gas engine produced 3,533,500 kilowatt hours or 67.0 per cent of the total power used by the plant during the year, 5,271,600 kilowatt hours. As the plant is the only supply of gas for space heating of the Bellevue Naval Housing Project, operation of the engine was curtailed during the months of December, January, February, and March. At these times gas was furnished the housing project and the Navy paid for the additional electrical energy which the sewage treatment plant required.

As in the previous year, several shutdowns were forced by difficulty with the air-gas mixture entering the intake manifold. Attention is being given to the possibility of reducing variations in the gas pressure to minimize this difficulty.

Operating Costs

The budgetary expenditures charged against the plant for the year amounted to $177,882. The unit cost including pumping was $4.00 per million gallons of sewage.

Following is a summary of operating data for the year 1943:

Summary of 1943 Operating Data at Washington, D. C.

Item	Yearly Average
Sewage treated	
Mean flow, m.g.d.	121.7
Kilowatt hours per m.g.	87.5
Grit	
Cu. yds. per day	9.1
Cu. ft. per m.g.	2.0
Per cent solids	72.1
Per cent volatile matter in solids	21.4

Summary of 1943 Operating Data at Washington, D. C.—Continued

Item	Yearly Average
Suspended solids	
Raw sewage, p.p.m.	172.0
Effluent, p.p.m.	105.0
Per cent removal	39.0
B.O.D.	
Raw sewage, p.p.m.	171.0
Effluent, p.p.m.	115.0
Per cent reduction	32.7
Raw sludge	
Suspended matter removed per day, dry pounds	68,000.0
pH	5.6
Specific gravity	1.01
Per cent solids	8.0
Per cent volatile matter in solids	64.4
Per cent fats in solids (chloroform)	20.1
Scum removed from settling tanks	
Removed per day, gallons	11,300.0
Per cent solids	16.0
Per cent volatile matter in solids	86.7
Sludge digestion	
Volatile solids added to digesters daily, dry pounds	55,826.0
pH digested sludge	7.3
Temperature digesting sludge, F. deg.	94.0
Per cent fats in digested sludge solids (chloroform)	6.3
Suspended solids in over flow liquor, p.p.m.	20,200.0
Sludge gas per capita per day	0.89
Sludge gas	
Methane, per cent by volume	59.3
Carbon monoxide, per cent by volume	0.0
Oxygen, per cent by volume	0.0
Hydrogen, per cent by volume	2.3
B.T.U. per cu. ft.	587.0
Elutriated sludge	
Specific gravity	1.03
Per cent solids	6.8
Per cent volatile matter in solids	42.7
Ratio wash water to sludge volume	2:1
Digested sludge alkalinity, p.p.m.	3,209.0
Elutriated sludge alkalinity, p.p.m.	681.0
Elutriate	
Suspended solids, p.p.m.	3,950.0
Alkalinity, p.p.m.	681.0
B.O.D., p.p.m.	631.0
Sludge dewatering operations	
Days dewatering, mean per month	20.0
Filter hours, mean per month	393.3
Cake produced, total wet tons	31,222.7
Solids in cake, per cent	27.8
Dry solids in cake, total tons	8,666.5
Yield, dry pounds solids per sq. ft., per hour	7.3
Ferric chloride, per cent dry basis	3.29

OPERATION REPORT: CRANSTON, RHODE ISLAND, FOR PERIOD FROM MARCH 1, 1942, TO DEC. 31, 1943

By Walter H. Brown, Jr., *Superintendent*

General Information

The plant serves the entire area of Cranston west of the main New York, New Haven & Hartford Railroad except part of the Meshanticut Park, all of Oaklawn, all of Fiskeville, and scattered outlying districts. The estimated population served is 25,000. The average design flow was 5.5 m.g.d. with a maximum of 12.0 m.g.d. Following are the plant units: One detritor, mechanically cleaned; one comminutor, for cutting up coarse material; one main Venturi meter, capacity 12.0 m.g.d.; one grease flotation unit; two primary settling tanks, approximately 170,000 gallons each; two aeration tanks, approximately 750,000 gallons each; two final settling tanks, approximately 300,000 gallons each; one chlorination channel, approximately 30,000 gallons; one chlorinator, 400 lbs. daily capacity; two sludge digestion tanks, approximately 420,000 gallons each; two elutriation tanks, approximately 50,000 gallons each; one sludge concentration tank, approximately 48,000 gallons; nine sludge pumps; three water pumps; two air blowers, 4,000 c.f.m. capacity each, and two vacuum filters, 200 sq. ft. each.

The entire sewage flow through plant is by gravity. All sludge flow is by pumping. The plant was placed in operation on March 1, 1942. The sewage treated is approximately 40 per cent industrial waste and 60 per cent domestic wastes.

Grease Flotation Unit

This is an American Well Works unit. The unit has removed 131,270 gallons of grease in 1942 and 177,910 gallons of grease in 1943.

Vacuum Filters

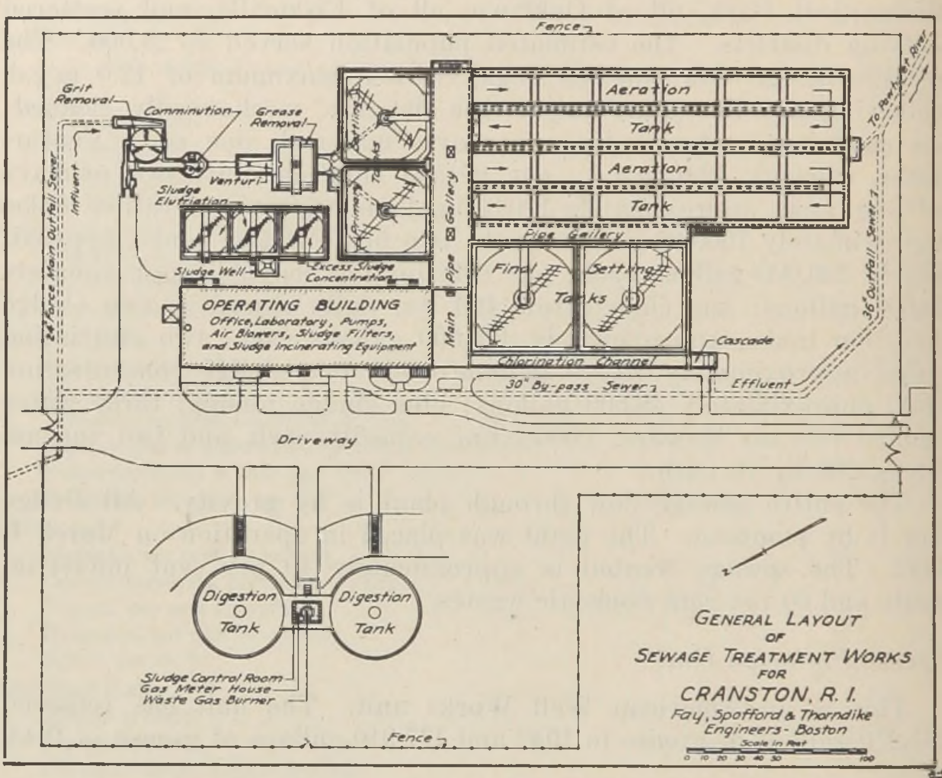
Quite a bit of trouble was experienced from these units due to insufficient length of the barometric leg. This was rectified only to find that the filtrate pumps would not discharge under a high vacuum. This also was overcome and since then, the filters and accessories have performed well. After quite a bit of experimentation, the ferric chloride injectors have steadied down in operation but these should be replaced with a more reliable type.

Sludge Pumps

The ball type check valve in sludge pumps has proven much more satisfactory and should be adopted in place of the flapper type check valve wherever possible. The principal advantage of the former type is freedom from clogging.

General Summary of Plant Operation and Results

The plant itself has proved highly satisfactory for the job it was designed to do. However, since the Narragansett Brewery Co. was connected, the B.O.D. load has been so great that it has been approximately 100 per cent above normal. This has prevented normal activated sludge operation and resulted in insufficient reduction of B.O.D. and suspended solids along with increased cost of operation.



The visual results have been an unsatisfactory effluent and occasional odors both at the plant and along the Pawtuxet River especially in warm weather. It is felt that the present difficulties arise from two different causes: 1. Large amounts of settleable solids (brewery grain, etc.) in the raw sewage. 2. An unusually high B.O.D. load due primarily to unsettleable solids.

The first of these could and should be taken care of at the source by the Narragansett Brewery. At the present time, even under ideal conditions, the grit removal unit is able to remove only a portion of the incoming grain and in freezing weather, it often has to go out of operation completely. The grain not thus removed eventually reaches the digester where it accumulates as an indigestible or a very slowly digestible floating layer which is already reaching such a depth as to pose a very troublesome and undoubtedly expensive removal problem.

For the past year, the removal of grain (6950 cu. ft.) from the grit chamber alone is estimated to have cost at least $500. Expressed in other terms, this is equal to the sewer rental from a one-family house for about 42 years.

The second item has prohibited the operation of the treatment works as an activated sludge plant. This is due to the fact that under present conditions, we are attempting to treat waste equivalent to a population of 11,400. Thus it may be readily seen that with the present flow, we are carrying a load which is approximately 100 per cent greater than anticipated in plant design. One result of this has been the required use of chlorine in amounts far greater than normally expected.

A suggested solution for this problem is either pretreatment on the part of the brewery to reduce its wastes to the strength of normal domestic sewage (approx. 200 p.p.m. B.O.D.) or the addition of sufficient high rate trickling filters at the treatment works to reduce the strength of the primary effluent to such a point that it may be properly handled by the activated sludge process. Such an addition would in all probability not only solve the brewery problem but also make possible the handling of other industrial wastes. Furthermore, by such an addition, the date of eventual plant expansion will be materially extended.

Operating Costs

The cost of operation in 1942 was $27,278.89 and in 1943 $30,255.62. This represents a cost of $74.77 and $79.24 per million gallons treated respectively.

Comment on Operating Costs

The cost of operation for the years 1942 and 1943 are relatively the same but when compared to that of other plants, they are high. This may be explained by noting that the average daily flow for the plant is only 1.0 m.g.d. Thus, when it is realized that our expenses will be essentially the same with an average daily flow of up to about 3 m.g.d. it is seen that the cost of treatment per million gallons will be one-third of $75, or about $25. In other words, our largest item at present is our fixed expenses (salaries, power, etc.) or overhead which will remain about the same up to a flow of about 3 m.g.d. When that flow is reached, our costs will be lower than most comparable plants.

Summary of Operating Data

Summary of Operating Data at Cranston, R. I., for Period from March 1, 1942, through Dec. 31, 1943

Total flow—million gallons	746.89
Total grit (including brewery grain)	6,993.00 cu. ft.
Total chlorine	30,374.00 lbs.
Total grease to digesters	307,180.00 gals.
Dry solids of grease—average	3.98 per cent

Total scum to digesters	892,440.00 gals.
Dry solids of scum—average	0.89 per cent
Average primary detention time	5.00 hours
Total primary sludge to digesters	10,268,530.00 gals.
Dry solids of primary sludge—average	3.86 per cent
Average aeration detention time	16.00 hours
Total air	1,660,492,000.00 cu. ft.
Air per gallon, settled sewage	2.2
Average final settling detention time	4.5 hours
Total gas produced	18,853,100.0 cu. ft.
Total gas used	2,562,100.0 cu. ft.
Per cent wasted	86.4 per cent
pH raw sewage—average	7.6
pH plant effluent—average	7.7
Alkalinity—average raw	208.0 p.p.m.
Alkalinity—average final	252.0 p.p.m.
Chlorides—average raw	47.0 p.p.m.
Chloride—average final	62.0 p.p.m.
B.O.D.—average raw	503.0 p.p.m.
B.O.D.—average final	177.0 p.p.m.
Per cent reduction	65.0 per cent
Total solids—average raw	1,035.0 p.p.m.
Total solids—average final	730.0 p.p.m.
Per cent reduction	30.0 per cent
Dissolved solids—average raw	700.0 p.p.m.
Dissolved solids—average final	645.0 p.p.m.
Per cent reduction	8.0 per cent
Suspended solids—average raw	335.0 p.p.m.
Suspended solids—average final	85.0 p.p.m.
Per cent reduction	75.0 per cent
Dry solids raw sludge—average	4.08 per cent
Per cent volatile	76.9 per cent
Dry solids digested sludge	3.67 per cent
Per cent volatile	60.8 per cent
Dry solids elutriated sludge	4.07 per cent
Per cent volatile	60.1 per cent
Total gallons elutriated sludge to filters	1,580,690.00 gals.
Total nos. dry solids filter cake	616,985.00 lbs.
Average per cent $FeCl_3$ (dry solids)	7.46 per cent
Average per cent moisture filter cake	80.00 per cent
Filter rate nos. per sq. ft. per hr.	3.26 lbs.
Average alkalinity of elutriated sludge	28.00 p.p.m.
Average sludge gas—cu. ft. per cap. per day	3.1 cu. ft.

Comment on Operating Data

It will be noted that some of the above averages are unlike those at any other sewage treatment plant. This is due to the fact that the plant has not had a consistent raw sewage to treat. For instance, there was a period when only domestic sewage was treated, then domestic plus brewery wastes, then domestic plus brewery plus print works wastes, and then back to domestic plus brewery wastes again.

GREATER WINNIPEG SANITARY DISTRICT: SUMMARY OF PLANT OPERATIONS FOR 1943 *

By D. L. McLean, *Superintendent*

A description of the plant units is contained in the previous extract * on this plant. Following is a summary of general plant operating data for the years 1942 and 1943, together with a special summary of elutriated sludge filtering in Table II:

Table I.—*Summary of Operating Data at Winnipeg, Manitoba, for 1942–43*

Item	1942 Average	1943 Average
Temperature of raw sewage, F. degrees	58.0	57.0
Sewage flow, m.g.d.	23.1	21.3
pH of raw sewage	7.5	7.5
Settling tank operation		
Settleable solids, influent, ml. per liter	7.3	7.7
Settleable solids, effluent, ml. per liter	1.7	2.1
Settleable solids, per cent removal	76.7	72.7
Suspended solids, influent, p.p.m.	318.0	315.0
Suspended solids, effluent, p.p.m.	134.0	138.0
Suspended solids, per cent removal	57.9	56.2
B.O.D., influent, p.p.m.	365.0	289.0
B.O.D., effluent, p.p.m.	264.0	222.0
B.O.D., per cent removal	27.6	23.2
Grit, cu. ft. per Imperial m.g.	1.9	1.8
Raw sludge to digesters, total solids, lbs.*	13,832,000.0	9,756,000.0
Raw sludge to digesters, volatile solids, lbs.*	9,457,000.0	6,289,000.0
Digested sludge elutriated, total gals. for year	10,350,869.0	7,557,800.0
Sludge cake, dry tons total for year	1,265.0	681.0
Ferric chloride used, ave. per cent (dry basis)	2.5	3.1
Sludge gas produced, cu. ft., total for year	85,224,000.0	64,003,000.0
Cost of plant operation, total for year, dollars	—	66,402.35

* Total for year.

Table II.—*Summary of Filtering of Elutriated Sludge, 1940–1943*

Item	Total for 4-Year Period
Wet sludge cake filtered, lbs. total	37,624.870.0
Average per cent water in sludge cake	70.7
Dry sludge cake filtered, lbs. total	11,071,828.0
Ferric chloride used, lbs. total	308.344.0
Ferric chloride used, per cent (dry basis) av.	2.8
Average filter rate, lbs. dry solids per sq. ft. per hr	3.9

Four-Year Observations on the Use of Elutriation and Ferric Chloride in Filtering Digested Primary Sludge

Table II above summarizes the results of filtering elutriated digested sludge using ferric chloride as a conditioner for the years 1940–1–2–3. The total cost of the ferric chloride for that four-year period was $13,051.80. It is estimated that a saving of over $16,800 in cost of ferric chloride was made by using the elutriation process for this period.

* 1941 report extracted in *This Journal*, 14, 1096 (September, 1942).

Any discussion of the savings in ferric chloride costs by the use of the elutriation process to reduce the amount of ferric chloride used to condition digested sludge for vacuum filtering, involves the fact that while certain portions of the collection system and treatment plant were designed for a population as at 1945, the war loadings on the sewer systems of the District have overloaded the plant so that the digesters have not been able to digest all the materials coming to them and they have had to be cleaned out from time to time (all four digesters had to be cleaned out in 1943). The elutriation process has also been overloaded and the amount of digested sludge going over the weirs of the elutriation tanks at times has been in excess of that going to the filters.

While this elutriation process has done all that was claimed it would do, experience here shows that some improvements may be made to it when installing it in a new plant or where extensions or changes are made. These improvements are:

1. A sump or raw sludge thickening tank for the raw sludge from the clarifiers to help deliver heavy sludge to the digesters and later, heavy sludge to the elutriation tanks.
2. Chemical feeders to condition the elutriated sludge, *placed close to the vacuum filters.*
3. Suitable wash water for the elutriation process.
4. Positive control of the feed of the digested sludge to the elutriation tanks.
5. Use of tanks of ample size for mixing and settling the sludge in the elutriation process.

Such improvements would save ferric chloride but unless their cost justified the expenditure there would be no gain in them.

As a check on the estimated $16,800 saving of ferric chloride for the past four years by the elutriation process, a full scale filter test was run on April 4, 1944, and this again demonstrated not only the practical value of the process but that the digested sludge at present coming from digester No. 1 could not be filtered using up to 6.4 per cent of ferric chloride, but that over 9 per cent of ferric chloride would be needed. With an alkalinity of 4,430 p.p.m., a water content of 93.8 per cent and a volatile matter of 57 per cent, this digested sludge required, therefore, over nine pounds of ferric chloride to produce 100 pounds of dry solids in the filter cake. On the basis of this test, the saving of ferric chloride by using the elutriation process for the last four years would not have been $16,800 but some $30,000.

THE GADGET DEPARTMENT

The devices described and illustrated here were the winners of the Gadget Competition sponsored by the New York State Sewage Works Association as part of the meeting held at Syracuse on June 16-17, 1944.

A fourth entry, still under consideration by the committee on Awards, is described in the "Tips and Quips" column of the March issue.

First Prize

A LIME MIXING DRUM

By Harold R. Fanning

Supt. of Sanitation, Bendix Aviation Corp., Elmira Hts., N. Y.

Figures 1 and 2 illustrate this device, the purpose of which is to slake and mix lime solutions for application to sewage or sludge as may be necessary during treatment. The central shaft is made of corrosion

Fig. 1.—Lime mixing drum devised by Harold R. Fanning, Elmira, N. Y.

resistant pipe, through which perforated paddles of ⅜-inch steel plate are mounted. A bronze collar-bearing is bolted to the bottom of the drum to receive the bottom of the shaft and another bronze collar is provided at the top guide and support, which is made of steel plate with welded flanges. The paddles are 4 inches wide and 1 foot 9 inches long and the perforations are 1-inch holes on a staggered 3-inch spacing. Assembly will be evident from the illustrations.

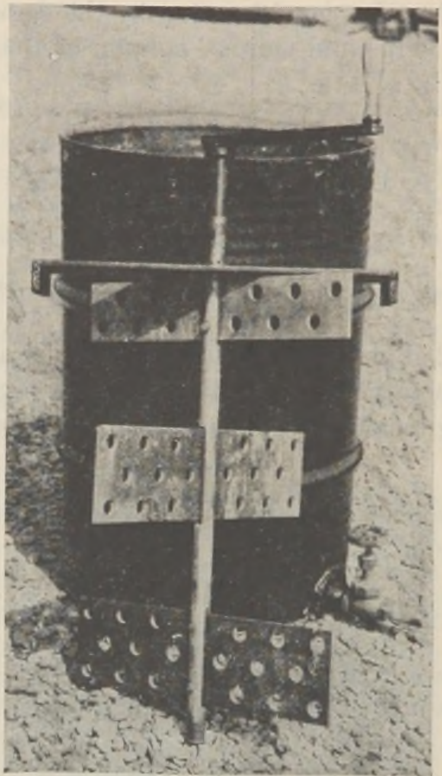


FIG. 2.—Paddle assembly for lime mixing drum.

SECOND PRIZE

A SLUDGE SAMPLER

By ALEXANDER S. ZELE

Chemist, Long Island State Park Commission, Brooklyn, N. Y.

Intended for use at sludge digestion or sedimentation tanks, this sludge sampler (Fig. 3) comprises a bucket with a hinged, gasketed cover and fitted with a long pipe handle attached with a swivel bolt to the two flanges on the side of the bucket. A wire, extending through

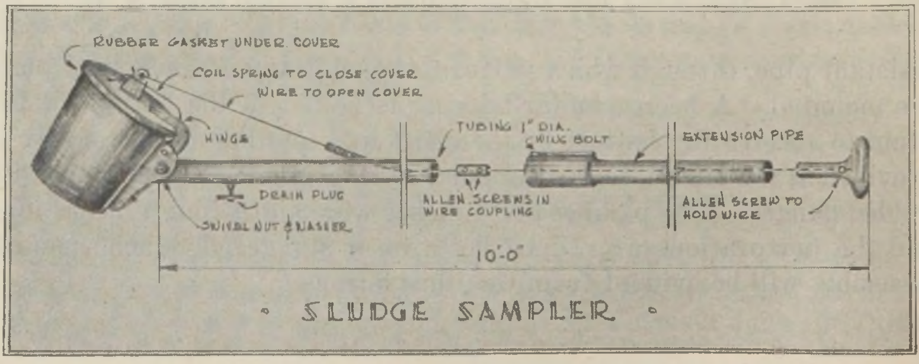


FIG. 3.—A sludge sampling bucket. By Alexander S. Zele, Brooklyn, N. Y.

the pipe handle, connects a sliding knob inserted at the end of the pipe handle to the bucket cover. When the bucket is immersed to the desired level in the sludge, the cover can be raised to admit a selected sample of sludge. A coil spring wire on the bucket is arranged to close the cover when the tension on the pull wire has been released.

Third Prize

A MULTI-LEVEL SLUDGE SAMPLER

By Byron B. Evans

Senior Operating Engineer, Pine Camp, N. Y.

This is a simple and easily constructed adaptation of the bottle-on-pole type of sampler, commonly used for the collection of digester samples at two or more levels. Details of construction are shown in Fig. 4.

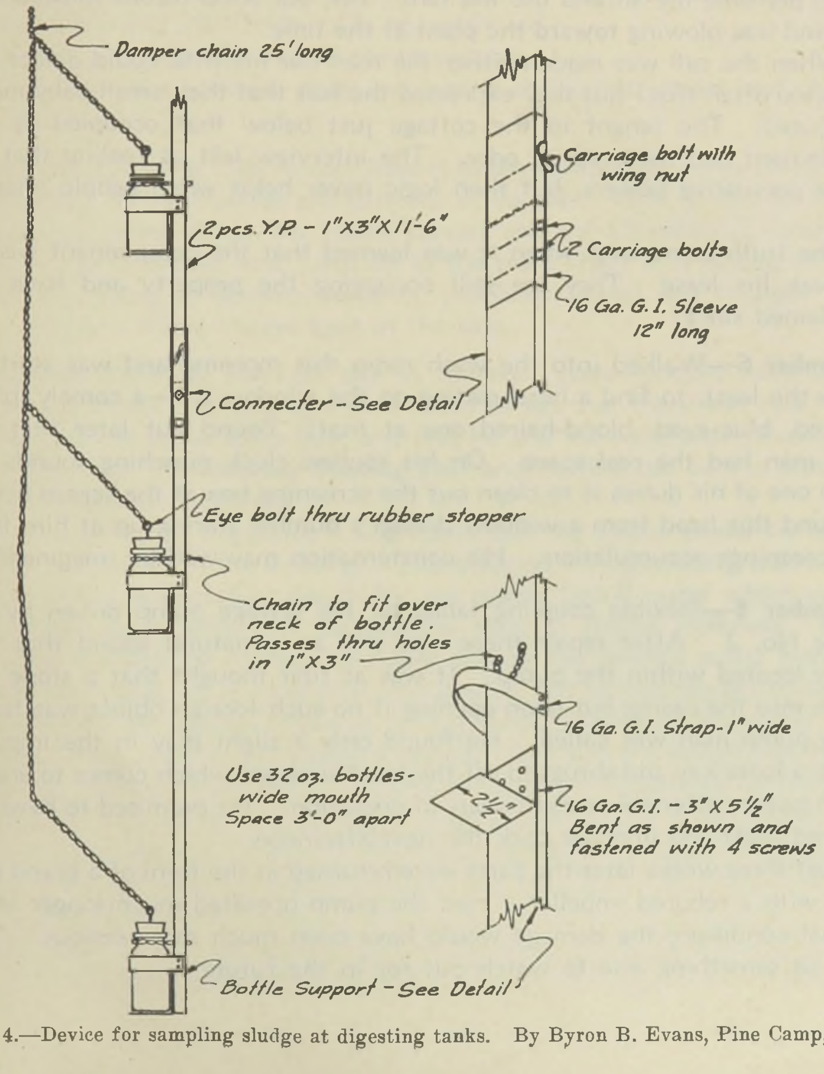


Fig. 4.—Device for sampling sludge at digesting tanks. By Byron B. Evans, Pine Camp, N. Y.

One feature of interest is the connector which permits the pole to be taken down into short lengths for convenience in handling and storage.

A complete series of 3-foot samples can be taken at the average digester with this device by one man in only ten minutes.

BARK FROM THE DAILY LOG

By Walter A. Sperry

Superintendent, Aurora Sanitary District

September 1—An interesting interview regarding an odor complaint with an irate tenant next door to the plant. The complaint was that the odors were so bad the night before that the man and his wife were unable to sleep and had to perfume the air and use the fan. Yet, our wind record showed that the wind was blowing **toward** the plant at the time.

When the call was made neither the man nor his wife could detect any odor (too often true) but they expressed the fear that their small baby might be injured. The tenant in the cottage just below that occupied by the complainant had detected no odor. The interview left us feeling that we lacked persuasive powers, but then logic never helps when people imagine odors.

The truth came later when it was learned that the complainant wished to break his lease. They are still occupying the property and have not complained since!

September 6—Walked into the wash room this morning and was startled, to say the least, to find a head resting on the window sill—a comely, pink-cheeked, blue-eyed, blond-haired one at that! Found out later that the night man had the real scare. On his routine clock punching rounds, on which one of his duties is to clean out the screening box at the screen house, he found this head from a window dresser's dummy staring up at him from the screenings accumulation. His consternation may well be imagined!

September 8—Flexible coupling failed on the sewage pump driven by gas engine No. 2. After repair there was still an unnatural sound that was finally located within the pump. It was at first thought that a stone had gotten into the casing but upon opening it no such foreign object was found and a pump man was called. He found only a slight play in the impeller due to a loose key and shrugged off the trouble as one which comes to engine driven pumps after six or eight years of operation. He promised to have the repaired shaft and impeller back the next afternoon.

Just three weeks later the parts were returned in the form of a brand new shaft with a rebored impeller. Had the pump operated much longer in its original condition, the damage would have been much more serious. This gives us something else to watch out for in the future.

September 11—Running paper mill tests today—a regular Monday job. Thereby hangs a tale, and this is Chapter 1 of a serial.

Aurora's only industrial waste is from a paper mill which manufactures book-back board from scrap paper. When the sewage treatment plant was started into operation, this mill installed an Oliver filter to act as a "save-all." Late in December, 1943, we discovered an unusual amount of fibrous waste from this mill. Increased settleable solids, a much larger quantity of primary sludge of high volatile content, a gray foam on the clarifiers, and rapidly filling digesters at the worst time of the year, all were eloquent of paper mill waste.

Routine records take a lot of patience and time but they are valuable aids and we took them along to demonstrate the effect of the wastes on the sewage treatment plant. The manager of the paper mill, who is a decent and co-operative chap, expressed great surprise at our story and disclosed that they had no means of knowing their losses. We immediately planned a campaign to determine how many tons of pulp (at $30 per ton) they were losing per week and in how much water the lost pulp was suspended. This was on December 29, 1943. (To be continued.)

Placed a want ad for men in the local paper.

Blew out the pressure rings and piping of Venturi meter and checked register.

September 12—The 13th Annual Report finally completed—two months late. First copies to the trustees and officers, of course. Then to the libraries of the schools round about, the Public Library and the Chamber of Commerce. The Annual is always first justified to the plant itself if it is a careful and complete record of accomplishments, problems solved and changes made. One complete file is always kept in the safe.

September 13—The blackest day in fourteen years—should have been a Friday. At 10 P.M. the night man called to say that there was two feet of water over the pump room floor and that he and the watchman needed help. We laid down the **Saturday Evening Post** and hurried out to the plant, not to get back until 3:30 A.M.

Upon arrival at the plant, it was found that the master power switch had kicked out earlier in the evening. This stopped the circulating water motor and caused a temperature rise in the gas engine jacket water which cut out the engine driven generator, putting the plant in Stygian darkness. Before this engine could be started the other driving the sewage pump went out. With everything out of operation, the level of the settled sewage in the wet well raised high enough to geyser from the open casing of the pump which was awaiting repair of its shaft and impeller and, before the wet well by-pass could be opened, there was 21,000 gallons of settled sewage in the pump room with five motors submerged. Some mess! (It had been believed that the suction valve on the pump taken down for repair was completely closed since three men had worked conscientiously to effect the closure when the pump was taken down.)

As soon as the emergency gasoline lanterns were lighted, the suction valve on the open pump was altogether closed, leaving us in the predicament of trying to figure out what to do next. The pump room floor is below the lowest river level and much longer suction and discharge connections were required than were immediately available. Furthermore, it would take a good long day just to rig the portable pump equipment.

Finally it was decided to call the volunteer fire department from the neighboring village of Oswego and these good sports left their warm beds to come to the rescue. Their fire truck was equipped with plenty of hose and with a small pump mounted in front of the radiator and they succeeded in getting out all of the water in an hour and a half, which prompt action saved two of the motors.

By 10:30 the next morning the plant was running in normal fashion and a visitor would never have known that we had been in trouble. It was a real pleasure to send an individual check to each of the Oswego fire fighters together with a generous one for their department fund.

The lesson from this experience is quite clear. On rainy days in the future, all large valves on suction and discharge lines will be occasionally worked and the number of turns to open or close will be determined and posted. Large valves in such locations are often not touched for long periods and they will inevitably fail when they are most needed.

September 15—Running routine Orsat test on plant gas and computing the fuel value.

Interview applicant answering our advertisement.

September 18—Worked all day on the Fox River stage and discharge curve to bring it up to date for officials of the local power company who are interested in the low flow days when sufficient cooling water for the steam turbines might be at a premium. A bit of "good neighbor" policy.

By using the Main Street dam as a weir, flow curves can be related to river elevation at the plant and readings taken from the water level recording instrument located there. In this way, a curve relating river elevation to discharge in C.F.S. can be constructed. From the results of D.O. tests of river samples and the streams flow data we are able to compute the pounds of oxygen available in the river and when this is compared to the oxygen demand of the plant effluent, we have a good measure of plant effectiveness. It is good river bookkeeping.

September 20—Revamped the emergency light arrangement. Gasoline lanterns give a brilliant light but the mantels are delicate, the gasoline soon evaporates, they are not easy to light and must be kept pumped up while in use. Electric battery lights give only a small lighted area and battery upkeep is expensive and a nuisance. The men were overwhelmingly in favor of the good old kerosene lantern which does not give such brilliant light but is always ready, easy to light, and will burn all night.

September 22—New man driving the sludge tractor smashed the jamb of the garage door. Takes a lot of patience to handle some of these wartime replacement employees.

The mayor and sewage plant operator from Wilmington visited us to inspect the plant and talk a bit of shop.

September 25—Drawing sludge from digester No. 2 to four drying beds. No alum used because good drying weather is anticipated for some time yet.

September 28—Rain today enabled us to catch up on several miscellaneous inside jobs such as cleaning pump room walls which were soiled during the "flood" two weeks ago. Also emptied accumulated water from the bottoms of the two idle clarifiers.

September 30—The shaft and impeller of sewage pump No. 2 finally received from the shop and the pump made ready for service.

Painting outside iron work and giving the lawn the final trimming of the season.

October 2—Every day is an adventure, usually enjoyed for their excitement, for they are mostly pleasant ones. Today was the occasional and rare exception.

At 4:30 P.M. the night man's wife called to say that he was sick and would not be able to work. A long distant call was finally successful in completing arrangements for a substitute—a new man not yet moved in from a neighboring town. He was not able to report, however, until 7:30 P.M. and it was up to the Superintendent to bridge the gap.

As we left the plant it was the darkest of nights and, what with a dense fog and drizzling rain, visibility was zero. All went well, however, until we reached the main line crossing of the Burlington at which the gates were up and the tower brightly lighted. Knowing that the crossing was rough, we started slowly and serenely across and crashed squarely into the side of a switch engine! The engine was just starting to pull out from the left side of the crossing and gave no warning by whistle, bell, steam, or smoke. Fortunately, we were only shaken up and bruised a bit. Incidentally, the onset of shock is an interesting study—the pains did not begin until about two hours later while we were trying to explain to friend wife.

Oh well, it is all part of the day's work!

TIPS AND QUIPS

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Those who came to Pittsburgh to attend the announced Fifth Annual Meeting of the Federation and returned home to read that they had been present at the Sixteenth Annual Meeting need not be alarmed at the thought that the story of Rip Van Winkle may have had some truth in it. It all came about through the decision of the Board of Control that the Federation need not be coy about stating its real age and that the annual business sessions of the Board of Control from 1928 to 1939, while not technical conferences, were actually meetings of the Federation and should have been counted as such. And so it shall be henceforth!

A fine meeting it was, and congratulations are due Local Chairman L. S. Morgan and his various management committees for an excellent job. Now that the event is a pleasant memory it can be told that it was mighty close to being cancelled at the last moment! Less than a week before the opening, hotel authorities advised that a walkout of all hotel employees in Pittsburgh had been scheduled for midnight on October 6 and that the meeting could not be held if final negotiations were not successful. It was not until Monday, October 9, that a temporary agreement was reached which made it possible to destroy the telegram which had been prepared to advise all those who had made advance reservations that the meeting was being cancelled!

Incidentally, the registration of 524 was very good under prevailing conditions, comparing quite favorably with the average registration recorded at the past five meetings of 534.

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Something must be done about this Convention Attendance Trophy if it is ever to carry the name of any other winner than that of the Central States Sewage Works Association. For the fourth consecutive year the award went to that nomadic tribe—this time by a margin of almost 15,000 man-miles over the perennial runner-up, the New York State Sewage Works Association. A tabulation of the leaders follows:

Association	Registered Members	Total Man-Miles
Central States	57	29,580
New York State	48	14,980
Pennsylvania	72	9,000
Federal	9	8,400
California	4	8,050
Canadian Institute	16	8,000
New England	16	7,320
New Jersey	21	5,670

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Year by year, the Quarter Century Operators Club grows in number and eminence. Seven veteran operators joined the ranks at Pittsburgh, bringing the membership to a total of 19. The new affiliates were Almon L. Fales of Boston, Harry M. Beaumont of Philadelphia, John V. Lewis of Rochester, H. W. Streeter of Cincinnati, C. D. McGuire of Columbus, Glenn Searles of Rochester and John S. Simmerman of Pitman, N. J.

Introduction of members of the Club at the Federation Luncheon at Pittsburgh was ably accomplished by Frank Woodbury Jones, founder of this elite organization.

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Other high-lights of the Sixteenth Annual Meeting . . . the Pennsylvania Luncheon, at which C. A. Emerson and H. E. Moses were signally honored . . . the gathering of 25 army officers who assembled in an extra-curricular session under the leadership of Lt. Col. J. J. Gilbert and Dr. F. W. Mohlman to discuss problems of sewage treatment in army posts . . . the awards presentation ceremony, so ably conducted by President Rawn . . . the introduction of the cigarette famine to those coming from points west of Pittsburgh . . . that man, "Dr. Holman," who was paged so persistently during the Smoker entertainment . . . the boisterous "Television Kids," who raised the roof and brought down the house at the Annual Dinner . . . the "Man from Mars" in the person of L. L. Langford of New York, as dressed in all the safety equipment he could carry during the very instructive and practical demonstration staged by L. W. Van Kleeck.

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Operators experiencing difficulty with corrosion at wet seal gas holders will be interested in a pamphlet recently made available by The Stacey Brothers Gas Construction Company, 5535 Vine St., Cincinnati, Ohio. Causes of corrosion, vulnerable points and recommended operation and maintenance practices are given. When writing, refer to Bulletin No. 1–44.

Don't be caught with your holders down!

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The footnote on page 952 of the September, 1944, *Journal* brought to the mind of City Engineer W. C. Miller of St. Thomas, Ontario, his boyhood plans for a real fishing spree, which plans were frustrated only by his inability to find any "cocculus indicus." Reference to the aforementioned footnote will reveal that cocculus indicus, the berry of an East Indies plant, is prohibited by law from discharge into California streams, much to the puzzlement of the State Division of Fish and Game.

The California authorities and others may be interested in Mr. Miller's quotation from an old encyclopedia * which he recovered from a resting place in the attic. The following is given under the caption, "The Chinese Art of Catching Fish":

> "Take Cocculus Indicus, pulverize and mix with dough, then scatter it broadcast over the water as you would sow seed. The fish will seize it with great avidity, and will instantly become so intoxicated that they will turn belly up on top of the water by dozens, hundreds or thousands as the case may be. All that you now have to do, is to have a boat or other convenience to gather them up, and as you gather them put them in a tub of clean water, and presently they will be lively and healthy as ever.
>
> "This means of taking fish and the manner of doing it has heretofore been known only to but few. The value of this knowledge admits of no question. This manner of taking fish does not injure the flesh in the least."

Now, if we just knew where one could buy some cocculus indicus!

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Speaking of California, we are reminded of the introductory remarks of President Rawn, when introducing Dr. Stewart of Pennsyl-

* "An Encyclopedia of Practical Information and Universal Formulary," by Robert Bradbury, M.D., published by the Century Book and Paper Co. of Chicago in 1889.

vania for the latter's address at the Pittsburgh meeting. Commenting on conditions in his home state, Mr. Rawn pointed out that California "has more rivers and less water than any place he had ever seen" and, later, that "stream pollution control in California was actually a sort of dust abatement program." All of which is quite in accord with what we hear about California's sunshine.

However, it does rain in Los Angeles on occasion, as proven by the accompanying view (Fig. 1) of a manhole on an overtaxed sewer in that fair city. The caption provided by Reuben F. Brown, Superintendent

FIG. 1.—Overflowing sewer manhole caused by a "heavy dew" in Los Angeles.

of Sewer Maintenance, even refers to a "heavy storm." The surcharge was so great that the 250-pound cover was raised 9 inches above the manhole ring at this time.

It would seem that the slogan, "when it rains, it pours" is apropos!

• • •

"Seems like an investment of $250 to $500 in a (sludge) grinder would be good business," commented A. W. Eustance of the New York State Department of Health while addressing the New York Association at Syracuse last June on the subject of "Dewatered Sludge Disposal." This view was founded on experience at Geneva, New York, where ground sludge was formerly sold for $7.00 per ton while the actual cost of handling was only $3.87 per ton. With no sludge grinder now on hand, the dried sludge as removed from the beds at Geneva brings only 75 cents per ton, which is about equal to the cost of handling.

No doubt about it, better preparation of air dried sludge will increase its usage and the revenue therefrom—particularly in plants in which the stockpile is overflowing!

• • •

A new sub-committee of the Sewage Works Practice Committee of the Federation will undertake a service which has been badly needed for a long time. Many operators have deplored the lack of uniformity in units used in reporting loadings of sewage treatment processes and other operation and analytical data. The new sub-committee, headed by Dr. Willem Rudolfs, who proposed the activity, will undertake to develop a standard schedule of reporting units in time to have it made a part of the new "Glossary of Water and Sewage Control Engineering" which is being compiled by a Joint Committee representing A. S. C. E., A. P. H. A., A. W. W. A. and F. S. W. A.

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As a closing tip, it is suggested that you send in your 1945 renewal dues immediately upon receipt of the first notice from the secretary of your Member Association. By doing so, you will avoid interruption in receipt of the *Journal* and the possible loss of one or more 1945 issues if stocks are exhausted before your dues are paid.

The *Journal* subscription of all delinquent members will be cut off before the March issue is distributed. If you have not already done so, mail a check immediately to the secretary of your association!

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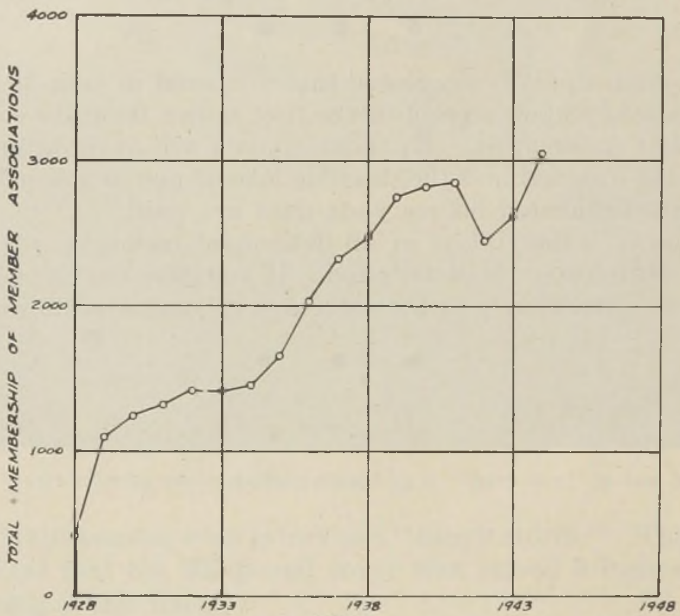
Editorials

THE FEDERATION "DEMAND" CURVE

There is always a natural satisfaction in the preparation of growth or development charts when there is advance assurance that the data will yield a good "picture." With this admission, the accompanying graphical representation of the increasing interest in the Federation since its inception is made the basis of these comments, although there is further justification in that a major milestone was passed when the aggregate membership of the associations comprising the Federation reached 3,000 in October, 1944, for the first time in history.



AGGREGATE GROWTH OF MEMBER ASSOCIATIONS OF F. S. W. A.

The striking similarity of the graph to our old friend, the biochemical oxygen demand curve, will be noted at first glance and it is pointed out that the meanings of the two are also analogous in that the membership chart likewise represents a "demand"—a growing demand for the type of service and sponsorship that the Federation has to offer. It may be of interest to carry the analogy further in the interpretation of the variations in rate of membership increase.

The "immediate demand" in 1928–29 constituted the thousand or so "charter" members, who appreciated the need of a publication such as Sewage Works Journal as a professional instrument. It is significant that the names of at least 75 per cent of this group are to be found in the current roster.

The "first stage demand" seems to have been reached at the end of about five years at approximately the 1,400 level. Then came the impetus of federal public works and the boom period of sewage works construction which brought a much wider interest in the Federation and its Member Associations. (It will be noted that the "second stage demand" is not being attributed to the nitrogenous matter represented in the huge quantity of paper used in the administration of PWA and WPA!) Reaching a temporary saturation level at about 2,850 in 1939–40, the curve shows that a mild inhibiting substance (the increase in Federation dues from $1.50 to $3.00 in 1942) caused a temporary sag. The toxic effects of this condition were completely overcome in less than three years, however, and the present trend of the curve predicts the onset of a "third stage demand" which bids fair to dwarf its predecessors. It is hoped that this indicated growth reflects the promise offered by the reorganized and expanded Federation and the tangible benefits of recent years.

At this point, pause must be taken to acknowledge the outstanding work of the officials and membership committees of the Member Associations in 1944. The net gain of 420 in aggregate Active and Corporate membership, the third largest in any year, must be credited entirely to promotional activities within the organizations affiliated with the Federation. Particular commendation is due the association secretaries for their enthusiastic support and individual efforts. The accomplishments of the various associations in this connection may be compared in the tabulation * appearing elsewhere in this issue.

Returning to the "demand" curve, the question arises as to the limits of the impending "third stage." It would be foolhardy, of course, to attempt to forecast an ultimate saturation level but mention can be made of several important factors which might be expected to influence future growth.

First, there is the fact that the 27 Member Associations of the Federation now encompass only 36 states, leaving 12 states and the foreign possessions of the U. S. yet to be developed into new domestic Member Associations. Next, since stream pollution recognizes no boundaries, there are potential Member Associations around the globe, particularly in those areas in which the war has brought a real consciousness of the importance of sanitation. More immediate growth is to be expected from the existing Member Associations; the cognizance being given sewage works construction in the postwar era gives assurance that this activity alone will make a "third stage" demand a certainty.

There will undoubtedly be several "stages" to the curve as it is continued through the years. The challenge of the moment, however, is to meet current needs and the impending future "demand" as it occurs.

W. H. W.

* See "Federation Affairs—Report of Executive Secretary-Editor."

HERBERT C. WHITEHEAD (1884–1944)

IN MEMORIAM

Among the outstanding members of the Sanitary Engineering profession in Great Britain was Herbert Cecil Whitehead, who recently died at Birmingham on May 3, 1944. He was born at Burnley, Lancashire, on February 1, 1884. His early education was in the grammar school at Burnley and the Manchester Technical School. His early engineering training was as an assistant under Mr. J. Corbett, Borough Engineer of Salford, and under Mr. J. D. Watson, Past President, Inst. C. E., on the engineering staff of the Birmingham, Tame and Rea District Drainage Board. In 1907 he was appointed Deputy Borough Engineer to the Corporation of Southend-on-Sea, serving until 1920, when he returned to Birmingham as Chief Assistant Engineer to the Drainage Board. In 1924 he succeeded Mr. Watson as Chief Engineer, which position he occupied until his death.

Mr. Whitehead was a well-known authority on matters of sewage purification and a very active and useful member of the Water Pollution Research Board of the British Ministry of Health and of the Committee of that Board appointed to investigate the effect of the discharge of crude sewage into the estuary of the Mersey, since their inception in 1927 and 1932, respectively.

Recently he had accepted an invitation from the Department of Scientific and Industrial Research to become Chairman of the Water Pollution Research Board in succession to Sir Robert Robertson. He was made a C.B.E. in January, 1944. Mr. Whitehead was elected an Associate Member of The Institution of Civil Engineers on February 2, 1909, and became a Member on March 5, 1929. From November, 1940, to October, 1943, he served as a Member of the Council. In 1931 he presented to The Institution of Civil Engineers, in collaboration with Mr. F. R. O'Shaughnessy, F.I.C., a paper entitled, "The Treatment of Sewage Sludge by Bacterial Digestion,"[1] for which a Telford premium was awarded; and in 1941, a paper on "The Design of Sewage Purification Works."[2] He was also a Fellow of the Institution of Sewage Purification, England, and President of the Institution in 1939–1940.

In July, 1910, he married Florence Annie Butcher, and had three sons and one daughter.

Those of us who met him at Birmingham recall a courteous host, thoroughly conversant with the art of sewage purification and the administration of the Birmingham Drainage Board. To his wife and children, who survive, we extend heartfelt sympathy in their bereavement.

(Data by courtesy of Institution of Civil Engineers)

Langdon Pearse

[1] *Min. Proc.*, Inst. C.E., Vol. 233 (1931–1932, Part I), p. 38.
[2] *Journal*, Inst. C. E., Vol. 16 (1940–1941), p. 3 (March, 1941).

Proceedings of Member Associations

NEW ENGLAND SEWAGE WORKS ASSOCIATION

Fifteenth Annual Meeting

Worcester, Massachusetts, September 13, 1944

The New England Sewage Works Association held its fifteenth annual meeting at the Hotel Bancroft in Worcester, Massachusetts, on Wednesday, September 13, 1944. Eighty-two members and guests were registered at this meeting. President Joseph A. Muldoon presided.

The following papers were presented during the technical session together with discussions by the members:

"Removal and Recovery of Grease from Sewage by Chlorination," by Harry A. Faber, Research Chemist, The Chlorine Institute, New York City.

"Proposed Improvements in Sewage Disposal and Treatment in the Boston Metropolitan District," by Karl R. Kennison, Chief Engineer, Metropolitan District Water Supply Commission, Boston, Massachusetts.

"Operating Staffs for Sewage Treatment Plants," by N. S. Holroyd, partner, Keis & Holroyd, Consulting Engineers, Troy, New York.

"A Modified Index for Sedimentation Efficiency," by Joseph Doman, Supervising Sanitary Engineer, Greenwich Public Works Department, Greenwich, Connecticut.

Immediately after the luncheon served in the Crystal Room of the Hotel Bancroft an address of welcome was given by the Honorable William A. Bennett, Mayor of Worcester. The following awards were made to operators of sewage treatment plants for outstanding annual operation reports: first prize and certificate of merit to John H. Brooks, Jr., Superintendent of Sewers, Worcester, Mass.; second prize to John R. Szymanski, Superintendent, New Britain Sewage Treatment Plant, New Britain Conn.; third prize to Paul V. Fleming, Superintendent, North Adams Sewage Treatment Plant, North Adams, Mass.

Following the presentation of these awards was a demonstration on the "Permutit Seawater 'Desalting' Method," by W. H. Reed of the Permutit Company, New York City.

The technical session of the afternoon included the following program:

Forum on "Federations' Committee Report on 'Qualifications of Sewage Treatment Plant Operators,'" conducted by LeRoy W. Van Kleeck, chairman of the committee.

"Plant Beautification," a discussion opened by Walter Capwell, Superintendent, New London, Connecticut, Sewage Treatment Plant.

"Use of Alum for Drying of Digested Sludge," a discussion opened by Walter Thompson, Superintendent, Stratford, Connecticut, Sewage Treatment Plant.

The following officers were elected for 1945:

President—Frank L. Flood
First Vice-President—George H. Craemer
Second Vice-President—Thomas R. Camp
Secretary-Treasurer—LeRoy W. Van Kleeck
Directors—E. Sherman Chase
Ernest G. Fenn, Jr.
Walter H. Brown, Jr.

LeRoy W. Van Kleeck, *Secretary-Treasurer*

NORTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

Sixteenth Annual Convention

Bismarck, North Dakota, September 12–13, 1944

The Sixteenth Annual Convention of the North Dakota Water and Sewage Works Conference was held at Bismarck on September 12 and 13. Approximately 100 delegates were registered.

The highlight of the Convention was a banquet at which 240 persons were present. An address on his recent tour of the British Isles as a guest of the British Ministry of Information was given by Earl Riley, Mayor of Portland, Oregon.

A panel discussion on the subject, "Planning for Water and Sewage Works Development and Operation," conducted by E. L. Lium, was primarily designed to apprise municipal officials of the problems encountered by water and sewage works men with the hope that interest in such work would be augmented.

Papers presented were:

"The Effect of Potato Dehydration Wastes on Sewage Treatment Plants," by E. L. Lium, Professor of Civil Engineering, University of North Dakota.

"Elevated Tank Maintenance and Cleaning," by M. L. Lovell, City Engineer, Beach, North Dakota.

Officers elected for the Conference year were:

President—F. W. Pinney, Fargo
Vice-President—S. K. Svenkeson, Minot
Secretary-Treasurer—K. C. Lauster, Bismarck
Directors—John Kleven, Grand Forks
Harley Quam, Lisbon
R. J. Lockner, Cooperstown
W. H. Swanson, St. Paul, Minn.

K. C. Lauster, *Secretary-Treasurer*

ROCKY MOUNTAIN SEWAGE WORKS ASSOCIATION

Business Meeting

Denver, Colorado, September 20, 1944

A business meeting of the Rocky Mountain Sewage Works Association was held at Denver, Colorado, on September 20, 1944, with President F. C. Hill presiding.

Dana E. Kepner, director of the Federation Board of Control to fill the unexpired term of L. O. Williams, reported on the Board of Control meeting held in October, 1943.

The Secretary presented a letter received from the Executive-Secretary of the Federation to the effect that the Rocky Mountain Sewage Works Association was eligible to designate one of its members to receive the 1944 *Kenneth Allen Award.* Upon a motion by Carroll Coberly and seconded by John Franks, Dana Ewart Kepner was named to receive the award by virtue of his many years of devoted service to the Association.

Upon J. D. Walker's suggestion it was moved and seconded that an editorial committee be appointed to handle a questionnaire to be sent to the membership concerning their operation and needs. The committee selected consisted of Mike Leonard of Wyoming, Ben Howe of Colorado, and the man who will be appointed as State Engineer in New Mexico.

The following officers were elected for the ensuing year:

President—Dana E. Kepner
Vice-President—Mike Leonard
Secretary-Treasurer—Carroll Coberly

CARROLL COBERLY, *Secretary-Treasurer*

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Date*
New York State Sewage Works Association	Hotel Pennsylvania, New York City, N. Y.	January 19
Texas Sewage Works Section	College Station, Texas	February 5–7
New Jersey Sewage Works Association	Stacy-Trent Hotel, Trenton, N. J.	March 22–23
Montana Sewage Works Association	Lewistown, Montana	April
New England Sewage Works Association	Hotel Statler, Boston, Mass.	May 2
Pacific Northwest Sewage Works Association	Gearhart, Oregon	May 17

Federation Affairs

MINUTES OF MEETING OF 1944 BOARD OF CONTROL

Hotel William Penn, Pittsburgh, Pa., October 11, 1944

The Annual Meeting of the 1944 Board of Control of the Federation of Sewage Works Associations was called to order by Vice President Albert E. Berry in the unavoidable absence of President A. M. Rawn, in the Forum Room of the Hotel William Penn at Pittsburgh, Pa., at 1:10 P.M., October 11, 1944.

Roll call was as follows, a quorum being represented:

PRESENT IN PERSON

Affiliate or Office Represented	*Represented by*
Vice President	A. E. Berry
Past President	G. J. Schroepfer
California Sewage Works Assn.	Wm. A. Allen
Federal Sewage Research Assn.	J. K. Hoskins
Georgia Water and Sewage Assn.	V. P. Enloe
Maryland-Delaware W. and S. Assn.	A. L. Genter
Missouri Water and Sewerage Conf.	W. Q. Kehr
New England Sewage Works Assn.	J. H. Brooks, Jr.
New Jersey Sewage Works Assn.	E. P. Molitor
Ohio Sewage Works Conf.	C. D. McGuire
Pennsylvania Sewage Works Assn.	F. S. Friel
Canadian Inst. on Sewage and Sanitation	Stanley Shupe
Director-at-Large	A. H. Niles
Director-at-Large	C. A. Emerson
Water and Sewage Works Mfgrs. Assn.	K. M. Mann
Water and Sewage Works Mfgrs. Assn.	L. H. Enslow
Water and Sewage Works Mfgrs. Assn.	W. B. Marshall
Publications Committee	F. W. Gilcreas
Sewage Works Practice Committee	Morris M. Cohn

PRESENT IN PERSON, ACTING BY PROXY

Affiliate or Office Represented	*Represented by*
Treasurer	W. H. Wisely (for W. W. DeBerard)
Central States Sewage Works Assn.	G. J. Schroepfer (for B. A. Poole)
Dakota Water and Sewage Wks. Conf.	A. L. Bavone (for K. C. Lauster)
Iowa Wastes Disposal Assn.	T. R. Lovell (for A. L. Wieters)
New York State Sewage Works Assn.	A. S. Bedell (for C. G. Andersen)
Texas Sewage Works Section	C. A. Emerson (for W. S. Mahlie)
Director-at-Large	H. S. Hutton (for W. J. Orchard)

By motion, seconded and carried, the minutes of the Board of Control meetings held at Chicago on October 20 and 23, 1943, were approved as published in SEWAGE WORKS JOURNAL, 16, 184.

It was moved that henceforth the Executive Secretary furnish each member of the Board a complete page proof of the minutes of all Board of Control meetings as soon as such proofs become available. Seconded and carried.

The Executive Secretary-Editor presented his report * for the year ended September 30, 1944. Particular attention was directed to the progress made in Federation activities, membership, sale of advertising and financial position. The report was accepted by motion, seconded and carried.

The report of the Treasurer was read by the Executive Secretary in the absence of Mr. DeBerard. The report stated that the unencumbered total balance in all banks as of September 30 was $19,121.31, distributed as follows:

Bank		Balance at September 30
First National (Champaign)	$6,025.32	
Less checks not cleared	746.94	$ 5,278.38
Busey's State (Urbana)		6,091.29
Continental-Illinois (Chicago)		7,751.64
Total Balance in Banks		$19,121.31

It was pointed out that these balances were in agreement with those indicated in the financial report of the Executive Secretary and with the statements provided by the various banks. With reference to the $7,000 in Series "G" U. S. Government bonds held by the Federation, the report stated that these bonds are now kept in a safe deposit box in the First National Bank of Champaign, which box is held in the name of the Federation with keys in the possession of the Treasurer and of the Executive Secretary. By motion, regularly seconded and carried, the report was accepted subject to the annual audit.

The report of the Executive Committee, offering the following three recommendations, was presented:

(1) The Convention Meeting Place Committee unanimously recommended that the 1945 Annual Meeting be held at Toronto, Ontario, Canada. This Committee urges approval by the Board of Control of that recommendation.

(2) The following budget for the fiscal year 1945 has been prepared by the Financial Advisory Committee and adoption by the Board of Control is recommended.

Receipts	*1945 Buget*
Member Dues	
Active	$ 8,400
Corporate	125
Associate	1,300
Nonmember Subscriptions	1,900
Advertising (Net)	12,000
Sale Misc. Publications (Net)	400
W. & S. Wks. Mfgrs. Contribution	5,000
Miscellaneous Income	500
	$29,625
Expenses	
Journal Printing and Mailing	$12,000
Executive Secretary—Salary	6,500
Office Salaries	5,000
Office Rent	720
Office Expense	1,400
Travel Expense	1,000
Editorial Expense	900
Administration Expense	300
Committee Expense	1,000
Convention Expense	400
Contingencies	405
	$29,625

* Published in entirety elsewhere in this issue.

(3) Subject to approval by the Finance Advisory Committee, it is recommended that an additional $8,000 of Federation funds now held in banks be invested in 2½%, Series "G," U. S. Government bonds.

By motion, regularly seconded and carried the above recommendations were accepted and favorable action urged by the 1945 Board.

Chairman Schroepfer presented the report of the General Policy Committee, which report contained recommendations concerning additional recognition by the Federation of the need for expanded programs in the design, maintenance and control of sewage collection systems and in the field of industrial waste treatment. The report was received and recommended for favorable action by the 1945 Board, by motion, seconded and carried.

The report of the Publications Committee was presented by Chairman Gilcreas. Activities of the Committee in developing the program of the Pittsburgh meeting, collaboration with other committees engaged in the production of publications and co-operation with the Editor in matters pertaining to the JOURNAL, were described. The report included the recommendation:

"The Publications Committee recommends that the Executive Secretary-Editor of the Federation be authorized to make any changes in the cover stock of the JOURNAL, consistent with maintaining the standard of appearance of the JOURNAL, that he may deem desirable from the point of view of more complete usage of the cover for advertising space."

By motion, regularly seconded and carried, the report was approved, with thanks to the Committee.

The report of the Organization Committee was next presented as follows:

"The activities of this Committee have been quite limited, and the report is correspondingly brief. During the year the amended constitution and by-laws of the Texas Sewage Works Section were submitted for review and were recommended to the Board of Control for acceptance.

"The Articles of Association of the Institute of Sewage Purification were submitted through Mr. W. F. Freeborn, 34 Cardinal's Walk, Hampton-on-Thames, Middlesex, England. The constitution of the organization is now undergoing change and pending such change, it is believed that the present Articles of Association may be regarded as a basis for an official tie between the Institute of Sewage Purification and this Federation. The Organization Committee recommends that suitable Board of Control action be taken to recognize and extend to the members of the Institute the privileges of membership in the Federation.

"The Ohio Conference on Sewage Treatment has revised Articles III and IV of its constitution to provide for corporate membership. The approval of this change has been recommended by the Organization Committee.

"The Committee again recommends to the Board of Control that the National emergency be recognized as sufficient reason for a further delay on the part of certain member organizations in submitting their constitution and by-law changes and that suitable action be taken by the Board of Control to continue the affiliation of the following associations which have not as yet submitted constitution and by-law changes, as nominal members of the Federation for the ensuing year:

Arizona
Georgia
Iowa
Maryland-Delaware
Oklahoma
Pacific Northwest
Pennsylvania

"In the cases of the Pacific Northwest Association, the Missouri Conference, and the Pennsylvania Association, certain recommendations were made by the Committee during the year 1942–43 upon which no action has as yet been recorded."

By motion, regularly seconded and carried, the report was approved.

The constitution and by-laws of the Georgia Water and Sewage Association, as amended in September, 1944, was presented for approval by the Board. The instrument was approved subject to the review of the Organization Committee, by motion, seconded and carried.

It was moved that the Organization Committee continue and intensify its efforts to strengthen the sewage works representation in those Member Associations serving the water and sewage works fields jointly. Seconded and carried.

Chairman Cohn presented the report * of the Sewage Works Practice Committee, summarizing the progress made in judicial matters referred to the Committee and the status of the several manuals of practice now in preparation. The report was accepted with commendation to the Committee, by motion, seconded and carried.

The report * of the Research Committee, next presented, reviewed the trends in research under wartime conditions and included substantiating statistics. By motion, seconded and carried, the report was accepted with commendation to the Committee.

The report of the Committee on Standard Methods of Sewage Analysis was presented as follows:

> "There is little report on the work of the Committee on Standard Methods since its immediate responsibility was fulfilled early this year when the complete material on sewage analyses for the Ninth Edition was turned over to Chairman John F. Norton.
>
> "Owing to the lack of adequate personnel in the offices engaged in the publication of the Ninth Edition, it appears that publication may be delayed to such an extent that certain currently proposed methods may require further revision. In view of these delays, the writer has suggested to Dr. Norton that the new material in the section on water analyses as proposed for the Ninth Edition be published in the near future in the journal of the A.W.W.A. and that the new material on sewage analyses be published in SEWAGE WORKS JOURNAL. Doctor Norton has indicated that this procedure might be an acceptable solution to the problem and proposes to take it up with officials of A.W.W.A. and A.P.H.A. in a conference which is to be held late in September.
>
> "It is recommended that the Board of Control give approval at this time to the publication of the section on sewage methods in SEWAGE WORKS JOURNAL in case it is decided by the Joint Committee that this procedure offers the best means of making the latest revisions in methods available to the field at the earliest time."

By motion, seconded and carried, the report was approved and it was ordered that, in the event that the Ninth Edition of *Standard Methods of Water and Sewage Analysis* is likely to be delayed for as long as one year, the revised sewage methods as prepared by the Committee be published in an early issue of the JOURNAL, subject to the decision of the Publications Committee that the material is in general accord with the editorial policy of the JOURNAL.

Mr. Cohn called attention to the constitutional requirement that any publication which undertakes to present technical standards in the name of the Federation must clear through the Sewage Works Practice Committee. It was moved, seconded and carried that the revised methods of sewage analyses, as proposed to be published, be referred to the Sewage Works Practice Committee for a report to the 1945 Board on October 14.

Next to be presented was the report * of the Committee on Sewage Works Nomenclature which reviewed the past work of A.S.C.E. and A.P.H.A. in publishing definitions of terms used in the sewage works field and described the development of the Joint Committee, comprising representatives of A.S.C.E., A.P.H.A., A.W.W.A. and the Federation, which is currently engaged in producing a glossary of water control engineering. The glossary is now in the course of editing and is expected to be ready for publication in 1945. During the discussion on the report, the Executive Secretary presented the

* Published in entirety elsewhere in this issue.

result of the letter ballot of the Board which was taken in July on the question of Federation participation in production of the glossary and immediate appropriation of $300 as the Federation's pro-rata contribution toward the cost of editing. Final tabulation of the ballots was: 31 in favor, 1 ballot not marked, and 8 ballots not voted, of the total of 40 ballots distributed. By motion, seconded and carried, the report was accepted as a statement of progress.

The Committee on Operation Reports presented a report containing recommendations for the establishment of an annual award for the outstanding sewage works operation report of each year, with each Member Association to be eligible to furnish one entry annually for judgment by the Committee. The report was received with a recommendation for favorable action by the 1945 Board, by motion, seconded and carried.

The report of the Committee on Publicity and Public Relations, listing several possible activities for the improvement of public relations and of the welfare of workers in the sewage works field, was presented. By motion, seconded and carried, the report was accepted and the suggestions referred to the Executive Secretary for attention, the Committee to be discharged with thanks for its past service.

No new report was presented by the Committee on Operator's Qualifications, the 1943 report (see THIS JOURNAL, 15, 1235) having been ordered presented to the membership for open discussion in the program of the 1944 Annual Meeting. The Executive Secretary advised that arrangement had been made for such discussion on October 14, 1944.

The report * of the War Services Committee, describing the present status of priorities, manpower, and civilian defense functions as they affect the sewage works field, was next presented. A plan for the joint action of nine national utility organizations in disaster emergencies, as proposed by the Technical Board of O.C.D. prior to its dissolution, was reviewed and reference made to the usage of civilian defense facilities on Long Island during the recent hurricane. The report closed with the recommendation:

> "Since most of its activities as a War Service Committee are being better performed through other channels, that its services be terminated with this report. If this does not seem feasible to the Board, it is recommended that the Committee should be dissolved with the elimination of either Germany or Japan from active hostilities."

By motion, seconded and carried, the report was accepted and the Committee discharged in accordance with its request.

The Executive Secretary read the results of the letter ballot of the Board in August on the report of the Committee on Honorary Membership. This report contained a unanimous nomination of Floyd William Mohlman to the grade of Honorary Member in accordance with a resolution * submitted by the Central States Sewage Works Association. The Executive Secretary was directed to cast a unanimous ballot for Dr. Mohlman's election to the grade of Honorary Member, by motion, seconded and carried.

The report * of the Committee on Awards was presented, the following recipients being recommended for recognition in 1944:

Award	*Recipient*
Harrison Prescott Eddy	John Raymond Snell
George Bradley Gascoigne	James T. Lynch, Uhl T. Mann
Charles Alvin Emerson	Willem Rudolfs
Kenneth Allen:	
Canadian Inst. on Sewage and San.	Albert Edward Berry
Georgia Water and Sewage Assn.	Van Porter Enloe
Maryland-Delaware W. and S. A.	Albert Legrand Genter
New England Sewage Works Assn.	F. Wellington Gilcreas
New York State Sewage Wks. Assn.	Charles A. Holmquist
Rocky Mountain S.W.A.	Dana Ewart Kepner
California Sewage Works Assn.	Leon Benedict Reynolds
Dakota Water and Sewerage Conf.	Wilson Waldo Towne

* Published in entirety elsewhere in this issue.

By motion, seconded and carried, the report was accepted and the awards approved as recommended.

A motion was made that future Awards Committees be instructed to have their reports in the hands of the Executive Secretary by August 1 of each year, for presentation to the Board of Control by letter ballot prior to the Annual Meeting. Seconded and carried.

The report of the Committee on Water and Sewage Works Development was presented by C. A. Emerson, Federation representative on this Joint Committee. The report summarized the accomplishments of the Committee in the past year and presented policies to govern future operations. It was moved, seconded and carried that the report be approved with the exception of the second paragraph on page 13, which dealt with policy on Federal financial aid in public works, and that the Committee be continued through 1945.

For the guidance of Federation representatives in the Joint Committee on Water and Sewage Works Development, it was moved that it is the sense of this Board that the Federation is in favor of Federal loans and grants toward the construction of sewage works only when it has been determined that the municipality is unable to finance such necessary works. Motion seconded and carried.

The Executive Secretary presented an application for admission into the Federation of the Montana Sewage Works Association, stating that the constitution and by-laws of the applicant had been approved by the Organization Committee. The application was approved and the Montana Sewage Works Association admitted as the 27th Member Association of the Federation, by motion, seconded and carried.

The Executive Secretary presented applications for admission into the Federation as Associate Members of the following corporations:

Mine Safety Appliances Company
Hersey Manufacturing Company
Ampco Metal, Incorporated
Fairbanks, Morse and Company
Hardinge Company, Incorporated
James A. Munroe and Sons

The applications were approved by motion, seconded and carried.

The Executive Secretary requested a statement of policy from the Board regarding the extent of Federation participation in legislative matters, several proposed measures of interest to the sewage works field having been referred to his office during the past year. It was pointed out that the Charter under which the Federation is incorporated contains the following statement:

> "The Federation shall be organized and operated exclusively for the scientific and educational purposes herein stated and . . . no part of its activities shall be devoted to carrying on propaganda or otherwise attempting to influence legislation."

It was moved, seconded and carried that it is the sense of this Board that the Federation express its views on legislative matters which affect the Federation and are not in conflict with the Charter.

By motion, seconded and carried, the Rowan Bill (H.R. 3610), introduced November 4, 1943, was referred to the Executive Committee.

The Executive Secretary was instructed to provide each member of the Board with a copy of the agenda at all future meetings.

Vice President Berry issued a call for a meeting of all Directors representing Member Associations to sit as an Election Committee in a session immediately following adjournment of this meeting.

The meeting adjourned *sine die* at 5:20 P.M.

W. H. Wisely, *Executive Secretary*

Approved:
A. E. Berry, *Presiding*

MINUTES OF MEETING OF ELECTION COMMITTEE

Hotel William Penn, Pittsburgh, Pa., October 11, 1944

The called meeting of the 1944 Election Committee of the Federation of Sewage Works Associations was brought to order at 5:25 P.M., October 11, 1944, in the Forum Room of the Hotel William Penn at Pittsburgh, Pa. Vice President A. E. Berry presided in the unavoidable absence of President A. M. Rawn.

Roll call of Directors representing Member Associations was as follows:

PRESENT IN PERSON

Member Association Represented	*Director*
California Sewage Works Assn.	Wm. A. Allen
Federal Sewage Research Assn.	J. K. Hoskins
Georgia Water and Sewage Assn.	V. P. Enloe
Maryland-Delaware W. and S. Assn.	A. L. Genter
Missouri Water and Sewerage Conf.	W. Q. Kehr
New England Sewage Works Assn.	J. H. Brooks, Jr.
New Jersey Sewage Works Assn.	E. P. Molitor
Ohio Sewage Works Conf.	C. D. McGuire
Pennsylvania Sewage Works Assn.	F. S. Friel
Canadian Inst. on Sewage and Sanitation	Stanley Shupe

PRESENT IN PERSON, ACTING BY PROXY

Member Association Represented	*Represented by*
Dakota Water and Sewage Works Conf.	A. L. Bavone (for K. C. Lauster)
Iowa Wastes Disposal Assn.	T. R. Lovell (for A. L. Wieters)
New York State Sewage Works Assn.	A. S. Bedell (for C. G. Andersen)
Rocky Mountain Sewage Works Assn.	G. J. Schroepfer (for D. E. Kepner)
Texas Sewage Works Section	C. A. Emerson (for W. S. Mahlie)

The above representation constituted a quorum.

In response to a call for nominations to the office of President for the year 1944–45, E. A. Berry (Canadian Institute) was duly nominated and a motion to close the nominations was seconded and carried. The election of Dr. Berry to the office of President was confirmed by *viva voce* vote and so declared.

Mr. J. K. Hoskins (Federal) was nominated to the office of Vice President for the year 1944–45 upon call for nominations to that office. There were no further nominations and a motion was made, seconded and carried, that the nominations be closed. The election of Mr. Hoskins as Vice President was confirmed by *viva voce* vote and so declared.

A request for nominations to the office of Treasurer for the year 1944–45 brought a renomination of Mr. W. W. DeBerard (Central States). No other names were offered and a motion to close the nominations was regularly seconded and carried. By *viva voce* vote, the election of Mr. DeBerard was confirmed and so declared.

Nominations for the office of Director-at-Large for a three-year term ending in October, 1947, were then in order. Dr. F. W. Mohlman (Honorary, Central States) was nominated and a motion made, seconded and carried that the nominations be closed. The election of Dr. Mohlman was confirmed by *viva voce* vote and so declared.

The meeting of the Committee was adjourned *sine die* at 5:45 P.M.

Approved: A. E. BERRY, *Presiding*

MINUTES OF MEETING OF 1945 BOARD OF CONTROL

Hotel William Penn, Pittsburgh, Pa., October 14, 1944

The organization meeting of the 1945 Board of Control of the Federation of Sewage Works Associations was called to order at 1:15 P.M., October 14, 1944, in the Adonis Room of the Hotel William Penn, Pittsburgh, Pa. The meeting was called to order by President A. M. Rawn.

Roll call was as follows, a quorum being represented:

PRESENT IN PERSON

Affiliate or Office Represented	*Represented by*
President	A. M. Rawn
President-elect	A. E. Berry
Vice President-elect	J. K. Hoskins
Central States Sewage Works Assn.	Maj. B. A. Poole
Florida Sewage Works Assn.	F. A. Eidsness
Federal Sewage Research Assn.	M. LeBosquet, Jr.
Maryland-Delaware W. and S. Assn.	A. L. Genter
Missouri Water and Sewerage Conf.	W. Q. Kehr
New England Sewage Works Assn.	J. H. Brooks, Jr.
New York State Sewage Works Assn.	C. G. Andersen
Ohio Sewage Works Conference	C. D. McGuire
Pacific Northwest Sewage Works Assn.	M. S. Campbell
Pennsylvania Sewage Works Assn.	F. S. Friel
Rocky Mountain Sewage Wks. Assn.	D. E. Kepner
Canadian Institute on Sewage and Sanitation	Stanley Shupe
Director-at-Large	F. W. Mohlman
Director-at-Large	C. A. Emerson
Director-at-Large	W. J. Orchard
Water and Sewage Works Mfgrs. Assn.	F. W. Lovett
Water and Sewage Works Mfgrs. Assn.	W. B. Marshall
Water and Sewage Works Mfgrs. Assn.	L. H. Enslow
Publications Committee	F. W. Gilcreas
Sewage Works Practice Committee	Morris M. Cohn
Research Committee	Willem Rudolfs

PRESENT IN PERSON, ACTING BY PROXY

Affiliate or Office Represented	*Represented by*
Arizona Sewage and Waterworks Assn.	W. D. Hatfield (for P. J. Martin)
California Sewage Works Assn.	W. A. Allen (for C. C. Kennedy)
Dakota Water and Sewage Works Conf.	A. L. Bavone (for K. C. Lauster)
Georgia Water and Sewage Assn.	V. P. Enloe (for new Director)
Iowa Wastes Disposal Assn.	T. R. Lovell (for J. W. Pray)
Michigan Sewage Works Assn.	M. P. Adams (for W. F. Shepherd)
New Jersey Sewage Works Assn.	L. J. Fontinelli (for E. P. Molitor)
Oklahoma Water and Sewage Conf.	A. S. Bedell (for F. S. Taylor)
Texas Sewage Works Section	E. J. M. Berg (for W. S. Mahlie)

The Executive Secretary presented the report of the Election Committee, which report listed the following officers to have been elected for the terms indicated: A. E. Berry, President; J. K. Hoskins, Vice President; W. W. DeBerard, Treasurer (all to serve until October, 1945); F. W. Mohlman, Director-at-Large (to serve until October, 1947).

In relinquishing the chair to President-elect Berry, Mr. Rawn expressed gratification at the progress made by the Federation in the past year and graciously acknowledged the assistance and co-operation extended him by all officers, committee chairmen and members of the Board.

In assuming the chair, President Berry bespoke his appreciation for the honor bestowed upon him by the Federation and gave assurance that his best efforts, energy and enthusiasm would be devoted toward the duties of his office. Continuing, President Berry said, "I would be remiss in my duty if I did not express to the retiring President, Mr. A. M. Rawn, the sincere appreciation of the Board, and the members of the Federation, for the high and effective manner in which he has carried on the duties of President during the past year. He has brought prestige and honor to the position, and has made a most valuable contribution during his term of office. As an expression of our appreciation I suggest that this Board stand and pay tribute to the retiring President." (Applause.)

There having been no opportunity to prepare formal minutes of the meeting of the 1944 Board held on October 11, the Executive Secretary reviewed the various actions taken, by reference to his notes.

The Executive Secretary presented a preliminary report for the Convention Management Committee on the registration and finances of the Annual Meeting just terminated. Total registration was 524, including 489 men and 35 ladies. Receipts from registration and sale of tickets totalled about $3,900 with expenses aggregating approximately $3,850, leaving an apparent surplus of about $50. By motion, seconded and carried, the Executive Secretary was directed to send an individual expression of appreciation in behalf of the Board to all members of the committees which functioned in connection with the Pittsburgh meeting, and to the management of the Hotel William Penn, for their respective contributions to the success of the 1944 Annual Meeting.

Chairman Orchard presented a verbal report for the Finance Advisory Committee. Approval of the audit made as of December 31, 1943, was given with commendation to the auditors. Reference was made to the increasing net worth of the Federation and to the cash surplus now held in banks. The following recommendations were offered for individual action by the Board:

1. It was moved that the Finance Advisory Committee, with the approval of the President, be authorized to invest a suitable portion of the cash on hand in legal securities of the U. S. or Canada. Motion duly seconded and carried.

2. It was moved that the 1945 budget, as presented by the Executive Committee and approved by the 1944 Board, be adopted. Motion duly seconded and carried.

3. It was moved that the Finance Advisory Committee and Secretary be authorized to determine the amount of the prizes to be offered for a membership contest in 1945 and to determine the source of such funds from the budgeted appropriations. Motion duly seconded and carried.

The report of the Operation Reports Committee, received by the 1944 Board and recommended to this Board for favorable action, was taken up for consideration. It was moved, seconded and carried that the report be accepted as a statement of progress and that the Committee be continued. It was the sense of the Board that a complete report providing for the mechanics of an Operation Report Award be submitted for action at the 1945 meeting of the Board.

Chairman Cohn reported for the Sewage Works Practice Committee, presenting the results of a poll of the Committee on the revised standard methods of sewage analysis as proposed to be published in the JOURNAL, which action had been requested by the 1944 Board for report at this time. Of eleven members of the Committee, seven members voted in favor of publication of the material and four members did not vote. Mr. Cohn interpreted this vote as approval of the revised standard methods by his Committee and moved for confirmation by the Board. Motion seconded and carried.

President Berry presented a tentative schedule of 1945 committee appointments which had been prepared for the guidance of the Board. First to be taken up were the constitutional committee appointments. In the discussion, it was pointed out that Dr. Rudolfs desired to be relieved temporarily of his duties as Chairman of the Research

Committee and the following appointments were approved, by motion, seconded and carried:

Executive Committee

A. E. Berry,* *Chairman* (Canadian Inst.)
W. B. Marshall (Mfgrs. Assn.)
F. S. Friel * (Pennsylvania)
Dana E. Kepner * (Rocky Mountain)
C. A. Emerson * (Director-at-Large)

General Policy Committee (Latest living Past President as Chairman, three Directors, three Members-at-Large, three of total to be operators. Three-year terms)

A. M. Rawn,* *Chairman* (Past President, Operator)
S. R. Probasco, 1945 (New Jersey, Operator), Member-at-Large
J. H. Brooks, Jr., 1946 (New England, Operator), Director
A. S. Bedell, 1946 (New York), Member-at-Large
M. S. Campbell,* 1947 (Pacific Northwest), Director
M. LeBosquet, Jr.,* 1947 (Federal), Director
D. E. Bloodgood,* 1947 (Central States), Member-at-Large

Publications Committee (Editor and at least four Members-at-Large)

F. W. Gilcreas, *Chairman* (New England)
W. H. Wisely (Editor)
F. W. Mohlman (Advisory Editor)
Rolf Eliassen (New York)
Carl Green (Pacific Northwest)
F. M. Veatch, Jr. (Kansas)
C. C. Larson (Central States)

Organization Committee (Three Members-at-Large)

Earnest Boyce, *Chairman* (Kansas)
C. R. Compton (California)
R. H. Suttie (New England)

Sewage Works Practice Committee (Editor and at least four Members-at-Large)

Morris M. Cohn, *Chairman* (New York)
W. H. Wisely (Editor)
F. W. Mohlman (Advisory Editor)
C. E. Keefer (Maryland-Delaware)
J. H. Brooks, Jr. (New England)
G. P. Edwards (New York)
H. F. Gray (California)
J. J. Wirts (Ohio)
J. R. Downes (New Jersey)
A. H. Niles (Ohio)
Langdon Pearse (Central States)
L. W. Van Kleeck (New England)
F. W. Gilcreas (New England)

Research Committee (At least four Members-at-Large appointed by Chairman, President concurring)

H. Heukelekian,* *Chairman*

The following discussion and minor revisions to the tentative special committee schedules, the following appoints were approved for 1945, by motion, seconded and carried:

* New member of committee.

Joint Committees of Some Years Standing

Committee on Standard Methods of Sewage Analysis

W. D. Hatfield, *Chairman* (Central States)
G. E. Symons (New York)
S. E. Coburn (New England)
G. P. Edwards (New York)
E. W. Moore (New England)
D. E. Bloodgood (Central States)
F. W. Gilcreas (New England)
E. F. Hurwitz (Central States)
Keeno Fraschino (California)
W. S. Mahlie (Texas)
M. Starr Nichols (Central States)
Richard Pomeroy (California)
C. C. Ruchhoft (Federal)
Willem Rudolfs (New Jersey)
H. W. Gehm * (New Jersey)
H. Heukelekian * (New Jersey)

Committee on Sewage Works Nomenclature (Three members serving with similar committees of A.S.C.E. and A.P.H.A.)

C. J. Velz, *Chairman* (New York)
C. A. Emerson * (Honorary)
C. E. Keefer (Maryland-Delaware)

Committee on Water and Sewage Works Development

C. A. Emerson, *Chairman* (Honorary)
G. J. Schroepfer (Central States)

Special Convention Committees

Convention Meeting Place Committee (President, Vice President, Past President and Secretary of Federation; President, chairman of Sewage Works Div. and Secretary-Manager of W. and S. Works Mfgrs. Assn.)

A. E. Berry, *Chairman* (President F.S.W.A.)
J. K. Hoskins * (Vice President F.S.W.A.)
A. M. Rawn (Past President F.S.W.A.)
W. H. Wisely (Secretary F.S.W.A.)
E. M. Jones * (President Mfgrs. Assn.)
L. H. Enslow * (Chairman, Mfgrs. Sewage Works Division)
A. T. Clark (Secretary-Manager Mfgrs. Assn.)

Publicity and Attendance Committee

L. H. Enslow, *Chairman*
E. J. Cleary
M. M. Cohn
Wm. S. Foster
A. Prescott Folwell
J. P. Russell
James A. Daly *

Convention Management Committee (Three F.S.W.A. representatives, two Mfgrs. Assn. representatives)

A. E. Berry *, *Chairman* (President F.S.W.A.)
Stanley Shupe * (Director F.S.W.A.)
W. H. Wisely (Secretary, F.S.W.A.)
W. J. Orchard * (Director, Manufacturer)
A. T. Clark (Secretary-Manager Mfgrs. Assn.)

* New member of committee.

Other Special Committees

Awards Committee

G. P. Edwards, *Chairman* (New York)
E. S. Chase (New England)
L. F. Warrick (Central States)
G. M. Ridenour * (Michigan)

Operation Reports Committee

H. E. Babbitt, *Chairman* (Central States)
Wm. A. Allen (California)
W. F. Shepherd (Michigan)

Operator's Qualifications Committee

L. W. Van Kleeck, *Chairman* (New England)
Wm. A. Allen * (California)
E. P. Molitor * (New Jersey)

Finance Advisory Committee

W. J. Orchard, *Chairman*
A. M. Rawn (Past President)
A. E. Berry * (President)

Industrial Wastes Committee (To be selected by Chairman, President concurring)

F. W. Mohlman, *Chairman* (Central States)

Honorary Membership Committee (President and four living Past Presidents, senior Past President as Chairman)

C. A. Emerson, *Chairman*
A. S. Bedell
G. J. Schroepfer
A. M. Rawn
A. E. Berry

The action of the 1944 Board in dissolving the War Service Committee was confirmed by motion, seconded and carried.

By motion, seconded and carried, it was ordered that, in the event of any national emergency or disaster, the Executive Committee is empowered to appoint a special Emergency Committee to provide such service as may be within its power. It was the sense of the Board that the Sewage Works Practice Committee might well give consideration to the production of a manual of practice on emergency sanitation service.

The report of the 1944 General Policy Committee, referred to this Board for action, was taken up for consideration. The report follows:

"Your General Policy Committee has, in the past year, given consideration to various matters in the Federations' interest. It is pleasantly cognizant of the present desirable situation of the Federation, both from the standpoint of increased service and activity, and from the membership viewpoint. It recognizes that the revitalization program envisioned and developed several years ago has brought definite results, possibly more real and tangible than the leaders in this movement could possibly have hoped for.

"In the interest of providing even greater service to present and prospective members of Associations comprising the Federation, your Committee makes the following recommendations:

"(1) That in view of the importance of the sewer system from a financial standpoint, and its relation with the operation of sewage treatment plants, a Federation of Sewer System Committees be appointed whose function and duty it shall be to promote the closer relationship between this field of sanitary engineering and the

* New member of committee.

allied activity of sewage treatment plant operation. Their activities shall include the direction of a program aimed at the development of this field of activity, from the engineering design and operation standpoint, as well as in the interest of men in this field, whose activities should be associated with those of the Federation.

"(2) That because of the effect of industrial wastes in sewage treatment plant operation and stream pollution, and the necessity and desirability of a closer association between industrial representatives in this field and the Federation, the Industrial Wastes Committee, the formation of which was authorized by the Board of Control in October, 1943, be continued and be made a standing Committee of the Federation. In addition to the investigational and technical phases of its activity, this committee shall direct a program, planned to acquaint workers in the industrial waste field with the opportunities of service from the Federation.

"(3) That proper provision for these two phases of activity continue to be made in the programs of the Federation and in the SEWAGE WORKS JOURNAL, and that activity in this regard be encouraged in the Member Associations."

A motion was made and seconded that a Committee on Sewer Systems be appointed in accordance with the first recommendation above. When the ensuing discussion brought forth the conclusions that considerable attention has been given recently to sewer system design, operation and maintenance in the JOURNAL and in the program of the Pittsburgh meeting, and that the functions of the proposed committee would invade to some extent the rights of the Member Associations, the motion was withdrawn with consent of the second. A motion was made, seconded and carried that it was the sense of the meeting that "proper provision *and emphasis* for these two phases of activity (i.e., sewage collection system functions and industrial waste treatment) continue to be made in the programs of the Federation and in SEWAGE WORKS JOURNAL, and that these activities be encouraged in the Member Associations."

Dr. Rudolfs called attention to the wide variation and irrelevancy which is now prevalent in the reporting of research and operation data and pointed out that the Federation could be of service in bringing about a uniform and standard practice in reporting such data. It was moved, seconded and carried that a Sub-Committee on Presentation of Sewage Works Data be appointed in the Sewage Works Practice Committee to fill this need.

Upon recommendation of the Executive Secretary, the following depositories for Federation funds were approved by motion, seconded and carried:

Continental Illinois National Bank and Trust Company of Chicago
Busey's State Bank of Urbana, Illinois
First National Bank of Champaign, Illinois

It was moved that the Finance Advisory Committee be empowered to select the auditors to conduct the audit of Federation accounts as of December 31, 1944. Motion seconded and carried.

The recommendation of the Executive Committee, urged for favorable action by the 1944 Board, that the 1945 Annual Meeting of the Federation be held in Toronto, Canada, was adopted by motion, duly seconded and carried.

The matter of the dates of the 1945 Annual meeting, with a preference for the month of September, was referred to the Convention Management Committee with power to act upon approval of the Executive Committee, by motion, seconded and carried. It was the sense of the meeting that every effort be made to correlate the time of the Federation meeting with that of the A.P.H.A. meeting, insofar as possible.

The following resolution pertaining to currently considered Federal stream pollution control legislation was introduced by Mr. Rawn:

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.

By motion, duly seconded and carried, the resolution was referred to the General Policy Committee with a request for a report within 90 days to the Executive Secretary, for his transmission to the Board for letter ballot.

It was moved, seconded and carried that the principle of annual membership contests be continued, and that suitable rules for such a contest in 1945 be developed by a committee comprising the President, Executive Secretary and a third member to be appointed by the President.

Mr. Emerson pointed out that the designation of the 1944 Annual Meeting as the fifth to be held by the Federation was incorrect, because annual meetings of the Board of Control have been held each year since the Federation was organized in 1928. Accordingly, it was moved, seconded and carried that the 1944 meeting be designated as the Sixteenth Annual Meeting of the Federation and future annual meetings be numbered therefrom.

Mr. Emerson referred to the continuing growth and interest in the Quarter Century Operator's Club and suggested that the Federation supply an official certificate of membership to each present and future member of the club. Following further discussion, it was moved, seconded and carried that the matter be referred to the General Policy Committee with a request for a report as promptly as feasible, in order that the question may be put to the Board for letter ballot at the earliest possible date.

Adjournment to the next annual meeting or upon call of the President was moved, seconded and carried at 4:05 P.M.

W. H. WISELY, *Executive Secretary*

Approved:

A. E. BERRY, *President*

REPORT OF EXECUTIVE SECRETARY-EDITOR

Year Ended September 30, 1944

All time highs in services to members, general activities, memberships, and several revenue classifications denote the continuing growth and strength of the Federation during the past year. While these accomplishments have been gratifying, some additional progress might have been possible were it not for the minor problems which were incident to the establishment of the new secretarial headquarters and the transfer of all functions to that office in January, 1944.

Since the equipping and opening of the new headquarters office on January 1, the Executive Secretary has been on full-time service. The office staff comprises an editorial assistant, a bookkeeper and a stenographer-clerk and has proven adequate to meet present needs. All details of business management and operation, including JOURNAL editorial and advertising functions, are now performed at the secretarial headquarters.

SEWAGE WORKS JOURNAL

Assumption of the duty of editing the JOURNAL took place with the January, 1944, issue. In accordance with the instructions of the Board, there has been strict adherence to the original editorial policies and only a few minor changes were made in format and makeup. The advice and guidance of Advisory Editor Mohlman were sought on numerous occasions and his gracious assistance is gratefully acknowledged.

Pages of paid advertising carried in each of the first five issues of 1944 established the highest totals in the history of the JOURNAL. The following tabulation shows the trend in paid advertising for the past three years:

Issue	*1942*	*1943*	*1944*
January	24 20/24	26 11/24	31 8/24
March	29 4/24	31 17/24	33 20/24
May	27 3/24	32 5/24	34 4/24
July	28 21/24	31 11/24	34 16/24
September ...	45 23/24	48 14/24	50 16/24
November	27 5/24	32 8/24	35 12/24
Totals ...	183 4/24	202 18/24	220 4/24

Paid circulation of the JOURNAL also reached its highest level, totaling 3,516 as of September 30, 1944, including 3,067 member and 449 non-member subscriptions. This represents an increase of 14 per cent for the year.

Co-operation with Member Associations

Wherever possible, the Executive Secretary has assisted and co-operated with Member Association secretaries in all matters pertaining to administration, operation, and development. The Executive Secretary also attended and participated in the programs of the following Member Association meetings during the year:

Association	*Date and Place of Meeting*
New York S.S.W.A.	New York City, Jan. 21, 1944
Texas Sewage Works Section	College Station, Feb. 1, 1944
New Jersey S.W.A.	Trenton, March 23–24, 1944
Michigan S.W.A.	E. Lansing, April 5–6, 1944
New England S.W.A.	Springfield, Mass., May 17, 1944
Central States S.W.A.	Oshkosh, Wis., June 22–24, 1944
Iowa Wastes Disp. Assn.	Ames, September 15, 1944

Other meetings at which the Federation was represented by the Executive Secretary were the Illinois Sewage Works Short Course at Urbana on March 27–31; Indiana Sewage Works Operation Association at Anderson on July 19; and a postwar planning conference sponsored by the Illinois Sanitary Water Board at Springfield on August 22.

Some effort was expended toward the development of new Member Associations and it is anticipated that a new Federation affiliate will be created in Montana in the near future. Preliminary interest has also been developed in Louisiana and Kentucky-Tennessee along these lines.

Committee Functions

In spite of wartime conditions, a great deal of progress was made in various committee activities. The Research, Standard Methods, Awards, Publications, and Operators' Qualifications Committees were well established at the beginning of the year and accomplished their functions effectively. The Sewage Works Practice Committee completed Manual of Practice Number 1 on "Occupational Hazards in the Operation of Sewage Systems" and this manual is expected to be distributed to the membership before the end of this year. Manual of Practice Number 2 on "Sewage Sludge as Fertilizer" is in a late stage of preparation and is expected to be available for distribution in 1945. The Committee on Operation Reports completed basic recommendations for the establishment of an operation reports award.

The Federation is continuing to participate in the Joint Committee on Water and Sewage Works Development. Another Joint Committee activity with A.S.C.E., A.P.H.A., and A.W.W.A. was initiated for the purpose of developing a "Glossary of Water and Sewage Control Engineering."

The Executive Secretary continued his usual participation in the various Convention Management committees in regard to preparations for the Fifth Annual Meeting.

Membership

There was no change in the number of Member Associations affiliated with the Federation during the year but it is gratifying to note that the Sanitary Engineering Division of the Argentina Society of Engineers reinstated its representation in the membership roster. The number of affiliated Member Associations remains at 26, subject to the possible admission of the Montana Sewage Association at the October meeting of the Board of Control.

Due to the very fine work of the Member Association secretaries and membership committees, the total Active membership in these associations reached the highest level

Net Membership of Member Associations *
September 30, 1944

Member Assn.	Membership—September 30, 1944				Total Members 9/30/43	Net Incr.	Per Cent Incr.	New Members Since 9/30/43
	Active		Corp.	Total 9/30/44				
	Regular	Alternate						
Arizona	10	—	—	10	15	−5	—	2
California	287	12	—	299	271	28	10	55
Central States	526	—	12	538	460	78	17	134
Dakota—North	22	—	—	41	32	9	28	14
South	19	—	—					
Federal	102	—	—	102	85	17	20	23
Florida	61	—	—	61	48	13	27	18
Georgia	53	—	—	53	24	29	121	32
Iowa	43	—	—	43	43	—	—	7
Kansas	19	—	—	19	19	—	—	3
Md.-Del.	27	—	—	27	22	5	23	7
Michigan	105	15	—	120	111	9	8	18
Missouri	37	—	—	37	13	24	185	17
New England	159	1	—	160	151	9	6	21
New Jersey	82	—	—	82	66	16	24	22
New York	483	4	1	488	473	15	3	42
No. Carolina	58	—	—	58	55	3	6	7
Ohio	105	—	—	105	90	15	17	20
Oklahoma	5	—	—	5	7	−2	—	1
Pac. Northwest	100	—	—	100	84	16	19	13
Pennsylvania	213	—	3	216	171	45	26	49
Rocky Mt.	71	—	—	71	33	38	115	42
Texas	63	—	—	63	36	27	75	34
Argentina	10	—	—	10	—	10	—	4
Canadian	151	—	—	151	117	34	29	35
I.S.E. (Eng.)	32	—	—	32	33	−1	—	0
I.S.P. (Eng.)	97	—	—	97	85	12	14	8
Totals	2,940	32	16	2,988	2,544	444	17.5	628

* Does not include dual members.

in the history of the Federation. As of September 30, there was a total of 2,972 Active members and 16 per cent Corporate members enrolled in the Member Associations, a gain of 444 or 17.4 per cent during the year. A detailed tabulation of the membership in the various Member Associations is attached herewith; it will be noted that twenty of them show substantial gains.

It will be of interest that the Central State Sewage Works Association has earned the privilege of designating one of its members as the recipient of one of the $100 War Bond membership prizes by virtue of its enrollment of 134 new members since September 30, 1943. The Missouri Water and Sewerage Conference showed the greatest per cent of increase in membership (185%) since the same date and is thereby privileged to name one of its members as the winner of the other $100 War Bond prize.

Membership in the Associate class also reached a new high level of 72 as compared to 65 as of September 30, 1943.

Financial

In accordance with Section 5, Article IV of the by-laws, each member of the Board of Control was furnished statements of receipts and disbursements dated December 31, 1943; March 31, 1944, and June 30, 1944.

Financial progress of the Federation in recent years is shown by the following:

Date	*Net Worth*
December 31, 1940	$ 3,075.78
December 31, 1941	7,098.54
December 31, 1942	13,489.73
December 31, 1943	21,981.73
September 30, 1944	28,299.55

Respectfully submitted,
W. H. Wisely, *Executive Secretary*

REPORT OF SEWAGE WORKS PRACTICE COMMITTEE

September 15, 1944

The Sewage Works Practice Committee has the pleasure to present herewith a brief report of its activities during the year 1943–44.

Again, as in the past, the work of the Committee has been of two types: (1) the serving in a judicial capacity upon standards and specifications as referred to the Federation and (2) work on the Manual of Practice which will eventually span the entire field of sewerage and sewage treatment and will become the official pronouncement of the Federation on matters of design, construction and maintenance.

Judicial Action

In December, 1943, the National Bureau of Standards, U. S. Dept. of Commerce, submitted to Secretary Wisely, the Recommended Commercial Standards for Bituminized-Fibre Drain and Sewer Pipe, TS–3619, with the request that the Federation make recommendation upon these standards. This matter was placed before the Sewage Works Practice Committee and on January 26, 1944, the Chairman circularized all of the members of the Committee, attaching copies of the tentative standards.

The reactions of Committee members were varied and it became evident that many of them had insufficient knowledge on the subject to warrant any conclusions on their part. Considerable correspondence was devoted to this matter, primarily because it represented the first venture of the Federation in the consideration and approval of national standards. In one sense, it showed that the Federation had reached national stature and that its approval was desired; in another sense, it involved grave responsibility on the part of the Federation to make certain that it establish proper policies on matters of this sort.

It was the consensus of opinion of members of the Committee that the Federation should not be placed in the position of approving or disapproving specifications for any special commercial product, and that future approvals of Federal standards should be based upon thorough investigation by special committees which would study all aspects of these problems before recording the views of the Federation.

While this matter was still under consideration by the Committee, the Bureau of Standards of the Dept. of Commerce officially adopted the proposed standards under No. 116–44 for Bituminized-Fibre Drain and Sewer Pipe, effective March 10, 1944, without action by the Federation. This closed the matter to the approval of this Committee because of its feeling that it was not in a position to either approve or disapprove these standards. On February 25, 1944, the Chairman wrote to President A. M. Rawn and stated as follows: "It might appear on the surface that the Committee had wasted considerable time in reviewing a matter which was subsequently taken out of its hands by the action of the Department of Commerce, in unexpectedly approving a specification which it seemed anxious to have us review before it was approved. However, I deem the time and effort as well spent. We have succeeded in getting a clarification of the opinions of the members of our Committee and of you, as President, and we have definite basis upon which to judge future action on matters of this sort. I would say, from the reactions of our Committee, that we must avoid any future action on such particularized materials as are covered by the specification we have just considered. I think that our future policy has been clarified."

Preparation of Manual

As might be expected, work on various Chapters of the Manual of Practice was impeded by the effect of war on committee personnel. However, considerable progress has been made and the present calendar year should see at least one Chapter prepared in final form and printed for distribution to the members. Work has continued on the following Chapters: (1) Use of Sewage Sludge for Fertilizing Purposes; (2) Occupational Health Hazards in the Operation of Sewerage Systems; (3) Maintenance of Sewers and Sewer Appurtenances and (4) Aeration of Sewage.

The subcommittee on the "Use of Sludge for Fertilizing Purposes," under the chairmanship of A. H. Niles, completed a preliminary draft of its proposed Chapter. This material was distributed among members of the Committee and it became evident that it could be reorganized and collated into a Chapter of very great value to the Federation. The subcommittee had accomplished an outstanding job of gathering data on this subject and their efforts are worthy of commendation. Later in 1943, Dr. Mohlman reviewed this material and referred it to Langdon Pearse who offered to reorganize and revise the Chapter. This material is now in his hands, and he has promised early completion of it. It is hoped that this Chapter will soon be ready for approval and publication.

The subcommittee on "Occupational Hazards in the Operation of Sewerage Systems" was under the chairmanship of L. W. Van Kleeck. An effort was made to obtain broad cross-sectional hazard experiences by means of an appeal made in the March issue of the Journal, asking members to supply the Committee with a record of such experiences. The Committee carried its work to completion during the year and after considerable review, this Chapter was placed in the hands of Mr. Wisely for the approval of the Executive Committee, the General Policy Committee and the Publication Committee. The personnel of these Committees have also made many comments and suggestions. While the Executive Committee on September 5 authorized Mr. Wisely to proceed with the printing and distribution of this Manual Chapter, there were a number of suggested changes which have made it impossible to publish this Chapter in time for distribution before the Convention. However, early publication is anticipated.

A revised outline of the chapter on "Aeration of Sewage" has been prepared by a subcommittee headed by John J. Wirts. Mr. Wirts states that his work has been impeded by the war effort and that it now appears impossible to complete the work until after the war. This Committee should be continued because of the importance of the problem it is studying.

The Committee on "Maintenance of Sewers and Sewer Appurtenances," under the chairmanship of John H. Brooks, Jr., has started work and specific assignments have been issued to Messrs. Reuben F. Brown, Los Angeles; Walter H. Brown, Jr., Cranston, R. I.; Roy E. Phillips, Meadville, Pa.; R. L. Patterson, Newport Beach, Calif.; Grant Olewiler, Ardmore, Pa.; C. George Anderson, Rockville Center, N. J.; Richard Pomeroy, Pasadena, Calif.; Robert P. Shea, Boston, Mass.; Geo. E. Fink, Baltimore, Md.; and Benjamin H. Grout.

This Committee has promised a preliminary draft by the October meeting date.

Work should be started on additional Chapters of the Manual, in anticipation of the early cessation of war hostilities and the return of Committee members to more normal conditions.

F. W. Gilcreas has accepted the chairmanship of the Committee to prepare a Chapter on "Use of Chlorine in Sewage Treatment." Another subcommittee on "Sludge Digestion" should be designated. A subcommittee on "Specific Aspects of Cross-connections Hazards in and Appurtenant to Sewerage Systems" has been suggested in lieu of including this matter under the heading of "Occupational Hazards in the Operation of Sewerage Systems." Suggestions are invited on the assignment of other Chapters for 1944–45. During the course of the year, Langdon Pearse and L. W. Van Kleeck have been added to the Committee and M. W. Tatlock has left the Committee while in military service. The splendid co-operation of all members of the Committee, of Chapter Committee chairmen and all Chapter Committee personnel is acknowledged with thanks.

Respectfully submitted,

Morris M. Cohn, *Chairman*
John H. Brooks, Jr.
John R. Downs
G. P. Edwards
H. F. Gray
C. E. Keefer
F. W. Mohlman
A. H. Niles
Langdon Pearse
L. W. Van Kleeck
J. J. Wirts

REPORT OF RESEARCH COMMITTEE

August 15, 1944

The Research Committee has published its customary annual critical review of the literature pertaining to sewage and waste treatment and stream pollution in the March issue of the Journal. In spite of the war a total of 275 papers were reviewed. It appears that the number of papers included in the review have not decreased on account of the war. This is indicated by the number of papers reviewed before and during the war:

1938—190
1939—267
1940—250
1941—232
1942—244
1943—275

It should be kept in mind that only a portion of the papers published are considered worthy of review; papers of a descriptive nature and many which present operating results and which do not materially contribute to new development are not mentioned. On the other hand the committe has been more and more thorough in the search for papers as years passed by. This undoubtedly has made up, in part, for any decrease in original papers published.

In an effort to determine whether the trend in sewage research has been materially influenced by the war and determine in general the direction of sewage research as far as specific topics are concerned, the references cited have been tabulated for the review years 1938 to 1943 inclusive. The reviews under consideration were made by substantially the same committee members. The compilation is of interest.

REFERENCES TO VARIOUS TOPICS

	1938	1939	1940	1941	1942	1943
Biological and chemical	8	29	24	11	14	18
Laboratory and methods	6	17	16	21	12	6
Sedimentation	9	—	13	7	3	7
Filters	9	43	32	31	26	44
Activated sludge	21	21	27	16	13	19
Chlorination	22	43	31	23	26	20
Sludge digestion	19	32	48	45	47	31
Sludge disposal	—	36	18	18	14	29
Mechanical and equipment	17	20	27	10	44	32
Industrial wastes	62	52	44	47	39	49
Stream pollution	17	17	15	18	33	55
Total	190	310	295	247	271	270

The total number of titles printed are somewhat lower than the number of references in this table, because some papers are referred to more than once, and in some cases topics which have been introduced did not run over the entire period.

In general, it appears that published results on fundamental studies of the biology and chemistry of sewage treatment and stream pollution and laboratory methods have decreased. The papers published on filters were substantially influenced by work done on high rate filter devices. Work on activated sludge during the last three years (1941–43) was somewhat less than during the previous three years (1938–40). It appears that the problem of sludge handling and disposal is still of great importance and these problems seem to receive more attention than any other single topic, including industrial waste treatment.

The question of industrial waste treatment has come to the front during the last few years and from general discussions the impression has been created that a considerable amount of work has been done. The references do not indicate this, and as a matter of fact, only 283 out of a total of 1,583 references, or less than 18 per cent of the references pertain to industrial waste treatment. Moreover, the tendency has not been to increase either relatively or absolutely. The field still appears wide open.

Chlorination studies have not increased, the tendency show a decrease. On the other hand the importance of stream pollution and attention given has, surprisingly, increased during the war.

In general, it would seem therefore that the trend in sewage research has been shifted to practical applications and less fundamental study. Work in activated sludge, chlorination, sludge digestion, and industrial wastes has not materially changed. More emphasis has been placed on mechanical development and equipment.

The Research Committee has again made a survey of research projects under study and has listed problems deemed desirable for investigation and study. The problems under study, in addition to those listed, last year were 94. A comparison of the number of titles is as follows:

	1943	*1944*
Sewage	70	35
Industrial waste	41	49
Stream pollution	11	5
Methods	6	5
	128	94

The problems suggested for investigations could be divided into:

	1943	1944
Sewage	14	15
Industrial waste	12	17
Stream pollution	3	0
Methods	2	9
	31	41

The annual review has been frequently commented upon as of value to those who wish to keep up with the literature and cannot read the mass of material printed. The listing of research projects appears to have been of interest and help to a considerable number of people.

Respectfully submitted,
WILLEM RUDOLFS, *Chairman, Research Committee*

REPORT OF COMMITTEE ON SEWAGE WORKS NOMENCLATURE

September 14, 1944

The first effort of formulating definitions of terms used in sewerage and sewage disposal practice was initiated by A.P.H.A. in 1915, the results of which committee work culminated in publication of a list of 97 terms in the *American Journal of Public Health*, October, 1917. Following this initial publication, revisions and extensions of the list continued to be the consideration of committees of the A.P.H.A. until 1924, when the A.S.C.E. also appointed a committee on definitions and suggested joint action by the two societies. A.S.C.E. Manual of Engineering Practice No. 2, "Definition of Terms Used in Sewerage and Sewage Disposal Practice," was published in 1928, the joint effort of A.S.C.E. and A.P.H.A.

Following the publication of A.S.C.E. Manual No. 2, there was immediately formulated a new joint committee under the chairmanship of Langdon Pearse, representing A.S.C.E., Paul Hansen, representing A.P.H.A., and Frank W. Jones, representing the Federation of Sewage Works Associations. The Federation's participation dates back to the early years of the Association's formation. This joint committee continued to give consideration to revisions and extensions of Manual No. 2, but no formal revisions were published, although a draft of a revision was prepared in 1940.

In the meantime, the supply of Manual No. 2 was exhausted, and the chairman of the Sanitary Engineering Division, A.S.C.E., thereupon appointed a committee of five under the chairmanship of W. W. Horner, in May, 1941, to revise and bring up to date Manual No. 2 of Engineering Practice, "Definition of Terms Used in Sewerage and Sewage Disposal Practice." After preliminary steps, the newly appointed committee of A.S.C.E. and the old joint committee of A.S.C.E., A.P.H.A., and Federation of Sewage Works Associations were combined into a new Joint Committee, with membership as follows:

General Chairman—W. W. Horner
A.S.C.E.—W. W. Horner, Langdon Pearse, E. Sherman Chase
A.P.H.A.—Paul Hansen (deceased, now replaced by Wm. C. Hoad), Gordon M. Fair, H. A. Whittaker
Federation of Sewage Works Associations—F. W. Jones, C. E. Keefer, C. J. Velz

This Joint Committee, of which the Federation's Committee on Sewage Works Nomenclature is a part, is directing its efforts exclusively to sewerage and sewage terminology, and to that end has reviewed a preliminary draft prepared largely by Mr. Pearse and Mr. Hansen prior to the organization of the present Joint Committee.

At the time of formation of the Joint Committee appointed to revise Manual No. 2, it was learned that two other committees were at work on terminology related to sanitary engineering:

1. National Resources Planning Board, under supervision of A.S.C.E., A.W.W.A., and A.P.H.A., sponsored preparation of a document entitled "Hydrologic, Hydraulic and Sanitary Engineering Nomenclature."
2. Joint Committee on Water Works and Sanitary Engineering Terms with representation as follows:

General Chairman—Thorndike Saville
A.W.W.A.—Thorndike Saville, Samuel B. Morse, H. E. Babbitt
A.S.C.E.—C. E. Brownell, R. S. Tyler, Arthur D. Weston
A.P.H.A.—Earle B. Phelps, Sol Pincus, R. E. Tarbett

Accordingly, there were in existence three independent joint committees engaged in developing a nomenclature concerning sanitary engineering and related fields which overlapped each other. The question arose as to the possibility of these three committees cooperating in a joint effort in publishing a single inclusive manual under the title of "Water Control Engineering," sponsored by the various associations involved, namely, A.S.C.E., A.W.W.A., A.P.H.A., and F.S.W.A.

At a meeting held in January, 1944, with representatives of A.S.C.E., A.W.W.A., A.P.H.A., and F.S.W.A., it was recommended that the societies should co-operate in editing and publishing a single manual of "Water Control Engineering," embodying the work of N.R.P.B., the Joint Committee on Water Works and Sanitary Engineering Terms, and the Joint Committee on Revision of "Definition of Terms Used in Sewerage and Sewage Disposal Practice." It was estimated that 32,000 (30,000 for distribution to members; 2,000 for reserve supply) would be required and that the cost of editing and printing would be $12,000. It was proposed that the cost be divided among the societies in proportion to the estimated membership as follows:

	Members	Proportionate Share	Total	1944 (Editing)	1945 (Printing)
A.S.C.E.	20,000	20/30	$8,000	$2,000	$6,000
A.W.W.A.	6,000	6/30	2,400	600	1,800
A.P.H.A.	1,000 (Engr. Sect.)	1/30	400	100	300
F.S.W.A.	3,000	3/30	1,200	300	900
Total	30,000		$12,000	$3,000	$9,000

These recommendations were acted upon by the various Boards of the four associations, and by August, 1944, appropriations of funds were made for the first year's work of editing.

Arrangements have been made with Mr. Clinton Bogert of New York City to undertake the work of editing for the sum of $2,500, which he estimates will be spent for stenographic and clerical services and incidental expenses, with his own time largely donated. It is estimated that editing will occupy the greater part of a year and that the manual will be ready in the latter part of 1945. A.S.C.E. has offered to handle the details and mechanics of publication when the editing has been completed. The drafts of definitions prepared by N.R.P.B. and the Joint Committee on Water Works and Sanitary Engineering Terms and the Joint Committee on Revision of "Definition of Terms Used in Sewerage and Sewage Disposal Practice" will be submitted to Mr. Bogert for editing. The joint committees will continue to maintain general supervision of the work and to issue final approval of the edited manual before publication.

As of September 1, 1944, the Joint Committee on Revision of "Definition of Terms Used in Sewerage and Sewage Disposal Practice," A.S.C.E. Manual No. 2, of which the Federation's Sewage Works Nomenclature Committee is a part, is in the process of preparing a second draft of revision of Manual No. 2, which it is expected will be distributed to all members of this Joint Committee in October for review prior to submission to Mr. Bogert for editing.

Certain matters of policy for action by committees of all four societies have arisen which require clarification, such as the inclusion of definition of proprietary names, inclusion of terms from allied arts such as bacteriology and chemistry, and change in title suggested by the Federation to include the word sewage, i.e., "Glossary of Water and Sewage Control Engineering." A joint meeting, including the editor, to consider these questions has been set tentatively for January, 1945, in New York City.

C. J. Velz, *Chairman*
C. E. Keefer
F. W. Jones

REPORT OF THE WAR SERVICE COMMITTEE

September 15, 1944

This report of the War Service Committee is submitted in a form similar to that of previous years.

1. Priorities. Since the last committee report the committee has had no work dealing directly with priorities. The matter of sewage works priorities has been most ably handled by President A. M. Rawn of Los Angeles, California, consultant to the War Production Board Sewerage and Sanitation Division. Revision of orders and regulations governing priorities for sewerage works have been made in such a way that steady improvement in the materials situation has been evident.

2. Manpower. The needs of the armed forces continued high through the past year and, therefore, additional sanitary engineers were lost for the duration of the emergency to the armed forces. While this has been felt distinctly in the service of sewage works, it also has made it possible for the military to provide a degree of sanitary engineering protection to men in all theaters of operation comparable to the protection they are accustomed to at home. The problem has been one of doing more with fewer men, but sewage works are in no worse position in this regard than many other civilian activities. Probably additional demands will be made and must be met until the war is won and rehabilitation is well under way.

3. Civilian Defense. This activity has practically passed out of existence with our enemies confined to fighting on their own soil. In most cases there is little fear of air activity in this country that would activate the Civilian Defense organization. In the last report a meeting called by the Technical Board of the Office of Civilian Defense in Washington, D. C., was reported. The meeting held in July, 1943, was for the discussion of post raid restoration work and also an attempt to bring together various utilities for unified action in the event of such an emergency. With the virtual elimination of the possibility of enemy air attack, this organization, though a very loose one, has taken the form of one to be generally prepared for disasters, whether they occur during peace or war time. To this end the Technical Board of the Office of Civilian Defense issued a draft of March 29, 1944, entitled "Co-ordinated Action by Utilities and Public Services" which follows:

Co-ordinated Action by Utilities and Public Services

(Draft of March 29, 1944)

1. This statement is issued in accordance with a recommendation made to the Technical Board of the Office of Civilian Defense on July 21, 1943, by representatives of seven national utility associations (with subsequent concurrence of 9 associations).

2. The recommendation was contained in the following Resolution: "Resolved that it is desirable for the O.C.D. to send a directive to Commanders of the Citizens Defense Corps, recommending that they invite the privately and publicly owned utilities (communication, public works, transportation, sewers, water, gas, electricity, and steam) to form working groups for co-ordinating post raid restoration work. Representatives preferably would be operating executives. Organization of these groups would be confined to the larger communities and critical areas."

3. The primary objective of this plan of action was restoration of services disrupted by air raids, the diminishing danger of which has caused announcement of the plan to be withheld

until this time. This danger has not entirely passed and it is desirable, as proposed in the resolution, that the plan be made available for application as projected or, as a subscribing association has proposed, to any type of wartime disaster. Therefore it is now released through Defense Councils and Utility Associations, to local authorities and public services.

4. As proposed by the utility representatives, the Office of Civilian Defense recommends that local civilian defense or governmental authorities take the initiative in organizing Utility Boards for action if and when occasion requires. All vital services should have Board representation. Representatives should possess the position and authority to act decisively, and to arrange for inter-utility co-operation and co-ordination as required, subject to consultation with local authorities and with emergency services.

5. It is recognized that Board jurisdictions and geographical boundaries will vary. The Board of a large city, for example, might have jurisdiction over the facilities of that city alone, whereas in an area containing a number of smaller cities, a central Board might serve any locality in the area. Each board should be independently constituted, selecting its own chairman, and determining its own practices and procedures. It would be subject to call only where damage is so extensive that co-ordinated action is imperative or where communities indicate the need of advance planning to meet an impending attack or disaster.

6. The proposed Boards would be distinct from, and not in conflict with, utility participation in the operation of the civilian defense control systems—as entirely different types of problems are involved. Information about damage would be assembled *during* an emergency through the civilian defense control system and utility trouble centers; while the restoration of utility service in general would not commence until immediately thereafter.

Accredited representatives of the Associations listed below have given their approval to the circular draft dated March 29. The representatives listed below have been designated association contacts to inform their respective memberships of the plan for joint action and to take such other steps as they may agree upon to implement the plan of joint action.

American Gas Association—C. George Segeler, 420 Lexington Avenue, New York 17, New York.
American Public Power Association—Carleton Nau, 726 Jackson Place, Washington, D. C.
American Public Works Association—Frederick Bass, 1313 East 60th Street, Chicago 37, Illinois.
American Transit Association—J. L. Martin, 820 Dauphin Street, Philadelphia 33, Pennsylvania.
Ronald G. Thring (Alt.), 3222 M Street, N.W., Washington 7, D. C.
American Water Works Association—Harry E. Jordan, 500 Fifth Avenue, New York 18, New York.
Council of Electric Operating Companies—Robert C. Hill, Homer Building, 13th and F Streets, Washington, D. C.
Federation of Sewage Works Associations—Ralph E. Fuhrman, Sewage Treatment Plant, Blue Plains, D. C.
W. H. Wisely (Alt.), 325 Illinois Building, Champaign, Illinois.
National District Heating Association—Glen D. Winans, 2000 Second Avenue, Detroit 26, Michigan.
U. S. Independent Telephone Association—Clyde S. Bailey, Munsey Building, Washington, D. C.

As the Technical Board of the Office of Civilian Defense ceased to operate June 24, 1944, it is obvious that there is no body to continue the promotion of such a scheme. It is clear that such co-ordination is highly desirable and at times of disaster invaluable. It also seems true that without a driving force much effort will be required on the parts of a few individuals to keep it alive.

In the last correspondence on this subject the Secretary of the Technical Board suggested that the American Gas Association supply an Acting Chairman, that the Council of Electric Operating Companies supply a Vice-Chairman, and that the American Water Works Association provide a Secretary. There the matter rests for the present.

The recent hurricane which advanced northward along the Atlantic Coast and passed over Long Island on the night of September 14–15 gives a current example of the desirability of co-ordinated utility action.

Immediately preceding and during the passage of the storm, heavy rain fell over the southeastern portion of the State and wind caused a very large amount of damage to trees, buildings, crops, shore installations and public utility services on Long Island. The velocity of the wind at the time of the hurricane was about 80 miles an hour and large numbers of trees were blown over, disrupting electric and utility services to water pumping stations and sewage disposal plants.

In Nassau County, public utility services were disrupted from several days to a week before same could be restored. Those water supplying pumping stations and sewage disposal plants which were equipped with standby gasoline engines, were enabled to continue operation. Many emergency water supply interconnections and gasoline engine standby equipment had been installed under the State Wide Mutual Aid Plan, directed by Mr. Earl Devendorf, State Co-ordinator, prior to the hurricane.

During the night of the hurricane, Mr. Richard A. White, Director of the Nassau County War Council, Office of Civilian Protection, together with Mr. W. Fred Welsch, were on duty at our headquarters Control Centre, at which time radio and telephone communications were received from various units of the local civilian protection offices reporting on damage which enabled this office, under the direction of Mr. J. C. Guibert, Commissioner of Public Works and Zone Co-ordinator, to take steps to restore utility services and to clear the roads of fallen trees.

This experience during the recent hurricane shows the wisdom of having an organization to function during a disaster of this kind.

4. Recommendations. The Committee recommends, since most of its activities as a war service committee are being better performed through other channels, that its services be terminated with this report. If this does not seem feasible to the Board, it is recommended that the Committee should be dissolved with the elimination of either Germany or Japan from active hostilities.

Respectfully submitted,

R. E. Fuhrman, *Chairman*
R. F. Goudy
W. F. Welsch
L. S. Kraus
W. B. Redfern
Dana Kepner
T. T. Quigley

REPORT OF COMMITTEE ON AWARDS

September 18, 1944

Following are the recommendations of the 1944 Committee on Awards:

1. That the *Harrison Prescott Eddy Award* be made to Dr. John R. Snell; primarily for his contribution to Sewage Works Journal entitled, "Anaerobic Digestion—II—Nitrogen Changes and Losses During Anaerobic Digestion" (Sewage Works Journal, January, 1943, page 56); and secondarily for his paper published in Sewage Works Journal entitled, "Anaerobic Digestion—III—Anaerobic Digestion of Undiluted Human Excreta" (Sewage Works Journal, July, 1943, page 679).

In connection with the *Harrison Prescott Eddy Award,* particular attention is directed to the contribution, "Modified Sewage Aeration—Part I," by Lloyd R. Setter (Sewage Works Journal, July, 1943, page 629), which work received strong consideration by this Committee. Further consideration of these studies by a future awards committee is urged at such time as subsequent discussion is published in the Journal.

2. That the *George Bradley Gascoigne Award* be made to James T. Lynch and Uhl T. Mann for their contribution to Sewage Works Journal entitled, "Rotary Vacuum Filtration of Sludge and the Effect of War on Operation" (Sewage Works Journal, September, 1943, page 807).

3. That the *Charles Alvin Emerson Award* be made to Dr. Willem Rudolfs with the following citation: "The Charles Alvin Emerson Award as of the year 1943 is hereby bestowed upon Willem Rudolfs in recognition of his valuable researches into the underlying principles of sewage and industrial waste treatment; of his many contributions to Sewage Works Journal; and of his unwavering loyalty to the welfare of the Federation."

4. Presentation has been authorized of the 1944 *Kenneth Allen Award* to the following, each of whom has been designated by his Member Association as having earned this recognition:

Albert Edward Berry (Canadian)
Van Porter Enloe (Georgia)
Albert Legrand Genter (Md.-Delaware)
F. Wellington Gilcreas (New England)
Charles A. Holmquist (New York)
Dana Ewart Kepner (Rocky Mountain)
Leon Benedict Reynolds (California)
Wilson Waldo Towne (Dakota)

Respectfully submitted,
Charles Gilman Hyde, *Chairman*
E. Sherman Chase
Gail P. Edwards
Carl C. Larson
Louis F. Warrick

DR. F. W. MOHLMAN BECOMES SEVENTH HONORARY MEMBER OF FEDERATION

One of the high-lights of the Sixteenth Annual Meeting at Pittsburgh was the election of Floyd William Mohlman to Honorary membership in the Federation, which action was climaxed by the presentation of his certificate by President Rawn at the Annual Dinner. Having held the appointive office of Editor of Sewage Works Journal until this year, Dr. Mohlman had not been eligible previously to qualify as an Honoray Member and the Board of Control was unanimous in conferring this well deserved honor at the first opportunity.

It would take many pages to present in detail a list of the innumerable contributions of Dr. Mohlman to the Federation and its activities. It is believed fitting at this time, however, to refer to the following resolution which was transmitted to the Board of Control by the Executive Committee of the Central States Sewage Works Association in nomination of Dr. Mohlman to the grade of Honorary Member:

Whereas: Floyd William Mohlman has served The Sanitary District of Chicago for the past twenty-four years; and

Whereas: through his technical ability and administrative skill, personal interest, untiring efforts and official capacity he has contributed greatly to the knowledge and scientific advancement in the fields of sewage treatment, stream pollution, control of industrial wastes, chemistry and public health in general; and

Whereas: Dr. Mohlman was one of the founders of the Central States Sewage Works Association and of the Federation of Sewage Works Associations and has diligently striven to help those organizations attain their present high standing by serving on committees, assisting with the arrangements and contributing outstanding papers for many successful programs presented at various annual meetings; and

Whereas: he has served as Editor of the Sewage Works Journal from its inception in 1928 until January, 1944, giving unstintingly of his time and effort, and has been the guiding force which has built up the Journal into an authoritative technical and scientific publication, with world wide circulation; now,

Therefore, Be It Resolved: that the Executive Committee of the Central States Sewage Works Association hereby nominates Floyd William Mohlman for Honorary membership in the Federation of Sewage Works Associations and hereby presents this nomination for consideration by the Board of Control of the Federation at its scheduled annual meeting in October, 1944.

Central States Sewage Works Association
By the Executive Committee:
Don E. Bloodgood, *President*
Dr. W. D. Hatfield, *Vice-President*
Major B. A. Poole, *Director*
Captain E. J. Beatty
P. W. Riedesel
Lt. K. L. Mick
J. C. Mackin, *Secretary-Treasurer*

1944 MEMBERSHIP PRIZE WINNERS ANNOUNCED

Five hard-working individuals who contributed notable membership activity to their Member Associations during the year ended September 30, 1944, have found that their efforts brought them fortune as well as considerable personal satisfaction. Due to the interest in the Federation of a well known leader in its affairs, who insists that his identity be withheld, a total of $200 face value in War Bonds was donated for distribution to the winners of the 1944 Membership Contest, rules for which were published on page 1244 of the November, 1943, *Journal.*

The Missouri Water and Sewerage Conference, by recording an increase of 185 per cent in membership for the period of the contest, earned the privilege of naming one of its members as winner of one of the $100 bonds. A review of the record showed that Mr. George L. Loelkes of Clayton, Missouri, Sanitary Engineer of the St. Louis County Health Department, had made the greatest individual contribution to the remarkable growth of the Missouri Conference and he was named as the sole winner of the prize. In the year covered by the contest, the Missouri Conference increased from a membership of 13 to a total of 37, the percentage increase represented being the greatest of any other Member Association in the Federation.

The second $100 bond was to be awarded to the individual judged to have been most responsible for the securing of the greatest number of new members for his Member Association. The Central States Sewage Works Association, by enrolling 134 new members in the one-year period, earned the right to designate the winner of this prize but found its problem complicated by the fact that several individuals were almost equally responsible for the fine job done. By a decision worthy of King Solomon himself, the Executive Committee of the Association decided that the prize should be divided among the four workers who secured the greatest number of new members from the four states comprising the Association, each of the four winners to receive a $25 denomination bond. Thus were the following designated as joint recipients of the prize: Martin A. Milling, Indianapolis, Ind. (29 new members); Douglas E. Dreier, Springfield, Illinois (22 new members); Maurice L. Robins, St. Paul, Minnesota (17 new members) and John C. Mackin, Madison, Wisconsin (10 new members).

Honorable mention goes to the Georgia, Rocky Mountain and Texas associations in the percentage increase contest and to the California, Pennsylvania, New York, Rocky Mountain and Canadian associations for the numbers of new members enrolled. Only six of the 26 Member Associations of the Federation failed to show an increase in membership for the year ended September 30, 1944.

Reviews and Abstracts*

Conducted by

GLADYS SWOPE

Mellon Institute of Industrial Research,
Pittsburgh 13, Pennsylvania

MICHIGAN'S WATER PROBLEMS

Water Conservation Conference, January, 1944.

This is a report (116 pp.) of a conference sponsored by the Michigan State Planning Commission, Michigan Department of Conservation, Michigan State College, and the University of Michigan, featuring fourteen speakers. Of interest to sanitary engineers is the chapter on "Water in its Relation to Pollution" by M. P. Adams (pp. 69–80), which covers controlling pollution; salt brines and chemical pollutants; inorganic wastes; treating sewage; work of stream control commission and policies; and a discussion by E. E. Stiff of beet sewage waste treatment.

LANGDON PEARSE

[*Editor's Note:* The abstract of the chapter by Mr. Adams follows.]

WATER IN ITS RELATION TO POLLUTION

BY MILTON P. ADAMS

More than half of the population of the State of Michigan depends on surface waters as a source of public water supply. In addition, these waters serve most of the major industrial plants, provide sport and commercial fishing, and support game and wildlife. Sewage and wastes must eventually reach the streams and lakes, and if pollution is not controlled the usefulness of the surface waters will be impaired or possibly completely destroyed.

The water in a stream or lake can supply the oxygen required by the pollution dumped into it, if the load is not too great. As the dissolved oxygen saturation value is lowest in the warm summer months, when the rate of oxygen utilization is highest, poorer stream conditions are apt to be found during these months. Domestic sewage and liquid wastes from paper mills, tanneries, slaughter houses, and other food processing plants are the principal oxygen-depleting offenders.

Bacteria in sewage is a second type of pollution and one that has a direct health significance. Primary treatment of sewage alone does not materially reduce the numbers. When oxidizing processes are used, however, the numbers are greatly reduced; roughly in proportion to the percentage removal of organic matter. Chlorination may be necessary in case the waters receiving the effluent are used for bathing or for domestic water supplies.

Other wastes have no oxygen demand or bacterial significance. Salt brine from oil fields or chemical plants is an example. The main constituents of this type of waste are the chlorides of sodium, calcium and magnesium. Total chlorides may vary from more than 200,000 p.p.m. in waste brines down to about four p.p.m. in the relatively pure water of Lake Superior. Apparently fresh water fish resist concentrations of these chlorides up to about 4,000 p.p.m.

* 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 public health departments, stream pollution control agencies, research organizations and educational institutions are particularly desired.

Strong acid or alkaline-bearing wastes must be at least partly neutralized before they are discharged into a stream if trouble is to be avoided. Cyanide wastes in very low concentrations have killed fish in Michigan. Livestock also have been killed by these wastes.

Oil wastes are troublesome in that they may seal off the surface and prevent the absorption of oxygen by the water. Such wastes may also cause damage by injury to wildlife, the coating of boat hulls, and other damage to property. There are records of cases where the stream actually catches fire.

Inorganic wastes, such as top soil washed from farm lands, and wastes from gravel washing and stone crushing plants, may clog waterways or discolor streams and lakes.

Frequently industry has found that by-products can be salvaged from wastes. This has been found true in the case of beet sugar plants, slaughter houses, tanneries, and paper mills. In the latter case pulp may be reclaimed, as well as the clarified water vehicle. Only in recent years have certain branches of industry gone beyond this point in efforts to abate pollution.

The Stream Control Commission consists of the heads of the departments of health, conservation, agriculture, highways, and law. It was formed to solve problems that do not yield readily to separate departmental effort. It conforms generally in function to the Sanitary Water Board of Illinois and Pennsylvania, the Water Pollution Committee of Wisconsin, and other similar state bodies.

The Commission policy since new construction and treatment facilities have been suspended by WPB order (April, 1942) has been as follows:

1. To obtain maximum possible results with existing facilities, giving first consideration to conflicts in water use by war industries;
2. To require improvised or temporary means of handling new or potentially critical problems by ponds, lagoons or other means, utilizing little or no critical materials;
3. To stimulate the preparation of reports, studies, research and construction plans for matured projects in order to contribute our share to postwar public works;
4. To stimulate thought and planning for the administration and financing of postwar projects;
5. Within the division of water itch control to continue useful studies and research in the administration of beach treatment measures, while servicing as many public frontages and resort owners as times and funds permit.

Since 1935 Michigan's percentage of urban sewage treatment has increased from 19 to 83 per cent. Some progress has been made in industrial waste treatment. Deficiencies in municipal sanitation and 52 separate industrial problems and 16 state institutional problems have been incorporated into a suggested postwar construction program. The Commission's report to the Michigan Planning Commission lists 237 projects. The cost of four of the seven groups of this program is tentatively estimated in excess of $48,000,000.

Discussion by E. E. Stiff (Great Lakes Sugar Co., Detroit)

Operation of beet sugar plants affords an example of what can be done in the treatment of industrial wastes. No one was aware of the pollution problems involved when the industry was born about 1900. Attention was called to the problem in 1906 when many complaints of fish killing were received. In 1910 studies were made of disposal methods in Germany. This resulted in the construction of pulp drying equipment at all beet sugar plants in Michigan. At some plants screening and sedimentation equipment was provided. Some of these were effective but others were too small or fell into disuse.

A few years study was made by the Commission after its organization in 1929. In co-operation with the Michigan State College Engineering Experiment Station a 100,000 gallon per day experimental plant was built at a beet sugar plant at Bay City and studies made in 1935. Further studies were made in 1936 in a 1,000,000 gallon per day plant.

On September 21, 1937, a general order was formulated by the Commission which established standards of oxygen demand for plant wastes. During the next three years the various firms proceeded with the construction of waste disposal plants. Standards set by the Commission have been substantially met.

T. L. Herrick

POSTWAR PROSPECTS FOR SEWERAGE IN CANADA

By Dr. A. E. Berry

Water and Sewage, 82, 20 (March, 1944)

At present it appears that there will be considerable extension of sewerage facilities in most urban centers in Canada after the war. Construction of substantial numbers of sewage treatment plants to reduce the pollution load on streams is likely.

Much of the twelve million population of Canada is rural, though the percentage is decreasing. Industrial development since the war has augmented the urban population and it is thought that this situation will continue in the postwar period.

Little use has been made of the sanitary district method of organization in Canada. However, a well known example of this kind of administration is found at Winnipeg, Man., where a group of municipalities are organized for the purpose of sewage disposal under the Greater Winnipeg Sanitary District. In Ontario the administration of utility services by public utility commissions has been successful, but there has been no tendency to place sewerage systems under these commissions. There is now an increasing interest in this direction and a change in legislation is being considered to facilitate procedure. Legislation has been passed in Ontario to permit the adaption of the sewer rental plan.

Capital charges for sewerage systems in Canada have been met by the municipal taxpayer, except for some governmental assistance during a limited period during the depression. However, during the war the government has paid its share where extensions were required because of war industries.

Trade wastes have not created the problems found in many American cities. There has been a change in recent years, however, and a modification of the practice of not requiring primary treatment at the industry may be in order.

There are about 500 sewer systems in Canada, in contrast to about 1,300 water supply systems. As regards sewage treatment, 115 municipalities have plants in operation, 52 of which provide primary treatment only. The activated sludge process has been very popular as a secondary treatment device, though trickling filters are again gaining favor for small plants. There are 48 activated sludge plants in Canada; 30 of them in Ontario.

Sludge handling has been a difficult problem and was intensified by the introduction of the activated sludge process. Heated digestion tanks have overcome odor troubles formerly encountered when attempting to handle undigested solids. Covered drying beds, in which only sufficient heat is used to prevent freezing, have been of value in improving methods of sludge handling. In recent years, however, vacuum filtration has gained favor, both for large and for small plants. As an economical method of handling; disposal as a fertilizer has been practised at some plants.

In planning for the future close attention must be paid to standards of treatment required. Over-emphasis must not be given economy in construction and operation to the detriment of the degree of treatment needed. High standards should be set for the conservation of natural resources, particularly water supplies.

T. L. Herrick

ACTIVATED SLUDGE OPERATING COSTS

By Lt.-Col. W. M. Veitch

Water and Sewage, 82, 19 (Sept., 1944)

London, Ontario, has three sewage treatment plants. The West End plant, the main plant of the city, is an activated sludge installation with a capacity of 7½ (Imp.) m.g.d.

The other two plants, each with a capacity of one m.g.d., are known as the South End and the East End plants. The former is an activated sludge plant, while the other comprises Imhoff tanks and trickling filters.

West End plant started construction in 1927. Additions were made and new features were installed from time to time until the final completion in 1937. New innovations were tested at the South End plant before installation at the large plant. Sewage enters the plant through a 48 in. sewer, the last mile of which is an inverted syphon; sewage is prechlorinated at the upper end of the syphon.

At the plant the sewage first passes through an air agitated grease separation chamber, thence to a grit chamber and then through a coarse screen and a fine screen. The coarse screen is made up of bars with ½ in. openings. A panel type fine screen is used, with the panels made up of 6 mesh wire cloth.

After screening the sewage passes directly to the aeration tanks. Three types of tanks are used. Standard spiral flow tanks with diffuser plates were installed in 1927. In 1931 additional tanks with semi-circular bottoms were built. Air is introduced through perforated pipes mounted on radial arms which rotate in an arc corresponding to the tank bottom. A tripping device is used to open and close the air valve so that air is admitted only during the lower one-third of the travel of the perforated pipe. There have been no deposits in these tanks but the air distribution is uneven and maintenance is more costly than in a later type of diffuser.

In 1935–36 this type was installed. Perforated pipes, laying perpendicular to the length of the tank, are located just above the bottom on 3 ft. centers. They hang from a rail mounted just above the surface. The whole mechanism is moved forward and back with a length of travel of 3 feet. Eight tanks are so equipped and a single drive shaft serves all of them.

Final settling tanks include two 50 ft. tanks and one 65 ft. tank, all with mechanisms, and one 52½ ft. by 65½ ft. plain settling tank. Effluent from the three mechanically equipped tanks is passed to the rectangular tank. At intervals this tank is given a short period for sedimentation, after which the upper two-thirds is decanted off and the remainder pumped to the plant inlet.

Sludge reaeration is carried on in six tanks in the older portion of the plant. Excess sludge is allowed to settle in these tanks, the top liquor decanted off and the sludge removed at moistures varying from 94 to 96 per cent. All sludge is used for fertilizer on farm lands. A contract was entered into with a private party who furnishes the tank trucks and distributes sludge to the farms.

Construction costs of the West End plant were $4.17 per capita and $46,690 per m.g.d. normal flow. Operating costs have been $0.51 per capita and $15.85 per million gallons treated.

T. L. Herrick

CONCENTRATION OF SEWAGE SLUDGE

A Symposium

Proc., A.S.C.E., 70, 1275–1296 (Oct., 1944)

Experience in Los Angeles, Calif. By R. F. Goudey (pp. 1276–1279). At the Los Angeles experimental plant various methods of concentrating activated and fresh solids were tried. Activated sludge was concentrated by a "batch" process, allowing 24 hours settling in a separate tank. After withdrawing the clear liquor the settled sludge averaged 97.76 per cent moisture.

Continuous return of waste activated sludge to the primary clarifier resulted in a sludge of 94.42 per cent moisture, compared to 91.96 per cent for primary sludge when activated sludge was not so returned.

In the third method, aeration tank liquor was removed continuously and settled in a separate tank at a rate of 600 gallons per square foot per day. Chlorine was added to maintain 1 p.p.m. in the clear liquor over the sludge. Sludge was pumped once daily and average moistures of 94 per cent were obtained. Moistures of 90 per cent were produced by the addition of lime.

Back River Sewage Works, Baltimore, Md. By C. E. KEEFER (pp. 1280–1282). The activated sludge units built as additions to the Back River sewage treatment works at Baltimore were placed in service in 1939. Two thickening tanks for waste activated sludge were provided, each 26 ft. in diameter with a working depth of 16 ft. The sludge removal mechanism carries vertical steel angles for thickening the sludge. Nozzles for dosing chlorine water are provided which terminate 12 inches below the surface.

It was estimated that the waste sludge would amount to 160,000 gallons per day containing 1.5 per cent dry solids when treating 40 million gallons per day. With one tank in service the surface loading would be 300 gallons per square foot per day. However, operating experience has indicated the desirability of using both tanks, even when the sewage flow is less than 20 m.g.d.

Operating results for 1940, 1941, and 1942 show sludge volume reductions of 88.3, 81.3 and 75.0 per cent. The solids concentrations of the thickened sludge were 1.9, 2.1 and 1.4 per cent.

A study of the results for the three year period have shown a correlation between the ratio of the solids in the thickened and unthickened sludge and the sludge index. This correlation can be formulated as follows:

$$R = 7.94\ s^{-0.3125}$$

In this equation R is the ratio of solids in the thickened sludge to the solids in the unthickened sludge, and s is the sludge index.

Some Results in the State of New Jersey. By WILLEM RUDOLFS (pp. 1283–1289). In the concentration of sludge the character of the sludge is of great importance. The initial concentration, time, and temperature have varying effects on fresh, activated, and digested solids.

At the Elizabeth Joint Meeting sewage treatment plant fresh solids are concentrated and barged to sea. The effect of temperature is quite pronounced, with materially greater concentration in summer compared to winter conditions. As an illustration records show that an initial concentration of 5.2 per cent solids increases in 96 hours to 11.5 per cent and 8.7 per cent under summer conditions (75–80° F.) and winter conditions (47–50° F.), respectively.

The effect of temperature has an effect on the pumping time through the 4,000 ft., 24 in. diameter line to the barge loading point. Records show that the pumping time per 1,000 tons of wet sludge varies as indicated in the following table.

Temperature Range, Deg. F.	Per Cent Solids	Pumping Time per 1,000 Tons, Min.	Average Temperature, Deg. F.
51–73	8.14	92	63.5
51–57	7.91	120	53.5
62–66	8.38	90	64.5
68–73	8.28	70	70.7

The increased pumping time with lower temperatures is due to increased viscosity of the sludge.

Compaction of activated sludge has been the subject of experiments over several years, using chemicals, inert materials, poisons and gases. In studies on flotation it was indicated that a dense sludge can be produced by the use of calcium hypochlorite. The initial concentration does not appear to be important but the degree of oxidation and size of floc are both factors. The liquor can be clarified by the use of ferric chloride or sulfuric acid with the calcium hypochlorite.

Concentration of Sewage Sludges, New York, N. Y. By Wellington Donaldson (pp. 1290–1296). The Coney Island plant in New York, capacity 70 m.g.d., utilizes plain sedimentation eight months of the year and chemical precipitation during the four summer months. All sludge is digested. It is hauled by scow to sand beds or lagoons on Marine Park. In 1941, when the plant capacity was half that at present, the analyses for primary and digested sludges were, respectively, 7.80 and 7.71 per cent solids and 63.1 and 49.0 per cent volatile. The concentration of the digested sludge is influenced to a great extent by the running schedule of the scows.

Wooden scows are used. They are owned by the city and towed by contract. City employees operate the pump for unloading. In 1941 the cost of sludge disposal by this method was $4.31 per ton dry solids, capital charges included.

At the Wards Island plant raw primary and waste activated sludges are barged to sea for disposal. Records for 1941 show an average solids content of the primary sludge of 6.33 per cent. In order to remove excess water from the waste activated sludge certain final settling tanks are used for this purpose. They are operated at a lower rate than the other tanks. In 1941 the returned activated sludge averaged 0.48 per cent solids while the thickened sludge averaged 2.28 per cent. The combined primary and thickened activated sludges had a computed weighted average of 4.30 per cent solids. The sludge as barged to sea contained 4.45 per cent solids, the increase being due to decantation of liquor before loading the barges.

The Diesel sludge vessels are owned and operated by the city. The cost of disposal in 1941 was $3.13 per ton dry solids including capital charges.

The Bowery Bay plant was operated as a primary treatment plant from November, 1939, to March, 1942, at which time activated sludge treatment was started. Primary and waste activated sludges are digested. Some of the digested sludge is hauled away wet and used for soil improvement after natural drying, but the bulk of it is barged to sea, as at Wards Island.

Two concentration tanks are provided for thickening activated sludge. They are 50 ft. in diameter and 9 ft. 10 in. deep at the side wall. Pickets are mounted on the rake arms to aid in thickening. They may be used for waste activated sludge or aeration tank liquor, though the latter method is used. For eight months of 1942 the per cent solids for aeration tank liquor, return sludge and concentrated sludge were, respectively, 0.16, 0.40, and 2.40 per cent. The solids in the primary sludge averaged 5.38 per cent during the same period, and the combined sludge fed to the digesters averaged about 4 per cent solids.

The Tallmans Island plant, an activated sludge plant was placed in service in 1939. Two concentration tanks, fed only waste activated sludge, are provided. They are 24 ft. in diameter and 18 ft. deep at the side wall. Thickening pickets are mounted on the rake arms. During the first five months of 1941 the concentrated waste activated sludge was fed into the primary tanks. The activated sludge contained 1.35 per cent solids and the primary sludge 5.41 per cent during this period. For the rest of the year the waste activated sludge was fed directly to the digesters. The solids content for the primary, activated, and combined sludges were 7.52, 3.48, and 6.41 per cent, respectively. For the entire year the solids content of the digested sludge to storage and to disposal were 5.94 and 7.23 per cent, respectively. The gain in the latter figure was due to decantation from the storage tanks. Part of the digested sludge has been hauled away in trucks to be used in soil improvement, and the rest has been barged.

Some experimental work has been done with the use of centrifuges for dewatering sludge. At the Jamaica, N. Y., plant digested sludge from the Coney Island plant was fed to a centrifuge installed for the purpose of dewatering fine screenings. Results were as follows: feed, 11.1 per cent solids; cake, 50.2 per cent solids, and effluent, 3.4 per cent solids.

At Wards Island a continuous centrifuge was set up and the following results obtained.

Per Cent Solids

Feed	Cake	Effluent
Return sludge, 0.398	4.72	0.0932
Excess sludge, 1.60	2.59	0.95

T. L. Herrick

NATIONAL INVENTORY OF NEEDS FOR SANITATION FACILITIES; III. SEWERAGE AND WATER POLLUTION ABATEMENT BY THE SANITARY ENGINEERING DIVISION, U. S. PUBLIC HEALTH SERVICE

Public Health Reports, 59, 857–882 (July 7, 1944)

Urban development created the serious sanitation problem of waste disposal and this problem was not adequately solved until public water supplies were established and the use of water-carriage sewage systems became possible. However the solution of this problem created another, that of pollution of the natural waterways and according to an estimate by the National Resources Committee the total volume of treated and untreated sewage discharged from public sewer systems in 1938 was 5.75 billion gallons daily. Approximately three-fifths of this volume was subjected to some degree of treatment.

The first comprehensive public sewer system in this country was designed for Chicago in 1855. In 1860 about 1,000,000 people representing 17 per cent of the total urban population were provided with some kind of sewerage. By 1900 these figures had increased to about 25,000,000 and 35 per cent, respectively. In 1942 they had become about 70,900,000 and 87 per cent. Thus during the past forty years the total population connected to sewer systems has increased about 3 times and the percentage of the urban population about 2.5 times.

In 1900 roughly 60 municipal treatment plants were serving a total population of 1,000,000 or only 4 per cent of the population living in sewered communities. In 1935 there were 3,700 municipal plants serving a population of 28,500,000 or 41 per cent of the population living in sewered communities. In 1942 there were 5,600 plants and the estimated connected population was 42,200,000 or about 60 per cent of the population connected to sewers. New construction except at war industries and military installations has been curtailed during the past three years. According to sewerage census data complete to the end of 1942 treatment facilities were distributed as follows:

Treatment	Number of Plants	Per Cent of Total Plants	Estimated Population Served	Per Cent of Total Population
Minor	50	0.9	3,300,000	7.8
Primary	2,848	50.8	15,900,000	37.7
Intermediate and secondary	2,712	48.3	23,000,000	54.5
Total	5,610	100.0	42,200,000	100.0
Plants with chlorination	1,168	20.8	14,980,000	35.5

Primary treatment may be assumed to effect about 35 per cent purification; intermediate treatment, 50 per cent; and complete treatment, 85 per cent. Minor treatment is assumed to effect no purification.

Applying the assumed purification efficiency factors to these data yields the information that the treated sewage, due to incomplete purification, has a residual polluting effect equivalent to the raw sewage from approximately 18,400,000 population. Added to the 28,700,000 discharging raw sewage this makes a total of about 47,000,000.

For the entire country it is estimated that the total pollution load derived from industrial wastes is equivalent to a population of about 60,000,000. This estimate was based on extensive data compiled for the Ohio River Basin and the assumption that the total industrial waste pollution in the 48 States would bear the same ratio to the corresponding total for the Ohio River Basin, both expressed in equivalent population, as is borne by the estimated financial values of the products manufactured by the waste-producing industries in these two respective areas. On this basis, therefore, the combined sewage and industrial waste pollution for the entire country is roughly the raw sewage equivalent of not less than 100,000,000 population.

Damages resulting from water pollution are classified as follows:

(1) Damage to public water supplies used for domestic purposes.
(2) Damage to agriculture and food fish propagation.
(3) Damage to industrial uses of water.
(4) Interference with navigation.
(5) Damage to recreational uses.
(6) Damage to land and property values.

The economic losses resulting from pollution of sources of public water supplies are serious. A variation from low to high pollution loads has been estimated to increase water treatment operating costs from $7.90 to $16.00 per million gallons. An increase in the yearly average raw water pollution load of coliform bacteria from 5,000 to 20,000 per 100 ml. has added about $1.00 per capita annually to the cost of water purification. These estimates do not take into account depreciation in palatability and health hazards.

The economic losses resulting from industrial waste pollution are so variable that no evaluation is possible at this time. However as an example it is estimated that acid mine drainage water causes $2,000,000 damage annually in the Ohio River Basin. This estimate was made in 1940 at which time about 25 per cent of the acid load had been eliminated by the mine sealing program.

An estimate of $100,000,000 total annual damage due to water pollution is probably substantially low.

In estimating sewerage needs throughout the nation 1940 U. S. census data and the 1942 Public Health Service sewerage census data were used. All incorporated communities having a population of more than 200 were included. For sewage treatment plants a design population 10 per cent greater than the 1940 population was used for communities under 10,000. An increase of 20 per cent was used for larger cities. While treatment facilities may not be needed in every case, the provision of at least primary treatment for all sewered communities has been contemplated as an ultimate goal and this plan was followed in estimating treatment needs.

A total of 16,752 incorporated communities having a total population of 83,766,379 was listed in the 1940 census. Of these 10,083 representing 4,315,843 population had less than 1,000 inhabitants. The bulk of the urban population (74,423,702) was in communities over 2,500 population.

New sewer systems are needed in a total of 7,718 communities having a total population of 4,835,847. Sixty per cent of the communities needing new sewer systems have less than 500 inhabitants and 87 per cent less than 1,000.

A total of 10,297,300 inhabitants live in 5,553 cities needing extensions to existing sewer systems. Approximately 1 out of 7 persons residing in sewered cities is not served by the existing system.

A total of 2,804 cities representing a population of 25,788,663 are not provided with any form of sewage treatment.

There are 10,522 communities in the nation with a total population of about 30,000,000 which lack public sewer systems or sewage treatment plants or both.

A total of 13,915 out of 16,752 communities in the United States present some type of sewage collection or treatment need. The difference between these two figures is made up of 1,537 communities with less than 200 population (not included in this study) and 1,300 communities now having systems which are adequate.

For estimating the costs of fulfilling sewerage needs, per capita cost figures based on 1933–39 construction costs increased by 32 per cent to bring them to the 1942 level were used. New collection systems and extensions were estimated to cost $41 per capita. Intercepting sewers were estimated to cost $5 per capita for populations under 10,000 and $10 per capita for populations over 10,000. Estimates for the cost of treatment plants were based on curves developed from the Ohio River Survey, one showing the per capita cost of primary treatment in relation to population served and the other showing a similar relationship for secondary treatment. As it was impossible in this study to determine the exact type of treatment needed a mean curve representing the average of the two per capita cost figures was used. As in the case of sewer construction estimates of treatment plant costs were increased by 32 per cent to bring them up to the 1942 price level.

Costs for the development of, and installation of, new types of industrial waste treatment are not known and were not included in any of the cost estimates. The Ohio River Survey figures cost data included only practical and proven treatment or other corrective measures.

The cost estimates for each State and the District of Columbia are presented in the following table in which costs are listed in *thousands* of dollars.

States	Sewers		Municipal Treatment			Independent Industrial Waste Correction	Combined Total
	New Systems and Extensions	Interceptors	Domestic Sewage	Industrial Wastes	Total		
Alabama	$ 16,240	$ 5,490	$ 11,280	$ 2,370	$ 13,650	$ 2,480	$ 37,860
Arizona	1,510	210	950	200	1,150	210	3,080
Arkansas	10,220	2,610	9,650	2,030	11,680	2,120	26,630
California	50,970	33,470	32,610	6,850	39,460	7,170	131,070
Colorado	5,440	810	5,610	1,180	6,790	1,230	14,270
Connecticut	6,780	2,660	5,310	1,110	6,420	1,170	17,030
Delaware	1,730	1,520	2,110	440	2,550	460	6,260
District of Columbia	8,580	8,580	6,600	1,390	7,990	1,450	26,600
Florida	20,660	7,440	12,540	2,630	15,170	2,760	46,030
Georgia	22,950	6,460	16,950	3,560	20,510	3,730	53,650
Idaho	5,720	1,400	5,030	1,060	6,090	1,110	14,320
Illinois	43,920	12,280	51,360	10,790	62,150	11,300	129,650
Indiana	20,420	13,040	20,890	4,390	25,280	4,600	63,340
Iowa	14,740	4,580	16,690	3,510	20,200	3,670	43,190
Kansas	11,170	2,850	10,040	2,110	12,150	2,210	28,380
Kentucky	9,970	12,780	11,930	2,500	14,430	2,620	39,800
Louisiana	11,760	9,760	11,200	2,350	13,550	2,460	37,530
Maine	3,670	4,310	4,260	890	5,150	940	14,070
Maryland	12,170	13,520	5,790	1,220	7,010	1,270	33,970
Massachusetts	16,080	48,090	37,220	7,820	45,040	8,190	117,400
Michigan	9,400	15,510	14,100	2,960	17,060	3,100	45,070
Minnesota	19,240	1,950	12,540	2,630	15,170	2,760	39,120
Mississippi	10,120	4,030	9,970	2,090	12,060	2,190	28,400
Missouri	24,140	18,770	27,250	5,720	32,970	6,000	81,880
Montana	2,450	2,130	4,180	880	5,060	920	10,560

States	Sewers		Municipal Treatment			Independent Industrial Waste Correction	Combined Total
	New Systems and Extensions	Interceptors	Domestic Sewage	Industrial Wastes	Total		
Nebraska	$ 7,080	$ 3,980	$ 10,300	$ 2,160	$ 12,460	$ 2,270	$ 25,790
Nevada	360	30	230	50	280	50	720
New Hampshire	3,200	3,060	3,200	670	3,870	700	10,830
New Jersey	13,690	9,750	13,830	2,900	16,730	3,040	43,210
New Mexico	2,710	100	1,240	260	1,500	270	4,580
New York	39,720	74,620	96,430	20,250	116,680	21,210	252,230
North Carolina	15,020	6,160	15,290	3,210	18,500	3,360	43,040
North Dakota	4,800	360	5,460	1,150	6,610	1,200	12,970
Oklahoma	8,610	1,800	12,150	2,550	14,700	2,670	27,780
Ohio	33,860	37,520	37,810	7,940	45,750	8,320	125,450
Oregon	3,790	8,980	7,470	1,570	9,040	1,640	23,450
Pennsylvania	53,840	102,510	80,870	16,980	97,850	17,790	271,990
Rhode Island	6,470	2,040	2,410	510	2,920	530	11,960
South Carolina	7,020	2,650	6,860	1,440	8,300	1,510	19,480
South Dakota	3,100	300	4,230	890	5,120	930	9,450
Tennessee	14,250	25,340	13,690	2,870	16,560	3,010	59,160
Texas	34,100	2,860	11,210	2,350	13,560	2,470	52,990
Utah	8,950	3,200	7,200	1,510	8,710	1,580	22,440
Vermont	1,090	1,310	3,070	640	3,710	670	6,780
Virginia	6,440	15,130	15,750	3,310	19,060	3,460	44,090
Washington	11,770	10,960	11,720	2,460	14,180	2,580	39,490
West Virginia	4,490	9,850	11,390	2,390	13,780	2,510	30,630
Wisconsin	10,550	1,680	7,290	1,530	8,820	1,600	22,650
Wyoming	1,230	720	2,020	420	2,440	440	4,830
Total	656,190	559,160	727,180	152,690	879,870	159,930	2,255,150

Logically the cost of interceptors and treatment plants may be lumped and this cost represents about 57 per cent of the total cost of the entire program. If industrial wastes are included then the cost of pollution abatement represents about 70 per cent of the program cost.

The question of financing the improvements is one which involves consideration of many elements other than local financing. Conclusions reached by Baity and Velz regarding Federal-State and State-local approaches to the problem are summarized briefly as advocating (1) Federal aid through financial assistance where needed, the development of sound technical methods and standards, and active co-operation with the States in working out well-balanced programs of pollution abatement, (2) State regulation of local pollution, with assistance to local communities, and (3) local responsibility for carrying out detailed projects for sewage treatment, sometimes jointly with industries and neighboring communities.

With interest at 3 per cent it is estimated that $115,000,000 would have to be set aside each year for an estimated useful life period of 30 years to liquidate the $2,255,150,000 program outlined. Similarly $81,500,000 per year would be required for the pollution abatement portion of the program (interceptors and treatment). When annual operating and maintenance costs of $35,000,000 are added to the latter figure the annual cost of pollution abatement is $116,500,000 which compares favorably with the previously cited figure of annual damages of $100,000,000. It thus appears that pollution abatement as a national project would be practically self-liquidating from a strictly financial standpoint and intangible benefits not subject to direct evaluation would probably greatly exceed the economic benefits.

From the standpoint of providing a public works program for the post-war period, sewerage projects are fully as important in the public interest as public water supply improvements. Because the public interest is so intimately involved in a broad sewerage program, Federal and State aid in financing is justified fully to the same extent that it is justified in other public works improvements affecting large numbers of people and large areas of the country. The importance of careful planning cannot be over-stressed. Close co-operation and effective leadership by Federal, State and local authorities will be essential to effective action.

Included in this paper are 7 tables of data and a bibliography with 15 references.

PAUL D. HANEY

BOOK REVIEW

Stream Sanitation. By EARLE B. PHELPS. With a Chapter on Stream Microbiology. By JAMES B. LACKEY. John Wiley and Sons, Inc., 1944. 264 pages. Price, $3.25.

This is an unusual book, because it contains not only fundamental data on stream pollution and self-purification, but also discussions of the author's development of mathematical means of expressing the degrees of stream defilement and regeneration, and suggestions of plausible theories of mechanism of sewage treatment processes and biochemical reactions. In addition, there are frequent unique comments or analogies that season the text and lend a flavor not usually found in a scientific treatise of this type. Few engineering books suggest the personality of the author, but this one clearly reflects the inquiring, searching, proving quality of Prof. Phelps' mind and judgment as applied to his life's work. He is not concerned with the assembling of innumerable facts, but rather with the formulation of the fundamental reactions of stream pollution and self-purification. The book is therefore not a text book, but rather a book of ideas built around the scientific memoirs of the distinguished senior author.

Dr. Lackey's contribution is of no mean order, but a valuable yet concise presentation of the types and functions of microorganisms in stream sanitation.

The seven chapters are headed: The Life History of a Stream; Biology of Growth and Decay; Aerobic Decomposition. Oxidation; Anaerobic Decomposition. Digestion; The Oxygen Balance; Public Health Aspects. Bacterial Pollution; and Stream Microbiology. There are thirty figures, and frequent references, which are placed, fortunately, at the bottom of the pages, so that one is more urgently reminded of the source of certain data than is the case when the references are at the end of a chapter.

The primary objective of the book appears to be to reduce, so far as possible, the transformations of nature to mathematical expressions. In this attempt Prof. Phelps, Prof. Fair and Mr. Streeter have been most assiduous, but as the stream "struggles when an attempt is made to confine it" (p. 1), so also it struggles within the bonds of fixed equations even though such bonds be loosened here and there by insertion of suitable constants and exponents, which, as stated on page 164, are usually far from constant. Also (p. 183), time of flow relations are so indeterminate that "it is never possible to apply the strict mathematical formulations to stream conditions, especially where these have been inadequately studied or are being investigated for the first time."

Although Prof. Phelps discusses and coordinates the mathematical relations of B.O.D., stream flow, reaeration, and sludge deposits more clearly and simply than has ever been done heretofore, it is difficult to apply the theory to a practical problem of stream pollution, especially when sludge deposits are an important factor. However, the work of Fair and Moore on benthal deposits defines their properties as studied in the laboratory and relates the magnitude of deoxygenation to the concentration of volatile solids per unit area.

The basic conceptions of oxygen balance are discussed with remarkable clarity by Prof. Phelps and with considerable ingenuity of analogy (p. 133). The opposing factors of B.O.D. and sludge deposits versus dilution, reaeration and photosynthesis are explained with suitable examples, and the discussions of reaeration and the sag curve are interesting and informative.

Some interjected remarks show a lively imagination that strikes the reader with surprise and pleasure, for example (p. 42) the expenditure of *vis viva* likened to "a tight rope walker balanced on a rope and apparently getting nowhere," the selective characteristics of *E. coli* (p. 111) which "might properly be likened to the upper classes of society who have the more menial duties of food preparation performed for them"; and the surprising recollection of the purity of sand filter effluents at Lawrence (page 192) such that "it was our regular custom to invite visitors, sometimes distinguished visitors from abroad, to drink of one of these effluents served from a cut-glass pitcher, in cut-glass tumblers." In the latter case, the amenities of courtesy and sanitation might have been carried a little further if a cut-glass decanter had been brought forth and some of its contents added to make a sand-filter highball.

Seriously, there are several concepts in the text that may be questioned. There may be disagreement with the statement on page 88, that oxidation of ammonia to nitrate in no way depletes the oxygen resources of a stream because the nitrate oxygen is potentially available. There is of course a very serious doubt in many minds whether nitrification by sewage treatment is worth what it costs, as discussed by the reviewer in an editorial in the SEWAGE WORKS JOURNAL, July, 1938, but it must be admitted that a low-rate standard filter which nitrifies most if not all of the applied ammonia does more work than a high-rate filter, with an effluent of equal B.O.D. but no nitrate (based on equal volumes). Whether the nitrate is or is not an asset depends upon the conditions of disposal.

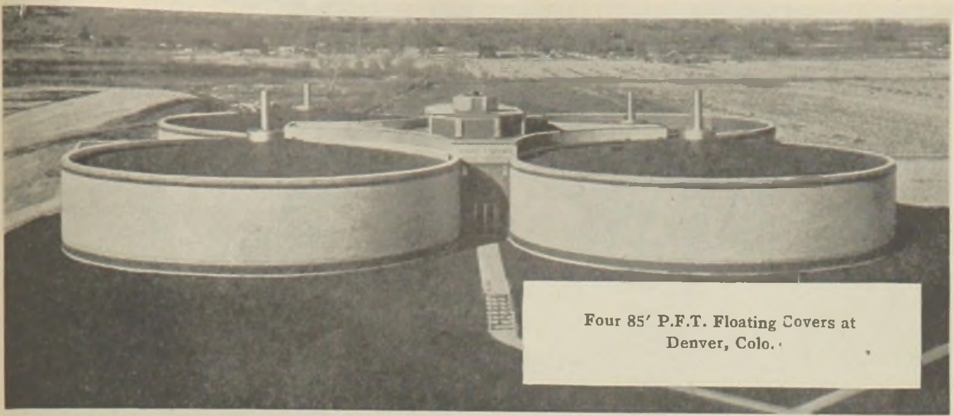
The secondary, or nitrogen, phase of the B.O.D. reaction is dismissed rather curtly by Prof. Phelps and most all equations relating to B.O.D. refer only to the first or carbon stage, extended. Sometimes, as in effluents undergoing incipient nitrification, the B.O.D. is almost completely in the nitrogen stage. In this case, it is surprising that the original study of Prof. Phelps of some 2600 methylene blue stabilities of sewage filters worked out to give the monomolecular curve used as the basis of stability. In effluents from biological treatment the second stage begins almost immediately, or within a few days, rather than between the tenth and twentieth day (p. 88).

The theory of activated sludge mechanism (pages 92 to 100), in which the normal rate of deoxygenation ($k = 0.1$) applies to about 85 per cent of the total, and a much higher rate to the remainder, is very interesting and warrants further study. The theory is extended to other systems in which sludge is present, in which the "pollute" is removed from the liquid to the solid phase.

There are many parts of this stimulating book that leads one to think more deeply about the underlying reactions in the entire field of biological sewage treatment and disposal of effluents in streams. In addition, the chapter on bacteria (VI) is highly readable and thought provoking. Finally, Dr. Lackey's chapter is full of valuable information on stream biology.

This book will be a great pleasure to those who have spent years in the study of stream pollution and for others it will reveal the complexity and fascination that these problems have, especially for those sanitary engineers who think in mathematical terms.

F. W. MOHLMAN



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All the requirements for the effective digestion of sewage solids are provided by digesters equipped with P.F.T. floating covers. Complete submergence of materials which normally float, with consequent acceleration of digestion, is assured at all times, regardless of varying operating conditions. Effective use is made of the natural forces of digestion by setting up conditions favorable to this process, without the need of employing mechanical operating equipment.

The P.F.T. floating cover assures the greatest flexibility obtainable. Two or more similar tanks equipped with floating covers may be used at will for either two stage or single stage digestion. Power costs are obviated and maintenance is reduced to a minimum. By the elimination of all moving parts, P.F.T. floating covers avoid the operating interruptions caused by breakdowns of mechanical equipment.

Catalog No. 232 shows the construction, advantages and typical installations of P.F.T. floating covers.

P.F.T. Equipment:

- Floating Cover Digesters
- Sludge Gas Control Equipments
- External Digester Heaters
- Supernatant Treaters
- Supernatant Selectors
- Supernatant Gauge, Sight Glass and Sampler
- Pre-Aerators and Grease Removers
- Laundry and Trade Waste Treaters
- Rotary Distributors
- Twin Tank Controls
- Alternating Siphons
- Sewage Siphons
- Sprinkling Filter Nozzles
- Air Diffusion Equipment
- Tray Clarifiers
- Sludge Pumps
- Sludge Samplers
- Flush-Tank Siphons and Regulators
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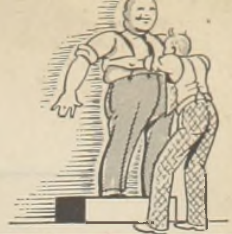
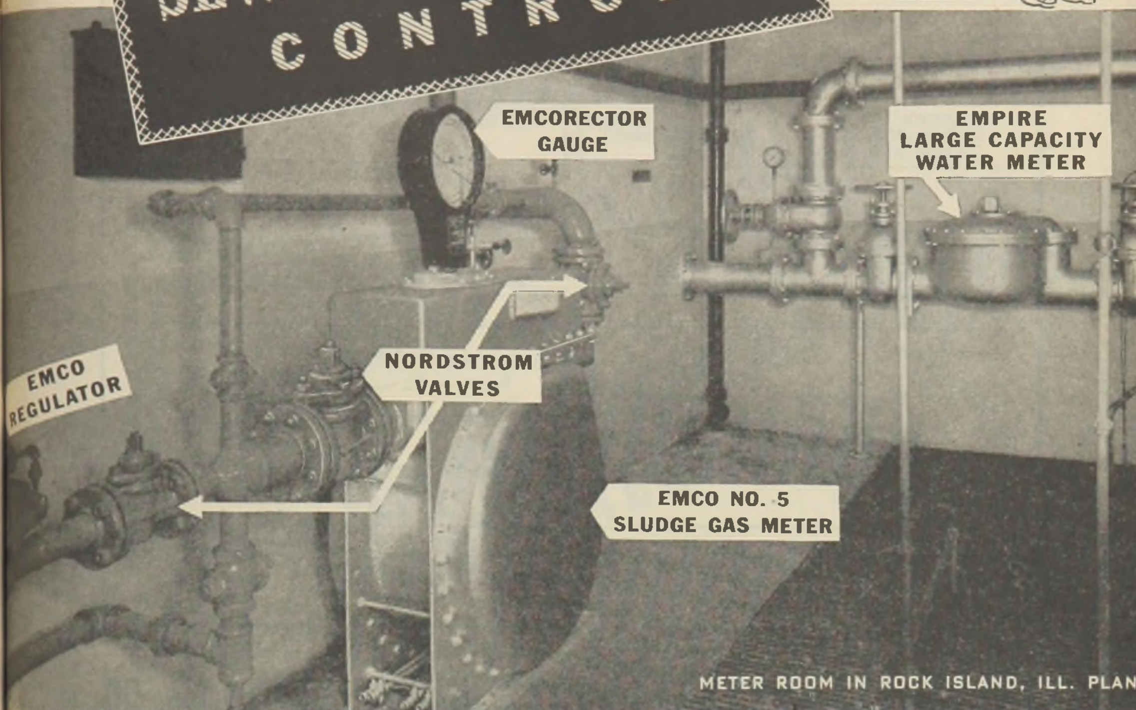


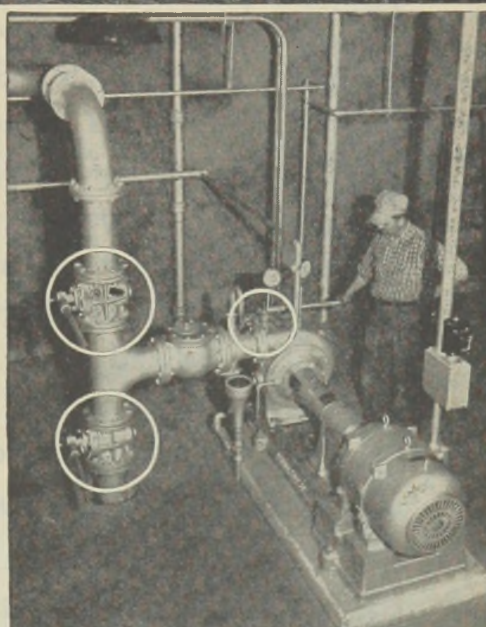


METER ROOM IN ROCK ISLAND, ILL. PLANT

FIT THE METERS AND VALVES TO THE SERVICE

Measurement and control go hand-in-hand in sewage disposal plants. It takes specialized equipment to control the diversity of services that are encountered in this field. Pittsburgh Equitable Meter Company and subsidiary, Merco Nordstrom Valve Company, have the necessary meters, regulators, and valves properly engineered for the installations involved and in a complete range of sizes, types, and working pressures for every requirement.

In the anticipated post-war sewage treatment construction boom, it would be well to remember that for the best results sanitation engineers, in the past, have specified Nordstrom Lubricated Valves, EMCO Sludge Gas Meters and Regulators, and Pittsburgh-Empire Hot and Cold Water Meters.



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