# SEWAGE WORKS JOURNAL

VOL. XVI MARCH, 1944 NO. 2

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Review of 1943 Literature—Research Committee

Army Camp Grease Removal—Eliassen and Schulhoff

Sewage Treatment Practice—Bedell

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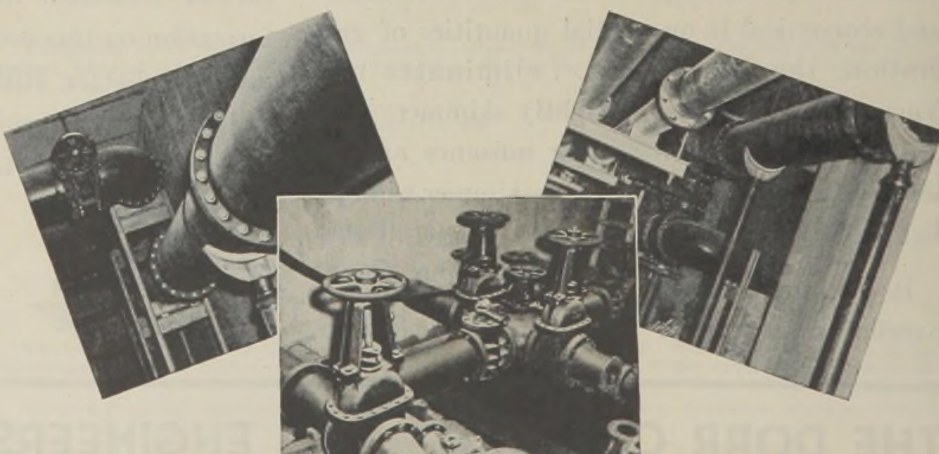

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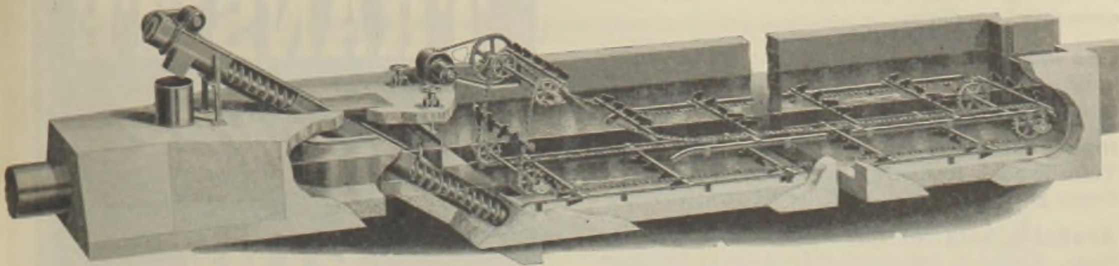



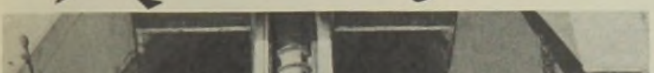

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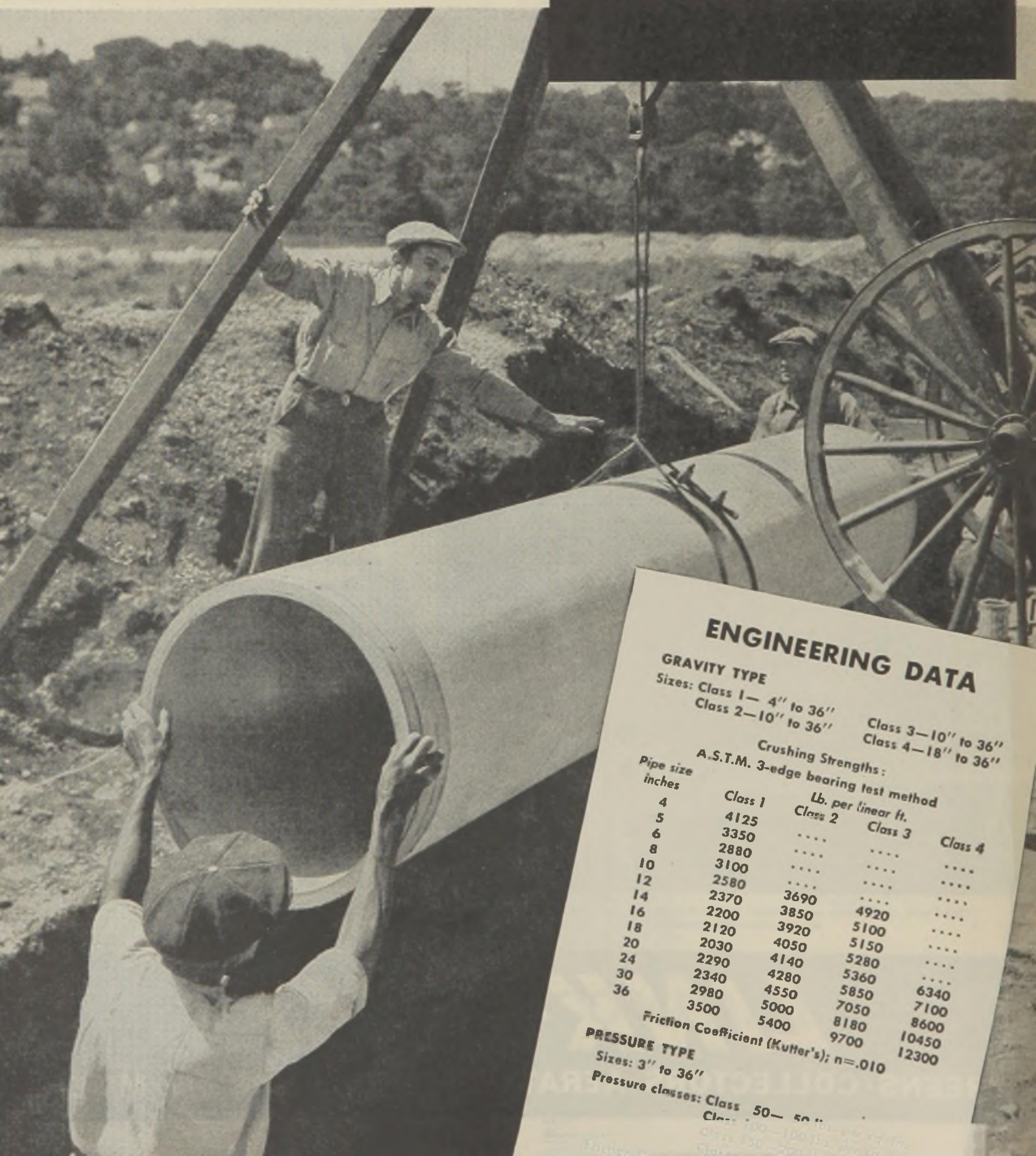

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|---|---|---|---|---|
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| 6 | 2880 | .... | .... | .... |
| 8 | 3100 | .... | .... | .... |
| 10 | 2580 | 3690 | 4920 | .... |
| 12 | 2370 | 3850 | 5100 | .... |
| 14 | 2200 | 3920 | 5150 | .... |
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| 18 | 2030 | 4140 | 5360 | 6340 |
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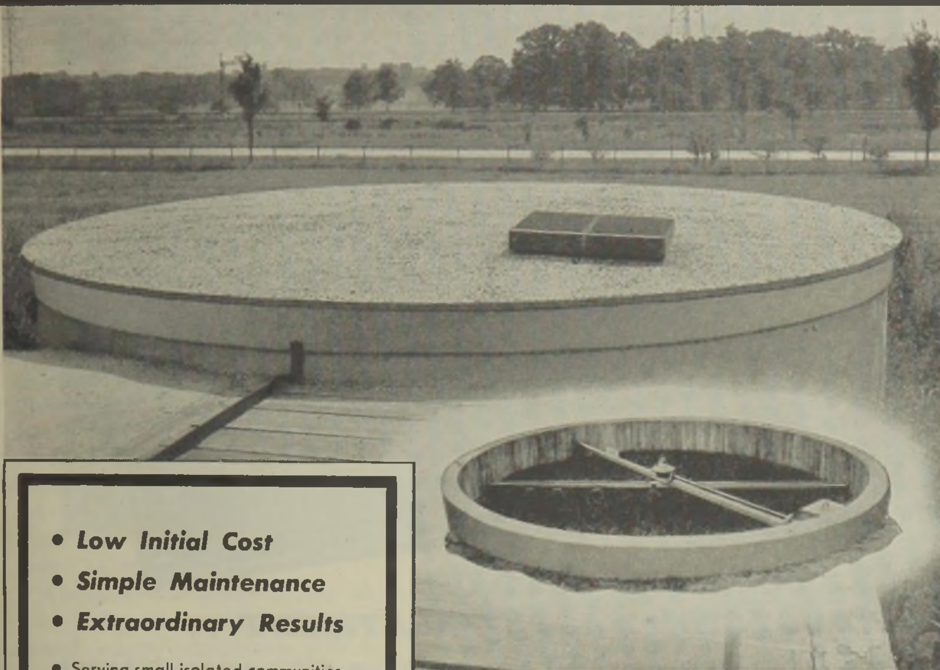

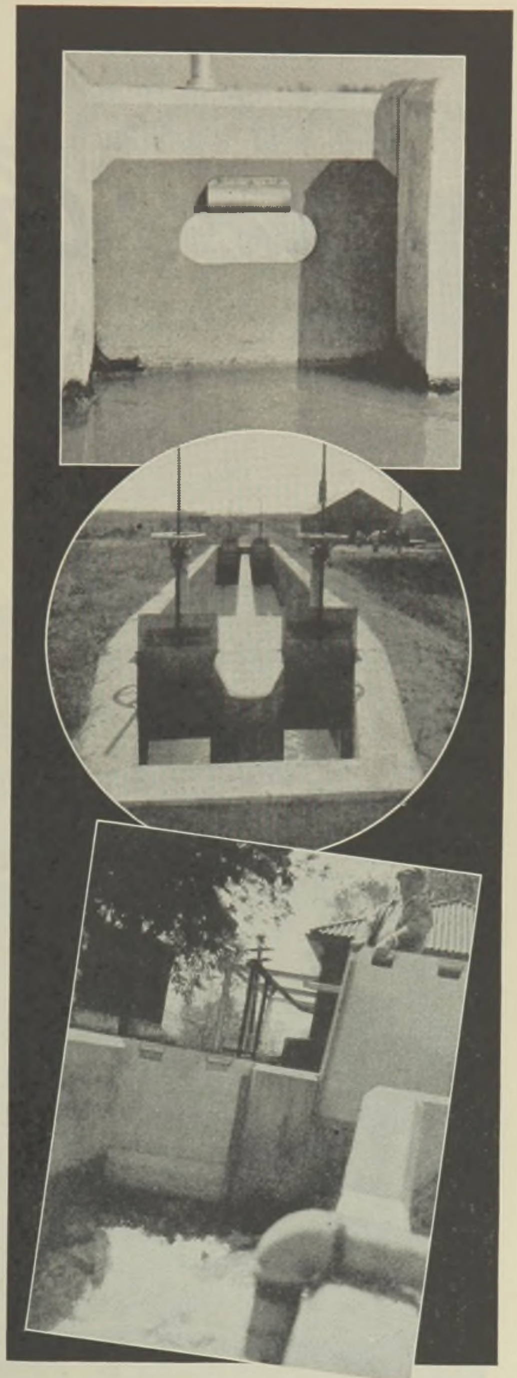

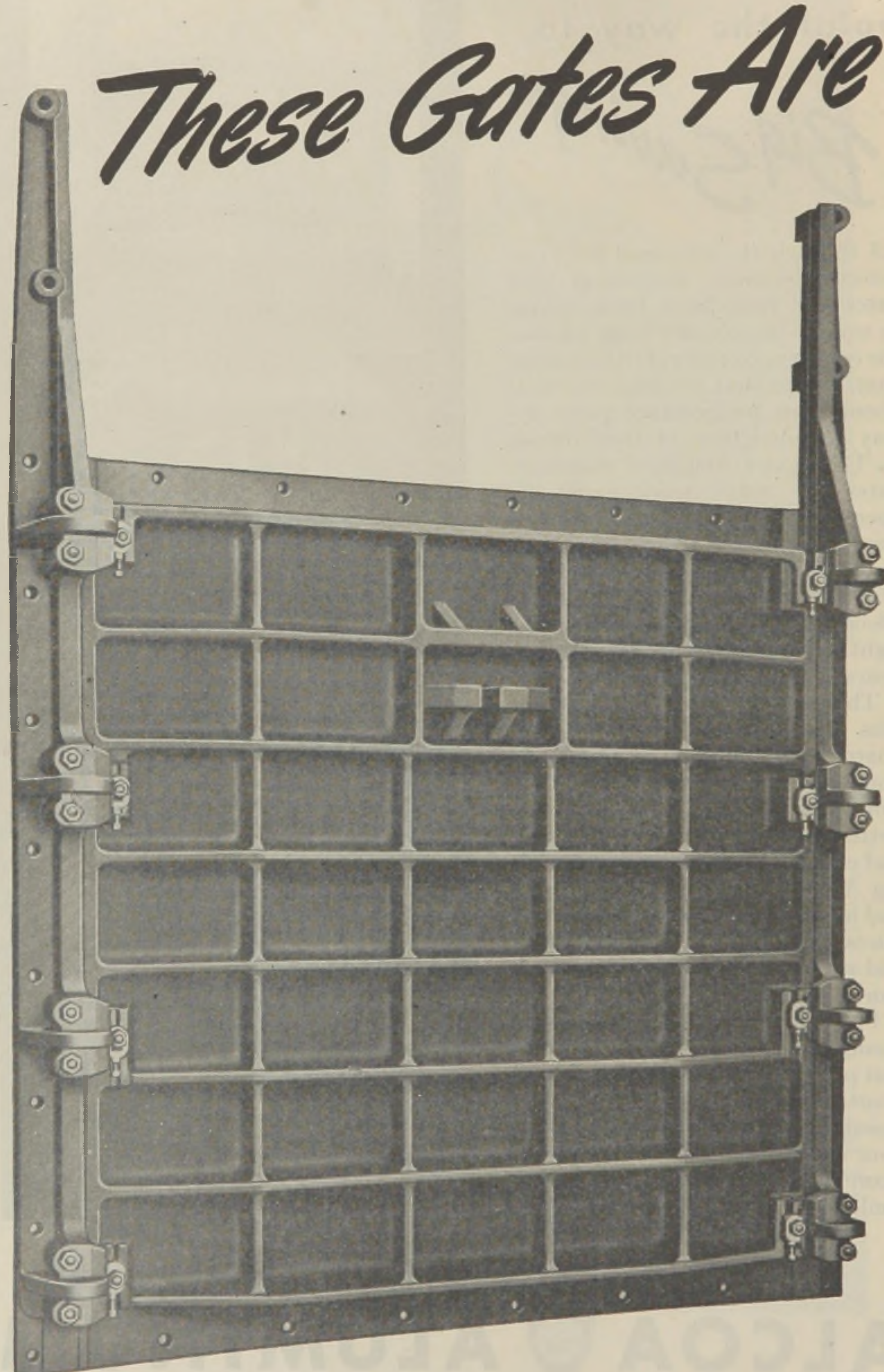
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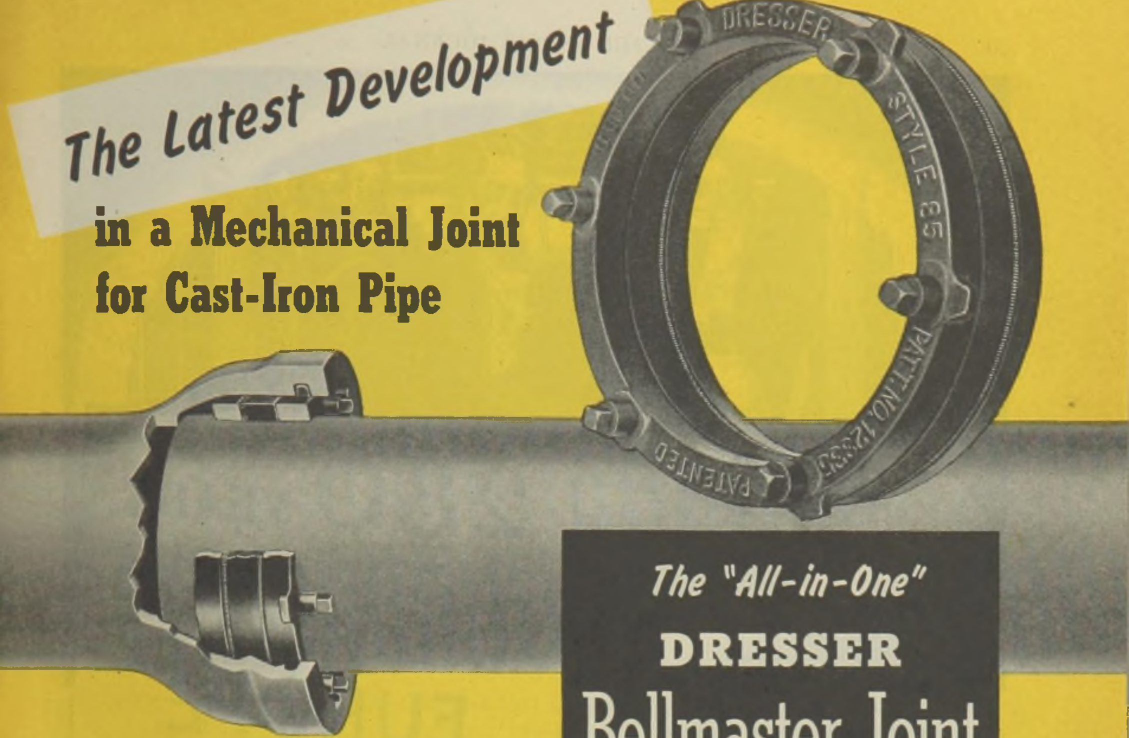


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**Plant Operation:**



**Sewage Research:**



**Sewage Works Design:**



**Operator's Corner:**



**Editorials:**



**Proceedings of Member Associations:**

# Plant Operation

## THE CHLORINATION OF SEWAGE AND INDUSTRIAL WASTE*

By Harry A. Faber

*Research Chemist, The Chlorine Institute, Inc., New York, N. Y.*

The purpose of this paper is to present a critical summary of past and present applications of chlorination, in the treatment of sewage and industrial waste, and to attempt an evaluation of its future utility.

The general adoption of sewage chlorination had its inception when liquid chlorine became available as an article of commerce in the United States; that is, about thirty years ago. Research in that application started even earlier, when chloride of lime was recognized as a suitable disinfectant for water and sewage. In all the research since that time, only very limited attention has been devoted to the fundamental chemical changes accomplished by chlorination. Those investigators who have contributed to the basic knowledge of sewage chlorination can just about be counted on the fingers of two hands.

Chlorination is represented in sewage literature mainly by reports on operation and by operating results. There is a large field and a real need for more fundamental research, particularly in some of the newer applications of chlorine. Such studies, leading to refinements of present practice, would be amply justified by improvements in plant operation and by economy of chlorine.

For the purpose of analyzing the present state of knowledge, it will be useful to comment upon those chlorine applications which may be considered as well established uses. The list will include only: disinfection, B.O.D. reduction, and the control of odors and septicity.

Chlorination for disinfection is well established, if wide acceptance of this use may be taken as a criterion. But much remains to be learned of the efficiency and the basic factors affecting the efficiency of this use. Considerable study has been given to disinfection results at the Buffalo plant. Sedimentation and chlorination provide the degree of treatment required at Buffalo, and extensive research by Symons (1) showed that the maintenance of 0.1 p.p.m. residual chlorine after 15 minutes contact, when the total contact time is 30 to 45 minutes, accomplishes a 98.6 per cent kill on both coliform and total bacteria. Stream pollution studies show the coliform content of the Niagara River has been reduced by approximately 98 per cent since the inception of sewage treatment at Buffalo. As an example of the benefits accruing from research during 1941, the chlorine demand of the raw sewage increased 28 per cent over

* Presented at the Fourth Annual Meeting of the Federation of Sewage Works Associations, Chicago, Illinois, October 22, 1943.

what it had been for the previous two years. However, an average dosage increase of only 18.4 per cent was required because improved plant operation was brought about through laboratory study of dosage control.

Early studies regarding the effect of chlorine on B.O.D. reduction were made by Mohlman (2) and by Baity (3). Baity's comments warrant repetition. He wrote: "It now appears to have been demonstrated to the satisfaction of the most conservative and critical sanitarians that chlorine, when properly applied in proper amounts, may be depended upon to reduce the oxygen demand of the organic non-settleable constituents of sewage by an average of 25 to 30 per cent, as measured by the conventional B.O.D. determination on the unchlorinated and chlorinated waste. But what is the actual and practical effect of such treatment upon the receiving stream? After all, we treat such wastes to relieve conditions of pollution or contamination in the receiving body of water, and unless the use of chlorine effects an improvement commensurate with its cost and trouble, it is a vain and wasteful process." After detailed study of this treatment for an entire summer, the actual and practical effects were: An improvement in the physical appearance of the receiving stream, the control of odors, an increase of dissolved oxygen in the stream, reduction of stream B.O.D. and of bacterial counts.

The control of odors and the control of septicity by chlorination are closely related functions. Usually odors are considered undesirable because of their psychological effect upon people, and septic sewage is undesirable because of its profound effect upon biological treatment processes. These effects are usually difficult to measure. Perhaps no more convincing accomplishment can be cited than that described by Rawn (4): "It is difficult to conceive of a situation where the capacity of an activated sludge plant was increased fourfold by the simple expedient of up-sewer chlorination—nevertheless, such was the case at the Joint Disposal Plant of the Los Angeles Sanitation District some ten years ago. During the early years of operation of the District's system, sewage delivered through the warm, slow flowing sewers was black and septic with the solids finely comminuted. It was high in dissolved sulfides and low in good sedimentation qualities. Despite the fact that the quantity of sewage flowing into the plant did not exceed that for which the plant was designed, the activated sludge process was incapable of producing anything resembling a good effluent. By by-passing a portion of the load, and increasing the quantity by-passed until the plant was capable of handling the remainder, it became apparent that the condition of the incoming raw sewage was such as to reduce the plant capacity to one-fourth of that for which it was designed. Fortunately there was a means of correction at hand, in this instance, chlorination of the sewage at strategic points throughout the collection system and its maintenance in a fresh state while flowing to the plant. By this means the design capacity of the plant was restored at reasonable cost and without plant expansion."

Three well-established applications in thirty years does not appear to be a high average. Other applications have been developed during this period. These include the use of chlorine for the control of activated sludge bulking, for the correction of trickling filter pooling, for the thickening of sludge, and for the removal of grease. Such applications of chlorination have proven to be thoroughly successful in some installations, of indifferent benefit in others, and useless or worse than useless in still others. Apparently that stage of chlorine utility has been reached in which further progress will depend upon the study of exactly how chlorine reacts in sewage and how to control its reactions. That is, certain principles not only must be recognized but must be applied in practice.

Biological processes of sewage treatment have been and are being given detailed study at individual treatment plants. As a result, many changes in practice have been adopted which improve the results accomplished by activated sludge, by trickling filters, and by still newer methods. In the same manner, the application of chlorine at individual plants warrants detailed study at those treatment plants because of its potential usefulness. Beyond its proven use as a means of killing pathogenic bacteria, its potential uses for the control of saprophytic bacteria, for reaction with organic matter, and for chemical oxidation, may make important contributions to plant operation. It must be kept clearly in mind that the process of sewage treatment is an integrated one, involving physical, chemical, and biological factors. Maximum efficiency is determined by no one of these factors alone but, rather, by each functioning in conjunction with the others.

A significant example is provided by the successful development of a process utilizing chlorine for the treatment of wool scouring waste, both to control a serious pollution load and to recover a valuable product. Chlorine was utilized for this purpose nearly twenty years ago, but never with entire success, despite the fact that it seemed the ideal chemical means for accomplishing such treatment. During the last two years, further study has been given to this application, at first with varying degrees of success. Only after detailed study was devoted to the physical, chemical, and biological characteristics of this waste, has it been possible to properly control the treatment. Once this was done, the process became a very simple one, requiring only that the wool scouring waste be treated fresh, and that calcium hypochlorite—chlorinated lime—be used instead of gaseous chlorine. Chlorine alone apparently reacts too vigorously with the protein matter but reacts in the desired manner when added as a chlorinated lime slurry. It may be of interest to mention that, after several months of pilot plant operation, this process is to be utilized at two woolen mills. One such treatment plant is in the design stage and one is under construction; the recovery of wool grease indicated at one mill is about one ton daily and, at the other, about two tons daily. The effluent produced will be fully acceptable from a pollution point of view, the process is odorless, and the recovered grease—at present prices—will return a profit on the plant installation and operation costs.

The special characteristics of chlorine have been applied to the treatment of other industrial wastes. For example, no suitable biological process was available for the handling of wastes containing cyanide compounds when such wastes created a new treatment problem. Chlorine is now used successfully as a chemical oxidizing agent to destroy cyanides in wastes from certain war industries. An experience has recently been cited in which the discharge of sulfur dye wastes increased the chlorine demand of a municipal sewage about five times over the normal demand. However, studies by the Connecticut State Water Commission have shown chlorine to be the cheapest and most satisfactory agent to treat this dye waste.

Perhaps the full possibilities of chlorination are not more widely and more successfully utilized because the process is regarded as such a simple one. It has been said that chlorination is not sufficiently dramatic. Usually no striking physical change is apparent when sewage is chlorinated, no impressive plant structures are required, nor do acres of aeration tanks or of trickling filters give visible evidence of the process.

But this may be misleading, for chlorination is not a simple process. Fortunately, to accomplish disinfection, some reduction of B.O.D. and the control of odors and septicity—it is necessary to determine only a sufficient dose and contact time. Yet there are other physical and chemical factors which must be taken into consideration if more specialized applications of chlorine are to be successfully and economically developed. Some of these factors, including the special reactions of certain organic and inorganic constituents of sewage and industrial waste have been pointed out in the sewage chlorination studies of Rudolfs (5).

There is another field, almost unexplored, which involves the application of chlorine in combination with other substances. Sufficient evidence has already appeared to indicate that the action of chlorine may be modified and controlled: (1) By applying it in conjunction with air, for more uniform distribution and more uniform reaction with organic matter; (2) by applying it as hypochlorous acid, after passage through limestone to remove the hydrochloric acid; (3) by applying it in mixture with lime, to provide an alkaline reaction instead of an acid one; (4) by applying it after reaction with iron or zinc, to limit its action upon organic matter. These are examples of chlorination control we already recognize and have used to a limited extent. There remain to be discovered many other combined uses suitable for special purposes.

Developments in chlorinating equipment have more than kept pace with chlorine applications. Chlorinators are now provided to feed gaseous chlorine, chlorine in solution, or hypochlorite solution. Such chlorinators operate by manual adjustment of dosage, by automatic adjustment of feed in proportion to volume of flow, by a program clock to maintain a different dosage rate at pre-selected intervals, and even by potential control which maintains a selected residual or sub-residual dosage corresponding to changes in both flow and chlorine demand of the sewage or waste.

At a time when physical and biological methods of sewage treatment are receiving more earnest and critical study than ever before, it appears that the potential uses of chlorine warrant the same study. Yet the two reports of the Federation Research Committee, published in the May and July issues of the *Journal* (6), include only six research projects involving chlorination out of a total list of 128 problems being investigated; and, actually, these involve study of only four different chlorination problems.

As newer and better methods of sewage treatment are developed and as the treatment of industrial wastes is more closely studied, chlorine still appears peculiarly suited for oxidizing, sterilizing, controlling odors, retarding the decomposition of protein matter, and coagulating, either alone or in combination with other chemicals. These characteristics should be utilized, among all other treatment means which engineers and operators have at their disposal. There is no better location to evaluate such applications on a given sewage or industrial waste than in the plant where that sewage or waste is treated.

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## Open Discussion of Paper by Harry A. Faber

*Mr. H. A. Riedesel* (Rockford, Ill.): Mr. Faber mentioned the treatment of wool scouring wastes. I would appreciate his discussing it more in detail.

*Mr. Faber:* There is not much more to be said. Treatment with chlorine gave erratic results and we found that the wastes had to be taken from the scouring train in a fresh state. If the waste was stale, bacterial changes took place which made treatment very difficult, but if the waste was received for treatment before septicity set in, a cracking resulted in the alkaline-chlorine solution much the same as when ferric chloride is applied to sewage sludge. There is a distinct separation of the solids from the liquid, the sludge collecting either at the bottom or on the top, leaving a clear yellow liquid having B.O.D. of about 50 p.p.m. This liquor imposes no appreciable load on the receiving stream or sewage treatment process.

The treatment is simple to control because of an immediate cracking effect which results from the addition of calcium hypochlorite. Air is used mainly for mixing and the process simply consists of taking the fresh wool scouring waste, aerating it and adding calcium hypochlorite in such a dose that cracking takes place, with separation occurring in a few hours.

So far the method has been operated as a batch process. The clear liquid is drawn off and the sludge is treated with sulphuric acid to reduce the chlorine from the hypochlorite and to bring the pH to three or four. Then the sludge is filter-pressed and the grease removed.

*Mr. C. D. McGuire* (Columbus, Ohio): It seems to me that much can yet be done in the development of a sort of inhibitor to be used with chlorine, just as we use inhibitors with acids. We find so often that a much more selective action takes place. I would like to hear Mr. Faber's opinion about this.

*Mr. Faber:* I think that is exactly true and meant to stress the point that we have not studied the use of chlorine in an alkaline combination or with metals or, perhaps, many other substances that we have considered heretofore.

*Mr. H. R. Shipman* (Mankato, Minn.): Would the speaker enlarge upon the use of chlorine in the treatment of cyanide waste?

*Mr. Faber:* You will find several references in the literature regarding the practical breaking point of these wastes when treated by chlorination. The treatment consists merely of the addition of chlorine to the extent of the chlorine demand of the waste, and at that point the cyanide is completely decomposed. Nitrogen is released by the reaction.

*Mr. H. L. Nelson* (Washington, D. C.): A recent discussion in connection with chlorination as used in water treatment has brought out that there is a series of breaking points, rather than a single, clear breaking point. It seems that new and complex products are continuously produced as chlorine is added and that these products progressively break down. Does this also appear in the chlorination of sewage?

*Mr. Faber:* Yes, definitely. We know that many materials are easily oxidized with small doses of chlorine but that other substances may require not only higher dosages, but longer contact periods as well.

At the present stage of our knowledge, it does not appear that the employment of very high dosages of chlorine to reach such extreme breaking points in sewage will be economical. While the problem is purely a chemical one, the reaction does not take place nearly as quickly as we might wish.

*Major Eliassen* (U. S. Engineer Corps): In regard to the treatment of wool scouring wastes, have you had any comparative results on the effectiveness of aeration alone as against aeration plus chlorination? Did you not do some work along these lines with wool scouring wastes and domestic sewage at Rochelle, Illinois?

*Mr. Faber:* Yes, I made a study several years ago at Rochelle, Illinois, but it was an example, in my opinion, of poor research because we were attempting to treat a waste which was highly variable in composition and rate of discharge. Satisfactory results by any treatment process depend, first of all, upon a uniform discharge of the waste, and in this particular installation we were confronted with very erratic conditions.

There are some limited data as to the removal by aeration alone and by aeration with chlorination, but the treatment was only moderately effective in this case because of the above condition. I believe that most industrial wastes should be treated in as concentrated form as possible rather than after dilution with domestic sewage. Such waste should preferably be treated at the source while fresh, and this was not done at Rochelle.

# POSTWAR PLANNING IN SYRACUSE AND ONONDAGA COUNTY*

Glenn D. Holmes

*Consulting Engineer, Syracuse, N. Y.*

Your reaction to Postwar Planning is perhaps like that of a great many others—"let's finish the war first." There are so many governmental agencies clamoring for lists of postwar projects we are becoming surfeited. The very name "postwar" causes a shudder and our hair to stand on end.

Our planning for Syracuse and Onondaga County is not a program to list or to make plans for all the conceivable projects which may be invented to make work or to give employment during the transition period which will follow the close of hostilities. If our program followed the stereotyped form with which you are all familiar, I would not be here to tell you about it. I am more certain I would not be contributing so much of my time and energy, with many others of our citizens, unless I believed it would be of benefit to our community and make our city a better and more enjoyable place in which to live.

Our city is a good place in which to live and make a home right now but like other wide-awake progressive cities, which have grown so rapidly, the development has not always been guided in the right direction.

Syracuse is advantageously located in the center of our State, near the center of Onondaga County and at the southern end of Onondaga Lake. Did you know that leading hotels of New York City acquired an enviable reputation by serving Onondaga Lake white fish? Their menus still carried Onondaga Lake white fish long after these fish had left for parts unknown.

Onondaga Lake and the lands for two miles "about it" was purchased by Sir William Johnson from the Indians in 1751. Industry started with the making of salt from nearby flowing springs. A grist mill, operated by water power, was built in 1805 and did a thriving business. When the old Erie Canal was completed in 1825 Syracuse salt was a most important cargo. The tolls collected for boating this salt went a long way toward paying the cost of the original canal.

At the time the New York Central Railroad was put through, about 1839, the merchants thought it too far from the center of the Village. The city was incorporated in 1847. It grew and prospered; the old canal has been filled and made a boulevard; the railroad has been moved from the center of the business district and elevated; no longer is Syracuse known as the town where the railroad runs through the streets but as the city of diversified manufacturing.

The story of Syracuse development is, of course, not greatly different from that of other American cities. Increases in population

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continually brought new problems which required study and planning for the future. Pollution of the water courses necessitated intercepting sewers and sewage treatment; congestion of traffic required the widening of streets, the opening of new boulevards, and the elimination of grade crossings; gradual encroachment on the channels of the waterways by buildings was not appreciated until flood prevention became a real problem.

When the need for some unusual or large undertaking such as these, requiring special study and investigation, became urgent, a commission of perhaps 3 or 5 outstanding citizens has usually been appointed for the planning and execution of the work.

From its unpretentious beginning in the midst of a forest which was once considered a wilderness, Syracuse is now a city with more than 200,000 people. Its metropolitan area includes thriving villages and unincorporated communities with additional thousands of individuals who look to Syracuse for employment, the necessities of life, recreation and pleasure.

Buildings and homes like people grow old. There comes a time when property values depreciate. The owners who have accumulated sufficient means to acquire a modern residence move to a more desirable home in the suburbs or country. Income from rental of the old home declines until it is no longer sufficient to take care of upkeep and taxes. The old neighborhood becomes a liability rather than an asset and delinquent taxes are a serious problem. This is but one of many problems facing all of the older cities today.

We are living in an impatient age; the people complain and begrudge the time in getting to and from work, the movies, the airport or the golf links. The city is too congested, there is too much noise and confusion. Taxes are too high. What can be done about it?

Syracuse is the home of many large industries, working night and day in an "all out" effort to speed war production. Many factories are engaged exclusively in war work. Attractive wages have brought hundreds of men and women to the city. Some day the war will end. What can be done to prevent a repetition of the period that followed the first World War with its frantic scramble to find worthwhile public work?

The citizens of Onondaga County propose to find the answer to these questions right now, by inaugurating a Master Postwar Plan—the replanning of the metropolitan area.

The county and the city are so closely related in many ways that it is logical to include the whole community in this investigation. Both city and county have had their planning commissions for many years but in general their activities have been restricted in scope to particular problems for which funds have been allocated.

Our farsighted Mayor, Tom Kennedy, and the resourceful Director of the Syracuse Planning Commission, Sergei N.. Grimm, must have burned gallons of midnight oil for they are responsible for putting an entirely new meaning into Postwar Planning. *Fortune* magazine learned of these activities and sent an investigator to learn more particulars. As a result *Fortune* magazine and the *Architectural Forum,* both interested in the "Domestic Economy," are co-operating generously by furnishing several recognized expert planning consultants to give assistance and advice in developing the Master Plan. These magazines are more interested in postwar economic problems. Syracuse is more interested in the kind of a community we are to have in the future.

It is not the intention to make our city the largest or even the most prosperous in the country but the most livable. This means planning not only for the postwar period but for the far distant future as well.

The development of such a program requires the combined effort and the best talent available of planning experts, engineers, architects, statisticians, industrialists, business men, transportation executives, bankers, lawyers and all other public minded citizens.

To eventuate this objective, fifty men and women have been appointed to serve as the Syracuse-Onondaga Postwar Planning Council. Each member was chosen because of special knowledge or experience in some particular field which would be helpful in formulating the Master Plan.

The Council is resolved into three groups and with the assistance of public and private agencies, sub-committees and individuals is making an intensive investigation and study of all the ramifications of this undertaking.

The Research and Planning Group is concerned with the factfinding as related to the present situation of the community and its future needs.

The Ways and Means Group are delegated the task of solving financial and legal difficulties anticipated in consummation of the Master Plan.

The Public Participation Group is engaged in finding out what the community desires, what it needs and in stimulating interest by keeping the public informed on the progress being made.

Various agencies of the city and county are co-operating wholeheartedly in this work. The Chamber of Commerce is investigating the requirements of industry and commerce; the Council of Social Agencies is assembling information pertinent to community health, recreation and social delinquency; the City Planning Commission is making available a voluminous fund of data accumulated over years of study and research; the Syracuse Housing Authority will have a plan for rehabilitation and revitalization of the declining residential and mercantile areas; the County Park and Planning Board is engaged in the study of recreational facilities outside the city; the County Public Works Commission is developing tentative preliminary plans for flood control, drainage, water supply and sanitation throughout the county.

There is probably no one factor of greater influence on planning than population. How many people will reside in Onondaga County in the future and where will they live? Will present trends of growth or of decline continue in different sections of the city, its suburbs and the villages, and for how long?

If these questions could be answered definitely and correctly, it would greatly simplify the problems of transportation, the widening of thoroughfares, the opening of new streets and highways. The most advantageous sites could be selected to best serve the future with new schools, fire stations, public buildings, parks and playgrounds. Plans for water supply, sewers, sewage treatment, garbage and rubbish collection and disposal as well as many others are dependent on the number of persons requiring service within a prescribed area.

Population statistics and related data are being assembled and made available to all groups by Prof. W. C. Lehman of Syracuse University who for many years has made this study a hobby. Duplication of effort by different groups is thus avoided, and more harmonious planning is assured.

The nature of the subsoil and the elevation of the ground water table is another subject of particular importance in planning structures where rock may be found not far from the surface on one side of a street and quicksand on the other. The abutments of the railroad bridge spanning Onondaga Creek, near the lake front, is supported on piles 220 feet long. Test piles driven to a depth of 120 feet for the Harbor Brook sewer floated the following day. Dr. E. T. Apfel, Geologist of Syracuse University, has completed a comprehensive survey of subsoil conditions, which will be of great value in all foundation problems.

You will observe that much of the work outlined is concerned with long range planning rather than for the immediate future.

One great difficulty at present is to obtain competent designers and draftsmen to prepare drawings. There are none to be found among the unemployed at present.

The program of the Council does not include the making of detail drawings and specifications for construction. This is the province of municipal departments, consulting engineers and architects. The Master Plan will initiate hundreds of construction jobs. These will be graded according to community needs and the ability to carry out. The Temporary State Commission, Postwar Public Works Planning, as an inducement to have plans and specifications completed and ready for awarding contracts, will pay half of the cost for such work. Application to the State Commission for such assistance has already been made for several of the projects included in the Master Plan.

In closing let me quote from a recent statement by our Mayor.

"Three important things must be kept in mind:

"First—That the initial concern of our country be to win the war.

"Second—That postwar planning be kept within the bounds of common sense.

"Third—That what is planned shall be within our means."

# Sewage Research

## A CRITICAL REVIEW OF THE LITERATURE OF 1943 ON SEWAGE AND WASTE TREATMENT AND STREAM POLLUTION

By Willem Rudolfs, *Chairman*, H. E. Babbitt, G. P. Edwards, H. A. Faber, A. J. Fischer, H. W. Gehm, A. L. Genter, H. Heukelekian, H. J. Miles, F. W. Mohlman, C. C. Ruchhoft, L. R. Setter, L. W. Van Kleeck

*Committee on Research, Section A, Federation of Sewage Works Associations*

The 1943 review of literature published on sewage and waste treatment reflects more accurately war conditions and war activities than any previous review. Last year the war activities were dominated by construction of new treatment plants, whereas now operation of plants is more in evidence.

In spite of the war activities the volume of printed matter pertaining to research, operators and developments is surprisingly large. Especially, since technical literature from foreign countries remained greatly curtailed. There is evidence that a considerable amount of research has been and is being performed in Russia, especially in connection with industrial waste treatment, such as sugar, dye, paper, pickling liquor, mine water, phenols, acids, and including disinfection and new methods. Unfortunately, few of the original publications and reports appear to be available in this country and the abstracts published contain insufficient detailed data to be of material value or allow judgment in regard to the importance of the work. It is hoped that some exchange arrangement may be made similar to that in force some years ago with the Moscow sewage experimental station.

The effect of war production plants discharging large quantities of more or less concentrated wastes has been a factor in stream pollution and operation of sewage treatment plants. Several surveys and studies published appear to indicate specific war-time wastes caused by explosives, alcohol and chemicals to be of greatest importance, while expansion of industry caused by war-time conditions are of importance to a lesser degree. Wastes produced by new products, including synthetic rubber and dehydrated foods are not a large problem for the country at large, but of some significance locally.

The revival of modified submerged contact aerators, with the construction of a considerable number of plants at military establishments, has brought to the fore the degree of purification accomplished, the difficulties in operation and cost. It appears that in this case again application outstripped basic knowledge, resulting in some confusion and difficulties.

Considerable information relating to various types of trickling filters was published. Although much of the material is valuable, no new principles were disclosed. Some pertinent information pertaining to high-rate filters has added to the still scant basic knowledge available. Much more is needed to evaluate accurately this type of filter in relation to various other oxidation devices.

Knowledge pertaining to the activated sludge process is gradually accumulating. Increased knowledge appears to lead to re-examination of the basic principles involved. Partial activation, with the return of various quantities of sludge and reduced quantities of air to produce clarification and partial oxidation has been under study and has been applied for several years, particularly abroad. Earlier laboratory and pilot plant experiments at Philadelphia, Amsterdam, and several other places led to new designs and seemed to point the way to effective and comparatively inexpensive treatment. Newer experiments along these lines, conducted in New York, appear to be of particular interest for the future.

Little new basic information regarding sludge digestion, which is still the heart of the sewage treatment problem at many places, has been published. Although a dozen problems were under study, according to the survey of research problems published in the May and July, 1943, issues of the *Journal,* peculiarly, no fundamental work was suggested. Some of the problems under study undoubtedly will add materially to our present knowledge. However, the question arises whether it is perhaps time to compile, examine and restudy the available information as a basis for further study.

Utilization of sludge for agricultural purposes, particularly for victory gardens, was widely discussed. Opinions on the use of sludge for such purposes have been crystallized and do not vary greatly from previous ideas. Economic factors and psychological reasons will continue to dominate the use of this by-product.

Chlorination, which is used more in this country than anywhere else, still presents a number of problems. It appears that research on potential uses of chlorine has not kept pace with studies pertaining to physical and biological methods. This valuable adjunct of treatment warrants additional fundamental study.

Although circumstantial evidence seemed to point to a relation between poliomyelitis and pollution, the trend of the argument is now definite that naturally the virus should be found in sewage, but that it cannot be considered a water-borne disease. This deduction is mainly made from epidemiological knowledge. The whole question should not be over emphasized, but still bears watching. It is very doubtful that plant research can add materially to increased knowledge.

Abatement and control of stream pollution has been complicated and accentuated by the war and war industries. In some sections of the United States pollution control and abatement has decreased, whereas in other sections a determined effort is being made to maintain prewar standards or increase abatement of pollution. In general, it appears that stream pollution has increased materially, primarily on account of increased industrial activities. In England the Central Advisory Water Committee considered the existing system of river pollution control generally inadequate and even sometimes wasteful. The creation of 29 new river boards to supersede existing authorities has resulted in considerable discussion. It seems that it is generally accepted that the drainage area is the best unit for river control. There is still a good deal of conflicting opinion in the United States regarding the best method of control. It seems that we are drifting into the possibility of some method of supervision, shared by Federal and State agencies, but no specific, uniform system, agreeable to all, has been developed or proposed.

Postwar planning has been succinctly expressed by "Blue Print Now." The blueprinting is thought of primarily in the sense of postwar construction. Construction is, however, only one phase of the entire problem. Both the legal phase and research form an integral part of postwar planning. It is only natural that these phases are lagging behind.

The annual review presented is not a complete enumeration of all papers published, but a more or less critical examination of the progress of the science and art. New processes rarely come to the surface spontaneously; a gradual development of new methods and a slow evaluation, based upon fundamental studies, is more logical. The review indicates a continued advancement in theory and practice, possibly leading to definite new developments.

## GENERAL

(See also Stream Pollution section)

*Disease.*—Maxcy (165) and Maxcy and Howe (166) in reviews of the available evidence regarding the dissemination of poliomyelitis virus came to the conclusion that at present the evidence is insufficient to justify the belief that water or sewage is a medium of any practical importance. It is true that the virus has been isolated on several occasions from sewage but it does not seem to survive very long in this medium. The disease does not behave like a water-borne disease and the incidence is not correlated with the quality of water supplies.

The recovery of antibacterial substances obtained from soil organisms has been duplicated by Carlson and McKhann (42) by the isolation of an active principle from activated sludge antagonistic to *Staphylococcus aureus, E. coli* and especially to poliomyelitis virus. The substance could only be recovered from activated sludge which had been allowed to digest anaerobically for some time. It is to be expected that with further search, other active antibacterial substances and bacteria capable of producing bactericidal substances might be isolated from sewage treatment processes. The failure of intestinal and pathogenic organisms to survive in polluted waters might be attributed to the presence of such substances.

Littman (154) described a rapid method for the isolation and identification of enteric pathogenic organisms from feces with the use of standard media. Monteverde and Ferramola (178) isolated bacteria belonging to the genus of Salmonella from Buenos Aires sewage.

Gordon (87) found viable cysts of intestinal protozoa such as Entamoeba in Moscow sewage as well as in effluents from the treatment plant. Standing for periods up to 6½ hours with and without $FeCl_3$, coagulation failed to eliminate all of the cysts. Exposure to concentrations of chlorine up to 12.7 p.p.m. for 30 minutes had no effect upon the cysts of *E. histolytica* (see also Cram references).

*Bacteria.*—Electron microscope examinations of bacterial cells have revealed according to Mudd (183), structural changes as a result of the action of germicidal agents dependent upon the penetration of the heavy metal ions or molecules into the cell and the interaction with the protoplasm resulting in the coagulation or escape of the protoplasm from the cell.

Zobell and Grant (275) have found that a medium containing only 0.1 p.p.m. glucose or peptone permits the growth of bacteria. This is a lower limiting concentration than reported before. The rate of multiplication and oxygen consumption in solutions containing less than 10 p.p.m. glucose and peptone is directly proportional to the concentration of the substrate. Sixty to seventy per cent of the organic substrate is oxidized and the balance is converted into bacterial protoplasm. Zobell (274) discussed the role of solid surfaces upon bacterial activity. He states that small quantities of organic matter are adsorbed from the water in dilute nutrient solutions containing less than 10 p.p.m. organic matter. The solid surfaces also provide a resting place for bacteria and may retard the diffusion of enzymes and hydrobyzates away from the cell thereby enhancing bacterial activity. The degree of roughness does not influence the attachment of bacteria but the solid surface must be distributed throughout the dilute solution to be most effective.

Grant and Zobell (90) have further demonstrated the ability of certain bacteria to oxidize hydrocarbons such as crude oil, petroleum ether, kerosene, gasoline and toluene. The concentration of the hydrocarbons used was 0.66 ml. per liter. The method of demonstration of the utilization of the hydrocarbons was by the measurement of oxygen utilization. The oxidation of other hydrocarbons such as paraffin wax, paraffin oil, vaseline, benzene, xylene, n-hexane, pyridine and naphthalene was also demonstrated. In general, aliphatic hydrocarbons are attacked more readily than cyclic or aromatic compounds and long-chains are more susceptible to bacterial oxidation than hydrocarbons of small molecular weight.

Wattie (254) states that zoogleal bacteria isolated from activated sludge and trickling filters might be considered in one group because of their similar cultural and biochemical characteristics. The floc-forming organisms isolated from trickling filters develop, under aeration, an activated sludge functionally similar to the floc-forming organisms isolated from activated sludge.

*Corrosion of Pipes.*—Soil corrosion of metallic iron through the activity of anaerobic sulfate-reducing bacteria was discussed by Starkey and Wight (235). Location of corrosive areas by the determination of oxidation-reduction potentials of the soil was attempted. The results indicate that highly reducing soil conditions can be detected from redox potential measurements. Since the development of sulfate-reducing bacteria and subsequent corrosion is associated with reducing conditions, such detection is of good diagnostic value. Good correlation between soil corrosiveness and degree of reduction of the soil was obtained.

Bunker (36) also subscribes and confirms to the theory advanced by Wolzogen Kühr on the role played by sulfate-reducing bacteria in the anaerobic corrosion of pipes in clay soils and discusses the effectiveness of a number of preventive measures such as pipe coatings, impregnated wrappings, cathodic protection, etc. He is doubtful of the value of the oxidation-reduction measurements as suggested by Starkey and Wight in locating corrosive areas.

*Fertility Value.*—Jenkins and Lockett (121) called attention to the loss of phosphorus in the effluent from sewage treatment plants. At Coleshill Sewage Works of the Birmingham Drainage Board, the total phosphorus in sewage is equal to 1.3 gm. of P per capita per day. The purified sewage contains 54 per cent of the P in the crude sewage. At Mogden (Middlesex Main Drainage Works) the crude sewage contains 1.56 gm. P per capita per day and the treated effluent 40 per cent of the amount present in the crude sewage.

Yushok and Bear (271), in discussing methods of preservation, deodorization and disinfection of poultry manure, state that whereas untreated manure lost a large percentage of its nitrogen as ammonia during storage, the addition of hydrated lime not only deodorized it but also reduced the losses of nitrogen. It also effectively killed most of the pathogenic bacteria in the manure.

*Hazards.*—The death of the three men from asphyxiation due to sludge gas from sludge flowing into a basement, reported by Brandt (32), brings forth once again the ever-present danger of sewer gas and the lack of adequate protection. As a method of reviving asphyxiation cases, Henderson (101) states emphatically that the pulmotor or ''resuscitator'' in which mechanical respiration by suck and blow method is used, is worse than useless and has been responsible for many deaths which might otherwise have been prevented. The fault with the device lies in the fact that the breathing induced by it is discordant and out of step with the patient's breathing and occasionally lung injury and hemorrhage is caused by mechanical damage done by the apparatus.

*Sewer Ventilation.*—Smith (226) discusses the experiences with forced sewer ventilation as a protection against sewer deterioration in Los Angeles. The section of North Outfall ventilated covered a length of six miles. The equipment consisted of a sawdust type blower which delivered 22,000 cubic feet of air per minute. The air was admitted through the manhole covers covering a distance of three miles. Ventilation caused the disappearance of the wet, stringy substance composed of sulfides covering the sides of the sewer. The tile became dry and cement joints which formerly had been the consistency of soft putty dried and hardened. The exhausted air had a humidity of 100 per cent and hydrogen sulfide content of 16 p.p.m. A permanent station has been nearly completed on the basis of the earlier experimental work.

## ANALYTICAL PROCEDURES

The approximate determination of dissolved oxygen by the amidol method has undergone a marked improvement by the spectrophotelometric measurements according to Ellis and Ellis (64). The red component of colors formed by amidol appeared proportional to the dissolved oxygen. The use of a spectrophotelometer set at 4,900 A.U. or a photelometer with a light filter which transmits primarily in the 4,900 to 6,000 A.U. zone was found desirable. The method was accurate to 0.1 p.p.m. in the range 0.2 to 2.5 p.p.m. and was effective up to 5.0 p.p.m. With provision to compensate for turbidities, the method should prove rapid and reliable.

The Massachusetts Department of Public Health (163), Elliassen and Schulhoff (63), Gehm (77) and others report control studies on the determination of grease in sewage or sludge. The status of grease determinations remains unchanged from that of the 1941 review of literature, except for the radical departure of extraction procedure reported by Gehm. In the latter case, the dewatered, dried, and weighed solids sample is extracted with hot mineral oil, filtered through a tared gooch, the residue washed with petrolic ether. After drying, the residue is weighed. The loss of weight yields a fair approximation of the amount of grease.

Mathis (164) satisfactorily substituted a clinical centrifuge for separating solids from the sample instead of vacuum filtration, in determining sewage influent and effluent suspended solids.

A new procedure was described by Klein (139) involving the use of ceric sulfate instead of $KMnO_4$ or dichromic acid for the oxygen consumed test of the strength of sewage. The ceric sulfate gave oxygen consumed values two-thirds that given by the dichromate test and two to three times that given by the permanganate test.

## SEDIMENTATION

Giles (83) describes various types of inlet and outlet designs for rectangular tanks and concludes that the inlet devised by Hubbell (*this Journal,* July, 1934) is to be preferred. He also recommends the use of sloping walls at inlet and outlet ends of tanks instead of the usual vertical type. Rostenbach and Waterman (198) conducted tests on two circular clarifiers to determine the effect of curved distribution vanes attached to the curved baffle around the central feed pipe of one of the tanks. Otherwise the clarifiers were identical. They found that the baffles had no effect on the efficiency of suspended solids removal.

Escritt (65) reviews English practice in the design of sedimentation tanks and describes the design of a constant velocity detritus channel, parabolic in cross-section, controlled by a standing wave flume.

Dobbins (56) presents the results of studies to extend the theory of the effect of turbulent flow on the vertical distribution of suspended matter in streams or settling basins under conditions when the suspended matter is in equilibrium conditions. He derived further evidence of the validity of the logarithmic law for the vertical distribution of sediment at the equilibrium condition. Other things being equal, equilibrium concentrations depend upon the amount of material available at the bottom up to the point of saturation. When the bottom is saturated with a given material, the equilibrium concentrations depend upon the hydraulic conditions of the bed. The equilibrium concentration above the bed is independent of the depth of fluid provided that the bottom is saturated.

Camp (40) proposed a method for estimating the effect of turbulence in retarding settling in open channel flows based on Dobbin's work.

Camp (41) presented a basis of a method of design of settling tanks where the mean velocity gradient of the tank will have the optimum value for the settling of a particular suspension. With regard to flocculation, the speed of flocculation is proportional to the velocity gradient at a point. In mixing chambers equipped with mechanical stirring the speed of flocculation may be controlled by the speed of the paddles independently of the discharge rate, provided that the inlet velocity is very low.

Wallace and Habermehl (252), reporting on two years of operation of the Detroit plant, showed 47.5 per cent suspended solids removal and 38.9 per cent B.O.D. removal with an average detention time of 1.5 hours, from original and suspended solids content in the sewage of 232 p.p.m. and B.O.D. of 132 p.p.m. Part of the high B.O.D. removal is attributed to chlorine application. The operation of sludge scraping mechanism is continuous.

## CHEMICAL AND MECHANICAL TREATMENT

Hyde and Rawn (118) in reviewing sewage treatment advances in America point out that despite few new installations of this type, interest in chemical treatment is still alive. This fact is evidenced both by the variety of papers and patents appearing in the recent literature and the number of research projects underway relating to it. An enumeration of the latter is found in a report by Rudolfs, et al. (202). Upon the fruition of such research depends the future of this method of treating sewage.

Extensive effort toward the improvement of processes employing lime continues. The approach has been toward providing a more thorough knowledge of this chemical and its function in sewage treatment. Although not concerned specifically with sewage treatment, a monograph by McAllister (167), dealing with the physical character of limes in respect to their applications, contains information of basic value.

The effect of production practice on settling characteristics, particle size, area and crystalline structure and electrostatic properties were studied. The conclusion derived was that the physical properties of lime can be controlled to an appreciable degree by the technique of manufacture. As a result of such research lime may in the future be "tailor made" to provide the characteristics best suited to a particular application such as sewage treatment.

Investigations by Rudolfs and Maggio (206) give a picture as to what physical qualities of a high calcium lime determine its effectiveness for sewage treatment. These authors state that with smaller particle sizes, clarification of sewage increases materially and lime having crystalline particle structure reacts more quickly in regard to pH adjustment as it is more soluble than amorphous types. They also conclude that the effectiveness of lime in reducing the coagulant demand of sewage is not merely a question of pH adjustment but that lime itself is an effective clarifying agent when properly applied.

Rudolfs and Nickol (208) studied the application of lime to sewage clarification and concluded that high calcium hydrate was the kind best suited. Lime in solution gave the best results in both pH control and clarification, a ten per cent slurry next best, and dry lime the poorest. Results approximately equal to those obtainable with lime solution were produced by adding dry lime to a portion of the sewage to be treated, stirring and adding this volume to the remaining sewage.

Burr (38), in discussing uses of ferric sulfate in sewage treatment, points out the odor controlling ability of this chemical and its apparent effect in increasing bacterial decomposition in sludge digestion and aerobic processes of sewage treatment when employed for treating the sewage.

Experiments of as yet purely academic interest are reported by Hansen and Gotaas (98) involving the clarification of sewage by flotation produced by surface active agents. A heterpolar laural amine hydrochloride of strong frothing and collecting properties was employed for most of the work. B.O.D. removals in the range of 85 per cent were obtained, when optimum dosages (60 p.p.m.) of the chemical were applied, on about 15 minutes aeration. The collected froth coalesced into clear liquid and sludge layers, and return of the former to untreated sewage reduced the dosage of chemical required from 20 to 25 per cent. The sludge obtained from this treatment digested readily despite the fact that the chemical was bactericidal to sewage. The reagent employed is, at present, too costly to consider practical application.

Operational reports brought out several new situations in which chemical treatment provided overload relief and added plant capacity in extraordinary circumstances. Leist (9) describes one such condition at Circleville, Ohio, where low sewage flows are treated by mechanical flocculation and sedimentation and chemical treatment is employed to keep plant performance at the same level during periods of high flow. The use of chemical treatment prior to the activated sludge process to relieve the latter of overload due to cannery and creamery wastes at Celina, Ohio, is described by Uhlmann (245). Average results of two years operation, treating a sewage with a B.O.D. of 636 p.p.m., showed reductions of 49 per cent by lime-iron salt treatment and 96 per cent by combined chemical and activated sludge treatment. Difficulties resulting from fluctuations in the character and strength of sewage on account of batch waste discharges were numerous, and skilful supervision and control was required. It is interesting to note that chemicals were employed only when discharge of industrial waste was received or expected, thus holding the chemical cost down to an annual figure of $4.35 per m.g. passing through the plant.

McKeeman (169) reports that at Freeport, L. I., increased population overloaded the sewage treatment plant by more than fifty per cent. Application of chemical treatment, after only minor changes and additions to the units, produced a satisfactory effluent by the existing plant.

Chronic bulking in a mechanically aerated activated sludge plant in England led Edmondson and Goodrich (60) to perform considerable laboratory and plant experimentation with chemical treatment in an effort to find a means of alleviating the condition. Of particular interest was the inclusion in the plant trials of chemical feed to the aerators. Alum applied in this manner helped for a short time but did not produce lasting results. Chemical treatment applied in the pre-sedimentation unit to reduce the B.O.D. of the sewage reaching the aerators was best accomplished with alum or sulfuric acid and alum. Such treatment of the highly comminuted sewage averaging daily as high as 841 p.p.m. B.O.D. proved too costly and erratic so that other means were employed to relieve the bulking. Failure of chemical treatment to provide economical pretreatment was probably due either to the character of the sewage or the lack of proper chemical feeding, mixing and flocculating equipment.

New Brunswick, New Jersey (8) extended the capacity of a plant designed to handle 9 m.g.d. to 13.5 m.g.d. capacity by providing additional chemical feeding equipment and changing piping, gates and wiers. The increased capacity was necessary due to expansions in population and industry resulting from the war and had to be provided without construction of additional plant units.

Eight recent patents related to chemical treatment were found in the literature, most of these relating to details concerning the application of well-known coagulating agents. One really new coagulant is described by Slagle (224). This is a basic alum of the emperical formula $Al_2Cl_2 \cdot (OH)_2SO_4$ and is produced by treating an alum solution with calcium chloride and soda ash. Rapid floc formation in sewage at dosages lower than those required with alum is claimed for this chemical. Patents relating to the use of iron, manganese and cobalt bearing coagulants were issued to Jung (128), Jung and Schröder (129), Schneider (215) and Brintzinger (35). Nothing particularly novel was expounded in these patents nor in one issued to Henry (103) pertaining to the use of suspensions of lime containing coke dust, clay, soot or ash.

Coleman (48) patented a process utilizing ferric chloride together with an insoluble phosphate as a coagulant for which he claims acceleration of settling and production of a readily filterable sludge. Daily (51) obtained a patent covering the use of ozonated air for clarifying sewage.

Fischer (70) (71), experimenting in both laboratory and plant, demonstrated that removal of suspended solids by vacuator treatment could be raised to over 90 per cent by the use of ferric chloride.

The use of mechanical flocculation without the aid of chemicals to help solve San Diego's sewage problem is described by Phelps (189). Three 100-foot diameter clariflocculators were included in the plant design. Rudgal (200) points to high removals of suspended solids at Kenosha, Wisconsin, effected by flocculator treatment of sewage containing metallic trade wastes.

## GREASE REMOVAL

Sufficient attention has been given grease removal in the past year to record here literature pertaining to it. Fales and Greeley (68) summarized the knowledge up to 1941 in creditable manner in a monograph on this subject.

Fischer (70) (71) presented two papers describing a process consisting of aerating sewage in a manner resulting in dispersion of fine bubbles of air in the sewage followed by reducing the atmospheric pressure above the sewage and resulting in rapid flotation of free grease and settleable solids. This process is known as "vacuation" and was shown to be capable of removing a considerable percentage of sewage solids and most of the free grease at extremely high overflow rates. Plant and laboratory experiments are presented dealing with the basic requirements and characteristics involved in the operation of the process and design of equipment employed is illustrated.

## TRICKLING FILTERS

During 1943 considerable information was published relating to various types of trickling filters from the standpoints of general principles, evaluation, operation, design, and experimentation. Although much of this material is of value to the designing engineer, plant operator and research engineer, nothing involving new principles has been disclosed. As W. Watson states (155): "The present tendency seems to be the investigation of combinations of well-tried older methods." Due to war conditions, some of the interesting material published abroad prior to 1943 has not become available for an earlier review.

*General.*—In a clear and instructive manner, Lovett (155) shows what happens when microorganisms are provided with a suitable "anchorage" in purifying settled sewage by the various modern methods of contact treatment. The initial anchorage for the effective biological slime varies from that artificially provided in trickling filters, intermittent sand filtration, and contact aerators to that originating in the suspended solids of the sewage itself in the activated sludge process, where the active surfaces become more concentrated in the sludge floc.

The various processes are classified according to the size of the material providing the anchorage, and the broad types and particular developments of the processes are described by Lovett and discussed by various authorities. Considerable attention is devoted to all practical types of trickling filters. Such filters are regarded as better suited to partial high-rate treatment and are more shock-proof than the activated sludge process. At best, simple high-rate filtration is to be regarded as a useful partial treatment process. Even in this case, uniform dosing is of prime importance. Double filtration, alternating, and with recirculation of the effluent will deal with double the amount of sewage per cubic yard of medium daily of that which can be dealt with in any single filtration and the results will be better.

In the light of the foregoing, several critical comparisons of a general nature by Goldthorpe (85), Walton (253), and Greeley (93), deserve study. By taking for his subject a cubic yard of percolating bed material and examining it in the light of numerous experimental results in England and this country, Goldthorpe (85) states that the surface action between rivulets of trickling sewage, air, and percolating bed area with its countless members of a vast bacteriological community results in many physical, chemical and biological changes. The final result is a coagulation and oxidation of the suspended matters and oxidation and precipitation of matters in solution. In high-rate filtration the main effect is coagulation which corresponds to the action taking place in the upper layers of a normal filter where the instantaneous dosing rate is high.

Several tables are presented showing data on various experimental factors; *e.g.*, variety of filter media, percentage voids, distribution, time of contact, and oxygen demand of suspended solids in both trickling filters and activated sludge. From the close agreement between the last two items Goldthorpe concludes that the biological slime on filter media appears to be similar to the flocs of activated sludge. In the former case, water trickles through a suspension of flocs in air and in the activated sludge plant, air bubbles through a suspension of flocs in water.

This paper was discussed by various English authorities. On the basis of experimental work done in England and this country, Lovett cited different answers to the question of optimum filter depth, that is, whether or not a cubic foot of filter media would do the same work in either a shallow (4 to 6 feet) or deep filter (10 feet). Those interested in this important question should read the comments made by Hamlin. Other points discussed relative to the Goldthorpe reference were effect of size of filter media on ponding and purification, slime growth, relation between time of contact and purification, area of air-liquid surface in a filter and activated sludge, frequency and amount of dosage.

Under the direction of the Board of State Health Commissioners Upper Mississippi River Basin Sanitation Agreement, a thoroughly instructive report on high-rate trickling filter performance has been arranged and edited by Walton (253). Warrick states that the objective of the study has been to answer as many questions as possible concerning operation efficiencies to be expected under the various conditions met in actual practice and to set forth a reasonable basis for design of high-rate filters. This report contains an elaborate digest of test survey data and information on the performance of nine different plants in four different states. Some of these plants treat domestic sewage containing appreciable amounts of waste from dairy products, corn canneries, packing houses, and poultry produce. Some of the biological factors involved are presented by Wilson.

The report shows that recirculation definitely increases the reduction in total suspended solids and B.O.D. over that obtained by single stage treatment. The dependence of results obtained on uniform distribution of dose are measured and evaluated in a novel manner. Furthermore, recirculation through the primary clarifier is found advantageous to the clarification process only if the recirculated liquor contains sufficient solids to materially increase the concentration in the primary tank. All B.O.D. reductions are coordinated with dosage rates expressed in gallons per square foot of filter media daily. Some engineers may disagree with this method of expressing such rates. However, Lovett in the foregoing citation aptly states:

> "The dose expressed as gallons per cubic yard per day gives no indication of the magnitude of the dose applied to the surface of the filter, which is coming to be regarded as a factor of great importance. For this reason, doses are sometimes given in terms of daily volume of sewage applied to a unit area. . . . An analogous rating to gallons per cubic yard per day widely used in America is million gallons per acre-foot per day."

By means of a broad analytical framework Greeley (93) presents a general critical comparison of the various methods of current biological treatment, including standard and high-rate trickling filters, activated sludge, and the Hays process of contact aeration. He defines current high-rate terms, briefly describes typical plants, and on the basis of reliable available operating data sets forth a logical illustrative procedure for comparing the different ratings of various types of high-rate treatment.

In computations for the performance of typical high-rate aeration plants the percentage removal of B.O.D. by aeration and final tanks is related to pounds of B.O.D. applied per 1,000 cubic feet of aeration tank. In such computations for trickling filters the percentage B.O.D. removal is related to the loading on filters in pounds B.O.D. per acre-foot per day. Possibilities for further studies and analytical factors are also indicated. As to the possible effect of temperature of applied sewage on trickling filter purification, he realizes the data submitted are at present not sufficient to include such a factor in a close appraisal. That the effect of seasonal temperature changes does have a definite influence on loading rates and filter bed depth is evident from the experimental work done at Baltimore by Keefer and Kratz (133) and at Johannesburg, S. A., by Wilson and Hamlin (260). Both of these studies were reviewed by this Committee in 1941. Furthermore, in a more recent report, Hamlin (97) emphasizes the possible influence of atmospheric humidity and evaporation on the temperature and depth of open trickling filters and criticizes comparisons made between plants in different geographic regions without regard to this factor.

Dixon discusses Greeley's paper from the practical considerations of the Army's point of view. Compared to ordinary municipal treatment plants, Army post sewage is not only stronger but the sudden variations between minimum and peak loads offer a much greater shock to any high-rate treatment plant. Based on Army experiences, the quality of high-rate filter plant effluents is more variable in character than that produced by standard filters. Based on records at the Dallas municipal plant and a few Army camps Dixon, shows that experience does not always bear out the contention that unfavorable operating conditions, like ponding, are encountered in the range between high and standard rate loadings. Army experience with high-rate filters also indicates that satisfactory treatment, in terms of B.O.D., can be obtained if the loadings and/or recirculation ratios are correctly maintained. Operating filters in series as at Fargo, N. D., shows that it becomes progressively harder to remove the B.O.D. fractions left from previous stages. The import of these last two statements is brought out in the Lovett reference already cited.

*Operation.*—Vokes and Jenkins (251) show the effect of acid trade waste on bacterial beds of the Yardley sewage disposal works before and after enlargement of the works and employment of bioflocculation at high rates of flow. The Engineering and Contract Record (10) presents data relating to over 200 biofiltration plants in use at municipal and military installations in the United States and Canada. From the information presented it is possible to draw conclusions regarding the design of biofiltration plants for varying conditions. Nelson (184) also presents a general explanation and description of single and two-stage biofiltration systems with the number and sizes of plants in operation and the overall reduction in B.O.D.

There were several interesting reports on operational and processing problems. Eldridge (61) describes the operation of a 154 square feet recirculating filter constructed of silo tile with a holding and settling tank treating slaughter house wastes. The overall B.O.D. removal through the filter was 92 to 97.6 per cent and through the entire plant was 96.6 to 99.2 per cent. Barton (27) presents a comparison between the merits of activated sludge and bioflocculation at Findlay, Ohio. Activated sludge decreased the cost of removal on a B.O.D. basis but increased the cost of treatment and amount of sludge to be digested by increasing the percentage of water in the sludge.

The story of various changes necessary to increase the B.O.D. reduction from 78 to 90 per cent through the filters at Corpus Christi, Texas, is related by Allison (3). Howson (112) also presents an account of solving some operational troubles and plant difficulties in operating low-rate trickling filters at Westfield, N. Y., where industrial waste from fruit processing adds to the plant B.O.D. load and excessive infiltration increases the liquid load. For another locality, Cokato, Minn., King

(136) shows the solution of a problem of treating sewage from 1,400 population and a large volume of corn canning wastes. During the canning season the wastes are lagooned adjacent to the domestic sewage treatment plant and continuously recirculated back to the lagoon through a high-rate filter equipped with tile media. The partially purified waste in the lagoon then received further treatment in the village disposal plant.

The solution of the problem of reclaiming and rehabilitating trickling filter beds at Elgin, Illinois, is presented by Johnson (123). At this plant the dolomitic stone installed disintegrated rapidly in the top zone of the beds and caused pooling.

*Military Installations.*—Reid (194) describes the trickling filter design adopted for the R.C.A.F. which combines the merits of the biofilter and aerofilter and is capable of having the efficiency increased by forced ventilation or by regulation of recirculation. McLellan (172) shows that the engineers of the R.C.A.F. recommend high-rate and biofilters in designs for air-training camps of over 2,000 population in Western Canada. Hatch (99) presents some design factors for low and high-rate trickling filters for military installations in the United States.

There were some interesting reports on specific problems at three different army cantonments. Jessup (122) describes how two-stage biofiltration helps provide a high degree of treatment where the plant effluent discharges near wells from which the army camp water supply is drawn. By using symmetrically installed, identical units with manifolded pumps the installation provides material flexibility. Franks (74) briefly reports on the comparison of design and actual loadings of biofilters in an army post. Porter (192) relates how a biofiltration plant at an army camp for 30,000 was put into partial use several months before the plant was completed. Due to the flatness of the plant site, shallow, high-rate trickling filters with progressive recirculation were installed.

*Research.*—Tomlinson (243) describes and shows several figures of some of the fungi which occur in experimental filters treating sewage by single and alternating double filtration. The fungi belong to the genera *Fusarium, Oospora, Phoma,* and *Sepedonium.* An interesting experiment is described in which glass slides were placed on the surface of one of the alternating double filters in the presence and absence of light. *Fusarium* was the dominant fungus grown in the light, while *Oospora* predominated in the dark. In studying the decomposition of fungus mycelium a bacterium was isolated which decomposed the starved mycelium of *Sepedonium.*

Goldthorpe and Nixon (86) describe high-rate and double filtration experiments undertaken at Huddersfield, England, to improve plant results which deteriorated as a result of increased toxicity and the heavy chemical nature of the sewage since the commencement of the war. Two-stage dosing of settled sewage in a primary and secondary filter at high rates somewhat improved plant results. No evidence was obtained of the flushing action of sewage at the higher rates. The biological observations made on these filters are presented by Reynoldson. He states that during the present wartime conditions the scouring activities of the *Psychoda* larvae were insufficient to maintain the primary filter in a condition suitable to effect reasonable purification. This condition was attained in the coarse half of the secondary filter and in the fine half during most of the year. The restriction of macrofauna to *Psychoda alternata* is undesirable both from purification and nuisance viewpoints.

Hamlin (97) again reports on the continuation of the forced draft and heating experiments on the two 100-foot diameter trickling filters at Johannesburg. Each of these filters is divided into twelve equal experimental sectors. The average flow of 138 gallons per cubic yard daily was increased to 357 gallons. The sectors provided with ventilation show the greatest purifying effect. In commenting on the results, Hamlin emphasizes another factor (meteorological) which effects the temperature and depth of open trickling filters and which other investigators seem to have overlooked. He points out that atmospheric conditions in South Africa differ from those in some other parts of the world, *i.e.,* the low climatic relative humidity and high evaporation result in rapid cooling of the top stone layer. He states: "Therefore, the value of the work done by a cubic yard of medium increases with the depth and yet one hears that some designers still believe it to be economical to construct shallow filters."

The report of the City of Manchester (160) relates some experiences with the filtration of settled sewage in a small, experimental, enclosed, aerated filter. During the four-months operation in 1941 when the dosing rate was slightly less than in 1940, the pressure required to force air through the filter gradually increased from 0.01 to 1.6 inches (water gauge). No improvement was brought about either by flow increase or by diluting with final effluent in varying proportions up to 50 per cent of the total volume. However, resting the filter on alternate days for three weeks brought about material improvement. The effluent at the dosing rates used did not meet the standard set by the Royal Commission of Sewage Disposal. One interesting observation is that the sludge collected in the humus tank averaged 8 per cent solids which was considerably denser than that normally produced by percolating filters. This sludge drained easily on open beds.

Schreiber (218) describes what is evidently a novel experimental trickling filter which was tried at the Stahnsdorf Sewage Works, Berlin. This filter contains a fine-grained medium (5 to 10 mm.), has a larger than normal contact area and smaller individual voids per unit volume of filter. It is aerated both from above and below and may be either backwashed with the medium in place or the medium is removed and washed by recirculation. It is claimed that this filter costs but one-half as much as the normal trickling filter and has an efficiency several times greater.

In discussing the role of filter-bed material in trickling filters, Demoll and Liebmann (54) claim that filter beds of lava have the best structure for retaining water over longer periods and for rapid and complete colonization by organisms. Brick is unsuitable due to its capillary surface structure.

In studying the effect of the addition of sodium nitrate to sewage, Heukelekian (104) shows that among other things this compound acts to reduce the B.O.D. The mixing of sewage with trickling filter effluent results in a B.O.D. removal equivalent to the nitrate content of the effluent.

Edmondson and Goodrich (60) studied the recycling of highly-nitrified effluent to the trickling filter. The filter was operated at 275–500 gallon rates per cubic yard, not including the recirculated effluent which varied from 1:3 to 1:1. The filter through which the nitrified effluent was recycled did not pond and produced an effluent with 11–19 p.p.m. B.O.D. Previous experience indicated that the rate of application without recirculation of nitrified effluent could not be increased beyond 50–70 gallons per cubic yard without deleterious effects. On occasion when the filter ponded the application of nitrified effluent alone for two days cleared up the stones. The nitrates applied to the filter were completely reduced at the 2½ foot level.

Tomlinson (244) reported that when the film from different levels of the filter was aerated the nitrifying activity of the film from the top foot of the single filter was very low. The films collected from the lower levels had a higher nitrifying activity than the films from the corresponding levels in the alternating double filter. The nitrifying activity in the secondary filter was higher than that at the same level in the primary filter. It was also higher in the summer than in the winter period. Holtje (107) described some of the common microorganisms found in trickling filters.

*Filter.*—A trickling filter in which the fouled material in the bottom of the bed is washed and replaced on top of the filter, was tried out some years ago on a pilot plant scale with some success. The allowable rates of application were very high. A similar device, using filter media ⅓ to ½ inch in diameter and with the addition of aeration devices has been described by Schreiber (217). A considerable increase in efficiency and economy of construction is claimed for this type of filter.

Through experiments made on a laboratory trickling filter but 22 inches deep, Cram (50) concludes there was evidence that amoeba cysts and helminth ova may pass through trickling filters.

*Patents.*—Yeomans (269) patented a means of setting the hollow central distributor column of a trickling filter in true position. Marshall (161) patented a self-cleaning centrifugal spray nozzle. Levine (152) obtained a patent on a method of removing excess biological slime from trickling filter media by a combination of back-washing and air-blowing.

## ACTIVATED SLUDGE

Based on comments and data furnished from 25 activated sludge plants, Wisely (265) has presented an excellent 27-page review of the practical methods of maintaining air diffusers, of disposing of waste activated sludge and of controlling the principal operating variables of activated sludge. These variables are the concentration of aeration tank solids, the rate of sludge return, the rate of air application, the aeration period and the condition of the sludge.

Some new work has been done on the biology of activated sludge. Hoffman (106) in a study of the biology of conventional activated sludge and of sludge to which asbestos had been added (Z process), found fewer protozoa both in species and individuals in tanks of the Z process than in the activated sludge tanks. The same degree of purification was obtained by the two processes, but 5 to 7 times as long was required for treatment by activated sludge. He believes that the longer aeration period and the reaeration of sludge in the activated sludge process encourages the growth of the protozoa. The lack of protozoa in the Z process indicated to him that these organisms are not necessary for the purification of sewage. About 10 times as many free-swimming bacteria were found in the Z process as in the activated sludge, but the zooglea developed to a much greater extent in the activated sludge. Hoffman thinks that the free bacteria of the Z process react more rapidly than the bacteria in the zoogleal floc.

On the other hand, the studies of Pillai (190) indicated that more sludge was formed and effluents of better quality were produced when protozoa were present with bacteria than when bacteria only were in the sewage. Protozoa aid especially in clarifying the sewage. Pillai and Subrahmanyan (191) found *Epistylis* was the most efficient of the protozoa in the purification of the sewage.

Ridenour, Carlson and McKhann (196) found that activated sludge in amounts as low as 1100 p.p.m. with a 6-hour aeration period, removed or inactivated the Poliomyelitis virus to the extent that it was non-effective to mice when injected intracerebrally.

Experiments conducted by Viehl (249) showed that an oxygen concentration of 1.5 p.p.m. in an aeration tank is sufficient for purification. The decomposition of organic matter was not accelerated at higher concentrations of oxygen although the rate of nitrification increased considerably. Rohlick (197) confirms this in his oxidation-reduction studies of activated sludge when he found that only if the dissolved oxygen content drops below 1.0 p.p.m. does the electrode potential begin to fall off. With a well-stabilized sludge, the drop in potential takes place quite slowly when aeration stops and intense reducing conditions will not occur for a long time following the cessation of aeration. Electrode potentials of aerated sludge depend upon the concentration of suspended solids and good correlation was found between the stage of oxidation of the sewage as measured by the rate of oxygen utilization and the oxidation-reduction potential.

Moore and Ruchhoft (179) also studied the oxidation-reduction potentials of fresh and stale sewage and activated sludge.

Gould (89) has reported on the operation of the Bowery Bay plant of New York City with its new type final settling tanks. The plant was designed for and has been operated with step-aeration. The first of the 4 passes was used for reaeration of return sludge and sewage was added in equal increments at the end of passes 1, 2 and 3. The volume of return sludge was kept at about forty per cent of the sewage flow so that the suspended solids in the first pass would be low enough to maintain dissolved oxygen. In the final tanks, the direction of the sludge scrapers was reversed and the point of sludge withdrawal was placed at the end of the tank opposite to the incoming flow. The scrapers now operate in the same direction as the natural flow along the bottom of the tank. Velocity measurements have shown currents ranging from 5 to 10 feet per minute along the bottom of the tank toward the effluent end. As the scraper mechanism was designed for a velocity of 3 feet per minute, the function of the flights is limited to the removal of deposits which might lodge on the floor. The number of flights might well be reduced. The volume of tank provided per m.g. daily flow at Bowery Bay is only 57 per cent of that at Wards Island.

After experimentation at Two Rivers, Wisconsin, Sawyer, Rohlich and Tomek (211) concluded that the addition of waste activated sludge to the raw sewage prior to aeration seemed desirable as it resulted in about 25 per cent greater removal of B.O.D. than plain settling alone. In an attempt to evaluate the effect of stage addition of return sludge, Sawyer and Rohlich (212) arranged to add return sludge at any of 6 points in the aeration tanks ranging from the head end to the tail end of the tank. Even when all the sludge was added at the effluent end of the tank, the solids at the influent end were so high that it seemed to make little difference where the return sludge was added. Inability to control the back-flow of the sludge in the aeration tanks prevented them from obtaining conclusive results.

Plain sewage aeration, sewage aeration with the return of aeration tank effluent, and sewage aeration with the return of sludge to maintain less than 500 p.p.m. suspended solids in the aerator were studied by Setter (221) in an experimental plant supplied with a constant flow of 15 gallons per minute of settled sewage. With 1.5 hours aeration, suspended solids and B.O.D. reductions of 30 to 40, 60 to 65 and 65 to 75 per cent were obtained by plain aeration, the return of aeration tank effluent and the return of sludge respectively. With 3 hours aeration, the suspended solids and B.O.D. removals were 60 to 65, 65 to 75 and 75 to 85 per cent respectively. The sludge produced from aeration periods of less than 3 hours could be wasted at a concentration of 4.0 to 5.0 per cent solids. On storage, the sludge deteriorates quickly at summer temperatures, producing a vile odor.

Rudolfs (203) reported on the concentrating of activated sludge by compacting and flotation. Best results were obtained with flotation resulting from the addition of 8 to 16 pounds of calcium hypochlorite per 1,000 gallons of sludge. In 48 hours, he was able to obtain a concentration of 6 to 10 per cent. Compacting seemed more affected by the condition of the sludge than by the original density. Well-oxidized sludges required less chemical than poorly-conditioned ones.

Return sludge chlorination for the correction of bulking has been practiced successfully at Lima, Ohio for 9 years. According to Smith (225) the dosage required is not less than 6 p.p.m. based on the sludge return flow or not less than 8 p.p.m. for each per cent of solids in the return sludge. Nearly complete recovery from bulking may be expected within 7 days after the beginning of the treatment. Smith emphasizes that chlorine should be used only for correction of bulking, not for prevention.

According to Wirts (263), the improved method of cleaning diffuser plates at Cleveland is to soak them for several hours in a cleaning solution consisting of a 2 per cent solution of sodium dichromate in sulfuric acid. Then the plates are drained and thoroughly cleaned in a special machine which forces air and water through the plates for about 1 minute. The cleaned plates have about 90 per cent of their original porosity. The cost of labor in handling the diffusers is about 80 per cent of the total cost of cleaning, which is about 45 cents per plate.

Some plant modification and enlargement has been reported from England. At the Yardley (250) plant in Birmingham, chemical precipitation with iron salts and lime has been used prior to aeration. Although the settled chemically-treated sewage contained 15–20 p.p.m. of iron, it responded well to treatment by activated sludge and showed no tendency to clog the diffuser plates.

Lamb (149) has described the new activated sludge unit at Worcester. It is twice as large as any of the existing units and was designed for a dry-weather flow of 1.5 m.g.d. If desirable, the new unit can be made to produce a high quality of sludge and the surplus transferred to any of the existing aeration tanks.

In order to overcome the bulking of activated sludge in the bio-aeration system (Sheffield type) at Coisley Hill Works at Sheffield, England, Edmondson and Goodrich (60) recycled a highly nitrified effluent from a high rate filter back to the aeration tanks. The effluent from the bio-aeration unit was applied to a special filter dosed at the rate of 500 gallons per cubic yard. With uniform rain-like distribution on the filter by spray jets, 20 p.p.m. of nitrate nitrogen was produced, which when returned to the settled sewage entering the aeration unit in the ratio of 1:1, contributed 70 p.p.m. of oxygen. During a period of one year when one of the bio-aeration units was operated on this basis the sludge did not bulk and produced a lower B.O.D. in the effluent than the other unit not receiving the recycled nitrified effluent.

Jackson (120) discusses the effect and control of large infestation of chironomid larvae in the activated sludge process. It destroys the clarification, purification and regeneration power of activated sludge. The sludge does not settle readily and decreases in volume. The larvae do not persist in the absence of D.O. in the tanks. They are found in the aeration and final settling tanks. They devour bacteria, protozoa and organic matter in the sludge. Pyrethrum compounds are the most effective means of control. The floc is not affected by doses used to control the insect. The effective dosage is 1 pound per 5,000–20,000 gallons of sludge.

## SUBMERGED CONTACT AERATORS

There are at present 74 plants being built or are in operation using the Hays contact aeration process. Most of them have been built recently and many of them are located in military establishments. Griffith (94) reviews the development of the process since 1930 and particularly since 1938 when experiments had reached a point to permit the application. In 1939 the first municipal plant employing this process was built in Elgin, Texas (pop. 1,230), which has given a B.O.D. reduction of 90–95 per cent. The typical layout provides for screening, primary settling and two-stage contact aeration, each stage followed by settling. The total detention time in the three settling tanks is 3.37 hours at average design flow. The contact plates best suited for this purpose are asbestos cement $\frac{3}{16}$ in. thick, set vertically and at right angles to the tank axis about $1\frac{1}{2}$ in. apart. Air is supplied from the bottom of the tank six inches below the plates. Slime forms and discharges from the plates. Complete treatment is accomplished in $1\frac{1}{2}$–$2\frac{1}{2}$ hours aeration period under average daily flow conditions. Design requirement calls for 82 square feet of plate area per pound of B.O.D. loading. Adequate aeration is supplied with about 0.33 cubic feet of air per minute per square foot of aerated water surface and a total air of 0.9 cubic feet per gallon of sewage. Certain mechanical and operational difficulties have been encountered.

Greeley (93) enumerates a number of operating and mechanical difficulties encountered in this type of plant. Although some of these operating troubles are not inherent to the process, the operation of the plants has been difficult. The difficulties have been less and performance better in smaller plants with weaker sewages. The operating results given for a small plant of this type indicate a B.O.D. reduction of 82 per cent in aeration and final tanks. The B.O.D. applied per 1,000 cubic feet of air was 0.47 pounds and was twice as high as in activated sludge plants.

Franks and Obma (75) state that there are six army plants utilizing the Hays process in the Seventh Service command territory, which have all given trouble both from the operating and reduction standpoints. Two of the plants turning out a clear effluent are loaded only about 60 per cent of design and a peculiar odor is in evidence even in these plants.

Lackey and Dixon (145) reported on the biological life in plants using the Hays process. The survey included eleven plants, both army and municipal. Out of seven of these plants for which B.O.D. values in the influent and effluent are given, two had B.O.D. values in the effluent of 11 p.p.m. or less, four with values of 45 to 62 p.p.m. and one with 93 p.p.m. The influent B.O.D. in the latter case was 391 p.p.m. The flora and fauna were sharply limited. In the plants producing a good effluent the protozoa, rotifers and worms were characteristic of good activated sludge or a standard trickling filter. In the plants containing no dissolved oxygen the dominant protozoa consisted of five genera of protozoa and four genera of flagellates characteristic of Imhoff tanks or foul waters. It is stated that the biological composition of the film indicated insufficient utilization of or access to air. Filamentous organisms such as *Beggiotoa* and *Sphaerotilus natans* were found in abundance. Great quantities of sulfur bacteria were characteristic of all plants.

## CHLORINATION

*Chlorination under Wartime Conditions.*—Describing the design and operation of sewage treatment plants at military installations, Hatch (99) notes that, where required, chlorination is provided for disinfection of effluents or control of odors. Specifications call for a contact period of 15 minutes based on the 4-hour average maximum flow and equipment is designed to supply a dosage of 80 pounds per m.g. based on the 24-hour average flow. As an emergency measure, prior to completion of secondary treatment units, Porter (193) constructed and operated successfully an automatic hypochlorite solution feeder at one plant. Sodium hypochlorite was employed because of the low freezing point of this solution (minus 10° F.) and was found to function satisfactorily at temperatures even below its freezing point. The use of a lagoon and the maintenance of 4 to 5 p.p.m. residual chlorine provided a satisfactory degree of treatment.

At the Buffalo plant, according to Johnson (124), injector tips (used in the chlorinator injector throats and normally fabricated of ''Isolantite'') were needed but not available. Serviceable duplicates were made of babbitt metal, but proved too heavy; of hard rubber, but this stock then became exhausted; and finally of phenolic base plastic, which is now giving satisfactory service.

*Chlorination for Disinfection.*—With its chlorine feeding capacity of 27 tons per day, Detroit ranks as the largest municipal installation in the world. Wallace and Habermehl (252) report that post-chlorination has been found to be more economical than prechlorination in this plant, because of the extreme and rapid fluctuations in the hourly chlorine demand values. Chlorine dosage rates are anticipated by determining the chlorine demand of the influent, thus providing a 90-minute period for testing and for manual setting of chlorinators. In 1942 the chlorine demand tests showed an average dosage of 6.0 p.p.m. (238 tons per month). The demand satisfaction of 103 per cent accomplished an average monthly reduction of 97 per cent in coliform bacteria except during two months when breaks in water mains interrupted the operation of feeding equipment. During these months, the average monthly reduction was above 90 per cent.

Since operation of the Cleveland Easterly plant, the waters of six adjacent Lake Erie bathing beaches have shown (7) reductions in total bacterial contamination of about 90 per cent and in coliform organisms of about 85 per cent. This modern activated sludge treatment plant employs effluent chlorination during the summer months, as described by Wirts (261). The chlorine dose averages between 4 and 5 p.p.m., and this provides a residual of 0.5 to 1.5 p.p.m. in the effluent.

The first contract for construction of the Toronto sewage treatment plant was reported (22) as awarded in September of 1942. This construction will include primary sedimentation, sludge digestion, and chlorination units.

*Chlorination for Control of Odors.*—At the Cokato, Mo., municipal sewage treatment plant, separate pretreatment of corn canning wastes is accomplished on a recirculating filter. According to King (136), this filter was a source of objectionable odors until it was enclosed. An exhaust fan is utilized to give increased circulation of air, the air is discharged through a duct above the roof, and chlorination of the exhaust air is provided for odor control. The plant effluent is also chlorinated for disinfection and oxygen demand reduction.

When a wartime increase in connected population doubled the sewage flows for which the Lawton, Oklahoma, activated sludge treatment plant was designed, the effluent quality was little better than the raw sewage. Hendrick (102) described how chemical coagulation and high-rate filter units were added to provide an adequate degree of treatment. The Scott-Darcey process is used to produce ferrous chloride for odor control and ferric chloride for coagulation.

*Chlorination for Control of Activated Sludge Bulking.*—In a review of activated sludge plant control practice by Wisely (265), five plants are reported to have found the chlorination of return sludge efficacious in controlling filamentous organisms and in reducing the high initial oxygen requirements of bulking sludge. It appears that, for best results, such treatment should be instituted as soon as bulking becomes imminent and the chlorine should be applied at carefully-controlled rates.

The chlorination of return sludge has been used as a control method by Smith (225) at Lima, Ohio, for more than nine years. His experience indicates that it should be used for correction rather than for prevention of bulking. The use of at least six p.p.m. chlorine based on return sludge flow, or of at least eight p.p.m. for each one per cent solids in the return sludge has been found a suitable dose at the Lima plant. This treatment effects nearly complete correction of bulking within seven days after the start of chlorination. Data show the use of chlorine for this purpose has risen gradually from about 1,100 pounds per year to 9,200 pounds, but this consumption is considered economical since the power requirements for air compression have been reduced to a reasonable figure despite the fact that the plant operates in excess of its rated capacity.

*Chlorination for Control of Filter Pooling.*—The construction of one standard-rate filter unit at the Westfield, N. Y., plant created an especially difficult ponding problem. Howson (112) studied the application of chlorine solution directly from the chlorinator discharge hose to the surface of the filter; this treatment removed the ponds but also inactivated the filter for about five weeks. Flooding the filter with chlorinated water (having a residual of about 10 p.p.m. after 20 minutes contact) also eliminated ponding for two weeks, but inactivated the filter for about three weeks. After a series of experiments, it was found that flooding the filter at monthly intervals, and by chlorinating the top 3 to 4 feet of water (5 to 8 p.p.m. residual) the ponding was kept under control with no apparent harm to the filter activity. At another trickling filter plant, employing aero-distributors and handling industrial wastes, Nussbaumer (112) employed prechlorination (a 70-lb. per mg. dose) and post-chlorination (a 30-lb. per mg. dose). This treatment controlled odors and gave a satisfactory residual for disinfection.

An operation report by Kunsch (143) notes that, since wastes received at the Danbury, Connecticut, plant are in a fresh condition, it has been possible to eliminate the original practice of chlorinating the settled sewage prior to its application to the trickling filters. Chlorine is now added only when filters are flooded and this routine has reduced the former 15 ton per year chlorine requirement by 20 per cent.

*Chlorine for Special Applications.*—Textile wastes containing sulfur dyes have long been recognized as causing a high chlorine demand. Van Kleeck (246) reports that, at one large municipal plant in Connecticut, the demand of such wastes was far in excess of the original chlorinator capacity. The normal domestic sewage demand of 10 to 12 p.p.m. was increased to 60 p.p.m. and higher (500 pounds of chlorine per m.g. of sewage treated). The construction of holding basins and even discharge of the waste has corrected the wide fluctuations in chlorine demand which previously caused dosage difficulties. Studies showed chlorine to be the cheapest and most satisfactory oxidizing agent to treat the sulfur dyes.

The excessive load imposed by returning digester supernatant liquor to chemical flocculation units is described by Bell (29) as reducing alum floc to a colloidal form impossible to settle. By applying a heavy dose of chlorine in the primary tank for a 2-hour period, during the discharge of supernatant liquor, this condition was corrected.

According to Barnes (26) exceptionally high water rates at the Bowling Green, Ohio plant led to the use of sewage effluent from final tanks to supply the chlorinator injector feed. Cost of the pumping installation was about $300 and this has been fully justified; the charge for water previously averaging $223 per year was reduced by this installation to $28 in 1942, and this in spite of an increased use of 1,000 pounds of chlorine in that year over the amount applied in previous years.

*Chlorination Research.*—In studying the concentration of an activated sludge, using various physical methods and adding chemicals, Rudolfs (203) found that flotation resulting from the addition of calcium hypochlorite produces a dense sludge, varying from 6 to 10 per cent solids in 48 hours compacting. The quantity of hypochlorite required varied from 8 to 16 pounds per 1,000 gallons of waste sludge. Compacting with this chemical is affected by the character of the sludge rather than by its original density. Well-oxidized sludge requiring less chemical than poorly-settling sludges. Turbidity and B.O.D. of the liquor increases, but the addition of 50 p.p.m. ferric chloride prior to the addition of calcium hypochlorite produces a clear transparent liquor with a lower B.O.D. than the original sewage. While this enhances drainability of the sludge, vacuum filter experiments indicate that a sludge compacting to 8 to 9 per cent solids dewaters slowly. The liquor contains some residual chlorine and upon return to the influent would have no detrimental effect or would conceivably aid in control of odors.

A report on an investigation of the effect of break-point superchlorination on the B.O.D. of oxidized and settled sewage effluents has been published by Groff and Ridenour (95). Their results indicate that the amount of chlorine required to obtain the "break" was dependent upon the amount of nitrogenous material present, and that it was measured by the total second-stage B.O.D. of the sewage. The laboratory experiments appeared to show no increased reduction in the 5-day B.O.D. over that obtained with the low dosages of chlorine commonly employed, but the reduction was permanent. Beyond the first few p.p.m. added, the B.O.D. of a chlorinated sewage varied directly with the residual chlorine.

In reviewing the reported studies of chlorination as a means of inactivating the virus of infantile paralysis, Maxcy and Howe (166) conclude there is no justification for the statement that present-day methods of chlorination are of little value for this purpose. They point out the technical difficulties of duplicating actual conditions in experimental studies.

At a time when physical and biological methods of sewage treatment are being more critically appraised than ever before, it appears that the potential uses of chlorine warrant the same study. Yet the two reports of the Federation Research Committee (202) include only six research projects involving chlorination out of a total list of 128 problems being investigated; and, actually, these involve study of only four different chlorination problems.

## SLUDGE DIGESTION

*General.*—McLean (170) (171) discusses the basic principles and important factors involved in sludge digestion.

*Research.*—Nitrogen changes during digestion were studied by Snell (230). Results showed that unless nitrogen were present in the form of nitrates or nitrites (a very unlikely condition), nitrogen gas would not be formed during digestion. This would indicate that further studies on the composition of digester gases would be worthwhile, as most digester gas analyses show an undetermined fraction assumed to be nitrogen.

Difficulties in digesting undiluted human excreta due to the formation of large amounts of ammonium carbonate are pointed out by Snell (231). Corrective measures by carbonating the digesting sludge or the addition of carbon dioxide producing substances are outlined. A design of digester in which there is a horizontal screen at an intermediate depth is suggested. It is highly questionable whether this design would be practical due to blinding of the screen.

Straub (236) described detailed experiments involving the digestion of carrots, cabbage and potatoes, and concludes that all three vegetables digest satisfactorily when properly seeded. Less gas was obtained than from ordinary raw sewage sludge. Strong odors, controllable by activated carbon or ortho-dichlor benzene were obtained in the cabbage digestion experiment.

The digestibility of paper pulp mixed with raw sewage sludge was studied by Straub (237). No harmful effects were noted in a C : N ratio range of 20 to 111. The addition of lime was necessary to correct acidity.

Rudolfs and Faulk (207) give results of experiments on the treatment of digester overflow liquor with lime and with ferric chloride. The use of both chemicals gave best clarification, but the oxygen consumed reduction did not exceed about 60 per cent.

*Design.*—A comprehensive outline on the method of computing heat losses from digesters is given by Wittwer (267). Similar design information is presented by Kozma (142) who stresses the importance of proper tank insulation for effecting heat economies.

Two methods of treating digester overflow liquor are described in *this Journal* (4) (186). In the first, the liquor is treated on a recirculating back-washed filter. In the second, an atomizing aerator is used.

*Operation.*—Bell (29) indicates the advantages of chlorination in the primary settling tank of a chemical precipitation plant where the digester overflow is returned to the raw sewage. Rowntree (199) describes a fish ladder aerator which improved the settling characteristics of the overflow liquor.

Berg (31) outlines methods of improving digester operation based on experiences at San Antonio. Gunson (96) describes methods used at Denver in stage digestion whereby the digestion was improved by controlled heating and mixing. In *Public Works* (13), improvements in digestion by reducing the amount of raw sludge pumped to the digester are described. *Sewage Works Engineering* (17) presents a round table discussion on the scum problem in digesters.

Schick (214) describes the damage to digester heating coils at Van Wert, Ohio, caused by electrolysis or corrosion. At Aurora, Illinois (18), studies were undertaken on the corrosiveness of sulfur in digester gas. Anderson (5) describes the overhauling and repairs to a gasometer at Rockville Center, New York, where severe pitting was caused by the corrosive action of the gas.

Operation of gas engines at Aurora, Illinois, is described by Sperry (233), and at Cedar Rapids, Iowa, by Gottlieb (88). In the first case 75 H.P. gas engines are connected directly to sewage pumps, and in the second a 210 H.P. unit drives a generator.

*Data.*—Operating data at Findlay, Ohio, are given by Barton (27); at the Cleveland Southerly and Westerly Plants by Flower (72) and Gerdel (80); at Aurora, Illinois, by Sperry (232); and at the Birmingham, England, Yardley Plant by Vokes and Jenkins (251). Many other annual plant reports have been prepared and presented during the past year. Unfortunately, their distribution has been necessarily limited and they are, therefore, not generally available. A more general abstracting of these reports and the publishing of these abstracts would be highly desirable.

*Patents.*—Bach (23) covers a digestion process wherein mesophilic digestion of sludge is followed by thermophilic digestion. Moerk and Eisenberg (175) describe a process wherein sludge is digested aerobically. Kurtz (144) shows a fixed-covered tank for stage digestion of sludge in which the tank is separated into compartments by vertical partitions, and in which there is a gas dome disposed within the cover communicating with each of the compartments. Downes (57) shows a stage digestion tank in which the unit is divided into two compartments by means of a horizontal partition. Means are provided to operate the compartments in series or parallel, and to prevent undue upward or downward pressure on the partition.

## SLUDGE DISPOSAL

In 1943 interest was centered on the following topics: Use of sludge as fertilizer; vacuum filter practice; sludge incineration; elutriation of sludge; and advantages of digestion of sewage sludge prior to final disposal.

*Use of Sludge as Fertilizer.*—Wisely (264) in a sound editorial suggested the use of digested, air-dried sludge in Victory gardens *only* when it is spread over the ground surface in the fall and spaded in before the garden is planted, with an admonition not to use any sludge where raw-edible vegetables are to be grown. The additional safeguard of using year-old sludge by domestic users is also suggested.

At least one municipal sewage treatment plant (141) (Rutherford, N. J.) planted a victory garden to demonstrate the beneficial effect of sewage sludge on vegetables, and Van Kleeck (247) suggested how it might be used in the war emergency.

Van Kleeck (247) in discussing digested or heat-dried activated sludge pleas for its more general use, not only for its fertilizer value, but particularly as a soil conditioner. He states that failure to make use of it is a waste of a natural resource. It is admitted that there are problems to be overcome at many treatment plants before all or (in some cases) even a part of the sludge cake can be disposed of as a soil conditioner, but in view of the dearth of farm manure, the outlook for such disposal is deemed encouraging with sound development.

Backmeyer (24) at Marion, Indiana, has discontinued vacuum filtration of digested sludge and delivers liquid sludge for use as fertilizer in Victory gardens and to farmers. This change has reduced the cost per ton of dry solids from $3.75 for vacuum filtration to $2.90 for liquid disposal. Such disposal is attended, however, by more public health hazards and there is likelihood of objectionable odor. It is surprising that the practice is acceptable for Victory gardens.

Cram (50), working with the co-operation of the personnel of the United States Public Health Service Station at Cincinnati, Ohio, reports interesting laboratory experiments with the effect of various treatment processes on the survival of protozoan and worm parasites in sewage. The sewage used in the experiments was artificially inoculated. Her findings regarding sludge bear comment. The protozoan parasites causing amoebic dysentery in man apparently are killed by ordinary digestion processes. However, the large round-worm and hookworm ova do survive both digestion and subsequent drying of sludge. The temperature of digestion appeared to have little effect on their survival and drying for as long as 118 days of indoor drying or 170 days of outdoor drying was required to impair their viability. Heating of dried sludge to 103° C. for three minutes destroyed all round-worm eggs. It is probable that flash-dried sludge (which is subject to 1,000° F. for 5 to 10 seconds) would be free of all parasitic eggs. The author's thoughts are timely since they focus attention on a possible health hazard in the use of sewage sludge as fertilizer as the war progresses. While examination of sludges from 16 municipal sewage treatment plants in California showed, with one exception, no eggs of parasitic helminths, 27, or slightly over one-third of the samples from 17 army camps in 8 southern states revealed such eggs. The return of parasitic infected military and other personnel from the tropics and Orient may conceivably cause these organisms to appear in numbers in municipal sewage. It is, therefore, a public health problem that will bear watching now and immediately after the war.

*Vacuum Filter Practice.*—Lynch and Mann (156) in a joint paper discuss vacuum filter operation at Auburn, New York, and Cortland, New York. At Cortland, when five different brands of high calcium lime (95 to 97 per cent CaO) were tried, filter yields from 6.4 to 10.5 pounds of dry solids per square foot per hour were obtained. The results, at least with Cortland's particular digested sludge, showed that the CaO content of the lime was not the only factor affecting its ability to coagulate solids for dewatering. Rudolfs (205) has previously shown that the CaO content of hydrated lime is not its only factor affecting coagulation of sewage. Apparently filter operators would do well to check commercially-available limes in their respective communities for their relative coagulating properties.

Backmeyer (24) increased his filter yields with higher lime additions and less ferric chloride, but reports more lime carbonate scale blinding the filter cloths and drum openings, and dismantling of the filtrate pump every few days for a cleaning with acid. In summer the stronger ammonia fumes in the filter room were also unpleasant.

The writers concur with previous writers that the best chemical mixing results are obtained with the shortest possible mixing time.

Again at Cortland, pH studies showed the filtering qualities of the conditioned sludge improved with each rise in pH up to about 10.0. Any pH above 10 and up to 13 failed to affect the filtrability of the sludge to any great extent. The Committee might comment that beyond a certain point, additions of lime do not increase the pH of the sludge mixture. Thus, an economy results in the use of lime through pH checks of the sludge filtrate.

The cleaning of filter cloths at both Auburn and Cortland has proved unsuccessful. Cloth failure seems to be more a matter of age than of hours of service, and unless cloths are in practically continuous operation, they do not seem to have the life to stand acid baths. Dundas (248) at Chicago also finds the life of filter cloths to be largely a function of time rather than tonnage output. Cloths are subject to rotting, and their life is frequently determined by a crust of iron oxide formed on the back of the cloth. The Committee has observed many filter installations at small plants where hours of actual cloth use are far below averages at larger plants, primarily because of the actual age of the cloths.

The time required to replace filter cloths at Auburn was greatly reduced by the substitution of half-round soft wood strips of moulding held in place by six finishing nails instead of the bars of brass with numerous brass screws used to insure a tight fit of the cloth between each compartment of the vacuum filter. The change netted a saving of $3.00 in cost of brass screws and 20 man-hours of labor for each change of filter cloth. Palmer (187) states that at Detroit, use of ½-inch sash cord for the metal bars has cut the time of reclothing in half and the required number of workmen by one-third. The sash cord has a useful life of about three reclothings. Velzy (248) at Buffalo also finds sash cord a satisfactory substitute for the metal strips. Apparently metal division bars will not be used by manufacturers of vacuum filters in the future. Because of cloth blinding conditions at the point of panel divisions on the filter, Palmer found that with all panel sash cords in place the loss in cake production may easily amount to more than 20 per cent. This is because the air blow is not as effective in cleaning the cloth at the divisional strips. With only every third panel sash cord in place the loss in cake production was reduced to less than 7 per cent.

Gerdel (80) has experienced trouble at the Westerly plant in Cleveland with scale deposits in the filter wire-supporting screens. A rubberized cloth used as an apron between the filter drum and agitator, containing hydrochloric acid, has dissolved the clogging scale. The acid bath is repeated every six months.

The same plant installed in 1940 a new filter cake chute to divert filter cake from the incinerators to a point outside the incineration building. Other plants have found this convenience a real help in sludge disposal during incinerator breakdowns and repairs, which do occur. Such a by-pass is a practical necessity at all sewage plants using incinerators.

Velzy (248) at Buffalo leans toward the use of manual rather than automatic devices for applying chemicals in sludge conditioning. Manual control is proving superior there and elsewhere in permitting operators to readily check the rates of chemical additions. Buffalo is also using muriatic acid for cleaning lime scale from filter screens and pipe lines. The strength of acid, amount and method of treatment are not detailed in the discussion.

At the District of Columbia plant, Fuhrman (248) has been troubled with sagging of hard-rubber pipes used for handling ferric chloride solution or conditioned sludge. Replacement of this pipe by steel pipe with a hard-rubber lining was the remedy. Here no lime is used for sludge conditioning and analyses of discarded filter cloths reveal 52 per cent iron salts. A 24-hour exposure to a 1 per cent solution of oxalic acid increases cloth life about 30 per cent. The acid is made up in the filter pan and the filter drum with the clogged cloth in place turned in the solution.

During week-end shutdowns the filter cloths at Washington, D. C. would develop fungus growths. Saturating the cloths every idle day in a 100 p.p.m. solution of copper sulfate placed in the filter pan has prevented cloth disintegration from this source. It is not stated whether the copper solution is salvaged or discarded each day.

Schroepfer (248) in the same symposium gives improvements in filter practice at Minneapolis-St. Paul since the start of operations. The costs of operation and maintenance of the sludge disposal processes (including incineration) have been decreased from $6.97 per dry ton in 1938 to $3.41 in 1941. This amounts to a total annual reduction of $50,000. This saving is attributed largely to the advantage of having a relatively large number of professional engineers and chemists in supervisory positions.

Every effort is made at Minneapolis-St. Paul to obtain a concentrated raw sludge for conditioning. Within limits, this is always desirable for high efficiency. An average of 9.35 per cent dry solids sludge is handled after concentration. Considerable attention has been given the process of mixing in the conditioning tanks. Compressed air for mixing has been decreased in pressure with more points of admission, baffling changed, riffle boards used for dispersion of chemicals, and the detention period reduced from 13 minutes to 7 minutes. An 8-ounce Canton flannel cloth has been adopted at this plant. Proper washing and an acid bath for cloths have prolonged their life from 150 to 250 more hours. One to two carboys of hydrochloric acid (in 600 gallons of water), together with an inhibitor, is used after 350 hours of service. Cloths are washed with a spray set to impinge along the filter drums almost at right angles to the drums. A washing every 4 to 8 hours has marked effects on the quantity of conditioning chemicals required. A method has been developed for washing cloths without filter shut-downs. The wash-water pipe and nozzles would be installed under the cake discharge apron so that the filter section next to submerge in the filter vat would be washed. A trough suspended immediately above the sludge level would return the spent wash water to the overflow box on the filter. To date (1942), because of its recent conception and the priorities required, this scheme has not been incorporated in the plant. If adopted, it will not only provide a clean filter medium, but, in effect, will result in providing additional filter area.

Schroepfer in this symposium has considerable to say about the economical filter rate. Filter rates of 8 to 10 lbs. per square foot per hour have been reduced to 3.55 pounds per square foot per hour, and indications are that 2 pounds per square foot per hour would be the most desirable at Minneapolis-St. Paul based on total annual charges. Based on the tonnages produced at this plant, a reduction in the filter rate from

7 pounds to 2 pounds per square foot per hour would result in a saving in operation and maintenance costs of approximately $125 a day, or about $45,000 annually.

Schroepfer suggests a more accurate index of filter rates than the commonly-used unit of pounds per square foot of installed filter capacity per hour. This, he points out, does not furnish an accurate measure of the number of square feet of filtering surface utilized in a given period, since it does not take into account varying filter speeds. The index, "pounds per square foot" based on actual filter surface used, is suggested. To compute this a revolution counter for the filter drum is the only addition required.

*Elutriation of Digested Sludge.*—Fuhrman, in a discussion previously mentioned (248), states that at Washington, D. C., without elutriation, the sludge produced would require about three times the ferric chloride now used for conditioning. Elutriation shows a saving of $11,000 per year, or enough to pay for its installation every 4 or 5 years. This brings to mind the Committee's report for 1942 in which the favorable results from elutriation at Hartford, Connecticut, were given.

Backmeyer (24) reports an interesting modification of elutriation in describing the washing of digested sludge from a primary digester with cold quarry water. The sludge is pumped at a rate of 50 g.p.m. and the quarry water at 110 g.p.m. to the secondary sludge digester. This unique method of digester operation tends to stop sludge gasification, gives a more concentrated sludge (about 3 per cent more total solids) and a clear supernatant for return to the sewage. Results over a limited period have been very promising.

*Sludge Drying and Incineration.*—Velzy (248) at Buffalo reports abrasion troubles with flash drying, especially in the dryer proper, the induced draft fan, and at bends in pipe lines and ducts handling gases, powdered sludge, and fly ash.

In the pipe lines and ducts an economical solution has been the use of concrete wear backs at the bends. The concrete stands wear for a considerable time and is easily replaced.

A lower speed in the cage mill of the flash dryer has increased its life from two to about five months. Adjustment in the type of assembly has resulted in easy replacement of worn parts and the re-use of portions of these parts.

Severe wear on the induced draft fan (with a blade life of only about two months) was corrected by moving the fan to the clean air side of the cyclone. One unit in this location has operated for more than a year to date (1943) without showing appreciable wear.

Velzy comments that this abrasion problem is one that may vary widely in severity in different plants. It would seem that the Buffalo sludge may have an unusually high percentage of inorganic fines.

Dundas and McLaughlin (248) list eight factors necessary for economical sludge drying, free from nuisances, to prepare sludge for efficient combustion or for use as a fertilizer:

(1) Maximum surface exposure.
(2) Thorough agitation of the wet material.
(3) Temperature potential of gas.
(4) Velocity of drying gas.
(5) Responsive and flexible temperature control.
(6) Deodorization of gases vented from the drying operation.
(7) Instantaneous water removal; and
(8) Preservation of fertilizer qualities.

They state all eight of them are efficiently performed in the flash drying equipment in use at Chicago.

In their discussion is an excellent presentation of the theory of sludge combustion. Most of the definitions of smoke, they state, are unsatisfactory and vague. The amount of visible solids discharged from a stack is not a complete indication of its nuisance value. For drying and incinerating sludge, they list as supplementary fuels in the order of their desirability: digester gas, natural gas, and fuel oil. In large installations, powdered coal is satisfactory.

Johnson (125) also discussed the problem of sludge disposal developments at the Southwest works in Chicago. The activated sludge from this plant as well as the North Side plant is mixed, concentrated and conditioned with $FeCl_3$ (6–9 per cent) and filtered on vacuum filters. The cake containing 80–85 per cent moisture is dried to 5 per cent moisture in flash driers having a capacity to evaporate 160,000 pounds of water per hour.

The cost of disposal of sludge at the Minneapolis-St. Paul sewage treatment plant was reported (16) to be $3.27 per ton. Ferric chloride dosage for conditioning was 1.2 per cent and lime 3.44 per cent as CaO of the dry weight of sludge. The average life of the filter cloth was 493 hours as compared to 326 hours in 1940. The average filter rate was reduced from 5.5 in 1940 to 3.4 pounds per square foot per hour in 1941 to save chemicals. The average moisture in the filter cake was 66.3 per cent.

The elutriation tanks in Detroit have been used for the treatment of digester supernatant which contains 4 per cent solids according to Wallace and Habermehl (252). After 6–8 hours sedimentation in these tanks the sludge compacts to 11–12 per cent solids. Filter production was 7.0 pounds dry solids per square foot per hour for raw sludge and 6.0 pounds for digested sludge. Slightly more chemicals were required for digested sludge than for raw. In 1942 mixed raw and digested sludge was filtered successfully, giving a filter production of 6.8 pounds of solids per square foot per hour with an average dosage of 8.3 per cent CaO and 2.7 per cent $FeCl_3$. The cake produced averaged 31.2 per cent solids. Canton flannel filter cloths have lasted 400 hours. In the incineration of the filter cake, 0.35 gallon of oil per ton of material was used, mostly during the warming up period.

At Cranston, R. I. plant the disposal of digested sludge by elutriation is reported to have saved 50 per cent of the cost of ferric chloride according to Horne (110). Elutriation is in two stages, the elutriate produced from the second tank being used in the first while in the former only clean water is used. The ratio of clean water to sludge is 3:1. The elutriated sludge is vacuum filtered and incinerated in a Nichols-Hereshoff multiple hearth incinerator.

The sludge disposal at the San Diego plant will be by elutriation, vacuum filtration, drying in Raymond flash drier, and the dried sludge will be sold as fertilizer, according to Phelps (189).

Wishart, Jepson and Klein (266) state that vacuum filtration of excess activated sludge is effected by the freshness and condition of the sludge. On storage of activated and raw sludge, reducing substances are produced which increase the ferric chloride demand. Aeration of such stale sludges for 1–2 hours reduces the ferric chloride demand. Aeration is beneficial even with fresh activated sludge.

*The Value of the Digestion of Sludge as an Intermediate Step in its Disposal.*—Velzy (248) and Genter (79) present again the advantages of digestion. Velzy points out that digestion tanks absorb the irregularities in quantity of raw sludge obtained, permit a shorter operating week for dewatering and incineration, provide gas as fuel for boilers and auxiliary heat for incinerators, and deliver a sludge of reasonably uniform characteristics for filtration and burning.

Genter (79) in discussing sludge disposal at Minneapolis-St. Paul, views sludge digestion as essentially a wet combustion process in which the solids are mineralized before further dewatering. In view, he says, of the fact that the bacteria in this process do this work for nothing and with much less wear and tear on the relatively long-lived equipment involved, produce much less solids to be dewatered, and plenty of gaseous fuel for plant heating, the economics of raw sludge incineration can be seriously questioned when compared with sludge digestion, elutriation, and vacuum filtration, especially on the sludges listed in his discussion. In fact, by using the latter procedure at Minneapolis-St. Paul, he doubts if final sludge incineration would be needed, because the digested sludge cake would have a soil value that is out of the question with raw sludge. Genter further states that the argument that initial costs and fixed charges for digestion and elutriation space and equipment may offset the gains due to sludge mineralization has lost its validity in the numerous installations practicing this procedure.

## MECHANICAL EQUIPMENT

Equipment in the field of sewage treatment was not an important subject for authors during 1943. Most articles on the subject deal with maintenance, a few with municipal installations, and fewer with military installations. Among the few makeshift innovations resulting from war conditions are timber and concrete manhole covers (11). Howson (112) indicates, in his discussion of his method of overcoming troubles with the trickling filter distributors at Westfield, N. Y., a typical example of the problems involved and how they are being overcome in wartime. Cohn (47) features the importance of maintenance of equipment in time of war, covering the more common types of equipment found in sewage treatment works. Gerdel (81) discusses maintenance problems in connection with the Westerly Plant at Cleveland, Ohio. Sperry (233) emphasizes the importance of proper care in the maintenance and operation of gas engines. Gottleib (88) uses his experience at Cedar Rapids for the same purpose, and Taylor (239) adds to knowledge gained from experience with gas engines.

Equipment in use at plants is listed in an excellent series of articles by various authors, including MacDowell (157), Kozma (140), Moseley (180), Horne (109), Squire (234), Frazier (76), King (137), and in an anonymous article (20) on the plant at Hartford, Connecticut. A series of excellent articles (21) is presented by a large number of authors in *Water Works and Sewerage.* These articles are set forth from the viewpoints of the manufacturer and of the user. Setter (221) describes a variable speed, variable stroke return sludge pump in use at Ward's Island; Allison (3) discusses the motor-driven and reaction-driven distributor arms at Corpus Christi; and Lynch and Mann (156) describe a unique vacuum filter at Auburn, New York.

The very few new installations include pumps at Freeport, Long Island, as described by McKeeman (169), driven by slip ring motors with variable speed control. Eldridge (61) states that a high-rate recirculating filter was installed to serve the Tetfer Packing Co. at Owassa, Michigan. Whether or not high-rate filters should be classed as equipment or process of treatment may be open to question but Greeley (93) points out that much effort has been given to their development during the past decade, and Dixon (55), in discussing Greeley's article brings out the importance of mechanical equipment in connection with such filters. Among the few sewage treatment plants involving new types of equipment is the Bowery Bay plant described by Gould (89) which includes an unconventional type of scraper mechanism in the settling tank, and the plant at Cranston, R. I., described by Horne (108) which is well provided with conventional mechanical equipment.

In view of the relatively large amount of work that has been done for military installations, the number of papers on such work is small. Hatch (99), in his article on military installations, fails even to mention mechanical equipment. Such cavalier treatment of the subject is not universal, however, for Reinke and Pratt (195) discuss the use of sewage treatment equipment in military establishments in California; Cleary (45) discusses developments in late 1942 and early 1943 with particular reference to army practice and the use of equipment; Franks and Obma (75) give recognition to the important part played by the equipment manufactured by every company in the United States when they state that in every case where the equipment is being applied to the job for which it was intended, an excellent performance is being obtained. White (259) tells of the installation of a mechanical grit collector and other mechanical equipment at Spartanburg, S. C., to aid in handling the sewage from Camp Croft.

Prospects for the future extensive use of sewage treatment equipment in South America are not good, according to Cleary (46), whereas he believes that the general prospects for postwar development in the United States and abroad are good. For the postwar period, Marshall (162) sounds an optimistic note when he "points with enthusiasm" to the very excellent and comprehensive lines of modern, time-tested materials, equipment and supplies available now for engineers, officials, and operators on postwar projects.

## STREAM POLLUTION

*Abatement and Control.*—The problems of stream pollution abatement and control have been complicated and accentuated by the war and war industries during the year. Weston (258) stated that in Massachusetts pollution due to wastes from war industries had increased in streams. Such cases were impracticable of correction at present and only in extremely bad situations had court action made possible construction of remedial works. Adams (1) discussed the gain in importance of the pollution control problems in the State of Michigan. The Stream Control Commission (173) reports that municipal control improvements are virtually at a standstill in Michigan unless a war-connected need can be met in no other way. In Ohio (14) a court held that a municipal corporation had no right to discharge sewage into a stream to pollute the same; and the Michigan Supreme Court (12) reversed a lower court and held that evidence supported the contention that the present raw sewage disposal method (at Huron, Mich.) constituted a menace to health and welfare, thus justifying the Stream Control Commission's order to construct a remedial plant. In Maine the Sanitary Water Board (19) studied the pollution of the Androscoggin River and recommended the construction of sewage treatment plants for all municipalities over 1,000 population. De Baun (53) discussed the stream pollution problem from the standpoint of organic fertilizer loss and suggests that with techniques now known most of these valuable substances could be recovered.

The bill (H.R. 98) introduced in the House of Representatives on January 7, 1943, to create a division of water pollution control in the United States Public Health Service was discussed by Beals (28). Mohlman (177) has pointed out that industrial pollution of streams is increasing from expansion of basic industries and the establishment of many new industries and has presented a program for curbing industrial pollution. Wolman (268) discussed the huge deferred demand for abatement that is accumulating during the war and estimated, on the basis of a $200,000,000 program for the Ohio River basin, a one billion dollar postwar pollution abatement program for the entire United States.

Weldert (256), Haupt (100) and Husmann (115) have discussed stream pollution problems in Germany. The Central Advisory Water Committee of England published its third report (43) and recommended the establishment of twenty-nine new river boards to supersede existing authorities and be responsible for all questions of drainage, water conservation, pollution, land irrigation, navigation and fishing. This board considered the existing system of river-control as generally inadequate and sometimes wasteful. Hurley (114) in reviewing the above report pointed out that it disappointed some groups because it did not recommend transfer of responsibility for sewage disposal to regional bodies. However, it was universally accepted that the present state of river-control in England was unsatisfactory and that the drainage area was the best unit for river-control. Hurley discussed the workability of what might be called quality and quantity boards for river-control and presented good reasons for regionalization of sewage disposal.

*Bacteriology and Biology.*—Petrilli (188) considered bacteriophage important in self-purification but Flu (73), on the other hand, found no increase in the phage titer and no participation of the bacteriophage during the process of self-purification. Hutchison, et al. (116) isolated a number of microorganisms antagonistic to *Esch. coli* from surface waters and studied the reduction in *Esch. coli* in the presence of these antagonists. Paracolon organisms are aberrant coliforms that are isolated especially during gastro-enteritis outbreaks and comprise a distinct biological group according to Stuart, et al. (238). These authors reported on the physiological properties and complex serological structure of paracolon but found no proof of pathogenicity. Gilliland and Vaughn (84) in a study of pigmented coliforms reported 12 strains in genus *Escherichia* and 3 in genus *Aerobacter* and found that most strains require relatively low temperatures (19° C.) for pigment formation. Sage and Spaulding (210) reported two biochemically atypical strains of *Eberthella typhosa* which caused classical form typhoid fever. Minkevich, et al. (174) studied the direct detection of typhoid and dysentery bacteria in water and the connection between the occurrence of typhoid and the presence of para agglutinating strains of *Bact. coli.* They obtained direct isolation of *B. para typhosus* in 38.3 per cent of samples and concluded that the bismuth sulphite method of Wilson and Blair should be used in direct detection studies. The available quantitative data on the relative prevalence of coliform organisms and *Eberthella typhosa* was summarized by Kehr and Butterfield (134) and presented as rates of *B. typhosa* per million coliforms at varying levels of typhoid fever morbidity in communities contributing such pollution. Evidence indicated that these ratios remained constant though bacterial reductions by natural purification processes. The data presented emphasize the basic value of the coliform test as an indicator of the possible presence of pathogens, for on the basis of the principles developed the authors showed that the calculated expectancy of typhoid fever in Detroit closely approached that actually developed.

A study of the plankton relationship to chemical factors and environment in the White River canal was made by Hupp (113) who reported that the heaviest plankton population was downstream from the point of sewage pollution, the location of the peak being governed by the rate of river flow. Brinley (33) also found pronounced variations in chemical properties and plankton populations along the course of the White River, apparently caused principally by the entrance of sewage. From additional studies, Brinley (34) concludes that secondary treatment effluents do not give the usual toxic degradation zones obtained with raw sewage and consequently the entire stream is benefitted biologically by the available plant foods introduced. Lackey (146) (147) reported on the effects of distillery wastes on the microscopic flora and fauna of a small creek and also studied the plankton, algae and protozoa of two Tennessee rivers. Lackey, et al. (148) showed that a small stream contained a large flora and fauna within 10 miles of head waters despite the lack of any pollution or fertilization other than rural agricultural drainage and that enrichment by phosphorus and nitrogen from a small town (6,700 pop.) sewage treatment plant failed to greatly increase either the species or numbers of algae and protozoa in a five-mile stretch below. Thomson (241) studied the effect of organic pollution and silt in rivers on the behavior of *Anopheles minimus* and reported that albuminoid ammonia and oxygen consumed were found to be the best analyses for indicating the suitability of breeding places. Both of these criteria were lowest in the type of water selected by *A. minimus.*

*Chemical Analyses and B.O.D.*—Grassy (91) studied the use of turbidity determinations in estimating suspended load in streams and concluded that turbidity measurements supplemented by a few gravimetric determinations may cut laboratory costs considerably in such studies, with little reduction in accuracy. Moshel (181) described a test for pollution based on foam formation of samples on shaking. Schwarz, et al. (220) have developed a method for determining the colloid content of a water polarographically. Eberling (59) determined the concentration of phenol wastes in water required to kill fish and reported that it was the higher boiling point fractions of the carbolic oil which were the most toxic in water. Ettinger et al. (66) pointed out that the standard methods procedure for preserving phenols in polluted river samples was ineffective and recommended copper sulfate treatment for preservation. Scott (219) described the procedure for phenols in water and also found copper sulfate effective for sample preservation.

The nitrate results on polluted streams over a period of years were analyzed by Rudolfs and Heukelekian (209). They found that the quantity of nitrates was materially higher in the spring and fall than in the summer and winter and that the amounts could be correlated with the volume of flow.

Tödt (242) developed an electrochemical method for the determination of dissolved oxygen by means of which the decrease of oxygen can be followed in sulfite solutions. Skopintsev (223) found that the dissolved oxygen reaches a maximum deficiency under ice coverage on the Volga. Zhdanov (272) also studied the low oxygen content which caused fish mortality on the Volga under ice coverage and reported that oxidation of wastes from paper and cellulose mills caused this condition. Other chemical studies of rivers in the U. S. S. R. were those of Inlev (119) on the Piasina and those of Drachev and Skopintsev on the

Volga (58), on the Dubra and other rivers (222). Pollution studies involving determinations of free $CO_2$, dissolved oxygen, alkalinity and H-ion concentrations were made on the principal streams, reservoirs, lakes and ponds in the Lake Ontario watershed by Faigenbaum (67).

Jordan (127) used "quality profiles" based on B.O.D. to indicate the condition for an entire watercourse. Lauster (150) reported on low temperature B.O.D. studies on the Red River of the North and concluded that the 30-day demand at 0° C. approximated the 5-day 20° C. B.O.D. and that adequate inoculation with low temperature organisms is important in low temperature studies. Gifft (82) reviewed the mathematics of the B.O.D. determination and proposed the following equation to simplify calculations without appreciable errors:

$$\text{B.O.D.} = \frac{W_2 - D_2}{P} + S_1 - W_2$$

where $W_2$ = D.O. in incubated diluting water (blank), $D_2$ = D.O. in incubated dilution (sample), $P$ = decimal proportion of sample in the dilution, $S_1$ = D.O. in the undiluted sample. A calculator of the alignment chart form was also presented.

*Standards.*—Burn (37) discussed classification of natural waters with regard to use and standards of quality for various uses, emphasizing that present and proposed future uses of water must be considered when a limiting standard for pollution is formulated. Cherkinskii and Ginsburg (44) studied the effect of arsenic and copper from the manufacture of Paris green in a river and concluded that limits of 2 to 4 p.p.m. of arsenic and 0.4 p.p.m. of copper did not interfere with self-purification in streams. From the hygienic standpoint, however, 0.15 p.p.m. of arsenic was considered the upper limit.

*Reaeration and Oxygen Sag.*—Howland (111) presented graphical methods which make it possible to apply the oxygen sag formula used by Streeter, with slight modification and under certain limitations to a stream in which occurs not only biochemical oxidation and reaeration, but sedimentation and absorption, and in which various constant proportional rates of oxygen utilization are being exerted by the sludge blanket. These methods constitute a direct computation of the constants of the equation from the experimental data and Howland suggests that they might also be used to advantage in the formulation of processes of sewage treatment.

*Surveys.*—McGauhey et al. (168) reported on a one-year study of a 22.5 mile stretch of the Roanoke River. This area received the sewage from a population of 100,000 besides tannery and viscose rayon plant wastes. The authors conclude that the stream is unfit for recreational purposes, detrimental to fish life and injurious to hydraulic machinery; and that the industrial wastes produce the greatest chemical and physical pollutional effects. The shore pollution studies conducted by Hyde (117) at San Francisco over a period of years showed a definite improvement in the physical and bacteriological condition of the water.

A very interesting report based on extensive investigation is made of the problem of sewage disposal and bay and shore pollution at Santa Monica Bay which has led to the quarantining of a 10-mile section of the beach (30). The Hyperion fine-screening plant and outfall built in 1925 has deteriorated and become overloaded by the increase of contributing population from 500,000 in 1920 to 1,757,000 in 1942. The 5,000-foot outfall leaks so badly that 20 to 80 per cent of the sewage fails to reach the end of the outfall. The currents in the bay are sufficient to prevent sludge bank formation but onshore surface currents carry in sewage, debris, grease and pollutional organisms. Studies of surf water, sand and sewage grease indicated the frequent presence of members of the typhoid organisms.

A study of the Meramec River which drains an area of 3,980 square miles, which is rugged in character and not well suited to agricultural purposes and which has been extensively developed for recreational purposes, was reported by Kehr and Johnson (135). Although the population of the Meramec watershed was about 131,700 in 1940, most cities have adequate sewage treatment works and the basin is relatively free of pollution. The dissolved oxygen was never under 50 per cent saturation at any point studied. With the exception of a few short stretches below sources of pollution, the median of all coliform determinations at all stations was less than 500 per 100 ml. The chemical determinations indicated that the stream was free from appreciable quantities of industrial or mine waste although some of the largest lead mines in the southwest are located in the basin. A tentative standard of purity of 500 coliforms per 100 ml. is suggested for streams used for swimming and other recreational uses and it was believed that this standard could be maintained by the construction of additional sewage treatment facilities, including chlorination.

The Maine Sanitary Water Board's study (159) of the Androscoggin River indicated that this river with a drainage area of 3,470 square miles was seriously polluted for a distance of 135 miles from Berlin, N. H., to Brunswick. Nuisance conditions exist on the river during summer and it is unfit for fishing or recreational purposes. About 96 per cent of the present pollution reaching the main river is due to industrial wastes and 92 per cent is due to pulp and paper wastes. An abatement program to make the river satisfactory for fishing or recreational purposes was considered impractical but it is proposed to prevent nuisance conditions by the maintenance of a standard of 2 p.p.m. of D.O. at all points, and remedial measures to attain this end were studied.

The final Ohio River Survey report (185) presents results of a survey directed by Section 5 of the River and Harbor Act, approved August 26, 1936. Information is presented pertaining to sources and amounts of polluting material from 3,700 municipalities and 1,800 industrial plants discharged into the watercourses of the 204,000 square miles of the Ohio River Basin. Effects of these discharges are indicated by the results of 131,000 tests made on 71,000 samples collected at 2,000 points on streams in the basin.

"Besides furnishing water for more than 7,000,000 persons and for industrial processes, the streams of the Ohio River Basin are used for the disposal of sewage by some 8,500,000 people and almost two-thirds of this sewage receives no treatment. Industrial wastes with an oxygen demand equivalent to sewage from almost 10,000,000 additional persons enter the streams. Pollution problems are further complicated by the effect of waters containing 1,800,000 tons of acid per year which flow or are pumped from active and abandoned coal mines in the extensive coal fields of the basin.

"Many water supplies, both domestic and industrial, suffer from the effects of these polluting substances and outbreaks of intestinal diseases, apparently water-borne, have occurred following periods of low stream flow. Recreation facilities have been damaged. Fish and other aquatic life have been detrimentally affected. Streamboats, barges, other river craft and structures, pumps, pipe lines and condensers exposed to acid stream waters have been attacked."

Cost estimates are presented covering a comprehensive pollution control program. The estimated total of approximately $180,000,000 includes interceptors and municipal treatment plants, industrial waste treatment or other industrial waste corrective measures and a mine-sealing program. Annual charges for operation, interest and amortization approximate $18,500,000. Cost estimates are based on average experience from 1928 to 1940.

The six supplements are as follows:

"A. Collection of Data on Sources of Pollution." This includes memoranda to field engineers, sample reports and a complete set of field inspection and summary forms.

"B. Organization and Methods of Laboratory Studies." This includes a brief discussion of the laboratory work, copies of laboratory memoranda on analytical procedures, the specifications for the mobile (trailer) laboratory units and a complete set of laboratory forms.

"C. Acid Mine Drainage Studies." This is a detailed report of the studies and is summarized in Volume I of the report proper.

"D. Industrial Waste Guides." This volume of industrial waste information is reviewed in SEWAGE WORKS JOURNAL, Volume XV, No. 2, March, 1943, p. 226.

"E. Epidemiological Studies." This supplement presents the results of field studies of water-borne disease in the Ohio River Basin made during 1939–40.

"F. Biological Studies." This is a special report on a study of stream biological communities and fish life in Ohio River Basin streams.

## INDUSTRIAL WASTES

*General.*—The 1943 literature on the disposal of industrial wastes was concerned primarily with those industries which manufacture munitions or supplies for war. Explosives, ordnance, petroleum, alcohol, synthetic rubber, metal trades, chemicals, dehydrated foods and meat products industries were expanded to an unprecedented degree and the resulting increased volumes of wastes imposed heavy loads on sewage treatment works, streams, lakes and harbors.

At Marion, Indiana (24), cannery and dairy wastes resulted in an increase of flow from 2.45 m.g.d. in 1941 to 3.65 m.g.d. in 1942; of solids removed, from 2.46 tons per day in 1942 to 4.45 tons per day in 1942; and of population equivalent, based on B.O.D., from 29,880 in 1941 to 37,220 in 1942. At Akron, Ohio, Schaetzle (213) reports that wastes from rubber reclaiming works were largely responsible for increasing the flow from 36 m.g.d. in 1938 to 55 m.g.d. in 1942–43 and sludge from 43 tons per day to 86 tons per day. Greatly increased volumes of colored wastes and heavy oil were received in 1942–43, one shot of oil amounting to 34 cu. yds. in two days. During a strike of five days, the suspended solids dropped from 339 to 181 p.p.m. and B.O.D. from 185 to 96 p.p.m.

Industrial wastes at Muskegon Heights, Michigan (6), interfered seriously with operation of the activated sludge plant. Wastes from metal-working industries contained oil, soda ash, cyanides and chromium and excessive concentrations of organic matter were discharged in strong wastes from a slaughter house. The latter wastes have been distributed more uniformly over the 24 hours, while the metal, oil and soda wastes have been discharged to a storm sewer and thence to the river, without any ill effects except occasional patches of floating oil.

An excessive loss of fuel oil was reported at the Easterly Sewage Treatment Works in Cleveland (262), traced to a drop forge company. It was estimated that 37,500 gallons of oil, worth $1,400, was lost during the month of May. The flow was stopped abruptly when the company was informed of the loss on June fourth.

*TNT Wastes.*—The most important explosive manufactured for war uses is TNT. A negligible tonnage was produced prior to the war, but in 1941 a number of large plants were constructed and production reached its peak in 1943. The raw materials for TNT are toluol, sulfuric acid, nitric acid and sodium sulfite. Nitric acid is made at the TNT plant by catalytic oxidation of liquid ammonia, and sodium sulfite from sodium carbonate plus sulfur dioxide produced by burning sulfur.

The wastes from TNT plants are of two types (176), yellow, highly acid wash waters, and the so-called ''red water'' from the purification of crude TNT by a solution of sodium sulfite called ''sellite.'' The composite wastes, before dilution with cooling water, are deep red with a color of 125 on the platinum-cobalt scale even after 1 to 500 dilution. They have a pH of 1.4 or less, contain about 4,500 p.p.m. acidity and about 3.5 per cent total solids. The wastes are very resistant to decomposition (216) and all available methods for removal of organic matter and color were found ineffective, except by the use of large amounts of chlorine (176, 216). However, restriction of use of chlorine led to the study of the disposal by dilution alone (227). It was found that a dilution of 1 to 10,000 would remove all objectionable color and permit the river water to be used for drinking purposes, after filtration, with only a slight increase in color of 15 or 20. If the water is not used for drinking purposes, a dilution of 1 to 3,000 is permissible. For lower dilutions, storage is provided, or where the dilution is quite low or the wastes are discharged into lakes or bays, complete evaporation of the concentrated wastes is practiced.

*Smokeless Powder.*—Wastes from smokeless powder contain a large amount of free sulfuric acid, some nitric acid, and a small amount of alcohol (227). The acid averages 2,000 p.p.m., equivalent to one pound per pound of product. The B.O.D. averages 50 p.p.m., giving a population equivalent of 2,500 per 100,000 lb. product per day.

*Other Explosives.*—Tetryl, a "booster" used for exploding the relatively inert TNT, is manufactured on a small scale as compared with TNT. The wastes are similar in composition and volume per unit of product (228). Nitroglycerine wastes (229) are relatively unimportant as sources of pollution. The glycerine recovered from waste fats is used very little for munitions in this country, but nitroglycerine is used in admixtures with guncotton to produce "cordite" used by the British as a propellant (52).

*Acid Wastes.*—Rudolfs (201) has reported that acid industrial wastes in the Rahway Valley trunk sewer reduced the pH to 2.5, with occasional alkaline wastes giving a pH of 9.6, and frequent fluctuations in this range. It was found that there was little mixing in the sewer, but the slugs of acid and alkali followed each other as discharged to the treatment works. The digesting sludge became acid, had an objectionable odor, and would not dry. Hydrated lime was then added in a pretreatment plant for the industrial wastes, with equalizing and mixing capacity of 1.0 hour for 1.0 m.g.d., and an average lime usage of 1,440 lb. per million gallons, added as a slurry after the wastes had equalized in the first set of tanks, which equalized the fluctuations to a range of pH from 4.9 to 9.0. After liming, mixing and settling, the pH varied from 7.1 to 8.5, and after admixture with the sewage, the pH levelled off at from 7.0 to 7.4.

Thatcher (240) describes a similar plant in England, where milk of lime is added to acid chemical wastes. At present 4 tons of hydrated lime are used per day. The wastes are mixed in a preliminary tank, then milk of lime is added at a fixed amount prior to mixing with submerged paddles, then additional milk of lime is added by a motorized valve controlled by an antimony electrode pH apparatus, to give an alkaline effluent after settling in final Mieder tanks.

A study of various alkalies was made by Rudolfs (204) to determine whether other alkalies improve the action of lime. It was found that a combination of dolomitic hydrated lime with soda ash was preferable over lime, soda ash or caustic soda alone. The smallest volume and lowest dry weight of sludge was obtained when using 80 per cent dolomitic lime and 20 per cent soda ash, but the sludge did not settle so well as when dolomitic lime was used alone.

*Metal Pickling.*—Recovery of sulfuric acid from spent iron pickling liquor was studied in the laboratory by Gehm (78). Acetone was used to separate crystals of ferrous sulfate. Addition of 250 cc. of acetone to 250 cc. of pickling liquor containing 15.75 per cent $FeSO_4$, reduced the $FeSO_4$ content to 2.75 per cent. It was estimated that 3 per cent of the acetone was lost. This procedure is similar to the de Lattre process, in which methanol is used to precipitate the ferrous sulfate.

Hodge (105) has patented apparatus and procedure, using acetone, for precipitating ferrous sulfate from waste pickling liquor. Mohlman (177) reported that in the Calumet area of Chicago, pickling wastes from nine steel plants discharge 3,500 tons of iron and 3,340 tons of sulfuric acid per year into the Calumet River. In spite of all the work that has been done on disposal of pickling liquor, the problem appears far from being solved. Hodge states that the big problem is still the utilization of the large amount of recoverable copperas, and hopes for increased use of iron salts in water and sewage treatment.

Pickling of brass and copper has greatly increased during the war. The toxic effect of copper salts on biological processes of sewage treatment has been known for many years, yet sewage treatment works still get into difficulties because of copper-bearing wastes. Rudgal (200) reports finding 3,000 p.p.m. copper in the bottom layers of sludge in heated digesters at Kenosha, Wisconsin. The sewer carrying the rinse waters from the brass plant, along with part of the city's sewage flow, was by-passed directly to Lake Michigan. The gas production then increased from 2,100 to 44,000 cu. ft. per day. Bottle experiments showed that 200 p.p.m. copper would inhibit digestion. Rudgal computed that if the sewage contained only 1.0 p.p.m. copper and half was removed by sedimentation, the average copper content of the sludge would be 215 p.p.m., enough to stop all sludge digestion in one week.

Removal of copper from brass mill wastes has been studied for years by the State Water Commission of Connecticut. In their Ninth Report (49) data are presented showing that about 90 per cent of the copper losses are in the wash waters, estimated to contain 355 p.p.m. sulfuric acid and 76 p.p.m. copper. Operation of a pilot plant is recommended to determine the results and costs of treating such liquors with lime.

Brass mill wastes also contain large amounts of oil, which is used along with a stream of water on the hot rolls to facilitate operation. Mohlman (176) reported loss of oil varying from 243 to 5,188 lb. per day and of copper from 277 to 1,744 lb. per day from a brass mill in Chicago, although a number of proprietary oil separators were installed in the plant. Van Kleeck (246) found cutting oils from machine shops to be very detrimental to operation of Connecticut sewage treatment works.

Chromium wastes have been studied in England with reference to their effect on sewage treatment. In Texas, Wells (257) reported such wastes interfered with operation of an activated sludge plant at Grand Prairie.

*Pulp and Paper.*—An extensive investigation of industrial wastes polluting the Androscoggin River in Maine was made by Metcalf and Eddy for the Maine Sanitary Water Board (159). Several large paper mills contribute 92 per cent of the total pollution, and concentrated sulfite wastes account for 71 per cent of the total. Storage lagoons costing one-half million dollars are recommended, in which these liquors will be held at times of low water flow and discharged in high water.

An extensive review of recent information on sulfite wastes is included in the report.

In Michigan, progress is being made by the Stream Control Commission (173) in study of the problem of disposal of paper mill wastes at Kalamazoo. An inventory of waste discharges of all mills in the valley has been made and pilot plant studies have been undertaken at 7 of the 14 mills to determine the relative efficiencies of plain settling and chemical precipitation of book and board mill wastes. A flotation type save-all has been installed at one mill for treatment of white water.

In Wisconsin (255) investigations are under way on methods of treatment of sulfite wastes, recently including operation of a 15-foot trickling filter, and study of methane fermentation, contact aeration and ponding with stream-flow control.

*Alcohol.*—The production of alcohol from sulfite waste has been undertaken on a plant scale recently, at the Thorold, Ontario, plant of the Ontario Paper Company (39). The process of fermentation used is stated to produce 18 gallons of alcohol per ton of pulp and it is expected this can be increased to 25 gallons. (One ton of pulp produces 2,000 gallons sulfite waste liquor.) The liquor contains 10 to 13 per cent solids, of which about 15 per cent is fermentable sugars. It is claimed that this process removes 60 per cent of the B.O.D. of the sulfite liquor, but this appears high and must be checked by further studies.

Klassen (138) calls attention to the increase of alcohol production in Illinois, and expresses concern over the effect of the wastes on the Illinois River. Mohlman (176) estimated that the wartime alcohol program, increasing from 272 million gallons in 1943 to 550 million gallons in 1944, would produce wastes equivalent, on the B.O.D. basis, to a population of 27 million, if no steps were taken to recover wastes by utilization of still slops.

*Glue and Gelatin.*—Jones (126) reports from Coventry, England, that a lime effluent from a gelatin works had caused stoppage of a 9-inch sewer, thus leading to studies on the treatment of the wastes. The plant discharged only 200 gallons per day of the strong lime waste and 100,000 g.p.d. of wash waters. Alumino-ferric was found to be the best coagulant. The lime wastes were diluted with four volumes of wash waters, treated with 20 lb. alumino-ferric, and allowed to settle. A clear, bright, odorless effluent was obtained which it was thought could be used again for process purposes. Duplicate tanks were proposed, and an ash bed for draining sludge.

The U. S. Glue Division of Peter Cooper Corporation (15) has installed a plant for treatment of wastes, consisting of a bar screen, two 6-ft. diameter revolving drum screens of a combined capacity of 3,500 g.p.m., and two 25 ft. by 125 ft. settling tanks, with scum skimmers. The screenings are reused for glue stock and grease is rendered from the scum.

*Laundry Wastes.*—Eliassen and Schulhoff (63a) report experimental work on treatment of laundry wastes by flotation. Ferric chloride, alum, sulfuric acid and lime were used as coagulants, alum proving to be the most economical for the results obtained. Use of 300 p.p.m. alum, with a few minutes aeration and vacuum treatment for 15 minutes, produced a scum which removed 78 per cent of the B.O.D. and 72 per cent of the grease. Nothing is reported on disposal of the scum.

*Milk Products.*—A treatment plant for milk products wastes in Indiana is described by Linderman (153). The plant consists of a holding tank and a high-rate recirculating filter 30 ft. in diameter and 6 ft. deep, with crushed boulders 3½ in. to 4 in. diameter as filter media. Wastes are pumped intermittently from a sump to the holding tank, and continuously from the holding tank to the filter, with recirculation back through the filter when no wastes are being pumped to the holding tank. The filter was designed to treat 16,000 g.p.d. with a B.O.D. of 1,050 and to effect 90 per cent removal of B.O.D. In two tests made by the State Board of Health on October 8 and November 24, 1942, the rates of flow were 12,700 and 11,000 g.p.d., respectively, but the B.O.D.'s were 2,390 and 2,900 p.p.m. Final effluents had B.O.D.'s of 346 and 262 p.p.m., the removals being 85.6 and 91.0 per cent. Suspended solids were reduced from 442 to 128 p.p.m. on October 8, and from 812 to 211 p.p.m. on November 24.

*Textile.*—Eldridge (62) has described experimental investigations of the treatment of textile wastes at the Yale Woolen Mills, Yale, Michigan. It was necessary to equalize the wastes in a holding tank in order to get consistent results. The optimum dosage of chemicals was 1 pound lime and 3 pounds ferric chloride per 1,000 gallons. Removals of B.O.D. varied from 66 to 78 per cent, and of suspended solids from 69 to 94 per cent. The sludge was very watery, containing only 2 per cent solids. Filter leaf tests indicated the moisture content could be reduced to 76 per cent by a vacuum filter.

*Food Products.*—Dehydration of foods became very important in 1943 because of the war shipping requirements and lend-lease quotas. Wastes from dehydration of vegetables and fruits are similar to set-pack cannery wastes in general characteristics. The heaviest tonnage of dehydrated vegetables is potatoes, for which the quota in 1943 was 136 million pounds out of a total of 356 million (176). Results of studies of potato dehydration wastes in California have been published by Gray and Ludwig (92). The potatoes are peeled by abrasive carborundum units, which rub off from 15 to 30 per cent of the potato solids. An average of 600 gal. of water is used per ton of potatoes and the B.O.D. averages about 1.0 lb. per ton, per percentage loss, or about 20 lb. per day. For a plant of ordinary size (one ton per hour) this amounts to 480 lb. per day. Further losses occur in the water in which the cut, peeled potatoes are washed. The volume is 2,500 gal. per ton of potatoes (four times the wash water volume) but the losses of B.O.D. are about equal to the loss of B.O.D. in the wash water, 480 lb. per day. Total losses, therefore, with 20 per cent lost in the peeler water, are 960 lb. B.O.D. per day for a plant with a capacity of one ton per hour.

Wastes are screened through a 60-mesh shaker screen, and the effluent is spread out on sand beds, of which there are seven, each 20 by 170 ft. in area. A new bed is used daily. It is doubtful whether this type of treatment would be successful elsewhere than in California or on sandy soils in southern states.

On the whole, however, dehydration wastes are not a large problem, estimated as amounting to a population equivalent of only 670,000 for the entire United States (176).

The problem of disposal of cannery wastes has been discussed by Fenlon (69). He gives results of analyses of wastes from various canning operations, reviews several methods of treatment including screens, chemical treatment, and disposal of ensilage juice. He states that industrial wastes can be treated more cheaply in conjunction with regular municipal wastes than alone.

Experimental studies have been reported by Young (270) on the treatment of cherry waste waters at North East, Pennsylvania. The wastes range in volume from 600 to 1,800 gallons per ton of cherries handled and in B.O.D. from 700 to 2,100 p.p.m. Pitter juices are highly concentrated, but amount to only 5 gallons per ton of cherries handled, and it is recommended that this waste be hauled away and disposed of on land. Experimental treatment of all wastes comprised screening through 40-mesh screens, coagulation with 22 gr. per gal. lime and 8 gr. per gal. ferrous sulfate, and settling for 2 hours. B.O.D. was reduced from 967 to 382 p.p.m., or 60 per cent, and suspended solids from 605 to 74 p.p.m., or 88 per cent.

*Meat Packing.*—The urgent need for improving the recovery of grease in meat packing plants led Mortenson (182) to make extensive investigations in the plants of Swift and Company of the efficiency, or lack of efficiency, of grease traps and grease basins in packinghouses. He reports the technique of the method he has developed for testing grease basins, which in brief consists of settling the effluent of such basins in a calibrated barrel, at such rates that the grease has time to rise to the surface. The grease is then skimmed, analyzed and computed to pounds per 1,000 lb. of live weight of animals slaughtered. For efficient basins, the loss should not exceed 0.1 lb. per 1,000 lb. animals slaughtered. Maximum capacities are 1 to 2 hours detention period and minimum velocities 0.25 to 0.50 ft. per minute. The WPB has widely circulated Mortenson's results and recommendations among the packinghouses of the U. S., and instigated the formation of a Committee of the Chicago Section of the American Chemical Society (9) for assistance to packers or other manufacturers who desire to improve their salvage of grease. The WPB consultant estimates that this program of salvage has resulted in an increased annual recovery by meat packing and processing companies throughout the nation of about 100 million pounds of grease.

Eldridge (62) reports results obtained with a high-rate recirculating filter treating waste from the small slaughterhouse of the Telfer Packing Company, Owosso, Michigan. Wastes were formerly emptied untreated into a ditch and created intense odors. The plant installed consisted of a storage tank holding one day's flow, from which wastes were pumped to a filter 14 feet in diameter and 6 feet deep with a granite rock media 3 to 4 inches in diameter. The rate of application was 20 m.g.a.d., with about 4.5 recirculations. Two tests showed B.O.D. in the final effluent of 18 and 57 p.p.m. and suspended solids 28 and 23 p.p.m., from raw wastes with 2,200 and 1,750 p.p.m. B.O.D. and 1,160 and 420 p.p.m. suspended solids (although 1,364 and 1,344 p.p.m. in settled effluent). The kill on the days of tests was 15 cattle on September 22 and 5 cattle, 4 lambs and 27 hogs on September 23 (not many, but still a lot of red points).

Mahlie (158) describes the various sources of wastes from packinghouses, consisting of wasted blood, wash waters from the killing floors, wastes from the wet rendering process, and paunch wastes. The wastes from rendering are almost eliminated if dry rendering is used. Most packers remove paunches and contents, which are about 1.0 cubic feet in volume and weigh 40 pounds. The contents are fibrous and have no value. A survey of wastes from four packinghouses in Ft. Worth indicated a loss of 5-day B.O.D. of from 2.3 to 4.5 pounds per "hog equivalent" which means about 250 pounds live weight (equal to 18.4 to 36.0 pounds per ton live weight). Packinghouse wastes receive more or less pretreatment in Ft. Worth, including fine screens, grease traps and settling basins. Effluents range from 740 to 2,580 p.p.m. B.O.D., 256 to 13,323 p.p.m. suspended solids, and 221 to 553 p.p.m. grease. The effect of these wastes on the Ft. Worth sewage treatment works is not discussed, but Mahlie states that the industry should not be allowed to introduce wastes which adversely affect the operation of a plant or sewage system and place an unwarranted burden on the city taxpayers, either by increased operation costs or increased plant construction.

*Phenol and Gas Plant Wastes.*—The simultaneous biological purification of phenolic wastes from coke ovens and gas plants with sewage is readily feasible if the amounts of phenol are relatively small (130). Experiments made under summer and winter conditions on trickling filters and by soil filtration showed that in spite of the presence of phenols, alcohols, pyridine and cyanides, purification and stabilization could be accomplished. The experiments showed that preliminary detarring is essential. Kazachkov (132) found that additions of aluminum hydroxide (waste waters from aluminum plants) causes a rapid precipitation and removal of finely-divided particles of coal and coke. Waste from gas generating stations can be purified according to Zhukov (273) by mixing with sewage and subjecting to biological filtration. The wastes can be treated by detarring by filtration or coagulation, followed by lime water addition to form non-volatile calcium salts and to separate the ammonia in the free state; the liquor can be distilled to obtain ammonia in the form of a 20–25 per cent aqueous solution. The water from the lime precipitate may be evaporated to concentrate the calcium salts of the fatty acids produced, followed by drying to obtain commercial salts. The vapors are washed with caustic materials whereby most of the phenols are separated in the form of sodium phenolate. The vapor condensate can be treated by biological filters or the purification can be accomplished by repeated adsorption before discharge into ponds or reservoirs. Agafoshin (2) gives a description of the extraction of phenols from waste waters and discusses the advantages and disadvantages of the extraction methods using benzene and tritolyl phosphate. These methods of extracting do not require preliminary detarring. Multistage extraction is preferable. Kazachkov (131) discusses the amounts of waste waters produced by the various departments of a coke-producing plant. The suspended solids vary greatly and the B.O.D. of the wastes depends upon the source of waste. Settling prior to biological treatment in ponds is feasible. Optimum purification results were obtained by the extraction and adsorption methods and from blowing out the phenols with steam (Koppers method). Dephenolization by chlorination requires large amounts of chlorine and caustic materials.

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# MODIFIED SEWAGE AERATION—PART II

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The modified sewage aeration studies previously reported (2) showed that an average of 75 to 85 per cent of the presettled sewage influent suspended solids and B.O.D. was removed after three hours aeration followed by one to two hours settling when the aeration tank suspended solids were maintained at 150 to 500 p.p.m. A lesser degree of treatment was achieved when only aeration tank effluent was returned. In the study 58 tests of seven or more days duration were grouped into three types of aeration and each type was further subdivided into 5 or 6 ranges of similar aeration period. Within a given range of similar aeration period the tests varied considerably with respect to the amount and concentration of returned sludge, the temperature or season of the year, the concentration of influent B.O.D. load, the aeration tank suspended solids, the dissolved oxygen condition in the aeration and final tanks, the adoption of step aeration, etc. Often several tests of apparently similar operating conditions produced significantly different effluent qualities.

It is the purpose of this paper to indicate a method of combining variables so that each test falls into a coherent pattern permitting rational interpretation and to indicate the limitations and possibilities of modified sewage aeration.

## Expression of Effluent Quality

The quality of the final effluent as measured in parts per million of suspended solids and B.O.D. is a function of the influent quality. Also, similar to many physical, chemical and biological reactions, the unimolecular reaction may be assumed to apply to modified sewage aeration. The unimolecular reaction mathematically says that a constant percentage of remaining substance reacts in unit time. Thus if 50 per cent or 50 of 100 p.p.m. are removed in 1 hour then 50 per cent of the remaining or 25 p.p.m. will be removed in the second hour and 50 per cent of the remaining or 12.5 p.p.m. will be removed in the third hour. Many will recognize this as the law of diminishing returns. Seemingly discrepant results of sewage aeration fit into a logical treatment pattern when the effluent on tests of relatively similar detention, temperature, and operating conditions is expressed as a percentage of the influent quality.

## The Aeration Period

Since the above reaction rate bears a logarithmic relation to the time of contact it is important to have an accurate estimation of the aeration period. The calculation of the aeration period as the capacity of the aerator divided by the sewage flow plus the return flow may be entirely satisfactory for activated sludge when a return flow of 25 per cent or less is relatively constant. However, such a simple aeration period leads to gross errors when 20 to 100 per cent of aeration liquor or sludge is returned or when a process of step aeration is studied. In the pilot plant studies the sewage detention period obtained by dividing the capacity of the aerator in gallons by the sewage flow in gallons per hour and the aerator contact period obtained by dividing the capacity of the aerator in gallons by the sewage plus return flow in gallons per hour were averaged to give the aeration period in hours. In step aeration tests the contact period was determined separately for each pass and then totalized.

## Temperature

Tests performed during different seasons of the year under fairly similar operating conditions produced particularly discordant results. From a knowledge of the effect of temperature on the speed of chemical and biological reactions it was obvious that the most important factor contributing to the apparent discrepancies was that of temperature. In order to correct or account for the temperature variance resource was taken in Phelps' (1) comprehensive studies on the effect of temperature on the deoxygenation of dilute sewage. According to his investigations the deoxygenation coefficient at any temperature, $t$, is equal to 0.1 times $1.047^{(t-20)}$; where $t$ is the temperature in degrees Centigrade. The 0.1 factor in the formula refers to the deoxygenation at 20° C. for dilute sewage as in streams and applies to specific conditions of aerobic activity. The $1.047^{(t-20)}$ is the temperature factor which probably has general application to aerobic activity. Thus, the relative rather than the absolute deoxygenation value at different temperatures has special merit in sewage treatment. A convenient arrangement of the relative deoxygenation (or activity of aerobic microorganisms) at different temperatures in degrees Fahrenheit is as follows:

| Temp. ° F. | Relative Activity |
|---|---|
| 50 | 0.63 |
| 55 | 0.72 |
| 60 | 0.815 |
| 68 | 1.00 |
| 70 | 1.05 |
| 75 | 1.195 |
| 80 | 1.35 |

The table shows that over the normal sewage temperature range at Wards Island (50 to 80° F.) the microbial activity more than doubles. The higher the temperature the greater the activity or the more work (aerobic decomposition) done in unit time. Thus, the effect of temperature is one of lengthening or shortening the time factor or aeration period. In order to compensate for the effect of temperature so that summer and winter tests are directly comparable, it is necessary to multiply the observed aeration period by the relative activity factor to obtain an "equivalent aeration period" at 68° F. By the adoption of this method of combining variables otherwise discordant seasonal results fit into a logical pattern of treatment.

## Dissolved Oxygen

Tests performed under conditions of no dissolved oxygen in part of the system during part of each day usually produced poorer results than when oxygen was present throughout the system most of the time. Since the mixed liquor demand for oxygen varies from 1.5 to 3 p.p.m. in 30 minutes depending primarily on the momentary B.O.D. loading and the concentration of "returned" solids amounting to 100 to 400 p.p.m. of suspended solids in the aerator, a dissolved oxygen of about 3 p.p.m. in the aerator effluent was found necessary to maintain aerobic conditions throughout the system. At least traces of dissolved oxygen in the first pass of the aerator or in the final tank effluent seemed desirable for maximum efficiency. The classification of solids in the final tank apparently reduced the oxygen demand in the bulk of the final tank liquor so that septicity did not occur in 1 to 2 hours settling. The immediate return of a dilute sludge in modified sewage aeration apparently prevented gross septicity of the sludge.

If only the volume of aeration tank in which fair oxygen conditions is considered in calculating the detention period, the purification obtained corresponds to the "effective aeration period." This indicates that a degree of aeration insufficient to produce traces of dissolved oxygen in the liquor is not necessarily deleterious to the process and that the control of the dissolved oxygen in the aerator may afford a means of varying the "effective aeration period."

## Weekly Average Results of Modified Sewage Aeration

The individual effluent results of 25 tests of sewage aeration with the return of aeration tank effluent equal to from 20 to 100 per cent of the sewage flow is presented in the top curve of Fig. 1. Each circle, triangle, and square represents the average percentage of influent B.O.D. and suspended solids remaining in the effluent after 1.5 to 2.5 hours settling in the final tank. The logarithm of the percentage impurities remaining in the effluent are plotted against the equivalent detention or aeration period at 68° F. in hours. The mean curve for the open circles is representative of aeration with return liquor under "good" oxygen and operating conditions. The aeration tank suspended solids (A.T.S.S.) were roughly 80 p.p.m. or 20 to 30 per cent less than the influent suspended solids. The open squares represent tests in which the dissolved oxygen in the first pass was often found to be zero or the average dissolved oxygen of the aerator effluent was frequently less than 3 p.p.m.

The triangles are average results of tests in which the aerator solids became classified either due to a low air supply or usually a poor distribution of the air. Poor air distribution resulted when a grid of one inch pipe was placed in each pass of an aerator to double the wall or contact surface. Instead of getting increased treatment by doubling the contact surface, the pipe grid impeded the circulation of the liquid, caused poor air distribution in the bottom third of each pass, created septic sludge blankets, and substantially decreased the efficiency of treatment.

Modified sewage aeration in which final tank sludge was quickly returned in volumes of roughly 10 per cent of the sewage flow is shown in the bottom four curves of Fig. 1. The lowest curve is a single test run

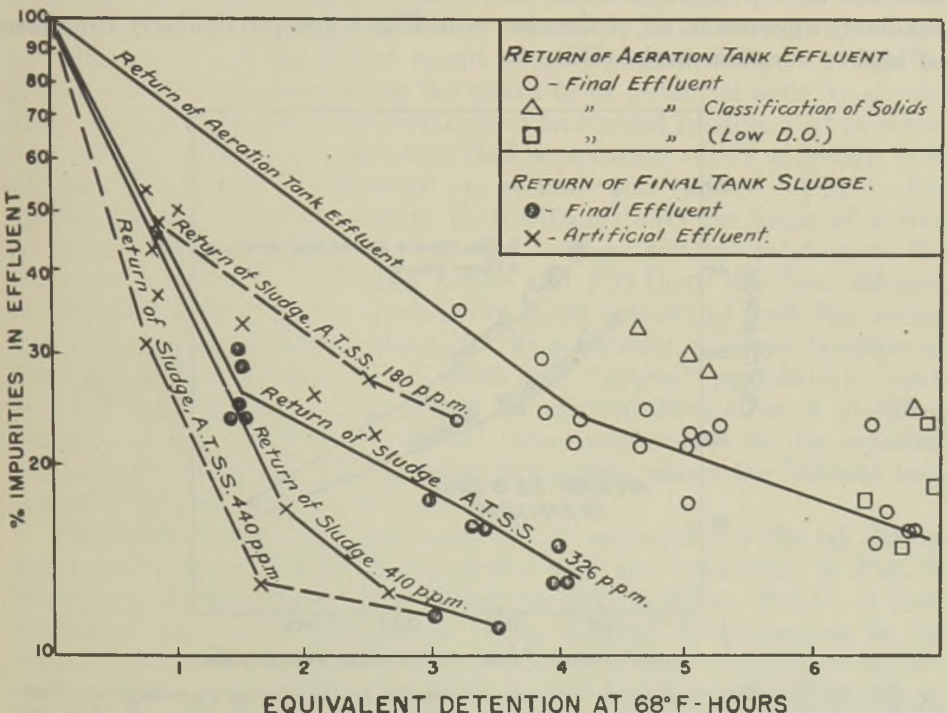


FIG. 1.—A correlation of secondary treatment efficiencies by modified sewage aeration at equivalent (68° F.) aeration periods.

consisting of one final tank effluent at 3 hours aeration and two artificial effluents at 0.75 and 1.63 hours aeration, respectively, and an aeration tank suspended solids average of 440 p.p.m. The curve is drawn connecting points. Similarly the next higher curve is a single test run of two artificial effluents (the supernatant of samples of aerator liquor settled for ten minutes) and one final effluent in which the aerator effluent averaged 410 p.p.m. The third or middle curve is a mean curve of 19 tests with an average aerator suspended solids of 326 p.p.m. For individual tests, the average temperature varied from 54 to 77° F., the aerator suspended solids varied from 105 to 370 p.p.m., and the influent B.O.D. varied from 99 to 178 p.p.m. In spite of the very great variations of conditions, it may be observed that the individual points group themselves closely about the mean curve when the per cent impurities in the effluent are plotted against the equivalent aeration period at 68° F.

The fourth curve from the bottom, similar to the two bottom curves, is a single test run at 77° F. with an average aerator suspended solids of 180 p.p.m.

The characteristic of the unimolecular reaction is that when the percentages of remaining reactants are plotted against time on semilogarithmic paper, the resulting curve is a straight line. However, it is frequently observed that if the time of reaction is prolonged, the rate of reaction decreases more than the theoretical and the curve gradually becomes asymptotic to the time axis. It is to be observed that this same tendency appears in all of the curves in Fig. 1 and particularly for those of higher aeration tank solids.

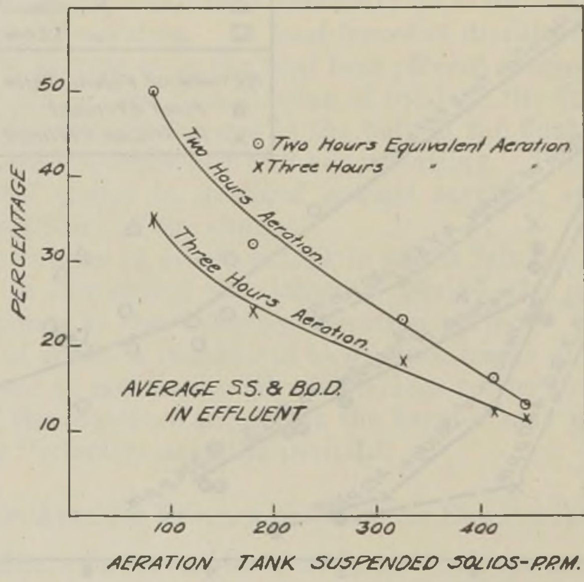


FIG. 2.—The effect of aeration tank suspended solids on the average percentage of influent B.O.D. and suspended solids remaining in the final effluent for a two hour and three hour modified sewage aeration period at 68° F.

A rough picture of the effect of aeration tank solids may be obtained by plotting the percentage of remaining impurities (suspended solids or B.O.D.) at a constant aeration period for each of the curves in Fig. 1 against the aeration tank suspended solids. The data for a two and three hour equivalent aeration period at 68° F. is presented in Fig. 2 showing the effect of aeration tank suspended solids exclusive of the wall film solids on the efficiency of secondary treatment. Up to a limiting value of 500 to 600 p.p.m. of aerator suspended solids, an increase in the suspended solids yields substantially improved effluents for relatively short aeration periods. However, a somewhat greater air supply will be needed to maintain satisfactory oxygen conditions and the very dense excess sludge at low aeration tank solids will become less dense at higher aerator solids for a given aeration period. Beyond 600 to

800 p.p.m. the effluent will become charged with impurities occasionally exceeding that of the influent, the excess sludge will become very thin, and aerobic condition will be maintained with difficulty. The high degree of treatment achieved by activated sludge requires a longer aeration period, somewhat higher aerator solids and a greater air supply. The solids concentration of excess activated sludge is usually relatively low.

## The Diurnal Effect

Just as the activated sludge process, the mechanism of purification by modified sewage aeration may be viewed as the result of physical and chemical reactions such as oxidation, reduction, and accretion which are initiated by or are the direct result of biological activity. A reliable practical method of measuring the quantity of potential activity should prove invaluable in the interpretation of treatment results. At present, the common index is the aeration tank suspended solids although it is probable that a variable fraction are actually the ''active solids.'' Assuming a good index of activity then within limits the ratio of active solids to influent (B.O.D.) load should bear an inverse relation to the parts per million of suspended solids and B.O.D. in the final effluent. In the pilot plant studies, a relatively large amount of wall film solids further complicated interpretations. Undoubtedly, a larger fraction of these solids than the suspended solids was ''active'' particularly when the wall film was thin. In studying the diurnal fluctuation in modified sewage aeration, the ''active solids'' were assumed to be the aeration tank suspended solids plus the wall film solids minus the influent suspended solids, all expressed in p.p.m.

The hourly results of experiment 5L (2) adjusted for the lag due to the aeration period were recapitulated and are presented in Fig. 3. The curves show that the final effluent quality in p.p.m. B.O.D. or percentage of the influent suspended solids and B.O.D. remaining in the effluent varies inversely as the ratio of ''active solids'' to influent B.O.D.

Somewhat contrary to practical plant operation, the pilot plant, which operated under constant sewage flow and constant wasting of excess sludge, was subject to high fluctuations of aerator solids. During the three days of hourly testing, the returned solids based on the mixed liquor flow (influent sewage plus return sludge flow) varied from 130 to 300 p.p.m. while the wall film solids amounted to 270 p.p.m. on the same basis. When the returned solids were at a minimum, the influent B.O.D. was rapidly approaching a late morning high value. Shortly before midnight, the ''active solids'' had reached a maximum while the influent B.O.D. was rapidly approaching a minimum. The ratio of ''active solids'' to influent B.O.D. (Fig. 3) varied from a minimum value of 2 between 2 and 4 P.M. to a maximum value of 3 to 4 at 10 A.M. It may be observed that when the ratio increased above 2.25 to 2.5 there was a definite improvement in the effluent B.O.D. and an effluent B.O.D. of less than 30 p.p.m. was achieved when the ratio exceeded about 3.5.

If the wall surface area to aerator capacity is reduced to that of a practical plant then the return of more final tank solids or a higher aeration tank suspended solids presumbly must be maintained to secure a high ratio of "active solids" to influent B.O.D. However, since 600 to 800 p.p.m. suspended solids in the final tank influent are critical values above which the efficiency of the final tank is drastically decreased, it is obvious that the ratio of "active solids" to influent B.O.D. will be quite low during a substantial part of the diurnal cycle when the influent B.O.D. exceeds 200 p.p.m. and as a consequence the effluent will deteriorate.

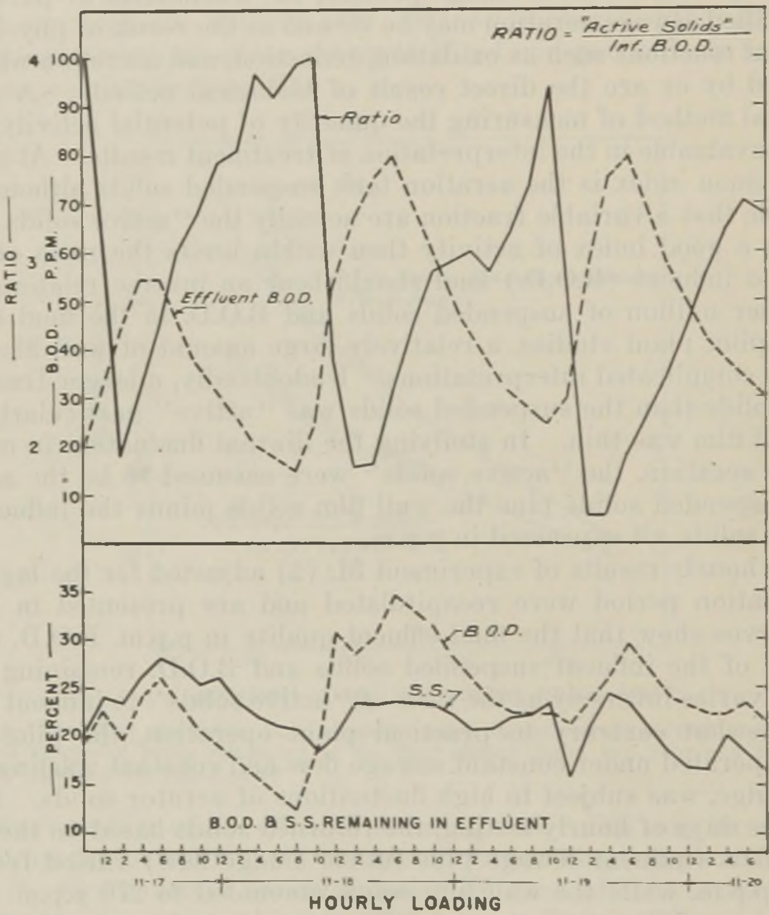


FIG. 3.—The diurnal fluctuation of effluent quality and the ratio of "active solids" to influent B.O.D. in modified sewage aeration expt. No. 5L, Nov. 17–20, 1942.

## A Comparison of Treatment at Different Temperatures

A summary of plain sewage aeration and modified sewage aeration at different temperatures is presented in Fig. 4. The five upper curves represent pilot plant aeration results computed to a temperature of 68° F. The bottom eight curves are two sets of four computed curves showing the quality of the effluent at different aerator suspended solids con-

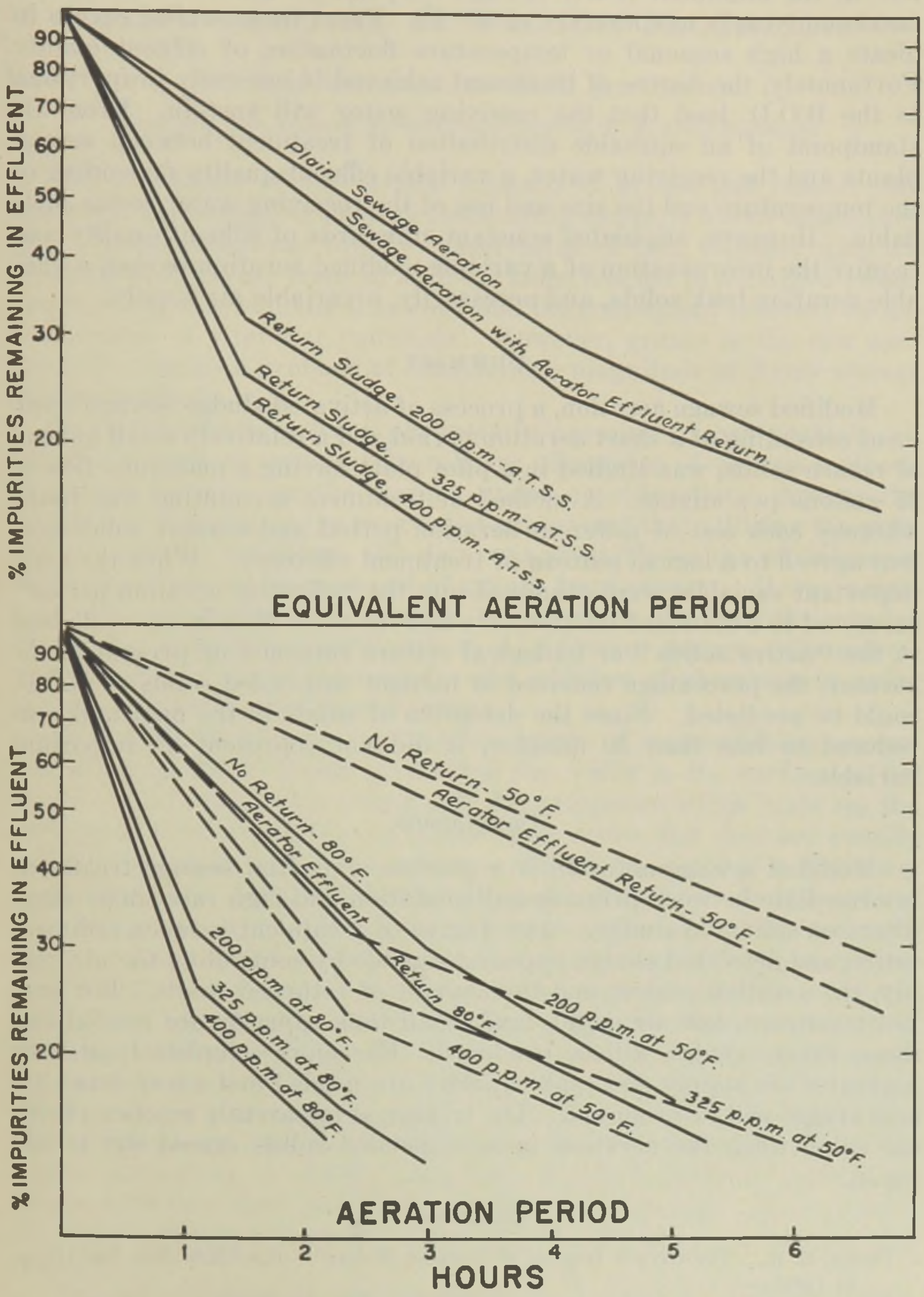


FIG. 4.—The effluent quality of plain sewage aeration and modified sewage aeration with varying amounts of aeration tank suspended solids for different aeration periods at 50° F., 80° F., and 68° F. (equivalent aeration period).

tent at the minimum yearly sewage temperature of 50° F. and at the maximum yearly temperature of 80° F. These three sets of curves indicate a high seasonal or temperature fluctuation of effluent quality. Fortunately, the degree of treatment achieved is inversely proportional to the B.O.D. load that the receiving water will sustain. From the standpoint of an equitable distribution of treatment between sewage plants and the receiving water, a variable effluent quality depending on the temperature and the size and use of the receiving water seems justifiable. However, stipulated constant standards of effluent quality may require the incorporation of a variable modified aeration period, a variable aeration tank solids, and necessarily, a variable air supply.

## Summary

Modified sewage aeration, a process of activated sludge sewage treatment consisting of a short aeration period and a relatively small amount of return solids, was studied in a pilot plant having a maximum flow of 25 gallons per minute. A method of treatment accounting was found whereby each test of different aeration period and aerator solids content agreed to a logical pattern of treatment efficiency. When the more important variables were combined into the ''effective aeration period'' corrected to a standard temperature and the ratio of influent solids load to the ''active solids'' or biological culture returned or present in the aerator, the percentage removed of influent suspended solids or B.O.D. could be predicted. Since the detention of solids in the final tank was reduced to less than 30 minutes, it did not represent an important variable.

## Conclusion

Modified sewage aeration is a process of partial sewage treatment intermediate between primary sedimentation and high rate single stage filters or activated sludge. Any degree of treatment between sedimentation and activated sludge appears possible by controlling the air supply, the aeration period, and the amount of returned solids. For partial treatment, low air supply and small tank capacity are needed and dense excess sludge will be produced. For more complete treatment, a greater air supply and tank capacity are needed and a less dense excess sludge will be produced. The treatment apparently reaches a critical value when the aeration tank suspended solids exceed 600 to 800 p.p.m.

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# GREASE REMOVAL BY VACUUM FLOTATION*

By Rolf Eliassen and H. B. Schulhoff

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The prevalence of appreciable amounts of grease and related substances in the sewage emanating from Army camps is a well established fact. Recent programs for the conservation of fats, together with the installation of grease traps in all mess halls, has led to a marked reduction in the grease content of sewage and the consequent recovery of untold pounds of vital war materials. However, grease in the raw sewage still presents a problem of considerable magnitude at Army sewage treatment plants.

In an attempt to solve a particularly pressing grease problem, an effort was made to evaluate the relative efficiencies of various methods of grease removal on the sewage under consideration. Among the methods of assisting in the removal of grease was that utilizing the principle of vacuum flotation.[1] No data was available on the effectiveness of this principle in the removal of grease from sewage. It was necessary to conduct pilot plant studies to determine the conditions under which this method was applicable to Army camp sewage. Consideration was also given to the need for the addition of chemicals in order to achieve greater removals of grease.

Vacuum flotation is merely another means of accomplishing separation of solids from liquids by floating the solids to the surface of the liquid. Most substances fitting into the categories which make up the ambiguous term of grease are lighter than water, but they are usually held in suspension by various means so that the separation is not easily accomplished by mere difference of specific gravities. In the case of sewage, the grease may be tied in with other solids so that the apparent specific gravity may be greater than that of water and the grease settles with the other sludges. It has been found that the addition of air to sewage will increase the release of grease. By the simple expedient of small air bubbles attaching themselves to particles of grease the apparent specific gravity of the combined matter is lowered and the grease will float to the surface more readily. By observation it has been noted that the smaller air bubbles are far more effective inasmuch as they will attach themselves to smaller particles of grease and will remain attached until they have reached the surface of the liquid. The principle of vacuum flotation does not alter this fundamental concept in any manner.

The use of vacuum is only for the purpose of inducing small air bubbles to form in the liquid. In order to make sure that enough air is present in the sewage to be released, a short period of aeration is em-

* Presented at the Fifteenth Annual Meeting of the New York State Sewage Works Association, New York City, January 22, 1943.

ployed prior to the application of vacuum. The purpose of this aeration is to saturate the sewage with air at atmospheric pressure. Aeration may be accomplished through mechanical devices or by diffusing air through the sewage. The large air bubbles resulting from this aeration must be released before vacuum is applied. A separate tank or vessel is utilized for this purpose. The application of vacuum causes the release of great numbers of very fine bubbles of air inasmuch as the amount of air which can be held in a saturated solution decreases with a decrease of pressure. These fine air bubbles will attach themselves to the well dispersed grease particles and bring about a very effective flotation of grease. It should be noted that the only purpose of the vacuum is to generate the fine air bubbles.

The apparatus employed in these pilot plant studies is shown in Fig. 1. The vessel in which vacuum flotation was achieved was a Lucite

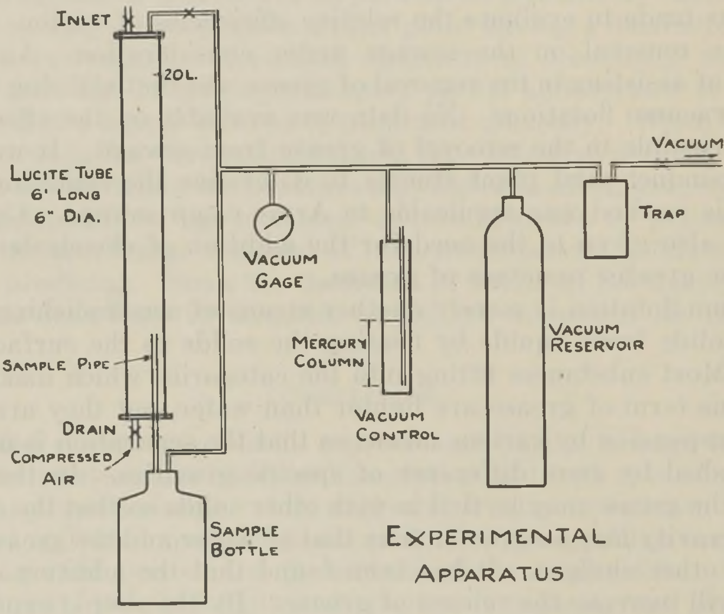


Fig. 1.—Experimental vacuum flotation apparatus.

tube, 6 ft. long and with a diameter of 6 inches. In order to simulate plant conditions, it was found that the depth was an important factor and, consequently, a 6 ft. tube was used. In like manner, it was found that the diameter of the tube had to be large enough to eliminate any effects of surface tension or other side wall influences which would occur if a smaller tube were used.

Twenty liters of sample were placed in the tube to the depth noted in Fig. 1. The sewage was aerated for five minutes by means of compressed air admitted at the bottom of the tube through a porous diffuser bulb. After aeration, several minutes were allotted for the larger bubbles of air to escape through the vent at the top of the tube. After closing the necessary valves, a vacuum equivalent to 15 inches of mercury was applied over the surface of the liquid in the tube. Experiments indicated that between eight and eighteen inches of mercury the degree of vacuum did not make much difference in removals accomplished. The selection of fifteen inches as the basis for the tests was made because it was found that the equipment could be handled most readily at this point.

In order to control the amount of vacuum within narrow limits, it was found necessary to employ a vacuum reservoir. This ironed out any irregularities in the operation of the vacuum pump. The degree of vacuum was closely regulated by means of the mercury column which acted as a vacuum control. In all the runs the vacuum was maintained for ten minutes. This allowed sufficient time for all of the air bubbles to form and rise to the surface. The rate of rise of these bubbles was quite rapid and varied with the size of solid matter being buoyed to the surface.

After flotation, a sample of the remaining sewage was withdrawn from the center of the tube as shown in Fig. 1, making sure that the vacuum was still maintained over the surface of the liquid. This was accomplished by manipulation of the valves noted over the sample bottle in Fig. 1. By placing the bottle on the tube under the same degree of vacuum, the sewage in the tube above the bottle would flow into the latter and the solid particles on the surface of the tube would not be disturbed to any appreciable extent. Analyses of the sewage sample were made for petroleum ether soluble matter and any other determinations of interest.

The basis of grease determination in the analyses was petroleum ether soluble matter in accordance with accepted practices in the sewage works field. In order to achieve consistent results within a reasonable time, it was necessary to refine the technique involved in the usual method of determining greases. This method has been reported in a previous paper by the authors.[2] It is significant to note that consistent results were obtainable and that many analyses could be made concurrently in the course of a day's work.

Tests were first conducted on raw sewage without the addition of other agents. The average results of these tests are presented in Table I and are shown graphically in Fig. 2. It will be noted that the per cent removal of petroleum ether soluble matter (hereafter called P.E.S.M.) increased with the strength of the sewage based on the value of the P.E.S.M. in the raw sewage. The removals of P.E.S.M. in the flotation process varied from 45 to 67 per cent.

Experiments were conducted to determine the effect of the addition of coagulants to the raw sewage. It was reasoned that the presence of a gelatinous floc would present a greater surface area to which the air bubbles could attach themselves. This would facilitate the coagulation and subsequent removal of greater quantities of grease. The results of experiments using ferric chloride are shown in Table II and are

TABLE I.—*Removal of P.E.S.M. by Vacuum Flotation*

| Number of Runs Averaged | P.E.S.M.—P.P.M. | | Per Cent Removal |
|---|---|---|---|
| | Raw Sewage | Treated Sewage | |
| 3 | 23 | 13 | 43 |
| 2 | 86 | 45 | 48 |
| 4 | 118 | 56 | 52 |
| 4 | 165 | 67 | 59 |
| 3 | 233 | 77 | 67 |

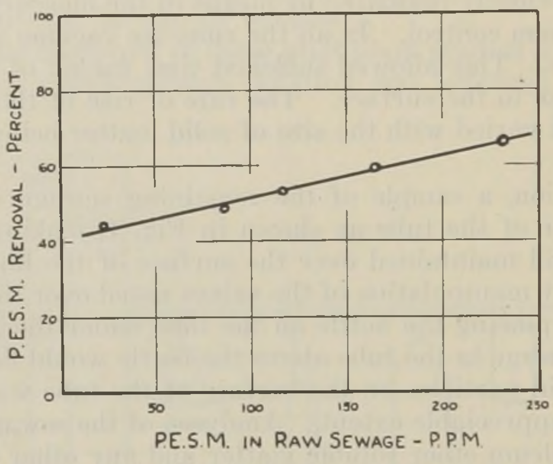


FIG. 2.—Removal of P.E.S.M. by vacuum flotation vs. strength of sewage.

presented graphically in Fig. 3. The dosages of ferric chloride are based upon 100 per cent $FeCl_3$. It will be noted that with sufficient dosages of iron salts it is possible to remove almost all of the grease. However, the cost involved would be too great for normal operating conditions. The addition of 50 p.p.m. $FeCl_3$ brought about the removal of 64 per cent of the P.E.S.M. or an increase of 47 per cent in the amount of grease floated. This dosage is within the range which may be employed in the coagulation of sewage in a chemical precipitation plant.

TABLE II.—*Removal of P.E.S.M. by Vacuum Flotation and Coagulation with Ferric Chloride*

| | Raw Sewage | Ferric Chloride Dosage—P.P.M. | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0 | 10 | 20 | 30 | 50 | 100 | 150 |
| Average P.E.S.M.—P.P.M. | 97 | 53 | 45 | 43 | 41 | 35 | 25 | 11 |
| Per Cent Removal | — | 45 | 53 | 56 | 58 | 64 | 74 | 89 |

Experiments were also conducted on the use of alum as the coagulant. The results of these tests are shown in Table III. Dosages of alum are indicated as p.p.m. of commercial alum. The increase of re-

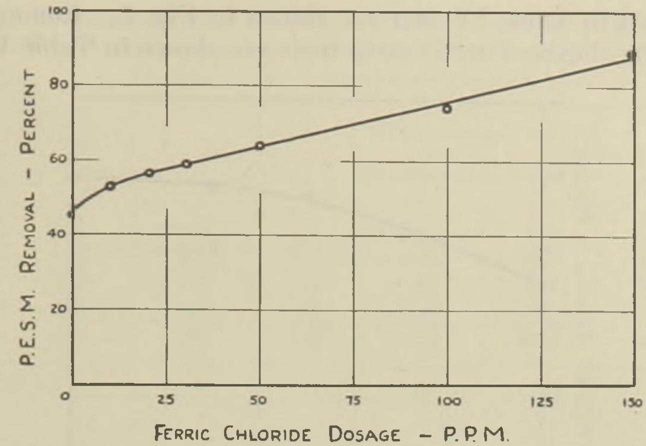


Fig. 3.—Effect of ferric chloride on P.E.S.M. removal.

moval obtainable through the use of this chemical is appreciable but the large quantities necessary for markedly different results would preclude its use under normal circumstances.

Vacuum flotation has been employed in the paper industry for some years as a means of recovery of fibers before discharging white water to streams or other methods of disposal.[3] The machinery in which this is accomplished is known as the Adka Save-All. Since paper pulp is

Table III.—*Removal of P.E.S.M. by Vacuum Flotation and Coagulation with Alum*

| | Raw Sewage | Alum Dosage—P.P.M | | |
|---|---|---|---|---|
| | | 0 | 50 | 100 |
| Average P.E.S.M.—P.P.M. | 137 | 79 | 62 | 48 |
| Per Cent Removal | — | 42 | 55 | 65 |

floated readily by the fine bubbles produced in the vacuum flotation unit, it was decided to observe the effect of paper pulp on the removal of grease from sewage. The results of these experiments are indicated in Fig. 4. It may be seen that high removals of grease may be accomplished but large quantities of paper pulp would be required. While the cost of this would be quite low, the problem of sludge disposal would be aggravated. The use of this material would not be practicable unless high removals could be achieved with low dosages of paper pulp.

Of late years, considerable interest has been evidenced among sanitary engineers in the application of chlorine gas together with air to raw sewage to facilitate the removal of grease.[4, 5] Experiments were conducted on the effect of aero-chlorination on the removals of grease by the vacuum flotation unit. Chlorine gas was added to the air used for aeration of the sewage for ten minutes prior to flotation. Removals of petroleum ether soluble matter achieved in the course of these tests are presented in Table IV and are shown in Fig. 5. Removals of suspended solids obtained in the same tests are shown in Table V. Similar

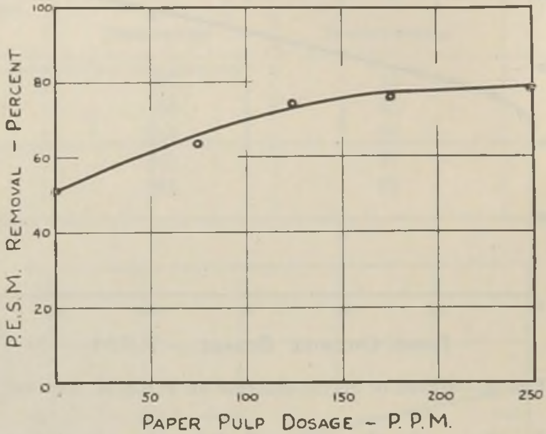


FIG. 4.—Effect of paper pulp on P.E.S.M. removal.

TABLE IV.—*P.E.S.M. Removal by Aero-Chlorination and Vacuum Flotation*

| Run No. | P.E.S.M. in Raw Sewage P.P.M. | P.E.S.M. in Treated Sewage—P.P.M. Chlorine Dosage—P.P.M. 0 | 5 | 10 | 15 | 20 | 25 |
|---|---|---|---|---|---|---|---|
| 1 | 139 | 45 | 45 | 51 | 56 | 38 | 65 |
| 2 | 152 | 77 | 95 | 90 | 99 | 63 | 88 |
| 3 | 153 | 55 | 61 | 83 | 82 | 83 | 85 |
| 4 | 187 | 75 | 81 | 88 | 78 | 79 | 89 |
| Ave. | 158 | 63 | 70 | 78 | 79 | 66 | 82 |
| Per Cent Removal | | 60 | 55 | 51 | 50 | 58 | 48 |

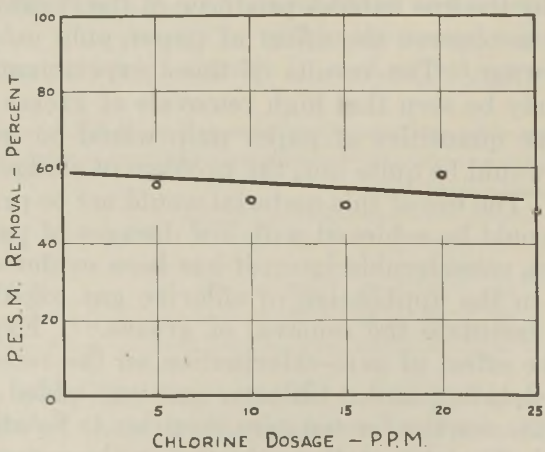


FIG. 5.—Effect of aero-chlorination on P.E.S.M. removal.

TABLE V.—*Suspended Solids Removal by Aero-Chlorination and Vacuum Flotation*

| Run No. | Susp. Sol. in Raw Sewage P.P.M. | Susp. Sol. in Treated Sewage—P.P.M. Chlorine Dosage—P.P.M. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 5 | 10 | 15 | 20 | 25 |
| 1 | 502 | 193 | 221 | 157 | 158 | 169 | 200 |
| 2 | 576 | 324 | 360 | 342 | 358 | 292 | 306 |
| 3 | 466 | 322 | 300 | 290 | 270 | 268 | 310 |
| 4 | 584 | 287 | 350 | 326 | 329 | 333 | 309 |
| Ave. | 532 | 282 | 308 | 279 | 279 | 266 | 281 |
| Per Cent Removal | | 47 | 42 | 47 | 47 | 50 | 47 |

results on B.O.D. removals are shown in Table VI. It will be noted that the addition of chlorine gas to the air had no appreciable effect one way or the other on the removal of grease, suspended solids, or B.O.D., from the sewage in the vacuum flotation unit.

Experiments were also conducted to determine the effect of the addition of sulphuric acid to the sewage. Additions of acid up to 250 p.p.m. had no effect on removal of grease from the sewage.

TABLE VI.—*B.O.D. Removal by Aero-Chlorination and Vacuum Flotation*

| Run No. | B.O.D. in Raw Sewage P.P.M. | B.O.D. in Treated Sewage—P.P.M. Chlorine Dosage—P.P.M. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 5 | 10 | 15 | 20 | 25 |
| 1 | 660 | 500 | 500 | 520 | 460 | 550 | 490 |
| 3 | 420 | 350 | 360 | 290 | 240 | 320 | 250 |
| 4 | 633 | 486 | 509 | 497 | 475 | 520 | 497 |
| Ave. | 571 | 444 | 456 | 436 | 392 | 463 | 412 |
| Per Cent Removal | | 22 | 20 | 24 | 31 | 19 | 28 |

## DISCUSSION

These experiments were conducted on Army camp sewage having a grease content of from 25 to 250 p.p.m. This is a much higher grease content than normally found in domestic sewage. Hence the results should be applied with limitations to sewage from municipal plants except in cases where industrial wastes such as those from packing houses or similar establishments discharge high quantities of grease-containing substances.

As far as Army camps are concerned, it may be noted that the vacuum flotation process is very effective in separating grease-containing solids from the liquid phase. The floated materials form a scum on the surface of the liquid in the flotation unit. By suitable mechanical skimmers this scum could readily be removed on a plant scale. Further removals of grease would undoubtedly follow in the settling tank and other treatment units which exist in the normal sewage treatment plant. The higher the grease content of the sewage the better the removals which would be obtained.

The addition of chemicals further increases the removal of grease. However, the use of chemicals in the normal plant would depend upon an economic balance between the need for additional removals as compared with the cost of chemicals. This in turn would depend upon the treatment given the sewage following the vacuum flotation unit. The commonly used coagulants, such as ferric chloride and alum, gave good results at fairly high dosages of chemicals. Paper pulp was successful in increasing the removal of grease from the sewage. The large quantities necessary for appreciable increase in grease removal precluded its effectiveness from a practical standpoint in view of the large quantity of increased sludges which would have to be handled.

Aero-chlorination was not effective in bringing about an increase in the removal of grease from the sewage in the vacuum flotation unit. No attempt was made to measure any increase or decrease in the amount of scum formed by the addition of chlorine gas to the air during the aeration period, or during the period of applying vacuum. The only criterion of grease removal was the P.E.S.M. content of the effluent from the vacuum flotation unit as compared with the P.E.S.M. content of the raw sewage. The reason for this criterion is that the problem at hand was the reduction of the grease content of the sewage entering an Army treatment plant in order to improve the operation of the secondary treatment process. This same reasoning would apply to most sewage treatment problems of this nature.

## Summary

Experiments conducted on Army camp sewage indicate that the vacuum flotation process may be used to advantage in the removal of grease from sewage. The process depends for its action upon the sewage first being saturated with air. This is accomplished by rapid aeration by mechanical or by diffused air. The sewage is then placed under a vacuum in which condition a super-saturation of air exists in the sewage. Air is released in a myriad of fine bubbles which adhere to particles of grease and other organic matter. Flotation of the combined air and solid matter ensues. The air is released at the surface of the liquid at which point the scum must be collected by mechanical means. Pilot plant tests utilizing this method indicate that removals of from 45 to 67 per cent of the petroleum ether soluble matter may be obtained from raw sewage depending upon its strength. Coagulants would further increase the removals of the solids. These coagulants include alum, ferric chloride and paper pulp. Aero-chlorination was found to have no effect on the removal of grease by this method. Based on these

experiments, the removals obtained without the addition of any chemicals should be satisfactory as long as primary sedimentation follows the vacuum flotation unit.


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# GREASE REMOVAL AT ARMY SEWAGE TREATMENT PLANTS

By Rolf Eliassen and H. B. Schulhoff

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The prevalence of grease in sewage emanating from Army camps is well known to the sewage works profession. Analyses of Army sewage for grease content have indicated daily averages of from 25 to 250 p.p.m. of petroleum ether soluble matter, with peak values running up to 1,000 p.p.m. over short periods of time. These values are far in excess of those ordinarily met with in sewage from a normal residential community.

High grease content in Army camp sewage as compared with municipal sewage may be attributed to a number of factors. In the first place, the rigorous physical life of the soldier requires the consumption of more meat by troops than the equivalent normal civilian population. This, together with the use of many fried foods, leads to greater quantities of fats present in spent dishwater. At each mess hall grease traps are installed following the sinks or dish washing machines. Experiments have shown that these grease traps will accomplish an average removal of approximately fifty per cent of the grease present in sink waste waters. The remaining grease passes to the sewer in relatively high concentrations.

Secondly, large quantities of soap are utilized in Army camps. The nature of the soldiers' activities and the stress on cleanliness lead to a greater number of daily shower baths per unit of population than would take place in an ordinary community. Shower water will contain a considerable amount of derivatives of fatty acids in the form of spent soaps. This is evident from observation of any of the sewage treatment plants at Army camps shortly after the morning or evening showers have been taken by the troops. Surfaces of settling tanks will be covered in many instances with a lather of suds and grease.

Many Army camps have large laundries installed. These would have a similar effect to those in a normal city. The effect of laundry waste on increasing the grease content of sewage is obvious. Analyses of these wastes have indicated grease contents of 500 to 1,000 p.p.m.

All of the above factors are subject to wide variations depending upon regulations or facilities prevailing at each Army post. One of the most important causes for variation in grease content has been the frequency and reliability of grease trap cleaning. Attempts have been made to enforce regulations that require the mess sergeants to clean the traps two or three times a week in order to prevent accumulated grease from passing into the sewerage system. Grease skimmed from the traps has been salvaged at many posts and sold to rendering establishments.

Of primary interest to the sanitary engineer is the effect of grease on the operation and maintenance of sewerage systems and sewage treatment plants. The grease contained in the hot liquids from the dish washing machines or sinks is usually in a molten state. When the dish water mixes with the contents of the sewers, the grease is cooled and may solidify if the temperature of the sewage is low enough. The affinity of grease for other surfaces may lead to deposition on the sides and invert of the sewer to such an extent that free flow is retarded or obstructed.

In one instance it was found that a ten inch steel pump discharge pipe carrying raw sewage was clogged to such an extent that an opening with an effective diameter of only 2½ in. remained. Consider the effect of this reduction in pipe size on the power requirements for the pumps. For a given quantity of sewage, the velocity will vary inversely as the area of the pipe or the square of the diameter. Since head loss and power vary as the square of the velocity, they must vary inversely as the fourth power of the diameter. In the case cited above, the diameter was cut to one-fourth of its original value. This means that the velocity was 16 times greater and the power requirements 256 times greater than would have been necessary to force the sewage through the same length of clean pump discharge pipe.

Grease problems in the various units of the sewage treatment plants are common. The skimming of primary settling tanks may be accomplished mechanically with varying degrees of effectiveness, depending upon the type of mechanism furnished in the plants. In a number of instances skimming mechanisms have not been provided, particularly at the smaller camps where Imhoff tanks or plain settling tanks were constructed. Skimming may be quite a problem to the plant operator if the grease content in the raw sewage is relatively high.

Experience has shown that grease containing substances will digest, giving a high yield of gas (1). If the grease is well interspersed among the other solids, no difficulty need be experienced in the digesters. However, in many instances the grease will separate from the other sludge particles and form a hard mat many feet thick riding as a scum at the top of the digester. This is particularly true where scum from the primary settling tanks is pumped directly to the digesters. Many Army sewage plants have been plagued with heavy blankets of scum which had to be broken up by some means, either hydraulic or mechanical. Several camps have resorted to separate disposal of scum by burial, burning or drying beds. None of these methods is acceptable for general practice. Most satisfactory results on the digestion of grease without attending difficulties have been obtained at those plants in which the primary digesters were provided either with high-speed mechanical stirring devices or sludge recirculation into the scum zone and at the point of entrance of raw sludge into the digester. Only by assurance of thorough dispersion of grease particles with raw and seed sludge can the operator be reasonably free from grease problems in sludge digesters.

Secondary treatment processes utilizing biological organisms to remove dissolved, colloidal, and suspended organic matter from sewage are frequently adversely affected by grease. Heukelekian (2) has demonstrated this in connection with activated sludge. As with anaerobic digestion, grease may be broken down, but at a slower rate. Hence, a longer period of aeration and a larger percentage of solids in the mixed liquor would be required to oxidize the grease without interference with the oxidation of the remaining putrescible organic matter removed from the sewage.

Similar situations have arisen with trickling filters. The presence of large amounts of grease in the effluents from primary settling tanks has resulted in coating some of the zoogleal jelly with grease. The slower oxidation of these substances has led to the lowering of oxidation capacity of trickling filters and the consequent need for larger rock volumes to affect the same degree of treatment were the grease not present in the sewage.

## Auxiliary Methods

The removal of grease from sewage ahead of secondary treatment is of primary interest to the operators of Army sewage treatment plants. All plants are equipped with primary settling tanks of some type. Consideration should, therefore, be given to the effect of the settling tank on the grease bearing particles in the sewage. Only three possibilities present themselves. The grease can either go up to form scum, go down to form sludge, or remain suspended in the sewage to contribute grease content to the effluent. Auxiliary methods of grease removal to augment the removals obtained by the rising or settling of grease in settling tanks have been sought by sanitary engineers for many decades. These have included the following:

*a.* Plain skimming tanks
*b.* Chemical precipitation
*c.* Diffused air aeration
*d.* Mechanical aeration
*e.* Aero-chlorination
*f.* Vacuum flotation

Each method must be followed by the primary settling tanks in order to accomplish removal of solids, as well as additional grease removal. These methods have been in use at Army sewage treatment plants operated under the jurisdiction of the authors.

Much has been written about the virtues of each process of grease removal, but few comparative studies have been made to indicate to designing engineers the conditions under which each process would be applicable. Such a study was undertaken by the authors to determine the increase in the efficiency of grease removal obtained by the application of the methods noted above to Army camp sewages.

A criterion of efficiency of grease removal had to be established in order to permit evaluation of the effect of each of these methods of grease removal. At the same time, consideration had to be given to the changing characteristics of the sewage at each plant and at different posts.

Since the most detrimental effect of grease on sewage is on the biological processes of secondary treatment, the condition of the primary clarifier effluent is of greatest importance. It is known that the primary tank will remove an appreciable percentage of grease as sludge or scum (3). What interests the operator is any further removal which can be obtained over and above primary settling. Thus, the quantity of grease removed by the settling tank can be accepted as the standard of comparison for each sewage. Any further increase in grease removal beyond the standard would indicate the effectiveness of the auxiliary method applied ahead of the settling tank.

Experiments were conducted in a number of different ways in an attempt to secure a true evaluation of the effectiveness of each method of grease removal. It was necessary to use laboratory and plant studies, alone and in combination, in order to secure a complete analysis. The details of each experiment will be outlined in conjunction with the presentation and discussion of the data.

Results of experimental work are only of value to the extent that analyses are made on representative samples of the material being studied. This is particularly true when low concentrations of grease are found in liquids such as sewage. The use of composite samples taken with the greatest care in accordance with accepted sampling procedure is highly essential. Wherever possible, statistical averages should be taken of a number of composite samples. This will lead to the greatest consistency of results and consequently the most accurate analysis of the processes under consideration. This procedure was followed where feasible in the work described in this paper.

Analytical work was carried out in the trailer laboratory specially equipped for sewage analysis. A previous paper (4) was devoted to a description of this laboratory. Standard methods of analysis (5) were used in most instances. It was necessary to develop a refinement of technique for the determination of petroleum ether soluble matter in sewage. This method has been reported in another paper (6) by the authors.

## Diffused Air Aeration

The practice of aerating sewage for a short period prior to settling has received wide acceptance. One of the most common methods of aeration is the diffusion of compressed air over a certain portion of the bottom area of the aeration tank by means of porous plates (7). A unit of this type had been installed at one of the Army sewage treatment plants (Plant A) operated under the supervision of the authors. Primary settling and secondary treatment by slow sand filtration followed the aeration process. It was desirable to make a study of the efficiency of this method of grease separation in order to determine whether similar units should be installed at other posts where grease difficulties were being experienced in secondary treatment processes.

It was unfortunate that the design of the raw sewage pumping station at this treatment plant permitted the accumulation of large quantities of grease in the wet well. Frequent discharges of grease in slugs made representative sampling difficult and results inconsistent. Pilot plant studies were resorted to as the best means of securing comparative results on removals of grease by aeration plus settling as compared with plain settling.

Samples of raw sewage were composited for a half hour by taking 5 gallon samples every few minutes until 50 gallons had been composited. Solids were kept in suspension by the agitation of dumping fresh samples into the tank. Two 20 gallon tanks were then filled with this sewage. To make certain that both tanks received similar sewages, the filling was switched from one tank to the other every few gallons. Subsequent analyses for grease and suspended solids showed that the sewages in each 20 gallon tank were virtually the same. The depth of liquid in each tank was two feet.

In one tank quiescent settling was begun immediately after filling. This settling took place for 30 minutes to approximate a settling rate of 4 feet per hour, or an overflow rate of 720 gallons per square foot per day, the normal value for primary settling tanks. After 30 minutes a sample was taken a few inches below the scum layer to represent the effluent from a plain settling tank.

In the other tank the sewage was subjected to aeration by diffused air for 10 minutes at a rate of 0.3 cubic foot per minute. This was equivalent to a rate of 0.15 cubic foot per gallon of sewage. After aeration quiescent settling was permitted to take place for 30 minutes at the same rate as noted above for the unaerated sample. A sample taken under the scum layer represented the effluent from a settling tank preceded by diffused air aeration.

Aero-chlorination was also studied as part of these experiments. Chlorine gas was added directly to the air in accordance with standard practice (8). Dosages of 5 and 10 p.p.m. were added over the entire aeration period. The settling period following aero-chlorination was the same as with the previous experiments.

The results of these experiments have been averaged and are presented in Table I. These can best be interpreted by means of graphical representation. If individual analyses were plotted, the scatter diagrams which resulted would give a good indication of trends. As pointed out previously, when dealing with grease analyses of sewage, it is far better to average the results of many composite samples. This has been done wherever possible by averaging the results into various groups depending upon the value of the grease contained in the raw sewage.

Fig. 1 shows the average results obtained during the course of the many runs utilizing the apparatus and procedure noted above. It was

TABLE I.—*Removal of Grease by Aeration and Settling—Plant A*

| Raw Sewage Grease P.P.M. | Settling | | | Aeration Plus Settling | | | | Difference Per Cent Removed |
|---|---|---|---|---|---|---|---|---|
| | Effl. P.P.M. | Removed | | $Cl_2$ P.P.M. | Effl. P.P.M. | Removed | | |
| | | P.P.M. | % | | | P.P.M. | % | |
| 37 | 20 | 17 | 46 | 0 | 21 | 16 | 43 | −3 |
| 40 | 28 | 12 | 30 | 10 | 30 | 10 | 25 | −5 |
| 49 | 32 | 17 | 35 | 5 | 31 | 18 | 37 | +2 |
| 64 | 32 | 32 | 50 | 0 | 33 | 31 | 48 | −2 |
| 64 | 42 | 22 | 34 | 10 | 42 | 22 | 34 | 0 |
| 66 | 35 | 31 | 47 | 5 | 36 | 30 | 46 | −1 |
| 97 | 43 | 54 | 56 | 0 | 44 | 53 | 55 | −1 |
| 115 | 54 | 61 | 53 | 10 | 52 | 63 | 55 | +2 |
| 130 | 43 | 87 | 67 | 5 | 49 | 81 | 62 | −5 |
| 132 | 38 | 94 | 71 | 0 | 41 | 91 | 69 | −2 |

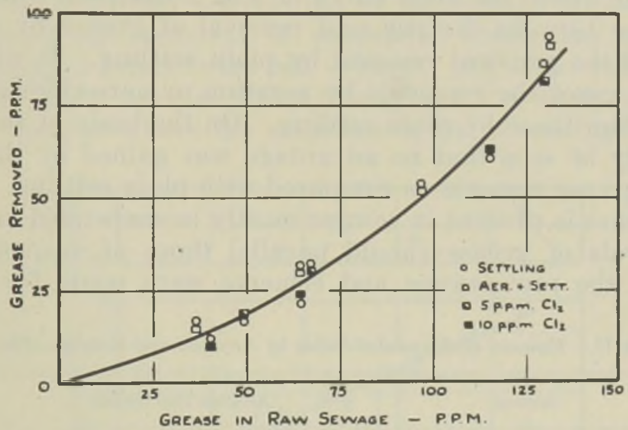


FIG. 1.—Removal of grease by aeration and settling—Plant A.

found expedient to express results in terms of grease removed in the process. This was obtained from the difference between the grease contents of the raw and treated sewages. In Fig. 1 the grease removed in p.p.m. has been plotted against the grease content of the raw sewage. All methods have been plotted on the same graph, namely, plain settling, aeration followed by settling and aero-chlorination with 5 and 10 p.p.m. of chlorine preceding settling. It will be noted that all of the results lie on virtually the same curve, indicating that no further increase in removal can be expected over plain settling by any of the methods used in this series of experiments.

This conclusion is more clearly brought out by the method of presentation indicated in Fig. 2. In this curve, the percentage of grease removed has been plotted against the grease in the raw sewage. It will be seen that no difference is noted in the results obtained by any of these methods as compared with plain settling.

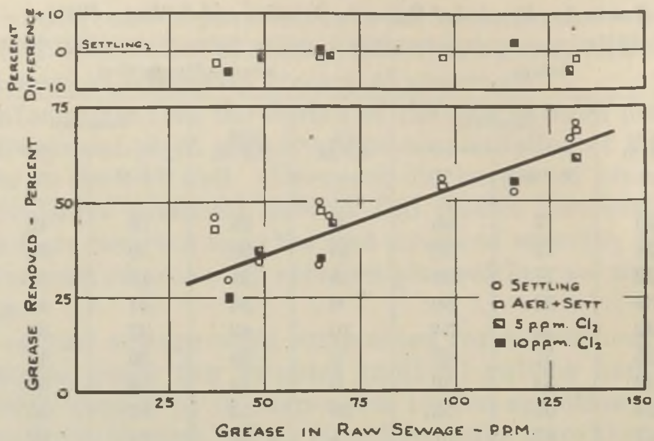


FIG. 2.—Comparison of per cent removals of grease by aeration and settling.

The graph above the main curve of Fig. 2 has been drawn to show the difference between the per cent removal of grease by each of the methods and the per cent removal by plain settling. It will be noted that in most cases the removals by aeration or aero-chlorination were no greater than those by plain settling. On the basis of these results, it can readily be seen that no advantage was gained by the auxiliary methods of grease removal as compared with plain settling.

Since grease is present in sewage mostly in suspended and colloidal form, removals of grease should parallel those of suspended solids. Analyses of the raw sewage and effluents were made for suspended

TABLE II.—*Removal of Suspended Solids by Aeration and Settling—Plant A*

| Raw Sewage Susp. Solids P.P.M. | Settling | | | Aeration Plus Settling | | | | Difference Per Cent Removed |
|---|---|---|---|---|---|---|---|---|
| | Eff. P.P.M. | Removed | | $Cl_2$ P.P.M. | Eff. P.P.M. | Removed | | |
| | | P.P.M. | % | | | P.P.M. | % | |
| 109 | 77 | 32 | 29 | 0 | 76 | 33 | 30 | + 1 |
| 143 | 80 | 63 | 44 | 5 | 94 | 49 | 34 | −10 |
| 170 | 98 | 72 | 42 | 0 | 96 | 74 | 43 | + 1 |
| 174 | 100 | 74 | 43 | 10 | 109 | 65 | 37 | − 6 |
| 225 | 102 | 123 | 55 | 5 | 112 | 113 | 50 | − 5 |
| 231 | 110 | 121 | 52 | 10 | 107 | 124 | 54 | + 2 |
| 244 | 124 | 120 | 49 | 0 | 127 | 117 | 48 | − 1 |
| 320 | 134 | 186 | 58 | 5 | 146 | 174 | 54 | − 4 |
| 433 | 142 | 291 | 67 | 10 | 125 | 308 | 71 | + 4 |

solids in order to serve as a check on results obtained by means of grease analyses. The average results are shown in Table II. These have been plotted in Fig. 3, with removal of suspended solids plotted against the suspended solids content of the raw sewage. The results are similar to those obtained with grease analyses; removals of sus-

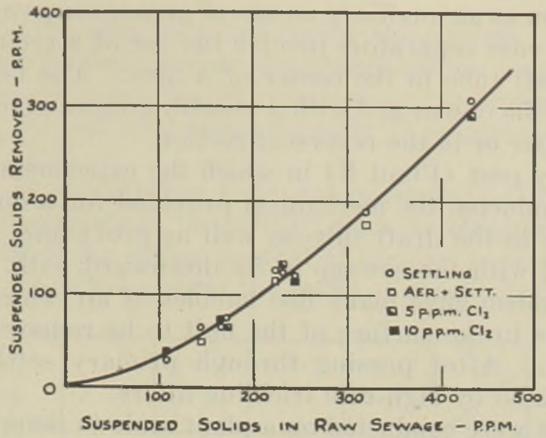


FIG. 3.—Removal of suspended solids by aeration and settling—Plant A.

pended solids are the same for aeration, aero-chlorination and plain settling. This is further emphasized by the method of presentation in Fig. 4. Percentage removal of suspended solids has been plotted against suspended solids in the raw sewage. All of the values are clustered within fairly narrow limits throughout the whole range of the curve. On the plot above the main curve, the percentage removal by

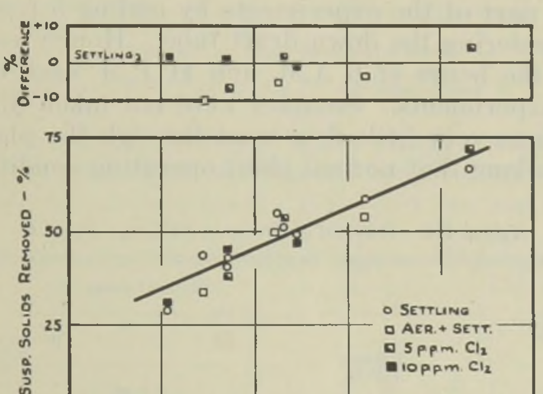


FIG. 4.—Comparison of per cent removals of suspended solids by aeration and settling.

plain settling has been established as the standard. The results using the auxiliary methods in addition to settling indicate that no particular advantage accrued from the use of these auxiliary methods inasmuch as the per cent removals were only slightly different from those obtained by plain settling.

## Mechanical Aeration

A number of plants which have been installed throughout the country for the treatment of sewage and industrial wastes have utilized mechanical aeration as an auxiliary means of grease removal (9). In most instances the grease separators involve the use of a recirculating pump located in a draft tube in the center of a tank. The flow through the tube may either be downward with a resulting upward motion of liquid in the tank proper or in the reverse direction.

At the Army post (Plant B) in which the experiments on this type of unit were conducted the mechanism provided for a downward movement of sewage in the draft tube as well as provisions for drawing in air to be mixed with the sewage in its downward path. It was noted that this mechanism gave many fine bubbles of air which brought considerable grease to the surface of the unit to be removed by the skimmer mechanism. After passing through primary settling tanks, the sewage was treated by high-rate trickling filters.

Experiments were conducted on a plant scale to determine the effectiveness of this grease separator unit on increasing the removals of grease over the results which would have been obtained by plain settling. The procedure adopted involved running the plant utilizing sedimentation alone for a week, and by-passing the aerator. The following week the grease separator was operated and was followed by the settling tanks. This was repeated for almost two months in order to obtain a sufficient amount of data for statistical averages which could be relied upon to give a fair analysis of the problem. Aero-chlorination was utilized during part of the experiments by adding 5 p.p.m. of chlorine gas to the air entering the down draft tube. Hourly composites were taken between the hours of 6 A.M. and 11 P.M. each day during the course of the experiments. Samples were not taken during the night hours inasmuch as very little flow went through the plant. Retention periods were so long that normal plant operating conditions would not

TABLE III.—*Removal of Grease by Settling—Plant B*

| Raw Sewage Grease P.P.M. | Settled Sewage | | |
|---|---|---|---|
| | Effluent P.P.M. | Removed | |
| | | P.P.M. | Per Cent |
| 51 | 9 | 42 | 82 |
| 56 | 12 | 44 | 79 |
| 67 | 37 | 30 | 45 |
| 67 | 27 | 40 | 60 |
| 75 | 14 | 61 | 81 |
| 82 | 20 | 60 | 73 |
| 83 | 22 | 61 | 74 |
| 102 | 41 | 61 | 60 |
| 114 | 59 | 55 | 48 |
| 125 | 28 | 97 | 78 |
| 152 | 49 | 103 | 68 |
| 161 | 45 | 116 | 73 |
| 230 | 74 | 156 | 68 |
| 233 | 44 | 189 | 81 |

be represented in the samples taken during these hours. The composite samples obtained by this procedure represented the results obtained in a normal course of operation of this sewage treatment plant, with a nominal flow of 3 m.g.d. and approximately 15 minutes detention in the aeration tank.

The results of the settling tests are presented in Table III. The average grease removals in the settling tank, as obtained by the difference in the values of the grease content of the raw sewage and the clarifier effluent, were plotted against the value of grease in the raw sewage,

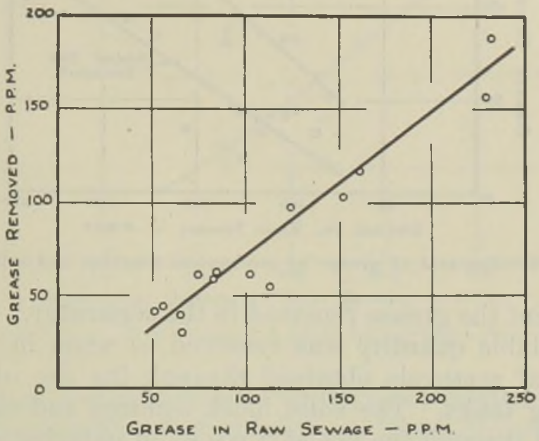


FIG. 5.—Removal of grease by settling—Plant B.

as shown in Fig. 5. Each of the points shown represents the composite of a day's run involving eighteen separate samples. The curve will be used later to compare results obtained through the use of the aerator.

TABLE IV.—*Grease Removal by Mechanical Aeration Plus Settling—Plant B*

| Chlorine Dosage P.P.M. | Raw Sewage Grease P.P.M. | Grease Separator | | | Settling Tank | | |
|---|---|---|---|---|---|---|---|
| | | Eff. P.P.M. | Removed | | Eff. P.P.M. | Removed | |
| | | | P.P.M. | % | | P.P.M. | % |
| 0 | 80 | 63 | 17 | 21 | 29 | 51 | 64 |
| 0 | 88 | 57 | 31 | 35 | 25 | 63 | 72 |
| 0 | 98 | 53 | 45 | 46 | 16 | 82 | 84 |
| 0 | 103 | 61 | 42 | 41 | 21 | 82 | 80 |
| 0 | 116 | 85 | 31 | 27 | 29 | 87 | 75 |
| 0 | 125 | 105 | 20 | 16 | 36 | 89 | 71 |
| 5 | 128 | 84 | 44 | 34 | 32 | 96 | 75 |
| 0 | 134 | 53 | 81 | 60 | 48 | 86 | 64 |
| 5 | 155 | 120 | 35 | 23 | 45 | 110 | 71 |
| 0 | 171 | 60 | 111 | 65 | 25 | 146 | 85 |
| 0 | 171 | 86 | 85 | 50 | 19 | 152 | 89 |
| 5 | 189 | 98 | 91 | 48 | 49 | 150 | 79 |
| 5 | 230 | 112 | 118 | 51 | 55 | 175 | 76 |
| 5 | 241 | 137 | 104 | 43 | 51 | 190 | 79 |

The values of grease removal versus grease in the raw sewage using the grease separator followed by the primary clarifiers are presented in Table IV. The average values have been plotted in Fig. 6. The

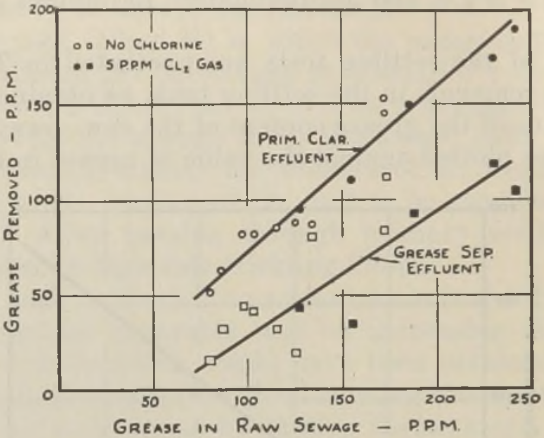


Fig. 6.—Removal of grease by mechanical aeration and settling.

squares represent the grease removed in the separator. It will be noted that an appreciable quantity was removed as scum in this unit. The circles represent removals obtained through the use of the separator and the settling tanks. The solid black squares and circles represent values obtained through the use of 5 p.p.m. of chlorine gas in the process. From Fig. 6, it will be noted that no increase in removals was obtained through the use of aero-chlorination.

In order to visualize the difference between the results obtained through the use of settling alone as against aeration plus settling, Fig. 7

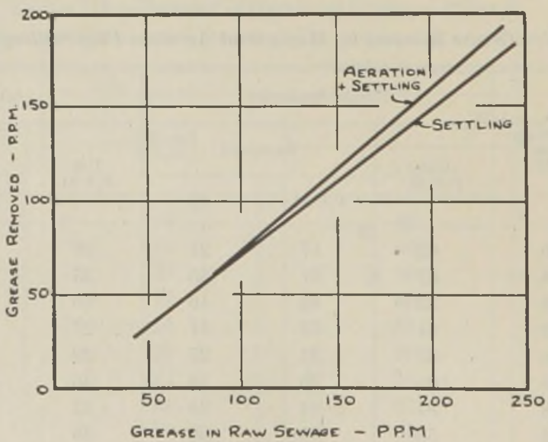


Fig. 7.—Comparative grease removals by mechanical aeration and settling.

has been drawn, using the same curves as shown in Figs. 5 and 6. It will be noted that when the grease content in the raw sewage rises above 100 p.p.m. there is a slight difference in the removal of grease in favor of aeration plus settling.

Suspended solids analyses were also made at the same time as the analytical work was done for the determination of grease content of the raw sewage and effluents. The results of the removal of suspended solids versus the suspended solids content of the raw sewage by plain settling are indicated in Fig. 8. Similar results obtained through the

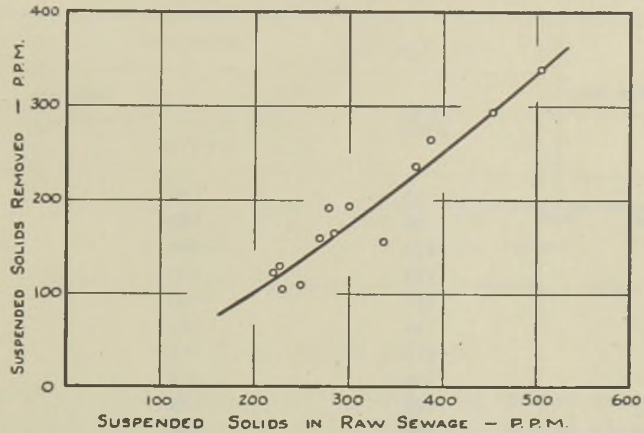


FIG. 8.—Removal of suspended solids by settling—Plant B.

use of the aeration tank followed by settling are plotted in Fig. 9. Tables V and VI present the tabulated data on which the curves are based. The results obtained through the use of aero-chlorination are shown in

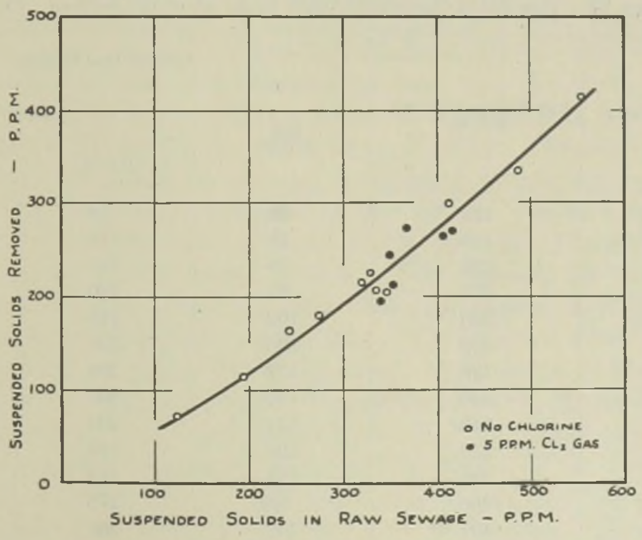


FIG. 9.—Removal of suspended solids by mechanical aeration plus settling.

solid circles in the latter figure. It will be noted that these values confirm the previous findings with grease, namely that aero-chlorination with 5 p.p.m. of chlorine does not give any further removal of grease.

These curves have been transposed to Fig. 10. It will be noted that there is only a slight difference in the removal of suspended solids through the use of the aerator followed by settling.

TABLE V.—*Removal of Suspended Solids by Plain Settling—Plant B*

| Raw Sewage Susp. Sol. P.P.M. | Settling Tank | | |
|---|---|---|---|
| | Eff. P.P.M. | Removed | |
| | | P.P.M. | Per Cent |
| 220 | 97 | 123 | 56 |
| 224 | 98 | 126 | 56 |
| 229 | 123 | 106 | 46 |
| 249 | 139 | 110 | 44 |
| 271 | 111 | 160 | 59 |
| 280 | 88 | 192 | 68 |
| 283 | 119 | 164 | 58 |
| 300 | 106 | 194 | 65 |
| 338 | 180 | 158 | 47 |
| 374 | 136 | 238 | 64 |
| 388 | 126 | 262 | 68 |
| 454 | 158 | 296 | 65 |
| 504 | 164 | 340 | 67 |

TABLE VI.—*Removal of Suspended Solids by Aeration and Settling—Plant B*

| Chlorine Dosage P.P.M. | Raw Sewage Susp. Sol. P.P.M. | Aeration Plus Settling | | |
|---|---|---|---|---|
| | | Eff. P.P.M. | Removed | |
| | | | P.P.M. | Per Cent |
| 0 | 123 | 49 | 74 | 60 |
| 0 | 196 | 78 | 118 | 60 |
| 0 | 242 | 78 | 164 | 68 |
| 0 | 275 | 95 | 180 | 65 |
| 0 | 320 | 102 | 218 | 68 |
| 0 | 332 | 106 | 226 | 68 |
| 0 | 338 | 132 | 206 | 61 |
| 5 | 340 | 140 | 200 | 59 |
| 0 | 346 | 144 | 202 | 58 |
| 5 | 350 | 106 | 244 | 70 |
| 5 | 358 | 144 | 214 | 60 |
| 5 | 366 | 88 | 278 | 76 |
| 5 | 407 | 142 | 265 | 65 |
| 0 | 414 | 114 | 300 | 72 |
| 5 | 418 | 146 | 272 | 65 |
| 0 | 486 | 148 | 338 | 69 |
| 0 | 558 | 144 | 414 | 74 |

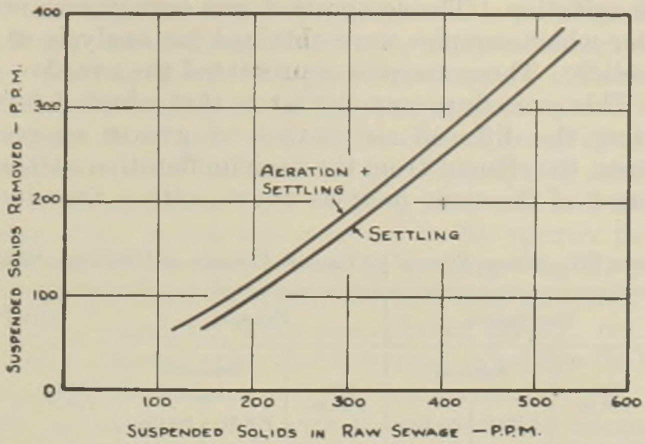


FIG. 10.—Comparative suspended solids removals by mechanical aeration and settling.

## Vacuum Flotation

Of late years there have been a number of grease removal units installed at sewage treatment plants and in industrial plants employing the principle of vacuum flotation (10). A functional part of this apparatus is the pre-aeration unit in which sewage is aerated by a high speed mechanism for less than a minute to saturate the liquid with air at atmospheric pressure. The large air bubbles are released immediately, after which the sewage passes into the vacuum tank. This unit is comprised of a detention tank in which the sewage is retained for approximately 20 minutes. A rotating skimmer and sludge collecting mechanism are provided. The whole tank, either of steel or concrete, is inclosed and a vacuum of 10 inches applied over the surface of the sewage. A myriad of fine bubbles is released, inasmuch as the sewage is supersaturated with air at the decreased pressure. These bubbles attach themselves to particles of sewage containing grease and other organic matter. The buoyancy provided by the fine air bubbles carries the attached particles to the surface from which they are skimmed by a mechanism and swept to the scum trough. The skimmings pass through a barometric leg into a scum pit from which the material is pumped to the digester or other means of disposal. One of these units had been installed ahead of an activated sludge plant at an Army sewage treatment plant (Plant C) operated under the supervision of the authors.

Experimental procedure consisted of both plant and laboratory studies. In order to secure information over a wide range of grease contents in the raw sewages, samples were composited every 5 minutes over a period of an hour at various times of the day. The twelve samples which resulted comprised one run. Many of these runs were made during the course of the experiments. It was found that the best method of securing results worthy of interpretation was to collect large samples of raw sewage to obtain a composite over the course of an hour of approximately 20 gallons. The frequent addition of samples kept the liquid in agitation. The composited raw sewage was settled for 30 minutes, after which samples were obtained for analysis of grease and suspended solids. These samples represented the overflow from a settling tank. This procedure was similar to that adopted for the experiments utilizing the diffused air method of grease separation. In a similar manner, the effluent from the vacuum flotation unit was sampled over the course of the same hour as above, with a time interval of 15

TABLE VII.—*Grease Removal by Vacuum Flotation and Settling—Plant C*

| Raw Sewage Grease P.P.M. | Plain Settling | | | Flotation | | | Flot. Plus Settling | | |
|---|---|---|---|---|---|---|---|---|---|
| | Effl. P.P.M. | Removed | | Effl. P.P.M. | Removed | | Effl. P.P.M. | Removed | |
| | | P.P.M. | Per Cent | | P.P.M. | Per Cent | | P.P.M. | Per Cent |
| 85 | 36 | 49 | 58 | 49 | 36 | 42 | 36 | 49 | 58 |
| 123 | 53 | 70 | 57 | 64 | 59 | 48 | 54 | 69 | 56 |
| 141 | 59 | 82 | 58 | 66 | 72 | 53 | 46 | 95 | 67 |
| 170 | 62 | 108 | 63 | 68 | 102 | 60 | 48 | 122 | 71 |
| 189 | 58 | 131 | 69 | 67 | 122 | 65 | 51 | 138 | 73 |

minutes to account for the flow-through time in the flotation tank. This material was allowed to settle for 30 minutes. Samples were then taken to represent the overflow from a settling tank following vacuum flotation. Samples of raw sewage and flotation tank effluent were also taken for analysis. Actual plant studies on settling tank effluent following the flotation unit paralleled the results obtained by the pilot plant studies

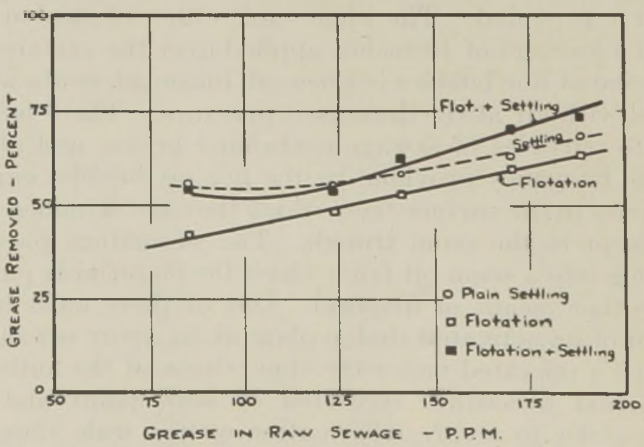


FIG. 11.—Grease removal by vacuum flotation and settling—Plant C.

and showed that the method adopted would give more consistent results and still represent an accurate picture of what was being accomplished in the plant itself.

The results of these experiments are given in Table VII. These results have been averaged and presented graphically in Fig. 11. It will be noted that flotation removes a considerable portion of the grease without resorting to settling. However, plain settling will remove slightly more than flotation. Passing the flotation effluent through a settling tank does succeed in removing more grease. As with the other auxiliary methods of grease removal the overall removal of grease obtained through the use of the flotation unit followed by settling is only a few per cent greater than with settling alone, as will be seen from Fig. 11. Most of the grease was removed in the vacuum flotation tank and very little was left to be removed by settling. In the operation of the activated sludge plant in which the unit was installed, the grease load on the primary settling tanks was relieved greatly, but the overall removal of grease was not appreciable enough to relieve the grease load going to the activated sludge.

Aero-chlorination was tried with the use of this vacuum flotation unit. These studies were made on a laboratory scale to facilitate the addition of large quantities of gaseous chlorine to the aeration mechanism. The results of these experiments have been reported in a previous paper by the authors (11). In order to complete the picture of the work done in connection with grease separation at Army sewage treatment plants, it would be advisable to present Fig. 12 from the afore-

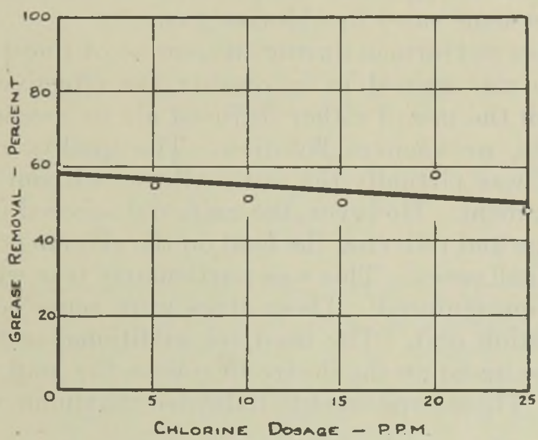


FIG. 12.—Grease removal by aero-chlorination and vacuum flotation.

mentioned paper. This illustrates the results obtained through the use of various dosages of chlorine ranging up to 25 p.p.m. in the aeration unit preceding vacuum flotation. It will be noted that chlorine had no effect on increasing the removal of grease by this unit.

## Discussion

These studies have covered experiments using various auxiliary methods applied ahead of primary settling tanks to assist in the removal of grease from sewage at Army sewage treatment plants. The plants at which the investigations were carried out utilized various biological secondary treatment processes which would be adversely effected by grease in the effluent from primary settling tanks. No attempt was made in the course of these tests to evaluate the effect of pre-aeration on the supply of oxygen to the sewage to facilitate odor control or oxygenate the sewage. This is a different phenomenon from that involved in the separation of grease from sewage in that dissolved oxygen is of prime consideration, instead of the buoyant effect of air bubbles. Similarly, no evaluation was made of the effect of the addition of chlorine to sewage for the same purpose. These subjects have been the subject of much discussion in the literature and elsewhere. The studies were confined to the effect of the auxiliary method on increasing the removal of grease from that which was obtained in parallel studies utilizing plain settling tanks. The quality of the effluent from the primary settling tanks was used as the criterion of the effectiveness of grease removal.

Tests were not conducted on the effect of chemical precipitation on the removal of grease. This subject has been investigated by a number of authors (12). It is known that by the addition of chemicals in sufficient quantity, practically all of the grease could be removed from raw sewage. Cost is a major consideration. The methods being studied were only those involving air as the principal medium added to sewage, supplemented in some cases by chlorine gas.

In all the tests performed during the course of these studies, no distinct advantage was gained in increasing the effectiveness of grease removal through the use of either diffused air or mechanical aeration, aero-chlorination, or vacuum flotation. The quality of the primary clarifier effluent was virtually the same with or without these auxiliary methods of treatment. However, the units did succeed in taking grease out of the sewage and relieving the load on the skimmers of the primary settling tanks in all cases. This was particularly true when heavy slugs of grease were encountered. These slugs were removed to a great extent in the aeration unit. The need for additional methods of grease removal must be based on the desire to relieve the load on the primary settling tanks. These experiments indicated maximum effectiveness in this direction.

The opinions expressed in this article are those of the authors based upon the results of their research on grease removal. They are not to be construed as indicative of War Department policy in these matters.

## Conclusions

1. Diffused air aeration had no appreciable effect on increasing grease removal over the removal accomplished by plain settling.

2. Aero-chlorination with 5 or 10 p.p.m. of chlorine gas added to the air being diffused into the sewage had no effect on increasing grease removal.

3. Mechanical aeration increased the removal of grease a few per cent when grease was present in the raw sewage in concentrations over

100 p.p.m. Approximately 50 per cent of the grease was removed in the aeration unit.

4. Aero-chlorination with 5 p.p.m. of chlorine gas showed no further increase in grease removal over that obtained by the mechanical aeration.

5. Vacuum flotation increased the removal of grease a few per cent when the grease in the raw sewage was over 150 p.p.m. Over 75 per cent of the grease was removed in the flotation unit.

6. Aero-chlorination with chlorine up to 25 p.p.m. added in the aeration stage preceding flotation showed no effect on increasing the removal of grease.

7. Plain settling is one of the most effective means of removing grease from raw sewage.

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## Discussion of Paper by Eliassen and Schulhoff

By W. S. Mahlie

Not much attention was given to grease removal methods until the army camp plants were put into operation, and then the operators became "grease conscious." Kessler and Norgaard in their study of army camp plants (Sewage Works Journal, July 1942) pointed out the need for better grease removal methods, and this paper appears to be an answer to the question confronting army camp plant operators as to what can be done to improve grease removal methods. The title of this paper would, in a measure, exclude any discussions from one who has no contact with army camp treatment plans; hence the following remarks must be accepted with that in mind.

In view of the amount of publicity various methods of grease removal have received, the conclusions reached by the authors may bring forth some discussion.

An excellent paper "The Grease Problem in Sewage," by Messrs. Fales and Greeley, in *Trans. A. S. C. E.*, Vol. 108 (1943), p. 507, gives some results obtained at various plants. I have taken their figures and platted them to the same scale as in the authors' Fig. 1 and it is surprising to see the close agreement as to grease removal by plain settling.

On examining the results shown in Table I which covers about the range of grease quantities as are usually found in sewage, we find that when the grease content is below 97 p.p.m. a removal of 40 per cent is obtained by plain settling, and when the grease is in excess of this the removal is somewhat greater, *i.e.*, 61 per cent. In the data submitted in the Fales and Greeley paper, on sewage containing up to 80 p.p.m., the average removal is 39 per cent. In analyzing the results on Table III, Plant B, the percentage removed is somewhat higher than that of Plant A. For sewages up to 100 p.pm. the removal is 71 per cent, while for sewage from 100 to 233 p.p.m. the removal is 68 per cent.

The fact that no appreciable difference in grease removal between plain settling and aeration before settling was found will come as a surprise to most of us as this method has been widely exploited. The experiments show results from 43 to 69 per cent removal, while results reported from actual plant operations run from 34 to 75 per cent.

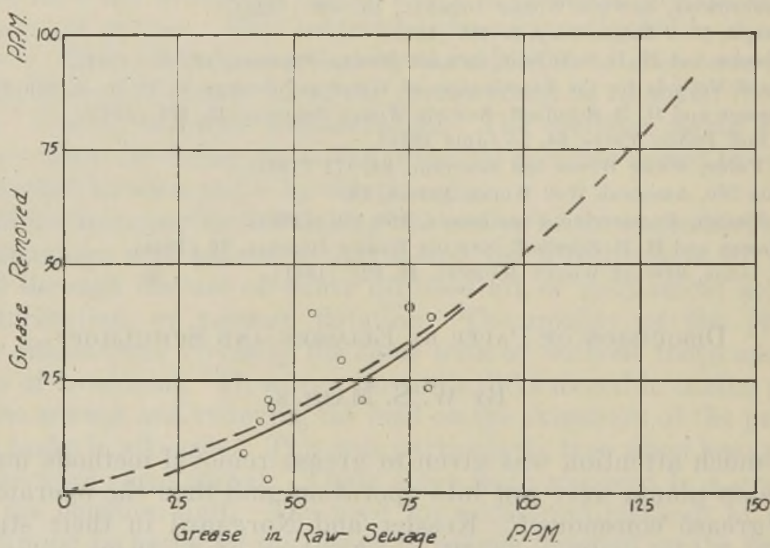


**Fig. 1.**—Comparison of grease removal by plain sedimentation as determined by Fales and Greeley (*Trans. A. S. C. E.*, Paper 2187, 1943) and by Eliassen and Schulhoff.

Gehm (*this Journal*, July 1942), however, points out that aeration and settling does result in greater removals than by settling alone. However, his experiments were conducted under different conditions than the authors' in that he aerated for longer periods of time. The amount of air was not given. Gehm used three liter samples of sewage—the authors used 20 gallons.

I have been informed that at several large packing house waste treatment plants where grease recovery is practiced, that when the aeration was discontinued no appreciable change in the amount recovered was noticed, and as a result aeration was discontinued. It should be mentioned, however, that a flocculator was used in combination with aeration, and that flocculation was not discontinued.

The conclusions drawn by the authors regarding the ineffectiveness of aero-chlorination will no doubt bring forth some discussion in view of the results reported by Weist at Lancaster, Pa. (*Water Works and Sewerage,* Dec. 1938), who reports 38 per cent removal by settling alone, 50 per cent removal by aeration and settling, and 80 per cent by aero-chlorination and settling.

The authors are to be complimented on their approach to this study. In all sewage experiments the difficulty of sampling is considerable and with the use of large quantities of sewage, the errors are minimized. Unless one has actually done so, no one can fully realize the time consuming methods of accurate grease determination, and I would like to take this opportunity to express my appreciation of their efforts.

In view of the shortage of fats at present and the fat saving program, some of us no doubt will wonder why we are not giving more study to the recovery of fats at sewage disposal plants. It must be remembered that the grease received at the ordinary sewage treatment plant is not nearly as pure as that recovered from the kitchens. It contains large quantities of mineral oils. True fats consist of a glycerine base united to a fatty acid constituent. During saponification in the manufacture of soap these two constituents are separated from each other, and the glycerine is set free, while the fatty acids combine with the lye to form a soap, and it is here that the glycerine is recovered. We are saving fats not for the fatty acids but for the glycerine which can be converted to explosives. Soaps either used or unused have no value for glycerine recovery. As a consequence grease removed from ordinary sewage has generally little value in the fat recovery program.

In normal times we might say that in soap manufacture the glycerine is a by-product and the soap is the more important, but in war times the situation is reversed and glycerine becomes the more important and the soap of lesser importance. Then, too, greases recovered from sewage present a most difficult refining problem.

## Discussion of Paper by Major Rolf Eliassen Entitled "Grease Removal at Army Sewage Treatment Plants"

By Harry W. Gehm

The justification of units providing very short detention periods (15 min. or less) for the purpose of grease removal, placed prior to primary sedimentation tanks, has never been proved. Before evaluating such a device it is necessary to decide what its function in operation is and what results may be expected. We may formulate the function in the question: Is such a device intended to produce in conjunction with the clarifier an effluent decidedly lower in grease content or to remove only a very small part of the grease, easily separated, which causes rapid scum formation in the clarifier? If it is the function to produce an effluent lower in grease content, it may immediately be concluded that such devices, as have been common in the past will not appreciably aid the overall removal of grease because they were never effective in lowering the suspended solids content (of which the grease is part) of the effluent of clarifiers materially. Devices employing detention periods of greater duration (30 min. or more) have been able to reduce the suspended solids, hence the grease content of clarifier effluents. Aerators and flocculators are examples of these.

Major Eliassen's work thoroughly covers this phase of grease removal and definitely shows again that short detention devices do not increase appreciably the quantities of grease removed by normal periods of sedimentation.

Major Eliassen's observation concerning the failure of aeration and aerochlorination to remove grease as measured by analysis of the sewage is easily understandable. When we consider grease removal figures observed by others who collected, weighed and analyzed the grease separated and reported the results in terms of pounds per million gallons of grease collected and convert the data into parts per million, we find:

| | *P.P.M. Grease Removed* | |
|---|---|---|
| | by Aeration | by Aerochlorination |
| Kieffer | 0.1 | 0.4 |
| Gehm | 5 | 7 |

The magnitude of these figures is well within the sampling and analytical error dealt with in sewage. Expressed in this way, the removal effected by the combination of aeration or aerochlorination and settling is no greater than that by settling alone. This issue has been clouded by the use of percentage increase removal figures. For instance: Four-tenths p.p.m. removal of grease is three hundred per cent higher than one-tenth p.p.m. but despite this it is still only four-tenths of one p.p.m.

It has been noted, however, that by separating the easily removable portion devices for the removal of grease have aided plant operation by taking the load off the skimming devices of the sedimentation tanks. As most of these are tied in with the sludging mechanism it is necessary to run both at the same time. Thus it is often impossible to skim the tanks frequently enough to prevent surface accumulation without interfering with sludge compaction.

Considerable doubt may be expressed concerning the economy of separate devices for removal of this relatively small quantity of grease. Independently operated skimming devices of efficient design embodied in the clarifier appear to be a more logical answer to this problem. Such devices exist and probably could be used to better advantage. Oxidation devices of adequate capacity, treating domestic or institutional sewage, will not be overloaded or upset if adequate sedimentation and skimming facilities precede the oxidation device. In some instances observed, as in the case of the sewages dealt with in Army camps, the grease content of the sewage was high and no difficulties resulted.

To produce clarifier effluents lower in grease content than normally obtained, some of the newer mechanical devices show distinct promise. Fine-bubble aerators and vacuum flotation devices are examples of these new developments. The ability of chemical treatment to remove practically all the grease from sewage should be kept in mind when grease removal is discussed. Some data published on the removal of grease by copperas alone is interesting enough to bear repetition:

*Grease Removed by Copperas*

| Sample | P.P.M. Grease in Settled Sewage | P.P.M. Iron (Copperas) | P.P.M. Grease in Treated and Settled Sewage |
|---|---|---|---|
| 1 | 50 | 15 | 12 |
| 2 | 20 | 10 | 6 |
| 3 | 29 | 5 | 13 |
| 4 | 31 | 15 | 5 |
| 5 | 33 | 15 | 8 |
| Average | 35 | 12 | 9 |

These results show that with a very low copperas dosage it was possible to remove an average of more than two-thirds of the grease present in the same sewage treated by settling alone. Such pretreatment might provide a solution at a relatively low cost where grease actually interferes with secondary treatment.

Added weight is given Major Eliassen's work by the fact that he dealt with sewage of high initial grease content. If high removals could be produced by aeration, aerochlorination, or chlorination followed by aeration as practiced at present, they would certainly have shown up in the large number of data collected. The writer was privileged to be in close contact with this work and feels that it was carefully executed in every way possible. In a most convincing manner, Major Eliassen has indeed filled a gap in our knowledge of this subject.

# Sewage Works Design

## SEWAGE TREATMENT PRACTICE–STANDARDS FOR MUNICIPAL SEWAGE TREATMENT PLANTS*

By Arthur S. Bedell

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In discussing the standards for the design of municipal sewage treatment plants and more particularly as concerns the practice in the New York State Department of Health, it seems desirable to spend a few moments on the background of the standards, especially as to the purpose and need for such standards. Although neither the Federal Government of the United States of America nor New York State has promulgated any laws or published any standards on the quality of sewage effluents, such as has been done by the Royal Commission on Sewage Disposal in England, nevertheless the Federal Government maintains jurisdiction over all waters insofar as interference with navigation is concerned and limits its activities in general to problems involving deposits in navigable channels and the problem of oil pollution. It is true that in very recent times the Federal Government has taken an active interest in pollution of waters from a public health point of view and probably will become increasingly active in this regard.

Until quite recently it has not generally been the custom for State governments to establish definite standards on the quality of sewage effluents on a state-wide basis. There has been a tendency and, I believe, wisely so, to consider each case of stream pollution or sewage disposal on its own merits. This broad view and to some a haphazard policy gives a very necessary flexibility in considering stream pollution cases since there are so many factors to be considered other than volumetric dilution and dissolved oxygen content in the receiving stream. During the past fifteen years there have been promulgated a number of Interstate Compacts on regulating the cleanliness of various streams or bodies of water in the U. S. A. Also in recent years there has been a tendency to classify streams on the basis of their present or potential purity and use. The State of Pennsylvania and, more recently, the New England States have taken definite steps in this direction. In New York State the Interstate Sanitation Commission acting under a tri-state compact to which New York, New Jersey and Connecticut are signatory has classified the metropolitan tidal waters in the vicinity of New York City into Class A and Class B waters, the former being waters to be used primarily for recreational purposes, shellfish culture and development of fish life.

* Presented on October 28, 1943, at the Tenth Annual Convention of the Canadian Institute on Sewage and Sanitation, Niagara Falls, Canada.

Although hard and fast standards have not been formally adopted in most states, it is the custom to follow "good sanitary engineering practice" in the endeavor to secure the common law rights of riparian owners. Fortunately there is a good deal of unanimity of opinion in the States so that the consulting engineers and the state authority usually see "eye to eye" in these matters.

Although somewhat apart from this discussion, I would like to call your particular attention to two references to a topic that is closely allied; namely, the matter of stream pollution and stream standards without which, of course, there would be no point in setting up standards for sewage treatment effluents. I have in mind particularly a paper prepared by George J. Schroepfer, Past President of the Sewage Works Federation, the paper being entitled "An Analysis of Stream Pollution and Stream Standards" which appeared in the September, 1942, issue of SEWAGE WORKS JOURNAL, pages 1030 to 1063. The paper contains a compilation of data on the hourly, daily and other variations in stream conditions, in addition to an admirable summary of standards throughout the United States and an excellent bibliography. The second article appears in the same JOURNAL and it is by Warren J. Scott, Director of the Bureau of Sanitary Engineering of the Connecticut State Department of Health, the paper being entitled "Classification of Inland and Shore Waters" and appears on pages 1064 to 1073. Here we have probably the most recent attempt at interstate cooperation on stream pollution matters.

Restricting our field now to New York State practice, which we believe is a reasonable reflection of American practice, we find first the authority of the State Department of Health dates back to 1889 when the Village Law required that sewer systems for villages should be comprehensive in scope and the plans must be approved by the State Department of Health before construction was commenced. This law is still in force although it has been amended several times. It has proven of great value to the people of the State in providing for intelligent planning for the future.

Actual legal control over stream pollution in New York State would appear to date from the year 1903 when the so-called "Anti-Pollution Law" was passed. This law in addition to setting up the modus operandi for the protection of the watersheds used as sources of water supply for New York City required that any person, corporation or municipality discharging wastes into the waters of the State in quantities injurious to public health must secure a permit from the State Commissioner of Health and in the granting of such permit the State Commissioner of Health might stipulate the conditions under which such sewage or waste discharge might be permitted. It might safely be said that since that time the State Department of Health has approved no plans for new public sewer systems unless adequate treatment of the sewage has been provided. It is true that from time to time plans have been approved for lateral sewer extensions to *existing sewer systems* in a number of communities not provided with sewage treatment works.

However, in such approvals we have always reserved the right to require treatment whenever we deem it necessary and in many instances have set definite time limits or specified dates on which plans should be submitted and the works constructed.

To complete the legal picture it might be well to note that in addition to requirements of the Public Health Law and the Village Law sewerage matters are also governed in unincorporated places by the provisions of the Town Law, which provide for setting up sewer districts, and furthermore before any sewer district can be formed plans for the sewer system and sewage treatment works must first receive the approval of the State Commissioner of Health. The question of the approval of plans for the interception and treatment of sewage in cities is adequately covered in the Public Health Law. It might be well to add at this point that this law also provides for the formation of sanitary sewer districts where in the interest of public health contiguous areas might profit by joint collection and disposal of their sewage irrespective of their form or lack of incorporation. Thus far the difficulties of formation and financing have been such that no advantage has been taken of the provisions of this law. However, special legislation has enabled two counties to establish trunk sewer systems and treatment works to serve large areas, including incorporated cities and villages as well as unincorporated places. Likewise in the case of the City of Buffalo a special act of the legislature enabled the formation of the Buffalo Sewer Authority, which in many respects is independent of the city government and depends on sewer rentals for its operating income and for the interest and amortization of its bonded indebtedness. This authority also has the power to provide trunk sewer capacity for and to treat the sewage from adjacent areas outside the city limits.

Shortly after the passage of the Anti-Pollution Law in 1903, it became evident that it would be desirable to establish definite requirements regarding the preparation and submission of plans for sewers and sewage and waste treatment works and to set up certain standards for the design of the different units of treatment. The following quotation from one of the earlier bulletins setting up these requirements is of general interest:

> "The Department will in general approve only of plans which include disposal works for such complete purification as will produce a clear and 'stable' effluent. This requirement may be increased or diminished according to local conditions, the volume and use of the stream below the discharge and the necessity for protecting water supplies, bathing, etc."

From this, it would appear that in the early part of this century the Department was willing only to consider plans for sewage treatment that provided some form of secondary treatment. However, the regulations also provided for the temporary omission from construction of certain portions of the works provided for the complete purification of the sewage. In other words, the Department then felt and still does feel that adequate forethought should be given to the ultimate needs of the community as to population growth, strength of sewage, decreasing dilution in the receiving body of water and change in use of the water in the receiving body. It is interesting to note that 40 years after the establishment of most of these standards or criteria for design we find that essentially while our modern methods of approach to the problem may vary somewhat owing to our greater knowledge of the processes at work in the treatment of sewage, nevertheless the standards then established are still considered good sanitary engineering practice not only in New York State but throughout the United States. It is also interesting to note that with the passing of time these regulations have become more and more detailed and yet are still basically broad enough to be generally applicable throughout the State.

In discussing this general topic of standards for sewage treatment in New York State I feel constrained to discuss not only the standards and criteria but also the so-called rules and regulations set up by the State Department of Health as a basis on which plans for sewage treatment are reviewed by the engineering personnel of the Department, since the rules and regulations cover considerably more than merely the standards which some might conclude refer only to the biology and chemistry of sewage treatment. At the present time considerable thought is given in the review of plans to plant operation, not only as to provisions for the safety and health of the operator himself but also for ease in operation.

I referred above to the remarkable foresight of the engineer who originally drafted the rules and regulations, yet after all, this may be due in large part to the fact that so far as degree of treatment required for sewage is concerned, it is largely a matter of the available dilution in the receiving stream and the use to which the water in the receiving stream is put. The fundamental work done at the Lawrence Experiment Station in the State of Massachusetts on the efficiency of various types of sewage treatment and the measure of dilution required in the stream to prevent conditions of nuisance established more or less at the same time our basic standards of treatment plant design which still seem to hold true even though in those remote days very little was known about B.O.D.

While the rules and regulations of the Department do not definitely set forth any basic standards in terms of B.O.D. or suspended solids, the Department follows what is generally considered good sanitary engineering practice and frequently, where there is no existing sewer system and the treatment works are designed simultaneously with the sewer system, it is necessary to proceed on purely theoretical grounds. On this basis it is considered that the flow of sewage in a municipal system will be 100 gallons per capita per day and, unless there are some industrial wastes which are unusual in quantity or quality, the sewage should have a strength of 250 parts per million of suspended solids and a 5 day B.O.D. of 0.17 pounds per day, which is approximately 200 parts per million of B.O.D. So far as dilution in the receiving stream is concerned, purely on a basis of preventing nuisance conditions, it is generally considered that settled effluent can be discharged into a normal stream without creating conditions of nuisance if there is dilution water to the extent of at least 4 c.f.s. per 1,000 population. In general this minimum flow is based on the average flow for the minimum two weeks where the records extend over a considerable period of time. It is felt that the above criteria are somewhat close to the margin in dealing with unknown factors so that frequently in considering the design of smaller plants a factor of safety should be introduced, particularly since one cannot expect the perfection in operating technique in a small community that one could expect in a larger one. In a similar way we have found through experience that, even where consulting engineers have spent considerable time in the careful consideration of the quantity and strength of a known sewage and planned for reasonable efficiencies of the various units of sewage treatment, nevertheless the actual operation of the plant after construction has indicated that all expectations could not be realized and the plant did not have the anticipated capacity. This, however, is seldom catastrophic since it frequently means merely that the anticipated life of the plant has been decreased and that additions will have to be made at an earlier date than anticipated.

With the above fundamentals in mind I would like to hastily run through some of the New York State requirements and standards that have proven desirable to secure expected efficiencies and to provide ease of operation. Although population estimates are now rather uncertain and our conception of them has undergone a fundamental change in the past decade, we expect that the capacity of the treatment plant should provide for an estimated future population 10 to 15 years hence. The plant site in general should provide sufficient area so that not only can the plant be enlarged to take care of the probable ultimate quantity of sewage but also an increased degree of treatment can be provided should this prove necessary. Although we understand some large municipal sewage treatment works are odorless in their operation, nevertheless, we feel that isolation of the site is extremely important.

With regard to main sewage pumping plants, at least three pumping units are desirable and the total capacity of the pumping station should be such that if the largest pumping unit is out of service the remaining units could pump the maximum flow of sewage. The pump sizes should be proportionate to the varying rates of flow and frequently an extra pump will greatly increase the efficiency of the plant by providing greater uniformity of flow. All pumps should be protected by screens and suitable ventilation should be provided both in the wet well and the pump room.

### Screens

Bar screens should be provided at the entrance of all sewage treatment works, and in all but the smallest treatment works mechanically cleaned screens or their equivalent are now found desirable. Frequently the screenings are ground or shredded and returned to the sewage flow where they are removed with the settled sludge and the troublesome problem of handling screenings is eliminated.

## Grit Chambers

Although somewhat contrary to the general opinion, our Department has found it desirable to require grit chambers even on separate sanitary systems. Experience has shown that grit does find its way into most sanitary sewage systems and its presence in the settled sludge always gives considerable trouble in the digestion compartments and in the handling of the sludge.

## Sedimentation Tanks

While the septic tank was once considered a marvelous discovery in the treatment of sewage, advance in the art of sewage treatment has definitely indicated its deficiencies, so that in New York State we no longer will approve septic tanks for municipal sewage treatment plants. A two story Imhoff tank still has many things in its favor in spite of the popularity of sedimentation tanks with mechanical removal of sludge and separate sludge digestion. Two hour sedimentation is generally considered adequate and in recent years we have found it necessary to increase the capacity of the sludge digestion chambers in Imhoff tanks, particularly for the smaller populations. In general, for populations less than 5,000 we require 3 cu. ft. per capita for sludge digestion. A minimum of 2 cu. ft. per capita is permitted for populations over 10,000. In sedimentation tanks with mechanical removal of sludge two hour detention is generally considered satisfactory and the optimum depth of 8 feet provides an overflow rate of approximately 700 gallons per sq. ft. per 24 hrs. More and more attention is being given to the design of inlets and outlets and the Department is always open to conviction on this until some large body of experience will prove that one arrangement is superior to another in securing effective sedimentation. In separate sludge digestion tanks a digestion capacity of from 3 to 4 cu. ft. per capita is required, and where the design population exceeds 2,500, it is generally anticipated that heating of the sludge will be provided, in which case the cubic content is reduced in proportion to the increasing populations ranging from three cubic feet per capita for populations of 3,000 to two cubic feet per capita for populations greater than 10,000. Adequate safety precautions are required for the collection and utilization of the gas, and provisions for auxiliary heat in case of emergency are usually required.

No fixed standards have been adopted regarding chemical precipitation and there are only a very few installations in the State.

In the design of units for the secondary treatment of sewage, careful consideration must be given to the organic strength of the sewage in terms of the five day biochemical oxygen demand. The following standards are based on a sewage flow of 100 gallons per capita per day having a B.O.D. of 0.17 pounds per capita per day. Within reasonable limits, therefore, the size of the units depends almost entirely on the basis of the population tributary.

## Intermittent Sand Filters

General good engineering practice is followed in the design of sewage sand filters and a depth of 3 feet of sand is expected, the sand having an effective size of between 0.25 and 0.5 mm. with a uniformity coefficient preferably not over 4.0. The rate of application of the effluent to the sand bed should not exceed 100,000 gallons per acre per day based upon a per capita flow of 100 g.p.d. In cases where a settled trickling filter effluent is applied to the sand filter, the rate of application may be increased four times, while on limited watersheds used as sources of public water supply only 50 per cent of the above rates is permitted.

## Trickling Filters

Trickling filters should in general have depths between 6 and 10 feet, a filter medium of carefully selected material of fairly uniform size between the limits of 1 and 2½ inches and an area sufficient to give a rate of filtration of 300,000 gallons per acre per day per foot of the effective depth (based upon a per capita flow of 100 g.p.d.). It is always required that the trickling filter effluent be passed through a final settling tank before discharge into a stream and a detention period of an hour and a half is required. Provisions for frequent and regular removal of the sludge are required and the sludge is usually carried to the inlet of the primary sedimentation tank or to the separate sludge digestion tank, and 25 per cent additional sludge digestion capacity is required. No standards have as yet been adopted for high capacity filters, although two types of such filter are now in operation at municipal plants in the state and the results of operation are being carefully studied.

## Activated Sludge

Activated sludge treatment may be either of the diffused air or mechanical aeration type. The aeration tank should have an aeration period of not less than six hours for the diffused air type and an aeration period of not less than eight hours for the mechanical aeration type. The capacity of these tanks is based on the daily flow of sewage plus 25 per cent for returned activated sludge. At least 1 cu. ft. of air for a gallon of sewage, with a pressure of 5 to 10 lbs. per sq. in. must be provided. Primary sedimentation tanks preceding the aeration tanks should have capacities equivalent to 30 to 60 minutes average daily flow of sewage. Tanks for the digestion of the excess activated sludge must have capacities of not less than 5 cu. ft. per capita unless provision is made for heating and conditioning the sludge. The effluent from the aeration tank should be passed through final settling tanks having a two hour detention period before discharge into the receiving stream.

## Sludge Beds

Lines carrying sludge must be so arranged as to permit draining and flushing after use and the invert of the pipe discharging onto the sand bed must be at least 12 inches above the surface of the sand and a suitable splash plate must be provided to prevent scouring the sand. The sand bed should have about 6 inches of sand on 6 inches of graded gravel and must be constructed of specification sand since otherwise there is a tendency to use run-of-bank sand and frequently even ordinary soil for such purposes which, of course, is entirely unsatisfactory. Where the bed is surrounded with a wall to support a glass superstructure the top of the wall must not be more than 18 inches above the sand surface and adequate provisions for ventilating with the side sash opening inward should be made. The beds must be divided into small units to permit flexibility of operation and suitable facilities must be provided for the removal of the dried sludge.

## Disinfection

Chlorination by means of chlorine gas in water solutions or hypochlorite solutions is the only means of disinfection used in New York State; the latter because of expense is rarely used in municipal plants. A contact period of at least 15 minutes under maximum flow conditions is required for adequate disinfection and it is usually required that 0.5 p.p.m. of chlorine residual be maintained in the effluent. Ordinarily where the discharge of a chlorinated, settled effluent is permitted, it is expected that pre-chlorination will be practiced since in this way a longer period of contact is possible and any irregularities in flow will be taken care of. Application of chlorine through solution feed apparatus is generally required since the direct feed of chlorine gas in sewage is not generally satisfactory. The chlorine apparatus is required to be placed in a separate room with an outside entrance only and with provisions for heating during the winter season where year round chlorination is practiced. In checking the capacity of chlorine apparatus and based on the average sewage flows, we expect the apparatus to have a capacity of 18 p.p.m. for sedimentation tank effluent, 12 p.p.m. for trickling filter effluent and 6 p.p.m. for sand filter effluent. In the disinfection of trickling filter effluents the chlorine solution is generally applied to the inlet of the final settling tank and in the case of sand filter effluents a special reaction tank of at least 15 minutes detention period is required.

## Bypasses

In the past the Department was very loath to approve bypasses around the sewage treatment plant because of the possible abuse of the use of such devices. However, with the increasing mechanization of treatment works and the need for temporarily shutting down certain portions of the works for repairs, it is now generally deemed advisable to provide bypasses around various units of the plant, provided they are safeguarded against unauthorized and unwarranted operation. In certain critical cases we have gone so far as to require that the gate valves on bypasses be locked and the key be kept in the possession of either the chief operator or some other municipal official.

It is now generally recognized throughout the State that the State Health Department is interested in a sewage treatment works even after it has passed upon the design as adequate. To this end, it is required, therefore, that every plant be provided with some means of measuring sewage flow and, if possible, to have some recording and integrating device to provide a continuous record. In the moderate sized plants Venturi flumes have been installed immediately after the grit chamber and in this way we secure the means not only of measuring the flow but of controlling the velocity through the grit chamber so that the deposition of grit will be most efficient. In addition all new plants must be provided with adequate laboratory space and equipment for the laboratory control of the operation of the plant. The number and type of tests, of course, vary in accordance with the needs of each individual case. Furthermore, it is expected that all necessary operating tools be provided at the time the plant is built and not leave to the operator the unhappy necessity of securing this equipment from the municipal government when they are in a less complaisant mood.

## Industrial Wastes

While the treatment of industrial wastes is not a part of the topic under discussion, nevertheless due consideration should be given to the problem of industrial wastes in a municipality when the sewage treatment plant is being designed and the importance of making a careful study of the industrial wastes tributary to the sewage treatment works and their probable effect on the operation of the plant cannot be overemphasized. In a number of instances, these wastes are of such a character that they can be discharged into the plant with the domestic sewage and the only thought that need be given to them is to provide adequate volumetric capacity. On the other hand there will be in many instances wastes that will require pre-treatment at the industry before they should be discharged into the sanitary sewer system. In this connection we have in mind such matters as pickling liquids from steel plants, which unless neutralized at the industry might seriously damage not only the sewer system and other structures but would seriously interfere with the operation of secondary devices such as trickling filters. To this end the Department usually includes among the conditions in its permits to municipalities for the discharge of sewage effluent into the waters of the State, one requiring that all industrial wastes shall be adequately pre-treated before discharge into the sewer system.

Reference has been made above to the necessity for providing for the health and safety of the operators. Among other points, there is the matter of water supply that in the past was probably overlooked and we feel that not only should the public water supply be protected from pollution but also the health of the operator should be safeguarded. Therefore in order to protect the public water supply from backsiphonage of polluted water from the sewage treatment works, the public water supply line should be provided at the point of entrance with an approved installation of double check valves of the Special Factory Mutual type. Furthermore, within the plant itself all small service lines in lavatory basins, or at other points where drinking water might be obtained, should be on a separate line from the main plant supply in order that they may not be contaminated by backsiphonage.

While I have gone into the above matters in some considerable detail, it is not at all a comprehensive statement and I have endeavored to emphasize the more important points that might be considered somewhat controversial or novel. Again it might be considered that these standards and regulations set up by the State must perforce be of such universal application that either they cannot be detailed to any extent or that, if so detailed, frequent deviations from the standard would have to be permitted. Such, however, is not the case, largely due perhaps to the fact that although some of the standards or regulations appear very detailed in statement, nevertheless they are based on sound fundamental principles and little deviation from them is found to be necessary. The Department has always been open-minded when an engineer has made a very careful study of the problem and presents a sound rational analysis of the situation and in a number of instances under such conditions reasonable allowances have been made to fit the local conditions.

I have known several cases, however, where experience later showed that the Department might have been well advised to have held to the original standards.

In closing I wish to say that in the application of these standards and regulations in our review of plans we have always found the consulting engineers not only in our own state but from other states to be most cooperative and open to suggestion especially where such suggestions have been based on our own observation of operation of sewage treatment plants in our own state. Furthermore, we owe a great deal to the sewage treatment plant operators in our state for keeping accurate records of operation of their plants and making timely observations, not only enabling them and our district engineers to spot the cause of operating troubles but frequently such observations have resulted in modifying practices in design. Furthermore, such records of operation in a number of instances have proven invaluable in permitting economy in design of future additions to the plants in question since we had exact operating experience upon which to base our new design.

# SEWAGE TREATMENT FOR HOMES AND INSTITUTIONS *

By A. E. Berry

*Ontario Department of Health, Toronto*

Public sewerage systems now serve about 150 urban communities in Ontario. This represents approximately 60 per cent of the entire population. A substantial percentage of the total number of citizens reside in rural and in semi-urban centres. While it is anticipated that the postwar development will extend these services considerably there will still remain many sections which can be served only by private sewerage works. The expansion of hydro-electric power to the rural areas and to villages will do much to enable home owners to secure these sanitary facilities, even when neither water works nor sewers has been constructed as a public enterprise.

In addition to private residences there is being continuously constructed buildings of various kinds so far removed from public sewers that they must provide for their own disposal works. These include schools, colleges, institutions, industries, war and peace-time camps, hospitals, and small groups of houses. In this paper there will be considered only water carried sewage systems.

## Engineer's Responsibility

The municipal engineer has not always been directly associated with the installation of sewage disposal works for private residences or for small institutions. This work is more frequently supervised by the local health officer or his representative, such as the plumbing inspector or sanitary officer. It is believed that the local engineer can play a more useful part in this field, and that his assistance is likely to be sought to a greater extent in the future, even for work at private residences. For larger systems his guidance becomes a necessity.

## Legislation

The Ontario statutes contain references to non-municipal sewerage works. Two of these are in the Public Health Act. The first in Schedule B, Section 14, requires that the approval of the local medical officer of health be obtained before septic tanks, cesspools and similar systems are installed.

The other section is a recent amendment to the Public Health Act, Section 101, which requires the approval of the Provincial Department of Health for all sewerage projects whether they be undertaken by public bodies or private parties.

* Presented at Tenth Annual Meeting of Canadian Institute on Sewage and Sanitation, Niagara Falls, Canada, October 28, 1943.

## Private Residences

For private dwellings the septic tank installation is almost the universal choice when no public sewers are available. They have been used for many years with no major change in design or operation. Their success depends on proper design to meet local conditions. There appears to be considerable misunderstanding in respect to the functioning of these systems, and since they are built by many who are inexperienced, and under varying conditions, this is not surprising. It seems desirable, therefore, to discuss some of the factors involved, both in the construction and operation, in these septic tank systems.

## Design of Septic Tanks

Operating experience seems to indicate that design features are of major consideration in the success or failure of a septic tank unit. This must be correlated to local requirements. These tanks are similar to those used in the past for municipal purposes with the exception that they are smaller, and the flow of sewage is likely to be more variable. Yet this fact appears to be overlooked all too frequently, and the septic tank is regarded as a mysterious device for producing an effluent of superlative quality.

The function of this tank, as in the case of the larger one, is the separation of the solids by sedimentation in order to permit the disposal of the liquid by filtration and to prevent choking of the pores of the soil. The deposited solids must digest in order to prevent an excessive accumulation in the tank and frequent cleaning.

The size of the tank is determined by the flow of sewage to be treated. A liquid capacity equal to a 24-hour flow is generally recognized as satisfactory for the small tank, with this decreasing to 12 hours for larger units.

Sewage flow of approximately 50 gallons per capita per day may be assumed as an average for private residences, and to this may be added an allowance for sludge accumulation. A figure of 15 to 20 gallons per person per year for this is often suggested as reasonable, and with an allowance being made for two years storage. This volume for a settling tank may seem high, but it is necessary in order to provide for the wide fluctuations in sewage flow reaching the tank. As the size increases less provision is necessary and the flow will be more uniform.

A minimum size of tank should be specified for residences where only a few persons are using the system. This minimum is set at different figures by various authorities. It is suggested as between 300 and 500 gallons. This volume is designed to overcome the problem of intermittent excessive flow in comparison with the volume of the tank.

Baffles on both the inlet and outlet of the tank are required. For small units a Tee section of pipe is sufficient, but for larger units a baffle board across the full width is desirable. The inlet pipe should be kept about 3 inches above the flow line in the tank.

### Dosing Chambers

Dosing tanks, with siphons for intermittent discharge of the settled sewage to the field bed, are generally included in the designs of septic tanks, but there is some question as to their necessity for small units. The loss in head where one is used, makes them workable chiefly where the ground is sloping. For small tanks the rate of discharge at one time will be large in respect to the volume of the distributing tiles, and a proportion of the bed can be filled accordingly.

When dosing tanks are employed they should be sufficient to fill the tiles about three-quarters full at one time. The frequency of operation of the siphon should not be too great. Three or four times a day is a suitable objective but this will be influenced by the nature of the soil.

### Subsurface Disposal Field

The liquid discharged from the septic tank still contains finely divided solids and it is offensive. This should not be discharged to a ditch or to a storm sewer. In most cases it must be further treated in a sub-surface filter bed.

The efficiency of these beds is dependent to a major degree on the absorptive qualities of the soil. They cannot function where this is heavy clay, or where inadequate drainage is provided. The laterals are best made of 4 in. tile, either farm drain tile or bell and spigot pipe. The joints should be left one-half inch apart in order to permit the free escape of the liquid. The use of stone or gravel around the joints is preferred to tar-paper covering. The tiles should be laid in rows of equal length, and generally should not exceed 100 ft. in length. Otherwise, even distribution is less likely to take place. The tiles can be laid practically flat where a siphon is used—or about 2 to 4 inches per 100 ft. where no siphon is used. This slope can be increased to about 6 in. per 100 ft.

The rows of tiles are spaced about 4 or 5 ft. apart, or at least three times the width of the trench. Where space is available it is desirable to use more land for distribution of the tank effluent. The depth of the tiles can be controlled by available drainage. If these are placed 18 to 30 in. below the surface better results are likely to be obtained in most situations. This arrangement also is less likely to pollute the underground water. Where, however, frost penetrates some distance, or where the grade does not permit of shallow trenches the tiles can be laid at depth, and if drainage from the area is good, little trouble is likely to develop.

### Amount of Tile Required

The amount of tile required for distribution of sewage is a problem in most places. This depends largely on the porosity and drainage properties of the soil. The length required is generally given as about 20 to 50 feet per person. This, however, is more an approximation than an accurate estimate. Much information on requirements can be obtained by percolation tests on the area in question. This is done by excavating a hole 1 foot square to the depth of the tile trenches, adding water to a depth of about 6 inches and observing the time required for the water to seep away. The time for the water to fall 1 inch may be correlated to the rate of sewage loading per square foot per day on the bottom of the sewage trench. The following figures are suggested:

| Time for Water to Fall 1 Inch | Sewage Loading per Sq. Ft. of Trench per Day |
|---|---|
| 1 min. | 3.5 gal. |
| 2 min. | 3.0 gal. |
| 5 min. | 2.0 gal. |
| 10 min. | 1.5 gal. |
| 30 min. | 0.7 gal. |
| 60 min. | 0.5 gal. |

Some judgment is necessary in making this test to ensure that the condition of the soil is not abnormally dry or wet, but is representative of average conditions.

Where soil is excessively dense, it may be necessary to use sand filter trenches. These consist of a bed of sand placed between the distributing tiles and the underdrains. Difficulties may be experienced in the operation of these, but they may be the only alternative. Care is essential to ensure that the bed is not overloaded.

Similarly cesspools may be used in some places instead of tiles, but these will choke in time unless the soil is quite porous.

## Operation of Septic Tanks

Considerable confusion exists in respect to the operation of septic tank systems. It is well to keep in mind that these tanks are quite similar to the larger municipal units. Their size makes them subject to the effects of variation in the contents of the sewage. In general it may be said that all household wastes may be discharged into these systems. Their successful operation over many years is sufficient proof of this.

The cleaning of sludge from tanks is usually neglected, and so long as the system continues to operate at all they are given little attention. Unless this sludge is removed it may be carried into the tiles and result in choking. Removal of sludge about every two years is considered desirable.

Grease, laundry waters and other wastes may be handled readily in these tanks. Where grease is excessive, as in the case of dining rooms, it is desirable to use grease traps to prevent choking of the sewer, as well as too frequent removal of the accumulation from the septic tank. These grease traps, to be of value, must be cleaned regularly, as required.

## Institutional Plants

When sewage must be treated from premises involving larger flows than in private residences, it is necessary to consider the feasibility of other methods. Septic tanks with subsurface filter beds are not intended for very large flows. The cost of such an installation may also exceed that of others which will give equally good results.

The flow of sewage must first be estimated as closely as feasible. These flows will vary considerably, but the following daily figures are given as suggestions only:

| | |
|---|---|
| Schools | 15 gallons per person |
| Hospitals | 100 to 175 gallons per person |
| Institutions | 75 to 100 gallons per person |
| Factories | 20 to 30 gallons per person |
| Camps (civil) | 25 to 50 gallons per person |
| Military Camps | 75 gallons per person |
| Hotels | 75 gallons per person |

While it is possible to construct septic tank systems using large amounts of field tile it is not considered a desirable project unless the soil is quite porous and the whole area can be drained readily. If more than 1,500 to 2,000 feet of tile is needed it is well to study relative costs of other methods of treatment. In several school systems in this province cesspools or leaching wells have been used in conjunction with tiles, and in this way the length of the latter is curtailed. This is recommended only for porous soils.

For institutional use the trickling filter can be employed with satisfaction, and with the assurance that a minimum of expert attention will be required. The modern method of recirculating part of the treated effluent increases the efficiency, and extends the application of this to conditions where a higher degree of treatment may be essential.

Similarly the intermittent sand filter, while an old method, can be employed under some conditions for larger units. The effluent is a most satisfactory one.

In summarizing sewage treatment methods for homes and institutions, it may be emphasized that they are not greatly unlike the municipal systems, but on a smaller scale. For this reason, however, care is necessary in the application of these methods to the treatment of small quantities of sewage. It is hoped that municipal engineers will assist health officers in the supervision of these systems within their territories.

# THE OPERATOR'S CORNER

## THE VALUE OF OPEN DISCUSSIONS ON OPERATION PROBLEMS

The entire *Operator's Corner* in this issue comprises only the edited transcript of the Breakfast Forum discussion which was a part of the program of the Second Wartime Conference held at Chicago last October. We have always been a proponent of such open discussions of operation problems but have not yet encountered a transcript record which better justifies them than the one which is presented here.

Our reaction, while engaged in the somewhat arduous task of editing, was that the material was refreshingly frank and untempered by the conservative qualification of opinion that is so evident (and properly so) in written manuscripts. When one is faced with a problem which is common to many others, there is much satisfaction in "taking down the hair" and in listening while his contemporaries do the same. Furthermore, there is a surprisingly valuable exchange of ideas and viewpoints which leads to a better understanding between those engaged in the various phases of the sewage works field.

The success of these discussions is in direct ratio to the manner in which they are handled by the leader or chairman. We feel that Chairman John C. Mackin and Messrs. Niles, Bedell, Downer and Nelson, who directed the Forum, should be credited with a task well done. Chairman Mackin is due additional recognition for his planning of the entire symposium.

Here's to more open forum discussions of similar character. May you find the transcript as interesting and informative to read as we found it to be while preparing it for publication.

W. H. W.

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## THE OPERATOR'S FORUM *

JOHN C. MACKIN, *Chairman*

### I. USE OF SLUDGE IN THE VICTORY GARDEN CAMPAIGN

LEROY W. VAN KLEECK, DAVID A. BACKMEYER, HENRY A. RIEDESEL, P. W. RIEDESEL, AND A. H. NILES, *Leader*

*Mr. Niles:* When Pearl Harbor came, we immediately had a demand for nitrogen for war purposes and that meant, of course, a shortage of

* Symposium presented at Federation's Second Wartime Conference on Sanitation, Chicago, Illinois, October 21–23, 1943.

nitrogen for the growing of foodstuffs. We were certainly limited as to the total amount of nitrogen available. Then, with the tremendous impetus that was given to Victory Gardens, the interest in sewage sludge increased by tremendous percentages. I don't think there is a sewage plant operator who has not been almost swamped with sludge business, if he put it out at all for consumption.

The interest aroused has led to this panel discussion. We shall begin with a few papers and then open the topic to general discussion from the floor. The first speaker will be Mr. LeRoy W. Van Kleeck, of the Connecticut State Department of Health.

*Mr. Van Kleeck:* Mr. Niles, gentlemen, I am not going to read a paper. I have six items here that I will discuss very briefly. On all of them I hope there will be discussion from the floor.

In regard to the success of our own Victory Garden program in Connecticut this year, we produce in Connecticut roughly 18,000 tons of digested sludge cake a year. In spite of concerted efforts for the last 13 years to get that sludge back on the land, where I think it belongs, farmers and others have probably not used more than a third of our output up to this year. This year, it is estimated that we are using at least half of the output.

One thing that helped a great deal was to get the Connecticut Agricultural Station interested. I went down and talked with Dr. Lunt, the head of the Soils Department. He didn't know a great deal about sludge although he had heard about it. The Director of the Station often wondered why sanitary engineers hadn't pushed it's use and asked the doctor to work along with me. Dr. Lunt ran experiments this summer on cabbage, string beans, and so on. He is behind the movement now and the Station has been releasing newspaper publicity to which garden supervisors will give far more attention than to me or any other sanitary engineer. It is the old story, that if the agricultural department says it is good, it must be good.

My advice and my number one point would be to see the local county agents or agricultural men in your own states. Get them interested in pushing the program and advising the farmers how to use it. It will help a great deal.

The second item I have is not to expect heavy yields from heavy applications of sludge. It has been my experience in experimenting with various sludges in my own garden, and I have also seen references in the literature, particularly by Dr. Rudolfs, pointing out that frequently the heavier the application, the lower the yield. This is also borne out in the statement you hear, "Well, my potato crop did a lot better the second year than the first year, when I used sludge on the soil." There is a reason behind that. I didn't understand it until Dr. Lunt explained it to me. He says any humus material low in nitrogen—cow manure, sludge or anything—must first undergo further breaking down of the organic matter to bring it to the humus form. While the microorganisms are breaking down and oxidizing this organic matter in the sludge, they are robbing the soil of nitrogen, which the roots of the crop require. Until this process is fairly completed, sufficient nitrogen isn't available to the plants. Therefore, there is a retardation of the growth of the early spring crops.

The third point involves my impression of refuse incinerators built in conjunction with a sewage plant, and utilizing the waste heat from the incinerator to dry sludge. We have one fairly large plant of this type in Connecticut that is about to go into operation. It is designed for an average flow of 10 m.g.d. and comprises the common plain sedimentation and separate sludge digestion system. The vacuum filter cake goes to a flash dryer and the heat to operate that system will be taken from the refuse incinerator. After drying down to a five per cent moisture content, they can either burn the sludge in their refuse incinerator or by-pass and bag it for use as fertilizer, which I certainly hope they will do.

This practice impresses me because in the past we have rather felt that ordinary primary digested sludge did not have enough fertilizing value to warrant expensive equipment for drying, but here is a means of getting waste heat for practically nothing and it looks as though it would really be an economical plan.

In this connection, Mr. McDonald, Supt. of the Springfield, Massachusetts plant, tells me that enough sludge gas is produced by his digestion tanks to provide all the fuel he needs for drying sludge without burning any of it.

My fourth item is of interest in connection with vacuum filtration of sludges conditioned with lime and ferric chloride. As you know, if you are conditioning digested sludge with lime, the pH is pretty certain to be at least 10; the usual range will be 10 to 11. It occurred to me that such a high pH in the sludge cake might adversely affect the soil over a period of time. In New England at least, most crops do best with a soil pH between 6 and 7. Dr. Lunt undertook some work on this problem and the first thing he found was that sludge cake having a pH of 11 at the time of collection, dropped to about pH 7.5 after 2 or 3 days. All the samples that were selected did likewise and he attributed it to the loss of free ammonia in the cake. After the initial drop, most of them seemed to average around pH 7.5. He mixed various amounts of soil with the cake, some acid, some neutral, and some a little on the alkaline side, and he found most of the overall mixtures to be near the neutral point. He found all of the mixtures to be suitable for growing crops.

I obtained a similar answer to this question in talking with Mr. Bauer, the superintendent of the Middletown, Connecticut, plant. He has a garden about 30 feet wide by 150 feet long and has been growing crops on it for about 10 years. He has never used anything but sludge and has applied it at about 1¼ cubic yards per 1,000 square feet. If you figure that out on an acreage basis you will find it is a pretty high application. He has been doing this for five years on this garden plot, and the sludge is lime-conditioned with a high pH. I took samples around his garden before any crops were planted, with a core bore, and of the six samples collected, the average pH was 6.9, which is perfect.

Thus it would appear from this limited information that lime-conditioned sludges will not have the effect of making soils too alkaline.

Incidentally, you would be amazed at the kill of bacteria in these lime-conditioned sludge cakes of high pH. Both the plate counts and coli counts are reduced enormously by the high pH. I have taken samples directly from the filter aprons (using sterilized forceps) in a number of plants and have not found a really bad sample yet. Of course, we can not depend on a high pH at all times. I am not trying to tell you that such sludge is sterile but there is a marked reduction of bacteria.

Had I not heard Dr. Cram's remarks * yesterday, my fifth point would have been that the fall is the time to put sludge on the land to avoid health hazards. I will modify this statement to this extent: The above recommendation applies for the present only to the northern part of the United States. Apparently, if I understand Dr. Cram correctly, the eggs of parasitic worms have not been isolated as yet in municipal sludge but we may have this problem after the war or as the soldiers return. I hope Dr. Cram will enter the discussion this morning.

I have wondered what would happen if such infected sludge is spread over the land, and allowed to stay on through the winter, as a great many health departments recommend. After spring plowing and mixing of this sludge with the soil, would there still be a possibility that parasitic eggs would be present after the crop is grown and the vegetables prepared by the usual methods for eating?

The other worm hazard, as I understand it, is that of infection through personal contact with the sludge. I haven't personally come to the point of going into the garden in my bare feet so as to get hook worm. Could one become infected with these worms by having sludge on his hands for a few hours? I am interested in what chance there is of getting infection in that way.

One thing we have learned about the application of sludge to avoid health hazards. It does little good to tell the Victory gardener with a small garden plot to avoid putting sludge on crops that are going to be eaten raw—to leave the sludge off those crops and put it only on corn or other vegetables that will be cooked. For that reason, from a practical standpoint, our Connecticut Agricultural Experiment Station is putting on a campaign to get digested sludge on the land now and let it stay there over the winter. We feel it will be safe next spring for anything that the ground might be used to grow.

My sixth and last point is a question I would like to put to the Minneapolis-St. Paul plant personnel. I know they have had experiments underway on the use of their raw primary sludge as a fertilizer. I believe their agricultural station is working with them on this. It has always been my understanding that raw sludge, because it is not humified, will not be a satisfactory fertilizer, and I am wondering whether their material is sufficiently humified to do a good job.

* See article by Dr. Cram, *This Journal,* Nov. 1943, Vol. 15, No. 6, page 1119—Ed.

With your permission, I would like to read a very short excerpt from an article by Sir Albert Howard who has written several articles on the use of sludge for the British Institute of Sanitary Engineers. These articles have been published in their *Journal* and if you want some good reading, you should review them. He is rather rabid on this subject of getting sludge into use on the land. He says in respect to the usage of humified material:

"The utilization of vegetable and animal wastes in crop production involves two definite steps: One, the formation of humus and its incorporation in the soil, and two, slow oxidation of this product accompanied by the production of available nitrogen. Both of these stages are brought about by microorganisms for which suitable environmental conditions are essential. The requirements of the first phase, the preparation of humus and its incorporation in the soil, are so intense that if the process takes place in the soil itself rather than in a digestion tank, it is certain to interfere with the development of the crop."

That is more or less what I meant under my second point, and I think the better digested the sludge the heavier the application that can be made to the soil.

"The soil, in fact," continues Sir Albert Howard, "gets indigestion. This explains to a large extent why crude sewage, crude refuse and some of the sewage and refuse derivatives have been found wanting or even harmful by cultivators. In some places, worse has happened but it is clear in many cases that the first phase has not been sufficiently prolonged to allow the second to come into operation before the stuff was offered to the crop."

*Mr. Niles:* We shall defer discussion of the matters that Mr. Van Kleeck has brought up until we conclude the rest of the scheduled program.

I would like to take my prerogative as chairman to offer a few remarks. Mr. Van Kleeck's point about the interest of state and county agents is extremely important and one that Ohio neglected in the early days of the preparation and sale of sludge. As a result, much prejudice developed on the part of the Agricultural Department. This was difficult to overcome.

Now, due to the fact that a shortage of nitrogen exists, the county agents are actually beginning to admit that sewage sludge has value. They put it in a negative manner rather than a positive one because we made a poor beginning with the State Department of Agriculture.

Speaking of fall applications, it is extremely good practice to put a chunky sludge or partially dried sludge out in the fall, because the weathering of the elements certainly helps break it down and make it much more usable in the spring.

The next part of the program pertains to a topic of considerable interest at present—the use of sludge in a liquid state. We are fortunate in having with us Mr. David A. Backmeyer of Marion, Indiana, who has had a lot of experience in this practice.

*Mr. Backmeyer:* When Mr. Mackin asked that I take part in the discussion on fertilizing Victory gardens with sewage sludge, I prepared a short questionnaire on the subject and mailed copies to several of our

Indiana sewage treatment plants. Replies were received from eleven plants, and the data herein given is primarily from their reports.

The cities contacted are geographically distributed throughout the entire state. They range in population from 11,000 to 130,000, and the volume of sewage treated from 1.4 m.g.d. to 26.5 m.g.d.

All of the sewage plants disposing of sludge for garden use were digesting the sludge prior to disposal on the land. One plant reported a digestion period as short as 10 days, while several of the plants were able to hold the sludge from 40 days up to 100 days. None of our Indiana plants are equipped for complete drying of the sludge and sale of same as a commercial fertilizer.

Very few plants in Indiana are making a charge for the sludge other than the cost of removing the fertilizer material from the plant grounds. In most cases the sludge is dewatered on sand beds (covered or open) or stored in a lagoon until dry enough for removal. At present there are no vacuum filters being operated in the state. Muncie, Richmond, LaPorte, Anderson, Marion, and several other plants have used liquid disposal methods of one kind or another within the past year.

Very little advertising in newspapers or bulletins has been used to date. When interested customers call for the sludge, the plant superintendent usually points out that the sludge fertilizer is an excellent soil conditioner as well as an economical source of essential plant food. He might also add that it is not a ''world beater.'' It will not make potatoes grow on a concrete slab or beans thrive in a rock pile. As proof that one cannot use too much of the stuff he will probably show the prospective customer the remains of the thousands of tomato plants that grew in the sludge stock pile the previous season. Well kept lawns about the plant grounds are another good means of advertising the sludge.

Muncie, Indiana, population 50,000, average sewage flow 8.0 m.g.d., dries its digested sludge on glass covered beds. In 1942, all the sludge was removed from the beds (without charge) as it became sufficiently dry for handling. This year, due to labor and hauling shortage, only 50 per cent was removed from the drying beds in the corresponding period of time. Superintendent Paul White has equipped two tank trucks for hauling the liquid sludge that must be removed from the digesters when the drying beds are loaded full. Superintendent Ross of Richmond uses a similar system, and reports good results with the liquid disposal method.

At Marion, Indiana, population 28,000, average sewage flow 4.2 m.g.d., liquid disposal of digested sludge has entirely replaced the vacuum filtration method of sludge treatment. In February, 1943, the first liquid sludge was removed by hauling in a dump body type truck outfitted with a reinforced wooden tank of 1,000 gallons capacity. A portable pump was mounted on the end gate of the truck, and the sludge could be unloaded either by gravity or by pumping. This method has proven satisfactory and is being used at the present time. It shows some economy over the former method of dewatering the sludge on the vacuum filter and subsequent disposal of the filter cake by spreading on farm and garden land. During the past spring months of March, April, and May, more than 50 Victory gardens were treated with liquid sludge in Marion. A full tank, comprising 930 gallons of sludge, was delivered and applied to the garden plot at a charge of from $1.00 to $2.50, depending upon the distance the sludge had to be hauled. The average distance traveled per round trip was five miles, and the average cost per load was $1.50. Revenues received from liquid disposal for the period from March 15 to April 30 totaled $215.00.

What was the customer getting for his money? Since the sludge averaged 8.6 per cent total dry solids, a tank load contained 667 lbs. of dry solids. Tests of the sludge made at Purdue University show the nitrogen content to be 2.0 per cent and the phosphorous content to be 2.4 per cent. Each truck load, therefore, contained about 16 lbs. of phosphate and 13 lbs. of nitrogen. The combined value of these elements is $2.62 when nitrogen is figured at 14c per lb. and phosphate at 5c per lb. Incidentally, our sludge is a mixture of primary and activated sludge with ground garbage.

It is apparent from the above figures that even if the soil conditioning value of the sludge is disregarded, its application in a concentrated liquid form to farm and garden land makes an attractive bargain for the purchaser.

Two of the three larger plants reported upon, Ft. Wayne and Hammond, showed a definite increase in the amount of sludge put on Victory gardens in 1943 as compared to the previous year. Mr. Brunner at Ft. Wayne reports an increase of 50 per cent, while Mr. Carpenter at Hammond reports an increase of approximately 900 per cent. Mr. Mathews at Gary reports a slight decrease in the amount of sludge taken from the drying beds which he attributes to labor and hauling difficulties.

A special committee of the Indiana State Sewage Works Association is now at work preparing some literature for publication that is intended to stimulate the sale and disposal of sludge fertilizer throughout the state. A better Victory garden market is therefore expected for 1944 than was experienced in this past year.

I might add that we had the cooperation of our county farm agent in establishing the fertilizing value of the sludge. He was of great assistance in getting the farmers, especially those in the vicinity of our plant, interested in using it.

*Mr. Niles:* I am sure that many of you would be interested in asking questions of Mr. Backmeyer, but we shall defer open discussion until we hear from the next two speakers.

May I say in passing, that if any of you wish to do some experimenting with different kinds of sludge, try some of the filtrate from your open sludge drying beds and see what it will do. We know; we have tried it.

We shall next hear from Mr. Henry A. Riedesel, Superintendent of the Rockford (Illinois) Sanitary District. Mr. Riedesel has been through the business of fertilizer production and marketing and then gone out of it, so his remarks should be interesting.

*Mr. H. A. Riedesel:* The need for utilization of all of our natural resources in the winning of the war is recognized as paramount. Any campaign to use sewage sludge in Victory Gardens is, for that reason, a timely subject.

The Sanitary District of Rockford, however, has been very cautious about recommending dried sludge for garden purposes. We recommend it for lawns, golf courses and the like, and it has been used very extensively and successfully in this way. Yet, while we recognize its fertilizing values for home gardens and truck gardens and know of no disease being traceable to its use, we have desisted in recommending it generally, because of the possibility of passing on pathogenic bacteria in certain vegetables.

We continue to encourage its use as a grass conditioner and are now working with the Winnebago County Farm Advisor's office in the disposal of it for pasture lands. Pasture lands, seldom fertilized, are one place where more emphasis could, and should, be placed in the winning of the war and, in the opinion of Mr. Brunnemeyer, our Farm Advisor, it is especially true in this particular area, since we dwell in a large milk shed ourselves and border on a much larger one. The need for more milk is quite apparent in view of our present shortages and the many ration points needed to secure some of its by-products. Hence, we are hoping to help increase the yield by supplying ''bossy'' with more grass.

In the September, 1943, issue of *Sewage Works Engineering,* the ''Round Table'' editor comprehensively explored the use of sewage sludge for Victory gardens. From this reference, one receives some very enlightening information as to the extent to which sewage sludge as a fertilizer is being used in this country for Victory gardens and the ways and means developed in disposing of it. Mr. N. G. Damoose, Director of Public Service, Battle Creek, Michigan, replied at length concerning the topic and the campaign his Victory Garden Committee put on in getting the material moving. For further detailed information on this subject, I refer you to Mr. Damoose or the article. He also indicated another very interesting point—''liquid fertilizer.'' To quote Mr. Damoose, ''I again urge you to do what you can to increase interest in this liquid material.'' In this connection, Mr. Phil Schriner, Superintendent at Kankakee, Illinois, has, for some years, been advocating using liquid fertilizer. At the Battle Creek plant they recently provided suitable connections easily available to the public wanting ''liquid fertilizer'' (liquid digested sludge). In this same Round Table discussion, the remark of Mr. James M. Glynn, Superintendent, Sewage Treatment Plant, Reno, Nevada, is mentioned particularly for the contrast. I quote: ''Our sludge is not fit for fertilizer.''

Sears, Roebuck and Company has sampled and tested our product and has surveyed the possibilities of packaging it in small bags and selling it through their national chain, as have others with a similar view in mind, but as yet, at least as far as we are concerned, without any tangible results.

Some years ago, the Sanitary District of Rockford undertook the drying and sacking of sludge in one hundred pound bags. Financial success, although theoretically apparent on paper, did not crown the venture, as successive difficulties placed stones in its pathway. Our sludge comes from a primary treatment plant with two-stage digestion units and has a large and varied amount of industrial waste in it. As a fertilizer, it does not compare favorably, when prepared and marketed, with commercial fertilizers.

Our problem in recent years has been providing adequate means for making the material rather than marketing it. At present, we have expanded our sludge-handling facilities to meet the increasing load placed upon them and, of course, have, in turn, increased our yield. We have been able, however, to dispose of the sludge easily as it is free of charge, f.o.b. plant, for those desiring it, with the understanding aforementioned as to its use.

Part of this previous and present history on sludge use in Rockford digresses somewhat from the subject at hand but, nevertheless, is related to it. The fact that limestone outcroppings throughout the county are in abundance and pulverized limestone is used extensively in the area is another tangent which could be developed further.

I might mention one other matter. We are working with the Midwest Extraction Company, Rockford, Illinois, manufacturers of vitamins and chlorophylls, in the extraction of a hormone, a trace compound, from the scum or the supernatant. All that we have done so far in this connection is to start laying the ground work for continuing the research.

Digressing as I have brings to mind the story of the mother who, upon hearing unusual noises in the living room called to her small son, "Johnny, Johnny." "What, Ma?" "Johnny, are you spitting in the goldfish bowl?" "No, Ma, but I'm comin' close."

Recent analysis of our sludge, in accordance with the method suggested by Mr. Harry W. Gehm, Associate, Department of Water and Sewage Research, New Jersey Agricultural Experiment Station, New Brunswick, New Jersey, indicates that we have upwards of one-third grease in our raw sludge. It is to this end: the extraction of the grease, and recommending the dried sludge for pasture lands, that we have been bending our thoughts and efforts in the utilization of the sludge to help win the war.

*Mr. Niles:* We shall now be pleased to hear from Mr. P. W. Riedesel of the Division of Sanitation, Minnesota State Department of Health.

*Mr. P. W. Riedesel:* The Minnesota Department of Health is often called upon for information relative to the health aspects involved in the use of sludge obtained from human sewage as fertilizer. Some tests have been made by the Division of Preventable Diseases in regard to the presence and viability of pathogenic organisms in raw and stored sludge cake which has been conditioned with lime and ferric chloride. The Division of Sanitation of the Minnesota Department of Health has also carried on some tests on the most probable number of coli-form organisms remaining in piles of stored sludge which had been conditioned with ferric chloride at the sewage treatment plant to improve drainage. Little or no information has been secured on other types of sludge.

Studies on the most probable number of coli-form organisms in raw, undigested sludge as compared to sludge conditioned for dewatering with ferric chloride and stored in piles on garden plots showed 28,700,000 coli-form organisms per gram dry weight for the raw sludge, and 22,900,000 per gram dry weight after conditioning with ferric chloride. This same sludge stored in piles on garden plots during the winter showed 800 most probable number of coli-form organisms per gram dry weight when tested early the following spring. The stored sludge was frozen and undigested. Putrefaction and further multiplication of organic life could be expected with the advent of warmer weather.

The Division of Sanitation sampled sludges in various stages of storage as deposited on the stock pile at the Minneapolis-St. Paul plant and the laboratory work was done largely in the Division of Preventable Diseases of the State Health Department. In the experiments, the sludges were mixed with a saline solution and centrifuged, followed by attempts to reproduce disease in guinea pigs. It was demonstrated that sludge stored a longer period than one week did not show any positive results in causing typhoid, paratyphoid or tuberculosis. I believe that it was from six samples of very fresh sludge that tuberculosis was developed in the guinea pigs.

Because of the limited amount of information on conditioned sludge, and with little or no information available on other types of sludge, no attempt has been made by the Minnesota Department of Health to prepare a bulletin on health aspects involved in the use of sludge as fertilizer. The policy has been to recognize the value of sludge and to recommend it as a fertilizer and soil conditioner for ordinary farm crops and for some vegetable and truck crops, the edible portions of which do not come in contact with the soil. Its use as a fertilizer for vegetable and truck crops which are eaten raw is not recommended.

Mr. Van Kleeck mentioned that it is impractical to expect the Victory gardener to apply sludge only to the parts of his garden in which cooked vegetables will be grown. Perhaps the user could be induced to avoid planting raw-edible vegetables in sludge treated soil until a year had elapsed, after which time I feel it would be quite safe.

*Mr. Niles:* This concludes the prepared papers and we shall now have open discussion on this topic. I am sure that enough thoughts have been given out to provoke some good questions and answers.

*Dr. Eloise B. Cram:* I have been wanting to talk to Mr. Van Kleeck about some of these matters. I am fully in accord with him in his enthusiasm for the use of this reservoir of good material, but I am interested in seeing that the public health aspects are taken into consideration, and this situation is still a big question mark. The work that I did was the first of its kind and still leaves many questions unanswered.

As to the concentration of this parasitic material, it was, of course, much more concentrated in my tests, which was necessary under experimental conditions, in order to recover a sufficient number of the organisms to make a study of the effect of the treatment processes on them. I don't think ordinarily you would ever get any such concentration in municipal sewerage systems. We might in epidemics. Anybody who was at all connected with the Chicago situation here during the outbreak of amoebic dysentery and saw the large percentage of people in certain hotels that were affected, must realize it doesn't take much polluted material to start an epidemic.

As to infection of the hands, I think that hookworm might easily be acquired that way in the south or any place where you might get sufficient concentration.

In going back to the matter of concentration in the army camps that we examined, we only examined a five-gram sample, which is very small and found these parasite eggs in a large percentage. This was really astonishing to us in 1941 when the incidence of this large intestinal parasite was fairly low in this country. So with the greatly increased incidence, especially in camps or hospitals where food is coming back from epidemic areas in which these parasites are prevalent, there is going to be a huge increase in numbers contained in the sewage.

*Mr. Van Kleeck:* Dr. Cram, just how does hookworm infection occur? Do the eggs in the sludge hatch and the worms then go into the skin?

*Dr. Cram:* I think so but it would depend a little on the conditions. The large intestinal round worm doesn't hatch. That would have to be a hand-to-mouth thing. There are some interesting observations in the tropical countries. In Africa in the prisons there was such a high incidence of these worm parasites among the prisoners and yet the sanitary conditions were relatively good and they weren't out in contact with the soil at all, yet they had a much higher incidence than the general population. It was found here that the cooks and people handling the vegetables in the kitchen became carriers just from washing the vegetables. In that case, fertilizer wasn't being used on the vegetables. They were not eaten raw, but the food handlers had to wash the fresh vegetables before they were cooked. They became so heavily infected they acted as carriers to the other people in the prisons.

Of course, it isn't perhaps the worm parasites that one would become so worried about as amoebic dysentery, especially in connection with the use of the wet sludge.

I was very interested to hear that one plant reported using sludge after only 10 days digestion, because that would be in a period in which I still found amoebae exists and infects. I understand that sludge should be digested for at least 30 days. We don't know the upper limit of the infectivity. I think we are now in our studies about where the typhoid people were about 20 years ago as far as being able to culture the amoeba, and the typhoid methods of study have improved so greatly that it has made a very different situation in being able to do really comprehensive work now.

I am very hopeful that these remarks will arouse your interest and that anyone who has a chance to make any studies, either in universities or elsewhere, will do so, so there will be supplementary work to answer some of these questions.

*Mr. W. W. Mathews (Gary, Ind.):* I would like to ask if any experiments have ever been made by anyone as to the condition of the soil after using sludge for a year or six months or three months, knowing that there is a destructive effect from the soil on the pathogenic bacteria. As far as I know, there have been no studies of the soil itself after the use of sludge as a fertilizer for any length of time.

*Mr. L. H. Enslow (New York):* I would like to ask a question along the same line as Mr. Mathews'. I am thinking of the primitive practice in China, and I just wonder what the history may be in China after all these thousands of years of using this material, not digested either, as I understand it.

Another question is, do I understand the amoebas were found in the digested sludge as well as raw sludge?

*Dr. Cram:* I will answer the last question first. The amoebas were only in experimental, inoculated sludge. There hasn't been any real study in this country as to amoeba in the natural state in sludge but the experiments did not include inoculation of digesting sludge, and I felt that there was a considerable safety factor in that the limit of time in which I could recover the effective amoeba was only about 12 or 14 days in digesting sludge, so I felt it would not survive the digestion process up to a really ripe sludge (30 days or more—Ed. note). So if the sludge were used before that period there might be a real danger.

As to the other question concerning the destruction of pathogenic bacteria in the soil, I am not sure that much is known on that as yet. I think the recommendation, at least in the north, that the sludge be put on in the fall is very good, because the low temperatures, especially freezing temperatures, would be very deleterious to a high percentage of organisms. It would also mean the sludge would not be handled or put on vegetables during the early stages.

*Mr. Morris M. Cohn (New York):* Does that apply to sludge that might be stored in the open during the winter months and applied to the soil in the spring?

*Dr. Cram:* I would think so if it was stored where it actually froze. Of course, spreading would be even better because drying is a good control factor, especially with amoeba, and spreading it in thin layers would mean better drying.

*Mr. Cohn:* How about the other parasitic organisms?

*Dr. Cram:* The same would certainly be true of hookworm. As for the other parasites, I think they would also be reduced to fairly low numbers. Drying is one of the best control factors.

*Mr. Mathews:* How about applying the sludge in a finer state, as with limestone? The government requires, say 70 per cent to pass through an eighth-mesh screen. If we pulverize the sludge to that extent and then spread it, we can distribute it better and expose it to the extreme temperatures which help destroy the bacteria and parasites. Also, the sludge would dry out better if in a fine state.

*Dr. Cram:* I agree that such preparation of the sludge would be a wise measure.

*Mr. C. C. Larson (Springfield, Ill.):* We have a splendid group of guinea pigs in the operators who work around our plants. One cannot work around a sewage plant without getting into the sewage, yet we have never had any infections among our men. Has anyone here any information as to infections among men working in contact with sewage?

*Mr. Niles:* This is a very good question. While we can't go into it like we should, I would like to ask for a showing of hands. Does anyone in the room know of any instance of infection by pathogenic bacteria that came from sewage sludge or sewage itself? (One hand; Mr. McGuire—Ed.)

*Mr. C. D. McGuire (Columbus, Ohio):* We use a grab bucket with an electric hoist to remove the sludge cake in excess of our incinerator capacity from a pit near the incinerator. One day a man who was excited (and slightly intoxicated, we found out afterward) grabbed the open edge of the bucket to guide it. When he tried to let loose he couldn't and it closed and cut off several fingers. His hands were covered with sludge, of course, and tetanus developed in about 6 or 8 hours. He had a desperate time and finally lost the arm just below the elbow. That is our only experience with such infections and it, as you can see, was a result of an unusual exposure.

*Dr. Cram:* May I mention that the reason we made some of these tests in municipalities in California was because an operator contracted amoebic dysentery and thought he got it from the sludge. As I said, we did not recover them in that case. I do not believe that the negative results should be stressed as much as they have. As all of you know, the fact we do not find anything in a few samples of sludge does not mean we can generalize and say there is no hazard. It would be a very interesting survey to see if any more cases were found.

*Mr. Cohn:* Mr. Niles, I wonder if I can bring this discussion down to a practical level. Many of you who have been marketing sludge for a long time and then listened to Dr. Cram's talk may think you were in a very unfortunate situation.

I don't mind taking myself for a specific example; I have been marketing sludge for 19 years. You can imagine my reaction when I got this repetition of a previous warning we had received in a chapter of a manual prepared by Mr. Gilcreas.* Therefore, I felt very unfortunate in that I was an operator who had been marketing something that was potentially hazardous by analysis. But to cap the situation, the Sewage Works Practice Committee of the Federation has been preparing its first chapter of our proposed manual of practices, and the first chapter carries the title "The Use of Sludge as a Fertilizer," exactly the same

* F. W. Gilcreas (New York).

title as is carried in this important panel discussion. We are now faced with the publication of that manual.

One of the sections of the manual deals with the health hazards involved in the use of sludge as a fertilizer. That section was prepared by Mr. Gilcreas, who reviewed the literature and pointed out the possibility that parasitic infections may be spread by the use of sludge as fertilizer.

I do wish to raise this hypothetical question. I hope you can answer it. If it is embarrassing to you, please don't, but if we can get an answer it would help our committee tremendously in addition to helping those of us who are caught on the horns of a very serious dilemma.

In view of the present interest in the use of sludge as a fertilizer; in view of all the past negative experiences regarding the transmission of diseases or parasitic infections as a result of the use of sludge as a fertilizer; in view of your own studies as they relate to theoretical infections or infusions, if I may use that word; in view of the fact there have been no studies made of soil which has been treated with sludge; would you advise the discontinuance of the use of sludge as a fertilizer?

May I say one thing more, please? I am groping for guidance or some ray of sunshine in this rather dark picture that has suddenly appeared on our horizon. You see my point?

*Dr. Cram:* I do not care to make a blanket endorsement or condemnation one way or the other, because I do not feel, with the present status of our knowledge, one could say. I think one should advance cautiously and should be familiar with the possibilities of potential danger to the public health. Under the present conditions or the past conditions where infections were so light, I think it was a minor matter. That is my personal opinion. But with increasing severity of infections and with the returning military and civilian personnel, we do get a condition that is comparable to those in Germany and Russia and some other European countries, to say nothing of China where infections are so frequent. If we are in for a comparable situation in relation to parasitic infections, then I think that one could come to the conclusion there was a real menace. At this time, however, I do not think we know enough about it and should give more consideration to the future than the present.

*Mr. Cohn:* May I ask a supplementary question now which may help the situation? I consider it very important for the guidance of the committee as well as everyone here. In view of these doubts, in view of the fact that there may be a possibility of infection, are there a set of regulations or protective rules which we might set up? For example, we have already said that the spreading of sludge on land over the winter months should diminish greatly the dangers involved. Is that right? Is there further possibility that we could cut down again the hazards involved by setting up regulations about keeping sludge off crops that go on the table uncooked or do you feel that the possibility of infection through the hands by working in the garden is sufficient hazard to put up the warning sign for us?

*Dr. Cram:* I feel that we are hardly in a position to make any such definite set of rules. I think the observations are too limited, both as regards experimental work and actual practice. I think it would be good to aim toward conditional investigations but I doubt if at present one could lay down hard and fast rules.

*Mr. Gilcreas:* Mr. Chairman, I have two comments. I would first like to thank Dr. Cram for her unqualified support of my chapter in the manual. Second, because I do think there is a potentiality, and that the Federation of Sewage Works Associations should realize there is a potentiality, and we can't ignore it. Dr. Cram has again brought that to you.

It seems to me in one way we are losing sight of the fact that our primary job is to take care of sewage and that getting rid of the sludge is only one part of that task.

*Mr. Niles:* Surely some of you must have questions you would like to ask Mr. Backmeyer on the use of liquid sludge. Perhaps we are treading on dangerous ground, but I, for one, know we have had some very interesting experiments and work in Toledo, and I know they have had some in Battle Creek. I know Mr. Backmeyer would be glad to answer your questions.

*Mr. Enslow:* I would like to ask Mr. Backmeyer for a little more detail about the quantities of liquid sludge applied.

*Mr. Backmeyer:* On Victory gardens, we put on a truckload, that is, 930 gallons to a 40 by 40 foot area. On farm land the application is quite a bit lighter than that. We put it on by gravity and apply about 7 to 12 truckloads to an acre of ground. Just about two weeks ago we put 26 truckloads on a five-acre plot of ground which had been sowed with wheat and will have a good chance to see what that will do. Some of the other farmers are applying about 5 to 7 truckloads, the equivalent of about 930 gallons of it to the acre.

*Mr. McGuire:* That is 8 per cent total solids?

*Mr. Backmeyer:* It varies from 8 to 10 per cent. There is an important comparison when you are hauling out filter cake which runs about 27 per cent solids. When we are hauling liquid, we are hauling 9 per cent solids but it is cheaper for us to make three times as many trips with the truck hauling 9 per cent solids than it is to produce the 27 per cent solids and haul it out as filter cake.

*Mr. W. A. Allen (Pasadena, Calif.):* Mr. Chairman, I would like to ask Dr. Cram if she ever ran any tests on heat-dried, ground sludge, either digested or activated.

*Dr. Cram:* Heat dried sludge? No, I have not.

*Mr. W. A. Moore (Cincinnatti, Ohio):* Our laboratory performed a small experiment using pulverized sludge of 30 per cent moisture content and we found that the organisms were killed in about three minutes by a temperature of about 100° C. I feel sure that heat-dried sludge, which is dried at a much higher temperature would involve no danger at all.

*Chairman Mackin:* I would conclude from this discussion that it would be wise to take all the precautions that have been mentioned and

I also feel that, if you are not now practicing liquid application of sludge, I could recommend it only as a future development. I think we might conclude in a practical way that the status quo should be observed until some further information is obtained along these lines. Many questions have been brought up and we have not had the time to answer them, but I am sure that you have all received a letter from the Research Committee of the Federation asking for projects that could well be undertaken or that were in progress. I suggest that you list some of the questions that have come to your mind this morning. This discussion may leave you feeling just a little bit guilty perhaps, as Mr. Cohn suggested, so be sure the questions that would make good research projects are transmitted to the Research Committee.

## II. SECONDARY TREATMENT—PRESENT AND FUTURE

Donald W. Walker, A. W. West, Linn H. Enslow, and
Arthur S. Bedell, *Leader*

*Mr. Bedell:* Although our title provides only for the present and future of secondary treatment, I have no doubt but that we shall delve into its past also, before we conclude this discussion. Perhaps we should begin with a definition. What do we mean by "secondary treatment"? In kindergarten, we learn that two comes after one, but this is not necessarily true in sewage treatment because we do have secondary treatment without any primary treatment. I have in mind that in primary treatment of sewage we usually expect the removal of suspended solids by physical and mechanical deposition, while secondary treatment connotes to most of us the further removal of suspended solids, with some of the colloids and dissolved solids, by oxidation, coagulation and adsorption. Physical, chemical and biological forces are all strongly at work in the secondary processes.

If we hold to this definition, we find there are a number of so-called secondary treatment methods and processes used without benefit of primary treatment. We immediately think of the sand filtration as practiced early in England and in New England in the early part of the century, where raw sewage was applied directly, and treated quite satisfactorily within our conception of what we expect of secondary treatment.

On this basis we might include the treatment of sewage by chemical precipitation, although to many of us chemical precipitation is an adaptation or extension of primary treatment by sedimentation. Plain flocculation is also considered as an augmentation of primary treatment by sedimentation.

To get the perspective, I think it is well to look back and see how we have developed the art of sewage treatment. Our advancement has been by surges. We have advanced not only in the technique of treatment but also in our ideas and ideals regarding stream pollution. I can remember when in school I had a course in the purification of water and sewage, and we meant *purification* of the sewage. In other words, one of our usual inspection trips was to go to the Lawrence Experiment Station and be offered a glass of the filtered effluent. We rather suspected it might have been disinfected. It was supposed to have been sand filtered.

I think it is well from some of the questions that were raised in our preliminary correspondence regarding this panel discussion to examine a few statistics on what we have in the way of secondary treatment in the country. Unfortunately, due to the lack of personnel and time on my own part, I was unable to make a review of the splendid census of treatment works in the U. S. made by the United States Public Health Service and would have brought us up to date. I had to limit myself for most recent statistics to the *Engineering News-Record* census of 1938.

In that 1938 census there were 4,667 treatment plants listed in the United States. Of those 4,667 there were 2,110, or 45 per cent, provided with secondary treatment devices. It was rather a surprise to me at that time to note the high percentage of secondary treatment plants. Of the 1,773 communities employing filtration in its various forms, there were 1,140 trickling filter, 109 contact bed and 524 sand filter plants. There were 223 activated sludge plants and 114 chemical precipitation plants.

In New York State I have made a comparison of conditions at several stages. The first attempt by the State Health Department to require municipalities to install sewage treatment plants and to submit plans of them was made in 1903. This might be taken as the inception of our present anti-pollution program. At that time we had four public sewage treatment plants in the state, a rather astounding condition. In 1917 we had 47 sewage treatment plants serving about a quarter of a million population. Of the 47 plants, 33 employed secondary devices, including 15 contact beds, 8 trickling filters, 7 sand filters, and 3 chemical precipitation plants.

In 1940, the total population of the state exclusive of New York City, was 6,200,000 people. Sewage treatment was provided for just half of that, and there were 269 treatment works in the state, of which 103 or 35 per cent used secondary devices. In contrast to that, we have the State of Massachusetts, where in 1918 they had 33 sewage treatment plants, all of which provided secondary treatment. Most of us are familiar with the fact that natural sand beds are readily available in Massachusetts and also that, with certain minor exceptions, there are no large streams or bodies of water within the state in which disposal by dilution would be possible.

In 1938 there were 79 sewage treatment plants in the State of Massachusetts and here again 39 of these, or half of them, included secondary treatment. Apparently nearly all of the plants built in the interim 20-year period provided only primary treatment.

Fundamentally, we have seven types of secondary treatment, *i.e.*, broad irrigation, fish ponds (which we do not have in the U. S.), biological filters, contact beds, activated sludge, chemical precipitation, and finally, disinfection.

As to broad irrigation, it was interesting to me to note the extent to which it is used in certain places, as in the western states where we have arid and semi-arid conditions. In 1938 we had 113 places using broad irrigation as a method of sewage disposal in this country. As a rule, preliminary sedimentation is provided. At San Antonio, Texas, 20,000,000 gallons a day is sold to a private company which disposes of the sewage on 4,000 acres. In the winter time, it is necessary to store the sewage so they have a pond or a lake of 1,000 acres in extent, which serves as a reservoir during the winter, and allows them to carry on the rest of the year. In Europe, of course, sewage farms are quite common, large ones being located adjacent to Paris and Berlin.

Fish ponds, the next type of secondary treatment on my list, are employed along the Elbe River in Europe with fairly satisfactory results. The removal of organic matter and reported nitrification is surprisingly good. In general, very shallow ponds 1.0 to 1.5 feet deep are used except that deeper ponds are necessary for the protection of the fish in winter when they hibernate. The ponds are stocked in the spring with fish, clams and, sometimes, ducks. As applied to the ponds, the sewage is diluted with one to four volumes of water—otherwise offensive conditions would result. It is reported that 88 per cent of the organic matter is removed and that the bacterial count is reduced to about 10,000 per ml. by the treatment. A clear effluent is claimed. The fish yield is said to be about 500 pounds per acre, which is interesting from a commercial standpoint.

Coming to filters, we have three general types: the contact bed, the intermittent sand filter and the trickling filter. The contact bed might be considered as a separate process and I shall discuss it first, although contact beds are now largely replaced by more efficient and economical methods.

The application rate for contact beds is about 400,000 gallons per acre per day. Ordinarily, contact beds are about four feet deep and have an efficiency of 60 to 70 per cent of B.O.D. removal, if operating satisfactorily. In all of these discussions we are trying to think of the future and it is my opinion that contact beds have no future.

The sand filters, of course, are best justified where there are natural sand beds. We cannot very well afford to build up a large, artificial bed of sand to take care of large quantities of sewage. The usual loading is about 500 to 1000 population per acre for a settled effluent. Rest periods are necessary, so additional beds must be provided. Sand filters give excellent results with B.O.D. and suspended matter removals in the order of 95 and 99 per cent, respectively. Bacterial removals are also very good.

This brings us to present day methods of secondary treatment of sewage and I shall ask you to take over the discussion from here.

*Chairman Mackin:* Thank you very much, Mr. Bedell. I shall now call on J. D. Walker, Sanitary Engineer of the American Well Works, to continue this discussion.

*Mr. J. Donald Walker:* I trust that you will permit me to speak more or less freely and without the necessity of backing up my remarks with a great array of scientific data, if any such thing can be gathered in this field. I shall speak briefly on the various devices that are used for secondary treatment, confining myself mostly to trickling filters and activated sludge and combinations, and if there are any questions, I shall be pleased to answer them if I can.

In the first place, I would like to define secondary treatment. There has always been a question in my mind as to what we mean by secondary treatment, and in order to confine this discussion to one channel, I will define secondary treatment as Wisely did a few years ago when he suggested that the effluent of an activated sludge plant should contain not more than 10 or 15 parts per million of B.O.D. which means 85 to 95 per cent removal of B.O.D.; also, that it should show at least a positive trace of nitrification. I presume by that he meant to spot the point on the curve at which the plant was operating, so that the 5-day B.O.D. could be correlated in terms of total B.O.D. In other words, you had some definite idea as to the degree of stability being obtained.

Accordingly, I shall discuss the secondary treatment units on the basis that they are capable of producing nitrification, in other words, stabilized effluents. I think there has been a great deal of discrepancy. I talked to a sewage plant operator a few days ago and he had a low rate filter and a high rate filter of common design in his plant. The low rate filter was producing about 85 per cent removal of B.O.D. and the high rate unit was effecting slightly greater removal, say, 86 or 87 per cent removal. The operator was very confused because the relative stability samples would stand up approximately ten days on the low rate filter and would only stand up five or six days on the high rate filter. Even though the high rate filter was giving a greater removal of B.O.D., he was using the stability results as an index to illustrate that the low rate filter was doing better work.

I think that requires some clearing up, because the point has been frequently brought up to a good many consulting engineers, and I think that if we understand the difference between 5-day B.O.D. when there is nitrification present and when there is not, we can have a better understanding between the equipment manufacturer, the designing engineer and the plant operator.

Let me make it clear at this point that even though some secondary treatment units may not be producing an effluent containing nitrates, it does not mean that the unit or plant is no good. Neither does it mean that the unit, be it trickling filter or activated sludge, would not be capable of producing nitrification if designed a little more liberally. It is up to the engineer to decide whether he wants nitrification or whether he does not. At the same time he should clearly decide whether he wants B.O.D. removal on the stabilization end of the curve or the other end.

In speaking of high capacity filters, I would like to put, if I may, high capacity filters and activated sludge in the same classification, because I think they more or less follow along the same general lines. For instance, I noticed in Mr. Larson's report of the Springfield plant, when they have a protracted dry period he often puts down a memorandum on the day it rains and how the activated sludge plant operation has improved thereby. We are led to believe that the rainfall carried down dissolved oxygen and created better operating conditions in his plant and allowed him to have a much happier activated sludge. If that is true, it seems that some form of recirculation is quite desirable for the satisfactory operation of most sewage plants. I wouldn't care to make the statement that it is necessary for the operation of all sewage plants, but I do think that all sewage plants should have recirculation so that, if necessary, the operator could call upon recirculation to freshen up the primary settling tank or otherwise improve operating conditions. Recirculation seems to give us more consistent operation.

Activated sludge can be operated with little or no nitrification or it can be operated with long detention periods and high mixed liquor solids to effect a high degree of nitrification and stability.

High-capacity filters can be operated in the same fashion notwithstanding the fact that there will be a lot of argument to the contrary. As I said, I again take the privilege of making my statements subject to your challenge. High-capacity filters can be operated with a relatively small amount of media present for the amount of organic load being applied to obtain a given result, and then, of course, the filter can be more liberally designed to increase the nitrification within the unit and give more stable operating characteristics.

I feel that this same thought can be carried on to all of the other types of secondary treatment, which might be combinations of trickling filters and activated sludge or combinations of trickling filters and slow sand filters or slow sand filters alone. Incidentally, I would like to challenge a remark that Mr. Bedell made. I do not agree that slow sand filters domestically require a tremendous amount of sand. I think that by applying more modern methods of design, or, to be specific, by using rotary distributors, better underdrains and smaller dosing tanks, that a small amount of sand will yield a very high degree of efficiency. The use of a washed sand, screened to a given specification, might even be justified. I have seen a sand filter in Michigan used in that fashion, and it has proved to be very economical. The operation has been just as good as the old-fashioned, conventional sand filters which were loaded only about 30 per cent of the time because of the inability to distribute all of the load over the entire surface of the unit.

I suggest that this same line of reasoning will apply to the newer processes such as the Emscher filters that we saw tried in connection with a Dow Chemical Co. problem at Midland, Michigan, and I believe the failure there was probably due to trying to work the filters too hard. It also applies to the Hays process, concerning which I would like to add the comment that the best Hays plants, and I have seen some doing a very good job, seem to be those plants which were more liberally designed, or to say it conversely, those which were not being loaded to such a great extent.

*Chairman Mackin:* Thank you very much, Mr. Walker. To continue with the discussion, I shall now call upon Mr. A. W. West, former sanitary engineer with the Board of Health of the State of Wisconsin, who is now associated with Mr. E. B. Mallory.

*Mr. A. W. West:* We are privileged characters up here, so I am again going to take advantage by dragging out an old horse, and you will excuse me, I hope. I refer to the absolute need for the collection of complete and comprehensive operation data in sewage treatment plants. I can think back to a number of cases, sometimes the smaller communities, more particularly in Imhoff tank installations, primary treatment plants, and some of the grossly overloaded complete treatment plants, in which the operators have discontinued collecting some of this vitally important data. This was done by them with the firm conviction that their particular treatment plant was, shall we say, inflexible or overloaded to such an extent that no amount of records could help them to improve the efficiency of their process or to obtain a better effluent.

As we all know, they are overlooking one very important factor, that such a situation means that some day they are going to have additional treatment facilities or a new plant. If they have neglected to gather this information very conscientiously, they are doing a disservice to the community, because the lack of such information may lead to additional difficulties when the new structures are in, and might even be responsible for the waste of public funds on the construction of a sewage treatment plant that does not fit the needs of that community.

We have seen in the past some of the results from lack of such data. In the rush days of PWA many plants had to be constructed hurriedly without adequate consideration of flow and other factors of loading. The census figure was often used and sometimes we used population equivalents of industrial waste. May I say a very unkind word about population equivalents? It is, we believe, a very loose term and suggest that it is much better to consider the B.O.D. and flow separately and not to incorporate them into a single statistic such as population equivalent. The B.O.D. and the flow each exert their individual and correlated influence on the design of new structures.

It is axiomatic that we cannot design one plant that will take care of any and all conditions. If you have a sewage treatment plant receiving a high B.O.D. and a low flow, it must be designed altogether differently than if these characteristics were reversed.

Let us consider some activated sludge treatment plants. I believe one thing that is general is that when the design or the operating characteristics of some of these activated sludge plants are examined in the light of present knowledge on what that plant can handle and how it must operate, we find that the majority are capable of producing the optimum results for a primary effluent B.O.D. in the range of 200 to 250 parts per million. For average figures, I believe it is pretty well known that most of our domestic sewage after primary treatment average about 150 parts per million B.O.D. In other words, the plant is designed to handle one type of sewage and it must operate on another type of sewage.

We mentioned something about the high rate processes before, and I would like to speak of the activated sludge process as a very high rate process also. It is a most efficient one if we understand the underlying principles and the fixed physical relationships that really govern the operation of such a plant.

We are fortunate at present in that we can eliminate trial and error groping for the exact method by which activated sludge plants must be operated. That has been illustrated time and time again where operators have gone over many years of trial and error operation in order to find the point at which their plant can do a decent job and, unfortunately, some operators have not as yet found that point. In the light of present day knowledge, it is necessary that we recognize one important factor which is that the relationship between the aeration holding capacity and the final clarifier holding capacity is one of the important things that governs the method by which that plant must be operated. When the plant is set down in front of you to be operated, that relationship is fixed and nothing you can do can change the method by which that plant must be controlled. Therefore, in the past you could find the optimum conditions if you had enough time to do it, but now it is possible to actually predict, evaluate and compute within a matter of minutes how the plant must be operated. You don't have to grope around.

Take our old friend the 20 or 25 per cent return sludge. We know that is not the factor in all sewage treatment plants. Plants have been found where an attempt was made to operate at that ratio when they required 50, and at one place 100 per cent return sludge to get proper operation. When those values are fixed, the plant must be operated in accordance with the physical principles that govern, and the same thing goes back to the plant design. You must have the basic information on B.O.D. and flow so that you can design a particular plant that will stand up and produce the best under those particular conditions, and not be limited by a characteristic of the sewage that is not most readily amenable to treatment in that particular cycle.

I would like to say something about final effluent quality. I think a high quality effluent can be considered that which has a B.O.D. and suspended solids of around 2, 3, or 5 parts per million, say, an average of 5, and never exceeding 10. That is what we consider to be a high quality effluent.

May I go back? We were talking about each plant having to be operated according to a definite set of rules. Have any of you ever operated an activated sludge plant with a high suspended solids condition? There is one plant of which I know that is operating between 3,500 and 9,500 parts per million of suspended solids in the mixed liquor and on one occasion they had to increase the suspended solids content to 13,000 parts per million because the conditions of load demanded that.

I think my time is up. I just wanted to introduce some of these remarks and hope that it will bring about discussion from the floor.

*Chairman Mackin:* Thank you very much, Mr. West. I am happy to call on Mr. L. H. Enslow, Editor of *Water Works and Sewerage,* to conclude the discussion of this subject, and then I shall call for questions and comments from the floor.

*Mr. L. H. Enslow (New York City):* Mr. Chairman, members and guests: I was specifically told to talk a bit about chlorination as secondary treatment. I told Mr. Mackin I had not thought of chlorination as a secondary treatment, but he said it was an adjunct, and therefore, I should cover that part of the topic.

We are running behind time and I can see faces in this audience of men who have heard me speak on this same topic so often that I am going to hurry through it, because it is somewhat repetitious.

Now, of course, as an adjunct to secondary treatment, we are all familiar with the use of chlorine in conjunction with trickling filters for a multiple purpose; for controlling odors as the first and primary use, for eliminating or controlling ponding and also for control of fly breeding. In some plants fly breeding is not controlled to the extent that it should be by chlorination alone, the reason being, I think, largely because of inadequate coverage of the filter media by the spray. In other words, this fly breeding control, as Morris Cohn pointed out long ago, is due apparently to the elimination of the thicker film which forms around the upper stones. Unless you can have some method of eliminating that film, the flies will breed in those areas where the film persists. I have seen filters which were very effectively controlled by chlorination.

When it comes to ponding, there seems to be a good deal of success in that direction and every now and then we hear of a new case where chlorine has been effective.

Now I might say too, that chlorination at trickling filters has an effect somewhat along the line of high rate filtration. That is, it does keep the film on the filter moving out and, therefore, keeps a thinner film which apparently is a much healthier film, as Morris Cohn expressed, in oxidation and nitrification.

Therefore, when you chlorinate, instead of getting a deficiency in effective oxidation, you actually get an increased efficiency in most cases. Of course, that was quite revolutionary at the time we discovered it and hardly anyone believed it. Everybody does know chlorine does kill bacteria and they do not know how chlorination on top of a biological film would be helpful anyway.

Messrs. Bedell and Walker both mentioned sand filters. It might interest you to know that I have seen plants in New Jersey chlorinating ahead of the slow sand filters. That really is a little upsetting to most of us but it actually improved the effluent of the plants, but more interesting, I think, was the fact that most of the filters took a much higher volume loading due to the fact that the zoögleal film on the sand seemed to be kept in a granular condition rather than a gummy condition. I was rather impressed with Mr. Walker's idea of going back a bit in re-establishing, you might say, the slow sand filter and I think of this only for small plants. I don't think there is anyone in the room who will not agree with me that when you observe a slow sand filter plant you are rather disturbed to see that in most cases the sewage does not reach thoroughly over the sand bed. The settled sewage being applied does not get good distribution and that means that part of the area is loaded until it clogs. When you get clogging, that part is dead and suffers from oxygen deficiency while the other part is put to work naturally because the sewage runs onto it. So at no time, then, do you have 100 per cent of the sand bed operating effectively. You have half the bed unused and the other half over-used and then you get putrefaction in the clogged part while the other half becomes overloaded. It leaves you between two horns of the dilemma at all times.

It strikes me that Mr. Walker reached a logical conclusion when he pointed out that slow sand filters still have a place in small plants if provided with efficient distribution facilities. Everyone here knows that it is hard to beat a slow sand filter in the production of a good effluent when it is operated correctly and given good care.

Speaking of high rate filters, we all know that the argument as to the stability versus B.O.D. of the effluent is one that could last all night, but I look at it this way. The stability test is a very useful index, particularly where we do not have the more scientific B.O.D. test, but all that the stability test tells you is how far down the stream the effluent will go before it becomes devoid of oxygen, providing that there is no natural reaeration in the stream. Unless I am badly mistaken that is all it does show.

Now we know we don't usually have covered streams. Out in Iowa, there was a covered stream which acted as a wonderful septic tank because it was sealed over from any air. Ordinarily, we have reaeration going on, so I don't know why we get excited about the stability number on any effluent except to predict as to about how far down the stream that would go if it had no aeration whatever. I do not see that it has a real practical application. I would like to hear discussion on that. I think it is an interesting subject and a lot of these plant operators are very much confused, especially the uninitiated ones as to the stability number versus B.O.D.

When it comes to secondary treatment and chlorination, I have one more application and the effectiveness of it is exhibited right here in the State of Illinois at Downer's Grove. I understand that for 12 years or so at Downer's Grove the effluent of a heavily overloaded sprinkling filter is being chlorinated every summer, primarily for the purpose of raising the stability number. It does it. It increases the stability number so that instead of going bad in five days it will only go bad in 10 days, as shown by a survey of the small brook which receives that effluent. I examined the stream about a year and a half ago in the late summer when conditions were proper for showing up bad results, if ever, because it was dry and had been a very hot period, and I did find the brook to be remarkably clean and also free of odors.

The same thing has been done at any number of places and more scientifically where there are industrial wastes involved, canning wastes in particular. I know plants that have been treating canning wastes without chlorination of the effluent; naturally, they do get a putrid condition which seems very bad in the eyes of the farmers. These nasty looking slime growths lead the farmer to think that the stream is dirty as soon as he sees them. If he does not see the growth but sees clean sand and clean branches along the stream instead, he is not so excited. It reminds me of the fellow who smells a sewage treatment plant through his eyes. That is just the case in this situation. There are cases, in other words, where you can use chlorination as a palliative, as a temporary relief measure, and in the case of Downer's Grove they have never yet seen fit to add more to that plant as long as chlorination is doing the job it has been doing.

*Chairman Mackin:* Thank you very much, Mr. Enslow. I shall now ask for discussion from the floor on the topic of secondary treatment.

*Mr. C. A. Emerson (New York City):* Mr. Chairman, I would like to ask Mr. Enslow the question, bearing in mind that the progress of sewage treatment for the past 30 or 40 years has been uniformly toward more intensive methods without full development of standards, are we in danger of running into a condition wherein we are going too fast? We are told in these days of rubber and gasoline shortage that 35 miles an hour is two or three times as easy on the car. It cuts the death rate down. The car operates more efficiently. What is the speed limit?

*Chairman Mackin:* Mr. Emerson poses a very interesting question. What is the speed limit? I shall ask Mr. Enslow to answer it when he sums up this discussion later.

*W. D. Hatfield (Decatur, Illinois):* I would like to comment upon something I have read between the lines in a good deal of this secondary treatment discussion. It seems to me if we look back into the history of the activated sludge process we find it to be one of the first processes in which we returned a considerable quantity of the effluent back into the process. We happened to return solids along with about 95 per cent of the effluent back into the sewage and we had the activated sludge process. Then more recently we have started pumping the effluent from the trickling filter back to the head end of the plant with some rather astonishing loading results.

Now there are any number of different processes proposed in which we are going back to the original activated sludge plant practice of pumping back still larger volumes and getting much better operation. Two or three different processes use 50, 100, 200, 300 or 400 per cent return. What I am thinking of is final effluent rather than sludge. I am wondering if the keynote of the future in this secondary treatment is not some form of recirculation.

*Major Rolf Eliassen:* One thing I wanted to bring up. When Mr.

West mentioned the very high concentration of solids in the mixed liquor you would also bring in power consumption or air consumption, because I have noticed a number of times in Mr. Mallory's paper in New York he was very evasive about air requirements, and that is what costs the money. As far as we are concerned, we have to remember that we can get treatment but we have to realize economy in some of those things.

There is just one more point. We can still have our slide rule and our tables but we still need the operators to pull us out of difficulty!

*Mr. Van Kleeck:* Mr. Chairman, a question for Mr. Walker. Could you give us any figure, Mr. Walker, as to how high the rate could be on the slow sand filter, using the rotary distributor? We usually think of the rate as 100,000 gallons per acre per day. Could you offer 200,000 or 500,000 g.a.d. or aren't you prepared to say?

*Mr. Walker:* I would rather answer that by saying I don't think that it should be rated in terms of flow. It should be in terms of pounds of B.O.D. or some other measure of the amount of organic matter being applied to the filter.

*Chairman Mackin:* Mr. Walker, what do you mean by the amount of organic matter?

*Mr. Walker:* Go back to the B.O.D. Rated in terms of B.O.D. applied to the filter or, if you please, with apologies to Mr. West, population equivalent. It is my belief that with better primary treatment, such as preliminary treatment on high capacity filters, or some other form of removal of the more dense solids, that you could increase the loading probably six or seven or eight times. I have seen work done where the loads were increased ten times over and above the standard as set up as a point of departure for the Illinois Department of Health, which I think compares favorably with the other Boards of Health.

*Operator* (*Camp Breckenridge, Ky.*)*:* I would like to ask what figure Mr. West uses to determine the best operation for an activated sludge plant. He spoke of a measure which operators should use to govern the rates of return sludge to the mixed liquor and the solids content. Which figure does he prefer to use as the best measure?

*Mr. West:* You must use both. As far as the percentage of return sludge, that is governed solely by the relationship between the holding capacity of the aeration tanks and final settling tanks. In other words, if you have one combination, if I may just go back, the formula is 2A over C minus 1. In using that, K, the return would be the actual sewage flow divided by 2A over C minus 2. May I say that this value is fixed and that the conditions in your plant will govern the percentage of circulation you must use to keep the optimum. As far as the B.O.D. loading, that will be shown by the other simple tests in the process, the centrifuge, the settleometer, and your sludge blanket. The conditions in your tank will show the magnitude of the loading and what effect it has on the process and will tell you what should be done to bring that process back into equilibrium.

*Chairman Mackin:* Is that of some help? The latter part of his discussion I think is the part that related to the specific prescription for suspended solids.

Are there any other questions? Does anyone have any comments to make about the future of secondary treatment?

*Mr. W. W. Mathews (Gary, Ind.):* Mr. Chairman, I haven't heard anyone say what he thought was going to be the next advance in sewage treatment, with these processes coming out that guarantee such a high reduction. They leave only one or two parts per million to go. Where do we go from that?

*Chairman Mackin:* When we get there I don't think we will have much to worry about from that point on. The only basic thing to seek then will be a bacteria-free effluent.

*Mr. W. A. Allen (Pasadena, Cal.):* Mr. Chairman, I would suggest that sewage plants ought not be burdened with water treatment.

*Mr. Emerson:* What I had in mind when I asked about the speed limit was that it is all very well to sit down with a slide rule and plotting paper and get your $A$ times $C$, divided by $X$ equation, or something like that, but that we cannot just ignore some 30 or 40 years of sewage treatment experience.

When we set the plant up we try to know in advance just what we are going to get but often find the sewage isn't that way, which puts the poor operator in a position where he has to handle that sewage in the summer and the fall and the winter, each season differently. The thing we must bear in mind is to always provide a factor of safety but you cannot get these things down to the nth degree of accuracy.

*Mr. McGuire:* Who is going to pay for the factor of safety?

*Mr. Emerson:* The point was raised, where do we go from here. You have to look at it from a practical standpoint, to which the State Departments of Health are coming more and more as to how much purification is required for the particular needs of each stream. We must develop first a means of determining a safe measurement for the particular method of treatment which is under consideration. We must estimate what it will do, and then apply that to the requirements of the stream, because most assuredly we are going to have to design in the future more on a dollar basis than we have. It certainly is a waste of public funds to provide a higher degree of treatment or purification than is required for the specific stream conditions. If old Dame Nature will pick up where you leave off and continue things nuisance free and without a menace to health, that is the cheapest way in the world to get that 2, 5, 10, or 20 p.p.m. effluent, or whatever the local conditions demand. You operators don't have to fight with the council to get the appropriation for the initial design as the engineer sometimes must do. That is the difficulty tomorrow.

*Chairman Mackin:* I think we appreciate your point of view, Mr. Emerson, but it is my feeling that perhaps we haven't done quite as much as we could. As sanitary engineers, we have been too willing to accept "no we can't afford it." I wonder if in the future it isn't going to be scrutinized pretty carefully as to whether or not some such improved form of treatment for almost every community in the country is indicated if they wish to keep their self-respect in our society. The discussion yesterday brought out the fact that our national income may level off at around 125 billion dollars, and I could conceive that even if the job is expensive, as long as it isn't out of line with our pocketbooks, it would be desirable to go much further in treatment. It has been done in the past, because communities often feel much better about doing a job to a greater extent even though it might not be absolutely essential. I feel that with high quality effluents going into most of our streams, the fauna and flora of those streams would change almost completely and certainly for the better. I make these remarks freely and without inviting any questioning of them, and you are all free to do likewise, but my mind just runs along those idealistic lines.

The pocketbook isn't so important as long as you don't go too far, and I am sure we have not gone far enough nor has the proper share of the tax dollar been spent for sanitary improvements that will produce the high quality effluent that science is capable of giving us in these days.

*Mr. Morris M. Cohn:* Mr. Chairman, I rise because yesterday afternoon I propounded a philosophy that with a national income of 125 billion dollars a year and with 100 billion dollars a year now being expended for the job of human slaughter, that there will come a time when we can expend a reasonable percentage of the national income for the job of protecting our nation's greatest asset, which is human public health. But if you recall, I tempered that idealistic viewpoint with one statement that attracted some attention and which caused people to buttonhole me last evening. I said this, "that the idealistic viewpoint as far as I was concerned was treatment for every gallon of sewage and industrial waste," and if I had said period thereafter, that would have been, in my opinion, an improper statement. But I went on and said, "commensurate with the needs of the stream," and I merely rise to second the feeling of Mr. Emerson that we must temper our idealistic viewpoints on treatment of sewage and industrial wastes by an intelligent appraisal of the needs of the stream into which these wastes are going.

In fact, I have often propounded the philosophy of fitting the stream to the effluent when we cannot fit the effluent to the stream. I have talked before several communities in the country where engineers with good intelligence have actually diverted more diluting water to a stream in order to permit the treatment plant to do a lesser job of purification. I speak particularly now of an interesting experience at Lockport, New York, where the diversion of water from a canal permitted the use of a primary treatment plant rather than a complete treatment plant. I merely offer this as further proof that the engineering intelligence of the future will prevent the wastage of public funds for the carrying out of treatment beyond the actual needs of the stream.

*Mr. Wm. A. Allen:* I think that we have heard this morning all the more reason why this group and the Federation should sometimes come out to the west and the southwest. All we hear about is diluting streams. We have no streams.

*Chairman Mackin:* That brings a thought to mind. We should look to the west for the future of secondary treatment.

*Mr. Allen:* I was about to mention that it is predicted that our whole climate is going to change. Perhaps some day you will have arid conditions. You may not have the streams and we will have them, and we will be fortunate and that will be your hard luck. I think perhaps we should look at the matter of sewage treatment not so much in the light of the receiving stream because there are some localities that do not have any.

*Mr. Lloyd Nelson (Washington, D. C.):* I am afraid Mr. Emerson and Mr. Cohn are perhaps not looking far enough ahead into the future in the attitude they are taking at present. I am very much in disagreement with the thinking we have had in our ears for a decade or more, that we are coming to a part of the development of our country at which we are leveling off. For example, that we are going to round off at perhaps 150,000,000 population. I think that is a very foolish idea and I think that by carrying on with the best known methods of sanitation, we can support a much larger population satisfactorily and look forward to a period of development as great as any we have had in the past in the United States.

*Dr. Hatfield:* May I support the proponents of more complete treatment? While costs may be higher, some figures I compiled several years ago showed that in Illinois we were completely treating sewage at about $1.00 to $2.00 per capita or about $3.00 or $4.00 per family per year. At that time I figured out that it did not equal the cost of toilet paper for a family for the whole year. Now we talk about these tremendous figures, thinking of how many million dollars it costs to build the plant, but we can certainly spend as much money for sewage treatment as for toilet paper!

*Chairman Mackin:* That, perhaps, suggests a new basis for the engineers to use.

I certainly want to thank you all for your attendance here this morning and your splendid attention. I shall now call upon Mr. Enslow to summarize this discussion.

*Mr. Enslow:* I will comment on two or three highlights of the remarks made and will begin with Mr. Walker's statement about dilution with recirculated effluent. I would like to consider dilution with stream water also. As I have often said, if I were a sewage plant operator and had a sewer going under a creek, I would punch a nice hole in the sewer and fix it so I could turn the creek into the sewer whenever I felt pleased to do so. I think 90 per cent of the sewage plant operators I have met would be pleased to do it at certain times of the year.

Mr. Walter Sperry has been doing that very thing for several years at Aurora, Illinois, and my guess is that he will continue doing it. It has helped him out a great deal by winning a $10,000 odor nuisance suit and in producing a better effluent from his sprinkling filters. I think that is a highlight.

Mr. Cohn mentioned the diversion of stream water for dilution of partially treated sewage as an adjunct to the sewage treatment plant. This might be done by developing reservoirs for that purpose. Pennsylvania is working in that very direction. It not only applies to domestic sewage but to industrial pollution also, in this case mine drainage in Pennsylvania.

Speaking on Mr. West's topic, I do not think anyone can help but be very highly impressed when they go to these plants that are using the Mallory method of control and finding out that they really are getting pretty good results. Here is something that has upset most of you here. It did me. You go to the Ann Arbor plant and you find a bulking sludge condition, the sludge going over the effluent weirs. The operator would then immediately test A to Z to determine if he had any dissolved oxygen in his aeration tanks. If he did not do this as a regular routine test, he probably would in any event just to make sure. We find four or five parts of dissolved oxygen. You say, "I have plenty of air. What could this be? The sludge is poisoned. What am I going to do about it?" He tries as many things as he knows how. The sludge continues to bulk. It may take three or four days to get it back on an even keel. As I understand, what they do when they have such a condition is to take as much sludge out of the process as possible, and get rid of that, they reduce the sludge blanket in the final tank to the minimum at which they can safely operate and increase the air. There you are. You have already four parts per million of dissolved oxygen and still in this case the remedy seems to be increasing the air and within an hour and a half the sludge in the final settling tank was down and well behaved, and the effluent was clear and you could see the sludge blanket. I must say when people can do something of that nature it is something to look at. You can't ignore it.

On the other hand, you heard Mr. West mention one case of 13,000 p.p.m. aeration solids. Well, that is an awful load of sludge, much more than we ordinarily conceive of but it worked in that particular case. We are a long way from solving the riddle of activated sludge plant control.

I can certainly appreciate the position of the operator from Camp Breckenridge. I realize his situation even though I have never seen his plant. His case is additional proof that there is much more studying to be done in activated sludge control methods.

We come to this critical question that Emerson proposed. I think we can look to operators like Mackin and Hatfield as the very life savers of sewage treatment, as we now know it today. I am telling you that if some of the expensive plants that have been built over this country had not had operators like Hatfield and Mackin, our hides would have been nailed to the door a long time ago as sanitary engineers. The plant would have been on the junk heap and our reputations would have been lost.

The public can be sold on good sewage treatment, but Emerson has a very important point, particularly at this time when we are talking about doing something tomorrow, and trying to do it right. That is to say, if you will take Schroepfer's plant up at Minneapolis, that is to my mind an outstanding plant. There was a place where all the evidence would seem to indicate activated sludge treatment or some secondary treatment, whether it be trickling filter or activated sludge. On the other hand, there was one original thought brought into the picture and the State Board of Health and the United States Public Health Service said, "We will try chapter one first," and chapter one was primary treatment. However, the design also provided for chemical treatment, and if this proved inadequate, secondary treatment was to be provided later. The answer is that the plant has been operated several years and they have not found it necessary to go beyond good primary treatment. That is good common sense and economics and it should be good sanitary engineering. I leave it to you gentlemen if we haven't got to think in those terms from here on.

## III. WARTIME OPERATING PROBLEMS IN MUNICIPAL AND ARMY SEWAGE TREATMENT PLANTS

Major Rolf Eliassen, Martin A. Milling, Edward C. Cardwell, and William J. Downer, *Leader*

*Chairman Mackin:* This topic will be of unusual interest. I take pleasure in presenting its leader, Mr. Wm. J. Downer, Chief Sanitary Engineer of the Illinois Department of Public Health and Technical Secretary of the State Sanitary Water Board.

*Mr. Downer:* My remarks will pertain mainly to the sewage treatment problems that have confronted the Department of Public Health in the past year. Owing to the fact that we have only two men in the central office who specialize in sewage treatment work and that they are unable to spend appreciable time in the field, we are not nearly as well informed on present day problems as we would like to be. Previous to the war, we had ten men engaged in sewerage and stream pollution work along with 32 district engineers, so our present situation will be apparent.

Accordingly, most of my remarks will be based on what we have heard, what has come to us by correspondence or what our two remaining sewage works engineers have learned in their very infrequent trips to the field.

The first and primary problem that we are up against in wartime operation is that of personnel. You heard something about it last Thursday afternoon. We have it here in Illinois. We have lost several of our good operators to the Army, the Navy, the Marine Corps, and the Coast Guard. We have lost them also to industry and to those war industries that pay much higher salaries. It has been necessary to replace these men to keep the plants going and you know as well as I what the replacements are to a large extent. A lot of the replacements need training in order to operate the plants satisfactorily and they look to the State Department of Health to give them the training. What can we do with only two trained men on our staff? So the plants must get along as well as possible under existing conditions.

Not only have many good operators left for more lucrative positions and for military service, but some cities and municipalities have felt free to make changes because of political reasons, which is to be deplored at this time.

From our standpoint, we are trying to do the best we can to train these new men but we just do not have the personnel ourselves to do it. We have been very fortunate, in some instances to be able to call upon some of our better sewage plant operators to give us a helping hand and they have kindly consented to do it and helped us greatly in this emergency.

I also do not overlook the point that many of our equipment companies have been very gracious and gone out into the field, especially where they have had equipment installed, and have helped operators in the proper operation of their plants.

Now the second item, besides personnel, is the general wear and tear and deterioration of equipment and of the plant structures. That would come whether we have a war or not, but probably more so because of the type of personnel we are getting into our plants who cannot appreciate what should be done to keep these structures in proper condition and the machinery properly repaired, lubricated and adjusted. A sewage plant operator, we will all agree, should have some mechanical ability, and a lot of the men that are being placed now know nothing about mechanical equipment or its proper care.

The third thing, and I am being very brief, is the problem of introduction of industrial wastes to many of our sewage treatment plants, such as oil, the by-products from cheese and milk products and also other war industries, as Dr. Mohlman described in his paper. You can appreciate how some of these problems would trouble even a good operator, and what happens when we have a poor operator!

As to the Army camps here in Illinois, I can give you no information because they give none to us. The only time we hear from the Army camp plants is when something goes radically wrong and they need some help. As far as Army camp plant operation is concerned, I will leave that to two of the other speakers on this panel.

I shall now call upon Major Rolf Eliassen of the Corps of Engineers, U. S. Army.

*Major Eliassen:* To everything that Mr. Downer has said, we can say amen, because the same things happen in Army plants but in a different way, perhaps.

In the first place, personnel is critical. Yes, we have a manpower shortage and Congress is clamping down on our expenditures to a considerable extent. We cannot pay the salaries that some of the industrial plants can pay to attract employees. Furthermore, we have been cut considerably in the number of personnel available for operation of utilities. This is the same story that is found in municipal operation.

We have had to solve the problem by holding a number of training schools at local universities. We have also recruited men from all over, many of whom had never before seen a sewage treatment plant. As Mr. Downer said, if we can get a man with some mechanical background and give him a little bit of training, we can make a good operator out of him in a reasonable length of time. We still have to exercise considerable supervision over a man of this type because he does not have the outlook of the person associated with the sewage treatment field for a number of years.

Our problems at some of these posts have been similar to those in municipalities on account of the increase in population. However, our population rises have been meteoric in nature at various times. As was mentioned the other day, very frequently higher authority makes a decision to double-bunk the barracks which means that twice the population can be accommodated almost over night. No time is available for increasing utilities facilities and, therefore, twice the load occurs on the water and sewage treatment plants.

Industrial wastes have been quite a problem at a number of posts. This is not ordinarily thought of in connection with Army wastes but some posts have special missions particularly those engaged in manufacturing. A number of different problems confront us from time to time.

One of the most interesting and the most perplexing of these problems was that encountered at an activated sludge sewage treatment plant. Large photographic laboratories were connected to the sewer. These laboratories discharged wastes containing silver and other reducing compounds such as hyposulphites. Efforts were made to blow air into the sewage to increase the dissolved oxygen content. At the same time these reducing compounds would utilize all of the dissolved oxygen with the result that no residual oxygen could be maintained in the mixed liquor for utilization by the bacteria in the activated sludge. We were applying as much as 4 cu. ft. of air per gallon of sewage and still getting nowhere. The net effect was to decrease the treatment on all of the organic wastes coming into the plant. It was felt better to give adequate treatment to this organic matter and by-pass the industrial waste entirely. The biological treatment plant would in no way treat these wastes except to decrease the oxygen demand. As a result, the stream took care of the photographic laboratory wastes and the activated sludge plant took care of the organic wastes.

All of the wastes were disconnected from the sewage except the X-ray laboratory at the hospital and the Post Exchange photographer. The quantity of photographic wastes from these two sources was so small that it did not effect the oxygen demand of the sewage to any appreciable extent. Everything went along smoothly until graduation of the Officers Candidate School when all of the proud mothers and fathers came to see their offspring with new gold bars on their shoulders. I do not know how many dozens of photographs were taken to the Post Exchange for developing at that time, but we do know that for several days following graduation no dissolved oxygen was found in the mixed liquor of the aeration tanks and the sludge bulked excessively. When these pictures were all developed, the plant operated to satisfaction again.

At another plant TNT wastes were discharged into the sewers causing some difficulties with the trickling filter plant. The wastes were diverted into a nearby lake and fish were killed near the outfall sewer. Experiments were conducted and it was found that activated carbon would remove the organic matter from these explosive wastes. However, for the sake of economy, the activated carbon had to be regenerated. This was done in a closed cell and worked fine until it was found that for complete regeneration the temperature had to be run so high that the whole mass exploded. Another method of carbon recovery had to be developed.

You see that problems of industrial wastes do come into the Army camp waste treatment picture as well as with all municipalities. No mention has been made of laundry wastes and grease which have created quite a problem at many posts: The amount of grease discharged at times has made the sewage look almost like packing house wastes. This is a familiar situation which has been spoken of by many people interested in the treatment of Army camp sewage.

Sludge drying beds have given us considerable difficulty. Some of the camps in the East have been located rather close to barracks and with limited room for expansion. Thus, we have not been able to resort to lagoons or other emergency methods of sludge disposal. The method developed by Mr. Sperry of Aurora, Ill., has been used with a great deal of success at a number of Army camps. That is, the addition of alum to the sludge as it is drawn to the beds. It does a remarkable job of drying and increasing sludge bed capacity and it has been a life saver to us until we could get additional sludge beds constructed.

You may not be very much interested in the subject of septic tanks and tile drain fields, but the Army has hundreds of these installations serving small outposts. Many of these tile fields have been installed in practically impervious soil and have had to be redesigned in order to accommodate the posts. Although we may be prone to think of large cities like Chicago and others, the sanitary engineer must be in a position to pay attention to sewage disposal facilities both large and small and to be able to dispose of the sewage without creating a nuisance under all conditions.

Conservation of critical materials has led to the use of wooden tanks in a number of instances. The shortage of seasoned lumber has led to embarrassing situations when trying to make tanks watertight. The use of green lumber did not permit necessary expansion to close all construction joints. Consequently much leakage occurred until the joints could be caulked with colloidal clay, oakum and asphaltic compounds.

On the whole, in spite of the many emergencies which have arisen, the Army has paid a great deal of attention to the treatment of sewage so that in most instances the receiving streams have not been damaged and we can point with pride to a number of streams which have been improved through the treatment of Army camp sewage.

*Mr. Downer:* Thank you, Major Eliassen. Now I wish to call upon Mr. Martin A. Milling, Senior Sanitary Engineer of the State Board of Health of Indiana.

*Mr. Martin A. Milling:* In order to understand better wartime operating problems at Indiana municipal and Army camp sewage treatment plants one must first know something about the number of sewage treatment plants, the kind of plants, and the population served by these plants. There are 126 sewage and industrial waste treatment plants in Indiana. They may be divided into three classes, namely, industrial and institutional plants, plants for Army camps and air bases, and municipal plants. There are 31 plants for institutions and for the treatment of industrial waste, 14 for Army camps and air bases and 81 for municipalities. There are 22 activated sludge type plants, 60 standard trickling filter type, 6 high capacity filter type, 22 plain sedimentation, 4 biochemical, 1 bio-activation, 6 sand filters, 1 magnetite filter, 2 contact beds, 1 neutralization plant and 1 with only coarse screens, making a total of 126.

About 1,127,640 people in the State are served by the municipal sewage treatment plants. This is 59.8 per cent of the urban population.

*Classification of Sewage and Waste Treatment Plants*

| Type of Plant | Number of Plants | | | Population | | Urban Pop. Served by Municipal S.T.P. |
|---|---|---|---|---|---|---|
| | Industrial Institutional | Sanitary Sewage | | 1940 Census | *Served by Plants 1943 | |
| | | Army and Air Bases | Municipal | | | |
| Activated Sludge | 6 | 2 | 14 | 884,278 | 794,500 | 42.1% |
| Biochemical | 1 | — | 3 | 107,122 | 49,500 | 2.6% |
| Bio-Activation | — | 1 | — | — | — | — |
| High Capacity Filters | 2 | 4 | — | — | — | — |
| Trickling Filters | 15 | 3 | 42 | 224,770 | 187,050 | 9.9% |
| Sand Filters | 4 | 2 | — | — | — | — |
| Magnetite Filters | — | — | 1 | 11,375 | 11,000 | 0.6% |
| Contact Beds | 1 | — | 1 | 3,075 | 2,000 | 0.1% |
| Plain Sedimentation | 1 | 2 | 19 | 54,748 | 33,590 | 1.8% |
| Coarse Screens | — | — | 1 | 97,062 | 50,000 | 2.6% |
| Neutralization | 1 | — | — | — | — | — |
| Total | 31 | 14 | 81 | 1,382,430 | 1,127,640 | 59.7% |

* Includes only the population served by plants now in operation.

| | |
|---|---|
| Urban population | 1,887,712 |
| Rural population | 1,540,084 |
| Total | 3,427,796 |

About 42 per cent of the urban population is served by activated sludge plants and about 10 per cent by trickling filter type plants.

At the beginning of World War II we found ourselves confronted with a number of problems without any past experience to fall back on for information and guidance. During World War I there were only five sewage treatment plants in Indiana and these were only of the septic tank variety. It is, therefore, understandable why, at the beginning of the war, many sewage works men were doubtful as to what would happen to the State's stream pollution abatement program.

One of the first problems at the beginning of the war was to come to an understanding with officials of army camps, air bases and ordnance plants as to what type of plant would be required to meet State laws and as to operating supervision of these plants. This problem was not found to be very difficult. In the first place local consulting engineers were employed to design most of the plants, and these engineers were sympathetic with the State's stream pollution abatement program.

After the plants were built the State was fortunate in being able to help place many locally trained operators in the plants to supervise their operation. It can now be said that very little additional stream pollution has been caused as a result of the discharge of sewage and industrial waste from war plants and camps into State streams.

Another problem that arose soon after the war started was that the construction on sewage treatment plants, which were not considered essential to the war effort, was stopped even though the construction on several of them was nearing completion.

There has been no real solution to this problem as yet. However, interested contractors and engineers are beginning to become active and it is hoped that at least some of the plants will be completed so that they can be placed in operation.

Another problem that came up soon after the war started was the demand on the part of some city officials to shut down their sewage treatment plants in order to economize by saving labor, electricity and the cost of operation. A newspaper in one of the larger cities came out with an editorial recommending that the sewage treatment plant be shut down. To combat this problem a publicity campaign was undertaken by plant superintendents, the State Sewage Works Association, and the State Board of Health, to impress upon the city officials and the public the importance of sewage treatment to the health and welfare of the people. Many plant superintendents distributed to the public small booklets describing their sewage treatment plants and the benefits derived therefrom. Sewage works meetings were also held in various parts of the State, all of which helped to acquaint the public as to the importance and necessity of sewage treatment. There have been no plant shutdowns in the State.

One of the biggest problems, at least worries, that we have had in Indiana has been about critical materials. The purpose of priorities is to distribute critical materials where they are most needed.

In order to find out the quantity of critical materials that have been purchased in the State since the beginning of the war, questionnaires were sent out to the superintendents of all the larger sewage treatment plants in the State. There were 54 of these questionnaires sent out to plants serving a population of 1,128,987, which is 63 per cent of the urban population of the State. Reports were received from 35 superintendents of plants serving a population of 969,622, which is 85 per cent of the population questioned. The results of these questionnaires showed that $36,937 has been spent for critical materials since the war started. This is less than 4 cents per person and, considering that Indiana has invested some $15,000,000 in sewage treatment plants, this is a very low figure.

There are a number of objections that have been raised to the priority system of distributing critical materials. One is that the regulations are too complicated and that there are too many changes. Another is that it works a hardship on the small plant operator who has no engineering and legal talent at his command for making out complicated application forms. Another objection is that the man who passes on the application is too far away and is not personally familiar with the need for the materials requested.

The critical material problem has been solved in several cases by the use of local machine shops for making machine parts and welding broken parts. This practice, however, has not always proven satisfactory. For example, in one city a machine shop attempted to make a bearing ring for a rotary distributor. This bearing ring was made out of soft material and was not in use but a few weeks until it was worn out. The part finally had to be ordered from the manufacturer and the outcome of it was that the plant was out of operation for a period of time. It was also a waste of material and labor.

Early in the war a Mutual Aid Plan was organized primarily for the purpose of listing surplus repair parts which could be used where needed in order to avoid the purchase of new critical materials. We have not had any major catastrophes in Indiana; however, Mutual Aid has already helped to a limited extent in at least one city. In this case a trained mechanic from one sewage treatment plant was loaned to another city for the purpose of making necessary repairs on a machine.

One solution of the critical material problem has been better maintenance. Machinery is gone over more often to see if it is properly greased and in good operating condition.

In some cases where the particular machine or part could not be purchased a substitute machine or part was used. This practice has not always proven satisfactory. In fact in many cases it has proven a gross waste of critical materials. In one instance that came to our attention only a small part was needed, but, not being able to get this part, it was necessary to purchase the entire machine, which by the way, was far inferior to the old one.

Indiana enjoys the distinction of having the third highest per cent employment increase in the country, being exceeded only by Michigan and Washington. This has resulted in many Indiana sewage works operators leaving their jobs for higher pay work in war plants. To help solve this problem the Indiana State Board of Health has acted somewhat as an employment agency in locating available operators. Valuable assistance in locating operators has also been received from the Central States Sewage Works Association through Mr. Mackin. Women have been employed in several of Indiana's sewage treatment plants as chemists, bookkeepers and secretaries.

It is hoped that out of the many operating problems that have arisen during World War II that we will at least have learned some lessons which we can pass on to future wartime sewage works operators of World War III. Some of these lessons are listed briefly as follows:

1. That sewage treatment is classified as one of the essential industries.

2. That complicated priority regulations are just so much scrap paper so far as the small sewage treatment plant operator is concerned. Large plants with highly skilled technical staffs, engineers, lawyers and maybe politicians, are likely to get more than their share of the critical materials.

3. That the useful life of machines, pumps, etc., can be extended several years if they are given proper care.

4. That it does not pay to make specialized machine parts in local machine shops. Such parts should be purchased from the company that manufactures the machine.

5. That better distribution of critical materials could be made if regulations were simplified and if Washington would work more through State and local governments.

6. That failure to make available repair machine parts often results in a waste of plant efficiency, labor and even of critical materials.

7. That women have proven to be good substitutes for men at sewage treatment plants as chemists, bookkeepers and secretaries.

*Mr. Downer:* Thank you Mr. Milling. At this time I would like to call on Mr. Edward C. Cardwell, Associate Sanitary Engineer, Truax Field, Madison, Wisconsin.

*Mr. Edward C. Cardwell:* Members of the Federation: I am a pretty small cog here after listening to these gentlemen, one covering all the camps from a particular Service Command and the other two gentlemen covering all the non-military camps in Indiana and Illinois. All I have is a small sewage treatment plant located at Madison, Wisconsin and Madison is part of the "Land of Lakes" which no one shall pollute. Therefore, we are forced to turn out a pretty good effluent—at least, we think it is.

Major Eliassen gave you a composite picture of interesting problems throughout his Service Command. I shall discuss a single plant of the trickling filter type.

Our flows are considerably over the per capita figures used in design and the sewage concentration is low for an Army camp but a little higher than domestic sewage. The B.O.D. ranges from 250 to 300 p.p.m. and the suspended solids from 200 to 250 p.p.m. The raw sewage contains about 1,800 pounds per day of B.O.D.

Our primary tanks are hopper bottomed. I have found that the hoppers must be pumped frequently for short periods. The primaries remove about 400 pounds of B.O.D. and about 800 pounds of solids daily. Our filters operate well, removing about 1,200 pounds of B.O.D. daily, although they are not heavily loaded. Due to the shortage of critical materials, we have no sludge collecting mechanisms in the flat-bottomed final settling tanks and we must pump them down at least weekly. Despite this, about 600 pounds of solids daily are removed by the final tanks. Our B.O.D. removals average about 22 per cent through the primary treatment, 91 per cent through the filters and 93.4 per cent through the plant. We are never below 90 per cent any more.

So much for the figures. Characteristic of a lot of army camps, we started operation in the middle of winter, in the month of December. It was a renovated plant and we had a hard time getting started. Sometimes we were getting only 80 per cent removal. As all operators know, you must take the plant as designed and make it operable and this is often not easy. I am not criticizing—merely pointing out that you may get many unexpected problems.

One of the features that we have found best was a change to a more rapid dosing cycle. As designed, the filter was dosed about 25 minutes each time but we have reduced the dosing tank until we now have a 5-minute dosage.

Another change was made in the post-chlorination procedure. We formerly applied about 100 pounds daily to the final tank effluent. Now, we chlorinate ahead of the final tank which has helped overcome the lack of sludge collection equipment.

Reducing the dosing tank cycle has helped to eliminate sedimentation in the dosing tank and has minimized septicity in the sewage. The original part of our plant is the old Burke plant built in 1914 and it comprised two stages of primary settling, a colloidal chamber and contact beds, all in series ahead of the trickling filters. You can see why it is important that we keep the sewage fresh.

We have not met very many pitfalls except we have fallen into the pitfall of grease, and we had grease in the digester, which caused much trouble. We had not heard about "super-heating" the digester at that time. It sounds very good, but we had to practice what we called a "flushing" policy and that consisted of building a raft inside the digester and scooping the scum out with pails. Anyway, we got it out and immediately the gas was released and the problem was over.

In conclusion, I would say that operation of the Army camp plants in our particular area was very comparable to municipal plants. I think we are doing our share in our part of the country to keep the effluents as clean as possible.

*Mr. Downer:* Thank you, Mr. Cardwell. Since the hour is late we must dispense with any discussion from the floor, which is regrettable. Before restoring the chair to Mr. Mackin, however, may I pass on a comment about grease control in Army camps that I heard this morning. It was suggested that automatic control would result if the mess sergeant were paid a few cents per pound for the grease that he salvaged in the kitchen. This might solve the problem to a surprising degree.

Mr. Mackin, the chair is yours.

*Chairman Mackin:* Thank you, Mr. Downer, for a most interesting discussion. We shall now hear from Mr. Lloyd Nelson of the War Production Board regarding a very significant topic of the times.

## IV. THE BROAD CONSERVATION PROGRAM OF THE WAR PRODUCTION BOARD

By Lloyd Nelson

*Special Consultant, WPB, Washington, D. C.*

*Mr. Nelson:* While sewage works are not directly involved in our conservation program, they can certainly be of help.

As the tempo of our war effort is increasing, demands for fuel and materials and equipment and manpower likewise increase, and to my mind, all of these things go back to that one question of manpower. It takes manpower to produce our fuel and transport it, to produce our equipment and process our materials. As the draft calls go out month after month, the manpower problem will be increasingly difficult, probably at least until the middle of the next year.

I was very much interested in some of the suggestions here. I know that in filter plant operation in the water industry, they are using quite a number of women operators and I presume the same could be done in sewage works. As men are called, in some cases their wives have been called in to help out under supervision, of course.

This broad conservation program is asking every citizen of the United States to stop waste and to conserve so as to save that fundamental manpower, to make our situation that much better. This might sound like a small program, but believe me, when you add up the savings through stoppage of waste in 30,000,000 homes in the United States, you will give a tremendous impetus to the war effort. It is estimated that if 18,000,000 homes which are heated with coal alone in the United States, would put into practice such simple "stop waste" conservation measures as learning how to fire the furnace properly, not overheating and opening the windows to cool the rooms off, as much as 18,000,000 or 20,000,000 tons of coal could be saved in home heating alone!

In the sewage works field your main use of electricity is in pumping, I presume. May I suggest that you call in the manufacturer's representative of the equipment you use and have him to check your method of operation to see if it can be operated more efficiently. Simple things, such as replacing the wearing rings in pumps at the proper time enable quite a large saving in power cost. This is money in your pockets and it is also a help to the war effort.

Might I also say that the War Production Board, in asking for conservation, is not asking anyone to stop necessary uses—only to stop unnecessary and wasteful uses. Certainly no one in the United States wants to use up something to no real purpose, just waste it. All that is being sought at the present time is that everyone co-operate in that type of program.

Turn out electric lights when you do not need them. It is estimated that such a simple thing as this will save as much as 75,000,000 light bulbs a year, and that means a saving in tungsten, which is extremely critical and is vitally needed in the manufacture of radar equipment for our armed services.

There are many other things you know about your own plants in which you can co-operate in the program better than I can tell you. I merely want to bring the program to your attention and ask your co-operation. Thank you.

*Chairman Mackin:* Thank you very much, Mr. Nelson. If there is nothing further to come before the meeting, I will declare it adjourned.

# Editorials

## THANKS TO THE CHEMICAL FOUNDATION

This issue of the *Journal* is notable for the fact that it is the *first* issue to be produced without some degree of participation by The Chemical Foundation of New York City, the institution which brought the Federation and the *Journal* into being. In view of the intensely important service rendered by Chemical Foundation and its modest, "behind-the-scene" role, a suitable acknowledgment is very much in order.

In March, 1928, the embryo Federation consisted of an Organization Committee headed by Charles A. Emerson, Jr., supplemented by a Committee of One Hundred comprising interested individuals from all parts of the United States. Progress was good until an impasse was encountered in the search for a publisher to undertake the printing and distribution of the proposed *Journal.* Then, through the good offices of Dr. Willem Rudolfs, Mr. W. W. Buffum became interested in the foundation of the Federation as a project for The Chemical Foundation and in May, 1928, a most unrestricted and liberal offer to underwrite the *Journal* was extended President Emerson and immediately accepted. Mr. Buffum was associated with Mr. Frances P. Garvan who served as Alien Property Custodian in World War I and the early funds made available for the sponsorship of the *Journal* by The Chemical Foundation came largely from the Imhoff patents which had been taken over by the Federal Government and assigned to the Foundation for the support of worthwhile scientific activities. Thus, Chemical Foundation takes a prominent place with such personages as C. A. Emerson, Jr., Willem Rudolfs, F. W. Mohlman, W. J. Orchard, Langdon Pearse, H. P. Eddy, George W. Fuller, John R. Downes, H. W. Streeter, John H. Gregory and others who were directly instrumental in bringing the Federation and its *Journal* into existence.

The generosity of the Foundation's original subsidy is apparent when the set-up of the first business office of the *Journal* is considered. Office facilities were provided in the Foundation headquarters and Mr. Buffum assumed the duties and responsibilities of Business Manager of the *Journal.* These duties included solicitation of subscriptions, solicitation and production of advertising, maintenance of mailing lists and financial accounts, and printing and mailing of the *Journal.* Finally, and of utmost importance, the Foundation undertook the obligation of meeting any deficit incurred in the entire venture. It may be of interest that the original agreement covered a period of but one year; yet Mr. Buffum continued to serve as Business Manager from May, 1928 to the time of his death in June, 1940, while the Foundation extended its participation to January, 1944.

At the death of Mr. Buffum in 1940, Dr. Rudolfs wrote fittingly of the work Mr. Buffum had performed in behalf of the Federation and the *Journal* (Volume 12, page 816; July, 1940):

"Those who have come in contact with Mr. Buffum can appreciate his work and encouragement to stimulate the development and research in sewage treatment. His identification with the *Journal* made it financially possible to reach a large number of sewage plant operators. His interest was an important factor in the rapid growth of sewage research, which had made this country the leader in the world. He was always ready to support any movement to fight diseases and secure cleaner streams. In the earlier years of the Federation his advice and help was an important factor in the rapid growth of Sewage Works Associations in this country. His business-like manner in handling the affairs of the *Journal,* his sympathy and support carried the *Journal* over several difficult periods."

The Foundation continued its service to the Federation and the *Journal* after Mr. Buffum's death, designating Mr. Arthur A. Clay to serve as Business Manager. Mr. Clay worked zealously and enthusiastically in the position and was particularly successful in giving impetus to the use of advertising facilities offered by the *Journal.* The first *Convention Number* was attempted at his suggestion and, under his guidance, proved to be an outstanding success.

In January, 1941, after Chemical Foundation had carried the *Journal* through its first twelve years of existence, the opening move was made to relieve the Foundation of this burden. It was then that the Federation Secretarial office was expanded to assume the bulk of the responsibilities of business management, but the Foundation was still retained to provide assistance in the mechanical production of *Journal* advertising. Mr. Clay's title was changed to Advertising Manager and the work was carried on under his supervision by Miss Gertrude R. Horan, his capable and efficient assistant. It is significant that more than 200 pages of paid advertising were carried in the *Journal* in 1943, an all-time high. Henceforth, all advertising functions associated with the *Journal* will be handled in the new Secretarial office of the Federation but Mr. Clay and Miss Horan kindly extended their assistance to include production of the January, 1944 issue in order that a minimum disruption of service would result during the transfer of the work.

At best, the writer can but echo the expressions of gratitude to The Chemical Foundation which are in the thoughts of Messrs. Emerson, Mohlman, Orchard, Rudolfs and others who have been so intimately familiar with the part taken by that agency in the development of the Federation. The writer can and does offer sincere thanks in his own right, however, for the courteous and complete cooperation that he has enjoyed during the past three years in his gradual assumption of the functions formerly provided so efficiently and unostentatiously by the Foundation. Every member of the Federation should likewise be grateful for the progress in the sewage works field that has come through such participation.

Chemical Foundation, the Federation thanks you, deeply and sincerely!

W. H. W.

## PAUL HANSEN (1879–1944)—IN MEMORIAM

Paul Hansen was born at Arlington, Va., on August 9, 1879, the only son of John and Pauline (Meyenberg) Hansen. His early education was in the public schools of Washington, D. C. In 1903 he was graduated from the Massachusetts Institute of Technology with the degree of B.S. in Sanitary Engineering.

After a year with the Massachusetts State Board of Health, he joined the Improved Water and Sewerage Work at Columbus, Ohio, and later, the Pittsburgh Filter Co. He was first Assistant, and later Chief Engineer of the Ohio State Board of Health, from 1906 to 1910. From August, 1910 to October, 1911, he was State Sanitary Engineer of Kentucky. From 1911 to 1915, he was Chief Engineer of the Illinois State Water Survey, lecturing also at the University of Illinois. In 1915, he became Chief Engineer of the Illinois State Board of Health, serving until 1920. During the first World War he served for 19 months (1917–1919) with the A. E. F. as a staff officer with General Pershing, on water supply.

In May, 1920, he became a member of the firm of Pearse and Greeley, later known as Pearse, Greeley and Hansen, and since 1930 as Greeley and Hansen. In the course of his professional work he was engaged in the design and construction of numerous water supply and sewerage works, including projects for New York City; Boston, Mass.; Chicago, Ill.; Buffalo, N. Y.; Toledo, Ohio; Peoria, Ill.; and Philadelphia, Pa. He specialized in water purification and became an expert witness on water rates and valuation of water works. During the present World War he was concerned with consulting work for the War Department.

In 1905, he was married to Alison May Scott. He is survived by his widow, a daughter, Elizabeth Scott (Mrs. Henry Pope), and a son, Dr. Paul Scott Hansen, together with five grandchildren.

Among the earlier achievements of his career, he esteemed highly the organization of the public health engineering work for the State Boards of Health in Kentucky and Illinois. In the 40 years of his professional life he accomplished his ambition and became one of the prominent sanitary engineers in the United States. He was a skillful and resourceful engineer, and withal a student of human relations. Traveling widely in his professional work, he possessed a large circle of friends. He was helpful in the technical societies and presented papers which attracted attention. His works will live after him as a worthy monument.

Those of us who knew him well mourn the loss of a firm friend. His kindly humor enlivened many a meeting. To his wife and children, who survive, we extend heartfelt sympathy in their bereavement.

LANGDON PEARSE

# Proceedings of Member Associations

## NEW YORK STATE SEWAGE WORKS ASSOCIATION

**Sixteenth Annual Meeting**

**New York City, January 20–21, 1944**

The sixteenth annual meeting of the NYSSWA was held in New York City on January 20–21, 1944, with headquarters at the Hotel McAlpin. About 245 members and guests were registered at what turned out to be a most interesting and well attended meeting.

On January 20, 1944, the members of the NYSSWA were guests at the Sanitary Section meetings of the ASCE. The program for the ASCE included committee reports on "Sewerage and Sewage Treatment," "The Advancement of Sanitary Engineering," "Operations of the Committee for Sanitary Engineering of the Natural Research Council," a paper on "Plans for Post War Sanitary Engineering Works by the City of New York," an address on the work of the Committee on Water and Sewage Works Development, a symposium on engineering phases of Malaria Control in War Areas, the challenge to the sanitary engineer in regard to the return of tropical diseases and a paper on the "Impact of War on Chicago's South District Filtration Plant."

At the Executive Committee meeting of the NYSSWA the evening of January 20, 1944, William H. Larkin, District Sanitary Engineer, New York State Department of Health, was elected president for the year 1944 and Dr. George E. Symons, Associate Editor of *Water Works and Sewerage,* was elected vice-president. A. S. Bedell of the New York State Department of Health, Albany, New York, was reappointed secretary-treasurer. J. C. Brigham also from the Department of Health, Albany, New York, was reappointed assistant treasurer and A. W. Eustance, district sanitary engineer of the New York State Department of Health, Geneva, New York, was reappointed assistant secretary for the year 1944.

Charles L. Walker, Professor of Sanitary Engineering, Cornell University, Ithaca, New York; Uhl T. Mann, Superintendent, Sewage Treatment Plant, Cortland, New York; and Henry M. Rath, Chief Operator, Tallmans Island Works, New York City, were elected to the Executive Committee of the NYSSWA for a term of three years. Retiring members from the Executive Committee are W. L. Malcolm, Ithaca, E. C. McKeeman, Freeport, and Charles R. Velzy, New York City.

At the general business meeting on Friday, it was noted that the association now has an active membership of 590 with five local sections whose members number 180. The reports of the activities of these local sections, as well as of the various standing committees of the Association, were presented and discussed at the meeting.

W. H. Wisely, the Secretary, Editor and Advertising Manager of the Federation of Sewage Works Associations, spoke on Federation Affairs. Mr. Wisely advised that Dr. F. W. Mohlman, former editor of the *Journal,* has agreed to continue in an advisory capacity and that there will be no change in the policy of the *Journal.* The Federation, according to Mr. Wisely, is not just a journal publishing association but a service agency with its meetings, committees, etc., and his office is ready and willing to serve in any capacity within his power.

Mr. Wisely also spoke on the war time responsibility of the members of our profession advising that we should not lower standards because of present conditions but should take a lead in postwar planning work and maintain pride in our work now more than ever before.

The first paper to be given at the technical session on Friday morning was entitled, "Sewerage Developments and Prospects in Canada," and was presented by Albert E. Berry, Director, Sanitary Engineering Division, Provincial Department of Health, Toronto, Ontario, Canada. In this exceedingly interesting paper, Dr. Berry outlined methods of sewage disposal employed in Canada. He stated that there were some 1,300 water systems and 500 sewer systems in Canada but only 115 sewage treatment works. He is anticipating major developments in sewage disposal systems and expects that water and sewerage developments will take first place in the postwar planning program. Dr. Berry estimated that about forty million dollars are needed for new works in Ontario province alone. The method of financing these postwar projects whether by the local governments or by the provinces has not as yet been decided.

In the discussion of this paper, Mr. Donaldson of New York City, asked whether Canada had a definite target for the postwar program. Dr. Berry stated that the answer was unfortunately no. They had not as yet reached that stage. The question of the use of sludge was discussed and at several places in Canada the wet sludge is carted from the plants in tank trucks and spread over the ground for the use of field crops. No sludge has been used for gardens. Mr. Welsch of Nassau County asked Dr. Berry concerning the method of proportioning costs if several municipalities were served together by one system. Dr. Berry advised that the division was made on the basis of assessments. In answer to a question concerning water use, Dr. Berry answered that the maximum consumption was about 200 gallons per capita per day, the average being about 100 and the minimum being about 20 to 30 gallons. In Canada the provinces have the power to require municipalities to provide necessary sanitary installations and the question was asked whether this power could be used to require municipalities to provide plans for such installations under the postwar set-up. Dr. Berry stated that this power had not been used to that end because normally the cost of the plans are sufficiently low so that the municipality could finance that cost without any difficulty.

At the end of his paper Dr. Berry stated that this, to him, was a return engagement because President Smith and Secretary Bedell had attended the meeting of the Canadian Sewerage Works Association last summer.

The second paper in the morning session was on "Controlled Digestion," and was given by Harry E. Schlenz, Pacific Flush Tank Company, Chicago, Illinois. In this paper, Mr. Schlenz pointed out the results of experiments using ammonia nitrogen in the control of sludge digestion. There was considerable discussion of this paper and Dr. Rudolfs stated that the supernatant liquor concentration depended on the time and material in the sludge digestion tank. He thought it would be better to increase the digestion capacity and do away with numerous gadgets because in his opinion poor supernatant was caused by inadequate digestion space. Another comment from the floor was that the addition of ammonia might have a good deal of effect in certain industrial wastes but that sewage sludge was an entirely different story. A description was given of the operation of the digestion tank at Jamaica where excellent digestion was obtained without the addition of any chemicals, except a very little lime. Professor Fair stated he did not believe that now is the time to use nitrogen for this purpose because of the critical need of nitrogen in the war effort. In answer to the comment on lack of sludge digestion capacity, Mr. Schlenz stated he did not believe that adequate digestion capacity was the answer because one of the plants where he experimented had adequate sludge digestion capacity with no active digestion prior to the adding of the ammonia nitrogen.

The afternoon session opened with a symposium on grease removal. The first paper on this symposium was entitled, "Grease Interceptors for Use in or near Houses and Restaurants," and was given by F. M. Dawson, Dean of Engineering, University of Iowa, Iowa City, Iowa. This paper outlined the results of experiments undertaken by the writer to test various types of grease traps. The speaker pointed out that a successful grease trap must have adequate capacity, be properly baffled and be so placed as to be readily cleanable because unless a grease trap is cleaned, it is of absolutely no use.

The next paper was entitled, "Experiences of a Large City with the Grease Removal Problem," written by C. E. Keefer, Associate Engineer, Bureau of Sewers, Baltimore, Maryland, but given by Albert L. Genter, Consulting Engineer, Baltimore, Maryland.

The third paper was entitled, "Grease Removal Ordinances and Grease Problems in Sewer Maintenance," prepared by Morris M. Cohn, Sanitary Engineer, City of Schenectady, New York. In the absence of Mr. Cohn, this paper was read by A. W. Eustance, Assistant Secretary.

The last paper of the symposium entitled, "Utilization of Sewage Grease," was given by Wellington Donaldson, Chief, Bureau of Sewage Disposal Design, Department of Public Works, New York, New York. Mr. Donaldson described the method of grease utilization in the City of New York. Grease collected from the tops of settling tank is being sold to a rendering plant and such grease is used in the manufacture of soaps and similar products.

Following these papers, Messrs. Dawson, Genter and Donaldson acted as a board of experts to answer questions from the audience.

Doctor Rudolfs asked Mr. Dawson why he had chosen a fat content of 2½ per cent for his tests and Mr. Dawson replied that was just an arbitrary figure but was somewhere near the fat content in the wastes from restaurant dishwashing equipment. Mr. Dawson had given a figure of 90 per cent removal of floating material and Doctor Rudolfs desired to know whether this was 90 per cent of the total grease content. The answer to this question was that it was 90 per cent of the total grease added in their experiments. Major Eliassen stated that Army installations affected about 50 per cent removal of the grease. The main trouble with such installations has been that they have either not been properly cared for and were neglected, or else they were cleaned out too thoroughly, the grease being dumped down the sewer. Mr. Enslow stated that he had never until recently seen a grease trap which was at all satisfactory but at last he had found one which worked fairly well. In describing this, he stated that it was simply a cistern built into the ground, shaped something like a milk bottle, but egg shaped at the bottom. This type of trap seemed, to him, particularly good, especially because of the small neck which made it easy to remove the floating grease. Mr. Pincus of New York City discussed the danger in the transporting of the liquid grease from the New York City plants through the streets and stated that his department was recommending the processing of the grease at the various sewage plants. This subject of grease was further discussed by Mr. Van Kleeck, Major West, Dr. Gehm and Professor Fair.

This symposium on grease removal turned out to be a most interesting affair and it was regretted that Mr. Cohn of Schenectady was unable to be there to participate.

The final paper of the technical session was entitled, "The Determination of Grease in Sewage," prepared jointly by W. D. Hatfield, Superintendent Sanitary District of Decatur, Illinois, and George E. Symons, Associate Editor, *Water Works and Sewerage,* New York, New York, and was given by Dr. Symons. In giving this paper, Dr. Symons stated that it was more of a report of the committee's work in selecting a standard method for grease determination to be included in the ninth edition of Standard Methods. He stated that the comparative data of the several tests did not yield results which would make a definite selection of one method unquestionable but the committee was obligated to choose one method which they did, namely, the Hurwitz-Ludwig of grease determination.

There was considerable discussion on this paper because present in the audience were Major Eliassen, Mr. Schulhoff and Dr. Gehm, all three of them having done considerable work on this problem.

The technical session was adjourned at 4:40 P.M.

On Friday evening the members of the NYSSWA and the ASCE enjoyed the usual annual banquet and were greeted by Malcolm Pirnie, President-Elect of the American Society of Civil Engineers. Since the noon luncheon meeting of the NYSSWA was not held this year, the presentations of the NYSSWA awards were made at the banquet.

The Kenneth Allen Memorial Award, for the most meritorious paper of an engineering or research nature, was awarded jointly to Major Eliassen and H. B. Schulhoff for their work on determination of grease in sewage which was set forth in a paper, "Grease Extraction from Sewage and Sludge." The award was made by George E. Symons, a member of the Kenneth Allen Award Committee and Vice-president of the NYSSWA, and the acceptance was made by Major Eliassen, who introduced Mr. Schulhoff.

Edward J. Smith, the retiring President, was presented with the gold key bearing the emblem of the Association by Mr. William H. Larkin, President-Elect.

The guest speaker of the evening was Edward J. Cleary, Managing Editor, *Engineering News Record,* New York, New York, who spoke on "Wartime Engineering in South America." This was an exceedingly interesting discussion and was illustrated by numerous slides. In his paper, Mr. Cleary praised the work of the engineers from the United States who are now in South America, particularly those engaged in sanitary work. He pointed out that the problem of sanitation in South America is entirely different from the problem in this country and that much simpler methods of sewage disposal are employed. He also mentioned the problem of construction in South America where much of the work is still done by hand labor, which required that engineers from this country make considerable adjustments in their mode of thinking in order to successfully work in South America.

William J. Orchard as a master of ceremonies very graciously introduced the various speakers and provided some very enjoyable entertainment in the typical "Bill" Orchard manner.

As was the case last year, the Saturday inspection trip was not undertaken because of transportation difficulties.

The next meeting of the association will be held in Syracuse at the Hotel Syracuse on June 16 and 17, 1944.

A. W. Eustance, *Assistant Secretary*

## MEMBER ASSOCIATION MEETINGS

| *Association* | *Place* | *Date* |
|---|---|---|
| Michigan Sewage Works Association | Michigan State College, East Lansing | Apr. 5–6 |
| Pacific Northwest Sewage Works Association | Olympia, Washington | May 11 |
| Florida Sewage Works Association | Daytona Beach, Fla. | May 17–19 |
| Maryland-Delaware Water & Sewage Association | Lord Baltimore Hotel, Baltimore, Md. | May 19–20 |
| Central States Sewage Works Association | Oshkosh, Wis. | June 20–22 |
| California Sewage Works Association | Fresno | June 22–25 |
| Iowa Wastes Disposal Association | | June |
| Federation of Sewage Works Associations | Wm. Penn Hotel, Pittsburgh, Pa. | Oct. 12–14 |
| Pennsylvania Sewage Works Association | Wm. Penn Hotel, Pittsburgh, Pa. | Oct. 12–14 |

# Federation Affairs

## MILLING AND DE MARTINI WIN 1943 MEMBERSHIP PRIZES

For sterling service in the enrollment of new members in their respective Member Associations during 1943, Martin A. Milling (Central States Sewage Works Association) and Frank E. De Martini (Federal Sewage Research Association) have each been awarded a $25.00 denomination, Series E, War Bond as joint winners of the Federation's 1943 membership contest. Rules of the contest, which closed on December 31, 1943 (see *this Journal,* May, 1943, page 532), provided that duplicate prizes were to be awarded in case of a tie. Messrs. Milling and De Martini each secured 35 new members during the year.

Mr. Milling's efforts were in large measure responsible for the advance of the Central States Association into first place as the largest Member Association in the Federation in 1943. He, together with several other workers under the leadership of Secretary John C. Mackin, boosted that organization from a total of 426 members in 1942 to 510 in 1943, a gain of 84 for the year.

Mr. De Martini's accomplishment is remarkable in that he almost singlehandedly increased the membership of the Federal Sewage Research Association from 48 members in 1942 to 88 members in 1943, a gain of 82 per cent. As Secretary-Treasurer of his Association, he is to be further commended for the fact that only one of the 48 members in 1942 failed to renew for last year.

Honorable mention to other contestants goes to J. M. Schirk of the Rocky Mountain Sewage Works Association and A. W. Eustance of the New York State Sewage Works Association.

## FIFTH ANNUAL MEETING TO BE HELD AT PITTSBURGH

Preliminary arrangements for the Fifth Annual Meeting of the Federation to be held at the Hotel William Penn, Pittsburgh, Pa., on October 12–14, 1944, were recently completed by the Hotel Arrangements Committee, comprising F. S. Friel, Arthur T. Clark and W. H. Wisely. Precautions have been taken to preclude any conflict with other conventions such as occurred at Chicago in 1943.

The Pennsylvania Sewage Works Association will be host to the Federation. Mr. L. S. Morgan, District Engineer of the Pennsylvania State Department of Health, stationed at Greensburg, Pa., has accepted appointment as Chairman of the General Arrangements Committee.

## WANTED—SEWAGE WORKS ACCIDENT REPORTS

The Sewage Works Practice Committee, under chairmanship of Morris M. Cohn, has appointed a sub-committee to prepare a Chapter on "Occupational Health Hazards in the Operation of Sewerage Systems," for the Manual of Practice now under preparation.

This committee is very desirous of obtaining information on serious accidents in sewers, in sewage pumping stations and in sewage treatment plants occurring in recent years, especially those which resulted in the death or permanent disability of workers or which resulted in a fire or explosion.

Will any member of the Federation having information on such accidents send at once the name of the community, the nature of the accident, the approximate date of the mishap, and its cause, if known, to the committee's chairman: LeRoy W. Van Kleeck, Senior Sanitary Engineer, Connecticut State Department of Health, State Office Building, Hartford, Connecticut.

# Reviews and Abstracts

H. Gladys Swope

## T.N.T. WASTE

By Stuart Schott, C. C. Ruchhoft, and Stephen Megregian

*Industrial and Engineering Chemistry,* 35, 1122–1127 (Oct., 1943)

Liquid waste from the manufacture of T.N.T. is made up of the acid waste from the washing processes, sellite waste from the sulfite treatment and washing and cooling water. The table shows analysis of waste from three sources:

| Plant | Color P.P.M. | Odor Conc. | pH | Parts Per Million | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Acidity Methyl Red | Nitrogen | | | $SO_4$ | Solids | | | | Oxygen Cons. |
| | | | | | | | | | Total | | Susp. | | |
| | | | | | $NH_3$ | $NO_2$ | $NO_3$ | | Vol. | Ash | Vol. | Ash | |
| A | 7,100 | 70 | 2.4 | 291 | 5.3 | 15 | 107 | 672 | 1,004 | 1,273 | 22 | 144 | 795 |
| B | 6,300 | 16 | 2.7 | 134 | — | 20 | — | 604 | 868 | 1,123 | 14 | 15 | 551 |
| C* | 34,000 | 11 | 1.2 | 3,230 | 2.8 | 62 | 310 | 2,923 | 5,490 | 4,685 | 17 | 0 | 1,057 |

* No cooling water included.

The analyses indicate that the mixed composite waste has a low pH and is relatively high in total solids, sulfates and oxygen consumed (acid dichromate method). Red water (sellite waste) has a pH of 8.0 or higher, no odor, and is 3 to 6 times as concentrated in total solids, oxygen consumed, nitrites and nitrates. The color of the red water waste ranges from 100,000 to 300,000; that of the mixed composite waste ranges from 7,000 to 35,000.

### Treatment Processes

*Biological Treatment.*—Biochemical oxygen demand measurements to determine the extent to which these wastes can be purified in a stream or in a biological treatment plant resulted in no oxygen depletions during the 5-day, 20° C. test in concentrations up to 8 per cent of waste. In concentrations of 10 per cent the depletion obtained in 5 days was less than that of the control. These observations indicate that 10 per cent or more of the waste interferred with normal biochemical reaction. Furthermore, long-time studies (129 days) indicated that the salts of the nitrotoluene sulfonic acids in these wastes cannot be oxidized biochemically and that therefore self-purification of such wastes cannot be expected following discharge into a stream.

*Effect of Waste on Activated Sludge Purification.*—Tests to show the effect of these wastes on the activated sludge process indicated that they interferred definitely in sewage-waste mixtures containing 5 per cent or more of T.N.T. waste. The data collected showed a decrease in solids content of the sludge, a reduction in B.O.D. removal efficiency and loss of nitrification qualities of the sludge.

*Effect of Waste on Trickling Filters.*—Trickling filters were capable of handling up to 10 per cent of T.N.T. waste without appreciable loss in efficiency. When dosed with sewage containing 25 per cent waste, there was a marked decrease in B.O.D. removal.

In neither the trickling filter nor the activated sludge process was the color of the waste reduced appreciably.

*Chemical Treatment.*—Dosage with copperas, lime and caustic soda in amounts as high as 58 grains per gallon failed to show any satisfactory reductions of oxygen consumed, or color. Activated carbon up to 2,000 p.p.m. produced no reduction in oxygen consumed values. Ozonation for color removal failed to produce any significant effect. Distillation experiments indicated that a large percentage of the oxygen consuming organic matter remains in the residue regardless of the pH to which the waste is adjusted.

### Reduction of Nitro Compounds

Reduction of nitro compounds to amino sulfonic acids with acid and zinc, followed by biological treatment, indicated that the compounds formed by reduction were no more amenable to biological attack than the original material. Also chemical treatment of the reduced material showed no improvement over treatment of the original material with chemicals.

Electrolytic reduction for 24 hours did effect a 50 per cent removal of color and suggested possibility of greater removal with prolonged electrolysis.

### Color Removal

Attempts to extract the color from T.N.T. wastes with organic solvents were unsatisfactory in both acid and alkaline solution. Amyl and butyl alcohols extracted some color from the acid wastes but not from the red water.

Large doses of activated carbon (5 to 10 grams per liter) when boiled for 15 minutes with red water effected a satisfactory removal of color. The dose and treatment however are impractical. In doses of 10 grains per gallon, activated carbon was effective in removing the color from the combined waste diluted to 0.5 per cent. Suspensions of the carbon and waste were mechanically stirred for 15 minuutes and filtered.

Chlorination or bromination of wastes offers the only satisfactory and economical means of color reduction. Extinction values obtained by spectrophotometric methods showed definite decrease between treated and untreated dilutions. Chlorine was added in amounts up to 18 p.p.m.

### Tastes

Cincinnati water containing as much as 1,000 p.p.m. of combined T.N.T. waste tasted no different than tap water. Water containing 1,000 p.p.m. of waste and 1 p.p.m. of chlorine showed a definite enhancement of taste.

E. Hurwitz

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## GLUTAMIC ACID CONTENT OF STEFFEN'S WASTE

By David O'Day and Edward Bartow

*Industrial and Engineering Chemistry*, 35, 1153 (Nov., 1943)

Studies to determine the variations in the glutamic acid content of Steffen's waste and the reasons for these variations yielded no definite results but indicated that variations may be due to geographical locations and seasonal changes in temperature which effect the quality of the beet crop and to slight operational difficulties in the beet sugar refineries.

Steffen's waste from 22 sources in California, Colorado, Wyoming, Idaho, Iowa, Michigan, Montana, Nebraska, Ohio and Utah were analyzed. Yields of glutamic acid varied from 1.21 per cent to 6.13 per cent (1938 campaign) with the highest yields from factories in the midwestern states and California.

The method of recovery of glutamic acid from Steffen's waste was improved over that suggested by Benninghoff and Redmanbby using an extraction process to remove glutamic acid hydrochloride from the crude inorganic salts without the excessive use of water.

Steffen's waste is the waste water formed by the precipitation of tricalcium saccharate and the decomposition of this precipitate to sugar in the process of manufacturing sugar from beets. It contains several organic compounds extracted from the beets and some inorganic material originating both from the beets and from the manufacturing process. The amount of valuable constituents is low and this is recoverable only after the removal of large volumes of water.

E. HURWITZ

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## DISPOSAL OF CITRUS WASTES

BY HOWARD W. HALL

*Civil Engineering*, 14, 15–17 (Jan., 1944)

The production of citrus fruits has increased materially during the past twenty years, resulting in greater quantities available for processing. During the past ten years large plants for processing have been built. It is estimated that more than 800,000 tons of fruit are processed each year at the present time. The processing results in over 400,000 tons of waste products plus the water used in their disposal.

In canning, the waste products amount to approximately 60 per cent of the total weight of fruit. A typical analysis of citrus peel is shown in the following table.

*Analysis of Waste Citrus Peel, Dry Basis*

| Material | Crude Protein | Crude Fiber | Ether Extract | Nitrogen Free Extract | Ash |
|---|---|---|---|---|---|
| | Per Cent | | | | |
| Grapefruit-canning waste | 5.3 | 13.0 | 1.2 | 75.9 | 4.6 |
| Lemon residue | 9.87 | 16.7 | 0 | 68.5 | 4.9 |
| Orange residue | 5.8 | 10.0 | 2.4 | 77.7 | 4.0 |

In recent years some of the larger canneries have installed facilities for drying citrus peel and converting it into stock feed. Others have discharged the liquid and solid wastes to large storage beds. Here the liquid portion was allowed to evaporate or seep away, and the residue material was removed for use as fertilizer when partially dry.

Cannery wastes disposal is discussed in a bulletin of the Department of Agriculture, Bureau of Agricultural Chemistry and Engineering, "Experimental Treatment of Citrus-Cannery Effluent in Florida," subtitle, "Food Research Unit Contribution No. 513." Five methods are discussed, as follows: (1) Emptying into lakes, (2) handling by city sewerage systems, (3) primary settling tanks, (4) flooding on waste lands, and (5) disposal in tidewater rivers. It is pointed out that when handled by city sewerage systems, such wastes have caused damage to pumps and piping, foaming in Imhoff tanks, and clogging of sand beds. Most municipalities are reluctant to handle these wastes. It was noted in the use of primary settling tanks that the material showed little tendency to flocculate and settle. Addition of chemicals to help flocculation was not helpful. No significant improvement in the 5-day B.O.D. value is shown by filtering the wastes.

In the manufacture of chemicals there are end liquors that must be disposed of, in addition to the peel and fiber. As with canning wastes, drying of the material for use as stock feed has reduced quantities for disposal. The following table shows a typical analysis of liquid effluent from a chemical manufacturing plant.

*Analysis of Liquid Effluent from Plants Manufacturing Chemicals from Citrus Fruits*

| | Per Cent of Total Solids | P.p.m. |
|---|---|---|
| Total solids | 100.00 | 18,918 |
| Total solids ash | 18.85 | 3,566 |
| Dissolved solids | 81.74 | 15,464 |
| Dissolved solids ash | 16.33 | 3,090 |
| Suspended solids | 18.26 | 3,454 |
| Suspended solids ash | 2.52 | 476 |
| Total nitrogen | 1.48 | 280 |
| Crude protein (N × 6.25) | 9.26 | 1,750 |
| Nitrogen free extract | 60.90 | 11,522 |
| Pectin (dispersed in filtered portion) | 10.68 | 2,020 |
| Crude fiber | 10.98 | 2,077 |
| Oxygen consuming | | 4,800 |

A typical method of disposal consists of screening all wastes through rotating screens (0.050-inch mesh) and depositing the screened solids in storage tanks where they are allowed to disintegrate. Liquid resulting from the disintegration process is pumped to settling beds along with the screened effluent. The beds, large natural sand and gravel filters, are filled to a depth of about 2.5 feet. When the water has seeped away and deposited solids, largely cellulose, have dried they are raked off and burned.

T. L. Herrick

## SLUDGE DISPOSAL AT HORSHAM

By P. S. Browne

*The Surveyor,* 102, xii (Oct. 1, 1943)

The article describes the operation of a Porteous sludge disposal plant at Horsham. (For description of the plant see *The Surveyor,* June 3, 1938.) The plant has a capacity to treat 6,000 gallons per day of raw sludge.

Treatment consists of heating the sludge, which has previously been disintegrated by a mechanical device known as a Hathorn Davey disintegrator, to a temperature of 360° F. for half an hour, decanting the supernatant and pressing the residue without the aid of chemicals in sludge presses. The resultant sludge is stated to contain about 40 per cent moisture.

Raw sludge is pumped to an overhead supply tank, being disintegrated on the way to the tank. A second pump takes sludge from the supply tank and forces it through a heat exchanger into sludge heaters. The raw sludge passes through the outer tube of the exchanger; the inner tube of the exchanger contains sludge from the sludge heaters. Heat from the heated sludge is thus transferred to the raw sludge. The process of exchange preheats the raw sludge to 310° F. and cools the heated sludge to 150° F.

There are three sludge heaters, each designed to treat 250 gallons per batch, and each heated by a steam jet. As one heater is being filled, another is being emptied through the heat exchanger, and the third is being heated. The heated sludge is forced through the exchanger by the steam pressure in the heater.

The filter press cake is further air dried and then used as fuel in the boiler along with coke.

K. V. Hill

## FROM WATER LIQUORS TO WAR ALCOHOL

By John R. Callaham

*Chemical and Metallurgical Engineering*, 50, 104–107 (December, 1943)

The first successful plant in North America to produce alcohol from waste sulfite liquor is located at Thorold, Ontario, Canada, and is operated by the Ontario Paper Company. The plant was originally designed for an annual output of 600,000 U. S. gallons of 190 proof alcohol but process improvements have increased this to 800,000 gallons. This is enough alcohol to produce two million pounds of Buna S rubber.

The process involves the following steps: (1) waste sulfite liquor from the pump mill is cooled, aerated for $SO_2$ removal and neutralized with lime to a degree suitable for subsequent fermentation ($pH = 6.5$); (2) lime sludge is separated and the liquor is pumped to the fermentation tanks where yeast and a trace of nutritive salts are added; (3) the fermented liquor is run through centrifugal separators which remove the yeast; and (4) the clarified liquid contains about 1 per cent alcohol which is recovered by fractional distillation.

The yeast recovered from the separators is re-used in the next fermentation cycle.

Projected manufacturing costs for alcohol production employing this process indicate an approximate direct cost 12.4¢ per gallon for plants of average size.

There are three photographs of the alcohol plant and one flow sheet.

Paul D. Haney

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## PREDICTING FLOW–FRICTION DATA FOR SLUDGES

By Joseph D. Parent

*Chemical and Metallurgical Engineering*, 51, 101–103 (January, 1944)

Two methods of correlating plastic flow data are presented. One method involves the use of tabulated data or graphs showing the relationship between velocity of flow and apparent viscosity for both streamline and turbulent flow. For each range the viscosity may be expressed as a function of velocity and simple equations derived for both types of flow. The usefulness of this method is limited by the fact that it is necessary to have viscosity and velocity data before friction losses may be computed and by other factors. Hatfield has reported viscosity data on sewage sludges in the Sewage Works Journal, 10, pp. 3 and 272 (1938).

A second method of attack leads to a complex equation for evaluating friction loss which, however, can be solved graphically. This equation is limited to the laminar flow range. For the turbulent range the author recommends the use of the method described by Babbitt and Caldwell in *Bulletin* 323, Illinois University Engineering Exp. Station or "The Flow of Muds, Sludges, and Suspensions in Circular Pipe," *Trans.* Am. Inst. Chem. Engrs., 37, 237 (1939).

Paul D. Haney

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"The Application of Ferric Salts in Water and Sewage Treatment." Francis K. Burr, pp. 347–51.

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"Disposal of Sludge in Small Plants." G. A. Parkes, pp. 384–85.

"An Easier Method For Determining Suspended Solids." Alice L. Mathis, pp. 386–87.

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# FEDERATION OF SEWAGE WORKS ASSOCIATIONS

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Any individual desiring to affiliate with the Federation as an Active Member, may do so by joining one of the Member Associations listed below. Write to the Secretary for particulars.

| *Association* | *Secretary* | *Address* |
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| Arizona Sewage and Water Works Association | Richard Bennett | City Water Dept., Phoenix, Arizona |
| California Sewage Works Association | J. A. Harmon | 703 California State Bldg., Los Angeles 12, Calif. |
| Central States Sewage Works Association | John C. Mackin | c/o Nine Springs Sewage Treatment Plant, Route No. 4, Madison 5, Wisconsin |
| Dakota Water and Sewage Works Conference | | |
| (North Dakota Section) | K. C. Lauster | c/o State Dept. of Health, Bismarck, South Dakota |
| (South Dakota Section) | Glen J. Hopkins | Div. of San. Engr., State Bd. of Health, Pierre, South Dakota |
| Federal Sewage Research Association | Frank E. DeMartini | U. S. P. H. S., 2000 Mass. Ave., N.W., Washington, D. C. |
| Florida Sewage Works Association | J. R. Hoy | 404 Hildebrandt Bldg., Jacksonville, Fla. |
| Georgia Water and Sewage Association | V. P. Enloe | R. F. D. No. 5, Box 363, Atlanta, Ga. |
| Iowa Wastes Disposal Association | L. J. Murphy | Iowa State College, Ames, Iowa |
| Kansas Water and Sewage Works Association | Paul D. Haney | Room 2, Marvin Hall, University of Kansas, Lawrence, Kansas |
| Maryland-Delaware Water and Sewerage Association | Miss E. V. Gipe | State Dept. of Health, 2411 N. Charles St., Baltimore, Md. |
| Michigan Sewage Works Association | R. J. Smith | Michigan Dept. of Health, State Office Bldg., Lansing, Michigan |
| Missouri Water and Sewerage Conference | Warren Kramer | State Board of Health, 200 Monroe St., Jefferson City, Mo. |
| New England Sewage Works Association | LeRoy W. Van Kleeck | State Dept. of Health, State Office Bldg., Hartford, Conn. |
| New Jersey Sewage Conference | John R. Downes | P.O. Box 11, Dunellen, N. J. |
| New York State Sewage Works Association | A. S. Bedell | c/o State Dept. of Health, Albany, N. Y. |
| North Carolina Sewage Works Association | D. M. Williams | P.O. Box 1170, Durham, N. C. |
| Ohio Sewage Works Conference Group | D. D. Heffelfinger | 1101 E. Walnut, Alliance, Ohio |
| Oklahoma Water and Sewage Conference | H. J. Darcey | State Dept. of Health, Oklahoma City, Okla. |
| Pacific Northwest Sewage Works Association | W. P. Hughes | City Engineer, Lewiston, Idaho |
| Pennsylvania Sewage Works Association | B. S. Bush | Pa. Dept. of Health, Kirby Health Center, Wilkes-Barre, Pa. |
| Rocky Mountain Sewage Works Association | Carroll N. Coberly | 1441 Welton St., Denver, Colo. |
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## December 31, 1943

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Borquist, E. S., Prof., Head Dept. of Civil Engr., University of Arizona, Tucson, Ariz.
Cook, John O., Sanitary Inspector, U. S. Dept. of Interior, Grand Canyon Nat'l Park, Grand Canyon, Ariz.
Cushing, Robert, 948 Ash Ave., Tempe, Ariz.
Gilbert, A. J., Water Service Foreman, So. Pacific R. R., Tucson, Ariz.
Johannessen & Girand, Consulting Engineers, Ellis Bldg., Phoenix, Ariz.
Jones, A. N., Upper Verde Utilities Co., Clarkdale, Ariz.
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Alexander, Louis J., 1206 Maple Ave., Los Angeles, Calif.
Allen, William A., City Hall, Pasadena, Calif.
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Anaya, Marvin, Sanitary Engr., Designer, 367 City Hall, San Francisco, Calif.
Arnold, G. E., Regional Sanitary Engr., U. S. Public Health Service, 477 Colon Ave., San Francisco, Calif.
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Batty, Frederic A., Supt. of Sewers, 231 S. Cliffwood Ave., Los Angeles, Calif.
Becker, Fred G., Opr. Azusa Sew. Treat. Plant, 909 San Gabriel Ave., Azusa, Calif.
Belt, Elmer B., Owner, Squires-Belt Material Co., 153 12th St., Box 1097, San Diego, Calif.
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Craig, J. D. Georgia
Craig, Robt. H. Pennsylvania
Cramerton Mills, Inc. North Carolina
Cranch, Eugene T. New York
Crane Company. Associate
Crane, H. R. California
Crask, Rex. Central States
Craun, J. M. Ohio
Crawford, H. V. New York
Crawford, L. C. Iowa
Creears, T. H. (Alt.) California
Crockett, Vernon P. Federal
Crohurst, Harry R. Federal
Crooks, Howard. Michigan
Cropsey, W. H. Central States
Crow, Harry B. Pacific Northwest
Crundall, S. F. W. England (I. S. P.)
Culley, Walter M. New York
Cullison, Eugene F. New York
Cunningham, H. L. Pennsylvania
Cunningham, John W. Pacific Northwest
Cunningham, M. B. Oklahoma
Currie, Frank S. California
Curtiss Wright Corporation (Corporate) Missouri
Cushing, Robert. Arizona
Cushman, S. P. Central States
Cyr, Rene. Canada
Czerepinski, Henry Peter. Central States

Dagger, G. E. Rocky Mountain
D'Alec, A. R. New York
Daley, Stanley J. Central States
Daly, James A. Canada
Damon, Nelson A. New England
Damon, Wayne F. New England
Daniels, F. E. Pennsylvania
Daniels, P. N. New Jersey
Darby, George M. New England
Darby, W. A. Pennsylvania
Darcey, H. J. Oklahoma
Darling, E. H. Canada
Dashiell, Walter N. Federal
Davey, H. W. (Alt.) California
Davids, E. M. California
Davidson, J. F. California
Davidson, Philip. Central States
Davis, Arthur E. New York
Davis, Charles A. Rocky Mt.
Davis, Clarence A. New York
Davis, D. A. Central States
Davis, F. R., Jr. Central States
Davis, G., Jr. Pacific Northwest
Davis, Howard A. Central States

Davis, H. F. North Carolina
Davis, P. D. North Carolina
Davis, T. J. Georgia
Dawson, Arthur. New York
Dawson, F. M. Iowa
Dawson, Norman. Central States
Dawson, Thomas T. Pennsylvania
Day, L. A. Central States
Dayton, Alfred E. (Alt.) New York
DeBerard, W. W. Central States
Debrun, John W., Jr. Central States
Decker, C. D. Ohio
Decker, Edward P. New Jersey
Decker, Herbert M. Federal
Decker, Walter G. Central States
Deckert, Christ. Central States
DeGroat, Frank N. New York
DeHass, Nicholas. (Alt.) New England
DeHooghe, Bernard A. Michigan
deJarnette, N. M. Georgia
De Lano, Huntley. (Alt.) Michigan
DeLeuw, C. E. Central States
DeMartini, Frank E. California (Dual—Federal)
Deming, P. H. California
Demorest, S. L. Michigan
DeMoss, Samuel. Pacific Northwest
DeMunn, E. M. New York
Denise, Wm. D. New York
Dennis, Carl E. Michigan
Dent, Harry. New York
DePoy, A. G. Central States
Depp, David. Central States
Derby, Ray L. California
Dermitt, Chas. W. Pennsylvania
Deslauriers, A. J. Canada
Desmarais, R. J. Canada
Des Moines, City of. Iowa
Deuchler, Walter E. Central States
Devendorf, Earl. New York
Dewante, Randolph H. California
Dewart, Donald M. New York
DeWolf, A. B. Florida
Dick, Robert. Central States
Dickey, Clay Mfg. Co. Associate
Att'n: A. G. Frerking
Dickson, D. B. Texas
Diefendorf, Fred G. Pennsylvnia
Dietz, Irving M. Texas
Dietz, Jess C. Central States
Dietz, John. Central States
Diller, Walter W. Central States
Dimmitt, Bruce S. Central States
Dion, Clarence K. New England
Disario, G. M. New England
Dixon, F. G. South Dakota
Dixon, G. Gale. Ohio
Dixon, R. M. Texas
Doane, C. C. California
Dobson, Wm. T. New York
Dobstaff, Robert, Jr. New York
Dobstaff, Robert W., Sr. New York
Dodd, C. K. S. Florida
Dodge, H. P. Michigan
Dodson, Lewis. Texas
Dodson, Roy E., Jr. Pacific Northwest
Doman, Joseph. New England (Dual—New York)
Domke, L. C. Central States
Domogalla, Bernhard. Central States
Donaldson, Wellington. New York
Donnell, Geo. M. Rocky Mt.
Donnini, Frank L. New England
Donohue, Jerry. Central States
Dopmeyer, A. L. Federal
Dorr Co. Associate
Dorr, Fred. Michigan
Dow Chemical Co. Associate
Dowd, Ira. Michigan
Downer, Wm. J. Central States
Downes, John R. New Jersey
Downing, Francis J. New York
Doyle, Thomas J. Michigan
Doyle, Wm. H. Central States
Drake, James A. Central States
Dreier, D. E. Central States
Drew, Leland F. Florida
Drew, Samuel T. New England
Drexel, Frederick. New York
Driscoll, Timothy J. New York
Drummond, A. H. England (I. S. P.)
Dudley, D. E. Central States
Dudley, Richard E. New England
Duell, Garth H. California
Duffy, Ora. Kansas
Dundas, Wm. A. Central States
Dunmire, E. H. Central States
Dunn, Town of (North Car.) North Carolina
Dunstan, Gilbert H. California
Durand, Edwin M. Michigan
Durham Water Dept. (North Car.) North Carolina
Durr, John J., Jr. Pennsylvania
Durrant, W. K. F. Canada
Dust, Joseph V. Central States
Duvall, Arndt J. Central States
Dwyer, John W. Central States
Dyckman, Warren W. New York
Dyer, Samuel. New England

Eager, Vernon. New York
Earl, Ralph. Georgia
Early, Fred J., Jr. California
Early, Mart. Pacific Northwest
Earnest, Lloyd. Georgia
Easdale, W. C. England (I. S. E.)

Easley, G. E. California
Eastburn, W. H. Pennsylvania
Easter, Charles W. New England
Eckelcamp, Joseph (Alt.) Michigan
Eddy, Harrison P., Jr. New England
Edgecomb, G. H. Canada
Edgerley, Edward. Pennsylvania
Edighoffer, Albert. New York
Edinger, Harry F. New York
Edmond, H. P. Georgia
Edmondson, J. H. England (I. S. P.)
Edwards, Gail P. New York
Edwards, William L. New York
Egan, J. H. California
Egger, Oscar O. Central States
Eglof, Dr. Warren K. New York
Ehle, Virgil. New York
Eich, Henry F. New York
Eidsness, Fred A. Florida
Eimco Corporation. Associate
Elder, Leiton J. California
Eldridge, E. F. Michigan
Electro Rust-Proofing Co. Associate
Elgin, Sanitary District of (Ill.) (Corporate) Central States
Elias, Geo. A. Pennsylvania
Eliassen, Rolf. New York
Ellms, J. W. Ohio
Ellsworth, Samuel M. New England
Elnor, Geo. E. Canada
Elsdon, Dr. G. D. England (I. S. P.)
Ely, E. H. England (I. S. E.)
Emerson, C. A. Pennsylvania
Emigh, Wm. C. Pennsylvania
Engineering News-Record. Associate
English, Joseph, Jr. Pennsylvania
Enloe, V. P. Georgia
Enoch Pratt Free Library. Maryland-Delaware
Enslow, L. H. New York
Epler, J. E. Central States
Epstein, Herman. New England
Erickson, Carl V. Central States
Erickson, E. J. Michigan
Erickson, W. J. New York
Ettinger, M. B. Federal
Eustance, Arthur W. New York
Eustance, Harry W. New York
Evans, Byron B. New York
Evans, David A. Pennsylvania
Evans, F. M. New Jersey
Evans, R. W. Central States
Evans, S. C. England (I. S. P.)
Everson Manufacturing Co. Associate
Everson, R. B. Central States
Ewart, K. L. Ohio

Faber, Harry A. New York (Dual—Pennsylvania)
Fair, Gordon M. New England (Dual—New York)
Fairbanks, E. G. California
Fales, Almon L. New England
Falls, O. M. Canada
Fanning, Harold R. New York
Farnsworth, George L., Jr. Central States
Farrant, James. New Jersey
Farrar, J. H. California
Farrell, Michael. New York
Faulkner, T. G. England (I. S. E.)
Fassnacht, Geo. G. Central States
Fawls, James F. New York
Feierstein, Jacob L. New York
Feldhake, C. J. Federal
Feltham, John C. Florida
Feltz, Fred C. Central States
Fenger, J. W. New York
Fenn, Ernest G. New England
Fenton, John V. New York
Ferebee, James L. Central States
Ferguson, G. H. Canada
Ferguson, Gerals W. Florida
Ferris, James E. New England (Dual—New York)
Field, Emerson & Morgan, Inc. New York
Field, Wm. T. New York
Figeley, Paul. Central States
Filkins, D. A. (Alt.) Michigan
Finch, J. England (I. S. P.)
Finch, Lewis S. Central States
Finch, R. M. Central States
Finck, G. E. Maryland-Delaware
Findlay, A. New York
Fink, Wm. Kenneth. California
Finkbeiner, Carleton S. Ohio
Finley, Dexter L. California
Fischback, Hyman S. Federal
Fischer, Anthony J. New York
Fischer, F. P. Ohio
Fishbeck, Kenneth. Michigan
Fisher, Lawrence M. Federal
Fiskett, F. J. Central States
Fitch, T. A. California
Fittro, Louis L. Federal
Fitzgerald, Edw. P. Central States
Fitzgerald, J. A. New York
Fitzgibbons, F. C. Central States
Fitzmaurice, E. W. California
Five, Helge. New York
Fiveash, Charles E. Florida
Flanagan, Joseph E., Jr. Pennsylvania
Flannery, Harold J. California
Flatt, Truman L. Central States
Fleet, Gerald A. New York
Fleming, M. C. Pennsylvania
Fleming, Paul V. New England
Fletcher, Cecil C. Federal

Flexible Sewer-Rod Equipt. Co. Associate
Flood, Frank L. New England
Flower, G. E. Ohio
Flowers, E. England (I. S. P.)
Fontenelli, Louis. New Jersey
Foote, Kenneth E. New England
Forbes, Albert F. New York
Ford, J. R. Central States
Foreman, Merle S. (Alt.) California
Forsbeck, C. D. Pacific Northwest
Fort, Edwin J. New York
Fortenbaugh, J. Warren. New York
Forton, R. G. Michigan
Foster, Chas. Central States
Foster, Herbert, Jr. California
Foster, Norman. Pennsylvania
Foster, Richard G. Michigan
Foster, William Floyd. California
Foth, Herbert S. Central States
Fowler, G. J. England (I. S. P.)
Fowler, H. D. Pacific Northwest
Fowler, James D. Texas
Fox, Paul S. Rocky Mt.
Foxboro Company. Associate
Francis, Geo. W. Michigan
Francis Hankin & Co. Canada
Franklin, W. M. North Carolina
Franks, John T. Rocky Mt.
Fraschina, Keeno. California
Fraser, Charles E. Canada
Fraters, E. W. California
Frazier, Ernest. Central States
Frazier, Leonard H. New York
Frazier, Royall C. Georgia
Frazier, R. W. Central States
Freeborn, W. F. England (I. S. P.)
Freeburn, H. M. Pennsylvania
Freeland, B. H. Central States
Freeman, A. B. Federal
Freeman, W. B. Rocky Mt.
French, R. Del. Canada
Freund, J. P. Pennsylvania
Frick, A. L., Jr. California
Fricker, Augustus E. Pennsylvania
Frickstad, Walter N. California
Fridley, Jesse R. Oklahoma
Friedman, S. N. New Jersey
Friedman, Wm. M., Jr. New York
Friel, F. S. Pennsylvania
Friendly, Hugo H. New York
Frith, Gilbert R. Georgia
Froehde, F. C. California
Frye, Jacob E. New Jersey
Fuchs, Abraham W. Federal
Fuehrer, Carl W. Pennsylvania
Fuhrman, Ralph E. Federal
Fuller, H. L. Missouri
Fuller, Nelson M. New York
Fuller, Raymond H. Ohio
Fulmer, Frank E. Central States
Funk, John B. Maryland-Delaware
Funk, John T., Jr. Pennsylvania
Fynn, Geo. F. New York

Gadomski, Albert J. New Jersey
Gail, A. L. Central States
Gale Oil Separator Co. Associate
Gard, Chas. M. New York
Gardiner, W. E. Canada
Gardner, Geo. W. New York
Gardner, R. T. California
Garland, Chesley F. Florida
Garlock, Samuel C. New York
Garner, J. H. England (I. S. P.)
Garrett, R. W. Canada
Garthe, E. C. Federal
Garwood, Kirk. Iowa
Gatley, H. K. New Jersey
Gauntt, W. C. Texas
Gause, Frank. Central States
Gavett, Weston. New York
Gearhart, J. N. Pacific Northwest
Gehm, Harry Willard, Jr. New Jersey
Gelbke, Arthur W. New York
Gelston, W. R. Central States
General Chemical Co. Associate
General Electric Co. Associate
Genter, Albert L. Maryland-Delaware
Gentsch, Edward. Michigan
George, J. E. Missouri
Gerard, F. A. Central States
Gerdel, W. E. Ohio
Gere, William S. New York
Gerhart, Edgar. Pennsylvania
Gerling, Philip C. New York
Getz, Murray A. Central States
Geyer, John C. Maryland-Delaware
Gibbons, E. V. Canada
Gibbons, M. M. New Jersey
Gibbs, Frederick S. New England
Gibbs, R. C. England (I. S. P.)
Gibeau, H. A. Canada
Gidley, H. K. Pennsylvania
Giesey, J. K. Central States
Gifford, Earl W. Central States
Gifford, J. B. Central States
Gift, H. M. New York
Gilbert, A. J. Arizona
Gilbert, J. J. Pennsylvania
Gilbert, J. Miles. Florida
Gilbertson, W. E. North Dakota
Gilcreas, F. Wellington. New England (Dual —New York)
Giles, J. Henry L. New England
Gilkey, A. E. California
Gill, A. F. Canada

Gill, John B. California
Gill, Paul. Pennsylvania
Gillard, J. E. England (I. S. P.)
Gillespie, C. G. California
Gillespie, Wylie W. Florida
Gilligan, Howard. Pennsylvania
Gilman, Floyd. New York
Gilman, Harry I. Georgia
Gilman, N. A. Pacific Northwest
Gisborne, Frank R. (Alt.) New England
Glace, I. M., Jr. Pennsylvania
Glace, I. M. Pennsylvania (Dual—New York)
Gladding, Charles. California
Gladue, Donat J. New England
Glamorgan Pipe & Foundry Co. Associate
Glynn, William J. New York
Godfroy, J. I. Michigan
Goff, James S. New England
Goff, Wm. A. Pennsylvania
Goicoechea, Prof. Leandro de. Florida
Goldsmith, Philip. New York
Goldthorpe, H. H. England (I. S. P.)
Golly, M. R. Central States
Gooch, E. W. Pacific Northwest
Goodman, Arnold H. Central States
Goodnight, V. L. Pacific Northwest
Goodridge, Harry E. California
Goodwin, S. E. Canada
Gordon, Arthur. Central States
Gordon, J. B. Federal
Gorman, Richard C., Jr. New York
Gotaas, Harold B. North Carolina
Goudey, R. F. California
Gough, Andrew B. New England
Gould, Richard H. New York
Grabbe Construction Co., H. A. Central States
Graber, Ralph Carl. Federal
Gracenin, Sylvester. Pennsylvania
Graden, Paul W. Central States
Graemiger, Joseph A. New England
Graham, James E. Michigan
Gran, Dr. John E. Georgia
Granger, Geo. (Alt.) Michigan
Grantham, Geo. R. Central States
Graul, Leroy H. New Jersey
Graver Tank & Mfg. Co., Inc. Associate
Gray, Earl G. Michigan
Gray, Harold F. California
Greeley, Richard F. New England
Greeley, Samuel A. Central States
Green, Alvin W. Pacific Northwest
Green Bay Fdy. & Machine Wks. Associate
Green, Carl E. Pacific Northwest
Green, Howard R. Iowa
Green, Wingate. Florida
Greene, J. F. Rocky Mountain
Greene, R. A. Michigan
Greenleaf, John W., Jr. New England
Gregory, L. L. England (I. S. E.)
Gregory, Ted R. California
Gregory, The John H. Sanitary & Municipal Reference Library. California
Greiff, V. New York
Greig, John M. M. New York
Grelick, David. New York
Griffen, F. T. New York
Griffin, A. E. New Jersey
Griffin, Guy E. New England
Griffith, L. B. Texas
Grimsley, J. T. Federal
Grinnell, Russell. Michigan
Groen, Michael A. Michigan
Gross, Carl D. Central States
Gross, Dwight D. Rocky Mt.
Grossart, L. J. H. Pennsylvania
Grosshans, Edw. W. Central States
Grover, Robert H. New York
Grubin, Herman. New York
Gruendler Crusher & Pulverizer Co. Associate
Gruss, A. W. California
Gutierrez, Andrew. North Carolina
Gwin, Thomas. California

Haag, Gerald. Central States
Haberer, John C. New York
Habermehl, C. Austin. Michigan
Hackett, Peter. New York
Haddock, Fred R. Pennsylvania
Hadin, Lion A. Pacific Northwest
Haemmerlein, Victor E. New York
Hager, Fred. Central States
Hagerty, L. T. Ohio
Hagestad, Herman T. Central States
Hale, Arnold H. New York
Hale, Frank C. Central States
Halff, Albert H. Central States
Hall, Frank H. New York
Hall, G. Albro. Ohio
Hall, G. D. Pacific Northwest
Hall, Geo. M. Central States
Hall, Harry R. Maryland-Delaware
Hall, S. P. Central States
Hall, W. H. North Carolina
Hall, W. N. Canada
Hallam, G. C. Pacific Northwest
Hallgren, R. A. Canada
Hallock, Emerson C. New York
Halpin, John. New York
Halvorson, H. O. Central States
Hambleton, F. T. England (I. S. P.)
Hamblett, W. C. Federal
Hamilton, Loeman A. Central States
Hamilton, R. F. Pacific Northwest
Hamlin, C. H. England (I. S. P.)
Hamm, Wm. C. New York

Hammer, Vernon Benjamin. Iowa
Hammond Bd. of Sanitary Commissioners (Corporate). Central States
Hammond, Robt. California
Handley, L. H. Georgia
Hanes, Gilbert C. California
Haney, Paul A. Kansas
Hanlon, D. A. Florida
Hansell, Wm. A. (deceased). Georgia
Hansell, Wm. A., Jr. Georgia
Hansen, Chris A. Federal
Hansen, Paul. Central States
Hanson, George I. New England
Hanson, Harry G. North Dakota (Dual—Federal)
Hanson, John R. New York
Hapgood, E. P. California
Harbin, Wm. Central States
Hardenbergh, W. A. New York
Harding, Carl G. Florida
Harding, J. C. New York
Harding, Rogert G. Pacific Northwest
Hardman, Thomas T. Central States
Hardy, C. Asa. New York
Harley, Frank E. New Jersey
Harmeson, D. K. Central States
Harmon, Jacob A. Central States
Harmon, Judson A. California
Harper, Charles E. Central States
Harper, M. J. New England
Harper, Travis C. California
Harr, Neal. Kansas
Harris, Geo. C. Central States
Harris, I. England (I. S. P.)
Harris, R. C. Canada
Harris, T. R. Central States
Harrison, B. D. Pacific Northwest
Harrison, Edw. F. New York
Harrison, John B. California
Harshbarger, J. R. Central States
Hart, Chas. G. New York
Hart, W. B. Pennsylvania
Hartley, G. R. New Jersey
Hartley, John R. New England
Hartline, Wm. C. Florida
Hartman, B. J. Central States
Hartmen, Byron K. Central States (Dual—New York)
Hartom, R. A. New Jersey
Hartung, N. E. Central States
Hartzell, E. F. Pennsylvania
Harvey, Carl. New York
Harvey, J. R. Pennsylvania
Harwell, Glen A. Missouri
Haseltine, T. R. Pennsylvania
Hasfurther, Wm. A. Central States
Haskins, Chas. A. Missouri
Hastie, James. New York
Hatfield, W. D. Central States
Hattery, Chas. E. Central States
Hauck, Chas. F. Ohio
Hauer, Gerals E. Michigan
Havens, William L. Ohio
Hawken, Dalton. Michigan
Hawley, Arthur A. New York
Haworth, J. Victor. Pennsylvania
Haworth, W. D. England (I. S. E.)
Hay, T. T. Central States
Haydock, Chas. Pennsylvania
Hayes, John A. New York
Hayob, Henry. Missouri
Hayward, Homer J. Michigan
Hasen, Richard. New York
Heaslit, Walter. Rocky Mt.
Hedgepeth, L. L. Pennsylvania (Dual—New York)
Heffelfinger, D. D. Ohio
Heider, Robt. W. Central States
Heinrikson, J. J. Kansas
Heiple, Loren R. Central States
Heisig, H. M. Central States
Heiss, Edw. A. Pacific Northwest
Helland, H. R. F. Texas
Heller, Austin N. New York
Henderson, Chas. F. New York
Hendryx, Clarence E. Rocky Mountain
Henn, Donald E. Central States
Henry, Thomas B. Ohio
Hensel, Eugene C. Central States
Herberger, Arthur Henry. New York
Herda, N. Michigan
Hermann, F. X. Central States
Herr, H. N. Pennsylvania
Herrick, T. L. Central States
Herzig, S. B. Central States
Herzog, Henry. New York
Hesford, L. England (I. S. E.)
Hess, Daniel J., Jr. Pennsylvania
Hess, John S. Ohio
Hess, Seth G. New York
Heubi, Thomas. New York
Heukelekian, H. New Jersey
Hewitt, A. C. Pennsylvania
Heyward, T. C. North Carolina
Hibschman, Charles A. Pennsylvania
Hicklin, R. G. Georgia
Hicks, Cyril. (Alt.) Michigan
Hicks, Geo. W. Central States
Hicks, R. England (I. S. P.)
Higgins, William J. New York
Hill, Frank C. Rocky Mountain
Hill, G. Everett. New York
Hill, K. V. Central States
Hill, Theo. C. Pennsylvania
Hill, W. R. Pacific Northwest

Hiller, Paul W. New England (Dual—New York)
Hillis, Leonard. Michigan
Hilton, E. M. (Alt.) California
Hines, Leon H. New York
Hirschel, Leslie (deceased). New York
Hirst, J. England (I. S. P.)
Hoag C. C. New York
Hoag, Henry J. California
Hoagland, D. Ohio
Hoak, Richard D. Pennsylvania
Hobbs, Roy L. Georgia
Hodek, James J. Maryland-Delaware
Hodge, W. W. Pennsylvania
Hodges, H. E. W. England (I. S. E.)
Hodgson, E. England (I. S. P.)
Hodgson, J. J. N. England (I. S. P.)
Hodkinson, C. T. Central States
Hoeflich, G. C. Pennsylvania
Hoey, A. C. Canada
Hoey, John B. New York
Hoffert, J. R. Pennsylvania
Hoffman, Howard F. New York
Hogan, James W. T., New York
Hogan, M. S. Missouri
Hogan, William J. New York
Hoganson, Lester O. Central States
Holderby, J. M. Central States
Holderman, John S. Central States
Holland, Frank H. Central States
Holmes, Glenn D. New York
Holmes, Harry E. New England
Holmes, Kenneth H. New England
Holmquist, Chas. A. New York
Holroyd, A. England (I. S. P.)
Holst, J. S. South Dakota
Holt, Clayton M. Central States
Holter, A. L. Pacific Northwest
Holtje, Ralph H. New Jersey
Holtkamp, Leo. Iowa
Holway, O. C. Central States
Homan, Arthur R. Missouri
Homelite Corporation. Associate
Hommon, Charles C. Ohio
Hommon, H. B. California (Dual—Federal)
Hoot, Ralph A. Central States
Hope, Malcolm C. Federal
Hopkins, E. S. Maryland-Delaware
Hopkins, Glen J. South Dakota
Hopkins, L. S. R. New York
Hopkins, Omar C. Federal
Hopler, Harold S. Federal
Hopper, Allen O. New York
Horgan, John J. New York (Dual—New England)
Horne, Ralph W. New England
Horner, J. L. Texas
Hoskins, J. K. Federal
Hoskinson, Carl M. California
Hotchkiss, H. T., Jr. New York
Hoth, Fred. Central States
Houser, George C. New England
Houston, W. J. Georgia
Howard, C. M. Pacific Northwest
Howard, P. F. New England
Howard, R. R. Missouri
Howarth, J. P. England (I. S. P.)
Howe, Ben V. Rocky Mountain
Howe, J. P. Canada
Howe, W. A. Central States
Howell, Eugene M. California
Howland, W. E. Central States
Howson, J. T. New York
Howson, L. R. Central States
Hoy, J. R. Florida
Hoy, M. J. South Dakota
Hoydar, Albert L. Pacific Northwest
Hoyle, W. H. England (I. S. P.)
Hoyt, Clinton W. New York
Hromada, Frank M. Central States
Hubbell, Geo. E. Michigan
Hubel, J. H. Canada
Huber, Harold J. New York
Hudson, L. D. Central States
Huebner, Ludwig. California
Huffman, Fred. California
Huffman, Lloyd C. Ohio
Hufford, L. E. Ohio
Hughes, W. P. Pacific Northwest
Humphreys, Walter. California
Humphries, J. I. Georgia
Hunt, Geo. W. California
Hunt, Henry J. Central States
Hunt, H. S. Michigan
Hunt, L. W. Central States
Hunt, Raymond L. New York
Hunter, A. England (I. S. P.)
Hupp, John E., Jr. Central States
Hurd, Charles H. Central States
Hurd, Edwin C. Central States
Hurley, J. England (I. S. P.)
Hurst, Chas. Central States
Hurst, Howard M. California
Hurst, William C. New York
Hurwitz, Emanuel. Central States
Hussong, Ernest W. Central States
Hutcheson, H. D. New York
Hutchins, Will A. Central States
Huth, Norman A. California
Hutton, H. S. Pennsylvania
Hyde, Charles Gilman. California

Illinois Dept. of Public Health (Corporate). Central States
Indiana State Bd. of Health (Corporate). Central States

Infilco, Inc. (Corporate) Associate. Central States
Ingols, Robert. New Jersey
Ingram, Wm. T. California
Iowa City, City of. Iowa
Iowa Valve Co. Associate
Irwin, Forrest. Ohio
Irwin, G. M. Pacific Northwest

Jack, David. Canada
Jack, Grant R. Canada
Jackson, J. Frederick. New England
Jackson, John F. New Jersey
Jackson, R. B. Michigan
Jackson, T. L. Michigan
Jacobs, L. L. Georgia
Jacobson, Geo. L. South Dakota
James, Glenn. Central States
James, Norman S. Florida
Janes, N. D. Ohio
Jardine, M. E. Canada
Jarlinski, Thaddeus T. New York
Jeffrey, H. H. California
Jeffrey Manufacturing Co. Associate
Jenckes, J. Franklin, Jr. New England
Jenks, Glen. Rocky Mountain
Jenks, Harry N. California
Jennings, A. England (I. S. P.)
Jennings, L. R. Michigan
Jensen, Emil C. Pacific Northwest
Jenson, Theodore B. Florida
Jerge, Ray. New York
Jessop, A. H. California
Jeup, Bernard H. Central States
Jewell, H. W. California
Job, Richard C. Georgia
Johannessen & Girand. Arizona
Johns-Manville Corp. Associate
Johnson, Arthur N. Central States
Johnson, Clement. (Alt.) New York
Johnson, Earle P. Pennsylvania
Johnson, Eskil C. New England
Johnson, Floyd E. Central States
Johnson, Herbert O. New York
Johnson, J. Clifford. New York
Johnson, Jess B. Central States
Johnson, John W. New York
Johnson, L. M. Central States
Johnson, R. J. Central States
Johnson, Russell. Rocky Mountain
Johnson, Robt. T. Iowa
Johnson, Verner C. California
Jonas, Milton R. Central States
Jones, A. N. Arizona
Jones, Arthur C. Florida
Jones, C. B. O. England (I. S. P.)
Jones, Daniel. New York
Jones, E. M. Pennsylvania
Jones, Frank E. Michigan
Jones, Frank O. Central States
Jones, Frank Woodbury. Ohio (Dual—Pennsylvania)
Jones, John N. Central States
Jones, Martha A., Miss. Central States
Jones, S. Leary. Federal
Jones, Wayland. California
Jordan, Harry E. New York
Jorgensen, Homer W. California
Joy, C. Fred, Jr. New England
Kaar, G. C. . Central States

Kachmar, John F. Federal
Kachorsky, M. S. New Jersey
Kafka, John. Central States
Kaiser, C. T. Georgia
Kaler, P. E. Kansas
Kaltenbach, Albert B. Maryland-Delaware
Kammerling, Lane. Michigan
Kane, R. D. Ohio
Kaplan, Bernard. New Jersey
Kaplovsky, A. J. New Jersey
Kappe, S. E. Pennsylvania (Dual—New England and New York)
Karsa, William J. New York
Kass, Nathan I. New York
Kassay, Albert E. New York
Kay, Frank E. Pennsylvania
Kearney, John J. Central States
Keefer, Clarence E. Maryland-Delaware
Keefer, R. K. Pennsylvania
Keeler, J. Harold. New York
Kehr, William Q. Missouri
Keirn, Kenneth A. California
Keller, Dwight. Ohio
Keller, H. James. California
Keller, Jacob. New York
Keller, Lyndon M. New York
Keller, S. K. Florida
Kelley, R. E. Michigan
Kellogg, Clarence E. New York
Kellogg, James W. North Carolina
Kelly, Clarence. New York
Kelly, Earl M. California
Kelly, Francis W. Pennsylvania
Kelsey, Walter. Pennsylvania & New York (Dual—New England)
Kemp, Harold A. New York
Kempkey, A. California
Kendrick, George I. Central States
Kennedy, C. C. California
Kennedy, D. R. California
Kennedy, R. R. California
Kennedy, Wm. New York
Kenney, Norman D. Maryland-Delaware
Kepner, Dana E. Rocky Mountain
Ker, M. F. Canada

Kern, Andrew G. Pennsylvania
Kershaw, Arnold. England (I. S. P.)
Ketcham, Joseph M.
Kibler, Harry J. New York
Kidd, Carl W. New York
Kieffer, Jos. D. New York
Kiker, John E., Jr. New York
Killam, E. T. New Jersey
Kilcawley, Edw. J. New York
Kimball, Jack H. California
Kin, Stephen R. North Carolina (Dual—New York)
Kinderman, Wm. Pennsylvania
King, Cooley B. Georgia
King, Henry R. Central States
King, Richard. Central States
King, Wendell. Kansas
Kingsbury, H. N. Central States
Kingston, Paul S. Central States
Kingston, T. M. S. Canada
Kingwell, E. G. Pacific Northwest
Kinney, E. F. Central States
Kinney, J. B. Canada
Kinsel, Harry L. Pennsylvania
Kipp, W. H. Pacific Northwest
Kirchoffer, W. G. Central States
Kirn, Matt. Central States
Kirsner, Charles. New York
Kittrell, F. W. Federal
Kivari, A. M. California
Kivell, Wayne A. New York
Kizler, Wilfred C. California
Kjellburg, G. (Alt.) California
Klann, Martin C. Michigan
Klegerman, M. H. New York
Klein, J. A. Central States
Klein, L. England (I. S. P.)
Kleiser, Paul J. Central States
Kleven, John. North Dakota
Klinck, Frank. New York
Kline, H. S. Ohio
Klippel, Floyd. Iowa
Knapp, Henry A. Georgia
Knapton, Wm. California
Knechtges, O. Central States
Knight, C. H. Canada
Knittel, E. A. Pacific Northwest
Knoedler, H. A. California
Knollman, Fred. Rocky Mountain
Knowles, Coyle E. New York
Knowlton, W. T. California
Koch & Fowler. Texas
Koch, Philip L. Central States
Kochin, Milton S. Pennsylvania
Kochtitzky, O. W., Jr. Federal
Koebig, A. H., Jr. California
Koeckeritz, R. C. Central States
Kolb, Fred W. (Alt.) California
Komline, T. R. New Jersey
Koon, Ray E. Pacific Northwest
Koplowitz, Sol. New York
Koruzo, John E. Georgia
Kozma, Albert B. New Jersey
Kramer, Harrison W. Pacific Northwest
Kramer, Harry P. Central States
Kratz, Fred R. Pennsylvania
Kraus, L. S. Central States
Krell, A. J. New York
Kressly, Paul E. California
Kreutter, Clarence. New York
Kronbach, Allan. Michigan
Kroone, T. H. Ohio
Krum, Harry J., Jr. Pennsylvania
Kuhner, Frank G. Central States
Kulberg, Abraham. New York
Kunsch, Walter. New England
Kunze, Albert T. Michigan
Kussmaul, T. C. Ohio

Lacey, Howard E. South Dakota
Lacy, Ilbert O. New York
Ladlow, John. Arizona
Lafferty, W. R. New Jersey
Lafreniere, Theo. J. Canada
Laidlaw, C. T. Canada
Lak, Gerard J. California
Lakeside Engineering Corp. Associate (Corporate) Central States
Lamar, Jones C. Texas
Lamb, Charles. Canada
Lamb, Clarence F. New England
Lamb, Miles. Central States
Lamb, P. England (I. S. P.)
Lambert, Lowell E. Federal
Lamoureux, Vincent B. Federal
Lamson, B. F. Canada
Lane, Calvin S. New England
Lang, Sheldon L. Federal
Lang, Wm. H. Pennsylvania
Langdon, B. J. Federal
Langdon, L. E. Central States
Langdon, Paul E. Central States
Langelier, W. F. California
Langford, Leonard L. New York (Dual—Pennsylvania and New England)
Langlais, Zochee. Canada
Langshaw, C. L. England (I. S. E.)
Langwell, Louie. Central States
Lannon, William. New England
Lanphear, Roy S. New England
Larkin, W. H. New York
Larsen, Ernest A. New York
Larsen, Stanley J. Central States
Larson, C. C. Central States

Larson, Keith D. Central States
Larson, L. L. Central States
La Rue, Luther. Ohio
Lauer, Charles N. Pennsylvania
Laughlin, William G. New York
Lauster, K. C. North Dakota
Lautz, Harold L. Central States
LaValley, Edward C. New York
Lawlor, J. P. Iowa
Lawrence, John. New York
Lawson, W. S., Layport, H. R. Pacific Northwest
Lea, J. E. England (I. S. P.)
Lea, W. S. Canada
Leach, Walter L. Ohio
Leatherman, W. L. Ohio
Le Bosquet, M. Federal
Le Chard, Joseph H. New Jersey
LeClerc, Arthur B. North Carolina
Lederer, K. California
Ledford, George L. New York
Lee, Chas. H. California
Lee, David B. Florida
Lee, Oliver. Central States
Leemaster, J. F. Michigan
Leh, Willard. Pennsylvania
Lehmann, Arthur F. New Jersey
Leigh, H. G. England (I. S. P.)
Leimbach, Harry. Pennsylvania
Leist, Ervin F. Ohio
Leithiser, E. Pennsylvania
Leland, Benn J. Central States
Leland, Raymond I. Central States
Lemcke, Ewald M. California
Lemieux, R. A. Canada
Lemon, Paul R. California
Lendall, Harry N. New Jersey
Lenneau, F. B. Georgia
Lentfoehr, Charles E. Central States
Leonard, W. V. Rocky Mountain
Leonhard, Harold M. Michigan
Lesher, Carl. Ohio
Lessig, D. H. Central States
Le Van, James H. Federal
Lewis, E. S. Arizona
Lewis, G. M. Federal
Lewis, John V. New York
Lewis, R. K. Central States
Ley, Charles H. Canada
Lieber, Maxim. New York
Lilly, Geo. M. Rocky Mountain.
Limestone Products Corp. of America. Associate.
Lind, A. Carlton. Central States
Lindell, O. V. Missouri
Linderman, Irving E. Central States
Linders, Edward. Federal
Lindsten, H. C. North Dakota
Link-Belt Company. Associate
Att'n: M. B. Tark. Pennsylvania (Dual—New York)
Link-Belt Company (Corporate). Central States. Att'n: Frank W. Lovett
Lippelt, Hans B. New York
Little, August. Missouri
Livingstone, Bard. California
Lloyd, G. H. Canada
Lobee, Frank A., Jr. New York
Locke, Edw. A. New England
Lockett, W. T. England (I. S. P.)
Lockwood, Bronson E. New England
Loelkes, Geo. L. Missouri
Logan, Robert P. New Jersey
Long, Frank V. California
Long, George S. Pennsylvania
Long, H. Maynard. Central States
Long, James C. New Jersey
Longbottom, V. England (I. S. P.)
Longlais, Zachie. Canada
Longley, Paul N. Pennsylvania
Loomis, Harry E. New York
Los Angeles Public Library. California (Municipal Reference Library)
Los Angeles Public Library. California (Serials Division)
Losee, James R. New York
Lourinch, Louis B. Central States
Love, James C. Central States
Lovejoy, W. L. Pacific Northwest
Lovell, Theodore R. Iowa
Lovett, F. W. Central States
Lovett, M. England (I. S. P.)
Lowe, Robt. P. California
Lowe, Walter M. New York
Lowther, Burton. California
Lozier, Wm. S. New York
Lubratovich, M. D. Central States
Luchtenberg, R. O. Ohio
Ludlow Valve Mfg. Co. Associate
Ludwig, Harvey F. California (Dual—Federal)
Ludwig, Russell G. California
Ludzack, F. J. Central States
Luebbers, Ralph H. California
Lueck, Bernard F. Central States
Luippold, G. T. California
Lumb, C. England (I. S. P.)
Lundstrom, Karl A. Central States
Lupher, Leon P., Jr. Central States
Lustig, Joseph. Central States
Luther, Robt. W. North Carolina
Lutz, Howland C. Pennsylvania
Lux, Kathleen E. Central States
Lyman, C. S. Ohio
Lynch, Daniel E., Jr. New York
Lynch, James T. New York

Lynchburg Foundry Company. Associate
Lyons, William. New York

McAfee, H. D. Texas
McAdoo & Allen Welting Co. (Corporate). Pennsylvania
McArthur, Franklin. Canada
McAuley, John Dennis. Federal
McAuley, Wm. F. Georgia
McBride, J. L. California
McCabe, Brother Joseph. New York
McCall, Robert G. Central States
McCallum, G. E. Federal
McCannel, D. A. R. Canada
McCarthy, Joseph A. New England
McCarthy, Justin J. New York
McCarthy, William F. New York
McCaslin, Walter R. Central States
McClane, S. Wood, Jr. New Jersey
McClenahan, W. J. Central States
McClintock, H. C. Rocky Mountain
McClure, Ernest. Central States
McCoy, Ted. Central States
McDade, Frank. New York
McDaniel, C. C. Central States
McDonald, John. New England
McDonald, N. G. Canada
McDonnell, Geo. H. New York
McFarlane, Walter D. Michigan
McFaul, W. L. Canada
McGann, Robt. J. New York
McGarth, C. P. Michigan
McGuire, C. D. Ohio
McGurk, Sam R., Jr. Central States
McHugh, Basil. Pacific Northwest
McIlvaine, Wm. D., Jr. Central States
McIntosh, Pierce B. California
McIntyre, F. J. Ohio
McIntyre, John C. Central States
McKay, R. Donald. Canada
McKee, Frank J. Central States
McKee, Jack E. New England
McKee, S. C. Ohio
McKeeman, Edwin C. New York
McKeen, William H. California
McKenna, Harold K. Michigan
McKinlay, Daniel. California
McLaren, Alfred M. California
McLaughlin, Carroll W. New York
McLaughlin, John. New Jersey
McLean, Clement. New York
McLean, R. F. Pacific Northwest
McMahon, Walter A. New England
McManamna, T. L. Canada
McMenamin, C. B. New Jersey
McMillan, Donald C. California
McMorrow, B. J. California
McNamee, Paul D. Federal
McNicholas, J. England (I. S. P.)
McNiece, L. G. Canada
McRice, Donald J. California
McWilliams, D. B. Canada
Mabbs, John W. Central States
Macabee, Lloyd C. California
Macauley, J. W. New York
MacCallum, C. New York
MacCrea, J. M. New York
MacDonald, J. C. Central States
MacDowell, R. F. Ohio
Machis, Alfred. Maryland-Delaware
MacKenzie, Vernon G. Federal
Mackin, J. C. Central States
MacLachlan, Angus. Ohio
MacLaren, J. F. Canada
MacLean, J. D. Canada
Maga, John A. California
Magee, Geo. W. New York
Maguire, Chas. A. New England
Mahlie, W. S. Texas
Maier, F. J. Federal
Mailloux, Wm. South Dakota
Main, Ralph A. Michigan
Makepeace, W. H. England (I. S. P.)
Malcolm, Wm. L. New York
Maldonado, Ardis. (Alt.) California
Mallmann, W. L. Michigan
Mallory, Edward B. Pennsylvania (Dual—Central States)
Malloy, Howard M. Michigan
Malone, J. R. North Carolina
Malony, W. L. Pacific Northwest
Mangones, Robt. J. New York
Mann, Alfred H. New York
Mann, Karl M. New York
Mann, Uhl T. New York
Mannheim, Robert. New England
Mansfield, M. G. Pennsylvania
Manteufel, Lawrence A. Central States
Marchon, Seigmund S. New York
Mariner, W. S. New England
Mark, Richard S. Federal
Marrs, Paul. Florida
Marsh, H. M. Canada
Marshall, E. A. New York
Marshall, J. C. (Alt.) Michigan
Marshall, Leslie S. New York
Marshall, W. B. New York
Martens, Myron M. Central States
Martin, A. E. New York
Martin, Alexander G. New York
Martin, Chas. P. California
Martin, Edw. J., Jr. New York
Martin, Geo. C. Central States
Martin, Sylvan C. Central States
Marx, Frank. New York

Maryland State Dept. of Health. Maryland-Delaware
Marx, Geo. W. Arizona
Mather, Edw. K. South Dakota
Mathers, Geo. New York
Mathews, E. R. South Dakota
Mathews, Frank E. Pacific Northwest
Mathews, W. W. Central States
Mathieson Alkali Works, Inc. Associate
Mathis, Alice. Arizona
Matter, L. D. Pennsylvania
May, D. C. Michigan
May, Harold L. California
McMullen, Wm. Central States
McRae, John C. Central States
Meara, John W. New York
Mebus, Geo. B. Pennsylvania
Mechler, L. W. California
Meckler, Wm. G. Federal
Medbery, H. Christopher. California
Meeker, Herbert J. New York
Melburg, Fred. Rocky Mountain
Mendelsohn, I. W. New York
Menefee, James H. Texas
Menzies, D. B. Canada
Menzies, J. Ross. Canada
Merkel, Paul P. Pennsylvania
Merlo, Louis A., Jr. Canada
Merrick, Ray. Central States
Merrill, Walter E. New England
Merz, H. Spencer. Central States
Mesner, Elmer C. New York
Metyko, Frank J. Michigan
Meyer, Louis P. H. California
Michael, A. M. North Carolina
Michaels, A. P. Florida
Michaels, Hohn. New York
Mick, K. L. Central States
Mickle, Chas. T. Central States
Micklethwaite, W. E. Canada
Middleton, Francis M. Federal
Miick, Fred E. California
Miles, Henry J. California
Miller, A. P. Federal
Miller, A. S. England (I. S. P.)
Miller, Basil. Central States
Miller, Alden W. Arizona
Miller, David R. Central States
Miller, John B. Florida
Miller, J. John. Pennsylvania
Miller, L. W. Central States
Miller, Lewis B. Pennsylvania
Miller, Maurice L. Central States
Miller, Noble. Central States
Miller, Norman A. Michigan
Miller, Robert G. Iowa
Miller, Wallace T. New York
Milligan, Francis B. Pennsylvania
Milling, Martin A. Central States
Mills, J. Ralph. California
Mills, S. W. Canada
Minneapolis-St. Paul Sanitary District (Corporate). Central States
Mitchell, Burton F. New England
Mitchell, Louis. New York
Mitchell, Robt. D. South Dakota
Modak, N. V. England (I. S. P.)
Moeller, Carl. Central States
Mogelnicki, Stanley. Michigan
Moggio, Wm. A. North Carolina
Mohlman, F. W. Central States
Molitor, Edward P. New Jersey
Molitor, Paul Sr. (Deceased). New Jersey (Dual—Pennsylvania)
Monfried, Leon. Central States
Monk, H. E. England (I. S. P.)
Monroe, S. G. Ohio
Monsanto Chemical Company. Associate
Monsell, Harry M. New York
Montgomery, J. R. Michigan
Montgomery, James M. California
Montreal, City of., Public Works Dept. Canada
Moon, James N. Pennsylvania
Moor, Alex. (Alt.) New York
Moor, W. C. Texas
Moore, Charles A. Pennsylvania
Moore, Edward W. New England
Moore, Lee S. Central States
Moore, F. Owen. England (I. S. E.)
Moore, George W. New York
Moore, Geo. S. North Carolina
Moore, Herbert. Central States
Moore, R. B. Central States
Moore, R. L. England (I. S. P.)
Moore, W. A. Federal
Moran, Alton B. Rocky Mountain
Morehouse, W. W. Ohio
Morey, Burrows. New York
Morgan, Edward F., Jr. New England
Morgan, George. Canada
Morgan, Philip F. Central States
Morgenroth, Fritz. New England
Morin, A. Canada
Morkert, Kenneth. Central States
Morrill, Arthur. Michigan
Morris, Arval. (Alt.) California
Morris, D. K. Central States
Morris, Lee. South Dakota
Morris, Paul J. Pennsylvania
Morrison, James E. Pacific Northwest
Morrissette, Romeo. Canada
Morrow, Ben S. Pacific Northwest
Moses, H. E. Pennsylvania
Moses, James E. North Carolina
Moss, E. H. North Carolina

Moss, F. J. Federal
Mott, C. A. Canada
Moudy, R. B. Rocky Mountain
Mountfort, L. F. England (I. S. P.)
Moutrey, Curtis. Oklahoma
Mowbray, Geo. A. New York
Mowrey, A. F. New Jersey
Mowrey, J. Hase. Pennsylvania
Mowry, R. B. New Jersey (Dual—Pennsylvania)
Mudgett, C. T. Michigan
Muegge, O. J. Central States
Mueller Company. Associate
Muldoon, Joseph A. New England
Mulholland, R. A. Texas
Mullinex, Chas. D. Iowa
Mulvihill, F. J. Pennsylvania
Mundling, Miss Germaine G. New York
Munroe, City of (N. Car.). North Carolina
Munroe, E. H. Canada
Munroe, W. C. Maryland-Delaware
Munson, Laura A. (Mrs.) California
Murdock, Wm. Pennsylvania
Murphy, John A. Central States
Murphy, Lindon J. Iowa
Murphy, Reginald A. New York
Murray, A. E. Scott. England (I. S. E.)
Murray, K. A. England (I. S. P.)
Murschel, Jacob. South Dakota
Musgrove, Robt. Michigan
Mutzberg, F. A. North Carolina
Myers, Harry L. Central States

Naehr, Harry F. Georgia
Nance, E. L. North Carolina
Nangle, B. A. South Dakota
Nasi, Kaarlo W. California (Dual—Federal)
National Water Main Cleaning Co. Associate
Nauer, Louis A., Jr. Central States
Naylor, William. New England
Neiman, W. T. Central States
Nelle, Richard S. Central States
Nelson, Ben O. Pacific Northwest
Nelson, D. H., Dr. Central States
Nelson, Frederick G. Ohio
Nesheim, Arnold. Federal
Nessa, Herbert. Iowa
Neumann, George B. Central States
Neves, Dr. Lourenco Baeta. New York
Nevitt, I. H. New York
Newell, Town of (Iowa). Iowa
Newlands, James A. New England
Newman, Alfred C. Florida
Newsom, Reeves. New York
Newton, City of (Iowa). Iowa
Newton, Donald. Central States
Nicholas, Forrest A. Central States
Nichols, A. E. New York
Nichols Engineering & Research Corp. Associate
Nichols, M. Starr. Central States
Nicholson, C. P. New York
Nickel, Jack B. Central States
Nicklin, H. S. Canada
Niebergall, Herbert J. New York
Nielsen, A. F. New York
Niemi, Arthur G. Central States
Niles, A. H. Ohio
Niles, Chas. A. New York
Niles, Thomas M. Central States
Nixon, J. England (I. S. P.)
Nixon, M. B. Georgia
Nixon, Ray. Kansas
Nold, Vern. Central States
Nordell, Carl H. Central States
Norfleet, Clark T. (Alt.) California
Norgaard, John. Michigan
Norman, G. A. Central States
Norman, James E. Texas
Norris, Francis I. Federal
Nugent, Franklin J. Pennsylvania
Nugent, Harold F. New York
Nugent, Lee M. California
Nussbaumer, Newell L. New York
Nussberger, Fred. New York
Nutter, Frank H. Central States

Obma, Chester A. Central States
O'Brien, Earl F. New York
Ocean City Sewer Service Co. New Jersey
Ockershausen, Richard W. New York
O'Connell, Wm. J., Jr. California
O'Connor, Wm. F. New York
Odbert, Eugene, Jr. Central States
O'Dell, W. H. New York
O'Donnell, Chas. F. New York
O'Donnell, R. Pennsylvania
Oeffler, W. A. Central States
Oeming, L. F. Michigan
O'Flaherty, Fred. Ohio
Ogden, Henry N. New York
Ogle, Harry B. California
O'Hara, Franklin. New York
O'Hara, John. Pennsylvania
Ohr, Milo F. Michigan
Oke, Ernest E. W. Canada
Okun, Abraham H. New York
Okun, Daniel A. Central States
Okun, W. H. New York
Old, H. N. Federal
Olewiler, Grant M. Pennsylvania
Olsen, W. C. North Carolina
Olson, Frank W. Central States
Olson, Herbert A. Michigan
Omega Machine Co. Associate
O'Neill, Ralph W. California

Orchard, W. J. New York
Ongerth, Henry J. California
Orr, Wm. S. Canada
Orton, J. W. Michigan
Osage, City of (Iowa). Iowa
Osborn, L. C. Rocky Mountain
Ousterhout, Alfred. New York
Owings, Noble L. Maryland-Delaware

Pacific Flush Tank Co. Associate (Corporate —Central States)
Paessler, Alfred H. Texas
Page, C. A. Georgia
Painter, Carl E. California
Palange, Ralph C. Federal
Pallo, Peter E. New York
Palmer, Benjamin M. New England
Palmer, C. L. Michigan
Palmer, Harold K. California
Palmer, John R. Central States
Palocsay, Frank S. Ohio
Pampa, City of (Texas). Texas
Parker, L. K. New England
Parks, G. A. California
Parrish, Rial T. Ohio
Parsons, Chase. Central States
Parsons, R. H. Canada
Patterson, Roy K. New York
Paul, Lewis C. New York
Paul, Richard B. Pennsylvania
Pawlak, John S. New York
Payrow, Harry G. Pennsylvania
Peake, J. B. New York
Pearl, Emanuel H. Texas
Pearsall, Ted. Central States
Pearse, Langdon. Central States
Pease, Maxfield. Ohio
Peaslee, Geo. A. Central States
Peck, Lawrence J. New York
Pecker, Joseph S. New York
Peightal, Wm. H. California
Peirce, W. A. Central States
Peirson, Henry C. (Alt.) California
Pence, Irel V. Central States
Pennsylvania Salt Mfg. Co. Associate
Perrine, J. Franklin. New York
Perry, Earl R. New England
Perry, J. S. Central States
Peterson, Earl L. New York
Peterson, Ivan C. Central States
Peterson, J. H. California
Peterson, Myhren C. Central States
Peterson, Ralph W. Central States
Petrie, Wm. P. New England
Pett, K. M. Central States
Pfiffer, Fred. California
Phelps, B. D. California
Phelps, E. B. New York
Phelps, Ellis K. Florida
Phelps, Geo. Canada
Phillips, H. N. New York
Phillips, R. S. North Carolina
Phillips, Roy L. Pennsylvania
Phillips, R. W. Texas
Piatt, Wm. M. North Carolina
Pierce, C. L. California
Pierce, George O. Central States
Pierce, H. M. South Dakota
Pierce, W. E. (Alt.) Michigan
Pierron, Wm., Sr. Pacific Northwest
Pincus, Sol. New York
Pinkney, Glenn E. New York
Pinney, F. W. North Dakota
Pirnie, Malcolm, Jr. Federal
Pisano, Frank. California
Pitkin, Ward H. New York
Pittsburgh-Des Moines Co. Associate
Pittsburgh Equitable Meter Co. Associate
Pizie, Stuart G. Florida
Plamondon, Sarto. Canada
Pledger, A. England (I. S. P.)
Plummer, Raymond B. Central States
Pohl, C. A. New York
Poindexter, G. G. Central States
Pollex, Elmer. Ohio
Pollock, John M. New York
Pomeroy, Clarence. Michigan
Pomeroy, Richard. California
Poole, B. A. Central States
Poole, S. B. England (I. S. P.)
Poole, Wm. A. California
Pope, Lester. New Jersey
Porges, Ralph. Federal
Porteous, W. K. England (I. S. E.)
Porter, H. California
Porter, William. New York
Poston, R. F. South Dakota
Potts, Clyde. New York
Potts, Harry G. Michigan
Powell, A. R. New York
Powell, Reuben R. Florida
Powell, S. T. Maryland-Delaware
Powell, W. L. Texas
Powers, E. C. Ohio
Powers, Thomas J. Michigan
Pratt, Gilbert H. New England
Pratt, Jack W. California
Pray, John W. Iowa
Prendergast, John W. Arizona
Price, Charles R. South Dakota
Pringle, H. L. Canada
Probasco, S. R. New Jersey
Proportioneers, Inc. Associate
Proudman, Chester F. New England
Provost, Andrew J. New York
Public Works Magazine. Associate

Puckhaber, Fred H. Texas
Puffer, Stephen P. New England
Purdie, David J. New York
Purser, John R., Jr. North Carolina
Pyle, Wm., Jr. Iowa

Quaely, Martin F. New York
Quartly, Eric V. California
Quigley Company, Inc. Associate
Quinn, Joseph L., Jr. Central States

Racek, L., Jr. Central States
Radcliff, Robert C. Rocky Mountain
Radcliffe, Jack C. New Jersey
Raisch, Wm. New York and New England
Ralston, Wilmer R. Pennsylvania
Ramseier, Roy E., Sr. California
Rankin, R. S. Central States
Rantsma, W. Frank. (Alt.) California
Ratcliffe, Clyde. North Carolina
Rath, Henry M. New York
Rawlins, George S. North Carolina
Rawn, A. M. California
Rawson, E. Otto. Canada
Ray, Clayton B. Georgia
Raymond, Nelson I. Michigan
Read, Homer V. Central States
Reames, H. S. (Alt.) Michigan
Reardon, Wm. R. Central States
Reaves, S. H. Georgia
Rector, K. E. Kansas
Redding, Harry P. North Carolina
Redfern, W. B. Canada
Redmon, Polk. Central States
Reed, Leon H. New England
Reedy, Timothy D. Michigan
Rees, N. B. Central States
Reese, Marshall. Pennsylvania
Reeve, Lester G. Pennsylvania
Reeves, C. F. California
Reeves, R. B. Kansas
Regester, Geo. E., Jr. Pennsylvania
Regester, Robt. T. Maryland-Delaware
Rehler, Joseph E. New York
Reid, Geo. W. Florida
Reid, G. Graham. Canada
Reidell, Alfred G. California
Rein, L. E. Central States
Reiners, A. H. New Jersey
Reinhardt, Arthur W. California
Reinke, E. A. California
Reinoehl, Don. California
Reisch, E. A. New York
Reisert, Michael J. New York
Remsburg, W. N. Kansas
Remsen, John. New York
Requardt, G. J. New York
Reuning, Howard T. Pennsylvania
Reybold, E. C. Rocky Mountain
Reynolds, Leon B. California
Reynoldson, C. G. Central States
Reynoldson, T. B. England (I. S. P.)
Rhoads, Edward J. Pennsylvania
Ribal, Raymond Robt. California
Ribner, Morris. New York
Ribreau, Gilbert E. New York
Rice, Archie H. Pacific Northwest
Rice, John E. Federal
Rice, John M. Pennsylvania
Rice, Lawrence G. New York
Richards, G. H. Canada
Richards, Paul W. Central States
Richardson, C. G. Associate (Dual—New England)
Richgruber, Martin. Central States
Richheimer, Chas. E. Florida
Richman, W. F. Central States
Richter, James B. Central States
Richter, Paul O. Central States
Rickard, Grover E. New York
Riddick, Thomas M. New York
Ridenour, G. M. Michigan
Riedel, John C. New York
Riedesel, Henry A. Central States
Riedesel, P. W. Central States
Riehl, W. H. Canada
Riffe, Norman T. California
Riis-Cartensen, Erik. New York
Riker, I. R. New Jersey
Ritter, Bruce. (Alt.) Michigan
Roab, F. H. Central States
Roahrig, Henry L. Central States
Roberton, L. T. Canada
Roberts, C. R. New York
Roberts, F. C., Jr. California (Dual—Federal)
Roberts, Jack. New York
Roberts, W. C. California
Robertson, Geo. E. New York
Robertson, John. California
Robins, Maurice L. Central States
Robinson, B. Canada
Robinson, Fred M. Central States
Robinson, G. G. Canada
Robinson, I. F. Canada
Robinson, Philip L. Georgia
Robinson, W. S. (Alt.) California
Rocco, John. New York
Rock, Harold F. New York
Rodwell, Robt. D. Central States
Roe, Frank C. Central States and New York
Roeller, R. S. Pennsylvania
Roetman, Edmond T. Pennsylvania
Rogers, Allan H. New York
Rogers, D. Paul. Pennsylvania
Rogers, Harvey G. Central States
Rogers, Jack C. Federal

Rogers, John A. New England
Rogers, M. W. Canada
Rogers, Milford E. Kansas
Rogers, W. F. Central States
Rohlick, Gerard A. Central States
Roll, A. H. Central States
Romaine, Burr. Central States
Romeiser, C. H. Central States
Rosemeyer, Alfred. Central States
Rosen, Milton. Central States
Rosengarten, W. E. Pennsylvania
Ross, Herman M. Central States
Ross, W. E. Central States
Roth, R. F. Ohio
Rowen, R. W. Central States
Rowntree, Bernard. California
Royer Foundry & Machine Co. Associate
Ruchhoft, C. C. Central States (Dual—Federal)
Ruck, Franklin. Ohio
Ruckel, Paul J. Rocky Mountain
Rudgal, H. T. Central States
Rudolfs, Willem. New Jersey
Rudolph, R. L. California
Ruge, J. Herman. Florida
Ruggles, M. H. Florida
Ruhmann, Ovid G. Central States
Rumble, G. B. Canada
Rumsey, James R. Michigan
Rupp, Daniel H. Ohio
Ruppert, E. L. Pacific Northwest
Russell, George. Missouri
Russell, George S. Missouri
Russell, J. P. Canada
Ryan, Alfred J. Rocky Mountain
Ryan, Joseph P. Central States
Ryan, J. Samuel. New York
Ryan, Wm. A. New York
Ryckman, Seymour J. New England
Rymer, Mary E., Mrs. Rocky Mountain

Saetre, Leif. New York
Sage, Howard D. New York
Sager, John C. Central States
Sala, David W. Central States
Salle, Anthony. New York
Salvato, J. A., Jr. New York
Sammis, L. A. New York
Samson, Channel. New York
Samuelson, Andy. New York
Sanborn, J. F. New York
Sanchis, Joseph M. California
Sander, Irwin P. New York
Sanders, M. D. Central States
Sanderson, W. W. New England (Dual—New York)
Sargent, Edward C. Ohio
Sauer, Victor W. California
Saunders, E. F. Central States
Savage, Edward. New York
Saville, Thorndike. New York
Sawyer, C. N. Central States
Sawyer, Lee. Michigan
Sawyer, Robt. W., Jr. New England
Scales, E. P. Georgia
Schade, Willard F. Ohio
Schaefer, Edw. J. New York
Schaetzle, T. C. Ohio
Schaut, Geo. G. Pennsylvania
Scheak, H. M. Canada
Scheffer, Louis K. Pennsylvania
Scheidt, Burton A. Central States
Schenk, E. F. Iowa
Schick, V. R. Ohio
Schier, Lester C. Central States
Schirk, J. M. Rocky Mountain
Schlenz, Harry E. Central States
Schliekelman, R. J. Iowa
Schmick, Mark F. Pennsylvania
Schmit, J. M. Rocky Mountain
Schneller, M. P. Central States
Schoeninger, C. J. Michigan
Schoepfle, O. F. Ohio
Scholl, Clarence E. Central States
Schott, Edgar C. California
Schouten, Ernest W. Oklahoma
Schrack, Bert. Iowa
Schreiner, W. R. New York
Schriner, P. J. Central States
Schroeder, Arthur W. Central States
Schroeder, W. L. South Dakota
Schroepfer, George J. Central States
Schubert, Frank J. Central States
Schuck, H. W. California
Schulhoff, Henry B. New York
Schureman, A. L. California
Schuyler, Howard L. Pennsylvania
Schwartz, Charles F. New York
Schwartz, H. L. Pennsylvania
Schwartz, Louis. New York
Schwartz, Oswald. Central States
Schwob, Carl E. Texas
Sciver, A. England (I. S. E.)
Scott, Cliffton A. Central States
Scott, Guy R. Federal
Scott, Ralph. Central States
Scott, Roger J. Central States
Scott, Rossiter S. New York
Scott, W. England (I. S. P.)
Scott, Warren J. New England
Scott, W. M. Canada
Scott, Walter M. New York
Scovill, John R. New York
Searight, Geo. P. Pennsylvania
Searls, Glenn. New York
Seaver, Wist D. Missouri

Sedlacek, A. J. Iowa
Seeger, M. Dean. Pacific Northwest
Segel, A. (Alt.) California
Seid, Sol. New Jersey
Seifert, Wm. P. New York
Seligmann, Irving S. Texas
Sellers, A. E. England (I. S. P.)
Seltzer, J. M. Pennsylvania
Senseman, Wm. B. California
Setter, Lloyd R. New York
Sewage Works Engineering. Associate
Shank, John J. Pennsylvania
Shapiro, Maurice A. Florida
Shapiro, Robert. New York
Shaw, Frank R. Federal
Shaw, Morton. Central States
Shaw, Paul A. California
Shaykin, Jerome D. Central States
Shea, Walter J. New England
Shearer, A. B. California
Sheen, Robt. T. Pennsylvania
Sheets, W. D. Ohio
Shehlee, Girard. New York
Shelton, M. J. California
Shephard, W. F. Michigan
Shepperd, Frederick. New York (Dual—New England)
Shera, Brian L. Pacific Northwest
Sherman, Leslie K. New England
Shertzer, J. H. Pennsylvania
Shipman, R. H. Central States
Shirley, Donald L. Pacific Northwest
Shockley, Homer G. New York
Shodron, John M. Central States
Shook, H. E. California
Shook, H. R. Canada
Showalter, Charles M. Pennsylvania
Shupe, S. Canada
Sickler, Archie H. New York
Sidle, R. S. England (I. S. P.)
Siebert, Christian L. Pennsylvania
Siegel, John A. California
Signor, C. V. Pacific Northwest
Sigworth, E. A. New York
Silberbauer, Walter R. California
Silberts, S. A. California
Simmerman, John S. New Jersey
Simmons, Harold. New York
Simmons, M. F. Georgia
Simon, Samuel S. New York
Simonton, Lewis R. Georgia
Simplex Valve & Meter Co. Associate
Simpson, Maynard. Central States
Simpson, R. W. New York
Simson, George, Jr. Rocky Mountain
Simson, Paul W. New York
Singer, Oscar C. Ohio
Singleton, M. T. Georgia
Siple, H. M. Pennsylvania
Sisler, H. H. Pacific Northwest
Skinner, J. F. California
Skinner, W. V. (Alt.) California
Sklarevsky, Rimma. Maryland-Delaware
Slagle, Elmer C. Central States
Slee, Angus E. Rocky Mountain
Slinger, J. F. Missouri
Sloan, Garrett. Federal
Slocum, Adelbert I. New York
Slough, John. New York
Small, R. L. Pacific Northwest
Smith, A. H. Ohio
A. P. Smith Manufacturing Co. Associate
Smith, Benjamin L. New York
Smith, C. A. California
Smith, Chas. L. California
Smith, E. A. Cappelen. New York
Smith, Earl T. (Alt.) Michigan
Smith, Edward J. New York
Smith, E. E. Ohio
Smith, F. Burton. Florida
Smith, Frank E. California
Smith, Frank J. New York
Smith, G. C. England (I. S. P.)
Smith, Gilbert M. Central States
Smith, H. G. California
Smith, Harold. New York
Smith, Harold L. Michigan
Smith, Harvey J. Pacific Northwest
Smith, J. Irwin. Central States
Smith, J. F. California
Smith, L. R. New York
Smith, Marvin L. Pennsylvania
Smith, Paul L. Maryland-Delaware
Smith, R. C. New Jersey
Smith, R. L. Central States
Smith, Russell S. Federal
Smith, R. Turmbull. Central States
Smith, Ralph A. Central States
Smith, Robt. J. Michigan
Smith, S. H. Michigan
Smith, W. Austin. Georgia
Smith, Walter E. Michigan
Smithson, Thomas. Pacific Northwest
Snedeker, L. Laverne. Michigan
Sneed, Glenn J. Central States
Snell, J. R. New England
Snelsire, Wm. Pennsylvania
Snook, W. F. A. England (I. S. P.)
Snow, Donald L. Central States
Snow, Willis J. New England (Dual—New York)
Snyder, Clifford A. Ohio
Snyder, John A., Jr. California
Snyder, M. K. Pacific Northwest
Snyder, N. S. New York
Snyder, R. F. Ohio

Solander, Arvo A. Federal
Solomon, G. R. New York
Somers, Verne. Central States
Sorbel, J. L. South Dakota
Souther, Fred L. California
Sowden, Howard J. Central States
Sowdon, Wm. K. New York
Spaeder, Harold J. Central States
Spaeth, Julius. Kansas
Sparr, A. E. New York
Spaulding, L. H. Pacific Northwest
Spear, Wm. B. Pennsylvania
Specht, James E. Ohio
Speiden, H. W. Pennsylvania
Spellman, W. A. Canada
Spencer, Chas. C. Federal
Spencer, City of (Iowa). Iowa
Sperbeck, George E. California
Sperling, Elmer J. Florida
Sperry, Walter A. Central States
Spiegel, Milton. Central States
Spieker, Roy G. South Dakota
Spies, Kenneth H. South Dakota
Spragg, H. J. Iowa
Spry, Fred J. New York
Spurgeon, Ralph. Central States
Staley, H. H. Kansas
Stanbridge, H. H. England (I. S. P.)
Standley, J. B. Texas
Stanhope, Clifford T. New York
Stankewich, M. J. New York
Stanley, C. M. Iowa
Stapf, R. J. South Dakota
Stapley, Edward R. Oklahoma
Stark, Louis. Michigan
Starling, Chas. H. North Carolina
Stauff, Paul V. Central States
Staynes, E. H. England (I. S. P.)
Steacy, John J. New York
Stearns, Donald E. New England
Steffen, A. J. Central States
Steffensen, S. W. New York
Steffes, Arnold M. Central States
Stegeman, Paul. Michigan
Steindorf, R. T. Central States
Steiner, S. K. New York
Stepleton, Harold A. Ohio
Sterling, Clarence I. New England
Sterns, Edw. A. New York
Stevens, Donald B. Federal
Stevens, Harry. Maryland-Delaware
Stevenson, Albert H. New York
Stevenson, Ralph A. California
Stewart, H. M. Pennsylvania
Stewart, Morgan E. California
Stewart, W. H. New York
Stiemke, Robt. E. North Carolina
Stilson, Alden E. New York
Stites, H. L. California
St. Louis County Health Dept. Missouri
St. Louis Public Library. Missouri
Stock, Mitchell B. New England
St. John, Conrad H. Florida
Stone, A. R. England (I. S. P.)
Storey, Benjamin M. Central States
Storrie, Wm. Canada
Stowell, E. Ralph. California
Straker, M. L. Ohio
Strang, J. A. Kansas
Strangard, Edward L. California
Stratton, Chas. H. New York
Straub, Conrad P. New York
Street, Haskell R. Texas
Streeter, H. W. Federal
Streeter, Robt. L. Rocky Mountain
Streeter, S. H. England (I. S. E.)
Strelow, J. L. Iowa
Strickland, Raymond. Central States
Stringer, R. M. Georgia
Strockbine, Walter. Pennsylvania
Stroessenreuther, G. A. Central States
Strong, Bruce F. New York
Strotkamp, Chas. E. California
Strowbridge, John C. New York
Stuart-Brumley Corp. Associate
Studebaker, Leo. New York
Stunkard, C. R. California
Sturgeon, R. G. Canada
Stutz, C. N. Central States
Sulentic, S. A. Kansas
Sullivan, R. H. Georgia
Summers, M. W. England (I. S. E.)
Sund, Gutorm. Central States
Susa, Stephen A. Pacific Northwest
Sutcliffe, H. W. Canada
Suter, Max. Central States
Sutherland, Henry M. New York
Suttie, R. H. New England
Sutton, R. W. England (I. S. P.)
Svenson, Sven H. New York
Svore, Jerome H. North Dakota
Swab, Bernal H. North Carolina
Swartz, Martin. North Carolina
Sweeney, J. Stanley. Florida
Sweeney, R. C. New York
Sweet, Theodore T. Florida
Swender, Harvey P. Iowa
Swenholt, John. New York
Swenson, John P. Georgia
Swinehart, Eugene B. Pennsylvania
Swope, Gladys. Central States
Sylliassen, M. O. Pacific Northwest
Sylvester, Wm. L. New York
Symons, G. E. New York
Szymanski, John R. New England

Taggart, Robt. S. New York
Talbot, F. D. California
Tallamy, Bertram Dalley. New York
Tamer, Paul. New York
Tapleshay, John A. Central States
Tapping, C. H. Central States
Tarbell, W. P. North Dakota
Tarbett, R. E. Federal
Tarlton, Ellis A. New England
Tatlock, M. W. Ohio
Taylor, Arthur. California
Taylor, D. R. Florida
Taylor, Frank S. Oklahoma
Taylor, F. W. Georgia
Taylor, Godfrey M. C. England (I. S. E.)
Taylor, H. England (I. S. P.)
Taylor, Henry W. New York
Taylor, J. England (I. S. P.)
Taylor, Warren G. New York
Teel, Jess W. California
Tempest, W. F. Central States
Tennant, H. V. Central States
Terhoeven, G. E. New York
Terhune, A. S. New Jersey
Ternent, A. Canada
Terry, Frank. New York
Tetzlaff, Frank. New York (Dual—Federal)
Thalheimer, Marce. Central States
Thamasett, Otto E. New York
Thatcher, Fred A. New York
Thatcher, H. D. England (I. S. P.)
Thayer, Paul M. Central States
Thayer, Reginald H. New York
Theriault, E. J. Federal
Theroux, Frank R. Michigan
Thews, Vernon W. California
Thiel, James A. Pacific Northwest
Thierman, Frank. Central States
Thoits, Edw. D. California
Tholin, A. L. Central States
Thomas, A. England (I. S. P.)
Thomas, A. H. R. Canada
Thomas, Ariel A. Central States
Thomas, E. R. North Carolina
Thompson, E. H. New England
Thompson, F. N. New York
Thompson, H. Loren. Central States
Thompson, J. T. England (I. S. P.)
Thompson, N. J. Rocky Mountain
Thompson, Robert B. New England
Thomson, J. B. F. New York
Thorn, William J. Pennsylvania
Tierney, Lawrence J. J. New England
Timm, Arthur. Central States
Timmons, Cyrus L. Florida
Tims, Wm. C. Florida
Todd, J. L. California
Todd, Stanley B. New York
Tolagson, Clarence F. California
Toledo, City of (Iowa). Iowa
Tolles, Frank C. Ohio
Tolman, S. L. New York
Tomek, Arthur O. Central States
Tomkins, Lloyd. Michigan
Tomm, La Vern M. New York
Toone, Dean Wm. California
Towne, W. W. South Dakota
Townend, C. B. England (I. S. P.)
Townsend, Darwin W. Central States
Trager, Leonard W. New England
Trautwein, Frederick. New York
Travaini, Dario. Arizona
Trebler, H. A. Pennsylvania
Troimper, Paul A. Central States
Trotter, Roy M. California
True, Albert O. North Carolina
Trulander, Wm. M. Central States
Tuhus, Kenneth. Central States
Turner, Homer G. Pennsylvania
Turner, J. R. Ohio
Turner, Wm. S. Pacific Northwest
Turpin, U. F. Central States
Tuttle, Leon E. New England
Twin City Testing & Engr. Laboratory (Corporate). Central States
Tygert, C. B. Pennsylvania
Tyler, R. G. Pacific Northwest

Udell, Harold. Federal
Uhlmann, Paul A. Ohio
Ulip, Anthony. New York
Ullrich, C. J. (Alt.) California
Umbenhauer, E. J. Pennsylvania
Underwood, J. E. Canada
United States Pipe & Foundry Co. Associate
University of Calif. Library. California
University of Southern California Genral Library. California
Updegraff, W. R. California
Upton, Frank W. New York
Urban, Robert C. New York
Urick, R. H. Iowa
Urquhart, M. B. Rocky Mountain
Ussery, A. E. Texas

Valdese Water Works (N. Car.). North Carolina
Van Atta, J. W. New York (Dual—New England and Pennsylvania)
Van Denburg, J. W. New York
Vanderlip, Arthur N. New York
Van Der Vliet, Henry. New Jersey
Van Deusen, E. J. New York
Van Horn, R. B. Pacific Northwest
Van Kleeck, LeRoy W. New England
Van Ness, Joseph A. Rocky Mountain
Van Praag, Alex., Jr. Central States
Van Wyck, George W. New York

Vapor Recovery Systems Co. Associate
Vaseen, V. A. Rocky Mountain
Vaughan, E. A. California
Veatch, F. M. Rocky Mountain
Veatch, F. M., Jr. Central States
Velz, C. J. New York
Velzy, C. R. New York
Venn, Frank. (Alt.) Michigan
Vensano, H. C. California
VerDow, William H. (Alt.) New York
Vest, W. E. North Carolina
Vickery, John U. Florida
Victoria, John. New York
Vivier, Harvey. New England
Vogelbein, Chas. J. Missouri
Vognild, R. O. Pacific Northwest
Voigt, Richard C. New York
Volpp, A. G. Pacific Northwest
Von Pelt, Richard. California
Vredenburg, Edward L. New York
Vrooman, Morrell. New York

Waddell, W. H. Canada
Wade, Clarence. Central States
Wade, W. J. Central States
Wadhams, S. H. New England
Wagenhals, H. H. New York
Waggoner, E. R. California
Wagner, Edward P. New York
Wagner, Edwin B. Pennsylvania
Wahlstrom, Carl A. Central States
Wailes Dove-Hermiston Corp. Associate
Walbridge, Thornton. Central States
Walker, C. C. Ohio
Walker, Chas. L. New York
Walker, Elton D. Pennsylvania
Walker, Miss Irene. Pacific Northwest
Walker, J. Donald. Central States
Walker, Philip B. New England
Walker, Walter J. (Alt.) California
Walker, William W. Federal
Wallace & Tiernan Co., Inc. Associate
Wallace, W. M. Michigan
Wallach, Arthur. Federal
Walters, F. Y. Canada
Walters, Grover L. California
Walton, Graham. Central States
Ward, A. R. England (I. S. P.)
Ward, C. N. Central States
Ward, Oscar. Central States
Ward, Paul. Pacific Northwest
Warden, Lotus A. Central States
Wardle, J. McClure. New York
Wardwell, T. M. Central States
Ware, Howard. New York
Warren, George D. New York
Warrenton Water Co. North Carolina
Warrick, L. F. Central States
Washburn, Howard C. New York
Washington State Pollution Commission. Pacific Northwest.
Water Department (Hemp, No. Car.). North Carolina
Water Works & Sewerage. Associate
Waterman, Earle L. Iowa
Waters, Geo. E. Central States
Waters, Leslie W. New York
Watmough, W. W. Canada
Watson, Carl H. New York
Watson, David M. England (I. S. E.)
Watson, Henry G. Rocky Mountain
Watson, W. England (I. S. P.)
Watters, T. C. Central States
Weachter, Horace. Pennsylvania
Weasner, Leo. Central States
Weatherby, Chas. H. New York
Weaver, W. H. Georgia
Webber, Roy H. Canada
Wechter, Wm. H. New York
Wedeman, John D. New York
Webber, Earl R. Michigan
Weeber, Wm. Keith. Central States
Weed, Sam A. California
Wiegel, S. R. Federal
Weiner, Daniel J. Federal
Weir, E. England (I. S. P.)
Weir, Paul. Georgia
Weisel, W. O. Pennsylvania
Weiss, R. H. Texas
Welch, Geo. C. New York
Welch, W. H. Texas
Welker, Leland A. New York
Wells, E. Roy. Central States
Wells, S. W. Florida
Welsch, W. Frederick. New York
Welsh, James M. Texas
Welsh, William J. New England
Wenger, J. H. Ohio
Wentworth, John P. New England
Wertz, C. F. Pennsylvania
Wertz, Leroy F. Ohio
West, A. W. Central States
West, Leslie E. New Jersey
Westergaard, Viggio. New York
Westfall, Milton. Central States
Weston, Arthur D. New England
Weston, Roy F. Pennsylvania
Weston, R. S. (Deceased). New England
Westwood, H. W. D. England (I. S. E.)
Wheeler, C. E., Jr. Central States
Wheeler, Robt. C. New York
Whelchel, H. E. Georgia
Whipple, Melville C. New England
Whitby, Stephen S. Pennsylvania
Whitcomb, Leon R. Pennsylvania
White, Geo. C. California
White, Paul R. Central States
White, R. E. California

White, R. H. England (I. S. E.)
White, W. W. California
Whitehead, F. E. New Jersey
Whitehead, H. C. England (I. S. P.)
Whitley, F. H. New York
Whitlock, Ernest W. New York
Whitlock, Henry C. New England
Whitney, Alfred C. Col. Central States
Whittaker, H. A. Central States
Wiegert, Lester O. Central States
Wiest, Gordon J. Pennsylvania
Wieters, A. H. Iowa
Wigley, Chester G. New York
Wilbanks, Lowry G. Georgia
Wild, Harry E. Florida
Wiley, John S. Federal
Wilkes, F. Dean. Canada
Wilkins, George F. California
Willett, C. K. Central States
Williams, A. C. Pennsylvania
Williams, C. C. Central States
Williams, Chas. H. Pacific Northwest
Williams, Chas. W. Central States
Williams, Clyde E. Central States
Williams, G. Bransby. England (I. S. E.)
Williams, J. E. Texas
Williams, Leon G. Central States
Williams, L. O., Jr. Rocky Mountain
Williams, R. L. New York
Williams, W. B. Michigan
Williamson, A. E. Florida
Williamson, F. Martin. Central States
Williamson, Joe, Jr. Florida
Williamson, R. C. Canada
Wilson, C. T. Iowa
Wilson, Harry L. Central States
Wilson, J. B. Central States
Wilson, John. Central States
Wilson, Murray A. Kansas
Wilson, R. D. Central States
Wilson, Robert A. Central States
Wilson, Wm. B. Canada
Winch, Norman M. New England
Windell, Talmage. Central States
Windridge, M. E. D. England (I. S. P.)
Winfield, Wilmer M. New York
Wing, Frederick K. New York
Winne, Geo. New York
Winslow, Wm. H. Pennsylvania
Winter, Orvan V. Central States
Wintersgill, A. T. California
Wirt, R. M. Pennsylvania
Wirth, Harvey E. Central States
Wirts, J. J. Ohio
Wisely, F. E. Central States
Wisely, W. H. Central States
Wishart, J. M. England (I. S. P.)
Wisniewski, Theo. Central States
Witcher, C. Preston. Michigan
Withington, C. Canada
Wittenborn, E. L. Central States
Wittmer, Earl F. Ohio
Wittwer, N. C. New Jersey
Woese, Carl F. New York
Wolfteich, John. New York
Wolman, Abel. Maryland-Delaware
Wolterink, Paul. Michigan
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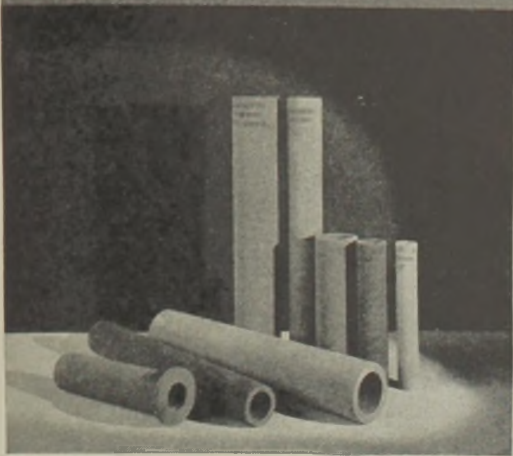



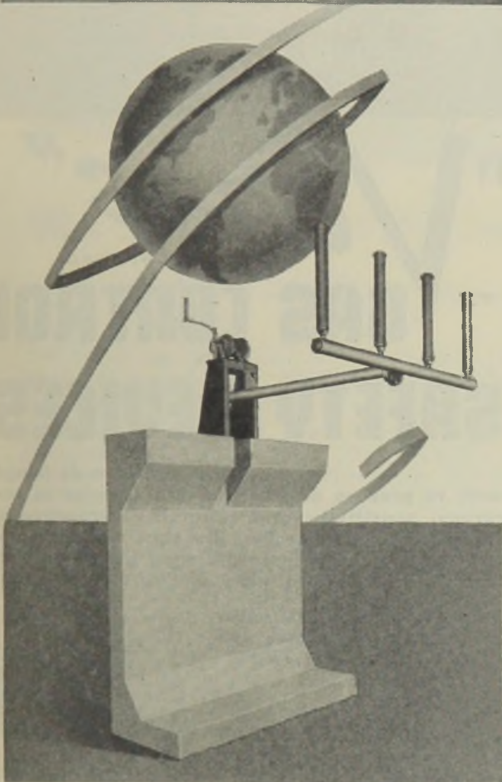

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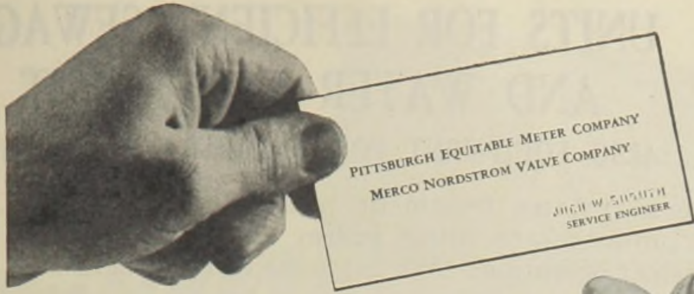


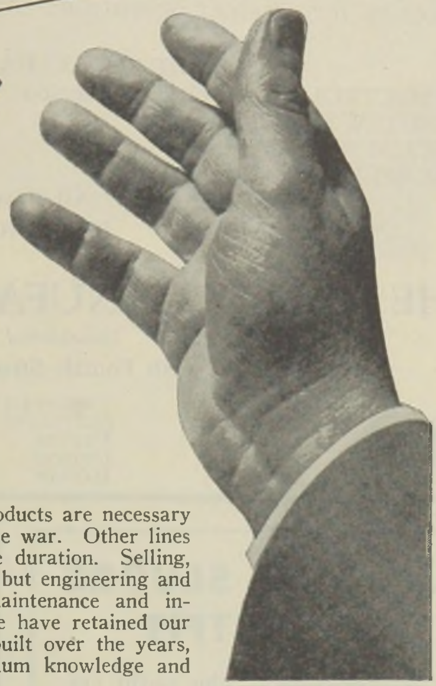

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