SEWAGE WORKS JOURNAL

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Special Features

Report of Research Committee

A New Grit Chamber—Camp

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SEWAGE WORKS JOURNAL

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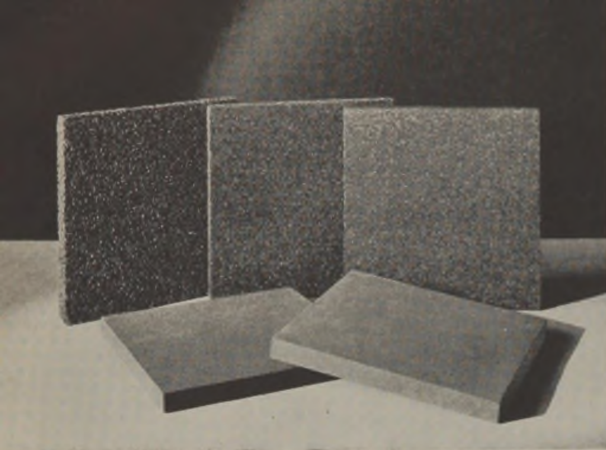

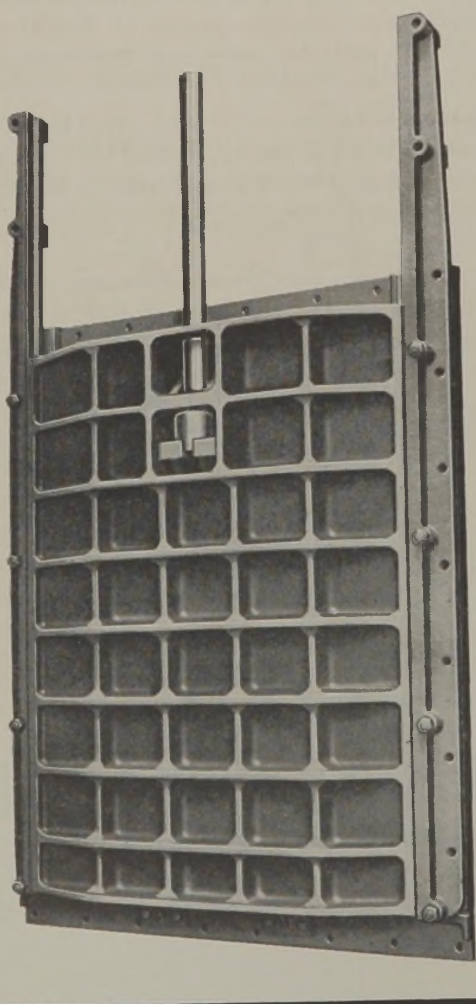

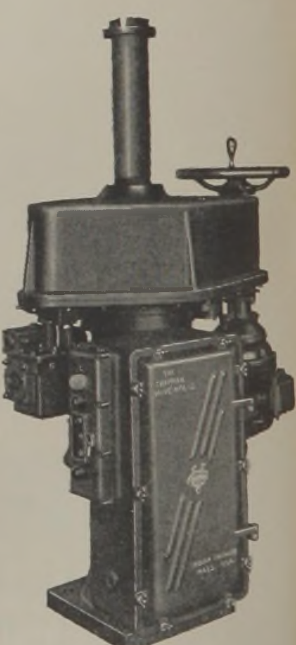


6 REASONS
WHY MODERN
SEWAGE LINES ARE
DRESSER-COUPLED

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Plant Operation:

Sewage Research:

Industrial Wastes:

The Operator's Corner:

Plant Operation

DESIGN OF SEWAGE TREATMENT PLANTS TO FACILITATE OPERATION *

By Stuart E. Coburn

Chief Chemist, Metcalf and Eddy, Boston, Mass.

More than twenty-five years of experience with the operation of plants for the treatment of sewage and industrial wastes has, naturally, resulted in the establishment in the author's mind of certain ideas as to the design of such plants, not as regards structural features but in the matter of operating ease and the economical accomplishment of as uniformly satisfactory purification as possible.

Too often both designer and operator forget that the objective to be obtained by operation of a sewage plant is the removal of impurities at the least cost consistent with securing the requisite degree of treatment. Too often the designer hopes to gain fame for himself by being the first to adopt some new device or process irrespective of the lack of demonstrated value under plant-scale conditions. Too often the operator hopes to discover new principles by running his plant as an experimental station. If designer and operator will consult one with the other and co-operate in cautious progress, improvements in plant design and the adaptation of new knowledge thereto can be brought about without venturing too far upon untried, uncharted courses which may lead to disaster.

General Considerations

Obviously, the first matter to be decided when an engineer is faced with the problem of design of a treatment plant is the degree of treatment required for the particular conditions involved. The engineer should have available, or should secure, information based upon a thorough investigation of the receiving body of water. This information should cover not only stream flow but also the use of water by lower riparian owners and the capacity of the stream for taking care of pollutional loads. The engineer should determine the requirements of the State or Federal authorities in regard to that particular body of water. He should determine also, within reasonable limits, the quantity and quality of sewage in the municipality and the probable effect of industrial wastes upon treatment processes. Too many times this basic information has not been secured, with unfortunate subsequent results.

With the type of treatment determined, the next decision must be the location of the plant. The site should be chosen as far away as pos-

* Presented at the Second Annual Convention of the Federation of Sewage Works Assns., New York City, Oct. 9, 1941.

sible from thickly populated districts and the land taken should be of sufficient area to allow for reasonable isolation and future enlargements.

Although ample land should be acquired, it does not necessarily follow that all of this land should be developed as a park area and beautifully landscaped. It costs money to keep lawns cut and watered, hedges and shrubs trimmed, and flower beds weeded. An anemic lawn or mangy shrubbery defeats the purpose of landscaping. A reasonable degree of beautification around treatment plants is highly desirable but it should always be remembered that sewage is a dirty material and that sewage treatment plants are not rose gardens.

Three Major Essentials of Design

Before taking up the details of design, the author wishes to discuss three major essentials of design which make for peace of mind for the operator. These three essentials are: simplicity, flexibility and convenience.

Simplicity.—It is a far cry from the simple intermittent sand filters of the latter part of the 19th century to the activated sludge plants of the present day. Yet these sand filters turned out and are turning out just as good, if not better, effluents than the complicated plants of modern times. Of course, these complicated plants of today make possible the treatment of the sewage of cities like New York and Chicago, an undertaking impossible with sand filters. On the other hand, there is seldom sound reason for designing activated sludge plants for small municipalities. The degree of complexity of design is dependent in considerable measure upon the size of the town for which treatment is to be provided. The small town ordinarily cannot afford to pay proper compensation for the highly skilled operators required for complicated plants. Even in the case of the larger municipalities, complications of design should be avoided unless there are grounds for believing such complications will increase efficiency or decrease operating costs.

Increase in complexity almost invariably increases the number of points at which trouble may occur. Small plants usually are without the necessary staff, either as regards number or as regards qualifications, to locate the causes of all troubles or to correct them when discovered. Even with large plants, the fewer complications, the fewer the headaches for the operators. Too many buttons to push may spoil the sewage.

Flexibility.—The second requirement, flexibility, may result in the designer having to compromise somewhat with the desirability of simplicity. However, when flexibility is provided, it must be done with as much simplicity as possible. With the simple treatment processes such as intermittent sand filtration, there isn't much opportunity or need for more flexibility than is inherent in the process; but, with the more elaborate processes, such as activated sludge, it is highly desirable that considerable flexibility be provided.

Well-known examples are the desirability of variable rates of air application and rates of return sludge, and provisions for more than one point to which waste sludge may be discharged. In separate sludge digestion it is well worth while to be able to vary the routing of raw, partly digested, and digested sludge. The bypassing of certain units and variation of loading may be called for in some plants.

Duplicate units, as in mechanical devices for the screening of raw sewage and alternate non-mechanical devices, are frequently of value. With the high-rate trickling filters, employing recirculation, flexibility is of course absolutely necessary. Duplication of essential units, such as sludge pumps, air compressors, sludge beds and the like, all add to the flexibility of operation. Duplication of units, or alternate methods for accomplishing the same results, are particularly essential where mechanical units, subject to breakdown, are involved.

Convenience.—Possibly the one thing the operator appreciates more than anything else is the ease and convenience of operation under all conditions of weather and climate, convenience for routine duties and convenience for making repairs or for special non-routine duties. Valves must be accessible and easy to operate. Big valves in big plants should be motor operated. Mechanical equipment, such as pumps, screens, heating devices and the like, must be readily accessible for repair and overhauling. Points of lubrication must be easy to get at. Lights should be provided at all important locations. Treatment plants as a whole must be as compact as site conditions will permit. Unnecessary space between units should be avoided. In large plants the housing of equipment, valves, etc. requiring much attention or manipulation, protects the operator from inclement weather and makes for efficiency.

Minor Features of Design

In general, treatment plant designers adequately handle the basic principles and capacity allowances. Most designers try to foresee operating difficulties and to provide against such difficulties. Too often, however, designers forget that sewage is not a simple fluid like water subject only to hydraulic laws. Sewage is a complex, unstable material, variable as regards composition and quantity. Sewage carries many substances and materials which are likely to cause trouble with mechanical devices and which are difficult to deal with either biologically or physically. The hydraulic engineer can estimate sludge friction but he cannot foretell when a piece of burlap, an old shoe or a two-by-four is going to get stuck at an elbow in a sludge pipe.

The designer should listen to the operator if he would learn some of the many vagaries to which sewage is subject; the unexpected things that happen, and the frequency with which a treatment plant fails to behave this year the way it did last. Above all, the designer should avoid accepting laboratory experiments and short time test runs as showing the whole truth with respect to new processes of treatment, or to new methods for control of old processes. Biological methods are readily susceptible to changes in climate and season, and to various other environmental factors. Chemical processes are susceptible to changes in sewage composition and mechanical devices are affected by the character and quantity of trash and grit.

Of late years there has been a marked trend towards the mechanization of sewage plants with the view to making them cleaner and less laborious to operate. Sometimes this means the substitution of one form of labor for another. Mechanical devices must be lubricated and maintained. Parts wear out and have to be replaced, and accidents and breakages occur. Power for operation must be available and the possibility of power failure involves provision for a duplicate source of power. With small plants there is some question as to whether the extreme of mechanization is worth what it costs. In large plants mechanization is inevitable and valuable.

Reference has been made to the complex character of sewage. Among the minor problems involved in its treatment is the handling of screenings, grit and skimmings. Compared with the whole flow of sewage, these substances are small in volume but big in nuisance value. The handling of these substances is among the most vexing of treatment plant operators' troubles. The grinding of screenings and their treatment with the sewage have been a big advance in the past few years. Grit is still something of a problem in spite of efforts to render it relatively unobjectionable. Skimmings are another source of difficulty and their removal from settling tanks and ultimate disposal remain in a not wholly satisfactory state.

In the design of settling tanks it seems to the operator that improvements may be made in inlets and outlets. One difficulty in this connection lies in the non-homogeneous character of sewage. This non-uniformity renders it hard to determine, either by computation or by hydraulic experiments, the best arrangements. The suspended matter in sewage varies in specific gravity, size of particles, quantity and quality. It varies with sewages from different cities and with sewage from the same city. Eddy currents and short-circuiting bring about unexpected results. The solids coming into a primary settling tank are quite different from those entering a final tank. Multiple outlet weirs appear desirable but an example of blind copying of an outlet design is the use of saw-tooth outlet weirs such as used by Imhoff where he wished to offset the settling of tanks located over coal mines in the Ruhr district.

In mechanically cleaned settling tanks the prevention of deposits of septic sludge is important and means to prevent the hanging-up of deposits of sludge upon the slopes of sludge hoppers is important. Pipes through which sludge, particularly raw sludge, is to be conveyed should be of ample size and of the shortest possible length from point of entry to point of discharge. Straight runs are most desirable but, where turns must be made, they should be made through plugged tees to permit rodding or flushing if clogging occurs.

In the distribution of sewage upon filters there is not much room for improvement. Distribution for sand filters and sludge beds should be arranged to prevent washing-out of sand at points of discharge. In the case of trickling filters, the tendency today is towards the use of traveling distributors. These have the advantage of permitting dosing the entire bed area with a high degree of uniformity. They are mechanical devices with moving parts and their nozzles are subject to clogging. The fixed nozzle type of distributor, with automatic inflow control, has been satisfactory on the whole; it is simple and not easily put out of order. This method, however, uses up considerable head and does not cover the filters as well as traveling distributors.

Another point in connection with trickling filters is the need for making provision for flooding to control *Psychoda*. So far, no better method has been developed although it has its serious disadvantages. High rate filters and filters having recirculation appear to be less subject to *Psychoda* than do conventional types. One precaution seems necessary and that is for the entire area of the filter to receive dosing.

In the activated sludge process, designers should attempt to secure the maximum of agitation and aeration, with the minimum expenditure of energy. Devices for determining the sludge blanket in the final tanks are highly important. Well lighted operating galleries of ample size are desirable. Consideration should be given for providing tapered loadings and possibly tapered aeration, although the latter appears the less logical.

The pumping of sludge is still somewhat troublesome, particularly in small plants, as the result of clogging, at times, of screw type pumps or the sloppiness of plunger types. Short, straight suction lines should be the aim of the designer.

Sludge digestion tanks should be well insulated and located, if possible, above ground water. Where gas is collected, suitable safety devices should be provided. Blow-off vents should terminate in the open air and never within enclosures. Opportunity for sampling the contents of the tank at several levels affords the operator a chance to control sludge and scum levels and to know the condition of the digesting material. Open flames should not be located in operating galleries. Ample ventilation of enclosed spaces should be provided.

Sludge drying beds should be designed to permit ease of removal of dried sludge. Particular care should be paid to the design of underdrains and open joints should be surrounded with carefully graded material to prevent the sand from entering. Where dried sludge is to be used for fertilizer either around the plant grounds or by farmers, provision for grinding the dried cake should be made and loading facilities provided. There is a tendency for the designing engineer to stop with the sludge on the bed. Emergency lagoon area is often helpful.

Conveniently located sampling points and provision for sampling will earn the gratitude of every operator. How samples may be collected easily at all times of day and at all seasons of the year deserves careful attention.

Buildings housing equipment should be so designed as to require the minimum of effort to keep clean. Curbs should be placed around sloppy equipment to prevent sewage or wash water splashing or running over the floor. Floors should be pitched to drains or sumps to facilitate washing down when necessary. Adequate ventilation, heat and lighting are essential.

Chlorine control and storage rooms should be separate from other rooms if located in the same building, and access to them should be from the outside only. Where piping to or from chlorine rooms passes through walls and floors, the annular space around the pipes should be plugged tight to prevent chlorine from possible leaks escaping through such openings.

Administration buildings should be neither too large nor too small. Elaborately expensive buildings are out of place at a sewage plant. Such buildings should be neat and dignified and of architecture suitable for the locality. The minimum provision for room facilities should be an office, a laboratory, men's locker room, and lavatories for both men and women.

It goes without saying that proper safety measures should be incorporated in the design. Open tanks and stairways should be protected by railings; explosion-proof electrical fixtures should be used where there may be danger of leaking gas, and adequate ventilation of enclosures provided. Cross connections between water piping and sewage pipes, tanks or other appurtenances must be carefully guarded against.

Time does not permit more than an outline of some of the various ways in which the careful design of sewage treatment plants may facilitate their operation. The purpose of this paper is primarily to provoke discussion and admittedly it is not a complete summary of the innumerable details involved in the design of the various types of sewage plants. If there is one point in particular which the author wishes to emphasize it is that simplification should be the aim of every designer. It has always seemed to the author that, if designing engineers and equipment manufacturers could spend as much time on simplification as they do on elaboration, the sewage plant operator's task would be appreciably lightened; however, that might mean less pay for the latter, which of course would never do.

Discussion

By Morris M. Cohn

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

Many a designing engineer has looked at a perfectly good sewage treatment plant that refused to live up to its expectations and has been reminded of the apt remark that "ideas are funny things—they won't work unless you do. . . ." To this pointed admonition by designers, many an operator has mentally said, "Yes, but its a poor idea that won't work when we work our heads off. . . ."

This, in brief, is the problem of design of sewage treatment to facilitate operation. Design and operation are related functions, since it is almost a platitude that the poorest design becomes good design in the hands of a good operator, while the best design won't work without the cooperation of an operator who is willing to work.

The functions of design, with all garnishment removed, are: to provide the degree of treatment desired; of the quantity and quality of sewage anticipated; at the most reasonable cost of construction and operation; with the greatest possible facility of operation; and with the greatest safety to the operating staff.

The art and science of sewage treatment has advanced to the stage where the ability to design for adequate treatment is unquestioned. But, in order to assure ease of operation, the designer must pose certain questions to himself concerning every unit and portion of his plant, among them being: Will it work? Can it be operated efficiently and safely? Can the operator get to it? Can he repair or replace it? Is it step-saving? Neck-saving? Will it be fool-proof? Trouble-proof? Nuisance-proof? Cuss-proof? How will it operate in 1950? And the crowning question—Could I operate it myself?

It takes vision to visualize the problems of operation, while a plant is in the planning stage, but such vision bears profits in efficiency, economy and safety of operation and maintenance. The plant which requires excessive labor, which involves cumbersome and laborous manipulations, which requires unnecessary steps and movements, which fails to use the right materials, cannot be classed as an efficient plant, regardless of the removal of suspended solids, the reduction in B.O.D. and the effectiveness of disposal of sludge and other residues.

Facility of design requires a facility of mind on the part of the designer.

There are gratifying trends toward designing with an eye toward operation. No one trend in sewage treatment has done as much for facility of operation as the mechanization of treatment processes. We have changed operation from a man-power to horse-power; from grunts to gears, from sweat to switches. In one swoop, unclean hand operations have been eliminated and treatment has changed from back-breaking to brain-cudgeling work.

Mechanization has provided the answer to every one of the functions of design: it has provided the treatment needed, at the most reasonable cost, and with exceptional facility and safety of operation. Fortunately, Rube Goldberg devices have been missing; the equipment has been time-tried, dependable, efficient and of reasonable life-span.

Of most encouraging nature has been the injection of operation knowledge into the personnel of designing engineering organizations. Examine the staffs of many consulting engineering offices and you will find men who have come up from the school of operation. It is significant that the Quarter Century Operators Club contains many men who are today in design work. These operators have the vision to translate design into operation. They can "see" how the plant will work *before* it is built and *must* work—for better or worse. They afford a design-operation "blend" in sewage plant planning which guarantees "anti-knock" performance.

Designers are answering the pertinent question: Could I operate it?, by assuming responsibility for operation during the first and trying year of operation of new plants, and for operation supervision for longer periods. This trend toward giving designers authority over and responsibility for operation should be more widely adopted. It will result in greater facility of operation and better design in the future.

We are learning to translate physical facilities into operation technique. I visited a great sewage work and found on the wall of the operators' locker room a complete piping diagram of the intricate plant, with a "1–2–3–4" series of operating rules. The designer who prepared the rules had to visualize the operation—and in this visualizing must have uncovered design mistakes which were correctible on paper, rather than in concrete and steel.

Perhaps the most business-like attempt to get the most out of plant design, in terms of facility of operation, will be found in the Operation Manual recently issued under the authorship of Mechanical Engineer Roy Hageman of the Southwest Works, Sanitary District of Chicago. This manual, written in style understandable to the operating staff, gives specific instruction on the operation of the mechanical equipment. This plant will work, because the men who operate it know how. Knowing how is the first requisite of successful operation.

The Other Side of the Picture

But facility of operation does not mean that operation becomes so easy that the operator is devoid of responsibilities. The person who said "you can't plow a field by turning it over in your mind," might well have said you can't operate a sewage plant merely by making it easy to operate. The operator has the responsibility of making the most of every device and feature of his plant just as the Sanitary District of Chicago Manual does.

Rather than cussing over something which the designer left out, or planned unwisely, it is the duty of the operator to make the plant work. Blaming it on the designer, is a common habit—but one which reflects little credit on the operator.

It is easy to grumble, but alibis do not make good effluents. The energetic operator applies what I like to call "operating localisms" to make his jobs easier, as the idiosyncrasies of each individual plant affect the design which could not have anticipated such oddities. In this connection, may I say that the operator must not lose sight of the proper place for a gadget and the proper place for standardized equipment. I view a gadget, not as a device in itself, but merely a "localism" which serves to facilitate a step in treatment without substituting for a more dependable, proven device. The greatest value of gadgets is that they prove operators are assuming proper responsibility for making their work simpler and easier.

During the World Series broadcasts, an announcer described DiMaggio as "making baseball look easy." The good operator makes operation look easy, rather than difficult. The best device which can be put into a plant is an operator who takes pride in making his plant function smoothly and effectively.

The best rule to remember in the dual task of design and operation is that "facility" is defined not only as "ease of performance" but as "dexterity." The designer supplies the first, but the operator must provide the second.

UTILIZATION OF SLUDGE GAS IN MODERATE SIZED TREATMENT PLANTS *

By George Martin

Superintendent, Sewage Treatment Works, Green Bay, Wis.

The Green Bay Metropolitan Sewerage District serves approximately 60,000 people living in the City of Green Bay and the adjoining townships. As this territory was fortunately located on both the Fox and East Rivers, sewage disposal did not at first present a serious problem, but as the population and the sulfite paper industry increased, both streams became grossly polluted and it was imperative that stream pollution be abated. To accomplish this the Green Bay Metropolitan Sewerage District was formed, and in January, 1935, interceptors and a sewage treatment plant serving the East River District were placed in operation. This was a 4.5 m.g.d. primary treatment, separate sludge digestion plant containing an 18 m.g.d. pumping station, bar screen, detritor, two 50-ft. center-feed clarifiers, two 40 ft. stationary-covered digesters, and all the appurtenant equipment of a modern sewage treatment plant. As the plans for this plant were made in 1933, when sludge gas engines were in the development stage, it was thought advisable not to include them, but in accordance with accepted practice two gas-fired heating boilers, a gas-burning hot water heater, and gas piping to the laboratory were installed. These units were directly connected to the digester gas domes through the proper safety devices. This provided a means of utilizing the sludge gas which proved quite satisfactory, but as no gas storage was available, there were times when there was a shortage of heat due to gas deficiencies. This, however, was expected and an auxiliary oil burner was originally installed in one of the gas-burning boilers, but it was seldom used until the plant was enlarged except for the first few months after the plant was placed in operation, at which time this oil burner and another rented oil burner provided the only source of heat. It was during these first few months of operation that the real value of utilizing sludge gas was determined as it was found that 200 gallons or $14 worth of oil per day were required to heat the plant and the digesters.

When the addition to the sewage treatment plant was completed and placed in operation in the spring of 1937 the capacity of the plant was doubled and two 50 ft. center-feed clarifiers, two 40-ft floating-covered digesters, two sludge gas engines and generators, a 50 ft. spherical gas holder, and two glass-covered and four open sludge beds had been added. This provided the District with a 9.0 m.g.d. primary treatment plant which now serves the entire Green Bay Metropolitan Sewerage District and does so with an operating cost of approximately $15.00 per million gallons, whereas the cost of operation of the original plant amounted to twice that much.

This new layout of plant and equipment gave the District a new means

* Presented at the Second Annual Convention of the Federation of Sewage Works Assns., New York City, Oct. 9, 1941.

of utilizing sludge gas which produced economies that far exceeded all expectations. Now, instead of utilizing the sludge gas just for heating, the gas is fed to two Worthington heavy-duty, type B.G., 514 r.p.m. gas engines; one a three-cylinder 90 hp. unit and the other a four-cylinder 120 hp. unit; one direct connected to an 80 k.v.a. and the other to a 105 k.v.a. 4000-volt induction generator, which produce almost all of the power that is needed to operate the sewage pumps and the various other electrical equipment in the plant and in addition produces about the same amount of hot water that would be obtained by burning the equivalent amount of gas under the plant boilers. While this may seem strange, nevertheless it is a fact that in this case the gas engines in addition to being electrical producers are just as good heating units as the gas-fired boilers. Undoubtedly this is due to the way in which the hot water is efficiently reclaimed from the engines by conducting the engine cooling water first through the cylinder jackets, then the manifold coolers and exhaust heat exchangers, and then through the entire plant heating system, thereby eliminating the losses due to hot-water heat exchangers. This system, however, was a difficult one to operate as it presented problems that were practically impossible to handle. For instance, the water leaving the engines must be held below a temperature of 160° F. whereas to heat the rooms of the plant properly the water temperature should be above 180° F. and the water entering the digester heating coils not over 135° F.

Referring to Figs. 1, 2, 3, and 4, which are schematic drawings of the plant heating system, it can be seen why the original layout could not be satisfactorily operated and what had to be done to overcome these difficulties. Figure 1 shows the simple layout before the plant was enlarged and

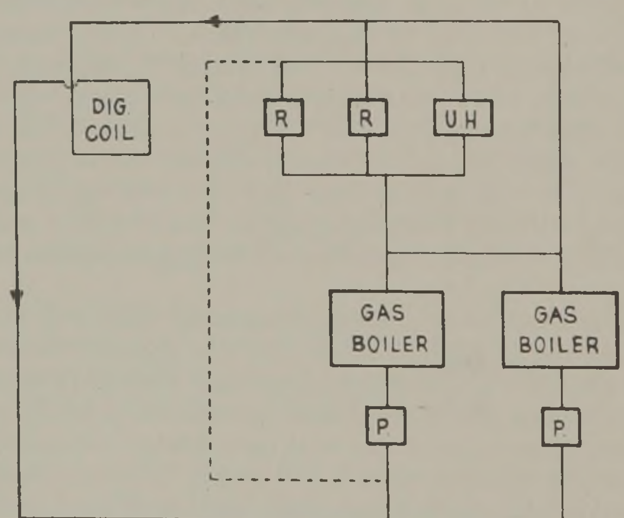

Fig. 1.

before gas engines were placed in operation. With this arrangement it was possible to operate the digester coils in series with the house-heating system in mild weather and in cold weather to separate the two, placing each on its own boiler which is thermostatically controlled.

Figure 2 shows the piping layout after the gas engines were installed. This system provides for both engines and an auxiliary coal-stoker fired boiler which had to be operated either singly or in parallel, with all units using the same piping from the boiler and gas-engine house to the plant, and with the heating water flowing directly to the house-heating system, thence to the gas-fired boilers into the clarifier unit heaters and on into the digester heating coils, thence back through the booster pump and the gas engines and boiler. When this system was first placed in operation

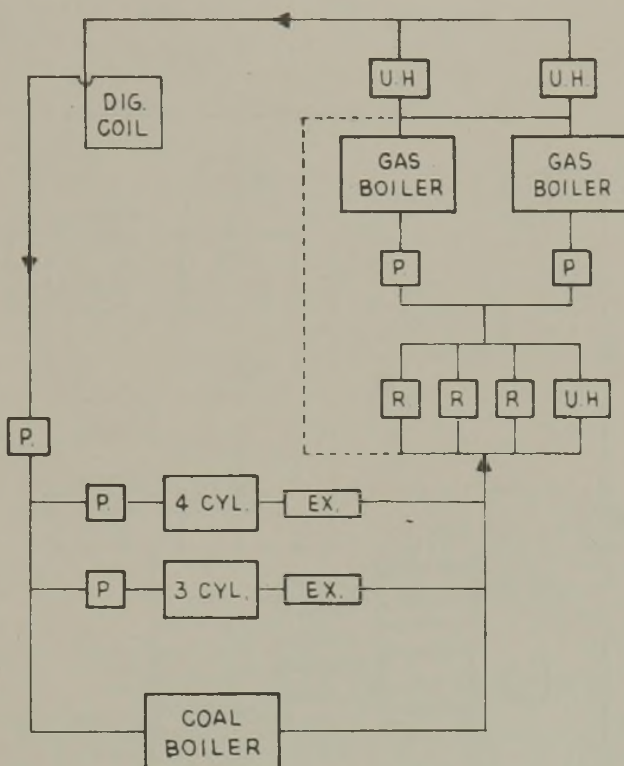

Fig. 2.

it worked satisfactorily because the weather was cool and there was sufficient cooling capacity in the clarifier unit heaters and the digester coils to keep the engines cool, but as the outside temperature rose the engines overheated and shut off. Thus, to keep on operating during the hot summer months it was necessary to install a cooling coil which was made up of 350 ft. of 1¼-in. steel pipe located in the influent channel. This coil was so arranged that the water was cooled before it passed through the digester heating coils. This arrangement, as shown in Fig. 3, worked very well for the summer months but as the flow through the cooling coil was controlled by manually operated valves, it required a great deal of attention to control the temperatures. During the winter months the additional plant heating load lowered the water temperatures to a point where the cooling coil was cut out. But due to the fact that the water leaving the engines was 160° F. or less, the rooms of the plant could not be maintained at a comfortable temperature. This meant that the house system had to be separated from the rest of the plant and operated independently by using either the gas-fired or the auxiliary oil-fired boiler. This left the gas engines on the digester coils and necessitated placing the cooling coil back in service. While this made it possible to run the gas engines, it produced an uneconomical means of heating the plant as it was often necessary to purchase fuel oil.

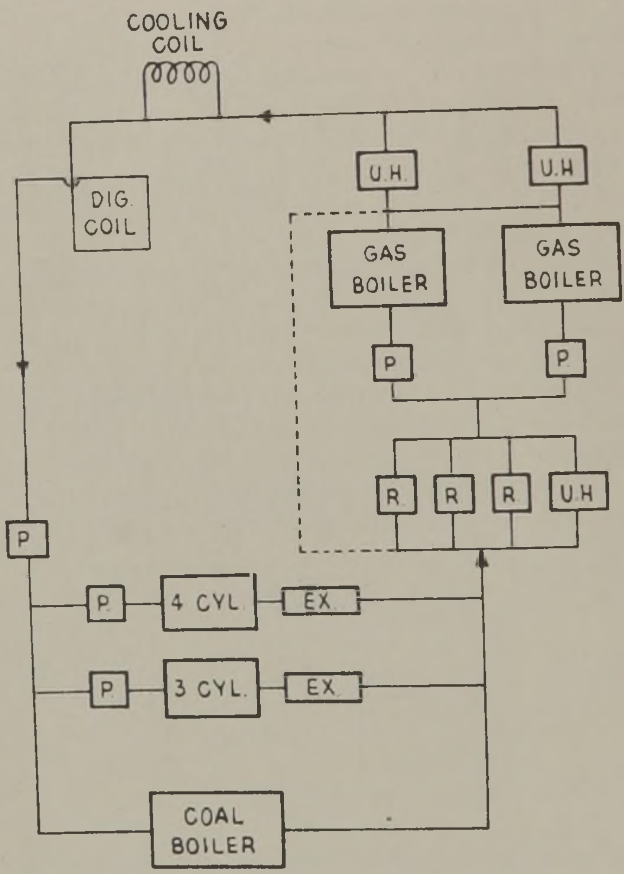

Fig. 3.

Soon after the gas engines were placed in operation air troubles developed and they continued until the closed system was changed to an open one, with the open tank installed at the highest point in the system, as shown in Fig. 4. Next it was found that the main reason why the cooling coil had to be used in winter, particularly when both engines were running, was that only 12 gallons of water per minute could be passed through each of the four digester coils, for a total of 40 to 45 gallons per minute, whereas approximately 90 gallons per minute were necessary if the engines were to be maintained at the desired temperatures. To get this flow the digester heating coils were placed on a bypass system which had its own booster pump. This layout, as shown in Fig. 4, materially improved the operation of the entire heating and cooling system but did nothing to eliminate the difficulty of maintaining the temperature of the clarifier rooms above the dew point and consequently these rooms dripped most of the time throughout the winter months.

Finally to make the entire system operate properly and produce comfortable room temperatures where needed, and still provide the proper

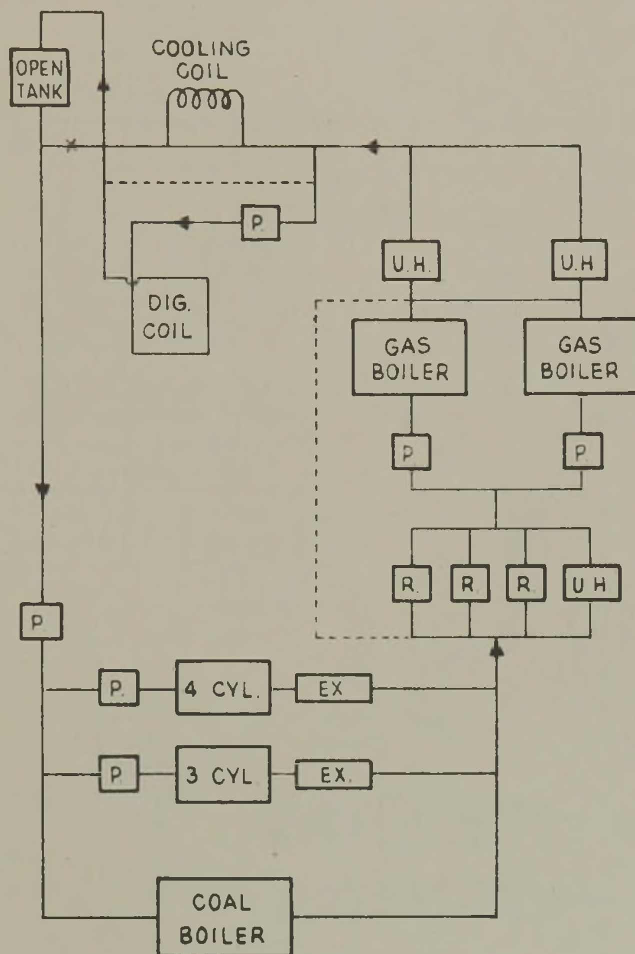

Fig. 4.

cooling for the engines, a major revision was made. This work is now being done at a cost of about $1,500 and will produce a layout as shown in Fig. 5. Normally the operation of this revised system will consist of running all of the boilers in series with the gas engines ahead of any radiators or unit heaters, thereby providing a means of obtaining almost any water temperature desired. As all boilers are aquastatically controlled, and as the temperature of the digester coils is controlled by a thermostatic valve and the cooling coil is controlled by a thermostatic valve which has its control element in the gas engine water discharge line, the entire system will be automatic. This, we are confident, will result in an economical, trouble-free heating system.

Now that the method of utilizing heat derived from the use of sludge gas has been described some mention of the gas collection system should be made. At Green Bay the layout is such that practically all of the equipment such as drip pots, meters, valves, and compressors are located

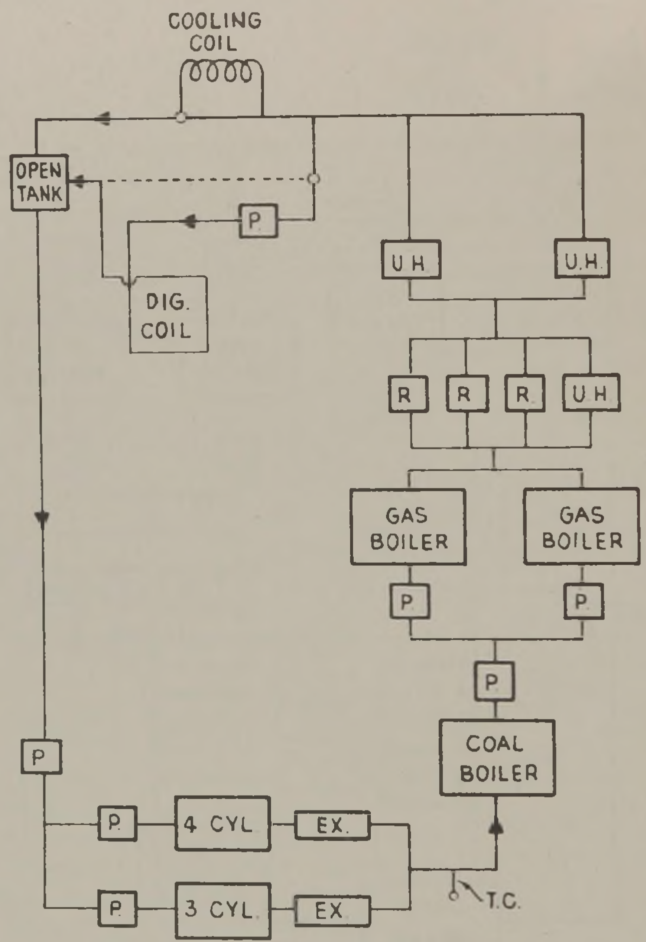

FIG. 5.

in one room separated from the rest of the plant by solid brick walls, with the only entrance located in an outside wall. All of the electrical equipment in this room is explosion proof and the room is continually ventilated by a motor-driven fan. This is the outgrowth of an accident which occurred shortly after the gas engines were installed. Originally the gas compressors, which are Worthington horizontal water-cooled 40 cu. ft. per min. units, were located in the gas engine room and one day while they were in service the water cooling system become air-bound, overheating one of the units and scoring the piston and piston-rod packing, thereby filling the room with sludge gas. Fortunately this was discovered before an explosion occurred. One such experience was enough and immediately thereafter the system was revised as shown in Fig. 6. In regular operation

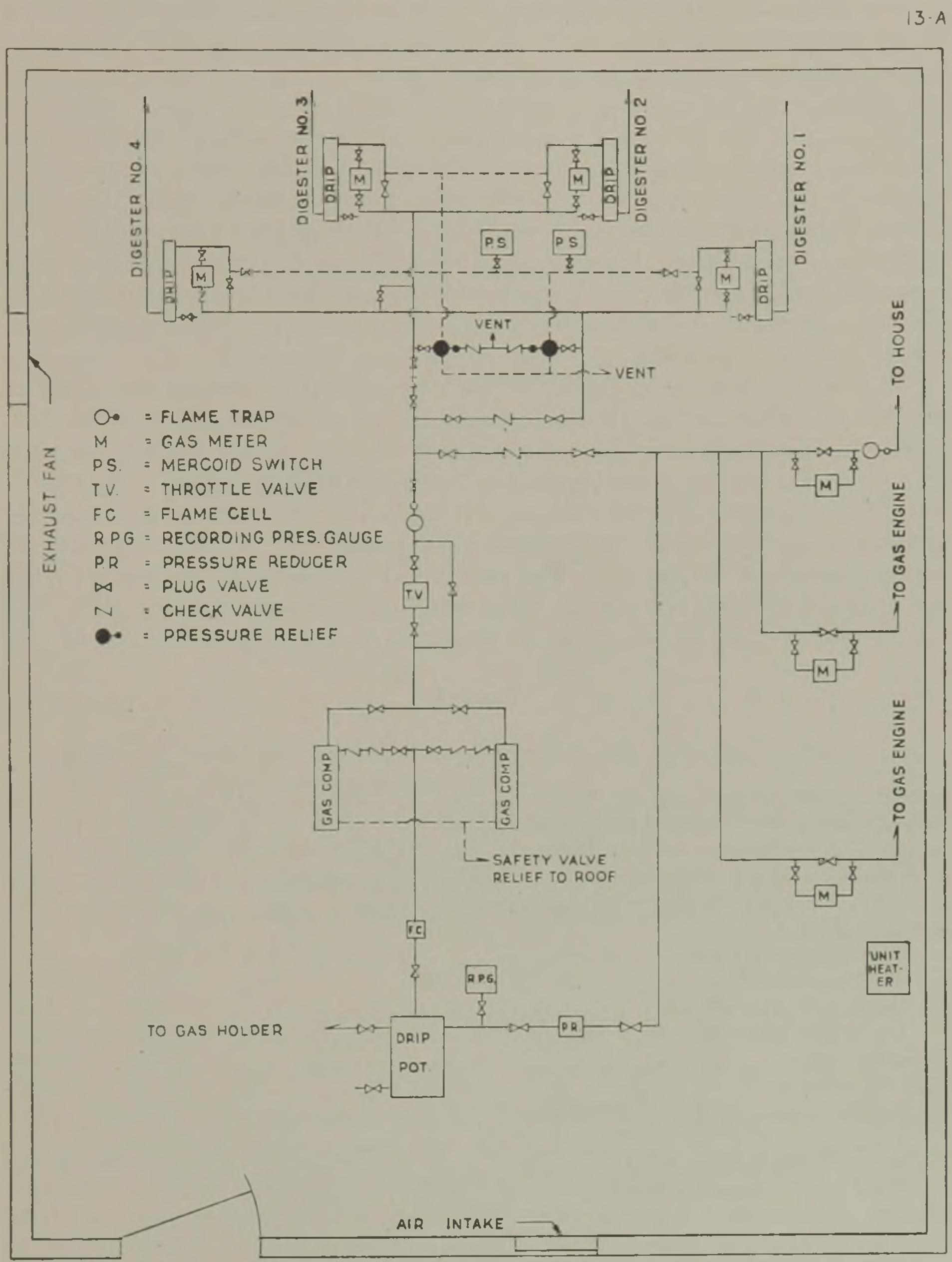

Fig. 6.

the gas flows under very low pressure from the digesters through drip pots, meters, pressure relief valves, and flame traps into the automatically operated compressors, which force the gas into the storage holder. Most of the units are so arranged that they can be by-passed, and in case of a shutdown, due to power failure, the gas can be bypassed directly into the distribution system. One of the novel features of this system is the pressure-operated regulating valve, which is installed in the suction lines of the compressors. This so regulates the suction opening that the compressors operate at all times so long as there is 1 in. of pressure in the gas domes.

In normal operation the engines draw their gas supply directly from the Hortonsphere, which holds approximately 175,000 cu. ft. of gas when under 40 lb. pressure. Four years of experience has proven that this holder is just exactly the right size for the Green Bay plant, as three or four times every year it is necessary to draw upon the holder for its entire capacity, and only once was it necessary to shut down the engines for lack of fuel. This was for only a few hours and occurred at the end of a prolonged period of flooding.

In 1940 an average of 8,200,000 gallons per day of sewage was treated and the sludge therefrom produced an average of 54,000 cu. ft. of gas per day, which is equivalent to approximately 1.0 cu. ft. per capita per day or 10.6 cu. ft. per lb. of volatile matter added to the digesters. By utilizing all of this gas the two engines produced 760,000 kwh. of power, consuming about 26 cu. ft. of gas per kwh. produced. Of this amount of power produced, 96 per cent was consumed in operating the plant, with the remaining 4 per cent going back into the utility company's high line.

Now the question arises as to whether or not such a system of gas

TABLE I

	Total Cost Inc. P.W.A. Grant	Dist. Cost
Interest on Capital Investment @ 2½%	$ 1,657.74	$ 935.84
Depreciation on Structures and Equipment	2,520.06	1,438.55
Insurance on Power House and Gas Holder	54.96	54.96
R. & M.—Gas Engines and Generators	124.05	124.05
R. & M.—Material and Labor—Gas Compressors	73.17	73.17
Lubricating Oil		
3 cyl. engine—175 gals.	98.71	98.71
4 cyl. engine—279 gals.	157.64	157.64
Gas compressors—73 gals.	41.26	41.26
Gas engine oilers—26 gals.	13.98	13.98
Operating Labor	277.89	277.89
R. & M. Labor	345.43	345.43
Workmen's Compensation @ $1.67/$100.00	10.41	10.41
Actual Operating Cost 40–41	$ 5,375.30	$ 3,571.89
Total Power Purchased 40–41	3,095.15	3,095.15
Annual Operating Cost 40–41	$ 8,470.45	$ 6,667.04
Value of Power Used (2¢ per K.W.H.)	17,524.80	17,524.80
Net Profit 4/1/40—3/31/41	$ 9,054.35	$10,857.76
Net Profit Previous to 4/1/40	10,519.65	15,924.42
Net Profit to Date	$19,574.00	$26,782.18

utilization really pays. To determine this the District set up a rather elaborate accounting system wherein all costs chargeable to the gas engines were kept. In order to be sure that there would be no criticism, approximately the same method of accounting was used as is employed by utility companies. This provided for interest on investment, depreciation of equipment and structures, repairs and maintenance, all operating supplies, and labor, which includes everything imaginable except land rental and the superintendent's time. As this was a P.W.A. project under which the government made a 45 per cent grant, two sets of accounts were kept, one taking into account the total investment while the other accounted for only the amount invested by the District (55 per cent of the total cost). After four years of operation, both of these accounts show a substantial profit, with the one considering only the moneys invested by the District producing a net return of $26,782 against $19,574 for the total investment account. A breakdown of these figures is listed in Table I.

TABLE II

	Total Cost Inc. P.W.A. Grant	Dist. Cost	Expected Life	Rate of Depreciation
Structures	$33,985.32	$19,389.80	50 years	2%
Gas Engines	17,414.22	9,948.72	15 years	$6\frac{2}{3}$%
Gas Holder	20,674.50	11,370.98	40 years	$2\frac{1}{2}$%
Gas Compressors	1,619.57	1,028.95	10 years	10%
	$73,693.61	$41,738.45		

Table II shows the capital investment of the various units, the expected life, and the depreciation rate of each.

From an analysis of Tables I and II it is quite evident that utilization of sludge gas at the Green Bay plant is a profitable business that should be employed in all medium-sized plants, particularly if gas engines can be used to pump sewage, compress air, or generate electricity.

DISCUSSION

BY PAUL D. MCNAMEE

Chemist, District of Columbia Sewage Treatment Plant

Mr. Martin has presented a clear accounting of the savings that can be realized by utilizing sludge gas. In the original plant where gas was used only for firing boilers, the savings amounted to $14.00 a day. Later, by installing two gas-engine generators, the savings increased to about $10,000 a year or roughly $27.00 a day. It is now possible to produce practically all the electrical power required by the plant and at the same time recover as much heat as could be produced by the plant boilers burning an equivalent amount of gas.

The difficulties encountered in utilizing the waste heat and the methods employed to overcome them are worthy of note. At Washington, the engine jacket water goes to a hot well from which it can be pumped through cooling coils before returning to the cold well. The water from the hot well can also be pumped through exhaust-gas heat exchangers before going to the digester coils. It is necessary to use the cooling coils most of the year. Of course, conditions are not the same at these two plants, owing to the difference in location.

Mr. Martin referred to the recent articles dealing with sludge gas utilization and there is probably no other subject in sewage treatment in which so many authors arrive at the same conclusion. In articles appearing in Sewage Works Journal, Sewage Works Engineering, The American City, etc., one is impressed by the enthusiasm expressed for sludge gas utilization. Estimates of the savings, expressed in the time the units pay for themselves, range from one to twelve years, or a return on the investment of between 8 and 100 per cent per year.

The use of safety devices and burners now on the market makes it possible for even small plants to utilize sludge gas. Units for heating small buildings are available which burn about 100 cu. ft. of gas per hour. Thus a plant serving a community of 2,000 people would produce enough gas to supply one of these units.

To date, sludge gas has been used for its fuel value. Other means of utilizing the gas exist but these get away from sewage treatment. For example, CO_2 is being recovered from flue gases which contain less CO_2 than sludge gas. Also, methane can be converted into hydrogen, carbon black, or chlorinated derivatives. These products would find little use in a sewage treatment plant, but the use of the sludge gas as fuel has proved its value. The utilization of sludge gas is now getting to be general practice and I agree with Mr. Martin that all medium sized plants should use it.

OPERATION AND MAINTENANCE OF SMALL PUMPING STATIONS *

By Grant M. Olewiler

Superintendent Sanitary Drainage, Lower Merion Township, Pennsylvania

Four sewage pumping stations are operated in Lower Merion Township.

Station A, the Mill Creek pumping station, is equipped with three electric-motor driven two-stage horizontal centrifugal pumps. It operates against a head of 252 ft. when using its largest pump, which discharges 1600 gal. per min. through 6671 ft. of 12-in. force main and at smaller heads when its other pumps, one of 1250 and the other of 1000 gal. per min. are in use.

Station D, the Gulley Run pumping station, is equipped with duplicate electric-motor driven horizontal two-stage centrifugal pumps. Each pump operates against a head of 175 ft. when discharging 500 gal. per min. through an 8-in. force main 4230 ft. long.

Station C, the Cynwyd pumping station, has duplicate electric-motor driven single-stage vertical centrifugal pumps, each of which operates against a head of 95 ft. when discharging 600 gal. per min. through 3510 ft. of 8-in. force main.

Station B, the Ardmore pumping station, has duplicate electric-motor driven single-stage horizontal centrifugal pumps, each of which operates against a head of 52 ft. when discharging 833 gal. per min. through 3310 ft. of 10-in. force main.

Pumping of sewage was started in the Township in 1904 at Stations A and B, using piston pumps driven by one-cylinder gas engines, which were supplied with two interchangeable carburetors, one for gasoline and the other for commercial illuminating gas. The cheaper fuel was selected whenever local fluctuation in prices would warrant a change.

At one time an Otto Gas Engine, operating on gas manufactured at the pumping station from anthracite coal, drove a centrifugal pump at Station A, but it was replaced with an electric motor because of the difficulty of operation and loss of economic value when the price of coal increased and electric current became much cheaper. Stations C and D were built in 1912 and 1925.

From the foregoing descriptions it is evident that we have quite a range in sizes and although I have seen smaller stations as to head or capacity, I will consider our equipment as illustrative of small pumping stations.

Although all our pumping stations have been built and are being operated under "temporary" permits from the Sanitary Water Board of Pennsylvania, which was created two years after we started operation, I must consider pumping stations as permanent equipment for the purpose of this discussion, and would urge the operator or engineer in charge to be

* Presented at the Second Annual Convention of the Federation of Sewage Works Assns., New York City, Oct. 10, 1941.

ever alert to take advantage of the many new aids to operation which are constantly being found to be basically sound and well constructed. Many worthwhile changes have been made in our plants, but I still find room for improvement.

In order to refrain from wandering along the many side paths which open as this article progresses, I have made the following divisions of the subject and will try to confine myself thereto: the pump; the motive power; auxiliary equipment; the building; personnel.

The Pump

The pump seems to be the very heart of the plant and must be considered of primary importance. It consists principally of an element to create pressure on the sewage and devices to maintain alignment of these parts. I will leave the question of design to the engineers and will assume that you also had no chance to select, but must operate that which you have been given.

The next time those rags get around your shaft, rubbers wind into a tight ball between the back of the impeller and the casing, a block of wood gets between the face of the impeller and the casing, with a resulting noise that makes you think the building is about to come down, or your pumping gauge shows a reduction in pressure or capacity, take a little time off and see what is happening.

What about your clearances? The present day welder in that reliable machine shop in your town can do much to replace that metal which was ground off by the friction caused by fine sand in your sewage. It is there—and it makes the finest abrasive possible for grinding the face of your impeller blades unless of course you are one of those few operators who are blessed with the latest style non-clog closed impellers.

What about the impeller itself? Are there any visible cracks which need welding? We have had open cast-iron impeller blades crack away from the hub in a direction opposite to the thrust caused by the normal operation, so you must look on both sides if you wish to keep out of trouble. If your sewage is corrosive, look for pitted places which might seriously reduce the strength of the impeller or cause a loss of the design curve which is so essential for high efficiencies.

Is your impeller tight on its shaft? In one case we had all kinds of difficulty trying to keep tight an impeller on the high pressure stage. We had to send it to the machinist several times before we were satisfied that it was tight. A wobbly impeller is no efficient machine and may so damage the shaft that a new one must be purchased.

How is the shaft where the packing presses against it? Those deep grooves mean that your expensive packing is being wasted rapidly. If you have a shaft which has replaceable wearing rings you are fortunate, otherwise you must balance the cost of packing and the appearance of that sloppy mess around the pump against the cost of a new shaft.

What about your packing—do you use considerable? Why not talk with the salesman of the company from which it is obtained? He has many and varied installations and can probably advise a more suitable style designed to overcome just such a situation as yours.

Is your pump equipped with a water seal ring? If so, you will find it a valuable device for keeping sand out of your packing, but do not connect it with your potable water supply line unless proper steps have been taken to prevent back flow at all times.

Next look at your pedestal bearings. What is that material in your oil reservoir? Is it oil or a mixture of oil and sewage caused by the travel of sewage along the shaft from the packing to the oil reservoir. The latest designed pumps use slingers, which are very effective in stopping this flow. You can make duplicates of them by cutting rubber disks with a hole in the center of a diameter slightly less than that of the shaft and place them on the shaft the next time you have the pump apart.

Does oil leak from around the opening through which the shaft passes? There is a rather inexpensive sealing ring made especially to prevent this.

What about your bearings—are they wearing evenly or are you getting all the wear on one side? If so, it might be a good plan to try some aligning. It will pay you in the reduction of power consumed as well as to make parts last longer. How did that word alignment steal into this paper? Why, that is one of our greatest troubles. We had one vertical installation which ran several years without trouble and then suddenly became a fiend. We lined this and lined that, placed steady bearings, which seemed to make it more unsteady, replaced base legs, made a new bed plate, all to no avail, several times a year that pump would go to pieces and new shafts and bearings would have to be installed. Pump men and machinists said that it was just the nature of that type and that they were constantly fixing similar pumps for other places.

One day we saw an advertisement of a flexible shaft using two universal joints, purchased one and installed it about a year ago, and—well we still have our fingers crossed. The same installation has a bearing placed in the pump casing so that it is subject to the pressure of the sewage. The original lubricant was a hard grease of the water pump type, which caused sand to become inbedded in it until it became almost a grinding collar. Black grease was recommended because of its adhesive nature, but when applied it did not have sufficient body to prevent sewage under pumping pressure from forcing itself back into the spring-feeding grease cup. Check valves were then placed in the line and operate in a very satisfactory manner. I should add that this pump operates only about thirteen minutes per run and during the time of running, sufficient grease is retained in the bearing to lubricate it so that as soon as the operating pressure is reduced the spring cup forces a new supply into place.

At the end of the pump shaft one finds a coupling. In all our present installations, except the one noted above, a rubber-bushed pin-type coupling is in use to connect the pump with the motor. These couplings had a wide flange around the outer circumference, supposedly to protect operators from the bolt heads, but some years ago the station operators found that a monkey wrench tightened on the flange would provide a good lever arm to turn the shaft when cleaning the pump. You guessed it—the majority of the flanges had notches broken out of them. When an 8-in. diameter coupling, with notches in its face, rotates at a speed of 1750 or 1175 r.p.m., it is not a nice thing to get against. In addition the notches tend to upset the dynamic balance of the shaft. These couplings have been turned down so that the flange is now very short. Cages have been placed so that the operator is not liable to touch them. Rubber bushings are replaced whenever inspection shows that the old ones have become worn.

The original installation of triplex plunger pumps was never very satisfactory. The sand in the sewage constantly cut the cylinder walls and piston rings so that in a very short time the back-pressure slip became considerable and the pumping capacity would become greatly reduced. The poppet valves were a constant source of trouble and had to have their covers removed and be cleaned of rags, rubbers and other foreign material which seemed to foul them constantly.

The Motive Power

This now brings us to the motor and its bearings. While some trouble has been experienced with the bearings, it has been very slight and can be traced to poor alignment. We once walked into Station "D" and found that practically all the oil had splashed out of the bearing when its cover had become dislodged or was not replaced correctly. Oil escaping from the ends of a motor reservoir at this station was eliminated by sealing rings.

We have been very fortunate with our electric motors, one of which has been in operation since 1919, in that they are practically free of trouble. I have been told that years ago the windings on one motor at Station "C" burned out during the night, probably due to bad fuse protection.

Because of the increasing age of our equipment we recently purchased a megger, volt and ammeter and expect to make periodic tests to obtain information on the condition of insulation and current consumption. Recent articles on electrical equipment maintenance in this *Journal*, May 1941, "Operators Corner," are very helpful in themselves and for the references which they contain.

Judging from all the records I can find, the original gas-gasoline engines were about on a par with automobile engines. Compressed air was used to turn the engine to a firing position. Spark was furnished by a magneto and starting current by a wet-cell battery.

While the multiple-cylinder gasoline auxiliary engines now being installed as stand-by power should be very reliable for small motor-driven stations, I regret that the only time I was at an automatic station where this equipment was installed, the operator opened the main switch to demonstrate the unit and although the battery turned the starting motor several times the engine failed to start, presumably because of a low battery condition. This, more than anything I have ever seen in outside stations, impressed me with the tremendous importance of proper maintenance because of the potential danger in such a condition. Had that been a real electric power failure the plant would have been out of commission until the electric power was restored.

Auxiliary Equipment

The most important auxiliary equipment is the switchboard and starter to cut the motor into the line. Two of the motors at Station "A" are started with a manual control, by which the current is turned into the motor with grid resistance in the circuit and the resistance is then cut out by a manual trolley control. Overload switches automatically break contact should an overload be applied. The most constant source of trouble on one board is the contact fingers in an oil-bath switch. Although made of laminated spring copper the contact does not seem to be sufficient to break without burning and arc tips must be replaced frequently. Until about twenty months ago the men did not understand the operation of this switch and the fingers were allowed to burn to such an extent that the entire rod had to be purchased rather than the tips, which are made separate so that they can be replaced at a small cost.

The third motor, the newest, is started by an automatic industrial controller, actuated by a float-switch control or a push-button station, which brings the motor on the line by a mechanical timer which releases the resistance at the end of a predetermined interval. In addition to the regular fuses this equipment is protected by a thermal control overload switch.

Prior to the beginning of this year all operation of this station was manual, since the pumps are horizontal type two-stage centrifugal pumps located above the level of the wet well, and it was necessary to prime them prior to starting. At that time automatic air release valves and a vacuum pump were installed to make the equipment self-priming, and to eliminate almost constant trouble with check valves. A float and control switch were connected to operate the automatic industrial controller so that we are now able to operate this station on two shifts in place of three.

Tests of the pressures found in the water seal ring in the packing stuffing box on the high pressure stage of the intermediate size pump proved that a small plunger pump, which supplied water from a reservoir connected with the adjacent stream, was not delivering sufficient pressure to overcome that in the casing, with the result that the sewage was not held away from the packing. Because the stream bed had washed out since the construction of the reservoir to such an extent that water could only be obtained by placing a row of stones slightly below the inlet holes, this method of obtaining water was abandoned and we installed a small storage tank in which the supply of city water was regulated by a float valve and ample pressure was supplied by a motor-driven centrifugal pump of small capacity manufactured especially for such a use.

An amusing incident which occurred when this pump was installed illustrates the value of observation and thought. Only one wall of the station was unencumbered with other equipment and this was selected as the best possible location for the electrical control equipment for the pressure water pump and vacuum pump for priming. The installation was made in cold weather and as soon as the connections were made a test run was made. The pump motor had hardly started before the thermal control to prevent operation of an overheated motor kicked out and the pump stopped. Examination of the motor showed that it was quite cold to the touch and that the wiring had no defects but a second run again threw out the thermal control. Here was indeed a mystery until someone observed that the switch had been placed directly above a heating radiator which at that time of year was quite warm and this heat, together with the use of a thermal unit which had the lowest possible heat release recommended for this size motor, had combined to cause the equipment to refuse to operate. The next size thermal unit was obtained and no further trouble was experienced, but I can easily imagine the fun which we would have had if the installation had been made during the summer and after operating with entire satisfaction for several months, it suddenly refused to work as soon as the weather became cold enough to cause the heating plant to be forced a little more than usual.

At Station B, where the pumps also are located above the level of the sewage, automatic priming of the pump and automatic starting has also been installed. Because of the very much smaller head against which these single-stage pumps operate, no water seal rings are placed in the stuffing box, but the packing and shaft are cooled by a water jacket through which city water is circulated. Automatic stopping and starting of the motor also required an automatic shut-off for this water line. A very convenient solution of the problem was found in a solenoid controlled water shut-off valve which starts the flow of cooling water as soon as the pump is started.

Stations C and D, being newer, have the pumps located below the level of the sewage. Starting and stopping is regulated by industrial controllers actuated by a float switch connected with a float in the wet well. That "connected with a float" sounds quite simple and yet for years we were plagued with constant trouble caused by breaking of chains and cables on floats, especially since these breaks caused the pumps to run until the operator arrived in the morning. About a year ago chains and cables were eliminated and all control floats were placed on lever arms made of galvanized iron piping. Connections to the switches were redesigned after the failure of efforts to purchase switches of the type which we needed because the manufacturers stated that they could not supply such an automatic switch. We have since learned that the Westinghouse Company makes this equipment but are now well satisfied with our own design.

Because none of our stations were provided with venturi meters or other devices to measure the inflow and pumping, we have constructed a pitometer station on the force main from each station to test the pumping capacity, but I regret to state that we have not had a chance to acquire sufficient data to elaborate upon their use.

Recording pressure gauges with daily charts are installed at each station and approximate reports of pumping are compiled from these data. Additional large dial pressure gauges are placed on the force main to inform the operator of the condition of his pumps from a distance.

In an endeavor to reduce the pressure fluctuations in the force main caused by the operation of the check valves and the surge of sewage, air-cushion chambers have been installed at Stations A, C and D, but it has been very difficult to maintain air in the chamber. The only case of serious flooding of the dry well at Station D was caused by the breaking of the air cushion sight glass during the night. By morning the level of the sewage had risen to the top of the motor, which had been stopped by a piece of burlap, used as a foot wiper on the bottom step, becoming wound around the shaft until it acted as a brake and actuated the overload cut-out switch. A control coil which burned at the same time may have been caused by the splash of sewage. Fortunately the motors were waterproof and after being washed out and dried for a short period, the duplicate motor, after having the old oil drained and new oil placed in the reservoir, was started without damage. The motor which had operated during the night was taken apart when inspection showed that the force of striking the sewage had either broken or badly bent the metal fins on the rotor which act as a fan to provide air circulation within the motor. New fins were placed and after tests to determine that it had suffered no other damage this motor was also placed in service.

At Station A, an automatic surge pressure-release valve has been placed on the main to relieve excess pressure by discharging back into the wet well as soon as a predetermined pressure is exceeded.

Since power charges are based upon the total demand load which may be applied at each station, the control panels must be so arranged that no two pump motors of duplicate installations may be operated at one time. This is effected by using de-energizing coils or contacts to render inoperative the starting control of the other motor during the use of one. At station A where three pumps are to be operated, a large knife switch is used to determine the motor which is to be placed in service. If the handle is placed in the closed position on the right hand side the smallest pump may be operated, if closed on the left hand side the intermediate size and if placed in the open position the largest size may be used. Again interlocking coils prevent the use of the other pump motors.

In automatic stations, where no operator is present for long periods during the day and night, it is highly desirable to be able to operate the second pump at a predetermined time after the first fails to operate. We have therefore arranged our float switches so that if the level of sewage in the basin continues to rise beyond the point at which the first pump should operate, a stop will engage the switch for the second pump and because of the interlock will disconnect the first pump. This has the advantage that opening of the overload switch will remove any damage to the first board without placing the station out of order, while a temporary loss of pumping capacity in one pump will be taken up by the operation of the second pump.

The Building

All our stations have a screen and grit chamber, a collecting well and a pump house.

When non-clogging impellers came into use the bar screens were removed. Trouble with foreign materials, especially in the two-stage pumps where the shaft passes through the suction elbow, has resulted in the replacement of the screens and strict requirements that they be cleaned whenever the level of the sewage on the upper side of the screen exceeds that on the lower side by an amount which will cause backing of sewage into the inlet pipe.

Screenings are placed in a compartment with a sloping floor and a drain to the screen chamber. After draining they are placed in covered cans and hauled to the Township incinerator. Prior to the use of the separate drying compartment, the incinerator operators complained about the difficulty of burning this material, but since they have been used we have had no complaints.

Examination of the material removed indicates that the majority of all the screenings could very well pass into the basin without harm to the pumps. Ours is a separate system relatively free from large objectionable materials but this large proportion of unobjectionable material must be removed in order to prevent rags and long stringy material from entering the pumps and fouling them and the priming equipment. For us the answer seems to lie in some form of shredder which will reduce this long material to small pieces and eliminate the cleaning of screens, which must be done not only when the sun is shining and the day beautiful, but in the midst of storms, both rain or snow, and at times when most sensible people are quite content to stay indoors and admire the beauty of nature without exposure to its elements. Unfortunately our stations are located so near to the road that no space is available for equipment of this nature, but we are still looking and hoping that somehow it can be fitted into our plant.

Sand chambers consist of small compartments where the velocity of the sewage is broken by baffles and a large portion of the grit content is deposited. These are cleaned by the sewer repair force whenever the operators find that they are becoming filled. Materials removed are buried in large holes dug in a meadow adjoining the Mill Creek pumping station and covered for a few years, after which time the Shade Tree Commission generally finds use for the material as a soil builder. Until recently the holes were cleaned out by local gardeners who had also discovered its value, but this practice is no longer allowed.

Collecting wells vary in size from 205,000 gallons at the Mill Creek Station to 7,000 gallons at the Gulley Run station. Slope on the floors range from 1 in 70 at Mill Creek to 1 in 4 at Gulley Run. In spite of the seemingly flat bottom at Mill Creek, sludge beds do not form to a great degree because sewage is pumped down to the level of the sump or suction hole at each run of the pumps. The sand which escapes the grit chambers is removed at least once a year and more often if an accumulation is noticed. Greases and fats which collect on the side walls of the wells are removed by scraping about twice a year, while float balls are cleaned quite often. Improvements in the operation of the Ardmore and Mill Creek basins were effected by cutting larger openings through partition walls originally designed to direct flows but which were operating to produce eddies with resulting accumulations of sludge.

The wet well at the Gulley Run station is divided into two compartments which are connected by an opening fitted with a sliding gate valve, so that either side may be closed for cleaning.

In normal operation the entire flow of sewage enters one compartment and passes into the second compartment through this valve, with the result that the larger portion of the heavy material remains in the basin which it first enters, while the second side remains relatively clean. As the impeller openings on these pumps are quite small and clog very easily, the pump connected to the second or clean side is used during the night when no operator is assigned to the station, while the other pump is used during the day when a man is available to remove stoppages.

Because two of our stations have the pumps located below the collecting well it is necessary to place them in a dry well. At the Cynwyd Pumping Station the pumps are mounted vertically in what amounts to a basement because its only connection with the upper floor is an "L" shaped stairway. An original heating unit, consisting of a cast iron laundry-type barrel stove, was placed on the first floor, but failed to provide heat for the basement. The recent installation of a hot water boiler and a radiator along one wall of the basement, together with ample radiation on the upper floor, has dried the walls to such an extent that no moisture is evident, and has reduced materially the amount of coal consumed during the heating season. This left several months during the year when we were still troubled by the excessive moisture in the air. An exhaust fan has been installed and with this in operation a considerable degree of relief has been evident.

The Gulley Run station has horizontal pumps placed in a dry well, but in this installation the ground floor consists only of a balcony 4 ft. wide around three sides of the room. The original heater was located on this balcony but was soon found to be unsatisfactory and was moved to the lower level, where it provided only a slight improvement. We expect in the near future to re-design this plant and install additional radiation. The normal ventilating areas in shop-type windows and a roof ventilator have failed to produce sufficient circulation of air for the summer months when no fire is in the boiler, with the result that on humid days water will actually run from the pumps and piping so that it is difficult to keep the paint looking presentable. This condition at times extends above the balcony and one day last summer became so bad that although the operator removed the recording pressure gauge chart several times during the day to dry it, there is no record of pumping during the night because the paper buckled and held the recording pen away from the chart.

The two other stations have basements only large enough to contain the heaters and coal storage bins. With the exception of the Gulley Run station all basements have caused trouble because of infiltration of ground water. At the Cynwyd station we excavated around the outside of the building and placed a heavy coat of cement mortar on both the outside and inside of the concrete wall. The interior walls were plastered at the other stations.

Although the newer stations have provision for hoisting the equipment built into the walls the older ones did not, and since they contained the heavier machinery, many of our men are now suffering from body strains caused by trying to lift or move heavy motors and pumps. Several years ago plans were made to install beams and travelling hoists. While we were planning construction of beams to span doorways and were being shocked by the cost of this type of support we came across a catalogue of a bridge-type hoist made for handling automobiles and rated at a capacity of two tons, which sold for about $125.00. Since none of our individual pieces exceeded this load we purchased one for trial. Shortly afterward we had to dismantle a pump at the Mill Creek station and in order to do this we have to move the motor and all. While no time studies were made to compare actual costs it is our belief that on this one job alone we saved the cost of the hoist in labor time. Needless to say the second hoist was purchased immediately.

With the passing of an older man who had charge of the stations, we felt that it was time that something be done to brighten their appearance and make them a credit to the community. Prior to this time the outside of the stations was painted each year or two but the paint was so thinned to make it go a long way that in less than a year the checks and blisters would become so pronounced that it would have to be done over. Painters' torches were purchased and all the old paint was removed from the woodwork by burning and scraping. The wood was given a priming coat, undercoat and enamel were placed on interior surfaces and two coats of lead and oil paint were placed on exterior surfaces. Openings between wood window frames and the brick walls were caulked with oakum and sealed with caulking compound. Steel was placed over windows and doorways where cracks had appeared in the brick walls and the cracks were cemented. The old brick walls were cleaned and painted a light buff color. Floors were cleaned and painted a light gray while pumps, motors and piping were painted black. It does not take long to write it but many a weary hour was spent by the pumpmen in scouring floors and walls to remove oil and grease which had accumulated for years.

The job has been a big one and although all the spare time of the men has been devoted to it, we are still working on the last of the four stations. By the time it is finished two years will have elapsed since we first started the work, but we now have a sound job which will last several years before it will have to be re-touched.

Serious and amusing incidents have happened during the work. At one time, acting upon the advice of our paint supply house, we had sealed the concrete wall in the Gulley Run Station dry well with water glass and then applied a coat of recommended paint. The next morning, when the operator entered the plant, he found that the paint had run from the walls and was on the floor. A call to the supply house brought the manager, but since he had never seen anything like it another call brought the chemist from the paint company. He soon saw the trouble, called our attention to a fungus growth on the wall, explained the difficulty in killing it but advised that we try washing the wall with copper sulfate and painting it before the growth could get a foothold. This was during the summer when moisture conditions were bad so we waited until the next dry day, did as directed and although the wall has been painted for a year, we have seen only slight traces of regrowth, which we expect to kill with another application of copper sulfate.

Personnel

Schedule of Working Time.—The force operating the stations consists of the Assistant Superintendent of Sanitary Drainage and nine pumpmen. Until recently these men had to cover three eight-hour shifts at the Mill Creek station (12–8; 8–4; 4–12), two at the Ardmore station (8–5 day and night) one each at the Cynwyd and Gully Run stations (8–5 day), a total of seven shifts. Each pumpman gets two days and one Saturday and Sunday off per month as well as two weeks vacation and whatever holidays can be arranged.

In order to give the men advance notice of their Saturday, Sunday and holidays off as well as to show a roughly equal assignment to night and day work at all the stations, an annual schedule is prepared and posted at each station. With seven men required for daily shifts two men are available to work as relief for men off or sick and to cover shifts where the men are on vacations. The most versatile man, a carpenter by trade, is used whenever available from relief work to help with maintenance, while the other relief post is moved among the men at three month intervals.

Although it is not encouraged, the men are permitted to exchange shifts if they show a justifiable cause, but since the schedule is arranged to have all Saturday, Sunday and holidays off during daytime shifts, the men who exchange shifts must surrender their holidays off during the time that they take a night shift from another man.

This requirement is caused by the loss of the relief man for two days each time he substitutes on a night shift.

In addition to the annual schedule a daily schedule is prepared for each half month showing where each man is each day so that there can be no chance of a misunderstanding.

As this scheduling of the nine men in seven positions could make no allowance for sickness, it is necessary in emergencies to have one man assigned to look after both Cynwyd and Gulley Run stations where operation was controlled by float switches. Since the men must supply their own transportation the operator would first stop at the station nearer to his home, see that it was operating correctly, do his housekeeping and then go to the more distant station until early afternoon, at which time he would return to the first station until time to leave for the day.

The three shifts at the Mill Creek Station were made necessary by the failure of the basin to hold the inflow between the hours of 5 and 8 P.M., but, since the installation and satisfactory operation of the vacuum priming and float switch control, the schedule at this station has been reduced to a day and night shift (8–5). This has eased somewhat the pressure for men and has released another man for general repairs and maintenance for a portion of the time.

Schedule of Operation.—Prior to the adoption of the present organization the men were instructed as to their general duties and then left on their own with a daily visit by the Engineer in Charge of Pumping Stations.

When the supervision of the pumping stations was given to the Assistant Superintendent he prepared a definite program of work which must be done each day. As this varied in minor details at each of the stations, typewritten instructions were posted on each bulletin board and the operator for each shift of the two-week period is held responsible for the fulfillment of his share of the work.

It seems that each operator had a different idea on how the fires to heat the building should be tended and in most cases these ideas violated many of the accepted standards recommended by the heating engineers. Check dampers were not used, fire doors were left open instead, fly ash and soot was not cleaned from the top of the hot water sections and often accumulated to an extent that it was remarkable that the heater gave out any heat. Standard directions were obtained from a local coal dealer, posted with the duties of the operator and the men were informed that the fires must be controlled in this manner. Conditions have improved to a marked degree but it is pretty hard to change a man's system after he has used it forty years.

The men have entered into the spirit of the schedule and after a station has been painted and placed in good condition they are anxious to keep it looking its best.

Selection.—The present operators were drawn from seven trades—three carpenters, one gardener, one taxi driver, one cement finisher, one machinist, one auto mechanic, one electrician. Length of service ranges from 29 years to 7 months with an average service of 14 years.

With the exception of the most recent appointment the men were selected largely upon the recommendation of the commissioner of the district from which the man to be replaced had resided and appointments were based chiefly upon the fact that the new man had a good reputation in the community and needed a job. Anyone could learn to start and stop the pumps, clean the station and keep it warm!

In the case of the last appointment, at the request of the Department, consideration was given only to men who had experience with motors, lining shafting, with switchboard work or as a millwright.

The older men are very willing to follow instructions and to help in any way possible but cannot be expected to advance ideas to better operation when they are not familiar with the basic theory. It is true that a large portion of the job is that of a janitor, but the value of the men to the municipality lies in their ability to operate the stations properly, the smallest of which will cost over $10,000, and not only to keep them in condition but to better the operation by improvements as they are developed by the engineers and manufacturers.

To the representatives of the municipalities I would say—it is not good economy to turn your plant over to that aged policeman or road foreman. He is a good man and needs a job, but poor operation or inexperience will soon cause your equipment to cost you more than the difference between his salary and that of an experienced man.

Designing engineers—you have done your best to create a good plant but your job is not complete until you place it in competent hands. It is your duty to impress the municipal authorities concerning the vital necessity of good operation.

Operators,—it is up to you! Unless you keep your station always at its best, study your equipment to obtain a maximum output for a minimum cost, keep an eye open for modern improvements, learn how and why each unit acts and then show that you know this by timely suggestions or recommendations, you cannot expect to be recognized when that most important day of the year arrives—the day when the annual budget is considered.

In conclusion, I wish to acknowledge the aid rendered by my Assistant Superintendent Clarence W. Hoff, who in the past two years has done so much to improve our stations and has unknowingly helped in the preparation of this paper by relating to me from time to time incidents encountered by him.

Discussion

By J. R. Hoffert

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I am sure you gentlemen of the Court will agree that Mr. Olewiler has qualified as an expert who not only has personal knowledge of the operators' problems and experiences, but who also knows those of the administrative official whose duties run the whole gamut from responsibility to the taxpayers for service, costs of operation, and maintenance of plant, to the scheduling of employees vacations and relief tricks.

He has so successfully covered so many of the manifold problems of operation in such thought-provoking manner in his excellent paper that it makes it very easy for the "Discussor"—he has merely to say "amen"—or else hard for him if he is to add anything really constructive.

I shall try to emphasize some of the best points made by Mr. Olewiler, and then I will call attention to some other matters connected with sewage pumping stations, with a full realization that although I can claim no particular originality for the suggestions, they may serve to remind us of things which are often overlooked in such stations.

First then, to give added weight to Mr. Olewiler's comments! Let us emphasize the importance of periodic checking of the overall plant efficiency. Payment for power is a principal cost in the operation of a pumping station and it is nearly as continuing as fixed charges. Rising costs for power will probably be quickly noticed by the accounting force—if you have one and it is alert—and yet it may be surprising how long it takes at some plants to discover reduced efficiency, which may be ascribed to increased sewage flows, increased friction in force main, poor power regulation, or unfortunate "demand" charges.

Moving parts *do* have an unfortunate habit of wearing and increased clearances of wearing rings, a slipping impeller or a broken or bent one, electrical losses, or a variety of defects may markedly reduce operating efficiencies and correspondingly increase costs. And even the best non-clogging pumps do not have a sufficiently high efficiency to waste any of it.

So determine your initial plant efficiency as soon as your plant is well tuned up and thereafter keep that as a goal. When costs rise, track them down by a process of test and elimination until you have localized the trouble. The pocketbook nerve is particularly sensitive.

But checking efficiencies requires that you measure your discharge and this brings up the importance of providing some sort of reliable meter in the original construction of every pumping station. Lacking a meter, preferably of the recording venturi tube, Kennison nozzle, Parshall flume, or similar non-clogging type, it may be necessary to resort to some type of weir, to a pitot tube traverse of the discharge line, to measuring the rise in the chamber receiving the pump discharge, or even to noting the time required to pump down a sump and estimating the amount of inflow. Actual *total* head at the center line of the pump, including dynamic suction head must be determined. This is most conveniently measured by means of a large diameter, carefully calibrated bourdon pressure gage on the discharge line and a similar vacuum gage on the suction line. Power consumption is best determined by the proper electric instruments but if these are not available, a good approximation can be had by counting the revolutions of the disc of the station meter for a sufficiently long period (with other power-consuming devices temporarily cut off) and applying the proper meter coefficient, which will either be marked on the meter or can be obtained from the power company.

A book might be written upon the testing of efficiencies but a simple method for computing efficiency is given by Homer Beckwith in the 1939 Journal of the Pennsylvania Water Works Operators' Association and in the May 1940 "Year Book" issue of *Waterworks and Sewerage.*

Correcting unnecessary consumption of power will pay big dividends and so will the elimination of unnecessarily high base charges. It will seldom be possible to pump principally on "off peak" power but reducing "demand" charges by installing only that rated horsepower actually required; by interlocking motors so that only certain motors can be operated simultaneously; by avoiding unnecessary use of auxiliary power when the main motors are running; and by careful regard for good power factor, will quickly repay any effort spent on this work.

Good pump packing practice; exclusion of water, sewage, and grit from bearings; proper alignment of parts; a careful choice of lubricants; and a regular schedule for oiling and greasing and renewing oil—all these and many more routine tasks are worth emphasizing again and again. Particularly would we stress the desirability of having a regular scheduled time for each item of maintenance and a card record of it so that no item is not at some time overlooked.

Rigidly supported but self-aligning bearings for long, vertical pump shafts might have been mentioned and reference could have been made to the present practice of using heavy H-beams with their top half filled with concrete, for support of such bearings.

Self-priming pumps *do* save many a headache for the operator whose pumps have a negative head or "lift" on the suction side. Air cushions which actually keep air out of the force main and pressure relief arrangements to reduce surge pressures in the force main; dependable arrangements to insure that the standby unit *will* function if the operating unit fails; auxiliary power arrangements, and emergency overflows, may prevent what would otherwise be a serious situation.

Some protection against clogging is necessary for all but the larger non-clogging pumps but screening cutters of the comminutor or triturator types will serve the same purpose and at the same time overcome one of the most vexatious tasks of the operator—the disposal of screenings.

Neatness of plant and grounds is essential—it marks a good operator and helps sustain his morale. Judicious use of paint and cleaning compounds; polished "brightwork" or clean, painted surfaces; rubber floor runners, and well kept switch gear and controls, speak for themselves, and attractive grounds appeal to every visitor. Leaking basement walls can cause no end of annoyance and ruin appearances and equipment. However, much can be done to remedy such conditions, even against outside water pressure by using the best of the very fast setting cements or certain waterproofing materials.

But *constant maintenance* is the crux of good pumping station operation whether it be switchpoints; fuse protection; automatic float control; automatic cutovers or just plain cleanliness. And it can't be emphasized too much that no station is so completely automatic that it does not require systematic maintenance and daily supervision to keep it "automatic."

Which brings us to that most important, most delicate, and at times temperamental part of the pumping station—its operating personnel. Regardless of how hard it may be to attain—even in your state—the goal should be to employ only competent, honest, dependable, and versatile men, even at the expense of some "political" disappointments—and then to direct them with tact, fairness, and decision.

All these things Mr. Olewiler has touched upon in an illuminating and, at times, humorous manner. His paper will merit careful re-reading so that its helpful suggestions may be put into effect at your station.

But Mr. Olewiler has had to accept his sewage pumping stations as they came to him with such modifications as time, funds, and experience permitted. I would like to carry the operation of sewage pumping stations further back—to the time when the station is only some lines on a drafting board or some thoughts in the mind of the designing engineer—

for the design and construction of the station have such a vital effect upon the operation of the station.

Pumping stations—even small ones—are of such varied types and include so many devices, that a volume could easily be written upon the subject. They may be isolated or part of some other building, such as a control house; they may be simple or complicated; completely automatic or manually operated; in nearly continuous operation or operating only intermittently; may use gas, diesel, steam, or electrical power; may be large or small factory-fabricated units placed wholly underground; and may vary widely in other respects.

But essentially, so far as effect on operation is concerned, they include the tributary main collecting sewer, a sump of some kind; the room containing the pumps or at least the prime movers, controls, etc.; and the force main.

It may be carrying coals to New Castle to mention some very obvious things which you gentlemen well know, but I have reviewed many pumping stations and designed some others and it is surprising at times how often the obvious is overlooked. First then, a few general remarks about the general design of the station:

It need scarcely be remarked that the site should be appropriate. It should be low enough to receive the sewage from all the area which will be tributary within a reasonable time in the future, with costs of lengthened main collecting sewer and force main and higher pumping head for a lower location balanced against the cost of prematurely moving the station farther down the drainage area for a station at a higher location. This need not unduly penalize costs. Smaller pumps may be installed at first, or additional units may be added in the future; or a smaller impeller may be used at first, with some sacrifice in efficiency.

The character of the neighborhood will have a vital bearing upon the station. The station may *have* to be and *can be* located in the midst of a closely built up, high grade development but this usually isn't desirable. But wherever located, the station should be in scale with the surroundings.

It should be architecturally pleasing in appearance. This does not necessarily mean it must be costly, since good appearance is largely a matter of the careful balancing of wall masses and openings and a choice of lines.

The grounds, however large or small, should be attractively planted with trees and shrubs appropriate to the site and of such variety of flowering seasons and habit as will maintain a good appearance for the longest time with the least labor and the least damage from dogs, insect pests, and adverse weather conditions.

The station should command attention by its appearance; not attract it by its odor. If you have a very long collecting sewer; have to hold the sewage for too long a period in hot weather, or have poorly designed sumps, perhaps it would be well to consider chlorination at strategic points to control the odors which you must not permit to occur.

Some screening protection of all but large pumps is necessary if the station is to be really automatic. Shredding devices for reducing the clogging solids in sewage can do away with one of the most troublesome features of pumping plant operation. But many plants will continue to use bar screens. Be sure these screens have sufficient area to handle the sewage between inspections; that they aren't so placed that the flow of sewage forces the screenings through them; provide in your design for a proper draining platform and at least sufficient room for the operator's feet when he's cleaning the screen; and a self-draining screening receptacle. Make the screen chamber or pit decently accessible and provide means to lift out the screenings can. Don't ask any self-respecting operator to lug a G.I. can of wet screenings up a long set of ladder rungs and then shove the can through a glorified manhole. Neither is it necessary to provide a ship's crane to remove the screenings. An overflow channel to bypass the screen is a very useful device. And an emergency sump overflow—used for emergency only and where there is no real menace to health—can be a very ready help in time of trouble—even if it must be sealed by the State Health Department—and may prevent what might otherwise be a very serious situation.

Wherever practicable, divide the sewage sump in two parts interconnected by gates of some sort—it certainly will be useful in case of repairs or cleaning. Give adequate slope to the floor of the sump to prevent stranding of solids and terminate the pump suctions in a low point of the sump in such a manner that the pumps will not lose their suction until the sump is practically empty. Also, provide convenient facilities for flushing the sump and screen chamber. And put the float controls where they won't be undesirably affected by pump action.

Let the building be sufficiently ample in size to make all the equipment *conveniently* accessible. It may cost a little more in the beginning but it pays large operating dividends. If an operator has to crawl over equipment while watching that his coat tail doesn't catch in some rotating part or that he doesn't make some electrical contact; or if he has to solve a problem in geometry each time that he tears down a pump or breaks a pipe line—well maybe he just won't do it soon enough the next time.

Pump controls and switch gear conveniently arranged around or near the walls of the room with the pumps and motors out in the room with ample space around them, and piping in trenches or so disposed above the floor as not to be a trap for the unwary, do much to help operation and improve appearance.

And let there be at least a wash bowl and in larger stations a toilet and perhaps a shower and locker room for the operator. And at least a small shelf or desk for making out reports, keeping records, etc. A suitable cupboard to keep equipment which might otherwise litter up a corner, and a well kept tool board, will make for convenience and good appearance. Ample window area for light and ventilation should be provided. Steel sash is added protection against vandalism.

We just mentioned ventilation but it is surprising how many otherwise well designed pumping stations are so deficient in good ventilation. The penalty is either stuffiness and possible danger from gases, or more generally, sweating walls, dripping, rusting equipment, scaling paint, and wet floors.

Wherever possible there should be complete separation between the wet and dry wells or the operating floor. A roof ventilator with a damper is desirable but provision should be made *to insure* a good circulation of air in the dry well and in all inside rooms or compartments and to insure venting of the wet well.

In some cases all that is necessary is to carry a duct to a point near the floor of the dry well and to rely on stairway openings or floor gratings to provide circulation. One large power company has very successfully ventilated its underground structures by merely carrying two small pipes from the same level in the pit to a point some distance up the side of an adjacent outside pole with the one pipe carried a little higher than the other. This slight difference provides a *continuous* gravity circulation of air which keeps the pits dry. However, positive ventilation by fans is so simple and so inexpensive that it is increasingly the best answer. But by whatever means, *get good ventilation.*

Also, provide a sump pump or at least a small valved line on the suction of the main pumps and carry it to a shallow sump in the floor so that water on the floor may be effectively removed.

Thus far we have said very little about what you may consider the heart of the whole station—the pumps and their motors. Well, since the designer does consider them so important, they usually do receive much careful consideration. And they cover such a very wide field that they are a subject in themselves. Even so, there may be some room for comments about them here.

The pumps themselves are nowadays nearly always centrifugals. Fortunately for the operator, the open shaft vertical pump in the wet well is not used so much anymore. Even the enclosed shaft motor in the wet well offers him enough trouble.

A dry well increases the size of the station but it certainly is a boon to the operator and wherever practicable should be provided, whether the pumps are vertical or horizontal.

Quick opening handholes for cleaning pumps, replaceable shaft sleeves and wearing rings, water deflectors, pressure water seals, drip piping, direct connection through flexible couplings to the prime movers—are all highly desirable. Shafting should be as short as possible.

The pumping capacity should be adequate and in duplicate for all normal requirements. If pumping is to be direct to a sewage treatment works, there will be less disturbance to the treatment processes if the pumping can be done by increments in pump capacity and sufficient sump capacity can be provided to permit the pumping to somewhat approximate sewage flows or help smooth out sudden peaks. This should, however, not induce too ready adoption of unduly small step changes by variable speed motors which carry their own troubles.

Wherever possible, the pumps should be so placed that they will have a positive head upon their suction lines and thus be self priming; otherwise an automatic priming device should be provided so as to do away with troublesome foot valves.

In order that each pump shall carry its own share of the load, each should be provided with a suction line direct to the sump but these should be interconnected by a manifold properly valved. The discharge piping should be carefully designed to meet its hydraulic requirements.

Again we would emphasize the desirability of providing, at the time the plant is constructed, a suitable means for measuring the discharge of the pumps.

Adequate standby power is essential in direct proportion to the seriousness of power failure. Connections to more than one public utility, an emergency generator, gasoline power, or whatever is most practicable and necessary, should be provided.

It would be possible to consider so many other features but this discussion has already exceeded its proper proportions—like the assisting minister who preaches his sermon when offering the prayer. But we cannot close without one final word. Don't make, permit, or continue any connection between a potable water supply and any sewage handling device or pipe line. If a float tube or meter is to be kept free of sewage solids by means of a small flow of clean water, see that it enters it from overhead by gravity through an air gap. If a venturi ring or some other device is to be flushed out by water pressure, see that the connection is only a *temporary* one which must be held in position by the operator while using it—and then don't permit it to be wired or clamped permanently in position. Be sure water seals are supplied from tanks supplied in turn by water entering over the top of the tank through an air gap, or use a water seal pump taking its supply from such a tank. Remember there's only one safe rule—don't permit any cross connection. The wholly improbable or the "impossible" has actually happened too often to take any chances.

SEWAGE DISPOSAL PROBLEMS AT ARMY CAMPS *

By Paul Hansen and K. V. Hill

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The problem of sewage disposal at army camps differs from municipal sewage disposal practice in several important particulars:

(1) Army camp sewage is domestic in character, unaffected by industrial wastes. It is relatively strong and high in grease, as compared with municipal sewage. The per capita flow of sewage is generally less than in municipalities, provided reasonable disciplinary restrictions on the use of water are maintained.

(2) Most of the sewage treatment plants at army camps are for temporary use only; that is to say, they are predicated on the assumption that the camps will be in active existence for a period of five years. This has a bearing on the economic balance, as between installation costs and operating costs, and implies simple and temporary construction to the extent possible.

(3) Speed is an essential factor in the design and construction of sewage disposal works for army camps, whereas municipal installations are seldom of an emergency character and generally can be preceded by adequate preliminary investigations.

Shortly after the initial program for the construction of army camps was under way, it became apparent that the various architect-engineers selected to design and supervise such camps had widely divergent ideas regarding what was necessary for the disposal of sewage. It also became apparent that there was considerable divergence in point of view among the State Departments of Health in the various states in which cantonments were being built. To harmonize these divergent ideas, two firms of engineers, Metcalf and Eddy of Boston and Greeley and Hansen of Chicago, were employed, to act jointly, in reviewing policy with reference to sewage disposal and for the purpose of indicating in general terms the degree of treatment required at each camp. These engineers prepared a report for the office of the Quartermaster General, Construction Division, Engineering Branch. In this report was embodied: (1) A review of the special problems involved in disposal of sewage from army camps; (2) Best available estimates of sewage quantities and sewage characteristics, and (3) Recommendations for loadings for various sewage treatment devices likely to be used at army camps.

In developing this report, the engineers kept constantly in mind:

(1) Security to the public health.
(2) Sufficient treatment of sewage to prevent serious nuisance.
(3) Economy.
(4) Speed of design and construction.

There are several general types of camps as affecting the design of sewage disposal plants, namely:

(1) Those built in conjunction with permanent army posts.
(2) Those built in new locations.

* Presented at the Fourteenth Annual Meeting of the Central States Sewage Works Assn., Fort Wayne, Ind., Oct. 6, 1941.

Sewage treatment plants for permanent posts are built on a permanent basis, as for municipalities. Sewage treatment works for temporary camps and cantonments are built as simply and cheaply as practicable. A special case arises where temporary camps and cantonments are built in conjunction with permanent posts, as at Fort Knox and Fort Riley. Where practicable, separate installations are desirable for the temporary camps and the permanent posts, as was done at Fort Riley. In some cases this is not practicable. If the permanent establishment is large as compared with the temporary establishment a single plant for both may be justifiable. This is the case at Fort Knox. A single plant was established for the entire post utilizing as much of an existing treatment works as practicable. Division of treatment devices into a suitable number of units will permit latitude in meeting wide variations in sewage flow represented by the entire post and by the permanent post alone. Where the natural outlet for all sewage is in one place and where the temporary establishment is relatively large it may be desirable to build sewage treatment works in two sections—one built on a basis for economical permanent operation and the other on a basis for economical temporary operation.

Sizes of the camps, as measured by the number of troops, vary from 1,500 to 60,000. The majority, however, range between 12,000 and 36,000 troops.

After a review of all of the available data on sewage quantities obtained during the war of 1917 and 1918, which data, incidentally, are meager, the consulting engineers estimated a water consumption of 100 gallons per capita per day and a sewage flow of 70 gallons per capita per day. It was realized, of course, that with uncontrolled use and waste of water both the water quantities and the sewage quantities might be greatly increased; but it was assumed that sufficient disciplinary control would be exercised to keep the water consumption and sewage flow quantities within these figures without sacrifice of convenience and cleanliness.

Because of the daily military routine which causes most of the population to be doing the same things at the same time, there will be rather violent fluctuations in sewage flow. To provide for this it was assumed that the flow for three or four hours might average double the average daily flow or at the rate of 140 gallons per capita per day. It was further assumed that peak flows passing through treatment works would be at three times the average rate, or 210 gallons per capita per day.

As to the characteristics of the sewage, the meager records of the war of 1917 and 1918 gave little help. Such records as could be found suggested the following characteristics:

	Parts per Million	Pounds per Capita per 24 Hours
Suspended solids	460	0.27
B.O.D. (5-day)	290	0.17
Ether-soluble matter	150	0.09

Security to Public Health

As indicated, the first consideration in connection with disposal of sewage at Army camps is security to public health. On this point there can be no compromise.

Public health is initially protected by the use of sanitary sewers only in all of the camps. Surface drainage is removed in ditches, through culverts and occasionally in relatively short covered drains. Thus there is no mixed sewage and storm water overflow whenever there is rainfall and therefore all sewage carrying infectious material may be passed through treatment works. While treatment works have by-passes, these are not to be used except during unusual emergencies. Duplicate units will always permit some treatment both primary and secondary. Even when by-passing, the sewage may be heavily chlorinated.

Public health may be affected by any one or all of the following uses of the receiving body of water:

(1) For public water supplies.
(2) For bathing and boating.
(3) For maneuvers including fording, crossing in small or improvised boats, bridge building, et cetera.

(1) *Protection of Public Water Supplies.*—There are no instances where it was impossible to find an outlet for sewage reasonably remote from water works intakes. In some instances, there are downstream intakes so far away that self-purification is adequate to avoid undue burden on water purification works. An additional factor of safety is afforded by chlorination of the final effluent, which is required in all cases for other reasons than the protection of water supplies.

(2) *Bathing and Boating.*—In but few cases was it necessary to discharge sewage from army camps in close proximity to places normally used by the public for bathing and boating. Where such recreational uses existed, chlorination of the final effluent was thought to be adequate to protect public health. In a few instances, a relatively high degree of B.O.D. reduction and clarification was sought to avoid any unsightliness.

(3) *Maneuvers.*—A number of streams into which sewage effluents are discharged are within maneuver areas. In ordinary fording in mechanized equipment, in horse drawn vehicles, or on horseback, there is little danger of acquiring a communicable disease. Even fording by foot soldiers, if necessary, is not a serious danger. Perhaps the greatest danger is when men fall into the stream especially a deep stream. All reasonable requirements for maneuvers may be met by an effluent that does not look bad, that does not smell bad, and which is also adequately chlorinated.

Prevention of Serious Nuisance

The degree of treatment necessary to prevent serious nuisance may be and was subject to rather wide divergence of opinion. The word "serious" implies the permissibility of some nuisance. Generally speaking, it was assumed that some discoloration, some turbidity, and an occasional slight odor would not be serious. Cases varied, however. In some situations the effluent outfall was just above a much traveled bridge, a cluster of dwellings, or otherwise frequented places. In these situations, more thought was given to the supression of odors and any visible evidence suggestive of sewage than would seem necessary where the receiving stream is remote from habitations and frequented areas.

Application of chlorine to the final effluent provides considerable latitude of control over nuisance, as well as being a safeguard to public health. Suitable chlorination of an effluent will retard putrefactive decomposition until the sewage effluent passes critical points, such as a much used bridge above mentioned. Decomposition may in many cases be retarded by chlorination, so that reaeration and dilution may take place more rapidly than the absorption of oxygen. Thus, a condition of non-odorous aerobic decomposition is maintained.

While the consulting engineers recognized that cases might occur which called for a high degree of treatment, stress was placed upon the minimum initial expenditure that would give acceptable results.

Devices and Loadings

As a result of the considerations outlined, the consulting engineers recommended that when the minimum average monthly flow in the receiving body of water was 4 cu. ft. or more per second per thousand population contributing sewage in the general locality of the camp—screening, sedimentation and chlorination would suffice. For flows less than this in the receiving body of water, the consulting engineers recommended biological treatment embodying standard-rate trickling filters, high-rate trickling filters, or activated sludge, as required by local conditions. High-rate trickling filters on account of lower costs, with final chlorination, were regarded as adequate, even where dilution was very small, or at times reduced to zero, unless there existed local conditions of a special nature demanding a higher degree of treatment.

A typical sewage treatment plant might include the following elements:

Bar screens—hand cleaned.
Measuring devices, with simple automatic recording instrument, such as a weir, Parshall flume, Palmer-Bowlus flume, but not a venturi meter.
Preliminary sedimentation tanks.
Biological treatment, using high-rate trickling filters with recirculation of effluent.
Final sedimentation tanks.
Chlorination equipment, with contact time in final sedimentation tanks, in separate contact tanks, in a lagoon or in an outfall sewer.
Sludge disposal structures, comprising digestion tanks (generally heated), sludge pumping station and sludge drying beds or sludge lagoons.

With minimum dilution during a driest month of 4 cu. ft., or more, per second per thousand population, the biological treatment and final sedimentation tanks would be omitted.

Loadings on the several devices were recommended, as follows:

Primary Sedimentation Tanks.—3 hours displacement on basis of average flow. With effluent from high-rate filters recirculated to the inlet of the primary sedimentation tanks, the volume of the tanks would be correspondingly increased. Where activated sludge was justified, the displacement period in the primary sedimentation tanks was reduced to 1.5 hours.

Trickling Filters.—Not over 3,000 pounds of B.O.D. per acre-foot per day, or a population load of 35,000 per acre-foot. This is applicable to southern camps. For northern camps, a more conservative population loading of not over 30,000 per acre-foot was recommended.

For standard-rate trickling filters, where justified, a maximum population loading of 5,000 per acre-foot for southern camps and 4,000 per acre-foot for northern camps was recommended.

Final Sedimentation Tanks.—A flow not to exceed 800 gal. per sq. ft. per 24 hours, based on average flow, and not less than 2¼ hours displacement period. With recirculation of effluent of final tanks to influent of high-rate filters, the capacity would be correspondingly enlarged.

Sludge Digestion Tanks.—2.0 to 3.0 cu. ft. per capita with heated tanks. For unheated tanks, 25 to 50 per cent was added to the capacity, using the larger figure for locations close to buildings. For plants using activated sludge, these figures were increased by 50 per cent.

Sludge Drying.—For standard sand drainage beds, 0.5 to 1.0 sq. ft. per capita for dry southerly climates was used, and 1.0 to 1.5 sq. ft. per capita for humid northerly climates. In warm dry climates in favorable locations, lagoons were used with areas of 2.0 to 3.0 sq. ft. per capita.

Attitude of State Departments of Health

Some engineers of State Departments of Health appear to have regarded the policy and plant loading outlined as too lenient. They felt that, having labored to educate the public to demand clean streams, adoption of lower standards of treatment on the part of the United States Government at army camps would undo much of the good work that had been accomplished after years of educational effort in their respective states. They believed that the Federal Government should not act to tear down standards, but should act to build them up. The psychology that methods of sewage treatment, practicable of application, are none too effective at best should, in their opinion, prevail.

The opposing attitude is, that cantonments, being of a temporary character, do not warrant elaborate treatment, and that any treatment which does not cause serious nuisance and which protects the public health is sufficient. It is also argued that the country is facing the grim possibility of war, at which time not a dollar should be spent for superfluities, and that every dollar should count to a maximum degree in bringing about effective national defense.

Economy

Broadly speaking, it is better to incur large operating costs for temporary camps, than to spend great sums of money on initial installation.

The liberal use of final chlorination, while somewhat costly in operation, makes it possible to get along with less biological treatment than might be required for permanent installations in municipalities. Not only may chlorine be used to retard decomposition, but it may be added in amounts that may result in some direct oxidation, where and when necessary.

The question of economy has already been touched on incidentally in discussing other objectives of sewage disposal from army camps. Three factors relating to economy may be stressed:

(1) It is desired to expend the least money necessary during the existence of the camps to protect the public health and otherwise obtain acceptable sewage disposal.

(2) A recognition of the fact that relatively high operating costs may be incurred for the short period during which the camps may be used, as a means of keeping down installation costs.

(3) Recognition of the fact that sewage disposal contributes but little to a successful defense effort.

With these criteria in view, the consulting engineers leaned toward relatively high loadings of sewage treatment devices, the use of high-rate trickling filters, with recirculation of the effluent, where secondary treatment was needed, and the elimination of final or polishing treatments. It sometimes happens, as in at least one instance in New England, where a high degree of treatment on intermittent sand filters proved to be the economical treatment, because the sand was already in place and required but little labor to put it in condition to receive sewage.

Speed in Design and Construction

An important factor in connection with army camps is speed in design and construction and the use of the least amount of materials. It was deemed important to have sewage treatment works in readiness to function as soon as troops arrived. Design was directed toward simplification of construction and the reduction of quantities of materials to a minimum. To this end, any devices requiring complicated reinforced concrete design were discouraged. For example, sedimentation tanks with mechanical removal of sludge were preferred to Imhoff tanks, even for relatively small installations, because of the more or less complicated concrete work inherent in Imhoff tank construction. Mechanically operated and cleaned screens were discouraged, because of the rather intricate concrete required for their installation. Trickling filters were preferred to the activated sludge process, because of relative simplicity. High-rate trickling filters were preferred over standard-rate trickling filters, because lesser quantities of filtering and other materials were required. Buildings were made of wood of simple design, except where there was a serious fire hazard. In such cases, the buildings were made of brick. Limited laboratory facilities were provided and where water supplies needed laboratory control, an effort was made to combine water and sewage laboratories.

Operation

Operation of sewage treatment works at army cantonments is not all that could be desired. No definite provision was made for operation until many of the cantonments were complete. Often the Architect-Engineers on the job had to make strong representations to obtain competent operators.

The general procedure was to assign the operation of both water works and sewage treatment plants to the Post Detachment. More often than not, the Post Detachment had no one qualified to deal with these problems. In some instances, chemists were certified from Civil Service lists. Some of these men did good work, but some had little experience or support. Suggestions were made that the operating personnel be taken from civil life, with the expectation that a suitable number of operators might be recruited from existing large sewage treatment plants and water purification works about the country. This suggestion did not progress very far, and in most instances, the Architect-Engineers were obliged to give a substantial amount of attention to operation of sewage treatment plants and the training of the personnel.

Recognizing the necessity of a more effective handling of the various special engineering problems in connection with army camps, there was established in the office of the Constructing Quartermaster General at Washington a staff of civilian engineers, comprising recognized experts in various fields, including sewerage. It is the duty of this group to advise regarding a well coordinated policy and control of both installation and operation of various utilities and structures at army establishments. In the matter of design and construction, the arrangement has been effective, but in the matter of supervision of operation, suitable lines or channels of information and control have apparently not yet been developed, though efforts are being made in this direction. It is difficult, for example, to obtain prompt and reliable information at headquarters in Washington as to performance of the various sewage treatment works, and it seems to be equally difficult for the headquarters in Washington to obtain prompt rectification of any defects, either in design or operation, that may come to the attention of headquarters.

Army personnel at camps is likely to be changing more or less constantly, as old units move out and new units move in. This has an upsetting effect on the continuity of management of the utilities. As disposal of sewage under cantonment conditions is essentially a civilian activity, and as continuity of control is essential, regardless of the changes in troop personnel, it would seem desirable to man all sewage treatment works with qualified, experienced civilian operators, and this principle has apparently been recognized. The efforts of these operators should be fully coordinated, by a central agency in Washington, using lines of contact which cut across usual military channels. In particular records should be kept, reviewed and summarized by experienced engineers for future use.

The attached table indicates the type of sewage disposal provided at 38 widely separated National Defense Projects.

Types of Sewage Treatment Plants for National Defense Projects—1941

Connection to City Sewer		2
Sedimentation Only		12
Imhoff Tank	1	
Separate Sedimentation and Sludge Digestion	11	
Trickling Filters		
Standard		8
Bio		7
Aero		4
Activated Sludge		4
Intermittent Sand Filters		1
		38

FIRST YEAR OF OPERATION OF THE GARY, INDIANA, SEWAGE TREATMENT PLANT *

By W. W. Mathews, *Superintendent*

September 17th, 1941, marked the completion of the first years' operation of the Gary, Indiana, Sewage Treatment Plant. This is an activated sludge plant, diffused air type, with separate sludge digestion and with garbage grinding facilities provided as a part of the treatment process. (Figure 1.) For descriptions of the design and construction of

Fig. 1.—Gary Sewage Treatment Plant. Foreground, aeration house; left, primary clarifiers and grit chambers; background, pump house and blower building.

the plant, the reader is referred to extensive articles in various technical journals (1), (2), (3).

Primary treatment started August 23, 1940, and secondary treatment September 17th. Raw sludge was first pumped to primary digesters August 25th, and daily since that date. By starting primary and secondary treatment on different dates the operators were gradually given time to become familiar with their duties. In the discussion that follows, the treatment process will be followed through the plant and performance of each unit noted. A table at the end of the paper summarizes the operating and analytical data. Since the plant has been in operation only a little more than one year, and operated through each season once, we are not able at this time to draw final conclusions as to what normal operating results will accomplish, or what the final operating procedure will be, but the results obtained so far are indicative of what we may expect. Opera-

* Presented at the Fourteenth Annual Meeting of the Central States Sewage Works Assn., Ft. Wayne, Ind., Oct. 6, 1941.

tion has demonstrated that each part of the plant functions properly and in the manner for which it was designed.

Screenings

As the sewage enters the plant it passes through 25 inch comminutors. The number operated depends upon the rate of flow and varies from two to five. Screenings and handling of screenings are not a problem. Practically all floating material is macerated by the comminutors so that the amount of screenings removed from the comminutor pits has been from .03 to .26 cu. ft. per million gallons. The greater part of material designated as screenings is grit that deposits in the bottom of the comminutor pits. Small blocks of wood, tree branches, rubber balls, etc., constitute such a small portion of material removed from the pits that no effort is made to separate the two classes of material and keep a seaprate record of each. After passing through the comminutors the sewage flows to the suction conduit where it is pumped to the grit chambers by one of the five sewage pumps.

Sewage Pumping

With a main interceptor to the plant from 72 in to 84 in. in diameter and slightly over three miles in length, it is possible to use this sewer as a reservoir and maintain a fairly uniform rate of pumpage throughout the twenty-four hours. The pump and blower house operators are now able to estimate the average daily flow within reasonable limits if there is not any excessive runoff due to rain. Rate of pumpage is controlled by throttling the cone valves on the discharge lines of the sewage pumps. The rate of pumpage is regulated so that the interceptor is pumped practically dry in the early part of the morning and before the morning peak flow has reached the plant. At times the sewer is pumped down to where the pump loses suction, and in that case the pump is shut down, the length of the shut down depending upon the hour of day and rate of flow in the sewer.

Typical average ranges in pumpage rates are from 15 to 24 m.g.d. or from 12 to 18 m.g.d. The maximum changes in rates are not usually made at one time, but may take place through one or several increments, depending upon the rate of rise of sewage in the comminutor pits. With the main interceptor pumped down, the morning peak comes down the interceptor almost in a wave, carrying with it any deposits that may have settled in the previous 24 hours. To date, inspections show that no septicity has developed in the interceptor, and the sewage reaches the plant with no indications of staleness. Sewage from the most distant point reaches the plant in about eight hours. Average time required for all sewage to reach the plant is approximately four hours.

With a uniform rate of flow "jolting" does not occur in any of the tanks, such as occurs where pumping is automatic through float controls with the pumps cutting on and off at intervals. The organic load on the aerators in particular is more uniform than where the rate of flow in the sewers has to be followed closely by rate of pumpage. If gas production is below normal, sewage pumps are operated at full capacity to conserve gas, and shut down during periods of minimum flow. As far as can be determined this has no effect on the efficiency of the treatment process.

Grit Removal

Grit removal equipment consists of two Link Belt straight-line grit collectors, with screw conveyors, of 20 m.g.d. capacity each. Average putrescible material in the grit averages 4.3 per cent with maximum of 10.2 per cent, and minimum of 0.77 per cent. Grit analyses are run weekly. The amount of grit removed per million gallons to date is lower than would be expected from the sandy area, characteristic of the lower end of Lake Michigan. Over a period of 11 months the average grit removal was 2.5 cu. ft. per m.g., ranging from a minimum of 0.68 to 4.05 cu. ft. per m.g. Grit is discharged into industrial cars which are moved with a small gasoline locomotive. The grit is used as fill about the plant site.

Primary Clarification

The sewage is clarified in four Door Company square, central feed radial-flow type clarifiers. Detention period is sixty minutes at a 40 m.g.d. rate. During the winter all four clarifiers were used to avoid freezing in units that otherwise would have been out of service. This resulted in a settling period somewhat in excess of two hours. Reduction of suspended solids in primary clarifiers ranges from 25 to 58 per cent, with an average of 38.5 per cent for the past 8 months.

A sludge blanket 18 in. in thickness at the outer edge of the clarifiers has been carried throughout the winter. This gives a total depth of sludge to bottom of sludge hopper of approximately 8 ft., and the total amount of sludge in storage in the primary tanks is equivalent to approximately 1,000,000 cu. ft. of gas. No septic action has been noticed in any of the clarifiers during the winter, but it has been necessary to reduce this thickness to 6 inches at times during the summer months. At various times all sludge ws pumped out of the primary clarifiers when gassing indicated this was advisable.

When sludge pumping started early in the fall the per cent of solids varied from 8 to 9 per cent. Later, with a rise of temperature in the summer months, this gradually declined to between 4 and 5 per cent, and at present is approximately 4.2 per cent. Average for 10 months is 5.3 per cent. It is possible that the early high solids content was due to old sludge deposits in the sewers being washed down to the plant when the interceptors were put into service. Numerous bulkheads were built in the sewers by the contractors and some sludge remained in the sewers for over a year. Some digestion undoubtedly occurred in the sewer during this period. This sludge would naturally be heavier than fresh sludge and tend to concentrate more in the primary tanks with the depth of sludge blanket maintained.

Raw sludge pumping is scheduled so as to disturb the sludge blanket as little as possible. Pumping out of primary tanks is in rotation at one hour intervals so that any tendency for the sewage to break through the blanket is kept at a minimum. With this schedule, sludge is removed from each primary tank once in four hours. Rate of pumpage is normally at an 80 g.p.m. rate with two pumps operating. With five primary digesters in service the total pumpage required to keep up gas production at present is either three or four hours per day to each primary, compared to two or three hours during the winter months. Volatile solids varied considerably, averaging 69 per cent for February and 51 per cent for June, when excessive rainfall caused "washouts" in the sewer system. In general, maximum percentages of volatile solids in the raw sludge occurred during the colder months. Two 4 in. single acting Marlow sludge pumps in each of four sludge control houses pump into adjacent digesters under normal operating routine.

Digesters and Gas Production

There are five primary digesters with concrete roofs, heated with five circumferential pipe coils 1½ in. in diameter, and three secondary digesters, not heated, with floating gas holders of 60,000 cu. ft. capacity each. All digesters are 90 ft. in diameter. The primary tanks have side depths of 20 ft., while the secondary digester walls are 23 ft. in height. Capacity of each digester is 1,000,000 gallons, so that total capacity is 6 cu. ft. per capita for the design population of 170,000. Transfer of sludge from primary to secondary digesters takes place when raw sludge is pumped to a primary tank. Piping is so arranged that sludge can be transferred from any primary to any secondary tank and vice-versa. Recirculation in the same tank is also possible by pumping.

Raw sludge pumping was started on August 25th, two days after starting the plant, and was continued until April, 1941, before any sludge was drained to the drying beds. The several primary digesters were placed in service without any trouble. At the time raw sludge pumping was started the primary digesters contained about 5 ft. of ground water, which had a pH of 7.3 and which was used by the contractor to test the tanks for water tightness. At this time one 300 hp. gas engine driving a 7,000 cu. ft. per min. Roots-Connersville rotary positive displacement blower was in service on city gas to supply heat for the digesters. Two digesters were filled first, namely Nos. 3 and 5. They passed through the normal fermentation and acid periods of digestion, the pH being controlled by the addition of hydrated lime. Daily checkings were made and lime added, usually twice a day in the amount of 100 to 200 pounds. Stabilization of digesters occurred at a pH of 7.1 and has remained constant since that period. The manholes on the digesters were left open and gas produced before the tanks were filled was allowed to escape. On October 8th Tank No. 5 was opened to the gas header, manholes were closed and the waste gas burner lighted. One day later Tank No. 3 was put into service. Daily gas analyses were made, and on October 26th the city gas was shut off, and the sludge gas used to pump sewage. Since that date no city gas has been used. Primary digesters Nos. 1, 7 and 2 were put into service on October 30th, December 9th, and December 26th, respectively. A total of 12,150 lb. of hydrated lime was used in conditioning the digesters. Average of three gas analyses in January is given below.

Table Showing Average of Gas Analyses
January to August 1941

No. Analyses	CO_2	O	CH_4	H	N	H_2S* Raw	H_2S* Scrubbed	Calorific Values B.t.u. Net	Calorific Values B.t.u. Gross
12	29.6%	0.0%	63.5%	4.3%	2.5%	24.1	7.6	610.2	658.9

* Hydrogen sulfide reported in grains per 100 cu. ft. Nitrogen determined by difference.

After seven months of pumping to the digesters without any drawoffs, the average per cent of solids in the various tanks as of April 1st was as follows:

Digester No.	1P	2P	3P	4S	5P	6S	7P	8S
Per cent Solids	6.8	5.0	4.3	1.5	4.5	1.0	2.1	0.9

P—Primary
S—Secondary

Raw sludge pumping to primary tanks is controlled by the amount of gas required for power and miscellaneous uses at the plant. The outside operators check the holders hourly, and if, in the early morning, they are near the upper limit of travel, sludge pumping is started on the basis of one hour with two sludge pumps into each primary digester. Then later in the day, if the holders show indication of lowering at a faster rate than usual, additional pumping is done. On the other hand, if all three holders are up against the stops, the waste gas burner is lighted to prevent a build-up in pressure and blowing of seals. At times the waste-gas burner and all unit heaters will be in service to relieve excess pressure. To prevent an excessive sludge blanket building up in the primary clarifiers, it is necessary at times to pump to the secondary digesters.

Supernatant liquor from the secondary digesters has no apparent effect on the treatment process. Using two-stage digestion and with the secondary digesters averaging approximately 80 degrees Fahrenheit during the summer, the supernatant has not been as strong as the sewage handled at some plants. The table below shows the average 5-day B.O.D. and suspended solids in the raw sewage and in the supernatant from the three secondary digesters, over the past eight months:

5-Day B.O.D. and Suspended Solids in Supernatant Liquor
From Secondary Digesters and in Raw Sewage
January to August, 1941

	Raw Sewage		No. 4 Digester		No. 6 Digester		No. 8 Digester	
	5 Day B.O.D.	Suspended Solids	5 Day B.O.D.	Suspended Solids	5 Day B.O.D.	Suspended Solids	5 Day B.O.D.	Suspended Solids
Jan.	112	142	166	448	126	279	163	231
Feb.	144	153	125	559	102	743	62	442
Mar.	214	212	287	1,023	222	733	157	318
Apr.	181	236	240	950	187	863	110	534
May	151	230	145	3,422	282	899	217	561
June	124	216	230	3,556	235	712	217	920
July	134	237	252	1,759	182	652	173	469
Aug.	170	191	385	646	169	713	153	526
Ave.	154	202	229	1,545	188	699	156	500

It will be noted from the table that there is little difference between the B.O.D. of the supernatant and the raw sewage. There are more solids in the supernatant, but these are largely inert, judging by the proportion of B.O.D. to suspended solids in the raw sewage.

Gas production has considerably exceeded original estimates. November was the first month in which sludge gas was produced throughout the entire month, and the average daily production was 125,670 cu. ft. or at the rate of 1.25 cu. ft. per capita per day. Oil dumped in the sewer system the latter part of December reduced gas production below the average. Since January average daily production has been approximately 155,000 cu. ft. per day, or 1.55 per capita.

Aeration

There are ten aeration tanks, each 300 ft. in length by 30 ft. in width, with an average water depth of 15 ft. Each basin is a complete straight flow-through unit, with individual piping, valves and meters. Air is distributed through stationery diffuser tubes, 3 by 24 in., staggered on 16 in. centers on a steel header. This header varies in size from 12 to 6 in., and extends the entire length of each tank. Each aeration basin has a capacity of approximately 1,000,000 gallons, or with a theoretical capacity of 4 m.g.d. per tank with a six-hour aeration period, not including return sludge.

Only four aerating basins have been in use since starting the plant, with the exception of 19 days in August, and the average aeration period for November to August was 4.53 hours with maximum and minimums of 5.4 and 3.78 hours respectively, including return sludge. Using this aeration period, and with a solids content in the mixed liquor of from 1800 to 2000 parts, air requirements are from 0.5 to 0.6 cu. ft. per gallon of sewage. This amount of air insures a dissolved oxygen residual at end of the aeration period of more than 2 p.p.m., which has prevented bulking over the seasons of the year that the plant has operated. No bulking trouble occurred during the dry period in July and August.

Final Settling Tanks

There are eight final settling tanks, each 75 ft. square, similar to the primary tanks with exception of grease skimmers, which are omitted in these tanks. Settling period is two hours at a 40 m.g.d. rate. (Figure 2.) To avoid having ice form in tanks out of service in cold weather six of the eight tanks were operated part of the time. The settling period averaged 2.7 hours from November to August, and 827 gallons per square foot, per 24 hr. for the same period.

Three return sludge pumps with capacities of 3, 4½ and 7 m.g.d. capacity are provided. These are centrifugal-type pumps and manually controlled. Shortly after starting operation it was found that if the rate of return sludge was allowed to get as low as 25 per cent septic conditions would develop in the final settling tanks. Rate of return is maintained so that no sludge blanket is carried at the edge of the final settling tanks. Depth of sludge blanket is determined by a conventional sounding rod carrying 3 bottles spaced for sampling at 6, 12 and 18 in. depths. Soundings usually show 6 in. of secondary sludge at the center of tank and less than 6 in. at the quarter point.

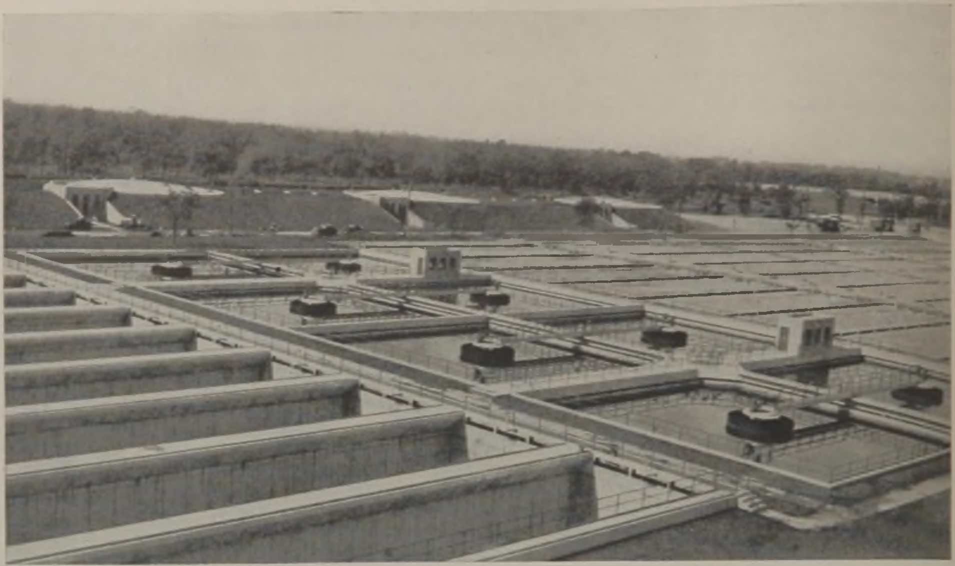

Fig. 2.—Gary Sewage Treatment Plant, showing three 60,000 cu. ft. gas holders down; secondary digesters; west end of aeration basin; secondary clarifiers, and part of sludge-drying beds.

Gas Engine Operation

There are five gas engine units in the plant. Three 175 hp., 5 cylinder Worthington engines drive sewage pumps with capacities of 20 m.g.d. each at 35 ft. total dynamic head. Two 300, 6-cylinder Cooper-Bessemer engines drive Roots-Connersville positive displacement type blowers of 7000 c.f.m. capacity at 8 lb. pressure. One sewage pump and one blower are used ordinarily with routine operation. The blower is operated at about 91 per cent of capacity and furnishes air at a rate of from 0.5 to 0.6 cu. ft. per gallon of sewage. Any variation in the quantity of air blown per gallon is due to variation in flow and not to any change in engine and blower speed. With normal gas production it has been possible to operate almost continuously since January, 1941, with sludge gas furnishing power for sewage pumping and aerating. (See table at end of paper.) The following table shows the sludge gas used for power from January to August, 1941, inclusive, and does not include the gas used for heating individual buildings with unit heaters in the winter months. In addition, sludge gas is used for heating hot water for the shower rooms and laboratory.

Use of Sludge Gas for Power, Gary Sanitary District, Gary, Indiana

Month 1941	Amount Used Cubic Feet	Value in Terms of Purchased Gas
January	3,784,700	$ 1,512.84
February	4,345,350	1,714.33
March	4,692,420	1,839.27
April	4,583,405	1,800.02
May	4,807,546	1,880.72
June	4,074,000	1,616.64
July	4,545,900	1,827.68
August	4,876,064	1,886.50
Totals	35,709,385	$14,078.00
Average	4,463,673	$ 1,759.75

The heat from the jacket water of the gas engines, plus exhaust gases, takes care of heating the digestion tanks and the main building, as well as heating a shower and locker room and tool room in the garage building. In the summer the heat exchangers are by-passed. It has not been found necessary to use the heating boilers except for a short time when the plant was first placed in operation. In computing the value of the gas used for power the unit prices in a contract with a local utility are used, adjusting the total to a 600 B.t.u. gas compared to a 1000 B.t.u. gas as per contract. No operating expenses are charged against the engines in computing the value of the sludge gas, for whether gas is purchased or produced at the plant, the same operating personnel is required and there would be no difference in oil and grease requirements. The totals shown are conservative in that a round figure of 600 B.t.u. is used for the sludge gas, where actual B.t.u. average is 610 over a period of the past 8 months. The experience in gas engine operation at Gary is one of numerous installations which demonstrate the economy of using sludge gas as a source of power in a sewage treatment plant.

Industrial Wastes

Industrial wastes have presented no operating problem up to this time. One industry dumps about 6000 gallons of ferrous sulfate per week, having an acidity of 5.2 per cent and 7.3 per cent volume ratio, expressed as total iron. This is a pickling liquor from a wire and bar mill. Grab samples taken as this liquor passed through the plant shows total iron content as noted below. (These are approximate averages only and vary with the rate of flow when dumping occurs.)

Location of Sample	P.p.m. Iron
Raw Sewage	310
Clarified Sewage	160
Mixed Liquor	140
Final Effluent	85

There is a noticeable increase in clarification efficiency over the 24-hour period when the iron is passing through the plant. The average per cent reduction of clarified to raw sewage by months varies from 25 to 58, while on days when the iron was passing through the plant the reduction has

Gary Sewage Treatment Plant

Monthly Summary—Operation and Analytical Data

1941

Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Average Daily Pumpage, M.G.D.	16.90	16.00	16.81	18.26	17.60	24.89	20.84	17.31	14.04	24.34	24.91	20.53	19.38
Per Cent Pumped with Sludge Gas	73.6	100	100	100	99.89	65.4	96.5	100	99.1	67.0	44.5	61.3	83.94
Cu. Ft. Air per Gallon Sewage	0.53	0.61	0.56	0.51	0.53	0.51	0.44	0.55	0.70	0.44	0.44	0.44	.522
Per Cent Air Blown with Sludge Gas	87.1	100	100	100	100	97.7	89.1	100	97.9	99.8	90.2	95.5	96.4
Lb. B.O.D. Removed per 1000 Cu. Ft. Air	1.20	1.67	1.80	1.70	1.73	1.64	1.61	1.70	0.94	1.01	0.96	1.33	1.44
Av. Daily Gas Production C.F.	130,480	165,700	158,677	156,600	159,000	134,650	151,120	155,600	146,030	144,400	119,107	132,507	146,156
Av. Daily Gas Production C.F./Capita	1.30	1.65	1.59	1.57	1.59	1.35	1.51	1.56	1.46	1.44	1.19	1.32	1.46
Gas Produced, Cu. Ft. per Lb. Solids Added	8.3	5.8	8.0	9.1	6.6	4.6	5.0	4.9	5.1	2.6	3.5	3.9	5.6
Gas Produced, Cu. Ft. per Lb. Vol. Solids Added	—	10.3	11.9	—	—	9.6	9.7	8.6	9.3	5.0	8.2	7.9	8.9
Screenings Removed, Cu. Ft./M.G.	0.08	0.05	0.03	0.11	0.26	0.12	0.08	0.06	0.18	0.12	0.048	0.031	0.097
Grit Removed, Cu. Ft./M.G.	1.90	0.68	2.80	2.86	3.86	4.05	2.31	2.75	5.72	5.28	3.92	6.04	3.51
Lb. Solids Removed Daily, Dry Basis	16,272	23,100	28,378	35,095	32,976	43,963	39,677	27,194	31,419	48,719	31,242	31,441	32,456
Lb. Solids Removed per M.G.	930	1,445	1,680	1,920	1,870	1,803	1,901	1,571	2,280	2,002	1,254	1,531	1,682
Lb. Per Capita per Day in Raw Sewage	0.1944	0.2437	0.2979	0.3602	0.3361	0.4496	0.4111	0.2755	0.3202	0.4986	0.3303	0.3243	0.3368
Settling Period in Hours	2.10	2.50	2.22	2.13	2.14	1.37	1.87	2.39	2.76	1.67	1.63	1.98	2.06
Lb. B.O.D. Removed Daily	13,787	21,900	28,715	25,806	21,802	24,195	30,000	23,293	21,209	21,948	24,196	18,858	22,976
Lb. B.O.D. Removed per M.G.	690	1,370	1,709	1,413	1,241	972	1,440	1,345	1,344	962	971	951	1,201
Lb. B.O.D. Per Cap. per Day in Raw Sewage	0.1578	0.2316	0.3002	0.2748	0.2318	0.2567	0.3200	0.2457	0.2266	0.2339	0.2568	0.1952	0.2443

Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
5-Day B.O.D. Raw Sewage, P.P.M.	112	144	214	181	151	124	184	170.3	193.6	115.3	123.7	114.1	152.25
5-Day B.O.D. Clarified Sewage, P.P.M.	93	110	145	121	119	80	96.3	121.4	91.6	52.7	49.2	74.2	96.1
Per Cent Reduction B.O.D., Clar./Raw	17	24	32.5	33	25	35.5	48	28.7	52.7	54.4	60.0	34.9	37.1
5-Day B.O.D., Final Effluent	15	8	9	5	9	7	11.8	8.8	12.3	7.1	7.1	3.9	8.6
Per Cent Reduction B.O.D., Final to Raw	86.3	94.7	95.7	97.2	94.1	94.2	93.6	94.8	93.8	93.8	94.2	96.6	94.08
Susp. Solids, Raw Sewage, P.P.M.	142	153	212	236	230	216	237	191.2	274.4	240	158.9	189.5	206.6
Susp. Solids, Clarified Sewage, P.P.M.	106	104	129	136	145	117	100	134.9	112.8	83.3	72.7	101.9	111.9
Per Cent Reduction Susp. Solids, Clar./Raw	25	31	39	42.8	37	46	58	29.5	58.9	65.3	54.2	46.2	44.4
Susp. Solids, Final Effluent, P.P.M.	26	8	10	6	4	5	10	2.4	5.1	5.6	8.4	12.2	10.4
Per Cent Reduction Susp. Solids, Final/Raw	81.0	94.8	95.2	97.4	98.2	97.8	95.8	98.7	98.1	97.7	94.7	96.8	95.52
Susp. Solids, Mixed Liquor, P.P.M.	1303	1710	1855	1630	2019	1470	1400	1160	1368	1426	1573	1714	1557
Sludge Index (Stan. Methods)	64	80	91	85	81	67	80	100	102	84	77	125	86.4
Susp. Solids, Return Sludge, P.P.M.	4717	7787	7089	5970	7050	4450	5625	4010	5417	4542	5709	4688	5588
Per Cent Return Sludge	27	29	29	29.8	29.6	28.9	27.6	35.0	34.3	25.2	27.8	33.3	29.7
Aeration Period, Hours	4.50	4.70	4.52	4.13	4.30	4.18	3.78	4.73	5.18	3.69	3.56	4.26	4.29
Secondary Settling Period, Hours	2.50	2.80	2.58	2.91	3.00	3.01	2.68	3.15	4.10	2.92	3.02	3.07	2.97
Secondary Settling Period, Gal./Sq. Ft.	903	780	843	752	725	726	815	695	533	748	728	720	747
Cost of Treatment per M.G.	$10.71	$11.53	$ 9.50	$10.21	$ 9.14	$ 6.89	$ 8.99	$10.19	$12.06	$ 7.50	$ 8.20	$ 8.11	$ 9.42
Cost Per Capita (100,000 Pop.)	0.056	0.0516	0.0495	0.0559	0.0498	0.0515	0.0581	0.0547	0.0508	0.0582	0.0612	0.0517	0.0541
Cost per 1000 Lb. B.O.D. Removed	13.56	8.40	5.56	7.22	7.92	7.09	6.25	7.58	9.57	8.20	11.86	11.11	8.69

been as high as from 75 to 89 per cent. pH in raw sewage drops from an average 7.1 to 6.9 as a result of the acid pickling liquor.

Waste oil interrupted the treatment process from December 20 until January 11, 1941. On December 20th oil from a heat-treatment process was discharged into the sewer system in sufficient quantity to cover the four primary clarifiers with a fluffy black scum about 1 in. in thickness. On December 27th another charge of oil was received, approximately one-half the quantity dumped on December 20th. The effect of this oil on the treatment process was felt within 24 hours. Gas production dropped from an average of 136,600 cu. ft. daily preceding the oil dumping to approximately 80,000 cu. ft. for a period of three weeks. Dissolved oxygen in the mixed liquor dropped from an average of 7 p.p.m. for 8 days preceding to 0.66 p.p.m. for a week after oil dumping.

Oil coated sludge particles in the secondary clarifiers, having a low specific gravity, carried over the effluent wiers so that the per cent removal of solids for complete treatment got as low as 54 per cent. Publicity in the local newspaper on the oil dumping apparently cleared up this trouble.

Administration

The Gary Sanitary District was organized in 1938 under The Indiana Sanitary District Act of 1917, and administration is under a Board of Three Sanitary Commissioners. Board members are W. P. Cottingham, President (who is also city engineer of Gary), Boyd E. Phelps, Vice-President, and Otto V. Gray, Secretary. One activated sludge plant serving 100,000 population, one Imhoff trickling filter plant serving 2,000 population, and three small lift stations are operated by the Gary Sanitary District. In addition there are approximately sixteen miles of intercepting sewer which were constructed by the District.

Operating Personnel

The operating force at the main plant at the present time is as follows:

1	Superintendent	4	Pump and Blower House Operators
1	Assistant Superintendent	4	Outside Operators
1	Chief Chemist	2	Maintenance Men
1	Assistant Chemist	2	Grounds Men
1	Clerk	2	Laborers
1	Chief Operator	1	Janitor
		21	

Additional temporary laborers will be required at times to clean sludge beds. Two additional employees operate the Imhoff plant and lift stations.

Acknowledgment is made here to Chief Chemist E. J. Ross and Asst. Chemist Julian Hay for assistance in checking and assembling analytical data presented herein.

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2. L. R. Howson, "The Plant That 'Steel' Built," *Sewage Works Engineering*, September, 1940.
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NEW DEVELOPMENTS IN SEWAGE DISPOSAL IN NEW YORK CITY

By Richard H. Gould

Acting Deputy Commissioner, Dept. of Public Works, New York City

Editor's Note: These photographs and drawings were received too late to be used with Mr. Gould's paper in the January, 1942, issue (page 70). The pictures are so instructive that they are presented here, as a visual exhibit of new developments in New York City's sewage disposal program.

Fig. 1.—Grit chamber, Coney Island Sewage Treatment Works.

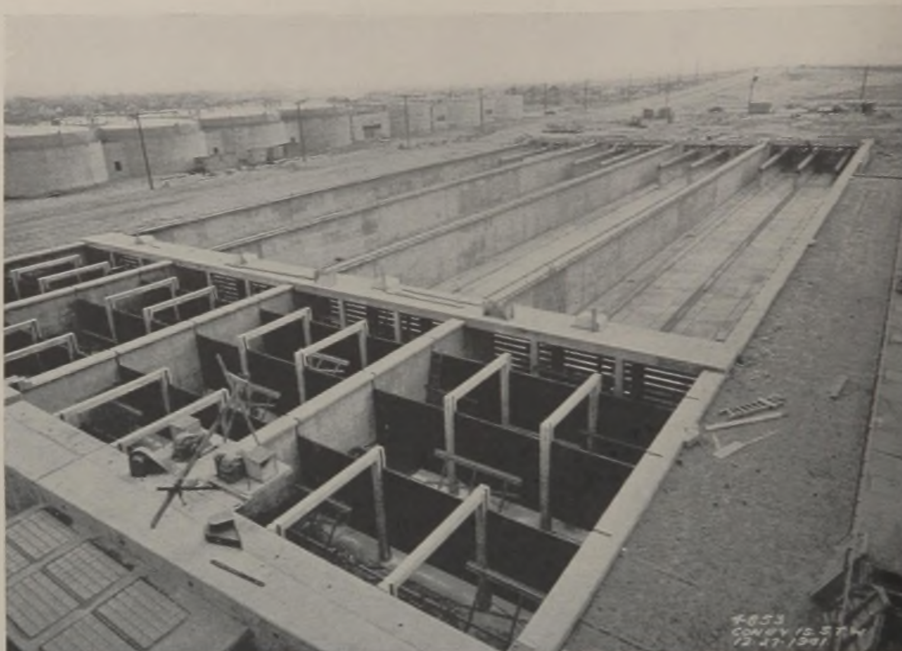

Fig. 2.—New flocculators and monorake-equipped settling tanks, Coney Island Sewage Treatment Works. Note old and new digestion tanks in background.

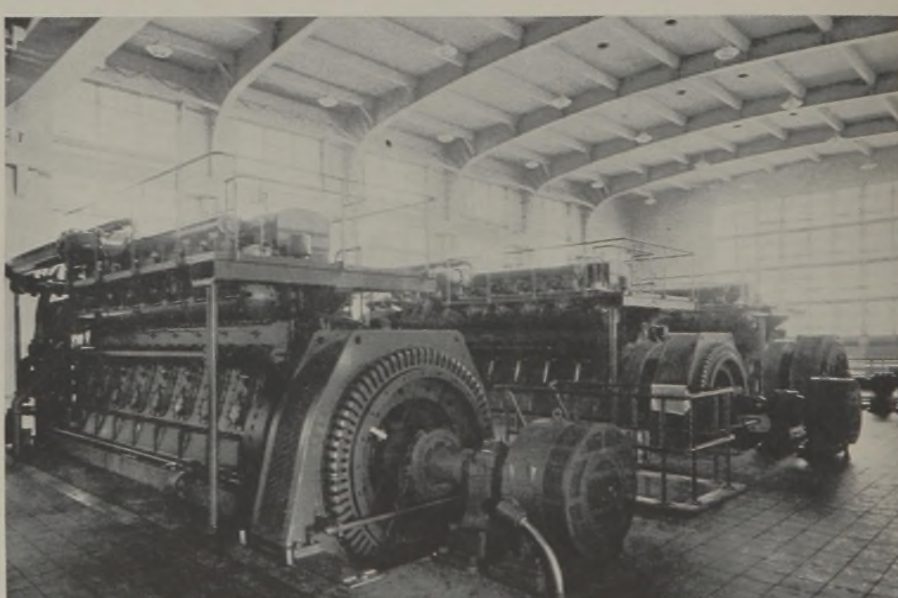

Fig. 3.—Three 900-hp. gas engine generators, Coney Island Sewage Treatment Works Extension.

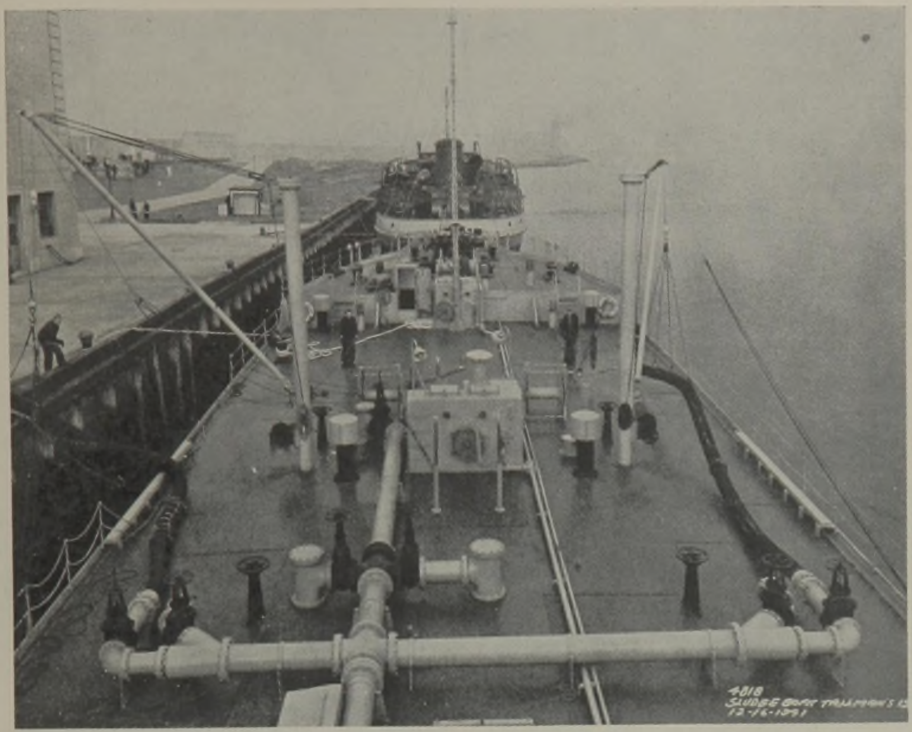

FIG. 4.—Vessels receiving cargo of raw sludge, Wards Island Sewage Treatment Works.

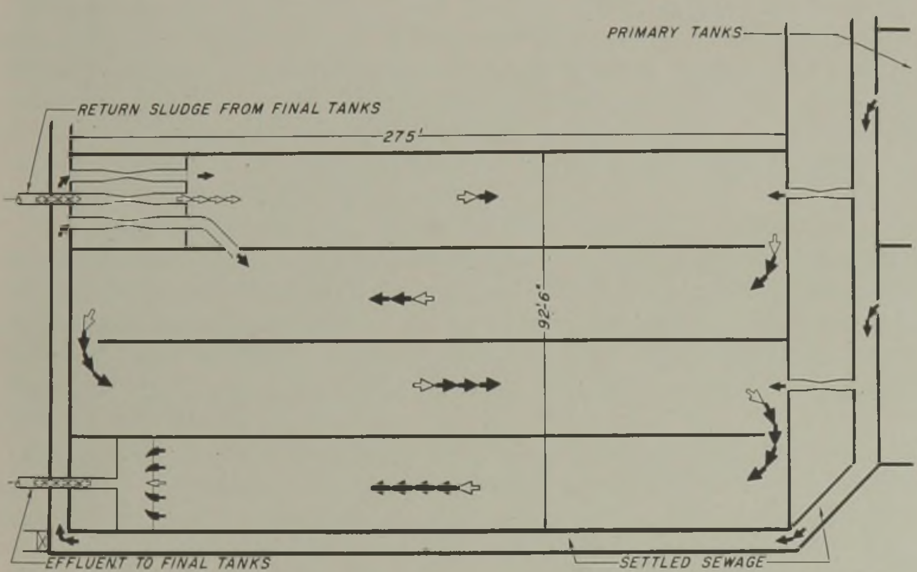

FIG. 5.—Step aeration as installed at Bowery Bay.

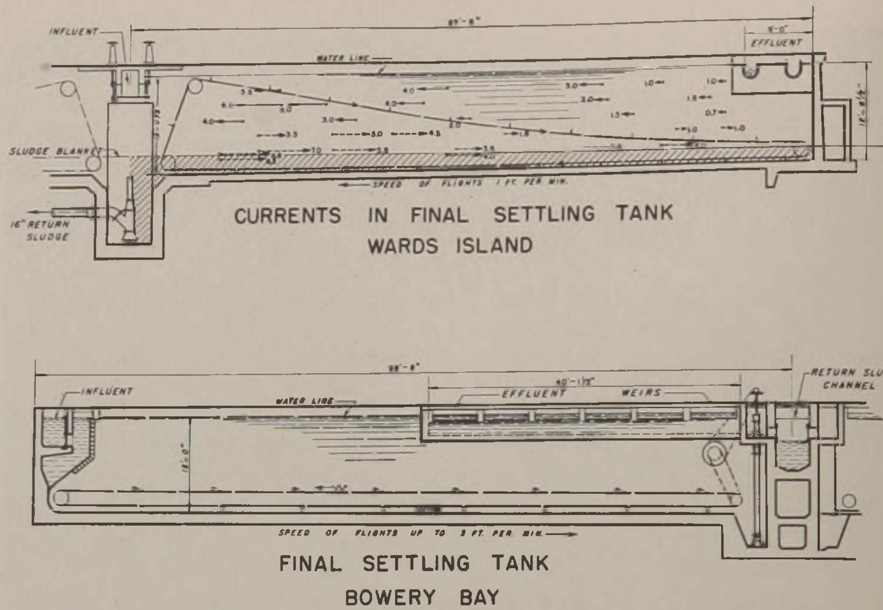
INFLUENT
WATER LINE
EFFLUENT
SLUDGE BLANKET
16" RETURN SLUDGE
SPEED OF FLIGHTS 1 FT PER MIN.
CURRENTS IN FINAL SETTLING TANK
WARDS ISLAND
INFLUENT
WATER LINE
EFFLUENT WEIRS
RETURN SLUDGE CHANNEL
SPEED OF FLIGHTS UP TO 3 FT. PER MIN.
FINAL SETTLING TANK
BOWERY BAY

FIG. 6.

Sewage Research

A CRITICAL REVIEW OF THE LITERATURE OF 1941 ON SEWAGE AND WASTE TREATMENT AND STREAM POLLUTION

By W. Rudolfs, *Chairman*, T. R. Camp, E. J. Cleary, G. P. Edwards, R. Eliassen, H. A. Faber, A. J. Fischer, H. W. Gehm, H. Heukelekian, R. W. Kehr, Ed. W. Moore, L. R. Setter, L. W. VanKleeck and S. I. Zack

Committee on Research, Federation of Sewage Works Associations

During 1941 literature published on sewage and waste treatment was apparently not greatly affected by the war. The foreign contributions reaching this country were considerably reduced. There seems to be a general impression that work in sewage and waste treatment has been decreased during the year. This impression is not substantiated by the volume of printed matter published pertaining to research, operation and development.

Again the increasing importance of industrial waste treatment is evident from the review. Brewery, distillery and yeast plant wastes, having very high potential pollution characteristics, have been under rather intensive study from various angles. In spite of the difficulties involved, considerable success is reported by different methods of treatment, although the problem does not seem to be solved. The difficulties with metal wastes treatment seems to be increasing, calling in some instances for highly specialized and complicated methods of treatment. The effect of industrial wastes on sewage treatment has again received attention. Much more information is desired from actual operation experiences as well as laboratory study.

The interest and shift to high-rate filtration has continued. The various systems which produce results between sedimentation and conventional trickling filters have been rather extensively adopted for army cantonments, camps and posts. It appears again that practice has outrun theory, while explanations and suppositions are somewhat at variance. In spite of the increase in high-rate filter systems, interest in chemical treatment is still evident.

The sludge treatment and disposal problems remain important at many plants, no matter whether the sludge is digested, dried on beds, dewatered by vacuum filtration, barged to sea for disposal or incinerated. Each method calls for further improvement with possible reduction in cost.

One of the questions in all types of sludge treatment is greater concentration. This question appears to have received more attention this year. The development in clarification of sewage by tray clarifiers is of interest. The removal of sludge (particularly activated sludge) from final settling tanks seems to be passing through a cycle. Some years ago some types of mechanically cleaned tanks were cleaned by passing the sludge to the outlet end. This resulted in disturbance and some deterioration of the effluent. Studies appear to indicate that with activated sludge the original method, possibly somewhat modified, may be better.

The health aspect of sewage treatment is again emphasized by the presence of poleomyelitis virus in sewage. The studies published are somewhat conflicting, but some recent unhappy cases may change the picture. It is possible that the virus is more resistant than coli organisms, which may modify the present requirements for disinfection. More fundamental research is required.

Considerable progress has been made in the determination of grease, but development of new and improved methods of analysis for research and operation is still needed. Further progress appears to have been made in connection with dissolved oxygen determinations. Several excellent papers have appeared on fundamental work pertaining to oxygen demand and reaeration in streams, with some work on the biology of polluted streams. Again a number of stream surveys were reported.

The annual review is again a record of progress. It is not complete, particularly with reference to foreign contributions, but the report indicates that, in spite of great upheavals, works of peace have continued and have been advanced.

Biology and Chemistry

Sewage and Disease.—In a study of the presence of typhoid bacteria in surface waters at Bandoeng (Netherlands East Indies) Shaeffer (171) found that relatively unpolluted water above the city contained no typhoid organisms. The numbers of these organisms in the surface waters within the city increased with increasing fecal pollution. Their numbers decreased rapidly thereafter so that relatively few were found 3.6 miles below the source of maximum pollution.

In a further investigation of the origin of typhoid bacteria in the sewerage system at Bandoeng, the same author (172) showed that the typhoid organisms in the sewage do not arise from the river water which is used to flush the sewers to prevent the sludge from settling in the lines. The results show that the typhoid organisms found in the sewage have their origin in the feces and urine. These organisms do not multiply in the sewage.

That poliomyelitis virus is found in sewage and surface waters was shown in further work reported by Trask and Paul (200). In spite of the occurence of the virus in contaminated waters the authors doubt that the disease is directly disseminated by water.

Paul (146) notes that the presence of infantile paralysis virus in sewage was demonstrated thirty years ago and has recently been given renewed study. Carriers of the virus are not restricted, yet one stool may provide from one to ten thousand infective virus doses for monkeys. Sewage appears to be a potential source of transmission and, while only crude experimental data are available, the virus is believed to be more resistant than *Bact. coli* organisms. Recent, but limited, studies to determine the effect of chlorine on the virus have given some extremely irregular results. In certain instances, the virus has been inactivated by 1 p.p.m. of chlorine, while in others it has survived as high as 15 p.p.m. Periodic tests of samples of sewage from the Manhattan grit chamber, New York City, disclosed the presence of active virus during the peak number of cases of this disease in the city.

Further work was reported by Kempf, Pierce and Soule (106) on the inactivating effect of chlorine compounds on the poliomyelitis virus. The present investigation was undertaken to determine the effect of hypochlorites on the virus. A solution of calcium hypochlorite in tap water containing 1.0 p.p.m. chlorine had no effect in 25 minutes. Sodium hypochlorite containing 1.5 p.p.m. of chlorine inactivated the virus in 20 minutes. In river water 0.55 p.p.m. chlorine inactivated the virus in one hour while 0.2 p.p.m. in the same substrate had no effect within the same time.

Bacterial Utilization of Waste Materials.—Gasoline, kerosene, light and heavy mineral oil and paraffin wax serve as a source of carbon and energy for the metabolism of various species of bacteria, according to Bushnell and Haas (29). Oil-bearing soil, sedimentation ponds and "water bottoms" of various petroleum storage tanks were found to be good sources for the isolation of the organisms, although non-oil-bearing habitats also yield organisms capable of destroying these products. The hydrocarbons were oxidized to carbon dioxide and water. Long-chain organic acids and unsaturated hydrocarbons were also formed. A fundamental study of microbial thermogenesis in the decomposition of plant materials was reported by Carlyle and Norman (31). They used a special adiabatic apparatus; the heat evolved in the decomposition of straw under aerobic condition was measured accurately. A temperature of 70° C. was obtained in 44 hours of incubation. The rate of temperature increase indicates two maxima, one at 40° C. and another at 60.2° C., with a low minimum intervening. It is suggested that the mesophilic population is responsible for the first maximum but as the temperature rises further, the activities of the group diminish and the rate of temperature change reaches a minimum at about 52 to 55° C. When the thermophilic population is established, a second maximum is reached at 60° C. The rate of carbon dioxide evolution is closely related to these temperature changes. The amount of decomposition is very small (less than 4 percent), only the readily available portion of the organic matter being utilized. Materials subjected to successive decomposition manifest lower rate of heat evolution. The first maximum rate of heat evolution was 3° C. per hour at 40° C. and 2° per hour at 60° C. This is attributed to the removal of the available materials by the mesophilic flora. The numbers of mesophilic and thermophilic bacteria increased greatly at the time of the most rapid heat evolution in their respective ranges. Low final counts of mesophilic organisms were obtained, indicating that the active mesophilic population is composed mainly of non-spore formers.

Methane Fermentation.—Barker (21) succeeded in obtaining a pure culture of methane bacteria: *M. omelianskii.* The organism is a non-motile thin rod which forms spores with low heat resistance. The optimum pH value for the organism is 7.0–7.2.

Mom (132) does not believe that methane arises from the direct splitting of acetic acid but agrees with the view of previous investigators that it arises from the reduction of carbon dioxide by the hydrogen liberated from alcohols acting as the hydrogen donator. He extends this theory to apply to the production of methane from organic acids as follows:—

$$8CH_3COOH + CO_2 \rightarrow 4COOH(CH_2)2COOH + CH_42H_2O + 38 \text{ K. Cal.}$$

To support the contention that in methane fermentation the organisms are adsorbed to inert particles, the author used activated carbon in the digestion of fresh solids. He concluded from the increased gas production during the period when activated carbon was added that his contention about the adsorption of bacteria on inert particles was true.

Miscellaneous.—Results of previous investigators showing lethal effect of soluble organic matter on nitrifying bacteria could not be confirmed by Bömecke (25). Although oxidation of ammonia and nitrite nitrogen may be inhibited by such organic substances, the residual respiration remains intact. In the absence of ammonia and nitrite nitrogen these organisms can utilize oxygen for the oxidation of their cellular organic substances.

Nitrate treatment of lagooned cannery waste as a means of eliminating odors was studied by Sanborn (166). From laboratory experiments it was concluded that the addition of sufficient nitrate to furnish oxygen to satisfy 50 per cent of the 5-day B.O.D. gave complete protection against offensive odors. These laboratory findings were applied to three experimental lagoons. The cost of nitrate treatment was 0.4 cent per case of pea waste and compared favorably with chemical and biological treatment with high initial investments.

Laboratory Methods and Analytical Procedures

During 1940 at least five articles have appeared on the determination of grease in sewage and sludges. Pomeroy and Wakeman (148) studied the effectiveness of different grease solvents and compared a "wet" extraction technique *vs.* "dry" extraction. The "wet" extraction technique, although tedious and time consuming may prove invaluable for certain industrial wastes. Pomeroy's results indicate that solvents such as hexane, petroleum ether, ethyl ether, iso-propyl ether, chloroform, and benzene produced insignificant differences by the wet extraction techniques.

Gehm and Trubnick (71) found eight hours of Soxhlet extraction was needed with petroleum ether extraction of dry samples. The sludge and scum samples were acidified and dried in the presence of diatomaceous earth prior to extraction. A method was reported for the determination of non-saponifiable grease.

Ludwig (117) suggested an estimation of greases by boiling the sample, followed by rapid chilling to congeal the grease on the surface. The grease in the skimmings may then be extracted by a simple wet procedure.

Okun, Hurwitz and Mohlman (140) modified and improved Ludwig's procedure by acidifying a sewage sample of one or more liters, boiling for a few minutes, cooling in the refrigerator overnight and filtering through a cotton mat over filter paper, supported on a perforated dish or funnel, with suction. The mat containing the residue was dried at 103° C., transferred to a Soxhlet extraction apparatus, and extracted with petroleum ether for several hours. The extracted grease was dried at 103° C. for 15 min. and weighed. In some cases extraction of the filtrate is recommended.

Gehm (69) concentrated the grease in four liters of sewage by alum-lime coagulation and filtration through a blanket of filter-aid paper on a Büchner funnel. The residue and filter mat were transferred to a porcelain dish, acidified and dried prior to applying a "dry" extraction procedure.

The status of grease determinations indicates that:

(*a*) The most satisfactory solvent appears to be petroleum ether or hexane. Chloroform should not be used because non-lipoidal substances may be extracted and a constant boiling point solvent is needed if the extractor is close to the boiling solvent.

(*b*) The extraction is probably more convenient and complete on pre-dried samples. Short time drying with a minimum of moisture to be evaporated is advisable to minimize loss of volatile fats in sewage and industrial wastes.

(*c*) The dewatering of either sludge or sewage sample and the conversion of salts to fatty acids may be accomplished by acidifying to pH 3 to 4 with HCl, heating, chilling, and filtering with suction through cotton-paper filter mat. Filtering and extracting periods will be shortened by adding a porous base, such as asbestos, equal to 2 to 10 times the weight of dry solids in the sample. The porous base should be added in a dry state to the chilled sample with gentle stirring just prior to filtering.

(*d*) The dewatered sample and filter mats should be dried for 30 to 60 minutes at 103° C. before transfer to an extraction thimble.

(*e*) A four to six-hour extraction period with petroleum ether or hexane in a Soxhlet apparatus is sufficient, provided the sample is mixed with a porous base before drying. The time of extracting should be doubled or trebled for activated sludge or primary sludge samples extracted without the porous base. The use of filter aids as a porous base may require more study.

(*f*) The extracted grease may be conveniently dried for a short time (30 min.) at 103° C. in a tared weighing bottle or an Erlynmeyer flask before cooling and weighing.

In the final analysis, the standardization of the grease technique is relatively simple compared to the great difficulty in obtaining representative sewage samples from treatment plants for control studies. The ease with which greases become separated even in fairly turbulent flow calls for special care in sampling.

In a study of the sampling technique and schedules of 50 sewage treatment plants, Hagerty (77) concludes that the data from no two plants can be compared because of variation in methods of sampling. Gross errors in plant control data can frequently be minimized by employing the simple but effective sampling buckets used at Aurora (11).

A useful nomograph for converting p.p.m. dissolved oxygen to percentage oxygen in air saturated water at various temperatures and salinities is presented by Hatfield (81).

Jansa and Akerlindh (99) have modified the deoxygenation-reaeration formulae for polluted streams to include the oxygen consumed by sludge deposits.

Cohen and Ruchoft (40) found sulfamic acid was equal to azide for eliminating nitrite interference in the Winkler dissolved oxygen test. The authors found that the addition of a reagent containing 4 per cent sulfamic acid in 20 per cent sulfuric acid was also a good preservative for field samples. The Winkler reagents and final titration could thus be delayed several hours with convenience.

The sulfamic acid preservative might well replace copper sulfate as a preservative and coagulant in the activated sludge D.O. technique according to Ruchhoft (158).

Ingols (97) reports a potentiometric determination of dissolved oxygen with a dropping mercury electrode. An instrument company is marketing a standard electrical unit based on this study, but no tests of its reliability have been reported in the literature.

Viehl (210) has shown that within the range of normal atmospheric saturation, the higher dissolved oxygen values give higher B.O.D. results. However, errors in the B.O.D. test due to the variable oxygen tension by the standard dilution method are not serious.

The cooperative study of B.O.D. dilution waters by many laboratories (159) indicates that, except for some nitrogen-deficient industrial wastes or streams polluted therefrom, the B.O.D. results are not significantly different for each of the three dilution waters studied. The advantage of one water over another seems to be in its keeping qualities and more universal use. The pH of ammonia-fortified Formula C water is independent of the age. This is a distinct advantage at laboratories where only a few samples are tested. Furthermore, the nitrogen-fortified mineralized phosphate water is particularly desirable for nitrogen-deficient industrial wastes, so that it is a more general purpose water. There may be some advantage from the standpoint of convenience to eliminate the iron solution and combine all minerals to make not more than two stable stock solutions.

Pomeroy (147) presents an improved technique on the determination of total sulfides in sewage and a conversion table of total sulfides to hydrogen sulfide, depending on the pH and salinity of the sewage.

A cold oxygen consumed method (62) utilizing alkaline KI and $Na_2S_2O_4$ is reported comparable to the hot $KMnO_4$ test.

A new method for determining the stability of polluted water by means of potassium ferricyanide was reported by Watanabe (214). The method is based on the utilization of potassium ferricyanide as an oxidizing agent. The ferricyanide is converted into ferrocyanide which is precipitated by the addition of zinc sulfate. The excess ferricyanide is determined iodimetrically.

The successful use of an automatic pH recording instrument for the control of chemical conditioning prior to sludge filtration is reported (22).

Dickinson (46) adds a solution of methylene blue to activated sludge in a 50-ml. cylinder. After ½ hour standing, a well regenerated sludge remains blue, whereas the dye is decolorized by an imperfectly regenerated sludge.

The oxidation-reduction potential gives a better index of the germicidal effect of chlorine in water containing organic matter than either the orthotolidine or starch iodide residual tests according to Mallman and Ardrey (121). Improvement in the maintenance of potentiometric recording instruments should thus improve disinfection control and chemical costs.

The comprehensive presentation of an inexpensive photoelectric photometer is of particular interest. Hatfield and Phillips (82) found the instrument well adapted to the colorimetric determination of a variety of sewage tests which are otherwise normally subject to considerable personal error.

Sedimentation

An interesting development during the past year was the construction of tray clarifiers for primary sedimentation at Springfield, Missouri. Frei (67) reports that two old 50-ft. square rectangular-flow tanks were converted to tray clarifiers by building circular steel radial-flow tanks, with three trays within each tank. The effective area was increased from 2500 to 7600 sq. ft. per tank, the new area including the bottom at about 2500 and three trays at 1722 sq. ft. each. The effective volume and detention periods were reduced.

These tanks formerly effected an average reduction of 41.2 per cent of the suspended solids with a flow of 3.5 m.g.d. The detention period was about 2 hours and the overflow rate was about 700 gal. per sq. ft. per 24 hr. The new tanks are operated at a rate of nearly 10 m.g.d., about half of which is sludge returned from intermediate and final clarifiers following trickling filters. The new detention time is 33 minutes and the overflow rate is 725 gal. per sq. ft. per 24 hr. The removal of suspended solids is reported to be 61 percent.

The large increase in percentage removal is doubtless due to the flocculating effect of the returned sludge and the correspondingly higher solids content in the influent. It is pertinent to note, however, that if the influent should contain only the raw sewage, the per cent removal should be about the same as before, if removal is determined entirely by overflow rate and it should be considerably less than in the old plant if removal is determined entirely by detention period. Despite the confusion due to the presence of the returned sludge, the test results at Springfield seem to confirm for flocculent suspensions what is known to be true for discrete suspensions; namely, that overflow rate is far more important than detention period in determining removal. Excellent facilities are available at Springfield for full-scale fundamental research on this aspect of sedimentation.

Experimental work (35) on the circular radial-flow final settling tanks at the Chicago Southwest activated sludge plant has shown that the influent currents are deflected downward by the center well baffle to the bottom. The flow is then outward just above the sludge blanket to the outer wall of the tank where high currents turn upward and carry clouds of sludge up into the area from which the final effluent is drawn. These findings agree with the results of model studies made by Hubbell (94) in 1936 on this type of settling tank. Efforts to remodel the inlets of the tanks at the Southwest plant have shown little effect on the flow pattern. A change in the method of withdrawing the effluent by the construction of two concentric additional weir troughs has proved effective in improving the effluent. The weirs are so set that a very small amount of effluent is withdrawn from the original weir at the tank periphery, a greater amount from the new trough nearest the outer wall and a still greater amount from the inside trough.

Thatcher (197) has pointed out the advantages of a single scraper blade type of (Mieder) of sludge scraping mechanism. The importance of frequent removal of sludge from the tank is shown by the effect of storing the sludge for a fortnight as against daily removal on increasing the B.O.D. in the effluent from 35 to 99 p.p.m.

Further progress has been made in adapting the turbulent-flow theory of Prandtl and von Karman to sediment transportation in open channels. Vanoni (207) has shown experimentally that the logarithmic velocity distribution predicted by the theory obtains in open channels, and that the distribution of suspended sediment conforms to the theory. Dobbins (47) has shown experimentally that the retarding effect of turbulence in the settling of discrete particles is accounted for by the theory, and that the amount of material held in suspension is determined by the conditions of scour at the bed.

Studies on factors influencing settling and thickening of aqueous suspensions of calcium carbonate, barium sulfate and silica were reported by Kammermeyer (102). The effect of stirring and the initial weight concentration of the suspension were determined.

Chemical Treatment and Flocculation

In a review covering developments in sewage treatment, Rudolfs (162) points out that we have stabilized on design and that we have reliable data on which to predict cost and performance of chemical treatment units.

A report on the operation of the chemical-mechanical plant at Minneapolis-St. Paul (Minn.) was presented by Schroepfer (168), covering a period of two years. The plant, designed to treat 134 m.g.d., is described and the requirements which it was designed to meet discussed. Most of the data presented deal with operation of the plant without chemical treatment and data are given on sludge handling. Some trials were made using ferric sulfate for coagulation, covering several days. During this time, half the plant was run as a plain settling unit and in the other half chemical treatment was employed. Twelve p.p.m. of iron increased the percentage suspended solids removal to 83 as compared to 73 for plain settling and the B.O.D. (5-day) removal from 35 per cent for plain settling to 55 per cent. The effluent filters were not in use during these tests.

In discussing this paper Roberts (156) included a somewhat detailed description of the Scott-Darcey process as applied in Arizona. He pointed out the purposes for which it is used and the features of chemical treatment of all types including chlorination.

The Ohio State Department of Health (139) ran a series of tests at the Wilmington and Lebanon, Ohio, plants to determine if claims that the Lewis Process is superior to ordinary methods of chemical treatment were valid. These towns were chosen due to existing similarities as to their sewage systems. Lebanon, employing the Lewis process, removed an average of 84 per cent of the suspended solids and 53 per cent of the B.O.D. at an operating cost of $3.41 per capita per year. At the Wilmington plant, suspended solids removals averaged 93 per cent and B.O.D. removals 74 per cent, employing an unpatented process. Operating cost per capita per year was calculated to be $1.62. The difficulty of drawing final conclusions from data collected in this manner is pointed out by the writers and they are inclined to discuss features of operation at each plant and to let the reader draw his own conclusions regarding the relative merit of the two processes.

Cost comparisons for different chemicals and combinations thereof based on experience at Waukegan and Chicago, Ill., were presented by Hurwitz (96). He found that ferric chloride and lime was the most expensive type of treatment and copperas and sodium silicate were the least costly. Alum alone, alum and sodium silicate, ferric chloride alone, and chlorinated copperas fell in between these two methods in cost. In interpreting these figures, the low price at which some of these chemicals are purchased at Chicago must be borne in mind. However, tables showing chemical dosages are presented so that cost calculations can be made for any price scale.

The use of carbon dioxide in the chemical treatment of sewage at Ridgewood, N. J., is described in detail by Hood (90). Here the digester gases are burned as a source of the gas; the heat produced is used to promote drying of sludge in enclosed beds. The alkalinity and pH of the sewage are reduced considerably by diffusion of the gas through the sewage prior to addition of alum. By reducing the pH value to 6.5 it was found that a considerable saving in alum resulted, excellent clarification was obtained, laundry wastes present in the sewage no longer offered a problem, flotation of sludge in the clarifier did not occur, and digester troubles due to former high alum dosages disappeared.

Operation of the Hasbrouck Heights, N. J., plant, employing chemical treatment with alum prior to slow sand filters is described by Milani (128). Snyder (183) describes the Massillon, Ohio, sewage treatment plant built to treat a maximum flow of 7.3 m.g.d. The chemical treatment unit consists of flash mixer, flocculator and chemical feed and control equipment.

The experiments on treatment of sewage high in greasy textile wastes at Halifax, England, were continued by Lumb and Barnes (118). Their laboratory work showed that precipitation of this sewage could be more economically accomplished by a combination of sulfuric acid and alumino-ferric than by acid alone. Plant-scale trials confirmed in general the laboratory findings.

Operation at Wakefield, England, was described by Artist (17). Here a sewage high in trade waste is pre-treated by dropping blocks of alumino-ferric in the influent channel. After settling the sewage is treated by the activated sludge process.

At the West Side Works at Chicago (35) experiments were made in treating Imhoff tank effluent by the Guggenheim Process. Results are not given. Here ferric sulfate was generated by passing air containing sulfur dioxide through copperas solution.

The work of Weiser, Milligan and Purcell (216) on alumina floc is of interest in that through such investigations more will become known about the mechanism of coagulation as applied to sewage treatment. Their studies are concerned with the character and composition of the aluminum sols formed from alum and other aluminum salts which they determine by various means including X-ray diffraction patterns. To date they believe that the precipitate formed under conditions most generally found in sewage treatment consists mainly of γ–$Al_2O_3 . H_2O$ and not basic sulfates. Those formed at pH values below 4.0 are of similar composition while the sols prepared at 5.5 show X-ray patterns which do not correspond to the others. Further study of this sol led them to believe that it is the basic sulfate $Al_2O_3 . SO_3 . 1.5H_2O$.

It is well known that at pH values around 5.5 alum is most effective in coagulating sewage. That basic sulfochlorides of aluminum are excellent coagulants has been demonstrated. One would conclude from these observations that the most effective clarification occurs during the formation of a basic sulfate rather than the precipitation of hydrated Al_2O_3.

Proteins were found to have a profound effect on sewage coagulation by Gehm (70). Additions of as little as 2 p.p.m. of gelatine produced a large ball-like floc which settled even during agitation and reduced the quantity of coagulant required considerably. A number of proteins were tried in conjunction with various coagulants. Gelatin was found to be the best and could be incorporated with ferric or aluminum chloride to give a compound which would produce the desired results. The efficiency of such compounds in treating sewage and the factors affecting their activity were investigated.

Gehm (68) conducted tests on the use of inert materials in conjunction with coagulants for sewage treatment. Flue dust, spent tan bark, iron oxide, sludge ash, activated carbon, bleaching clay, bentonite and diatomaceous earth were used in varying proportions. It was concluded that such materials are of little general value and while they may aid floc formation and sludge compacting, very large quantities are required. Digested sludge ash gave about the best results of any of the materials tried. Another coagulant known as Magno-iron-sol, consisting of a dry mixture of iron hydroxide, calcium and magnesium chlorides, was patented by Börner (26).

Patents. Three patents of interest involving chemical treatment were issued during 1941. Brownell and Woodham (27) claim that sewage of high colloid content can be clarified by releasing ozone within the liquid, thus exposing its surface to ozonized air. Another patent granted to Urbain and Stemen (204) involves the addition to sewage of fine magnetite, which becomes enmeshed in a floc formed by subsequent addition of a coagulant. Sedimentation of the floc is expected to be accelerated by electro-magnets whose attraction for the magnetite draws the floc particles to their surface thus separating them from the liquor.

Samuel (165) patented a flocculating agent composed of calcium sulfate and ferric chloride and/or aluminum chloride.

Mechanical Flocculation

Heukelekian (85) reviewed in detail the literature on flocculation without chemicals and similar processes. A valuable recapitulation of the connotations of the various terms which have been associated with flocculation is included, which serves to dispel confusion regarding this and related processes. Stirring and aeration are considered means of increasing the internal surface, thus promoting greater coalescence of suspended matter.

Paddle-wheel stirring was studied by Nichols (137) and valuable information regarding it was obtained. Although this work involved water treatment, the same principles apply in sewage. He concluded that the formation of vortices was important in the mixing process and that the design of a paddle that would cause the formation of the greatest number of these was desirable. Design suggestions are included which approach the production of optimum conditions and prevent short circuiting in flocculations. Tapered mixing is also discussed and is considered with favor, as the author believes it prevents floc masses from building too rapidly and thus excluding some particles from the agglomerates.

Trickling Filters

Army posts and defense plants witnessed the major activity in the construction of trickling filter plants in the United States during 1941. The majority of these plants have been of the high-rate type employing stage filtration and recirculation of filter effluent. (4) The acceptable bases of design of trickling filter plants for army camps have been outlined by consulting engineers for the Army (7).

Theory. Butterfield and Wattie (30) isolated in pure culture the predominant bacteria found in the growth on the stones of experimental and municipal trickling filters. These bacteria were present to the extent of 300,000,000 per ml. of filter growth. The isolated organisms were zoogleal in nature and were found to be similar to the predominant bacteria in activated sludge. When the pure-culture bacteria were applied to an experimental trickling filter unit, the growth on the stones was similar in appearance and in purification properties to the growth found on the normal trickling filters. The predominant bacteria of activated sludge in pure culture were shown to have the same ability to produce adherent growth on the stones of a filter which in growth appearance and in purifying powers simulated a normal trickling filter. It was also demonstrated that the bacteria isolated as the predominant organisms in a trickling filter would in pure culture produce a floc of the same general appearance as activated sludge. These bacteria were found to have the ability to grow in a liquid medium in a mass colony, bunching themselves together tenaciously to remain intact under the agitation of the aeration required to keep the solids suspended and to maintain aerobic conditions. This pure-culture activated sludge removed about 76 per cent of the 5-day B.O.D. of a polluted water during a 5-hour aeration period. Furthermore, it was found that a mixture of nine pure cultures of these zoogleal bacteria, in both trickling filter and activated sludge units, was more effective than any one strain in pure culture. The extent of purification brought about by such a mixture was equivalent to that produced by a trickling filter or by an activated sludge containing all of the flora and fauna of normal sewage. These results indicated that the members of the zoogleal bacteria isolated are the active agents in purification by biological processes and suggest that the maintenance of conditions favoring their growth would expedite such purification procedures.

Conventional Filters.—Construction of plants utilizing conventional filters of dosing rates from 2 to 4 m.g.a.d. has been reported by a number of authors. Kozma (109) reports on the new plant at Rutherford, N. J., which utilizes chemical precipitation prior to trickling filters, for the treatment of combined domestic and industrial wastes. These wastes are from textile, dyeing, paper, laundry, plating, ink, and other chemicals. The strong waste is dosed at the rate of 4.5 m.g.a.d. on four filters in a plant designed for a capacity of 4 m.g.d. Wolman and Fletcher (228) mention the various degrees of treatment utilized at Atlantic, Iowa, for the treatment of domestic waste by single or double filtration during most of the year, and the utilization of chemical precipitation during three months when corn, squash, and cannery wastes, with B.O.D. load equivalent to the population of the town, are discharged.

Citrus-cannery wastes were found to be amenable to treatment by means of trickling filters dosed at a rate of 1.5 m.g.a.d. Experimental work carried out by the Bureau of Agricultural Chemistry and Engineering at the U. S. Citrus Products Station in Florida has been reported by Von Loesecke, *et al.* (211). A trickling filter apparatus was used, with rock ranging in size from 1.0 to 3.0 inches. The biological film on the rock was built by adding dried skim-milk powder and cow dung. Later, orange and grapefruit juices were sprinkled on the bed. A satisfactory formation and growth were established in from two to three weeks. With a raw waste having a B.O.D. of about 900 p.p.m., an effluent of 100 p.p.m. B.O.D. was obtained, using two hours detention in a settling tank following the filter.

The tentative waste disposal code of the Michigan Stream Control Commission has been reported by Adams (1). The code recommends that treatment by trickling filters be given to wastes from milk-products plants, phenolic wastes, and certain types of cannery wastes.

A unique treatment plant combining the treatment of packing with domestic sewage is described by Hurst (95). Packinghouse wastes comprises half of the total sewage flow entering the plant at Tifton, Ga., and created a severe problem as the B.O.D. of the waste averaged 1000 p.p.m. The packinghouse waste is treated separately by primary clarification, aeration, secondary clarification, followed by trickling filters. Then it proceeds to the mixing well where it joins the raw sewage from the city. A combined flow is treated in a standard trickling filter plant, with primary and secondary clarifiers. The plant effluent averaged 30 p.p.m. suspended solids and 22 p.p.m. B.O.D.

Complete operating results for an entire year are presented by Sperry (30). Detailed data on the operation of the Aurora, Ill., trickling filter plant, including quantities of removals in various units of the plant, typical analyses, and operating costs will be of interest to plant operators. Similar results are presented by Brooks on the operation of the trickling filter plant at Worcester, Mass. (28).

Alternating Filters. The Water Pollution Research Board of England has been carrying out research on alternating operation of trickling filters, which was reported by Wishart and Wilkinson (226) at the annual summer conference at Manchester, England. Four filters were constructed (131), each 115 ft. in diameter and 6 ft. deep. The media for the filters ranged from 1 to 2½ inches in diameter. The filters were followed by settling tanks which provided seven hours detention when the filters were dosed at the rate of 1.16 m.g.a.d. One filter was operated as a single unit and the other two filters were operated as a pair in series. Every seven days these latter filters were alternated as primary and secondary filters. Results are presented to show that the two filters in series were able to treat twice as much settled sewage per cubic yard as the single filter and could produce a better effluent. When the filters were reversed each week, the B.O.D. of the primary filter effluent became progressively less, whereas that of the secondary filter increased during the latter half of the week. For one or two days after removal of the filters, there was no change in the appearance of the surface, but during the remainder of the week, the growth on the surface of the secondary filter rapidly disappeared. Meanwhile, the growth thickened on the primary filter. The two filters in series discharged humus constantly, whereas the single stage filter unloaded in the spring. The alternating filters were cleaner at the end of the test than at the beginning. In order to study the effect of more frequent alternation of filters, as well as other operating variables, eight smaller filters have been built to continue this study. The B.O.D. of the settled sewage applied to the filters averaged 160 p.p.m. while the effluent from the single-stage filter averaged 15 p.p.m. and from the two-stage filters slightly lower in B.O.D. The single-stage filters were dosed at a rate of approximately 0.7 m.g.a.d. (U. S. gallons). The two-stage units were dosed at rates from 1.0 to 1.9 m.g.a.d. on the basis of two filters or an actual dosing rate of twice this on each filter.

Tomlinson (199) reports on the biological aspects of the investigations. *Fusarium* and *Sepedonium* were found to be the predominant fungi, and they constituted a large part of the thick mat of growth on the surface of the single-stage filter and the primary unit of the two-stage system. There was considerable ponding on the single-stage filter from September to May, but any incipient ponding on either of the two filters in series quickly disappeared when the order was reversed. The disintegration of film was ascribed primarily to biological changes induced by the secondary effluent, inasmuch as treatment with distilled water in the laboratory did not loosen the film. No data were available on the relative merits of the filters as to fly nuisance. *Psychoda* emerged in greater numbers from the secondary than from the primary filter. The author concluded that the alternation of filters tends to repress to vigorous biological growth, which repression is desirable.

Reynoldson (153) studied the macroorganisms of the experimental high-rate filters at Huddersfield, England. The plant consisted of a double filtration system, the primary bed being run at 9 to 10 m.g.a.d., the secondary at the rate of 2 to 3 m.g.a.d., with intermediate sedimentation. The sewage contained large quantities of industrial waste and was very strong. On both the primary and secondary beds *Psychoda alternata* was the dominant species. The number of types of macroorganisms colonizing the secondary bed was higher than in the primary bed. The *Psychoda* larvae were more abundant at greater depths in the primary than in the secondary bed, due to clogging and septic conditions of the primary bed surface. The author doubts that the high rate of flow of sewage had an important effect on the vertical distribution of larvae, since on occasion, when bed conditions were favorable, the larvae moved into the upper layers. The fly output of the primary bed was lower than that of the secondary. As the rate of accumulation of sludge and film in the bed exceeds the rate at which they can be dislodged by the larvae, toxic conditions may be created for the organisms, which conditions in turn aggravate ponding. The author doubts that the discharge of growths and sludge deposits from the high-rate filter beds can be due to the flushing action of the high flow. The double filtration system can be effective in fly control, provided care is taken to control the rate of flow in the primary bed in such a way that it is high enough to be unfavorable to *Psychoda*, but still remains open. In the secondary bed the scarcity of food will control the fly problem.

Mohlman (131) discusses the significance of these results and compares them with American practice, pointing out that the B.O.D. applied at the maximum rate is only 2500 lb. per acre or 417 lb. per acre foot, per 24 hr., as compared with loadings from 2000 to 4000 lb. per acre foot per day customary in American high-rate filters. Mohlman points out that the experiments should not be considered as high-rate filtration, but rather as a procedure for obtaining higher loadings on standard filters, with very little, if any, sacrifice of quality of effluent.

Further studies by Wishart and Wilkinson (226) show the variations in temperature of sewage passing through filters during the different seasons of the year. Measurements were made with a thermograph of the temperature of the sewage on the surface and at depths of 8 inches, 3 and 9 feet below the surface, in single-filtration trickling filters. The data showed that during the year the temperature of the effluent was lower than the temperature of the settled sewage, except during the hot weather in August and September, when the temperatures were about the same. Of considerable interest is the fact that the temperature near the surface was always lower than the temperature in the interior of the bed. In colder weather the temperature of the settled sewage was slightly higher than the temperature in the interior of the filter, while in spring and fall it was about the same. During hot weather the temperature in the interior was appreciably higher than the temperature of the settled sewage. The question is brought up whether heat is produced by biological activities sufficient to cause an increase in temperature of the liquid.

High-Rate Filters.—A symposium on high-rate filtration was conducted at the Spring Meeting of the New York State Sewage Works Association at Niagara Falls. The discussions sought to clarify the salient factors of each specific type of high-rate filtration used in modern sewage treatment plants. Bachmann (19) reports on the Biofiltration System and presents many results and design factors on the basis of past experience at various plants throughout the country. The various flow sheets which come within the scope of the Jenks Biofiltration System patents are presented and virtues of each described. Essentially the process involves the return of filter effluent to mix with the incoming raw sewage to dilute this and furnish the proper bacteria for accomplishing some degree of treatment in the primary clarifiers. The advantages of passing sewage through the filter bed more than once by the methods of recirculation are also brought out. Further characteristics of Biofiltration include the following: The use of dosing rates on the filter in excess of 800 gal. per cu. yd. of filter medium per 24 hours; clarification of the filter effluent in either the detention tank preceding the filter or in a separate clarifier; recirculation of filter effluent, final clarifier overflow, or final clarifier underflow back to the new incoming feed; the use of filter beds having stone depth as shallow as three feet; the use of two-stage treatment where very strong sewage is encountered, or where a high degree of treatment is desired; high filter loadings based on raw sewage; and substantially continuous filter dosing.

Montgomery (133) reports on the system of high-rate filtration known as Aerofilters. He cites the experiments of Halvorson and the discovery that purification could be achieved more effectively if sewage were distributed over the rock in a very thin film, and that high capacities could be handled if this film were kept flowing continuously over the surfaces of the rock in all sections of the bed. Even with high capacities, if the sewage is distributed evenly over the bed at all times, the amount which strikes any square foot of area during any second of time is very small. The author distinguishes between the term "capacity" to designate the total daily flow of sewage in gallons per acre, and the term "rate of application" to designate the amount of sewage applied per square foot momentarily or during a second of time. Filters may then be discussed and compared in two respects, that of total daily raw sewage flow, and that of the methods used for distribution and the rates at which the sewage falls on various sections of the filter bed. The distinctive features of the Aero-filter are the use of artificial ventilation by means of fans during certain seasons of the year when conditions are unfavorable for sufficient natural ventilation; the use of 8 ft. of rock depth; and special mechanisms to secure uniform distribution of sewage over the filter beds. These mechanisms are of two distinct types, the first type being known as a disc distributor and used for filters 34 ft. or less in diamter. The disc distributor gives continual, complete, and approximately uniform coverage, approaching ideal distribution. For a larger filter it is necessary to utilize multiple-arm distributors operating from two to three r.p.m. Each arm is equipped with a number of branches at the outer end to secure a more uniform distribution. Experiments have shown that approximately 20 per cent momentary coverage of the bed is achieved by the centrifugal type of nozzles used. When rotating at 4 r.p.m., 32 contacts per minute are given on any radius using a 4-arm distributor with 8 branches. Many operating results are presented to indicate the efficiency of treatment to be expected using various flow sheets in conjunction with this type of filter.

The characteristics of the Accelo-filter are discussed by Gillard (73). Unlike the Biofiltration System, this method does not recirculate filter effluent back to the primary clarifier, but rather recirculates it directly back to the filter, or may recirculate secondary clarifier effluent or sludge back to the filter. Dosing rates are maintained at approximately 10 m.g.a.d. with approximately 100 per cent recirculation. Higher organic loads may be provided for by increasing the recirculation rate, keeping the actual filter dosage rate at about 20 m.g.a.d. to assure adequate flushing. The patented feature of this system is the method of direct recirculation of filter effluent. The author limits the speed of the 2-arm distributor to 2 r.p.m. and the 4-arm distributor to 1.4 r.p.m., undoubtedly to avoid infringement of other patents, as no advantages are claimed for this slow speed. No operating data are presented, although two charts showing B.O.D. removals versus dosing rate are shown, with no supporting data to indicate the derivation of these results. The article would indicate that only two plants of this type have been installed.

The application of high-rate filters to the treatment of sewage from Army camps has been reported by Eliassen (53), who pointed out that a two-stage Biofiltration System installed will permit great flexibility of operation so that the plant may be utilized for single-stage complete treatment or single-stage intermediate treatment, or even only primary treatment. By taking into account the fact that the dilution afforded the sewage treatment plant effluent in the receiving stream will vary with the amount of rainfall over the seasons, it is possible to select the flow-sheet which will give the desired quality of effluent. Graphs are presented to indicate the relationship between power consumption and sewage flow for various degrees of treatment, since at an Army camp the quantity of sewage treated will vary considerably, depending upon the population changes which are continually taking place. Further, the higher the permissible B.O.D. of the river below the treatment plant, the less the treatment required, and the lower the power costs. Tables and graphs are presented to illustrate this relationship. The author endeavors to emphasize the economy which can be achieved by varying the degree of treatment to meet stream requirements and correlates this with the fact that the Biofiltration System lends itself to such flexibility of operation that these economies can readily be achieved.

A further illustration of flexibility in plant operation is brought out by the Currie Engineering Company, (42). Two high-capacity filters of the aerofilter type are dosed at the rate of 15 m.g.a.d. When the sewage flow was not sufficient to maintain this dosing rate, secondary clarifier effluent is returned to the filter to make up the difference. At flows above 500 g.p.m., corresponding to a filter load of 25 m.g.a.d., the operation is changed from series to parallel in order not to flood the filter. Results are presented to show reductions in B.O.D. of approximately 93 per cent on the basis of sewage having a strength of 300 p.p.m. The unique feature of this trickling filter plant is the electrical control equipment. Automatic switches turn on the pumps in accordance with the sewage flow. Above 500 g.p.m. the relays and switches not only turn on an additional pump, but also operate the valves that effect the change from series to parallel operation.

Many industrial wastes have proved themselves amenable to treatment by high-rate trickling filters. Experimental work continues in this interesting and vital phase of sanitary engineering. Black and Klassen (24) report on the use of high-capacity filter for treating wastes from a yeast plant at Crystal Lake, Illinois. The receiving stream has a flow of only 250,000 g.p.d. of treated sewage from the municipal plant and 180,000 g.p.d. of cooling water from the yeast factory. The combined wastes amount to 150,000 g.p.d., exclusive of cooling water. They have a 5-day B.O.D. approximating 4500 p.p.m., with total solids averaging 9000 p.p.m., of which 75 per cent is volatile. The suspended solids amount to only 200 p.p.m. The waste treatment plant comprises a lagoon, high-capacity filter, final clarifier, and auxiliary equipment. The process wastes flow by gravity into the lagoon, which has an estimated capacity of 40,000,000 gallons. The waste in the lagoon serves as a buffer and also to dilute the incoming concentrated wastes. From the lagoon, waste is pumped continuously into the high-rate filter at a dosing rate of 24 m.g.a.d. It has been found that the filter will remove 2.7 lb. of B.O.D. per cu. yd. of rock during the summer months, giving a reduction of 70 per cent for applied wastes concentrations between 200 and 250 p.p.m. The filter is 7 ft. deep and 62 ft. in diameter, with rock from 2 to 3 inches in size. Distribution is accomplished by means of a reaction-type, multiple-arm rotary distributor. Provision is made for forced ventilation of air at times when the difference in temperature between the wastes and the surrounding atmosphere is not great enough to cause adequate ventilation. The filter is covered to minimize odors and to prevent freezing.

Distillery wastes have been successfully treated by high-rate filters, as reported by Fischer (63); with waste having a B.O.D. of 18,000 p.p.m., removals of 16 lb. per cu. yd. per day have been obtained. No data are presented on the percentage reduction of B.O.D. or the dosing rate necessary to accomplish this result. Eldridge (52) reports on the conversion of a standard milk-waste trickling filter to a high-rate filter using recirculation. The changes necessitated the installation of a higher capacity pump and a new rotary distributor. With the old filter, B.O.D. reductions of 76 per cent were accomplished, using a dosing rate of from 1 to 2 m.g.a.d. and a loading of 83 cu. ft./lb. (0.3 lb./cu. yd.). With the renovated plant using a rate of application of 20 m.g.a.d., removals of 90 per cent were accomplished on the basis of the raw waste having a B.O.D. of 537 p.p.m. The loading on this filter was approximately 1 lb./cu. yd./day. The author predicts that further renovations and new plants of this type will be constructed for the treatment of similar wastes in the near future, on account of the excellent results obtained from the plants now installed. Eldridge (51) summarizes the use of the recirculating high-rate filter in industrial waste treatment in another article and points out its application to various types of wastes which contain dissolved organic matter difficult to remove by other methods. In commenting on these results, the author states that the recirculating filter provides a simple, efficient, economical, and comparatively flexible method for the treatment of many organic industrial wastes. The cost of construction of this type of filter is about one-third that of the standard filter, due to the increased load which may be applied for the same degree of treatment. This increased load is made possible largely by recirculation of the filter effluent. A further study of this method of treatment may result in the variation of the design loading to meet desired effluent concentrations. Studies of this type are being conducted in the Biofiltration Pilot Plant at New York University, as reported by Eliassen (54). This plant is designed for flexibility in loading and operation in an attempt to evaluate some of the factors brought out in the discussion by Fischer (64) of the various flow sheets which may be used with the high-rate trickling filter. This past year has seen an accumulation of more data on this type of treatment plant and the continuation of research work in this field.

Activated Sludge

Theory.—Watanabe (213) in his biochemical studies found that the optimum pH for the decomposition of many carbohydrates by activated sludge was 7.0 but glycogen and starch were destroyed more efficiently at 8.2. Glucose, glycogen and starch were almost completely removed by activated sludge in eight hours. Xylose was only slightly decomposed.

Nitrogenous compounds were decomposed most completely between pH 6.3 and 7.3. The destruction of vegetable oil was considerably slower than was the decomposition of other organic material. As the optimum pH for hydrolytic enzymes is about 6.5, and the pH of the sludge mixture is about 7.0 to 7.4, enzymes of activated sludge do not act at their optimum pH value. Tests made with carbohydrates, organic acids, dyes and iodine indicate that activated sludge has a marked adsorption capacity. Adsorption and biological activity are interdependent. Watanabe made an analysis of the ash constituents of activated sludge and reported quantitative data on thirteen positive elements. He believes that small concentrations of some of these are important in the activated sludge process.

Viehl (210) operated four tanks under identical conditions except for the rate of air application. He concluded that too little or too much air is injurious and that maintenance of 1.5 p.p.m. of dissolved oxygen in the aeration tank is sufficient.

The operating fundamentals have been restated by Haseltine (79) who believes that the problem is to regulate the rate of biological oxidation so that it just keeps pace with adsorption during the aeration period. Oxidation progresses more rapidly than adsorption with over-aeration, too long aeration and lack of sufficient food. Oxidation lags behind adsorption (*a*) with an inadequate supply of oxygen, (*b*) with septic sewage or sludge, (*c*) with excessive grease content of the sludge, (*d*) with an inadequate detention period, (*e*) in the presence of germicidal wastes and (*f*) in the presence of excessive carbon dioxide. Haseltine emphasizes the importance of prompt sludge recirculation in maintaining the activity of the sludge.

Mallory (122) believes that the principal controlling factor in the operation of the activated sludge process is the relationship between the effective period of aeration and the effective period of sedimentation. The multitude of physical and chemical reactions respond to this relationship. He states that the relationship between the concentration of suspended solids maintained in the aeration tank and the concentration of suspended solids in the return sludge represent, under optimum conditions, a definite relationship to the aeration–sedimentation ratio. These factors have been combined in an "equilibrium index" which has an optimum value of 100. Values greater than 100 show a safety factor and those less than 100 are unsatisfactory. Simple tests with a centrifuge and a blanket finder are sufficient for control.

Lumb (119) concluded from a thirteen months laboratory experimental work on the suspended solids balance of activated sludge that the oxidation of the suspended solids of the sewage was negligible. The solids balance was based on the suspended and colloidal matter in the sewage fed and no account was taken of the dissolved matter which is also removed by the activated sludge process.

Sludge Bulking.—Ruchhoft and Kachmar (160) carried on experiments which indicated that bulking was a response of sludge organisms, such as zoogleal bacteria and probably others, to a sudden disturbance in biological equilibrium. Variations in one or more of the three main factors, the sludge, food and rate of oxygen supply, may produce a disturbance, causing bulking. This disturbance affects primarily the biophysical character of the matrix as indicated by a reduction in the short-time adsorption capacity and by the formation of a light fluffy floc. The oxidizing capacity of the floc is not immediately affected. The appearance of *Sphaerotilus* is not a primary cause of bulking but the disturbance which causes bulking sometimes stimulates *Sphaerotilus* growth.

Heukelekian and Ingols (87) disagree with this "shock" theory of bulking and question whether *Sphaerotilus* is a primary or secondary cause of bulking.

Heukelekian (84) has re-stated some fundamental facts about the activated sludge process to assist in obtaining a clearer understanding of the bulking process. He (86) has also made experiments to show that the important factor in bulking of activated sludge free from detectable quantities of carbohydrate wastes is the deficiency of oxygen created by the slow rate of diffusion of oxygen from the liquid into the floc and the high oxygen demand rate within the floc. The remedies recommended are: Maintenance of sufficient dissolved oxygen in the mixed liquor to allow a high diffusion gradient to the floc; maintenance of dissolved oxygen throughout the tank, perhaps by distributing the sewage load; maintenance of low sludge concentrations in the aeration tank; dilution of sewage with stream water, by recirculation of secondary effluent or by returning large volumes of thin activated sludge; reduction of the high oxygen demand rate during initial aeration by careful chlorination of return sludge or by other means.

At Mansfield, Ohio, Turner (202) found that chlorine aided in preventing bulking and in restoring sludge to normal after severe bulking. When Andersen (3) finds bulking imminent, he removes the sludge from the system as rapidly as possible.

Operation.—Anderson and King (35) in studies of circular and rectangular final settling tanks found that the aeration liquor entering the tank flows horizontally through a stratum immediately above the surface of the sludge blanket to the outer wall of the tank. There it rises and flows back at the top toward the influent end. This cycle of flow is probably caused by a difference in specific gravity between the supernatant liquor in the upper portion of the tank, the aeration liquor entering the tank and the activated sludge at the bottom. A large number of different types and shapes of baffles tried in the tank inlets had little or no effect.

At Marlboro, New Jersey, Ridenour (154) reported that with 13 to 17 hours aeration, the reduction in B.O.D. and suspended solids was practically the same when the aeration solids varied between 960 and 2200 p.p.m. The major result of varying the solids was the effect on the dissolved oxygen in the aeration liquor. Temperature had little or no effect on the residual dissolved oxygen or on the settleability of the sludge. The percentage of ash in the sludge, however, was consistently greater in summer than in winter. About 91 per cent removal of B.O.D. from the sewage liquor occurred at the inlet end of the aeration tank in between 5 and 30 minutes. Nitrification seemed to be closely related to the concentration of dissolved oxygen in the aeration tank.

At the Cleveland Southerly Plant, Flowers (65) reported that short aeration periods were used in tanks using diffuser tubes and diffuser plates. The detention period was 1.5 hours at a flow of 11 m.g.d. The combined aeration system operated at 20 m.g.d. Both employ tapered aeration and sewage may be added at any of four points. About 0.4 cu. ft. of air per gallon of sewage was used in these tanks.

Larvae of the chironomid fly were so plentiful in the activated sludge at Birmingham, Michigan in July, 1940, that poor settling was obtained in the secondary clarifiers. According to Mogelnicki (130), most of the worms were killed when pyrethrum powder was added to the tanks.

Mogelnicki (130) also reports that no sludge blanket is carried in the final settling tanks and all sludge is removed as quickly as possible. In this way, the solids concentration in the return sludge varies with the flow and the concentration in the aeration tanks remains constant.

Effluent Filters

Operating information for some of the large magnetite filter installations are now becoming available. For the installation of the Southerly Plant (39) at Cleveland, it is stated that little mechanical trouble was experienced even during the winter months. Some magnetite was lost in washing, and through the screen which necessitated cleaning out the space below the bed. Levelers have been somewhat effective in preventing bare spots and keeping more uniform thickness of filter media over the entire area. Chloride of lime and copper sulfate has been effective in controlling growths. Removals by the filter averaged 44% out of 59 p.p.m. suspended solids, applied.

It is reported (129) for the Minneapolis-St. Paul Sanitary District that the difficulties due to erosion of filter medium in long rectangular magnetite filters have been overcome. This was accomplished by enlarging side influent ports, providing new openings at the ends and between adjacent beds to equalize hydraulic head in front and behind the cleaners at any point in the course of travel backward and forward. These improvements aided by an automatic bed levelling device, and a new control system for staggering the movement of the cleaners has practically eliminated sand shifting difficulties. Winter operation has been simplified by replacing aluminum angles with wire trolley conductors and the addition of cables to overcome slipping. Factors of grating corrosion are being studied. Average removals of 26 p.p.m. suspended solids from an average of 78 p.p.m. reaching the filters in four tests of 2 weeks each at constant flows of 3 gal. per sq. ft. per min. more than exceeded the requirements necessary for acceptance. Suspended solids reaching the filters during the tests ranged from 39 to 170 p.p.m. The settling period preceding the filters averaged 1.3 hours for two tests of 2 weeks each and 2.0 and 3.0 hours respectively for the other tests. All tests were on plain settled sewage without chemical treatment.

Kozma (109) describes the installation at the Carlstadt-Rutherford Plant, of a silica-sand filter in two concentric rings having an area of 278 sq. ft. and 5½ in. deep, automatically cleaned by means of a row of hydraulic ejectors travelling through the beds. The average flow is 2.3 m.g.d. or equivalent to a filter rate of 0.58 gal. per sq. ft. per min. on the total filter area. Treatment preceding the effluent filter consists of primary settling with facilities for chemical addition, trickling filter and secondary settling.

The first year's operation (113) of a magnetite filter for polishing the effluent from Biofilter treatment at Liberty, N. Y., is of interest. Final filtered effluents were obtained averaging 8 p.p.m. B.O.D. and 7 p.p.m. suspended solids. The effluent filter removed about 60 per cent of suspended solids and B.O.D. applied. The size of magnetite at Liberty is about 0.7 mm. as compared to about 1.2 mm. in the installations at Cleveland and the Minneapolis-St. Paul Sanitary District.

Chlorination

Paradoxically, as chlorine becomes limited as to availability, new research data are presented which extend its potential field of usefulness. At no other time, perhaps, will careful studies of chlorine efficiency and economy show greater benefits.

Chlorine Availability.—The use of chlorine for direct defense needs imposed a general shortage of this material during 1941, but authoritative and reassuring statements concerning its availability for sewage treatment were forthcoming (9). However, at the end of the year, the shortage was so accentuated that it became necessary for the Office of Production Management to allocate all chlorine. After February 1, 1942, no chlorine may be delivered for any purpose without specific authorization (10). Sewage uses, together with water treatment, have been accorded the highest priority rating (A-2) of any civilian use, since they directly concern public health.

Emergency Chlorination.—Scott (170) notes that chlorination, at the average sewage treatment plant, is usually not dependent on electric power. Even if all other sewage treatment facilities fail and it becomes necessary to by-pass the plant, heavy chlorination to disinfect the sewage may protect the receiving stream. Provision of extra rubber hose and fittings to permit changing the point of chlorine application is recommended.

Faber (58) provides detailed data on chlorine and hypochlorite feeding devices available for emergency use, and describes temporary equipment which may be utilized for this purpose. Mobile chlorinating units, with a gasoline engine-driven pump to supply injector water (13) (14), can be used to meet increased chlorination needs of sewage treatment plants, and emergency hypochlorite feeders for the same purpose are available (16).

Chlorine for Disinfection.—Studies by Chang and Fair (34) indicate that cysts of *Endameba histolytica*, in polluted water, may be destroyed by doses of chlorine more reasonable than hitherto believed effective. Their data are of much practical interest since this disease appears to be relatively prevalent and to be transmitted by carriers.

Symons and Simpson (192) present a summary of 11,000 bacteriological analyses evaluating the effectiveness of chlorination at the Buffalo plant in reducing bacterial pollution of the Niagara River. It is shown that analysis of refrigerated composite samples for bacterial content (raw sewage or chlorinated effluents) gives erroneous results. Plant operating data indicate that maintenance of 0.1 p.p.m. residual chlorine after 15 minutes contact, when total contact time is 30 to 45 minutes, accomplishes a 98.6 per cent kill of coliform and total bacterial counts. 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.

At Detroit, according to Wallace and Morrill (212), flow in the Detroit River is very uniform and is never less than 300 times the average flow of sewage. Reduction in B.O.D. is of no practical importance, but nuisances, floating oil and grease, sludge banks, and discharge of sewage bacteria are important. After primary sedimentation, effluent is chlorinated—slightly in excess of the 6 to 7 p.p.m. indicated demand—but actual data on bacterial kill are not yet available. However, the load of sewage contamination in the Detroit River has been vastly reduced by chlorination to such an extent that treatment for water supply purposes is reasonably easy and safe. The authors point out an important factor in sewage treatment at Detroit, and at most other cities where bacterial pollution is significant; the discharge of diluted sewage from storm water overflows of combined sewer systems during heavy rains. Since the sewage treatment plant is able to handle only about 2 times the dry weather flow, perhaps 95 per cent of all sewage bacteria must be discharged without disinfection into the river. This imposes extreme vigilance upon water purification plants during such periods.

Chlorination of sewage is required, according to Hansen (78) in many Army sewage treatment plants. The temporary nature of these plants and their design to prevent nuisance justifies higher installation and operation costs. Use of chlorination for final disinfection and to retard decomposition of effluents, or of high-rate filtration with chlorination, favors such treatment in preference to more complete biological treatment.

Chlorination for Odor Control.—In a symposium edited by Wisely (224) chlorination is cited as by far the most widely used odor control measure. The special operating procedures and results at a considerable number of plants using chlorine for this purpose provide helpful information. Effective use of the Scott-Darcey process (ferrous chloride produced from scrap iron and chlorine) at a number of plants is described as being more economical when sewage as received already contains hydrogen sulfide. Ferrous sulfide is formed and less chlorine is consumed by reaction with organic matter. In another symposium (225) further data are given on the effective use of chlorine and ferrous chloride at more sewage treatment plants.

Removal of roots from sewers is reported by Hood (90) to reduce hydrogen sulfide production and odors at Ridgewood, N. J., making prechlorination more efficient and more economical. According to Milani (128) upsewer chlorination prevents hydrogen sulfide formation at the Hasbrouck Heights, N. J., plant.

Chlorination for Grease Removal.—Little new data on this subject have been available. Faber (57) reviewed the subject of aero-chlorination for grease removal and discussed its application.

Chlorine in Activated Sludge.—According to Heukelekian (86), reduction of high oxygen demand rate, during the initial aeration period, by careful chlorination of returned sludge, constitutes one of the recommended methods of controlling bulking of activated sludge.

Equipment for feeding chlorinated copperas is described by Parker and Watkins (143) for use at a plant treating combined domestic sewage and tannery wastes. In addition to use for coagulant production, chlorine may also be applied to raw sewage or trickling filter effluent.

Ponding of filters is controlled by heavy chlorination during low night flows at Manville, N. J., according to Kachorsky (101). A 20 p.p.m. dose is effective.

Operation.—Laboratory studies begun during the construction of the Buffalo treatment plant have been continued and Symons, Simpson, and Kin (191) report studies of chlorine demand data over a period of 27 months. Chlorine demand determinations are made hourly, within 15 minutes after samples are collected. Factors affecting variations are reviewed and it is shown that composite samples do not give a true demand when compared to the average of 24 hourly tests. Generally composite samples indicate a chlorine demand from 12 to 25 per cent low in raw sewage and 100 to 300 per cent low in the case of chlorinated effluents. Per capita chlorine demand of this sewage is 0.01 lb. per day.

Symons, Johnson, and Simpson (193) describe the methods of chlorine dosage determination and feed control developed at Buffalo, pointing out that the larger the plant, the more important is such control. Consideration must be given to economics and bactericidal efficiencies. Terms are defined and a chlorine nomograph is supplied to calculate chlorine dosage. Data on maintenance of chlorination equipment are of interest.

The new potentiometric control of sewage chlorination is used at a combination chemical-biological sewage treatment plant, according to Kozma (109). Prechlorination is automatically regulated by this method to proportion chlorine feed to varying flow and demand. It is provided for odor control and to assist chemical precipitation. Postchlorination, by means of a standard manual type chlorinator may be applied to the effluent of the secondary clarifier or at the sand filter. Heavy dosing of the latter with chlorine when necessary controls bacterial growths and decomposition of solids.

An outstanding engineering accomplishment, in which liquid chlorine is conveyed 1,600 feet from the mainland to the Atlantic City Island treatment plant, is described by Le Chard and Benbury (114). Special precautions are taken to avoid hydrostatic rupture of the pipe line by providing a gas expansion tank, and to prevent loss of liquid chlorine in case of line breakage by providing an automatically operating ball check valve closing at a withdrawal rate of 3,000 lb. of liquid chlorine per hour.

Sludge Digestion

Rudolfs (162), Wolman and Fletcher (228) and Fischer (63) discuss developments and trends in sludge digestion. Factors influencing digestion are also discussed generally in a booklet by Rudolfs (164). The curves on lime additions to correct the pH value of fresh solids (raw sludge) given in this booklet should be used with caution as they are based on data obtained from a specific sludge. They may be used as an illustration or guide.

Research.—Parkes (144) (145) in what may well be considered one of the year's outstanding accomplishments, describes methods of combating corrosion by electrolysis of digester mechanisms at Terminal Island. Keefer (104) compares the relative rate of digestion of primary clarifier scum and settled sludge. Conclusions drawn were that the scum digests as readily as the sludge and that there is no advantage in segregating the two products.

Shibata (173) in continuing his work on the production of fuel oil from the distillation of various types of raw and digested sludges, reports that the residue of activated sludge after fifteen days digestion produced 10 per cent fuel oil on distillation. Longer digestion periods increased gas production but decreased the fuel oil production, the total B.T.U.'s in gas and fuel oil, however, being about the same. Various proportions of seed sludge were used. Volatile acid production decreased as the proportion of seed sludge increased. Data on digestion of egg albumen are also presented.

Shibata and Sioya (174) present data on the absorptive power of carbon obtained from the distillation of various types of sludges, and on organic constituents in the distillate. Shibata (175) discusses the digestion of activated sludge obtained in the treatment of soybean waste.

Rudgal (161) gives some laboratory data on the effect of copper on the rate of sludge digestion. Wiest (221) presents data to show that the addition of activated carbon to digesting sludge improves the drainability of the digested end product. (See also Mom (132).)

Design.—Design data on the sludge digestion tanks at Rutherford, N. J. are presented by Kozma (109). Design information on digesters for army airports has been reported (5). Suggestions for eliminating gas hazards in connection with the design of digestion tanks are given by Pacific Flush Tank Co. (142). The digesters at Romford, England, are described by Snook (181).

Operation.—Nelson (136), from data obtained from thirty-three plants, attempts to correlate the various factors that may influence digestion. Raw sludge volatile content, digester loadings and stirring indicate a marked influence on the process.

Digester operating data at Rockville Center, N. Y. are given by Andersen (3), at Marion, Ind. by Backmeyer (20), at Danbury, Conn. by Kunsch (110), at Butler, Pa. by Kurtz (111), at Bakersfield, Calif. by Erickson (56), at San Francisco by Benas (23), at Cleveland by Flowers (65), at Muskegon Heights, Mich. by Anderson (2), at Green Bay, Wisc. by Martin (123), at De Kalb, Ill. by Henn (83), at Buffalo, N. Y. by Velzy and Symons (208), at Mansfield, Ohio by Turner (201), at Aurora, Ill. by Sperry (185), at Worcester, Mass. by Brooks (28), at Massillon, Ohio by Snyder (182), at Lima, Ohio by Smith (179), at Gary, Ind. by Mathews (125), at Anderson, Ind. by Christy (37). Excellent round table discussions on starting up of digesters have been presented (157).

Experiences in digestion tank scum control at a number of plants have been reported (141). Various control methods that have been found to be successful in practice are summarized. Scum problems at Buffalo, N. Y. are also discussed by Velzy (209). Methods used in inventorying the sludge digestion tanks at Buffalo are detailed by Symons (190).

The experiences with short-period mesophilic digestion at the Davyhulme plant of Manchester, England are described by Ardern, Jepson and Klein (15).

Patents.—Shibata (176) describes a method of obtaining fuel oil from digested sludge. Leitch and Bolton (115) show a digestion tank in which bottom digested sludge is recirculated through pipes and nozzles. Durdin (49) shows a digestion tank equipped with a gasometer cover which has a double roof, the lower one of which is so spaced as to submerge any floating material. Bach (18) shows a digester in which supernatant liquor from a lower compartment is displaced into an upper chamber where quiescent conditions favor clarification of the overflow.

Need For Further Study.—There is still a need for further data on two-stage thermophilic-mesophilic digestion. A fool-proof method of obtaining a well clarified digester overflow all year round is also much to be desired, especially where secondary treatment is practiced. More information on liquefaction of organic solids is desirable.

Sludge Disposal

Sludge as Fertilizer.—One of the outstanding phases of sewage sludge disposal as reflected in the technical articles of the past year is the increased interest of sludge as a soil conditioner. Supplementing Rudolfs' illuminating paper in 1940 on fertilizer and fertility value of sewage sludge (163) were contributions by Damoose (43) of Battle Creek, Michigan, and Rawn (152) of Los Angeles, California. Damoose has promoted the sale of liquid sludge at Battle Creek as a means of establishing and maintaining public good will. At first sludge cake was delivered to private grounds but slow drying by water-logged grain chaff in the sludge led to the trial of liquid sludge on the plant grounds. So successful was this experiment that a 600-gallon wood stave tank fitted with a 6-inch cover and a 2-inch valve on the bottom has been mounted on a delivery truck, equipped with a pump and hose, for delivery of liquid digested sludge to the public. The sludge is applied to lawns by a stream about 35 ft. in length. The appearance of the black layer of sludge and its odor have been successfully overcome by a wetting down process with water sprinklers following its application. No pathogens have been isolated in the liquid sludge. Astounding results were reported to be obtained from the use of this material. In addition to the plant food elements contained in the solid and liquid portions of the sludge, Damoose believes that vitamin B_1 may be playing an important role and he has reviewed in some detail the reasons for this belief. It is planned to replace the 600-gallon tank with one of 1,000-gallon capacity which will generously cover a plot 50 ft. by 100 ft. in one trip. A charge of $10.00 for this service is believed to be acceptable to the users in Battle Creek.

Rawn also reports on those "plus fertility" values of sewage sludges and states that many citrus groves in his state have been using sludge as the sole fertilizer for some thirteen years with convincing results. Dairy manure in his area is now selling for $1.50 per ton, delivered, roadside. This is the commercial variety containing about 1¼ per cent nitrogen. Digested sewage sludge, roadside delivery, is selling for $7.00 per ton in the same area. The difference in selling price is not indicative of high pressure salesmanship; to the contrary—it portrays better than any other factor the difference in value and is excellent proof of the fertility value of the product.

Industrial wastes and grease in digested sludge are unlikely to impair soils, according to Rawn. The hygienic considerations cannot be so easily dismissed, but with heat processing or digestion it should be reasonably safe. If applied to vegetables eaten raw, this should be with full knowledge of both producer and consumer. Generally, sludge cake is stored before application to the soil and if uncooked crops are to be raised, might not the sludge be applied in the spring before growth starts, thereby giving additional storage? Such practice it would seem would reduce to a minimum the health hazard.

Mogelnicki (130) finds freezing and thawing of digested sludge cake produces a fluffy and powdery material much in demand. Experiments with liquid sludge and dried sludge applied to plant lawns failed to show any advantage for the liquid sludge. However, the dried sludge cake did such wonders for the grass that one questions if the difference could be readily discerned by eye.

Disposal at Sea.—Disposal of liquid sludge at sea continues at New York City's Wards Island, Tallmans Island and Bowery Bay plants, and from the Joint Meeting Plant at Elizabeth, N. J., Kass (103) reports that a careful investigation of sludge dumping from New York's plants indicates that sludge odors and floating material disappear quickly and do not travel far. West (219) confirms this by a published table of analytical results of 142 samples collected from the Joint Meeting plant dumping area compared with samples from sea water removed from sludge dumping operations. Figures for suspended solids, dissolved oxygen, B.O.D. and bacteria were practically identical from both areas.

As a result of the New York City investigation, dumping continues at the original site approximately 12 miles from the Long Island and New Jersey shores.

Sludge concentration is employed at all three plants in New York City with marked economies. The application of chlorine to the top water in the sludge thickeners at Tallmans Island to subdue bio-activity in the sludge is cited.

Three sea-going crafts, Diesel propelled, cart New York's sludge to sea. Lieberman (116) has described this fleet and the all-gravity loading and unloading operation. These boats can be loaded in about 90 minutes and unloaded in as little as 5 minutes. When loaded, the surface of the sludge load is 5 ft. above the water line, and when unloaded, the bottom of the sludge compartments are about 9 in. above the water line. The space below the sludge compartment floor and the hull acts as a buoyancy chamber.

West (218) also points out the economy of sludge concentration prior to barging. The Joint Meeting plant has had a special problem in moving raw sludge through 4,400 ft. of 24-in. force main to the water front. When the sludge falls below 92 per cent water, it refuses to flow by gravity to the suction of the centrifugal pumps fast enough to satisfy the impeller speed. The friction head rises with an increase in solids content or a decrease in temperature. Cold weather heads of 50 ft. are encountered as compared with 15 ft. under optimum conditions. Compressed air for cleaning the force main, and conditioning of the sludge in storage prior to pumping by recirculation, sluicing with sewage, or pushing with compressed air has proven valuable in pumping operations. Sludge layer stratification in the storage tanks has been an operating difficulty successfully overcome by these sludge conditioning methods.

The cost of sea disposal in 1940 was $4.00 per ton of dry solids at Elizabeth and $2.40 per ton for New York's plants.

At New Haven, Conn. (55) disposal at sea was discontinued late in 1940 and a sludge dewatering and incineration unit placed in operation.

Dewatering of Sludge.—The vacuum filter continues in popularity for all but the small and some of the medium sized plants. However, where digestion may be affected by industrial wastes, even the small plants dewater raw sludge on vacuum filters.

Sludge elutriation is proving its worth and gaining in favor, particularly in view of the general inclination towards digestion.

Lumb (120) describes the installation and operating troubles of ten months' full-scale results and operating costs of heat treatment of a mixture of raw, humus sludge and waste activated sludge prior to filter pressing at Halifax, England. The pretreated sludge is cooked for 15 minutes at 360° F. at 150 lb. pressure. The sludge is then settled and decanted, supernatant liquor drawn off and the residue filtered in a filter press. The settled supernatant is returned to the raw sewage. The moisture content of the thickened sludge after heat treatment and decantation was reduced from the original 94.7 per cent to 89.3 per cent. With an average of 42 hours of pressing the moisture of the cake was reduced to 41.3 per cent. The decantated and press liquor contained 11,350 p.p.m. total solids and 4,220 ppm. B.O.D. The volume of liquor was on an average .21 per cent of the sewage flow. The operating cost less the revenue from dried cake was 15.2 pence per ton.

Sludge centrifuges continue to be unsatisfactory for the average plant setup except where the effluent can be excluded from the treatment system or where only a part of the total sludge production is so handled.

Several articles appeared this past year on vacuum filtration of sludge. Holderby (89) states it is desirable, even with digested sludge, to provide a holding tank so that a considerable amount of uniform sludge may be available for any filtering run. He gives the total cost of operation and maintenance per ton of dry solids at Neenah-Menasha for 1940 at $1.793. More data on the cost of dewatering from plants using sludge drying beds would be of interest for comparison.

At Lansing, Michigan (230), better sludge conditioning is obtained by adding the ferric chloride first and the lime last. Although contrary to theory this observation has been noted at other plants. Wyllie, Superintendent, reports considerable trouble with carbonate deposits in the vacuum filter, the piping and the filtrate pumps. Pounding of the supporting mesh, drainage strips and blowback strips with a hammer, scraping, sand blasting and submergence in a 10 per cent muriatic acid solution were all employed to loosen and dissolve the deposits. In the fall of 1940 all the piping from the interior of the filter was removed for cleaning. Some of the pipes were practically closed with lime deposits, especially at the elbows. It is believed that the filter can be kept in good condition by periodic acid treatment with the filter valve removed and its outlets plugged. A 5 to 10 per cent solution of inhibited muriatic acid will be applied to the various sections of the filter while they are in the upper position.

Mudgett (135) reports liming of pumps and piping at Muskegon, Michigan. After cutting the filter interior piping for cleaning, sections were replaced with radiator hose. He lists total operation cost at $7.996 per ton of dry solids. A revenue of $1.94 per ton of dry solids is realized. The variance in cost of filter operation as compared with Neenah-Menasha reflects the differences in size of plants and how this among other things affects total costs. Mudgett states that his filter rates and chemical consumption records are based on the actual pounds of sludge solids filtered without addition of the chemicals. He feels that since the chemicals added are a necessary evil and the problem is actually that of dewatering sludge, the filtration records should be based on sludge solids. This seems a controversial subject and depends on the information desired. Whether or not the chemicals are included in such results should be clearly stated in order that accurate comparisons may be made between plants.

Van Kleeck (206) in a general description of dewatering by vacuum filters continues to point out the advantages for filtration of digested sludge as compared with raw sludge. Major features in design are discussed including: flexibility of filter layouts, sampling points, chemical storage space, gravity feed of conditioned sludge, larger piping, vacuum pump protection against entrance of filtrate, cake spillage, cake disintegrators, location of filter exhausts to reduce odor and noise, filter room ventilation, safety features, and avoidance of cross-connections with potable water supplies. The major factors affecting successful filtration are discussed in this article.

By far the most exhaustive presentation of the factors influencing vacuum filtration of sludge has been presented by Genter (72) at the

Second Annual Convention of the Federation last year. Some thirty-two related general factors are discussed in detail, the article (72) crammed with the theory and practice of vacuum filtration. Van Kleeck in a discussion of the paper states: "Here appears to be the first attempt at coordinating the general mathematical principles of sludge filtration and actual practice without resorting to theoretical calculations, which after all are of little or no interest to the filter operator."

Sperry (184) of Aurora, Illinois, has given information on the use of alum with digested sludge to hasten dewatering on sand beds. While alum has been used in the past, its application might be called a "rediscovery." Its effectiveness is apparently due to its acid content; the acid acting on the carbonates in the sludge producing CO_2, which aids in flotation. The Aurora sludge contains on the average 6.9 per cent total solids of which 47.4 per cent is volatile. Alum has been applied normally at the rate of 1 lb. to 12.5 cu. ft. of sludge or 1 lb. to 93 gallons. Alum treated beds, if not too much rained on, can be cleaned in 12 to 15 days as against 20 to 25 days for untreated beds under equal weather conditions. The dewatering effects of alum reduced the frozen cake thickness at Aurora from one-third to one-half. Sulfuric acid as a coagulant was unsuccessful, and iron salts were more expensive, more difficult to store and handle and objectionable because of their tendency to plug the sand with oxidized iron. Minimum mixing of alum is important. Sand in the beds should be coarse. An adequate tile drainage system is necessary. The chemical is most effective on sludge with a total solids content under 9 per cent. Experiments indicate that alum-treated sludge cake has no adverse effect on plant life.

Sludge Loading.—In another article Sperry (186) describes a "saddle-bag" tractor in use at Aurora for loading sludge cake. Considering its adaptability and general usefulness, it seems surprising, says Sperry, that but three of these machines are in use in the U. S. In the summer of 1940 eight new sludge drying beds were constructed and trackage for these beds would have cost about $3,000. The tractor with side bins cost only $2,260 and in addition saved the District $1,600 over renting equipment during the construction period. The tractor saves over 50 per cent of the sludge removal costs as compared with former methods. A bull-dozer blade is being added to the tractor for clearing snow from plant driveways, trimming the sludge storage pile, and for maintenance of the gravel roadways. With this machine the beds must be kept well sanded to protect against the disturbing effect of tractor cleats.

New Developments and Aids to Practice

In the panorama of progress sketched by this review, certain developments lay claim to separate grouping. Classified as new aids to practice, these developments represent, in many cases, novelty and ingenuity directed toward better performance and economy of sewage disposal service.

For example, an important step in the improvement of final settling tank design was outlined by Gould (75) based on tests made on existing conventionally-designed, rectangular tanks. The tests showed that the flow of sludge along the tank bottom was counter to the drag of the collector mechanism; further the speed of the mechanism at 1 ft. per min. was too slow and permitted sludge to remain in the tank for many hours. To correct these conditions, the design of the new tank at the Bowery Bay activated sludge plant provides for taking off return sludge at the effluent end. The collector mechanism moves toward the effluent end, which is the same direction as the natural flow of the sludge along the tank bottom. The collector flights will be given a speed of up to 3 ft. per min. the blades being feathered on the return course to minimize eddy currents under these higher speeds.

Among the new devices available for sewage treatment, one of the most interesting is the multiple-tray clarifier. The first installation (67) was completed recently at Springfield, Mo. following several years experimental work by the Pacific Flush Tank Company. The clarifier consists essentially of a series of trays—one above the other—each provided with a revolving radial arm that serves as a sludge scraper. In effect, this provides a series of shallow settling basins superimposed on each other. A detention period of some 30 minutes is said to give results equivalent to those obtained in 1½ to 2 hours using conventional deep tanks. At Springfield, reduction of suspended solids was 61 per cent with a detention period of 33 minutes and a flow of 10 m.g.d.

Practical operating knowledge leading to more efficient performance of the combined garbage-sewage disposal system was revealed by two designers of such plants. From Lansing, Mich., Drury (48) reported that experimental work with four small digestion tanks indicates that the best way to digest sewage sludge and garbage is by using stage digestion. With a constantly decreasing rate of digestive activity in succeeding tanks, it was possible to obtain a progressively better sludge and supernatant so that the fourth tank produced a sludge ready for drying. It was shown that although a capacity of about 4 cu. ft. per capita should be provided for parallel operation, only 1.7 cu. ft. per capita capacity is required with series operation. Sludge that was filtrable and properly digested for handling could be obtained in 15 or 16 days. At Goshen, N. Y., Taylor (194) reported on the importance of screen sizes. A ¼-in. screen was first installed here but experience proved that this was too fine, required an unnecessary amount of power, and unduly reduced the capacity of the grinder. A ¾-in. spacing was adopted and a noticeable improvement in operation was experienced. It appears that screen sizes below 1 or 1¼ in. make only a slight difference in the physical characteristics of the ground material, but above this size the characteristics of the ground material change radically. However, power requirements and capacity were affected considerably by increasing the screen opening from ¼-in. to ¾-in. spacing.

In addition to the ever-increasing use of sludge gas for driving internal combustion engines (incomplete estimates indicating more than 180 installations producing 35,000 hp.), interesting developments have occured in the field of by-product recovery from sewage treatment. Baltimore (6) consummated an arrangement with the Bethlehem Steel Co. whereby the company will pay the city about $24,000 annually for 40 m.g.d. of treated sewage effluent; the steel company will use the effluent for industrial purposes to supplement a decreasing groundwater supply. Corpus Christi, Texas, is also selling disposal plant effluent to an oil refinery for condenser water.

Further evidence of the wide interest in by-product recovery was revealed by studies made in Atlanta, Ga. concerning the use of sludge gas for operating automotive equipment (8). The findings indicate that the city could save $8,000 annually if municipal trucks were converted to operate on compressed gas instead of gasoline. The scheme is held in abeyance, however, because the war effort made it impossible to get compressors and other equipment; meantime the gas has been piped to a nearby water pumping station where it is used for boiler fuel, thus saving the city some $6,000 per year. The gas used for this purpose is in excess of that already employed to generate power for plant uses.

Dramatic interest is attached to the information from Bradford, England (229), which revealed for the first time that the sewage disposal works at this place is supplying weekly 500 tons of grease to aid Britain's war effort. This valuable by-product, along with fertilizer, has been produced for almost four decades at Bradford, the center for many wool scouring industries. Wontner-Smith, sewage works engineer at Bradford, states there are no works anywhere in the world built on similar lines and no purification plants in existence which can claim an income in any way comparable with that at Bradford. In the financial year ending March 31, 1940, grease sales exceeded $400,000, but this year an amount several times this figure is expected.

To meet the problem of providing emergency sewage treatment facilities for 10,000 troops at Camp Croft, near Spartanburg, S. C., a sedimentation "tank" and a chlorine detention chamber were constructed simply by excavating holes in the ground. This proved to be a successful, cheap and sanitary expedient (180). For the sedimentation tank a basin 100 by 30 by 5 ft. deep was selected; an adjacent chlorination chamber to provide 20-minute detention fixed its size as 40 by 15 by 5 ft. deep. A solution of high-test calcium hypochlorite (containing 70 per cent available chlorine) was mixed in three wooden barrels interconnected to give 24-hour dosing capacity; average dosing was equivalent to 8 p.p.m. When the sewerage system of the camp was connected with permanent treatment facilities, the sedimentation tank simply was drained and backfilled: the sludge deposit was estimated to be 200 tons.

An outfall sewer which differs in size as well as method of joint construction from anything in American practice has been installed near Copenhagen, Denmark (76). The pre-cast box sewer unit, 50 ft. in length and rectangular in cross section (about 10 by 3½ ft.), contained three interior vertical partitions which formed a four-chamber conduit. The joint packing was wood-fiber rope, compressed in place by means of a novel hinged joint. The use of the hinged joint made it possible to apply a bending of 1,250,000 ft.-lb. which compressed the soft wood fiber packing to a consistency of almost solid wood.

A new aid in plant maintenance—a chlorinated rubber paint base—has been made available by the Hercules Powder Company (12). The new base, which is available to all paint manufacturers for their own formulation, is said to produce a paint which will resist the corrosive atmosphere encountered in sewage treatment plants.

Stream Pollution

Oxygen Demand—Reaeration.—Several excellent papers have appeared on this subject, particularly with reference to the effect of sludge deposits. Fair, Moore and Thomas (59) present an extended analysis of anaerobic-aerobic, "benthal," stabilization of sludge deposits, formulating such benthal decomposition as a retardant unimolecular curve

$$\frac{dy}{dt} = \frac{k}{1 + at}(L - y),$$

where y = oxygen demand exerted in time t,
L = ultimate oxygen demand,
k = reaction velocity constant,
and a = coefficient of retardation.

The experimental data, to which these curves are fitted by a least squares formulation, required from 0.3 (their experiments on fresh sludge solids plus inert mineral matter) to 0.4 to 1.5 years (5 reported British muds) for 50 per cent stabilization at temperatures of 18° to 25° C. Ninety per cent stabilization required correspondingly long periods of 1.5 to 6.5 years. A discussion of the effect of depth and other factors and a sample calculation under ideal conditions are also included. A second paper by these authors (60) presents an analysis of temperature coefficients and the changes occurring in nitrogen, iron and fuel values during benthal decomposition.

The third paper (61) of this series on sludge deposits discusses the reduced total oxygen demand occasioned by anaerobic decomposition, the effect of inorganic mixtures upon the rate of decomposition and the problem of continuous deposition. They report the total benthal oxygen demand as less than half of the potential requirement of the organic matter when the deposits exceed one kg. of volatile matter per square meter and the discrepancy to be largely accounted for by methane release. The addition of inorganic matter reduced both the rate and total amount of decomposition.

Application of Fair, Moore and Thomas' formulations to data from flowing streams is certain to be quite complicated by such factors as frequent scour (usually a matter of months instead of years) and the multiple sources of total oxygen demand of a stream, but the approach presented is basically important and worthy of considerable study by those interested in stream pollution.

To evaluate the effect of sludge deposits on the dissolved oxygen in a stream, Jansa and Akerlindh (99) propose a modification of Streeter and Phelps' oxygen sag formulation based on sedimentation rates for sludge solids and Streeter's (189) cumulative B.O.D. treatment. This interesting and relatively simple (for this problem) treatment results in application of the sludge demand to the oxygen sag curve at a rate equal to the rate of settlement of the sludge. It is unfortunate that the authors did not include the data on its use for the stream which they were studying, as the method appears promising.

Howland and Farr (93) present a graphical method of analysis of the oxygen sag curve which should prove useful as it simplifies the calculations involved, particularly where the normal curve is modified by inflow and increments of pollution.

In a study of the long-time B.O.D. of sewage and two river waters, Moore (134) obtained generally good agreements with accepted values except at low temperatures where low values were obtained. Values of k for the nitrification stage of sewage varied from about 0.06 at 20° C. to 0.025 for 5° to 7.5° C. Nitrification was irregular and greatly retarded at low temperatures in sewage and could not be satisfactorily formulated in the river waters.

Biology.—Lackey (112) reports certain species of Cryptophyceae and Chrysophyceae as showing clear-cut responses to the presence of pollution, their relative numbers being a good indication of the sanitary quality of the water.

In a study of the oxidation of dead fresh water plankton Skopintsev and Bruk (178) found that bacteria reached a maximum in 2 to 5 days, ammonification in 5 to 10 days and nitrites in 9 to 22 days, after which the nitrates increase sharply.

ZoBell (232) reported the practical absence of coliform bacteria in sea water except near land and in the intestines of marine fishes except those taken near land. The survey included analyses of 961 samples of sea water and 387 marine fishes.

Surveys.—Special mechanical equipment and the floating laboratory used on the Ohio River Survey have been described by Carnahan (32) and the mobile laboratory units of this survey by DeMartini (45). Cost data are included by the latter.

Scott (169) reports the results of a year's study (usually weekly samples), during 1936–37, of four polluted sections of the Tennessee River; the Knoxville, Chattanooga, Decatur and Tri-Cities areas. Times of flow were determined by floats. B.O.D. values were generally low due to high dilution and the increases below points of pollution slight or erratic except in the Knoxville stretch. Per capita contributions of coliform bacteria in the four stretches varied from 13 to 144 billions per day during winter and 20 to 180 during summer. Tests during a period of eight months indicated that fluoride accretions due to a phosphate fertilizer plant at Wilson Dam were negligible.

Kehr, Purdy, Lackey, Placak and Burns (105) report the results of 30 months' study of 115 river miles of the Scioto River in Ohio. The period of the study involved three types of sewage treatment at Columbus, Ohio, the point of heaviest pollution. Stream conditions were worse with plain sedimentation at Columbus than would be expected, considering the relative amounts of B.O.D. discharged during this period and the other two periods of sewage treatment, *i.e.*, an overloaded trickling filter and activated sludge treatment. Analytical data are grouped into three temperature and five flow ranges, the latter on a basis of uniform discharge per square mile. Rates of bacterial decrease were in the approximate range of rates previously observed on the Ohio and Illinois Rivers and were found to decrease with increasing stages in the relatively less polluted sections of the river. Extensive observations were made of plankton and bottom sediments. Although these failed to reflect conclusively the three periods of varying pollution at Columbus, certain plankton groups and the general picture of bottom sediments were found to present reasonably accurate indices of stream conditions.

In a brief report of conditions in the Potomac River with treatment of Washington, D. C. sewage, McNamee (126) shows the effect of flow variation and temperature upon the dissolved oxygen. He found, roughly, that a 25° F. rise in temperature, for one set of observations, was compensated for by a 6,300 c.f.s. increase of flow, comparable oxygen sag curves being obtained.

Schroepfer (168) (129) reports further data on the condition of the Mississippi River following chemical treatment of Minneapolis-St. Paul sewage. Low flows during 1940 apparently intensified conditions in the 10–15 mile stretch below the treatment plant outfall but resulted in general improvement farther downstream. Due to the discharge of untreated sewage and industrial wastes, it has not been possible to check the calculations used to determine the degree of treatment for Minneapolis-St. Paul sewage.

Wallace and Morrill (212) report considerable improvement in bacterial pollution of the Detroit River following preliminary treatment plus chlorination of Detroit sewage. Due to the uniform discharge of the river, however, they anticipate heavy bacterial pollution for short periods following the discharge of untreated storm water overflows.

An unusual report of a stream pollution survey, in that it deals largely with odors in waters of the Kanawha basin, was published by Watson (215). There have been recent increases in odors in this area as indicated by greatly increased usage of activated carbon at water treatment plants. The sources of these odors were traced to industrial plants on the Kanawha and Elk Rivers and a remedial program has been undertaken.

Industrial Wastes

General.—During the year a number of excellent general surveys of developments in the industrial waste field have been published. It does not seem appropriate to discuss these in detail in this report, but for the benefit of those who may not have seen them, the reviewer has adopted a policy of describing their contents in brief. One of the most outstanding of these reviews is that of Eldridge (52) who describes the requirements for a successful treatment process as a minimum need for technical operating personnel, low cost, high efficiency, and resistance to variations in flow and strength. As examples, plants are described for the treatment of paper board wastes by coagulation with alum, the treatment of sugar beet wastes, the treatment of milk waste by the Bio-chemical process, and the application of fabricated steel tanks to industrial waste treatment.

The papers of Black and Klassen (24) are also a notable contribution, furnishing an excellent picture of practical accomplishments in industrial pollution abatement within the last few years. The particular section of this paper dealing with yeast plant and other fermentation wastes has been reviewed in another part of this report, since the literature on this topic is obscure.

Adams (1) reviews the progress of abatement of industrial pollution in Michigan. Legal and financial aspects are discussed, and general standards for effluents are set up; namely, freedom from depositing materials, oil films, tainting or toxic substances, a pH value of 5.8 to 8.2, and the production of no material chemical change in the receiving water, which must maintain at least 4 p.p.m. of dissolved oxygen. More specific requirements are given for ten industries common in Michigan, these requirements being based on the well-known work of the Michigan Engineering Experiment Station.

Recent developments in Britain are covered in a paper by Windridge (223) which deals with the probable effect on manufacturers of the application of the Public Health Act of 1937, and the methods to be used in establishing standards for treatment. Recent developments in the treatment of viscose plant, board mill, gas plant, and milk plant wastes are also discussed.

Eldridge (51) suggests the use of recirculating filters for treatment of many organic industrial wastes. Design figures given for B.O.D. loading are 30 cu. ft. of media per lb. of applied B.O.D., and for rate of application of liquid 350 to 460 gal. per sq. ft. per day (15 to 20 m.g.a.d.). The design of holding tanks for the waste is of great importance, and values for the capacities of holding tanks are suggested on the basis of experience in milk waste treatment. It is made clear that these capacities are not necessarily proper for other wastes.

Beet Sugar.—Papers by Classen (38) and Werner (217) deal with the re-use of diffusion water in the industry. The former considers the difficulties encountered in this re-use to be due to the physical action of suspended pulp and slime and suggests mechanical or chemical coagulation; the latter considers them to be due to the pH value of the water, which should be maintained below 7.0.

Brewery.—Results of one year's operation of the waste treatment plant of the Gulf Brewing Company, previously described in *This Journal*, **11**, 295 (1939), were reported by Tolman (198) as showing that satisfactory treatment is obtained with trickling filters. The waste was applied to the filters at a rate of 10 lb. of 24-hour B.O.D. per 100 cu. ft. of stone, and at this rate a removal of 95 per cent of the B.O.D. was obtained. The sludge from the waste digested without difficulty.

Cannery.—Citrus cannery effluent is commonly disposed of in Florida by discharge into lakes, city sewers, or on waste lands. According to von Loesecke, *et al.* (211) preliminary screening, trickling filter treatment at 1.38 to 1.56 m.g.a.d., and secondary settling (2 hours) will remove 86.8 to 87.1 per cent of the B.O.D., producing an effluent of 79 to 101 p.p.m., suitable for discharge into lakes. The filters remove 41 lb. of B.O.D. per 1000 cu. ft., which furnishes a good basis for design. Chemical precipitation, activated sludge, contact filters, sand filters and chlorination gave no promise as methods of citrus waste treatment. Figures are given for the quantity and composition of citrus cannery effluents.

In his discussion of Knowlton's (108) paper, Ingram (98) summarized existing information on the proper screening of cannery waste as follows: mesh, greater than 20 but not over 40; loading, 2 to 12 gallons per minute per sq. ft. for drum screens, up to 37 for vibrating screens, up to 87 for band screens. A removal of 10 to 25 per cent of solids may be expected. Devices for macerating the garbage waste should not be permitted in a cannery.

van Antwerpen (205) has described the manufacture of stock feed from citrus peels by grinding with a small addition of lime solution, treatment with live steam, pressing and drying. The process is patented. The material commands a price of $30 per ton.

Coal Washery.—Yancey, *et al.* (231) have described a study made on the various materials used to flocculate coal washery slimes. The amount of flocculant required was greater for bituminous coal slimes than for anthracite slimes. Starchy materials were good for flocculation of coal suspensions but not for shale suspensions. Colloidal (starchy) materials plus an electrolyte such as ferric chloride were found to give the best flocculation. The addition of a wetting agent such as Aerosol OT to potato starch increased the rate of clarification by the starch.

Chemical Plant.—According to Mensing, *et al.* (127), the waste disposal system of the Calco Chemical Division of American Cyanamid, Bound Brook, N. J., begins with a 10 m.g. compositing basin having sufficient capacity to hold the wastes discharged in 24 hours. In this basin, mutual neutralization of the many wastes produced at the plant occurs, and any residual acidity is destroyed by calcium carbonate slurry obtained from the nearby Johns-Manville plant. The addition of calcium carbonate is controlled by an automatic pH controller. The neutralized effluent passes through a 60 m.g. settling tank, and is discharged into the Raritan River by means of a diffusion dam. Some of the various plant wastes are given special treatment, such as skimming or settling, before passing to the main treatment plant, and the domestic sewage is mixed with the acid waste in order to destroy its bacterial population.

Nolte, Meyer and Fromke (138) have developed a process for biological purification of phenolic waste waters, which consists merely of adding to the waters small quantities of various phosphates, before aeration with activated sludge (or other biological treatment). Where 420 p.p.m. of phenol had stopped the activity of an activated sludge plant, it was restored by the addition of 1 kg. of ammonium phosphate to 150 cu. m. of sewage. The process is covered by a German patent.

Corn Products.—As described by Pulfrey, *et al.* (150), the steps taken to reduce the pollutional load imposed by the wastes of the Argo plant of the Corn Products Refining Company include recirculation and evaporation of process waters from starch washing and gluten settling, and venting to the atmosphere of the organic vapors from the steep water evaporators. Alcohol was recovered from these vapors. The paper gives a detailed description of the studies made on all the principal wastes of the plant, the plans for reducing the quantity and concentration of these wastes, and the reduction in population equivalent expected.

Distillery and Yeast Plant Waste.—The treatment of distillery and yeast plant wastes is dealt with in Part I of the previously mentioned articles by Black and Klassen (24). The principal yeast plant waste, namely the "spent beer" from which the yeast is separated, is reported to have a B.O.D. of 7000 to 9000 p.p.m., and total solids of 1.5 per cent. The Pekin, Ill., plant of Standard Brands, Inc., treats yeast wastes by preliminary sedimentation and anaerobic fermentation in three stages, totaling 4 days of digestion. The waste fed to the digesters has a B.O.D. averaging 5150 p.p.m., and emerges with 1160 p.p.m. under present operating conditions.

The plant of the National Grain Yeast Corporation at Crystal Lake, Ill., provides treatment by passing the waste through a lagoon to a high-rate filter and a final clarifier, from which a portion of the effluent is returned to the lagoon to serve as a diluent and buffer. The remainder is diluted with cooling water before release.

The Peoria, Ill., plant of Commercial Solvents Corporation, operating a butanol-acetone fermentation process, recovers solids by evaporation and drying of the wastes. Vitamin B_2 is extracted from the solids.

Of the processes described by Black and Klassen for the treatment of distillery wastes, the only one not previously reviewed is the Atwood process, which modifies the fermentation procedure in such a way as to give a dealcoholized beer free of colloids and easily filtrable.

According to Rao (151) a molasses distillery waste was producing hydrogen sulfide in a stream. The condition was alleviated by centrifuging the liquid before distillation and removing the yeast from the dealcoholized liquid by treatment with lime, followed by filtration.

Metal Working.—A report of the Connecticut State Water Commission (41) deals with several industrial waste problems, chiefly those of metal working and plating plants. The use of barium sulfide, lime, and copper is recommended for the treatment of plating room liquors, to reduce chromates and precipitate the metals present. Spent brass pickling liquor may be treated electrolytically to regenerate pickle liquor and recover copper and zinc; the technique is discussed at length. Copper has been found to concentrate in sludge; its presence in sewage in an amount exceeding 1 p.p.m. will decrease the efficiency of sludge digestion. It may be removed from acid waste by scrap iron filters, and from alkaline waste by sodium or calcium sulfide and copperas. It is also stated that chromium in sewage should not exceed 1 p.p.m. for the same reason; however, if this chromium is reduced to the trivalent state it is relatively non-toxic.

Oil emulsion waste from ball-bearing plants can be cracked by acid and ferrous sulfate; the oil is then skimmed off and the settled sludge dried.

The report is based in part on the work of Hoover and Masselli (91) dealing with the composition and treatment of wastes from representative metal finishing plants. These wastes contain from 4.1 to 87 p.p.m. total chromium with varying amounts of other metals. It is often feasible to separate out the chromium plating solutions to produce a waste containing 87 to 643 p.p.m. of chromium. This waste may be treated by reduction and precipitation of trivalent Cr, direct precipitation of hexavalent chromium, and electrolytic treatment. From a waste containing 100 p.p.m. of chromium, treatment by means of sodium sulfide, barium sulfide, scrap iron or sulfur dioxide is able to precipitate the chromium completely and reduce the amount of cyanide. The precipitate is slow to settle and dries with difficulty if sodium sulfide is used, but settles and dries well with barium sulfide. Scrap iron in the presence of sulfuric acid produces a precipitate which settles readily but is not so easy to dewater. The use of sulfur dioxide is best if chromium is to be recovered, as chromium oxide is produced in a form usable as a green pigment when the filtered precipitate is roasted at 500° C. A plant to handle 40,000 to 100,000 gal. of waste, using any one of the four reagents, has been designed. Cost figures are computed for reduction with sodium sulfide and coagulation with copperas at 50 cents per 1000 gal., reduction with barium sulfide followed by lime and ferrous sulfate, at 54 cents, reduction of the acidified solution with scrap iron, at 40 cents, and reduction with sulfur dioxide and aeration at 42 cents.

Sierp (177) has published a review of the methods used for recovery of copper from wastes containing that metal.

Hodge (88), in reporting recent developments in the abatement of stream pollution from steel mill wastes, states that many plants have succeeded in reducing the total quantity of acid used in the pickling process, and also the concentration of free sulfuric acid in the waste pickle liquor. Many of the processes for the treatment of pickle liquors are based on the recovery of by-products, but the market for these by-products is not sufficient to care for more than a small fraction of the liquors produced.

Milk.—Comparative studies of three milk waste treatment plants, using respectively trickling filtration with primary and secondary settling, the Guggenheim or Bio-chemical process, and the lime-activated sludge process, have been reported by Hatch and Bass (80). Figures are given for milk-solids loss and composition of wastes from the plants. The results are best summarized by the following table:

Plant	Per cent reduction in		Initial 5-day B.O.D.	Total Cost per lb. of B.O.D. Removed
	Suspended Solids	5-day B.O.D.		
Trickling filter	93.4	98.2	1291	$0.0405
Guggenheim process	66.0	76.2	755	$0.0683
Activated sludge	96.1	98.9	1246	$0.0466

The cost figures include depreciation and interest, figured at 10 per cent. The trickling filter plant had much the highest capital cost, but the lowest operating cost per unit of work accomplished. (Note: It should be stated that the Guggenheim plant handled cheese factory waste, while the other plants received wastes from butter manufacture, evaporated milk production, etc. Cheese plant waste is conceded to be the most difficult to treat.)

The Mallory process for the treatment of milk plant wastes, as described by Eldridge (50), consists of an activated sludge treatment followed by chemical precipitation with lime and alum. The excess sludge is digested. The treatment is effected in pre-fabricated steel tanks of relatively simple design, which are claimed to cost one-half as much as concrete tanks of the same capacity. The Pennsylvania State Health Department has made a test of the operation of the process at a western Pennsylvania dairy. On two successive days, the suspended solids were reduced from 450 and 380 p.p.m. in the raw waste to 25 and 20 p.p.m. in the final effluent, and the B.O.D. from 969 and 890 p.p.m. to 6 and 5 p.p.m. During this time the plant used 24.6 lb. of alum and 7.4 lb. of lime per day. Air consumption was not stated.

A study of the oxidation of lactose by activated sludge, made by Jenkins and Wilkinson (100), showed that when sufficient nitrogen was added (optimum C–N ratio 10 to 1), lactose was removed rapidly during the first hour with the production of some lactic acid. Starting as normal activated sludge, the sludge finally became black, and was shown to be composed almost entirely of the fungus *Pullularia pullulans*, but did not bulk.

Packinghouse.—Childress (36), in a discussion of packing plant waste treatment, describes the use of chemical precipitation either by chlorine or ferric chloride, stating that neither furnishes a really satisfactory solution of the problem.

An extensive report on packinghouse wastes in Texas has been issued by the Texas State Department of Health (195). Figures given for the water consumption of plants furnish an index of the volume of waste to be expected. For the five companies for which detailed figures are reported, 127 gallons are used per hog equivalent slaughtered. Figures on the composition and volume of the wastes originating from the various operations show that the rendering tanks contribute the strongest wastes but the volume is comparatively small. Heavy loadings on city sewage treatment plants are produced by these wastes, and treatment by small septic tanks or skimming vats is quite inadequate.

Hurst (95) reports that the waste from the Armour Packing Company plant at Tifton, Ga., is treated by primary sedimentation, aeration, secondary sedimentation, and trickling filtration before being mixed with domestic sewage. The mixed waste is passed to a second trickling filter and final clarifier. Sludge is digested. From a city sewage of 260 p.p.m. B.O.D. and a packinghouse waste of 1000 p.p.m., a final effluent of 22 p.p.m. is produced. Suspended solids in the final effluent average 30 p.p.m.

Paper.—In a study of the determination of the B.O.D. of waste sulfite liquor, Martin and Miller (124) decided that the best dilution medium is water from the stream to which the waste is to be discharged, aged 10 to 20 days and seeded with water from the same source. Determined in this way, the population equivalent of a 100-ton sulfite mill will vary from 283,000 to 579,000 persons. Sulfite waste seems able to remove all of the soluble phosphorus from a stream.

Studies by Sawyer (167) on the rate of B.O.D. removal by activated sludge from mixtures of sewage and sulfite liquor showed the critical factor to be a deficiency of nitrogen and phosphorus in the mixtures containing over 8 percent of sulfite liquor. Addition of nitrogen and phosphorus to mixtures of sulfite waste and sewage prior to treatment would cost about $2.65 per ton of pulp. Although this is a heavy charge, it might be justified on the basis of savings in capital cost of treatment works and through recoveries of sludge and gas.

Wiley, *et al.* (222) have described fermentation of the sugars in sulfite liquor to acetone and butyl alcohol by a strain of *Clostridium butylicum.* The waste was first treated to remove sulfur dioxide, lignin and calcium, reducing the B.O.D. by 46.4 per cent. Fermentation effected a further reduction of 34.3 per cent of the original B.O.D. The initial B.O.D. was 28,150 p.p.m., the final 5425 p.p.m., an overall reduction of 80.7 per cent.

Spulkik, *et al.* (187) describe the use of sulfite liquor as a fertilizer; application of up to 80 tons of liquor per acre of land did not affect sunflowers. The waste increased the sulfur, potassium, calcium, and sulfate ions, and lowered the pH value of the soil. (This does not seem to indicate any extensive fertilizing value.)

Davis (44) has described an interesting treatment plant at the Springhill, La., plant of the Southern Kraft Paper Company. Pulp mill, bleach and paper mill wastes are combined in an impounding basin, where sedimentation, lime treatment, and the action of residual bleach liquors reduce the B.O.D. from 730 to 375 p.p.m. After detention and dilution by rain water, the B.O.D. of the effluent may be as low as 65 p.p.m. The impounded effluent was treated experimentally on a biofilter with considerable success, although the deficiency of nitrogen precluded a high rate of B.O.D. removal.

Petroleum.—The paper of Weston and Hart (220) is recommended as a complete and highly condensed survey of the waste treatment of the petroleum industry. The industry is divided into the fields of production, refining, and marketing, and the wastes from each field are described and their disposal discussed. A complete review is precluded by the scope of the paper. In production, the brine is the principal problem. In refining, emulsions of oils and bottom sludges are the general trouble makers. Cracking, polymerization, alkylation and related processes produce two difficult wastes, those from still-gas scrubbing (spent alkaline solutions of H_2S) and condensate waters from distillate separators, containing a variety of toxic chemicals. No general methods are given for treatment of these wastes. The disposal of waste caustic wash is also a major problem, as it contains taste and odor producing constituents in large quantities. In marketing, the principal waste is oil from leaks or spills.

The recovery of sulfuric acid from refinery sludge is shown diagrammatically in *Chemistry and Metallurgy* for May, 1941.

Tannery.—Pilot plant experiments by Riffenburg and Allison (155) indicate that tannery wastes may be treated by means of flue gas and lime. The waste from the soaking, bating, tanning, and bleaching operations should be mixed in a tank holding 24 to 36 hours flow. Flue gas is passed into the mixture until the pH is 6.4 to 6.7, and lime then added in an amount sufficient to produce phenolphthalein alkalinity. The supernatant is drawn off and given an identical secondary treatment. Sludge may be dried on cinder beds. In the experiments performed, the B.O.D. was reduced from 13,400 p.p.m. to 3000 p.p.m. by the first stage of treatment, and to 1140 p.p.m. by the second stage. Most of the color of the waste was eliminated.

Textile.—A study of the chemical precipitation of sulfur dye wastes on a plant scale by Porges, et al (149) revealed that concentrated wastes were best handled by fill-and-draw operation, and weaker wastes by continuous operation. Acids and alum gave large quantities of hydrogen sulfide when used to coagulate sulfur dye wastes, but acid coagulation is attractive since it precipitates the pure dye, which can be reused. Iron salts may be used without hydrogen sulfide evolution, but mechanical flocculation is detrimental to the floc produced with copperas. With strong wastes, filtration of the entire coagulated mixture without settling seems worth while, since dewatering is rapid.

According to the Connecticut State Water Commission (41) textile wastes may be treated by copperas and lime, removing 75 per cent of color and suspended solids. The dried sludge may be burned.

Gotaas (74) has also published a review of the textile waste problem, based mainly on the work done for the Textile Foundation.

A report on laboratory studies on the wastes from a textile factory, carried on by the Texas State Department of Health (196) showed that indigo wastes could be treated either by aeration, lime, ferric sulfate and lime, or alum, with approximately the same color reduction. It is stated that the ferric sulfate and lime treatment was best, even though most expensive. Weak sulfur dye waste was best treated by copperas and lime (800 and 2000 p.p.m. respectively) with an 80 per cent reduction in color. For strong sulfur dye waste, a treatment of 1600 p.p.m. ferric sulfate and 3200 p.p.m. lime was favored. This reduced the color 95.6 per cent.

Horton and Baity (92) have made recommendations for the treatment of textile wastes with domestic sewage, which include equalization of discharge, reduction of waste volume and recovery of by-products, and pretreatment if required.

Effect of Industrial Wastes on Sewage Treatment

General.—The problem of the admission of industrial wastes to sewers has been discussed by Knowlton (108), who states that industrial wastes constitute 20 percent of the flow at the Hyperion plant of the Los Angeles sewage disposal system. The total of the industrial flow is 26 m.g.d., of which 12 is accounted for by laundries, 8 by meat packing and slaughtering plants, and 5 by creameries and dairies. Permissible limits for wastes admitted to the sewers are 600 p.p.m. grease, 1000 p.p.m. suspended solids.

Sedimentation.—In a discussion of Knowlton's paper, Castro (33) cited experiments showing that 5 per cent of prune waste, 15 per cent of apricot waste, or 5 per cent of an equal mixture of the two could be added to sewage without souring of the mixture within 19 hours. This souring was believed to account for the periodic "turning over" of the Santa Clara sewage plant clarifier during operation of the canneries.

Kimball and May (107) describe the difficulties at the Palo Alto plant, where the volume of cannery wastes is sometimes twice the volume of domestic sewage. Figures are given on volumes and strengths of spinach, apricot, peach, pear and tomato wastes. Experiments showed that the greatest difficulty, that of rising sludge in the clarifiers, might be overcome by large doses of ferric chloride (50 to 70 p.p.m.), or by large doses (250 p.p.m. or more) of lime, with mixing and flocculation, or by heavy chlorination (15 p.p.m. or more). It was felt that chlorination of the waste at the cannery was the most logical treatment.

Digestion.—Fontenelli (66) has described digester troubles due to wastes from a chemical plant, the pH value of which ranged from 1.3 to 10.9. Heavy lime application was tried, but it was eventually necessary to withdraw most of the sludge from the primary digesters, and to build up new sludge by operating them as secondary digesters for a period, after which controlled additions of fresh solids were made. After 23 days, the digesters were restored to normal operation.

Chemical Precipitation.—Halifax sewage, containing 40 per cent of soapy and greasy textile wastes, has been treated for many years with sulfuric acid for grease recovery. Lumb and Barnes (118) found that the addition of 5 to 10 parts of hydrated aluminum sulfate (alumino-ferric) resulted in better grease removal with a saving in acid which more than counterbalanced the cost of the alum.

Activated Sludge.—Tyuda (203) has shown experimentally that soapy wastes produce rapid bulking of activated sludge. Wastes containing yeast press juice also cause bulking, whereas dyes and phenols in small concentrations do not. Carbohydrate- and protein-containing wastes are more readily purified by activated sludge than oily wastes. In the carbohydrate and oily wastes the pH shifted to the acid side during aeration, in the protein wastes to the alkaline side.

Trickling Filters.—According to Wittmer (227), the town of Marysville, O., found it necessary to use two stages of trickling filtration to handle peak loads of combined sewage and milk waste. The effluent from these filters was treated on sand beds.

Stewart (188) reports that gas plant waste from which only the tar had been recovered interfered with efficient operation of the Fargo, N. D., sewage treatment plant. Studies indicated that the phenols of the waste were not responsible, and suspicion was directed toward the tar acids and residues, which tend to accumulate on the rock film, and by destroying the bacterial flora, produce sloughing. Since the flow from the gas plant was fairly steady over a 24-hour period, the night sewage flow contained a higher proportion of gas plant waste. The gas plant was induced to store the liquor during the night, discharging only between 8 A.M. and 8 P.M. Better results were obtained by using only one-half of the trickling filter at a time, changing over when the accumulation of tarry residues was noted. The inactive portion of the filter appeared to clear itself of the residues within a reasonable time.

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GRIT CHAMBER DESIGN

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In America it is common practice to design grit chambers to remove grit in such a way as to avoid the inclusion of excess amounts of putrescible organic solids with the grit. Most grit chambers so designed have a velocity of 0.5 to 1.0 ft. per sec. and a detention period of about one minute. The American type grit chamber has a two-fold function: (1) to remove the grit from the sewage, and (2) to separate the grit from the putrescibles so that it may be disposed of without nuisance. The mechanism of this process has not been well understood in practice and has generally been referred to as "differential settling." There are in fact two processes at work: (1) settling of both grit and organics which is "differential" only in the sense that grit settles faster than most of the organic particles, and (2) "scour" or "bed-load movement" of the settled solids which is more effective in separating the organics than settling. It is the purpose of this paper to describe methods of design to take full advantage of both processes.

The material which may be appropriately classified as grit varies from plant to plant and includes sand, silt, coal dust, coffee grounds, fruit seeds, etc. Much of the grit is organic, but if it is not putrescible it may be disposed of readily as fill. Most of the putrescible organic solids are light and flocculent and may be separated from the grit in a properly designed grit chamber. The failure to obtain effective separation has led to the utilization in recent years of supplementary apparatus for washing the grit during or after removal from the grit chamber. The use of grit washers is necessary for some sewage and it is desirable if a very clean grit is required. However, the load on the washer may be reduced and the need for a washer may in some cases be eliminated if the grit chamber itself is designed to function more effectively in separating the putrescibles.

The most important function of the grit chamber is to remove grit from the sewage. Experience has indicated that if the chamber will remove all sand 0.2 mm. in size and larger (material retained on a 65-mesh sieve) it will remove most of the grit which gives trouble in treatment plants. Hence 0.2 mm. sand has been adopted by several designers as a limiting size for grit chamber design. In some exceptional cases the chambers may be required to remove material which settles more slowly than 0.2 mm. sand. Fig. 1 (1) shows experimental values for the settling velocity of quartz spheres and of sand. The settling velocity of 0.2 mm. sand is about 2.3 cm. per sec. $\left(\frac{2.3}{30.48} = 0.075 \text{ ft. per sec.}\right)$ but varies with the temperature and grain shape.

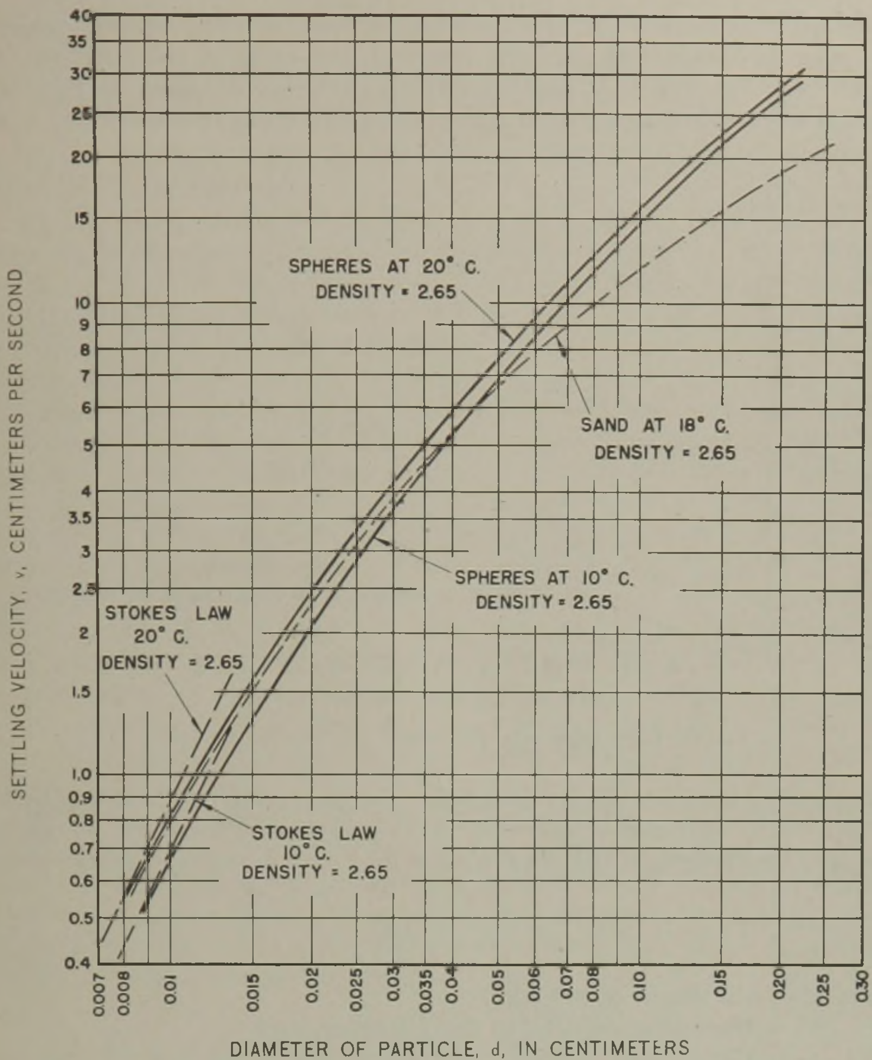

Fig. 1.

Figure 2 shows the settling velocity analysis of a sample of grit taken from the Leominster, Mass., grit chambers which are typical American type chambers. This sample was washed to remove putrescibles before the settling analysis was made. It will be noted that only about 7 per cent of this grit has a settling velocity less than that of 0.2 mm. sand, and that the non-washable organics amount to about 5 per cent of the grit.

A grit chamber may be designed to remove all particles which settle at velocities in excess of any particular value by a very simple method if it be assumed that the velocity of the sewage is the same in all parts of the chamber and there are no eddies. If these assumptions were true, all particles having the same settling velocity would settle along parallel paths from the inlet end towards the bottom as shown in Fig. 3. These paths are the resultant of the chamber velocity and the settling velocity. In order to obtain 100 per cent removal, the ratio of the length to the depth must be such that particles which enter the chamber at the water surface will settle along a path which will carry them to the bottom at the

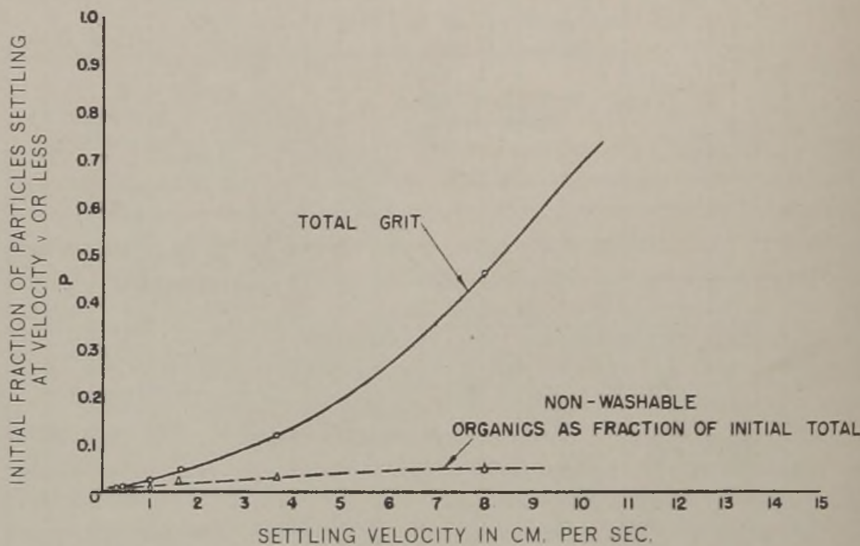

Fig. 2.—Settling velocity analysis of typical sewage grit.

outlet end of the effective settling zone. Such a path is that taken by the particle with settling velocity v_0 in the figure. Therefore, by similar triangles, the length of the effective settling zone in a grit chamber should be

$$L = \frac{V}{v_0} H \tag{1}$$

where H = the depth of sewage,
V = the mean velocity in the chamber, and
v_0 = the settling velocity of the particle to be just 100 per cent removed.

v_0 is sometimes called the "overflow rate," and it may be expressed as rate of flow per unit of surface area for chambers whose side walls are vertical.

Suppose for example, the depth H is 4 ft. and the velocity is 1.0 ft. per second. Then to remove all sand 0.2 mm. in size and larger, the effective

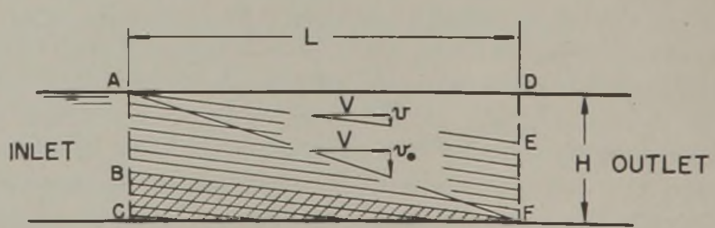

Fig. 3.

length of the grit chamber must be

$$L = \frac{1.0}{0.075} \times 4.0 = 53.3 \text{ ft.}$$

Since the velocity is 1.0 ft. per sec., the detention period in this chamber would be 53.3 seconds.

In an actual chamber the velocity is not the same at all points and there are eddies due to turbulence which retard settling. Experimental and theoretical studies reveal, however, that the error caused by these assumptions is of no practical significance for the settling of grit in American type grit chambers, provided the grit remains on the bottom when it reaches there.

Particles which settle with velocities, v, less than v_0 will be only partially removed in the chamber. In Fig. 3, such particles which enter the chamber above point b will be carried through the chamber, but those which enter below b will reach the bottom.

It will be noted that there is nothing in Equation (1) which establishes the chamber velocity V. Other things being equal a change in V would require a proportional change in the length L to obtain the same performance. In fact, a considerable change in velocity and length could be made with little effect on performance if the material which reaches the bottom would all remain there. An increase in velocity, however, increases the scour of the settled material. It is the scouring process therefore which determines the best velocity for the chamber and not the settling process.

In a theoretical study and extensive experiments by Shields (2) on the movement of granular materials by a flowing stream, a relation has been found for the "critical tractive force" required to start scour of material of a given size and density. Since the mean tractive force or shear on the walls and floor of a channel is related to the mean velocity of the stream, Shields' findings may be expressed as follows:

$$V_c = \sqrt{\frac{8B}{f} g(s - 1)d} \qquad (2)$$

in which V_c = the "critical velocity" required to start scour of particles whose size is d and specific gravity is s,

g = the acceleration of gravity,

f = the Weisbach-Darcy "friction factor" which may be taken at about 0.03 for grit chambers.

B = an experimental constant the value of which was found by Shields to be about 0.04 for unigranular material. For non-uniform and sticky material like grit a value of about 0.06 is probably safe for design.

As an example of the use of Equation (2), let it be required to estimate the limiting grit chamber velocity which will avoid scour of 0.2 mm. sand. The value of $d = \frac{0.2}{304.8} = 0.00066$ ft., $s = 2.65$ and $g = 32.2$ ft. per sec.^{2}

Therefore

$$V_c = \sqrt{\frac{8 \times 0.06}{0.03} \times 32.2\ (2.65\text{–}1)\ 0.00066} = 0.75 \text{ ft. per sec.}$$

From Equation (2) it may be seen that the relative size of organic particles and sand particles which will be scoured at the same velocity is $\frac{1.65}{s_p - 1}$ where s_p is the specific gravity of the putrescibles. Hence organic particles 8, 16 and 33 times as large as the sand will be scoured if their specific gravities are respectively 1.2, 1.1 and 1.05.

Now if the grit chamber velocity is made 1.5 ft. per sec. instead of 0.75, Equation (2) shows that particles four times as large will be started in motion along the bottom. Thus it may be seen why velocities from about 0.5 to 1.2 ft. per sec. have been found satisfactory in American grit

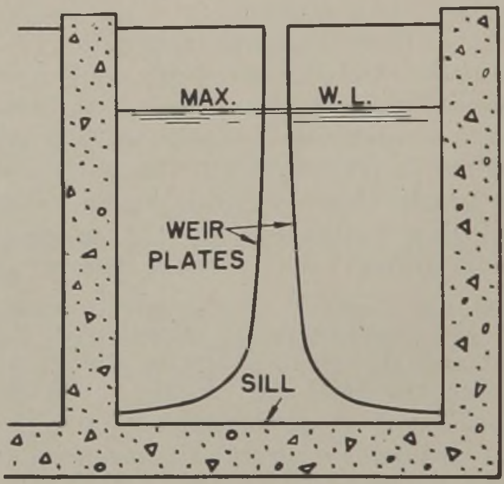

Fig. 4.—Sutro weir.

chamber practice. It will be noted from Equation (2) that the depth does not influence scour, although it does affect settling.

One of the principal difficulties in the design of a grit chamber is to maintain an optimum velocity regardless of the rate of flow through the plant. In older plants this was attempted by designing the chambers with a relatively constant depth and throwing chambers in or out of service as the flow changed. Obviously, this method requires that the number of chambers be proportional to the ratio of peak to minimum flow and that many of the chambers be out of service most of the time. An improvement on this method is the provision of a "control section" at the outlet end of a chamber designed to maintain a constant velocity in the chamber by properly varying the depth as the flow changes.

One of the most satisfactory types of control sections is the Sutro weir shown in Fig. 4. The shape of the opening between the plates of a Sutro weir is made so that the chamber depth will vary directly as the discharge when the sill of the weir is level with the bottom of the chamber. Hence the velocity will be maintained constant in a chamber of rectangular cross section. The theory of the Sutro weir was presented by E. A. Pratt (3) in 1914. Since the Sutro weir will not function properly if the sill is submerged by the tail water, it is necessary to provide for a head loss below the weir equal to the maximum depth in the grit chamber. Sutro weirs are being widely used today.

Another type of control section which has been used in a few plants is the "rectangular control section." The "Parshall flume" is a special type of rectangular control section which is conveniently used for flow measurement because the discharge coefficients are well-known through extensive measurements by R. L. Parshall (4). A peculiar feature of the Parshall flume is that head measurements are made on the side of the approach transition to the throat and the measured head does not include the velocity head. If the discharge through a rectangular control section is written in terms of the total head, the following relation holds:

$$Q = cbH^{3/2} \tag{3}$$

where Q = the rate of discharge,
c = the discharge coefficient whose value depends upon the shapes of the inlet and outlet transition (c = about 3.5),
b = the throat width, and
H = the total head at the throat.

If a rectangular control section is used to control the depth in a grit chamber, H may be taken equal to the depth in the chamber if the bottom is level with the invert at the throat. This is true because the velocity head in grit chambers is less than about 0.015 ft. and may be safely neglected. With this assumption it may be seen from Equation (3) that the discharge varies as the 3/2 power of the depth in the chamber. Hence a rectangular control section will not maintain a constant velocity in a grit chamber of rectangular cross section. Since $V = \frac{Q}{WH}$ where W is the width of a rectangular grit chamber, it may be seen from Equation (3) that

$$\frac{V_{\text{max.}}}{V_{\text{min.}}} = \sqrt[3]{\frac{Q_{\text{max.}}}{Q_{\text{min.}}}} \tag{4}$$

where $\frac{V_{\text{max.}}}{V_{\text{min.}}}$ = the ratio of the maximum to the minimum velocity in the chamber, and

$\frac{Q_{\text{max.}}}{Q_{\text{min.}}}$ = the ratio of the maximum to the minimum discharge.

For example, if the flow varies by a 5 to 1 ratio the minimum velocity will be 58.5 per cent of the maximum. Hence a rectangular control section is not satisfactory for velocity control in a grit chamber of rectangular cross section unless the discharge remains relatively constant.

A rectangular control section may be employed with eminent satisfaction, however, if the cross section of the grit chamber be shaped to maintain a constant velocity. This idea has been developed by the author and is protected by letters patent (5). There are a number of advantages

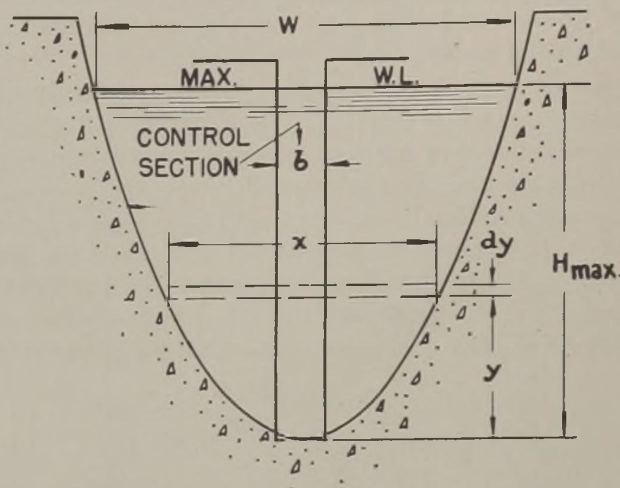

FIG. 5.

in using rectangular control sections which do not exist with Sutro weirs, as will be shown later. From Fig. 5, it may be seen that the cross-section area for any shape of grit chamber is

$$A = \int_0^H xdy \tag{5}$$

and since $Q = AV$,

$$Q = V \int_0^H xdy \tag{6}$$

The value of Q may be equated to the value of Q from Equation (3) with the following result:

$$\int_0^H xdy = \frac{cb}{V} H^{3/2} \tag{7}$$

In order to maintain a constant value for the velocity V, an expression for x in terms of y must be found for the integral which will produce the expression on the right side of the equality sign. The value of this expression is

$$x = \frac{3}{2} \frac{cb}{V} \sqrt{y} \tag{8}$$

Since this is the equation of a parabola, it follows that a rectangular control section of throat width b will maintain any constant velocity V in a grit chamber of parabolic shape conforming to Equation (8). In practice, it is not necessary to conform accurately to the theoretical profile. A shape such as shown in Fig. 6 will produce a nearly constant velocity, is simpler to construct and provides for grit removal blades.

American type grit chambers are now usually built with racks at the upstream end. If a control section is used for the grit chamber it will also control the velocity in the rack chamber. The velocity in the rack chamber should not be less than about 1.25 ft. per sec. at $Q_{min.}$ to avoid grit deposits nor more than about 3.0 ft. per sec. at any flow to avoid carrying screenings through the bars. The water level in the rack chamber will be higher than in the grit chamber by the head lost through the racks, and if the racks are kept clean by mechanical rakes this difference in level may be neglected in the hydraulic design.

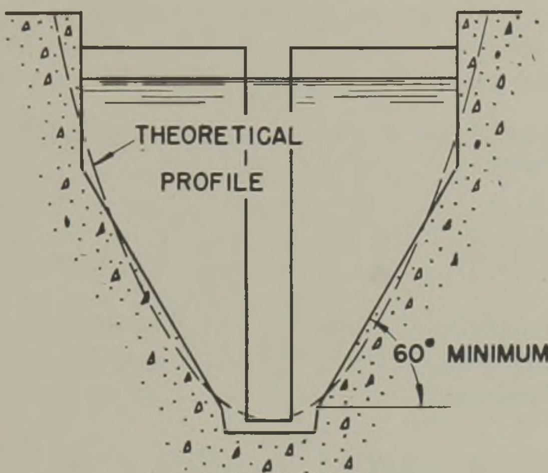

Fig. 6.

The maximum water level in the chambers should be established in design to cause as much "back-water" in the sewer at $Q_{max.}$ as is permitted by sewer velocity considerations. Back-water will reduce the sewer velocity, but so long as there is no back-water at $Q_{min.}$ there should be no trouble from deposits in the sewer. The purpose of establishing back-water at $Q_{max.}$ is to avoid or reduce the extent of "shooting flow" into the chamber at $Q_{min.}$. The cross-section area of the chambers must be greater than that of the sewer to effect the required reduction in velocity. The increase in area might be provided wholly through an increase in width except for the fact that too many grit chambers would usually be required. The dimensions of a single grit chamber should be such that the side wall slope is preferably not less than about 60° with the horizontal in order to keep the walls clean. This requirement limits the width W to about 25 per cent greater than the maximum depth $H_{max.}$.

From Equations (3) and (8) the depth $H_{max.}$ may be expressed as follows:

$$H_{max.} = \frac{1}{W} \frac{3}{2} \frac{Q_{max.}}{V} \tag{9}$$

and if W is made equal to 1.25 $H_{max.}$, the depth of each grit chamber in which the maximum flow is $Q_{max.}$ is

$$H_{max.} = 1.1\sqrt{\frac{Q_{max.}}{V}}. \tag{10}$$

The dimensions of the rack chamber may be established by the following procedure:

$$Q_{min.} = V_{R_{min.}} W_R H_R \tag{11}$$

and

$$Q_{max.} = V_{R_{max.}} W_R (H_R + \Delta H) \tag{12}$$

where ΔH = the change in water level in the rack chamber between $Q_{max.}$ and $Q_{min.}$ as determined from the grit chamber design,
H_R = the depth in the rack chamber at $Q_{min.}$, and
W_R and V_R = the width of and the velocity in the rack chamber.

If Equations (11) and (12) are solved simultaneously, the minimum depth in the rack chamber is

$$H_R = \frac{\Delta H}{\left(\frac{V_{R_{min.}}}{V_{R_{max.}}} \times \frac{Q_{max.}}{Q_{min.}}\right) - 1}. \tag{13}$$

A typical example is illustrated in Fig. 7 in which a 45-in. sewer discharges through one rack chamber into two parallel grit chambers. In

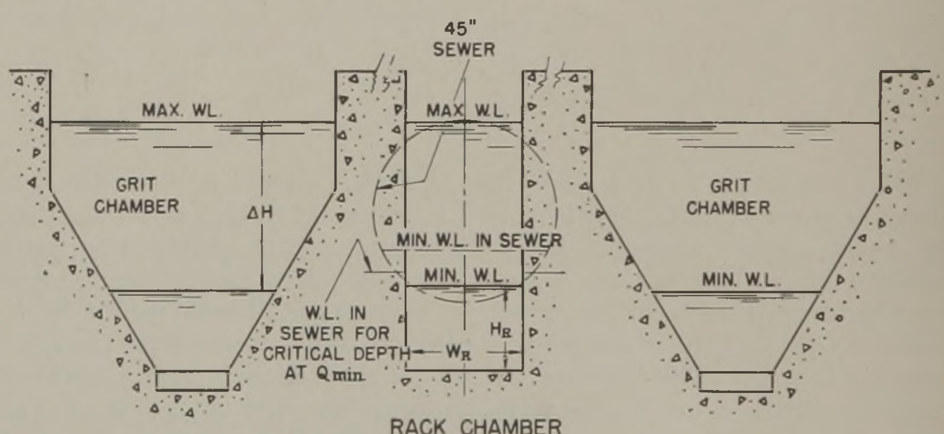

FIG. 7.

this example, $Q_{max.}$ = 25.0 cu. ft. per sec. and $Q_{min.}$ = 5.0 cu. ft. per sec. for the sewer and rack chamber. The velocity V in the grit chambers was set at 0.5 ft. per second. From (10),

$$H_{max.} = 1.1\sqrt{\frac{12.5}{0.5}} = 5.5 \text{ ft.}$$

For each grit chamber $W = 1.25 \times 5.5 = 6.87$ ft. From (3) the throat width $b = \dfrac{12.5}{3.5 \times 5.5^{3/2}} = 0.28$ ft. The shape of the grit chamber was determined from (8). From (3)

$$H_{\text{min.}} = H_{\text{max.}} \left(\frac{Q_{\text{min.}}}{Q_{\text{max.}}} \right)^{2/3} = 5.5 \left(\frac{2.5}{12.5} \right)^{2/3} = 1.72 \text{ ft.}$$

Hence $\Delta H = 5.5 - 1.72 = 3.78$ ft. For the rack chamber, $V_{R_{\text{min.}}}$ was set at 1.25 ft. per sec. and $V_{R_{\text{max.}}}$ at 2.0 ft. per second. From (13),

$$H_R = \frac{3.78}{\left(\frac{1.25}{2.0} \times \frac{25}{5} \right) - 1} = 1.78 \text{ ft.}$$

and from (11),

$$W_R = \frac{5.0}{1.25 \times 1.78} = 2.25 \text{ ft.}$$

It will be noted in Fig. 7 that the uniform-flow level in the sewer at $Q_{\text{min.}}$ is about 1.0 ft. higher than the minimum water level in the rack chamber. There will be a drawdown of the water surface in the sewer at $Q_{\text{min.}}$, therefore; and, since the water level for critical depth at the end of the sewer is also higher than the water surface in the rack chambers, the flow will pass to lower stage in the rack chamber which will be followed by a jump. The jump may be avoided by submerging the sewer 0.6 to 1.0 ft. If it is impractical to avoid the jump, it should be made to occur just downstream from the sewer by means of a depression in the chamber invert.

The optimum velocity for the grit chamber cannot be determined accurately by the designer before the chamber is built and it may change as the character of the sewage changes. In the above example, the velocity was fixed arbitrarily at 0.5 ft. per sec. by fixing the throat width at 0.28 ft. A velocity of 0.9 ft. per sec., for instance, might give better results; but there is no way of discovering this fact unless the plant operator can change the velocity after the chamber is in operation. From Equations (5) and (7) it will be noted that

$$V = b \left(\frac{cH^{3/2}}{A} \right) \tag{14}$$

For any depth H the quantity in parentheses is constant after the chamber is built. Hence if b is made adjustable, a change in the width of the throat will produce a proportional change in the grit chamber velocity. A change in velocity can thus be readily effected by means of an adjustable rectangular control section (6). Such a device is illustrated diagrammatically in Fig. 8. The adjustable feature is an advantage not possessed by Sutro weirs.

If the width b in the previous example be changed to 0.7 ft., the new velocity from (14) is

$$V' = \frac{0.7}{0.28} \times 0.5 = 1.25 \text{ ft. per sec.}$$

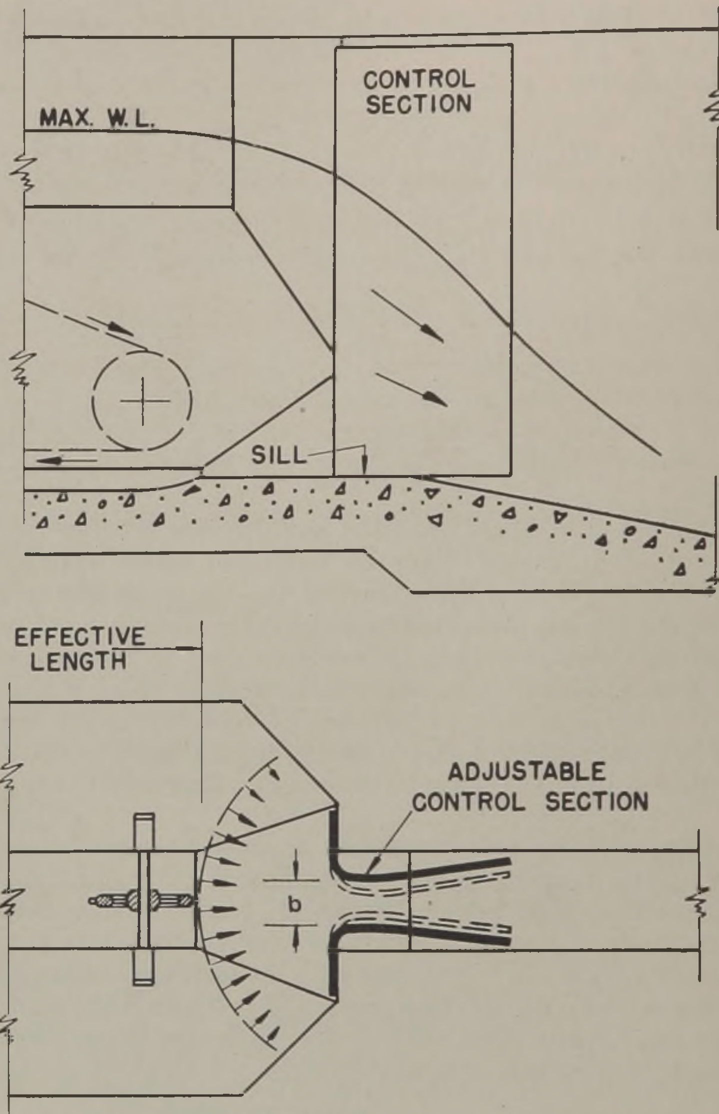

FIG. 8.

From (3) the new values of

$$H'_{\text{max.}} = \left(\frac{12.5}{3.5 \times 0.7}\right)^{2/3} = 2.96 \text{ ft.}$$

and

$$H'_{\text{min.}} = \left(\frac{2.5}{3.5 \times 0.7}\right)^{2/3} = 1.01 \text{ ft.}$$

There will be a corresponding reduction in depth at the rack chamber, so that $H'_R = 1.78 - (1.72 - 1.01) = 1.07$ ft. and $H'_R + \Delta H' = 1.07 + 1.95 = 3.02$ ft. The velocities in the rack chamber will therefore vary with the flow between 2.1 and 3.7 ft. per sec. when the throat width is set at 0.7 ft.

The hydraulic profiles in the grit chambers for both velocities are shown in Fig. 9. The effluent channel in this example is designed with a minimum velocity of 1.0 ft. per sec. and a maximum velocity of 4.17 ft. per second. The elevation of the invert of the effluent channel should be so fixed with reference to the sill of the control section that the control is not submerged more than about two-thirds the head H at minimum dis-

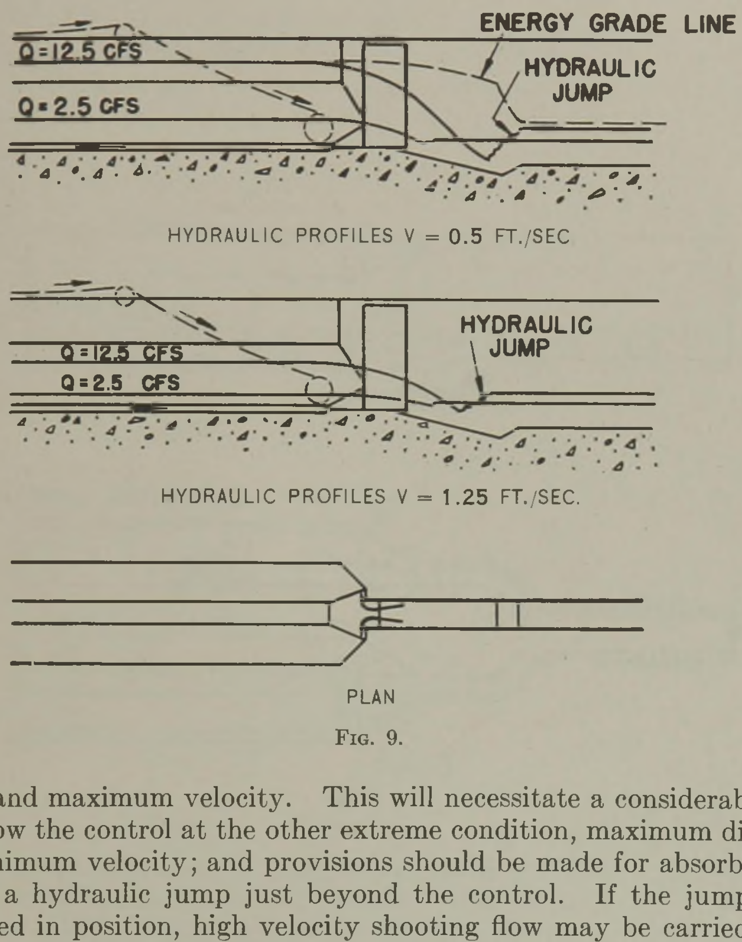

Fig. 9.

charge and maximum velocity. This will necessitate a considerable head loss below the control at the other extreme condition, maximum discharge and minimum velocity; and provisions should be made for absorbing this loss by a hydraulic jump just beyond the control. If the jump is not thus fixed in position, high velocity shooting flow may be carried downstream into the settling tanks.

In this example it has been possible to submerge the sill of the control section by more than 1 ft. with the maximum tail water depth without impairing its function. This is an advantage of rectangular controls over Sutro weirs where head is at a premium. A greater saving in head can be effected if the variation in discharge is less and the range for velocity regulation is made narrower.

It has been claimed that the use of Sutro weirs results in very high velocities at the sill which result in scouring grit from the chamber. The velocity at the sill is very high for both Sutro weirs and rectangular control sections. The sewage approaches the opening radially, however, as shown in Fig. 8; and the velocity a short distance in front of the throat is very low. The magnitude of the velocity may be estimated by dividing $Q_{max.}$ by the area of the surface through which the sewage flows. The velocity along the arc in Fig. 8 is approximately the same as the mean for the grit chamber. The effective length of the grit chamber may be taken to this arc.

At the inlet end of the grit chamber there is an expanding or diverging flow as the velocity decreases. This expansion takes place at an angle of about $7\frac{1}{2}°$ with the axis on each side for a rectangular cross section, and, if the walls diverge at a greater angle, separation and eddies will occur at the walls. It is probably not worth-while to build the walls to conform

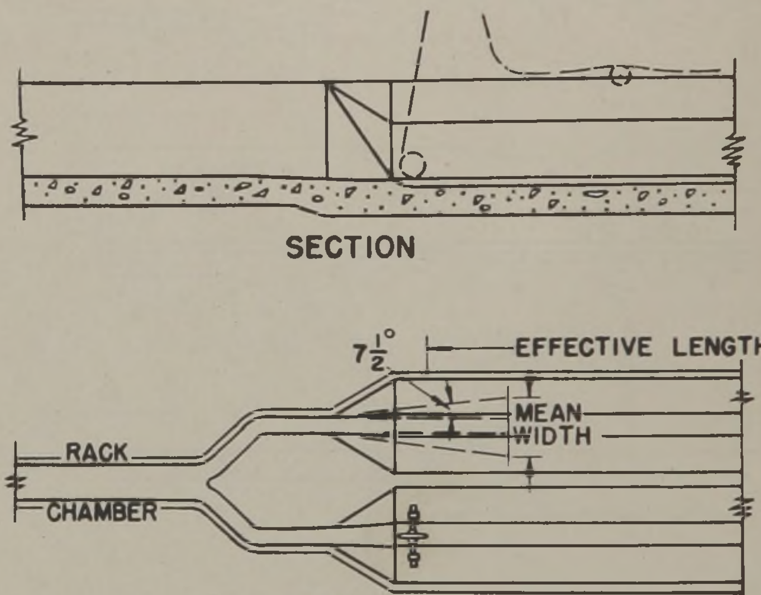

Fig. 10.

to the $7\frac{1}{2}°$ angle, but it is necessary to take account of the length of the transition in fixing the effective settling length. Since the grit chambers considered here are not rectangular in cross section, it is safe to assume that the expansion is complete at the mean width of the chamber. The expanding section is not wholly ineffective for settling grit, however, and about half its length may be used as part of the effective settling length as shown in Fig. 10. The effective settling length should be computed from Equation (1) for the maximum value of the product VH. In the example considered above $L = \frac{1.25}{0.075} \times 2.96 = 49.3$ ft. for complete removal of 0.2 mm. sand. Better settling will take place at all other flow conditions.

Any type of control section if properly installed and properly calibrated can serve as a flow meter for the sewage. Parshall flumes are used principally for this purpose in lieu of Venturi meters, and registers are commercially available. Control sections are superior to Venturi tubes for sewage flow measurement especially where head is scarce, but they are also cheaper in first cost. When a control section is used for the dual purpose of grit chamber velocity control and flow measurement, an appreciable saving in first cost can be had. Flow registers now available for rectangular control sections can be readily adapted to the adjustable width control, since the discharge varries directly as the throat width for any depth of sewage in the chamber.

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Industrial Wastes

TREATMENT OF DISTILLERY WASTES *

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The wastes from whiskey distilleries, called "slop," must be treated because of their injurious effect on marine life, creation of disagreeable odors, and development of unsightly conditions if discharged in large quantities into streams. Slop from the still constitutes the only waste of any volume and strength from a distillery operating on cereal grains.

This is a report of an investigation of the treatment of still slop from the Baltimore Pure Rye Distillery at Dundalk, Maryland. The choice of treatment of rye whiskey waste, instead of that from bourbon or mixtures of the two, was made because the slop from rye is the most difficult to treat. If it were possible to treat the rye wastes economically, treatment of the other types would be commercially feasible.

An indication of the problem can be seen by comparing the respective B.O.D. of sewage and of slop. The B.O.D. of domestic sewage (1) usually averages about 150 to 200 parts per million; that of still slop from 15,000 to 20,000 p.p.m. The problem, therefore, is to treat the slop to such an extent that the oxygen required by the treated waste will not interfere with fish life and that the dissolved and undissolved solids dumped into the stream will not cause any odors or nuisance.

Methods of Treatment

A number of methods of treatment have been suggested but as yet only a few are actually used.

Methods Proposed.—One (2) of the methods suggested is that of anaerobic digestion. This consists of bacterial decomposition of the organic matter in the slop, under controlled acidity and rate of flow, into methane and carbon dioxide, which mixture is used for heating purposes.

Another method (3, 4) suggested is the use of trickling filters along with sedimentation facilities.

A few plants filter the still slop of 4.0 to 7.0 per cent solids through screens of 20 to 40 mesh, dry the filtered solids, and dump the rest of the slop, called thin slop, into a near-by stream. These dried solids are valuable as cattle feed, but not as valuable as the soluble solids. This procedure effects a reduction of but 25 to 35 per cent in B.O.D. In certain places (4) the slop is spread over the ground and utilized as a fertilizer

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material or else as liquid cattle feed. These methods are applicable only for certain small plants in non-congested areas.

A study was made at Rutgers University using electrodialysis (5). The Industrial Associates, Inc., suggest (6) spray drying of the slop as a means of treatment.

Methods Used Commercially.—The usual method of meeting the slop problem is by first screening through a 20 to 40 mesh screen. The thin slop is then evaporated in multiple-effect evaporators and mixed with the filtered grain particles which have been pressed and dried. The mixture is further dried to about 10 per cent moisture and sold as cattle feed. The B.O.D. of the effluent from this treatment is from 50 to 100 p.p.m.

The chief difficulty in this procedure occurs during the evaporation of the screened thin slop. The fine colloidal particles in the slop gradually form a coating in the evaporator tubes which decreases the effective heat transfer coefficient, in turn causing a further clogging of the tubes.

This process can be made more economical if the solid content of the syrup from the multiple effect evaporator is increased, since it costs less to remove water in an evaporator than in a drier. Experimental data show that in the drier, for every pound of steam used, only 0.6 (7) to 0.75 (8) pound of evaporation is obtained; whereas, in the evaporator, for every pound of steam used, 2.5 (7) to 4.0 (8) pounds of evaporation are obtained. The range of 2.5 to 4.0 depends upon the number of effects in the evaporator.

Another advantage of utilizing the evaporator to increase the solid content of the thin slop to a maximum lies in the fact that operation in the drier is successful only when the solid content of the mixture of syrup and wet grain is above 40 per cent. This means that due to the high water content of the syrup and its greater per cent, by weight, in the mixture of syrup and pressed grain, additional grain of very low water content must be added to raise the solid content of the mixture entering the inlet of the drier. This additional dry grain must, of course, come from the outlet of the drier.

For example, at the Calvert Distillery in Maryland, for every 113,000 pounds of press cake, containing 28 per cent solids, produced daily, 165,000 pounds of syrup, having a water content of 72 per cent, come from the evaporator. This means that a mixture of the two yields a mass weighing 278,000 pounds with 72 per cent moisture. Therefore, 60,000 pounds of product having 92 per cent solids ($\frac{3}{4}$ of the total) must be recirculated, so that the material entering the drier has a solid content greater than 40 per cent. In other words, the capacity of the drier must be much larger than would be the case if no grain were recirculated.

In the preceding discussion the data presented deal with the slop of bourbon mashes. In all these operations much greater difficulties arise in treating slop from rye whiskey than from bourbon. This is especially true in the screening and evaporating processes. This is due to the rye protein being more hydrophilic (hygroscopic) and adhesive than that of bourbon mashes.

Two methods are now being used to reduce the colloidal particle content of the screened slop so that the slop can be evaporated to a higher solid content in the multiple-effect evaporators.

One method (9) used at the Hiram Walker plant at Peoria, Illinois, consists of centrifuging the thin slop, instead of passing it directly to the first effect of the multiple-effect evaporator. This removes 0.5 per cent of the 3.7 per cent solids in the thin slop. By removal of this amount of solids, the screened and centrifuged slop can then be evaporated up to 60 per cent solids, instead of 25, before it becomes too viscous to handle.

Another method (10) in removing the fine solids of the slop before evaporation is that of heating the slop momentarily with live steam and then filtering the coagulated suspended solids.

A similar treatment system (11) has been installed by the Sharples Corporation at Linfield, Pennsylvania.

Experimental Method

The procedure used here in the removal of the insoluble solids was that of chemical treatment, followed by filtration.

Technique and Apparatus.—The experimental work consisted of treating the thin slop with varying amounts of different chemicals and determining the respective filtering rates using suction. The main objective was to find the cheapest and most feasible method of removing the fine colloidal insoluble solids from the thin slop so that it would be easier to evaporate.

The chemicals were added to 500 cc. of slop, which was kept at 88 to 92° C., the mixture stirred at constant speed for five minutes and cooked for five additional minutes. Then a 65 cc. portion was taken from the treated thin slop and filtered through a No. 1 Whatman paper in a Buechner funnel.

On all runs, the following data were taken:

1. Solid content of the thin slop.
2. Amounts of chemicals used.
3. Temperature of the thin slop when filtering started.
4. Maximum suction obtained while filtering.
5. Solid content of the cake on the filter paper.
6. Time of filtering necessary to produce a filter cake of 40 per cent solid content.

In measuring the filtering times, experience made it possible to judge fairly well when the cake was about 40 per cent solids.

Besides these data, each day several determinations were made on the solid content of the treated thin slop so as to get an indication of the effective removal of the colloids in the thin slop.

The general inferences from colloidal chemistry texts, the work of Charles R. Hoover,[6] and discussion of this problem with Dr. Goldheim of Oldetyme Distillery at Cedarhurst, Maryland, and Dr. Wight of Penniman and Brown in Baltimore, both of whom had worked previously with chemical treatment of distillery slop, resulted in consideration of the use of the following chemicals:

1. Zinc or ferric chloride.
2. Phosphate fertilizer.
3. Phosphoric acid and lime (calcium hydroxide).
4. Bone black.
5. Calcium dibasic phosphate ($CaHPO_4$).
6. Alum and other aluminum salts.
7. Ammonium sulfate.
8. Waste liquor from steel mills and lime.
9. Crystal violet or fuchsin.
10. Multivalent salts of tartrates, acetates, or citrates.
11. Lime, sulfuric acid, or a combination of both.
12. Calcium sulfate.
13. Calcium carbonate.
14. Fullers earth.

In the choice of chemicals used, the following points were considered.

1. Toxicity of chemicals to cattle and fowl when taken internally.
2. Cost of chemicals.
3. Solubility of chemicals, since a very soluble chemical would not be carried down completely by the coagulum, thus resulting in a treated thin slop containing chemicals that might be detrimental to the food and commercial values of the dried slop.
4. Value, use, and ease of disposal of the coagulum.

Because of the limited time, only some of the chemicals listed above were used in the experiment. Those which seemed most promising were tried first.

Experimental Data

Lime and Sulfuric Acid.—In the first set of experiments where lime, sulfuric acid, and stoichiometric combinations of the two were used, the following observations were made:

1. If only lime were used, a very bad odor resulted. This is probably due to the decomposition of the organic matter at a high pH.

2. If only sulfuric acid were used, charring of the slop resulted.

3. If both were used, but one added before the other, then either charring or decomposition of the slop resulted. Both these effects were eliminated by simultaneous addition of the two.

4. If dry lime, instead of slaked lime, were added with the sulfuric acid, the filtration rates were decreased four to ten times, depending on both the amount of chemicals used and the solid content of the thin slop treated. This probably is due to the great amount of heat liberated and the chemical reactions involved by the slaking of the lime in the slop.

5. If the lime used were not fresh, i.e., it was wetted by the moisture in the air before slaking, then the filtration would be slowed down 2 to 15 times. This was probably due to incomplete slaking of the lime, which

resulted from a protective calcium hydroxide coating on the lime granules. This, in turn, probably caused incomplete reaction of the acid and lime, in the experiments where the lime used was not fresh, the filtrate from the treatment charred on drying, and a yellowish-white precipitate settled on the bottom of the beaker. The fact that both of these phenomena did not occur when fresh lime was used, tends to corroborate the hypothesis of incomplete reaction. These observations also explain the higher rates of filtration with fresh lime, since in one case a significant portion of the chemicals added did not react and in the other (where fresh lime was used) the reaction was practically complete.

The filtration rates obtained, using fresh slaked lime and sulfuric acid, stoichiometrically, in varying amounts of thin slop of different solid contents, are shown in Table I.

TABLE I.—*Summary of Filtration Rates Using Slaked Lime and Sulfuric Acid in Stoichiometric Amounts*

Thin Slop, Solid Content %	CaO Used Grams*	Time to Get Dry Cake approx. 40% Solids, Min.	Solid Content of Filtrate %
4.8	2.26	15	
4.8	2.46	7.5	
4.8	2.47	3	4.13
4.8	2.65	8	
4.8	2.96	1.16	3.95
4.8	3.46	0.83	
4.61	2.33	11	4.50
4.61	2.66	3.83	
4.61	2.82	1.67	4.07
4.61	2.96	1.5	
4.61	3.29	1	
4.61	3.35	0.83	
4.61	3.53	3.16	
4.43	2.21	18	
4.43	2.30	14.5	
4.43	2.36	8.5	
4.43	2.37	8	
4.43	2.48	7.5	
4.43	2.63	4.25	
4.43	2.69	3.5	4.01
4.43	2.94	2	
4.43	3.08	1.25	
4.43	3.12	1.33	
4.40	2.10	10	4.05
4.40	2.24	6	3.93
4.40	2.46	2.25	
4.40	2.51	2.5	
4.40	2.60	1.75	

For all runs, 65 c.c. of treated slop, at about 75° C., were filtered in a Buechner funnel under suction. If no chemicals were added, more than 30 minutes elapsed and only 20 to 30 c.c. of the 65 c.c. sample would be filtered.

* Grams per 500 c.c. were converted to pounds per thousand gallons, for plotting the graphs, by multiplying by 16.7.

TABLE I (*Contd.*)—*Summary of Filtration Rates Using Slaked Lime and Sulfuric Acid in Stoichiometric Amounts*

Thin Slop, Solid Content %	CaO Used Grams	Time to Get Dry Cake approx. 40% Solids, Min.	Solid Content of Filtrate %
4.40	2.76	2.33	
4.40	2.96	1.5	
4.40	3.19	1.5	
4.40	3.46	1	
4.40	3.89	0.75	
4.30	2.13	13	
4.30	2.16	13.5	4.26
4.30	2.26	11	
4.30	2.36	11	
4.30	2.47	5	
4.30	2.69	2.75	
4.30	2.76	1.33	3.81
4.30	2.86	2.25	
4.30	3.06	1.5	
4.30	3.29	1.33	3.73
4.30	3.54	1.33	
4.28	2.03	18	
4.28	2.27	14	4.05
4.28	2.38	9	
4.28	2.51	4.25	
4.28	2.61	5	
4.28	2.90	4.5	
4.28	3.24	3.33	
4.28	3.56	1.5	
4.28	3.79	4.5 (?)	

(?)—Result here seems much too high for the dosage used.

In comparing the rates of filtration for slop of different solid contents, using the same amounts of chemicals, one may see that the solid content is not highly significant. The technique of mixing the chemicals and the slop may be a greater factor than the solid content of the thin slop in influencing the filtration. Both factors, however, are not as important as the dosages. This may be seen from Fig. 1, which gives a fairly good curve without much scattering of the plotted points.

In actual industrial practice, economy of chemicals might be attained by further experimentation on a plant scale, since pH, stirring time, cooking time, technique of addition and mixing of the chemicals, and other factors affect filtration.

The absolute and relative amounts of solids removed for varying solid contents of thin slop are shown in Table II.

A study of the data in Table II results in the following conclusions:

1. For a definite solid content, increases in dosages result in increases in the removal of the colloidal solids from the slop. With greater rates of filtration, because of greater dosages, greater colloid removals are obtained.

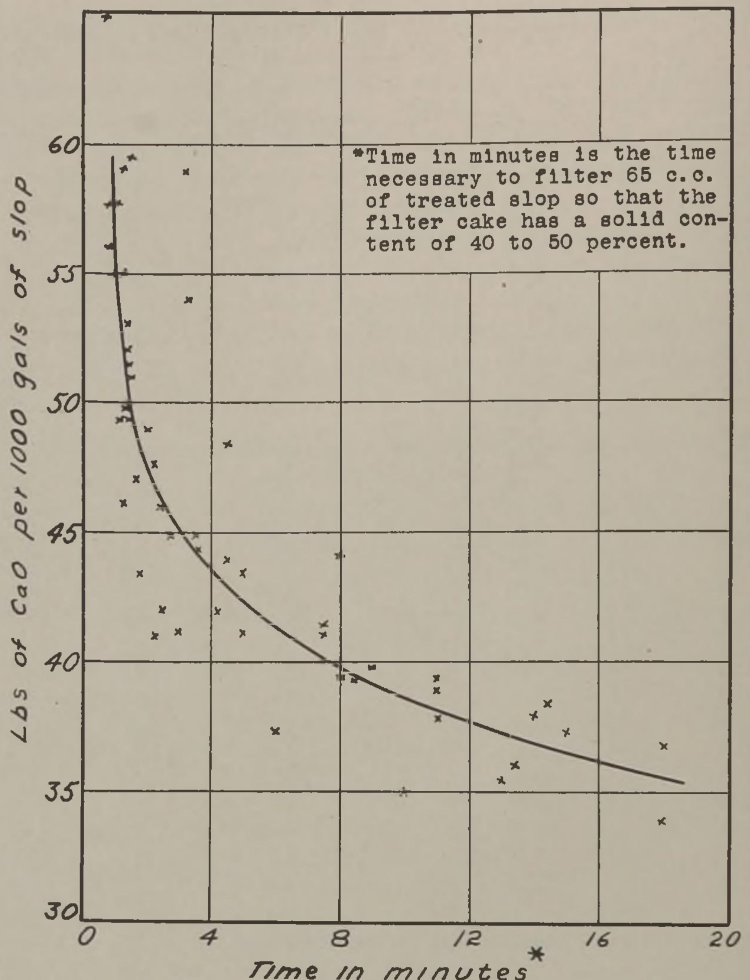

FIG. 1.—Filtration rates using CaO and H_2SO_4.

TABLE II.—*Summary of Effectiveness of Lime and Sulfuric Acid in Removal of Colloidal Solids in Thin Slop*

Thin Slop, Solid Content %	Solid Content After Treatment %	Respective Filtering Time Min.	Solids Removed, Per Cent	
			$CaSO_4$ Solubility Ignored	$CaSO_4$ Solubility Considered
4.8	4.13	3	14.0	17.3
4.8	3.95	1.16	17.7	21.9
4.61	4.50 (?)	11	2.4	6.7
4.61	4.07	1.67	11.7	16.1
4.43	4.01	3.5	9.5	14.0
4.40	4.05	10	7.95	12.5
4.40	3.93	6	10.7	15.2
4.30	4.26	13.5	1.0	5.45
4.30	3.81	1.33	11.4	16.0
4.30	3.73	1.33	13.3	17.9
4.28	4.05	9	5.4	10.0
4.28	3.95	6.5	7.7	12.4

(?)—Seems much too high.

2. For the same filtering time, the slop of higher initial solid content undergoes a greater per cent reduction in solid content than does the slop of lower initial solid content.

3. The *final* solid content of slop having different *original* solid contents, for the same filtering times, tends to approach the same value.

Calcium Sulfate.—For the next series of experiments, calcium sulfate was used. It was added dry, because caking resulted on the bottom of the beaker if added wet, and the additional water added would mean so much more (in commercial practice) water to evaporate.

The filtration rates obtained are shown in Table III.

The data in Table III show that, similar to the results obtained using lime and sulfuric acid, the amount of calcium sulfate needed to give certain filtering times was barely influenced by the solid content of the thin slop. Table III also shows that an increase in dosage causes an increase in the rate of filtration.

TABLE III.—*Summary of Filtration Rates Using Calcium Sulfate*

Thin Slop, Solid Content %	$CaSO_4$ Grams	Time to Get Dry Cake approx. 40% Solids, Min.	Solid Content of Filtrate %
4.65	13.1	13.5	
4.65	15.1	13.5	4.57
4.65	16.1	13	
4.65	19.1	10.5	
4.65	21.1	8.5	4.45
4.65	25.1	6	
4.65	31.1	5	4.40
4.65	37.1	3.5	
4.44	13.1	13	
4.44	15.1	10	
4.44	17.2	9.5	
4.44	19.2	7.5	4.43
4.44	21.2	7	
4.44	23.1	6.25	
4.44	26.1	6	4.32
4.44	29.1	4	
4.44	33.0	3.5	
4.44	37.1	3.67	
4.44	41.2	3	4.13
4.44	45.1	2.08	
4.36	13.5	15	
4.36	17.2	12.5	
4.36	20.7	9	
4.36	25.1	6.5	
4.36	28.6	5.5	4.13
4.36	35.1	4	4.15
4.36	43.0	2.5	
4.08	26.1	6	
4.08	32.1	4.5	
4.08	42.1	2.67	

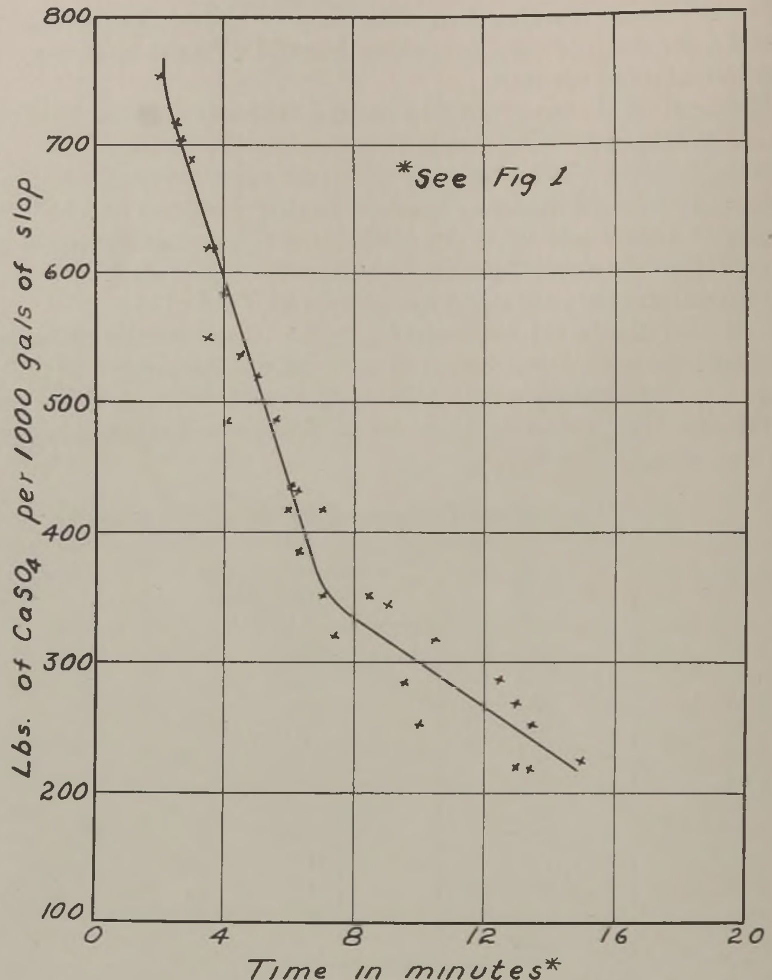

FIG. 2.—Filtration rates using $CaSO_4$.

TABLE IV.—*Summary of Effectiveness of Dry Calcium Sulfate in Removal of Colloidal Solids in Thin Slop*

Thin Slop, Solid Content %	Solid Content After Treatment %	Respective Filtering Time Min.	Solids Removed, Per Cent	
			$CaSO_4$ Solubility Ignored	$CaSO_4$ Solubility Considered
4.65	4.57	13.5	1.72	6.03
4.65	4.45	8.5	4.30	8.6
4.65	4.40	5.0	5.37	9.7
4.44	4.43	7.5	0.0	4.74
4.44	4.32	6	2.7	7.22
4.44	4.13	3	7.0	11.5
4.36	4.13	5.5	5.5	10.1
4.36	4.15	4	4.8	9.7

The results, plotted in Fig. 2, indicate that for best operations, the dosage should be in the region of 350 lb. per thousand gallons.

A tabulation similar to Table II, but using calcium sulfate instead of lime and sulfuric acid, is given in Table IV. Study of Table IV shows that increases in dosages usually cause corresponding increases in the removal of the solid content of the slop.

A comparison of the results with the lime and sulfuric acid treatment and with the dry calcium sulfate treatment is shown in Table V. The data for columns 2 and 3 in Table V are taken from Figs. 4 and 5. The figures in columns 6 and 7 are taken from Tables II and IV.

TABLE V.—*Comparison of Results in Treatment of Thin Slop, Lime and Sulfuric Acid vs. Calcium Sulfate*

Time to Get Dry Cake approx. 40% Solids, Min.	Lb. of Chemicals per Thou. Gal. of Slop			Ratio of Column 4 : 2	Solids Removed, $CaSO_4$ Solubility Ignored %		Ratio Column 7 : 6
	CaO	$CaSO_4$	Equivalent Weight of CaO in $CaSO_4$		CaO and H_2SO_4	$CaSO_4$	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2	47.4	761	314	6.63			
3.5	43.7	624	257	5.88	9.5	7.0*	1.36
6.0	41.4	434	179	4.32	10.7	2.7	3.96
7.5	40.4	344	142	3.51			
9.5	39.1	311	128	3.27			

* Three minutes filtration time.

The following conclusions may be drawn from the data in Table V.

1. For comparative filtration rates, less chemicals are needed with lime and sulfuric acid than with dry calcium sulfate. At the higher rates of filtration, this relationship is more marked.

2. The amount of solids removed, for the same filtration rates, is greater with the use of lime and acid.

Both these phenomena may perhaps be explained by the hypothesis that, when the Ca^{++} ions of the lime unite with the SO_4^{--} ions of the acid to form insoluble $CaSO_4$, they encircle the colloids (and perhaps some soluble solids, too) and encase them in calcium sulfate crystals. In other words, not only is there removal of the solids from the slop by physical means (as is the case when calcium sulfate is used), but also by chemical means, which factor increases in importance with larger doses of chemicals.

Calcium Carbonate.—For the third group of experiments, calcium carbonate ($CaCO_3$) was used. As with the calcium sulfate, the carbonate was added dry.

The data obtained, using the calcium carbonate, are shown in Table VI, and graphically in Fig. 3.

Study of the table and graph indicates that:

1. Increases in dosages cause increases in filtration.

Table VI.—*Summary of Filtration Rates Using Calcium Carbonate*

Thin Slop, Solid Content %	Grams $CaCO_3$ Used	Time to Get Dry Cake approx. 40% Solids, Min.	Solid Content of Filtrate %	Solids Removed %
4.65	10.1	3		
4.65	16.1	1.25		
4.08	4.75	15		
4.08	5.13	11	3.33	18.4
4.08	5.63	6.5		
4.08	7.15	5.67	3.23	20.8
4.08	10.14	2.75		
4.08	11.15	2.33		
4.08	11.84	2.08		
4.08	12.55	1.75	3.15	22.8
4.08	15.13	1.33		
4.08	17.18	1		
4.03	4.74	13.5		
4.03	5.31	10.25	3.28	18.7
4.03	5.66	8.75		
4.03	7.19	5.75	3.16	21.6
4.03	8.26	4.25		
4.03	13.25	1.5	3.07	23.8
4.03	17.20	1		

2. Dosages for best operation are in the range of 85 to 200 lb. per thousand gallons.

3. The present solids removed from the thin slop increase slightly with an increase in dosage.

4. The solid content of the original thin slop does not noticeably affect either the rates of filtration or the per cent of solids removed.

A comparison of the per cent solids removed in the calcium carbonate treatment, with per cent removed in the lime and acid treatment, shows that, for the same rates of filtration, the carbonate treatment is more effective. This is probably due to the effect on pH caused by the carbonate reaction.

Phosphate Fertilizer.—Phosphate fertilizer was also tried. This was discontinued after it was found that the solid content of the filtrate was higher than the initial solid content of thin slop. This effect was more marked with increased dosages.

Activated Alum.—When activated alum was used, it was found that there was no marked aid in the filtration of the thin slop.

Lime and Phosphoric Acid.—Lime and phosphoric acid were used, stoichiometrically, in two different ratios. The final product in one, theoretically, would be the insoluble calcium dibasic phosphate, $CaHPO_4$. In the other, the final product would be the very insoluble tribasic phosphate, $Ca_3(PO_4)_2$.

In the experiments where the tribasic phosphate was theoretically formed, cracking of the cake on the filter paper occurred, resulting in cakes

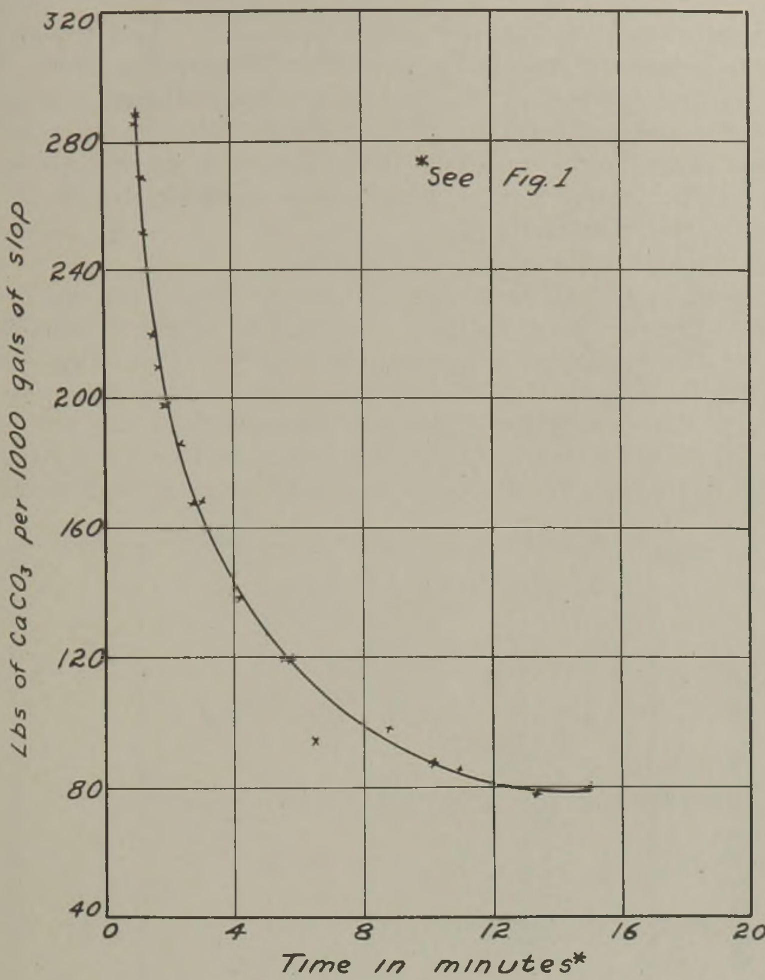

FIG. 3.—Filtration rates using $CaCO_3$.

TABLE VII.—*Summary of Filtration Rates Using Lime and Phosphoric Acid Theoretically Forming Tribasic Phosphate*

Thin Slop, Solid Content %	CaO Used Grams	Solids in Filter Cake %	Time to Get Dry Cake approx. 40% Solids, Min.	Solid Content of Filtrate %†	Solids Removed %
4.50	4.15	33.0	17		
4.50	5.15	28.0*	8.5		
4.50	6.21	30.8	6	3.96	12.0
4.50	7.15	30.2*	4.5		
4.50	8.27	32.6*	2.5	3.20	28.9
4.50	9.5	32.3*	1.83	3.23	28.2
3.82	4.40	25.9	4.5		
3.82	5.22	26.9	4.5		
3.82	8.28	30.7*	2		

* Cracking in the filter cake allowed air to enter into the vacuum chamber, thus preventing removal of water from the cake.

† The solubility of the dissolved phosphate salts was not considered.

of solid contents of not greater than 33 per cent. This would make it difficult to remove the water effectively from the cake in a drier. Another observation made was the formation of an odor reminiscent of the treatment of slop using lime alone. This indicated decomposition of the organic matter in the slop at a high pH. This odor was not noticed when the lime and phosphoric acid were added, stoichiometrically, to yield, supposedly, the dibasic phosphate.

The data are summarized in Table VII.

The most significant fact is brought out in the last column. The per cent solids removed is quite high. Comparing this treatment with the others, for the same filtration rates, one may see that this one is much more effective than all the others. The only exception is the carbonate treatment. Since both the carbonate treatment and this one were accompanied by the increases in pH, it would seem that an increase in pH causes an increase in the effectiveness of solid removal from the slop.

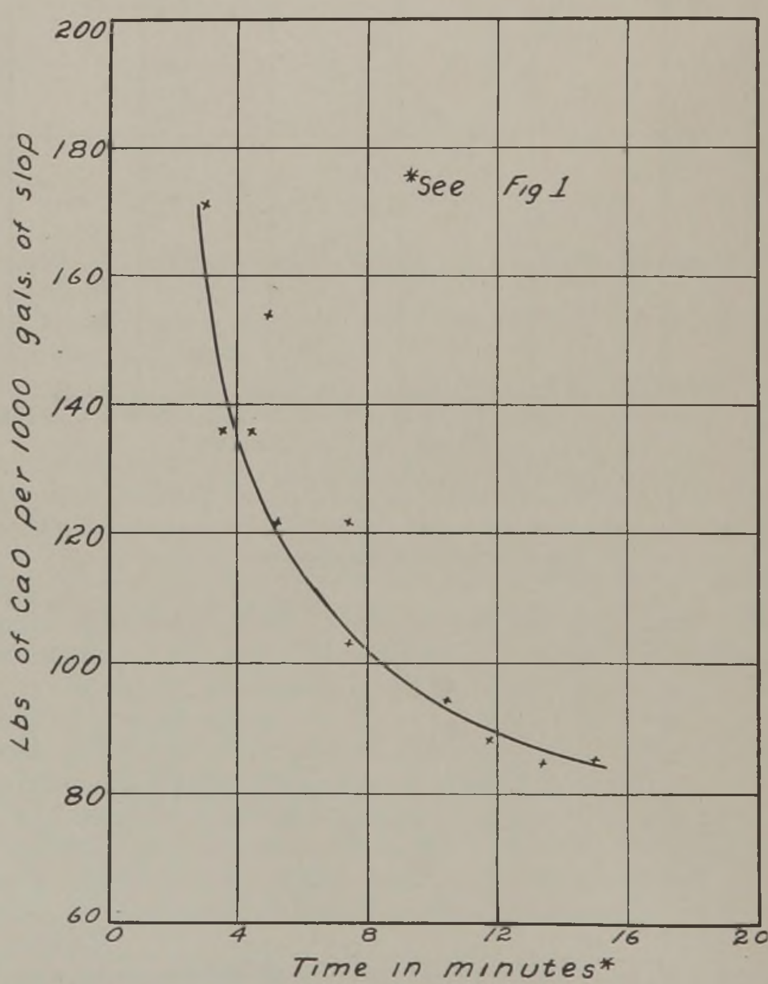

FIG. 4.—Filtration rates using CaO and H_3PO_4.

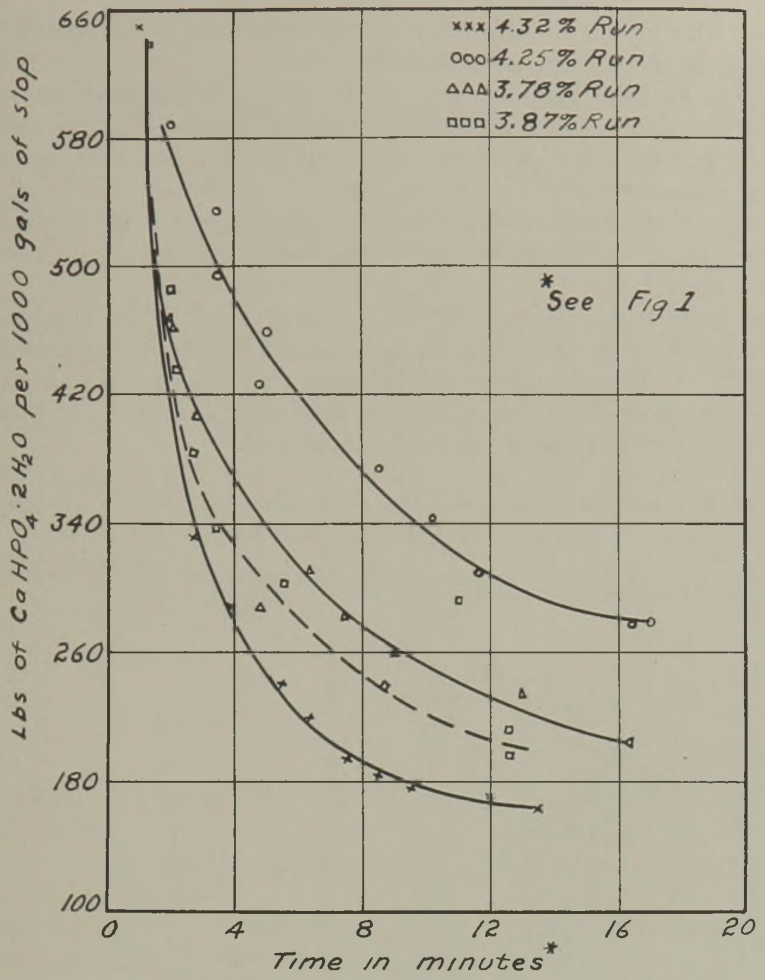

Fig. 5.—Filtration rates using $CaHPO_4$ and $2H_2O$.

Table VIII.—*Summary of Filtration Rates Using Lime and Phosphoric Acid Theoretically Forming Dibasic Phosphate*

Thin Slop, Solid Content %	CaO Used Grams	Time to Get Dry Cake approx. 40% Solids, Min.	Solid Content of Filtrate %*	Solids Removed %
4.50	5.13	13.5		
4.50	7.28	7.5		
4.50	8.13	4.5		
4.50	9.21	5		
3.82	5.14	15		
3.82	5.31	11.8		
3.82	5.67	10.5		
3.82	6.20	7.5	3.49	8.6
3.82	7.31	5.3	3.56	6.8
3.82	8.15	3.6	3.46	9.2
3.82	10.22	3		

* The dissolved phosphate salts were not considered.

When the lime and phosphoric acid were used to produce, theoretically, dibasic phosphate, no difficulties arose.

It must be understood that, due to the complexity of the reactions between lime, phosphoric acid and the intermediate products, no definite statement can be made as to the true final end-products without detailed chemical analysis.

The data obtained, using lime and phosphoric acid in proportions calculated to yield calcium dibasic phosphate, are shown in Table VIII and on Figure 4.

As may be noted from both the figure and the table, the results are somewhat similar in nature to those obtained by the use of lime and sulfuric acid. The major difference between the two sets of experiments is that, for the same filtration rates, the dosage of lime for the phosphoric acid is 2.5 to 3.8 that used for the sulfuric acid.

TABLE IX.—*Summary of Filtration Rates Using Calcium Dibasic Phosphate.* $CaHPO_4 \cdot 2H_2O$

Thin Slop, Solid Content %	Grams $CaHPO_4 \cdot 2H_2O$ Used	Time to Get Dry Cake approx. 40% Solids, Min.	Solid Content of Filtrate %	Solids Removed, Per Cent Solubility*	
				Ignored	Considered
4.32	10.1	13.5	3.93	9.0	14.8
4.32	10.3	12			
4.32	10.7	9.5			
4.32	11.1	8.5			
4.32	11.8	7.5	3.88	10.2	16.0
4.32	13.2	6.2			
4.32	14.5	5.5	3.77	12.7	18.5
4.32	17.1	3.8			
4.32	19.9	2.7			
4.32	27.5	1.67			
4.32	38.8	1.1			
4.32	58.8	0.5			
4.25	16.8	17			
4.25	16.9	16.5			
4.25	18.6	11.6			
4.25	20.6	10.2			
4.25	22.2	8.5			
4.25	25.6	4.8	2.97	30.1	36.0
4.25	27.5	5			
4.25	29.7	3.5	2.96	30.4	36.2
4.25	32.0	3.5			
4.25	35.2	2			
4.01 †	20.5 ‡	12			
4.01	24.6	10			
4.01	26.8	7.5	3.26	18.7	24.9
4.01	27.6	8.5			
4.01	31.8	7.5			
4.01	38.8	6	3.28	18.2	24.4

* Solubility taken as 0.05 grams per 100 c.c. of water at 70° C.
† Anhydrous salt was used.
‡ Doses, corrected to hydrated salt.

TABLE IX (*Contd.*)—*Summary of Filtration Rates Using* $CaHPO_4 \cdot 2H_2O$

Thin Slop, Solid Content %	Grams $CaHPO_4 \cdot 2H_2O$ Used	Time to Get Dry Cake approx. 40% Solids, Min.	Solid Content of Filtrate	Per Cent Solids Removed, Solubility	
				Ignored %	Considered %
3.78	27.8	1.8			
3.78	16.9	7.4			
3.78	18.6	6.3			
3.78	12.2	16.3			
3.78	24.3	2.9	2.83	25.2	25.8
3.78	17.1	4.8	3.28	18.3	19.9
3.78	15.5	9	2.16 (?)		
3.78	14.0	13			
3.78	27.8	2.1			
3.87	17.7	11			
3.87	29.0	2			
3.87	38.3	1.2			
3.87	25.0	2.7			
3.87	20.2	3.35	3.14	18.9	25.4
3.87	26.0	2.2	3.41	11.9	18.4
3.87	14.3	8.6	3.50	0.6	16.0
3.87	18.2	5.6			
3.87	11.8	12.6			
3.87	12.6	12.5			

Calcium Dibasic Phosphate.—The last series of experiments were made with calcium dibasic phosphate. For the first several runs, the anhydrous salt, $CaHPO_4$, was used; whereas for the remaining runs the hydrate, $CaHPO_4 \cdot 2H_2O$, was used.

The results, shown in Table IX and Figure 5, are similar, qualitatively, to those obtained by the use of lime and acid. Since the hydrated runs were made with chemicals containing 79 per cent $CaHPO_4$, the dosages for the anhydrous runs are divided by 0.79 so that the results are comparable.

A study of the amount of chemicals needed for the same rates of filtration, shows that much more anhydrous than hydrated salt is required. This is more marked at the higher rates. This may be due to the same phenomenon that caused the filtration rates of the lime-acid treatment to decrease markedly, when dry lime instead of hydrated lime was used. In other words, here too, the heat of hydration, if allowed to occur in the slop, adversely affects filtration. Because of this, the data obtained with the anhydrous salt were not plotted.

Comparison of the results with the lime and phosphoric acid treatment and with the dry calcium dibasic phosphate treatment, as set forth in Tables VIII and IX, is shown in Table X. The curves for the four sets of runs being different, comparisons were made with the results obtained on the 4.25 per cent slop, because they required greater dosages of chemicals. This was done so as to consider the most adverse conditions. The following conclusions may be drawn from a study of Table X.

1. For comparative filtration rates, less chemicals are needed when the hydrated salt, calcium dibasic phosphate, is used, than when lime and phosphoric acid are used. At the higher rates of filtration, this ratio increases slightly.

2. The amount of solids removed, for the same filtration rates, is greater with the use of the salt.

These observations are the exact opposite of those obtained by the comparison of the lime and sulfuric acid treatment with the calcium sulfate treatment. In the sulfate comparison, less chemicals were needed when the calcium sulfate was formed in the slop by acid and lime; whereas in the phosphate comparison, less chemicals were needed when the calcium dibasic phosphate was added as a salt (instead of being formed in the slop by lime and phosphoric acid).

TABLE X.—*Comparison of Results in Treatment of Thin Slop Lime and Phosphoric Acid vs. Calcium Dibasic Phosphate*

Time to Get Dry Cake approx. 40% Solids, Min.	Lb. of Chemicals per Thou. Gal. of Slop			Ratio of Column 4 : 2	Solids Removed, $CaHPO_4$ Solubility Ignored, %		Ratio of Column 7 : 6
	CaO	$CaHPO_4 \cdot 2H_2O$	Equivalent Weight of CaO in $CaHPO_4 \cdot 2H_2O$		CaO and H_3PO_4	$CaHPO_4$ $2H_2O$	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
13.5	86.8	294	95.8	1.11			
10.5	94.4	334	108.8	1.15			
7.5	106.9	394	128.3	1.20	8.6	10.2	1.19
5.5	120.2	444	144.8	1.21	6.8*	12.7	1.87
3.6	137.0	517	168.5	1.23			

* 5.3 minutes filtration time.

The results of the phosphate comparison are difficult to account for, unless they are due to the complexity of the reactions caused by lime and phosphoric acid, forming calcium phosphate salts.

ECONOMICS

The feasibility of this proposed method will depend on the economics of the treatment. Since the Baltimore Pure Rye Distillery, at present, recovers the wet grain profitably, the question resolves itself into treating the thin slop without financial loss.

Of all the chemicals or chemical combinations used, on a comparative performance basis, the lime and sulfuric acid treatment is the cheapest. However, the calcium sulfate-protein cake on the filter would have very little commercial value. On the other hand, calcium dibasic phosphate is used for prevention and cure of rickets in fowl and cattle. Since it is very insoluble (more so than calcium sulfate), practically none of it would be dissolved in the slop. This would mean that the chemical recovery would be practically complete or the cost of chemicals could be neglected. In fact, the cake would have additional food value, because of the colloidal proteins adsorbed or encased by the phosphate cake. Because of the above, the cost question is analyzed with respect to the data obtained using calcium dibasic phosphate. The curve in Fig. 5, formed by runs made on the 4.25 per cent slop, is used because the results do not show up as favorably as those on the other runs. This means a cost analysis under unfavorable conditions.

On the basis of a daily production of 48,000 gallons of still slop, there would be 381,000 lb. of thin slop (4.46 per cent solids), if the following assumptions are made:

1. The solid content of the still slop is 6.0 per cent.
2. The wet grain from the screening and pressing processes, 38 per cent solids, contains 29 per cent of the solids from the still slop.
3. The specific gravity of the slop is unity. (Actually, it is very close to one.)

Assuming a 25 per cent removal of the solid content in the 381,000 lb. of the thin slop by the use of 461 lb. of phosphate per thou. gal. of thin slop, the following results should be expected.

1. A filtration rate of two minutes for 65 c.c. of treated thin slop, using the laboratory filtration technique.
2. A daily production of 13.3 tons of cake with a 50 per cent moisture content. The cake would contain 22,200 lb. of calcium dibasic phosphate and 4,250 lb. of organic solids adsorbed from the slop.
3. The filtration would consist of 175 tons of treated thin slop, containing 3.6 per cent solids.

An Oliver type rotary filter, with an area of not more than 50 sq. ft., would be sufficiently large if the following information and assumptions are used:

1. The Buechner funnel has a diameter of 2.76 inches.
2. The available filtering area in the Buechner funnel is, at most, 10 to 15 per cent of the area of the filter paper. In industrial practice, the continuous filters have an available filtration area of 85 per cent of the total area.
3. 65 c.c. of the treated slop (461 lb. of dibasic phosphate per 1000 gal. dosage) filters in two minutes time to give a cake of 50 per cent solids.
4. 48,000 gallons of slop are produced daily,
5. The rotary filter is to operate 16 hr. daily. This is the length of time the still operates each day.

Using Chaplin Tyler's "Chemical Engineering Economics" (Second edition, 1938), the daily total costs for the filter, evaporator, and drier were calculated to be \$4.20, \$77.70, and \$14.70, respectively. This gives a total daily cost of \$96.60. This includes interest, depreciation, maintenance, power cost, accessories, and labor. Depreciation was taken at a uniform 10 per cent, and interest charges were taken as 6 per cent, assuming 270 days operation.

As explained before, the cost of the chemicals may be neglected. Freight cost would probably be more than covered by the value of the additional protein in the salt cake obtained from the thin slop. The value of the 2.1 tons of colloids removed daily would be at least $36.00.

The solids in the filtrate would average 6.35 tons each day (using the previous information and assumptions). Since the soluble solids in the slop are much more valuable than the rough screenings (wet grain) or colloidal solids, because of its higher protein content, a value of $20.00 per ton is assumed. Actually, the price would be higher, since solids from *still slop* average $18.00 to $20.00 per ton. The value of the thin slop, dried daily, would be $127.00. The net probable profit would appear, therefore, to be $30.40 each day of operation.

In actual commercial practice, a great deal of improvements can be made with experimentation in dosages, pH, etc.

The fact that the Hiram Walker Co. claims that their process is profitable, may indicate the practicability of this method. In their process, centrifuging is used to remove the troublesome colloids; whereas, filtration is used here. It would be a question of the cost of centrifuging, which would include power, labor and other related costs *vs.* the cost of filtration. One definite advantage that filtration has over centrifuging is that more of the colloids in the slop may be removed by the former.

Conclusions

Using various chemicals, a series of experiments were made to determine the effectiveness of the removal, by filtration, of the colloids in the thin slop of rye distilleries. Lime and sulfuric acid, calcium sulfate, phosphate fertilizer, activated alum, lime and phosphoric acid, and calcium dibasic phosphate were the chemicals used. The results obtained appear to warrant the following conclusions:

1. For the various treatments where crystalline substances are used (the alum liberated a flocculant material), increases in dosage give corresponding increases in filtration rates. For each chemical used, there is a range of dosage which is best for optimum economic operation. The range varies with the chemical.
2. For the treatments where insoluble crystalline substances are used (the phosphate fertilizer was soluble), increases in the dosage cause corresponding increases in the per cent of colloid removal from the slop. Here, too, there is an optimum range of operation.
3. An increase in pH causes an increase in the per cent solid removal.
4. For the same chemical dosages, a change in the solid content of the thin slop does not noticeably affect the filtration rates.
5. For the various treatments, the one involving lime and sulfuric acid necessitates the least expenditure of money and of amount of chemicals to give equal filtration rates.
6. The condition of the lime (used with acid), before slaking, affects the filtration rates. Lime moistened by the air, before slaking, is not as effective as dry lime.
7. If the heat of hydration of the applied chemicals is allowed to occur in the slop, the filtration rates seem to be affected adversely.

8. From an economic point of view, use of calcium dibasic phosphate is the best treatment, since it, alone, retains its commercial value after being used. In fact, its value is actually increased by the protein colloids it removes from the thin slop.

9. Removal of solids from thin slop, by the use of dibasic phosphate, varies from 15 to 36 per cent, depending on the dosages of chemicals used.

10. The treatment of thin slop with calcium dibasic phosphate may be an economically feasible solution of the disposal of "waste" from rye distilleries.

Acknowledgments

The experimental work described here was done in the laboratory of the Baltimore Pure Rye Distillery at Dundalk, Maryland. It was conducted under the supervision of Dr. Abel Wolman and Mr. John C. Geyer of the Johns Hopkins University.

Thanks are due to Mr. George L. Hall and Mr. Maurice H. Coblentz for the use of the correspondence of the Maryland State Department of Health on whiskey distilleries, as well as for other assistance which they afforded.

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STEEL MILL WASTES AND THEIR EFFECT ON THE CITY OF DUNKIRK'S SEWAGE TREATMENT PLANT *

By A. H. Woefle

Supt., Sewage Treatment Works, Dunkirk, N. Y.

The plant of the Allegheny Ludlum Steel Company is located in the southwestern section of our city. The Company manufactures special high grade carbon and alloy steels. During the various treatments of their steels, especially the small round and wire products, it is necessary to remove the scale by pickling in solutions of sulfuric, hydrochloric and other acids. After these acid solutions are weakened by use, they are discharged without treatment into our sewer system and eventually reach the treatment plant mixed with the other sewage.

Regardless of the dilution, these wastes have interfered with the proper operation of the sewage treatment plant, mainly, up to 1939, in maintenance of a chlorine residual of 0.5 p.p.m. in the effluent, during the times when the waste pickling liquor was discharged from the steel plant.

Since 1939, due to the vastly increased defense activities at the steel plant, an almost continuous discharge of acid pickling wastes has been received at the treatment plant, which has resulted in very unusual operation conditions. These conditions are as follows: The sludge is a sticky, heavy mass that will not settle through the slots into the digestion chambers. Sludge builds up in the flowing-through chambers until it is very near to the surface. The pH of the sludge drawn from the digestion chambers is around 4.0. It is not properly digested, and does not dry well. The acidity of the sewage has also affected the submerged iron and it has been necessary to replace the bar screens. I am in doubt as to the condition of a submerged pump in the final settling tank and also other submerged mechanisms.

During 1941 several corrective measures have been undertaken, with the aid of the State Department of Health. The Allegheny Ludlum Company has been contacted and preliminary plans have been developed for the construction of a neutralization plant for the treatment of the pickling liquor with burnt lime. The resulting sludge and effluent are to be discharged into the city sewer system for final disposal.

A duplex Marlow sludge pump, capacity 100 gallons per minute, was purchased and has been used to clean the scum from the vents and to pump the liquid from the flowing-through chambers. This resulted in the sludge settling into the digestion chamber. The scum from the vents and sludge from the digestion chambers was pumped to an open area south of the plant.

Last fall foaming in one of the tanks took place for about three months and 300 pounds of lime per day was added until the foaming stopped.

* Presented at Fall Meeting of the Western Section of the New York State Sewage Works Association, September 27, 1941, Dunkirk, N. Y.

Aluminum sulfate was added to the sludge drawn on the covered drying beds on two occasions. This greatly helped in the dewatering of the sludge.

Perhaps a more detailed description of the proposed pickling waste neutralization will be of interest. Approximately 6500 gallons of waste pickling liquor must be treated and 8000 gallons per 24 hours is possible, therefore, the plant is designed to handle 8000 gallons per day.

It is proposed to install two 1200-gallon concrete receiving tanks lined with brick set in special cementing material. One tank will be used to receive the waste liquor for 24 hours while the liquor in the other tank is being drained off for neutralization. At the end of the 24-hour period, a sample will be taken, the acidity of which will determine the amount of neutralizing agent to be used during the 24-hour period that this waste is being treated.

From these storage tanks the waste liquor will be pumped to a circular neutralizing tank where about 200 gallons will be diluted with four parts of water, burnt lime added and the solution agitated continuously for about ten minutes. After neutralization, the batch will be quickly emptied into a 3000-gallon tank, from which the sludge and liquid can be emptied into our sanitary sewer system at a constant rate which will be about 23.4 gallons per minute when treating 6500 gallons per 24 hours of waste pickling liquor.

It has been estimated that the wastes will produce approximately 2½ times the amount of sludge that would normally occur in a city the size of Dunkirk, and this sludge will have to be handled at our plant. It is planned to utilize the Marlow pump to pump the excess that cannot be handled in the covered drying beds to an area south of the Imhoff tanks, where it will dry in the open. It is hoped that after the installation of this plant the troubles experienced from manufacturing wastes at the sewage treatment plant will be eliminated and only the normal troubles of any treatment plant will have to be overcome.

INVESTIGATIONS ON TREATMENT AND DISPOSAL OF ACID INDUSTRIAL WASTES *

By L. S. Morgan

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This discussion will be limited to the major acid industrial waste problems encountered in Southwestern Pennsylvania, the general method of disposal of such wastes by dilution into waters of the state, and to presenting the effects of such methods of disposal and the need for proper control.

The predominating problems relative to acid industrial wastes encountered in the southwestern portion of Pennsylvania are those due to acid drainage from bituminous coal mines and spent pickle liquor wastes from metallurgical mills.

Acid Mine Drainage

Bituminous mine drainage is probably the source of the greatest pollution problem from acid wates. Such acid wastes are encountered particularly in the bituminous coal fields of Pennsylvania. Bituminous coal mining is encountered in at least twenty-three counties in the Commonwealth, located on such major watersheds as the Beaver, Ohio, Allegheny, Monongahela, Youghiogheny, Kiskiminetas, Clarion, Juniata, and Susquehanna Rivers.

Scattered throughout this area there were listed by the former Pennsylvania Mine Sealing Corp. as of August 1, 1936, 6,663 mines, of which 2,136 were active, 1,063 marginal and 3,464 abandoned.

While there are no accurate figures available concerning the acid pollution load from bituminous mines, it has been estimated by the former Mine Sealing Corp. that, as of 1936, these mines produced a daily load varying from ten million to eighteen million pounds of wastes calculated as sulfuric acid. These wastes are generally discharged without treatment from the bituminous coal mines into waters of the state for disposal by dilution.

The character of the waste waters produced from bituminous coal mines can be illustrated by several examples showing some of the chemical results obtained by analysis of the mine discharge.

The discharge of such waste waters in large volumes into surface streams decreases the alkalinity of the stream and increases the hardness, iron, manganese, and alumina content.

The total acidity of mine waters is due to the presence of free sulfuric acid and the acid salts of iron and aluminum sulfate. Calcium and magnesium are also generally present in high concentrations as sulfates, resulting in high permanent hardness.

* Presented at the Fourteenth Annual Conference of the Pennsylvania Sewage Works Association, State College, June 27, 1940.

CHEMICAL RESULTS EXPRESSED IN PARTS PER MILLION

	Mine No. 1	Mine No. 2
Total Residue	10,250	4,550
Volatile Matter	4,300	
Fixed Residue	5,950	
pH	3.0	2.8
Total Acidity	4,800	1,800
Hardness		2,800
Total Iron	2,000	450
Manganese	30	18
Sulfates	7,000	2,950
Aluminum	135	228

These acid salts are formed through the action of water and air on the iron pyrites associated with the coal. Ferrous sulfate, plus free sulfuric acid are formed first, the original iron sulfate probably changing to another form on further oxidation in the presence of sulfuric acid, with a probable further change in the character of the iron sulfate upon hydrolysis or reaction with alkaline substances, with the liberation of sulfuric acid.

When these mine waters are liberated into the streams, the free acid first attacks the natural alkalinity of the stream, reducing or exhausting it entirely. Liberation of additional sulfuric acid through hydrolysis, or reaction of the acid salts with any remaining stream alkalinity, further reduces the original alkalinity of the stream and results in the precipitation of hydrated iron oxides, which renders the streams turbid and during periods of low flows and accompanying low velocities, produces deposits on the banks and bed of the stream. These deposits may later be flushed out as the river rises, to form turbidity again in the form of iron precipitates in the water. Such occurrences form what are termed "sulfur mud waters" or "mottled waters" in the bituminous region.

The discharge of acid drainage from bituminous mines into streams in Southwestern Pennsylvania is of such magnitude that some of the major rivers, such as the Conemaugh, Kiskiminetas, Monongahela, and Youghiogheny Rivers, are acid throughout a great part of their length at all times, with such rivers as the Lower Allegheny and the Upper Ohio being acid during periods of low flow.

In the Southwestern Pennsylvania region, these large streams are depended upon as a source of raw water supply, both for domestic and industrial use, by many water purveyors and industries. Acid waters at waterworks and many industrial establishments must be rendered alkaline by the addition of chemicals for the purpose of removing any free mineral acid or acid salts which may be present in the supply. Other waterworks have found it necessary to adopt water softening to furnish a satisfactory supply for the consumers and provide for special adjustments in the treatment for the removal of iron, manganese, and alumina in the raw water supplies.

In the Southwestern Pennsylvania district alone, there are approximately fifty public waterworks on the watershed of the Ohio River using surface water supplies which are either acid at all times or during low flow seasons which furnish water to a population of approximately 1,300,000 persons living in 150 communities.

The City of Pittsburgh, at its Aspinwall slow sand filtration plant, uses water from the Allegheny River which is acid part-time. During periods of normal alkaline river water, it is unnecessary to add any chemicals except chlorine at this waterworks. During periods of low water and acid conditions it is necessary to add chemicals for neutralizing the river water prior to filtration. Mr. C. F. Drake, Superintendent of the Filtration Plant at Aspinwall, in his Annual Report for 1939 gives the amount of soda ash applied and the cost of soda ash treatment, exclusive of labor, for the past ten years, as follows:

Year	Lbs. Soda Ash Applied	Cost Soda Ash Applied
1930	650,410	$13,399.45
1931	1,753,400	33,169.52
1932	903,200	15,754.68
1933	1,593,000	24,710.89
1934	3,012,728	47,446.97
1935	996,100	13,979.74
1936	2,034,500	24,249.53
1937	104,600	1,588.86
1938	96,000	1,492.24
1939	568,700	8,735.91

Another waterworks using water from a stream acid practically at all times and containing a high degree of hardness, especially during periods of low flow, has found it necessary to use as much as twenty-seven tons of soda ash and twelve tons of lime per day to neutralize and soften approximately fourteen million gallons per day.

An example of the character of a raw water supply containing mine discharge which one waterworks had to use during a dry weather season is shown by the fact that the hardness of the supply reached 960 p.p.m., the total acidity 700, the total iron 100 and manganese 10 parts per million.

There are many other cases where waterworks have to resort to the use of excessive amounts of chemicals for neutralization and treatment of acid water, in addition to many industrial plants which also neutralize such waters for process use.

Streams made acid through the introduction of mine water do not support fish or other aquatic life, cannot be used to any degree for recreation or bathing purposes, are detrimental to structures constructed in the stream such as dams and bridges, and to river shipping equipment, and are not used for watering of stock and cattle.

There are some waterworks which would probably prefer to use a slightly acid raw water supply, that is, one containing just sufficient acid salts, to act as a good coagulant with lime treatment only, provided that the amount of acid, hardness, iron, and manganese in the supply due to the acid wastes could be controlled within reasonable limits. This might be preferable to using a supply of low alkalinity, where an alkali and an acid coagulating salt must be applied for proper coagulation and treatment.

Other effects of acid wastes discharged to streams are particularly noticeable, especially in relation to effects on sewage pollution, where large volumes of sewage are discharged untreated into acid waters.

Streams polluted with both acid wastes and sewage show a marked effect on the bacterial pollution by a very noticeable reduction in the coliform densities in such waters, especially during low flow periods when the concentration of acid wastes is at its greatest. Streams which would be expected to have a very high coliform density, because of the factors of dilution afforded for a heavy untreated sewage load, actually show coliform densities all out of a proportion to what would normally be expected.

Studies made of the pollution problem in the Upper Ohio River by the United States Public Health Service have shown a marked effect in the reduction of pollution in acid waters as indicated by calculated population equivalents and coliform indices uncorrected, and corrected for the effects of acid wastes. Mr. H. W. Streeter * shows, for instance, that with an estimated sewered population as of 1930 of 2,186,500 above the waterworks intake of Wheeling, West Virginia, the residual population equivalent at the intake uncorrected for acid wastes for winter periods was approximately 569,150 and corrected for acid wastes 155,800; for summer periods the reduction is from 391,280 to 3,680 for high stages and from 167,080 to 1,465 for low stages.

Calculated coliform indices based on the population equivalents above the Wheeling, West Virginia, waterworks intake for winter conditions are reduced from 49,900 uncorrected to 13,700 corrected for acid wastes; in summer periods reduced from 238,000 to 2,240 during high stages and from 400,000 to 3,760 for low stages. These calculated results compare with observed average coliform indices of 2,960 for winter and 4,470 for summer conditions.

In a survey made by the Pennsylvania Department of Health in the Upper Ohio River, which receives in the Metropolitan Pittsburgh District untreated sewage from a population of approximately 1,200,000, the effects of acid water on the coliform indices are very noticeable. With an average daily discharge in the Ohio River of 1500 cu. ft. per sec., affording a dilution factor based on sewered population alone of 1.2 c.f.s. per thousand population, coliform indices averaged 160, at a point several miles below the concentration point of the pollution, with a maximum of 700. At much higher flows, up to an average daily maximum of 44,000 c.f.s. and a dilution factor of 36.6 per thousand contributing population, the index averaged 5,300, with a maximum of 37,000. At low flow periods the water was acid, whereas at the higher flow periods the acid was neutralized through dilution. Other factors, such as velocity and time of transit through navigation pools, also have a decided influence in this reduction.

The best practical method which has as yet been demonstrated for the reduction of pollution from acid mine drainage is the sealing of abandoned coal mines. Eliminating the entrance of surface water into underground bituminous mine workings through diversion of the water to surface streams by the filling up of cave and crop holes, and by the effective sealing of openings against the circulation of air through underground workings, has resulted in material reductions, both in quantity of water discharged from mines and degree of acidity in the water issuing thereform. This

* "Surveys for Stream Pollution Control," Paper No. 2023, Am. Soc. Civil Engineers.

method of prevention of pollution is applicable to abandoned and worked-out portions of active and marginal mines. No real progress on any large scale has as yet been made in controlling the pollution from active coal mines.

Another factor in the reduction of pollution load of mine wastes lies in the use of large flood storage reservoirs, impounding alkaline waters on sheds of streams polluted with such wastes. The release of large volumes of such impounded flood waters during periods of low flow in acid streams, augmenting the natural low flow of the stream, would result in the dilution of the acid and hardness to appreciable degrees in some of the major rivers. This condition has already been noted in the Monongahela River through the release of water during the 1939 low water season from the Tygart Reservoir as reported by the United States Army Engineers office at Pittsburgh and confirmed by Mr. E. C. Trax, Chemist of the McKeesport waterworks. It is estimated by the Army Engineers that there was a reduction of approximately 200 p.p.m. in hardness and 30 p.p.m. in acidity of the Monongahela River at McKeesport during the months of September and October of 1939, as compared to similar droughts during previous periods, as a result of the augmentation of flow through the release of water from the Tygart Reservoir on the upper reaches of the stream.

Spent Pickle Liquors

Since the Pittsburgh Metropolitan District is the center of the steel industry, there are many metallurgical mills of large capacity which produce acid wastes in the process of "pickling." Ordinarily, such wastes have been disposed of by dilution in surface waters. Much influence is being exerted to find satisfactory methods for the treatment of such waste waters prior to their discharge into state waters and the recovery, if possible, of useful by-products. These wastes discharged into waters of the State have the effect of reducing alkalinity or increasing acidity and iron content of the streams receiving such wastes.

One example of the possible effect of such acid wastes as produced at large steel plants discharged to streams can be cited in the Metropolitan Pittsburgh area. One of the large steel industries determined on the construction of a large new steel mill involving the pickling process.

This industrial plant anticipated a total volume of waste waters containing pickle liquors to the amount of approximately 1.2 million gallons per day. The concentrated pickling liquor alone would have contained approximately 34,000 pounds of sulfuric acid and 105,000 pounds of iron sulfate.

During periods of maximum flow in the receiving body of water, the waste waters could have been discharged untreated without having any appreciable effect on the quality of the water in the stream into which the wastes were proposed to be discharged. However, during periods of drought flow similar to those which had occurred in previous years, the discharge of these wastes untreated would have caused a calculated increase in the concentration of iron sulfate of approximately 100 p.p.m. and in free acid of 30 p.p.m.

Rather than discharge such wastes untreated into the river and cause such pollution during periods of low flow, the company provided a treatment works consisting of facilities for complete neutralization of all the acid wastes and sedimentation of the resultant precipitates in large basins.

The precipitated materials are cleaned from the sedimentation basin and hauled away for disposal on a slag dump and the effluent from the treatment plant is discharged to the river. The treatment works have protected the receiving body of water against undue pollution which would have resulted at periods of low flow.

Other industrial plants producing pickling liquors have also undertaken the elimination of pollution caused by the discharge of these waste waters to surface streams. There are three other steel plants in the Pittsburgh district which are neutralizing and/or lagooning pickling liquor wastes, with beneficial results insofar as control of pollution is concerned.

In a district so highly industrialized as the bituminous coal and steel centers, problems of disposal of acid wastes on a large scale are encountered. The reduction of pollution of acid wastes will have to proceed hand-in-hand with the reduction of pollution of sewage and other industrial wastes in order to control pollution effectively. Elimination of acid wastes alone, without accompanying control of the sewage and other industrial wastes pollution, would bring about an aggravated problem; and control of sewage alone, without reduction in pollution from acid industrial wastes, would not afford the full use of our streams for all purposes.

THE OPERATOR'S CORNER

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EXPERIENCE IN SEWER MAINTENANCE

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General

Of all sewage works operation functions, that of sewer maintenance is usually considered the least pleasant and interesting, yet it is of utmost importance. There is somewhat of an inclination to neglect this essential "chore" in many cases even though the hazards of basement flooding and other effects of faulty sewer operation are appreciated. Good will that has been carefully built up by painstaking public relations activity can be easily destroyed in this way.

The public investment in sewers and appurtenant structures is always much greater than that in the sewage treatment plant. At the

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same time, an "oversize" sewer system (one having capacity in excess of that required to carry maximum rates of flow) is indeed rare. In use, the capacity of sewers is reduced by accumulations within them and continuous attention to proper maintenance is required to retain the original capacity. When the system is overburdened, good maintenance will minimize difficulties until the costly relief lines can be installed.

The phrase, "given attention as trouble develops," occurs much too frequently in discussions of sewer maintenance problems. It might better be replaced with, "cleaned every year, whether they need it or not," although it is realized that municipal budgets for sewer maintenance labor and equipment are seldom adequate to permit such an ideal to be attained. However, systematic planning, frequent inspection, complete and modern equipment and efficient personnel will derive the greatest possible yield from the sewer maintenance dollar, and expenditure of funds and effort along these lines is often more justified than in some of the less necessary but more spectacular phases of sewage treatment.

Maintenance Program—Records and Inspection

The most important item of equipment in any sewer department is a master map of the system, supplemented by larger scale sectional maps on which are shown important details such as direction of flow, exact manhole locations, sewer sizes and slopes, house connections, etc. Phelps (San Diego) has found that good maps save time and minimize damage to streets and private property, and recommends that all extensions to the system be plotted as made so that the reference maps will always be up-to-date. At Rockville Centre, New York, Anderson (1) keeps a card index for permanent notes and a log book for daily maintenance notes, both of which are indexed to the sectional maps. The log book is kept by the field crew and records the location of work, conditions found, equipment used and daily costs.

Practice as regards frequency of routine inspection varies widely. Several contributors report that inspections are made only as difficulty arises, while others confine routine inspection to those sewers which have given trouble previously. A number of those reporting this inspection practice indicate that lack of personnel obviates a regular schedule.

Most general inspection practice appears to be as follows: sewers on flat grades or previously troubled by roots—every three months; sewers in which no trouble has been recorded—once to twice yearly; main intercepting sewers—one to four times per month; flush tanks—every month; inverted siphons—one to four times monthly; storm water overflows—during and following heavy rains. Some larger cities maintain a trained inspection crew which is continuously engaged in following a prepared schedule.

Anderson (1) warns that a casual glance into the manhole does not constitute adequate inspection. Steelman (Ocean City) advises inspection of critical sections during peak flows, which advice is substantiated by experience at Urbana-Champaign, Illinois where an 18-inch interceptor appeared to be flowing freely during numerous dry weather observations but was found to be carrying only 25 per cent of capacity when surcharged at the upper end during a very wet season, due to an unusually bad root condition. "Lamping" a section, by looking through the sewer during low flows toward a flash light (explosion proof) held at the next manhole, is a common method of inspecting lines of 12-inch diameter and larger. Superintendent Case (Merchantville-Pennsauken, N. J.) employs an inspection crew of three men who ascertain the condition of the line by observation at the lower manhole while the line is being flushed or probed with light rods. A change in the color or solids content of the flow will indicate an accumulation. At Birmingham, Michigan, the condition of lateral sewers is ascertained whenever an opening is made for a new house service connection.

Where a program of routine cleaning "whether they need it or not" is possible, it is usually correlated with the inspection schedule. At Cimarron, Kansas, City Engineer R. R. Crusinberry has developed a schedule of routine cleaning that enables coverage of the entire system every year. At Rockville Centre, where there are 78 miles of sewers, Anderson (1) has planned to clean 26 miles of sewer each year, thus covering the entire system every three years. The work is carried out from March 15 to July 1 and from September to November, totalling about 150 days of the most suitable weather. Work in the business district is done between 4 A.M. and noon to avoid heavy traffic. A similar 3-year schedule for cleaning trunk line sewers, involving work on about 33 miles of sewer per year, has been developed by Superintendent George D. Carpenter at Ithaca, New York.

Baltimore, Maryland, has a well-organized plan for continuously servicing the 1900 miles of sewers and drains in that city (2). Five crews of three men each are assigned to definite territories and are equipped to clean street inlets and manholes, approximately 1200 to 1500 being cleaned weekly. Four crews of five men each are equipped for servicing house connections and small laterals and are constantly engaged in this work. One 6-man crew is equipped for work on large sewers and drains. The plan affords continuous maintenance, minimizing complaints and inconvenience to property owners.

Twenty-nine well equipped field crews are able to completely cover the 2800 miles of sewers in Los Angeles, California, twice each year by working according to a systematic plan (9).

Any routine sewer cleaning program must be arranged to allow for interruptions for emergency calls.

Sewer Maintenance Equipment

The efficiency of a sewer maintenance crew is directly dependent on the amount and suitability of its equipment. The cost of good equipment is more than justified by the quality of work performed and the saving in labor.

The size and type of sewers to be serviced, of course, determine largely the nature of equipment required, but certain items are essential to any efficient crew. Sanitary sewers will usually be troubled mostly by roots and grease while combined or storm sewers will nearly always accumulate grit and are most likely to receive miscellaneous debris. The equipment carried by the maintenance crew will be most adapted to the character of stoppages anticipated but there must also be equipment for handling the unexpected.

A typical list of essential equipment carried by a full-time, large city, maintenance crew, working on all types of sewers, has been developed from data furnished by the contributors to this article:

Major Equipment

2½ ton truck
Power winch
Portable, manually-operated winch
1000 feet flexible steel cable
1000 feet fire hose
600–800 feet flexible rods (power drive desirable)
500 feet interlocking wood sewer rods
Root cutters of assorted sizes
Sewer brushes of assorted sizes
Sand buckets, scoops and drags of assorted sizes
Turbine flushing heads
Steel sewer tapes and heavy wire (for small sewers)
Sewer flushing bags

Minor Equipment

Shovels, picks and mattocks
Assorted wrenches
Hydrant and manhole tools
Flash lights (explosion proof)
Rubber boots, coats and gloves
Buckets and rope

Safety Equipment *

Hydrogen sulfide detector
Carbon monoxide detector
Combustible gas indicator
Wolf safety lamp
Hose mask (double) with safety harness
Safety belts (2 or 3)
Complete first aid kit
Manhole guard rails
Traffic signs and flags
Oil lamps and flares

* A combination combustible gas indicator, oxygen deficiency lamp, and toxic gas detector is available on the market.

Commenting on the above list, the power winch for pulling scoops, brushes or buckets may be provided for in several ways. There are several excellent portable power units (Fig. 1) available, specifically

FIG. 1.—Turbine sewer cleaning machine in use at Bloomington, Illinois.

designed for sewer cleaning, in which the engine, cable reel (with control clutch) and pulley frame are mounted on wheels and can be moved about as a trailer. At Champaign, Illinois (Fig. 2), the winch is mounted on the truck and is powered by the truck motor. The sewer

FIG. 2.—Power winch mounted on truck used for sewer maintenance at Champaign, Illinois.

maintenance truck and trailer used at Ithaca, New York, is shown in Fig. 3.

The sewer service crew of the Joint Meeting Sewer Commission of New Jersey is equipped with several unusual items which have proven highly useful (3). A short-wave radio receiving set keeps the crew in contact with headquarters regardless of their location about the

Fig. 3.—Sewer maintenance truck and trailer, Ithaca, New York.

large area in which they must work; a portable platform derrick expedites heavy loading jobs and is used to transport the sewer cleaning winches; a portable, 1500-watt generator supplies current for floodlights used in night work and for the portable air blower employed in ventilating sewers and manholes as a safety measure. Portable generators are also carried on some of the sewer maintenance trucks used at Los Angeles (9).

The sewer maintenance departments of cities of moderate and small size are seldom equipped as completely as listed above, despite the fact that the best of equipment yields greatest economy. Commonly, the general purpose city truck is used to transport loose equipment or pull

Fig. 4.—Sewer maintenance trailer, Rock Falls, Illinois.

a small trailer (Fig. 4). The truck is sometimes used to pull scoops, drags or brushes as a substitute for more suitable power machines. There is also an unfortunate tendency for small city crews to work without adequate safety equipment and fatal accidents in such crews are much too common. Phelps (San Diego) suggests that the cooperation of the local gas company be obtained when special testing equipment is required for occasional gas surveys.

Character of Sewer Stoppages

The most common obstructions in sewers, in the order of greatest incidence, are (1) roots, (2) accumulations of grease, (3) grit and (4) miscellaneous debris.

Fig. 5.—Roots removed by power-driven flexible rods and cutter at San Diego, California.

Roots generally enter at faulty joints. Growth usually occurs from a single leader root which continues development inside the sewer until branches from the leader often fill the entire pipe. Phelps reports one root growth 30 feet in length (Fig. 5) removed from a sewer in San Diego. An unusual root removed from a 6-in. house connection in Portland, Oregon, is shown in Fig. 6. Care in making joints, use of proper jointing materials and careful tamping of backfill during sewer construction are good insurance against root troubles later.

Copper, toxic to most plants, has been employed to control root growths. A copper ring, made for the purpose, is available for placing in the joint at the time the sewer is laid. Killing of root growths in sewers by copper sulfate is successfully practiced at San Diego, California, and Greenville, Tennessee (4), and elsewhere, a handful of blue vitriol crystals being dropped into a manhole above the suspected root growth, while flow is taking place. Repeated applications may be necessary to kill the leader growth, which later breaks loose due to the water pressure behind it.

FIG. 6.—Root removed from 6-inch house connection, Portland, Oregon.

Superintendent Case at Merchantville, New Jersey, reports most root troubles caused by poplar and willow trees and these are removed where difficulty has been caused, to prevent recurrence.

Grease accumulations on the inside of the sewer and in the form of floating balls is a major problem at Atlantic City, New Jersey (5), and other places. Ordinarily discharged to the sewer with hot or warm water, the grease congeals as it cools and adheres to the walls of the sewer or develops into a ball with some small particle or object as a nucleus. These accumulations continue to build up until they materially reduce the capacity of the sewer.

Grit in the form of cinders, ashes, sand, mud, etc., which enters combined and storm sewers with surface water run-off and sanitary sewers with basement drainage, is often troublesome, particularly where sewers are on flat grades. At Rock Falls, Illinois, and elsewhere, unpaved streets are the source of excessive grit deposits in sewers. Sewers laid through quick-sand often shift due to the unstable foundation, opening at the joints and permitting the fine sand to enter. This condition is serious at East Aurora, New York, and, to a lesser extent, at Ocean City, New Jersey. Mud and sand originating at automobile wash racks is reported to be a cause of grit accumulation in sewers at Kehoka, Missouri, and Cimarron, Kansas.

The character of miscellaneous debris removed from sewers (combined and storm drains in particular) is almost unimaginable. Barrels, posts and a bed spring are on the list at Bloomington-Normal, Illinois, and a washing machine was once removed from a large line at Springfield, Illinois. Removal of some of these articles demands much ingenuity and patience on the part of sewer maintenance personnel.

Sewer Cleaning

Flushing.—Although not always positive, flushing of sewers is a convenient method of scouring out minor grit deposits and grease accumulations.

Surface water discharges during rains provide adequately for flushing storm and combined sewers, although supplementary flushing by fire hose is employed at Birmingham, Michigan, Portland, Oregon, and Sacramento, California, in conjunction with other cleaning operations, to clean lateral lines and to reduce odors at manholes in extended dry weather seasons. Routine flushing is a general practice in maintaining separate sanitary sewers but the frequencies reported vary from monthly to annually. At Orillia, Ontario, where the sanitary sewers have a minimum slope of 5 per cent, Engineer L. G. McNeice indicates that annual flushing is practically the only maintenance required. In some cases, as at Ithaca, New York, and Kahoka, Missouri, routine flushing is limited to critical lines on flat grades, which are flushed every two or three weeks. At Kahoka, some shallow lines are flushed after midnight by means of a time-clock actuated electric valve on the water service, giving a discharge of twenty minutes duration.

Many old sewer systems were equipped with automatic flush tanks, located at the upper ends of laterals to assure scouring of deposits. Present practice is to design sewers with adequate slopes and the use of such devices is confined to lines in which flat grades are unavoidable. A number of contributors to this article indicate that old flush tanks have been abandoned; others that they are still used occasionally.

From a practical study of the hydraulics of sewer flushing, Watson (6) concludes that the *depth* of the flushing flow in the sewer is equally as important as the velocity. This accounts for the fact that flushing is most effective when the sewer is plugged at the lower manhole, the fire hose used to loosen grit deposits and grease accumulations and, after a head of sewage and water is built up, the plug is suddenly removed to release the flush. Kilpatrick (Rolla, Mo.) emphasizes the importance of blocking the sewer in connection with flushing operations. Sewer "bags," having a hose connection at one end and a nozzle in the other, are available for plugging the sewer and adding flushing water at the same time.

Satisfactory flushing by means of "water wagons" is accomplished at Los Angeles (9) and Lower Merion Township, Pennsylvania (10). In the latter case, water is discharged at the upper manhole from a 625 gallon steel tank mounted on a truck, and having a 6-in. drain valve.

FIG. 7.—Root removed by flexible sewer rod equipment at Cimarron, Kansas, City Engineer Crusinberry at right.

Discharge is so rapid that an 8-in. sewer is completely filled, giving an effective flush of 500 to 800 feet of sewer.

Hydrogen sulfide formation in sewage is accelerated by the presence of septic sludge deposits in sewers. Bowlus (11) reports that sulfides are definitely reduced after flushing, indicating that the practice is beneficial in reducing odors at manholes and treatment works as well as in reducing damage to sewers and concrete structures.

FIG. 8.—Roots removed by power-driven flexible rods at San Diego, California.

Removal of Roots.—For cutting and removing root growths in sewers up to 15 in. in diameter, flexible type rods and cutters appear to be very popular, because of the time saved, compactness of the equipment and small labor requirement. An augur-like cutter is used, which is rotated by twisting the rods as they are forced down the sewer. The equipment can be operated easily with two men if the power drive is used, or four men if the rods must be twisted manually. Another advantage of this equipment is that it can be fed into the sewer from ground level and does not require entry into manholes. Accumulations of roots removed at Cimarron, Kansas, and San Diego, California, are shown in Figs. 7 and 8, respectively.

FIG. 9.—Manually operated sewer ''drag'' in use at Ithaca, New York.

For removing roots from larger sewers, or particularly obstinate ones from small sewers, cutting drags are pulled through by cables and winches, either power or manually operated (Fig. 9). This procedure is positively effective, and in many cities is the only method used.

At Ocean City and Merchantville, New Jersey, every effort is made to prevent recurrence of root growths which are removed from sewers. Steelman at Ocean City reports that defective joints admitting roots are immediately located and repaired and some very troublesome lines have been relaid in iron pipe. Poplar and willow trees causing trouble at Merchantville are removed. Permanent control of roots in house service lines is the aim at Birmingham, Michigan, where the City provides 6-in. cast iron pipe with leaded joints to the property line and requires not less than vitrified pipe with asphalt mastic joints inside the property. In case of root stoppage in old cement jointed vitrified pipe services (in the street), the City relays the service to the property line in cast iron pipe for a permit fee of $15.00.

Removal of Sand and Grit Deposits.—When flushing does not produce adequate results, sand buckets or scoops pulled through by the cable and winch outfit are universally depended upon for removing deposits of grit. This equipment (Fig. 1) is positive in effectiveness, regardless of the size of the accumulation.

Where the deposit is not too large, the "Turbine" cleaner which has a water powered, rotating cutter is effective. This device, dragged through the sewer by cable and winch, combines water jet flushing, cutting and dragging into one effective operation.

Rawn (7) describes an ingenious sewer "hoe" used by the Los Angeles County Sanitation Districts for removing grit accumulations from sewers over 30 in. in diameter with a minimum of labor. The device is propelled through the sewer by the pressure of sewage behind it and the invert and sides of the pipe are scoured as it moves. For sewers of 15 to 30 in. in diameter, a beach ball inflated to approximately the size of the sewer is used effectively in the same fashion as the "hoe."

Removal of Grease Accumulations.—Unless of industrial origin, sewer stoppages by grease are confined almost entirely to house services, however, the capacity of larger sewers is often reduced due to the development of a grease lining in the pipe.

Flat sewer tapes with various kinds of cleaning tools are used for removing grease obstructions from house connections at Ocean City, New Jersey. Large sewers give no trouble here. At Atlantic City, New Jersey (5), the most useful device for opening house connections has been found to be a 50-ft. length of quarter-inch steel wire. The end started into the sewer has a 6-in. bend which is rotated by cranking the other end as the wire is fed, thus gouging out the stoppage.

Grease accumulations in larger sewers are loosened to some extent by flushing, root-cutting and other maintenance operations. Sewer brushes, dragged through by the ever useful winch and cable equipment, are most positive, however, and many well-trained crews always use a brush drag to finish up a line that has been dragged with other tools.

Other Cleaning Devices.—It will be noted that certain types of equipment are best suited to specific cleaning problems, yet it may often be necessary to use practically all of the equipment carried for cleaning a single line. For instance, the flexible rod and root cutter and/or detachable wooden rods may be used to partially open a stoppage to permit a cable to be threaded through for use in dragging, and several types of drags may be employed. Unusual situations will often demand considerable thought and ingenuity on the part of the maintenance crew even though they are well equipped for ordinary problems.

The sewer "hoe" and beach ball cleaners described above are examples of such ingenuity. The Los Angeles County Sanitation Districts, where these labor-saving implements were devised, makes root cutting drags for 12 to 36-in. sewers from steel pipe (7); sewer brushes at Ithaca, New York, are made from old street-sweeper brooms; a knot of old chain has been found to constitute a serviceable root cutter and drag at Portland, Oregon; a 15-in. root cutter was made to service an 18-in. sewer at Urbana-Champaign, Illinois, by wrapping the periphery with barbed wire, further illustrating actual practice in meeting local problems.

Ground Water Infiltration

Although most ground water infiltration results from faulty sewer construction (poor joints or failure to use proper pipe through critical water-bearing soil formations), good maintenance and operation practices can reduce this problem. In referring to infiltration, nearly all of the contributors to this article mentioned the relatively new asphalt mastic jointing compounds as a curative measure, either in explaining why there was no serious infiltration problem or describing how it is being minimized in new extensions or old sewer repairs.

Where there is ample sewer capacity, gravity flow and no sewage treatment works, there is an inclination to disregard infiltration to some extent. Usually the allowance for infiltration in the design of separate sanitary sewers is only nominal but such leakage often proves to be of serious consequence; as at Ithaca, New York, where it amounts to 100 to 400 per cent of the dry weather sewage flow due to broken pipe and poor joints. Superintendent Carpenter indicates that correction can be accomplished only by replacement of the defective lines by cast iron or other suitable pipe.

Where sewage must be pumped, it has been found economical to locate and actually replace those lines admitting large amounts of ground water. This has been done at McHenry and Fox River Grove, Illinois, Rolla, Missouri, and elsewhere.

Steelman (Ocean City, New Jersey) and Bridges (Kahoka, Missouri) point out the necessity of careful control and inspection of house connections to minimize infiltration. The sharp increase in flow in sanitary sewers during rains is usually caused by illicit downspout connections which are most difficult to control since many of them are changed after the installation inspection is made. Constant vigilance, public education and rigid enforcement of ordinance provisions are the only possible means of minimizing this source of extraneous water. Kahoka, Missouri, and Birmingham, Michigan, sewer users are required to comply with strict specifications for workmanship and materials in constructing house sewers.

Maintenance of Appurtenant Sewerage Structures

Aside from ordinary inspection and replacement of broken manhole covers, it is important that manholes in unimproved or semi-permanent streets be maintained at the proper elevation. Considerable damage to such streets is done when an attempt is made to find a manhole which has been covered. Rattling manhole lids often create a nuisance and correction has been accomplished by: application of tar or asphalt around the entire rim or at three or four points (10); gaskets of rubber, jute or canvas; machining of the lid and casting; use of mechanical locking lids or low center of gravity types. Anderson (1), after trying several methods, now uses a tape packing made for the purpose which is placed around the entire periphery after thorough cleaning of the casting.

Other appurtenances common to separate sanitary sewers are inverted siphons, creek crossings and flush tanks. Inverted siphons must be inspected frequently as they are readily clogged by accumulations at the inlet or grit deposits in the siphon pipes. Two siphons on intercepting sewers at Champaign-Urbana, Illinois, are inspected at least weekly and cleared of inlet accumulations. Three siphons at Ithaca, New York, are flushed out every four months. Creek crossing structures are generally checked following wet seasons to ascertain erosion damage, replace protecting rip-rap or make repairs. Flush tanks maintained in regular service are inspected monthly and afforded cleaning and adjustment.

Frequent cleaning of catch basins on storm or combined sewer systems is justified by the protection they provide against grit deposits in the sewers. Practice appears to be to clean these at least annually where paved streets are drained and more often when streets do not have a permanent surface. Street inlets are inspected and cleared after every rain at Rock Falls, Illinois, to assure good street drainage. Storm water overflows are inspected and given necessary attention at least once monthly at Birmingham, Michigan, and Bloomington, Illinois, with more frequent attention being accorded in wet seasons. Sewage flow regulators and adjustable overflows in combined systems are best attended during high flows so that they may be adjusted to actual operating conditions.

Regulation of Use of Sewers

Probably no other public utility is mis-used to so great a degree as is the sewer system, yet there is always readiness on the part of the public to criticize faulty operation. This condition is no doubt largely due to the lack of public education and to the failure of city officials to adopt and *enforce* proper ordinances controlling the usage of sewers. Such an ordinance does no good if merely filed among the dusty archives of the municipality—it must set forth proper practices, contain adequate penalties and be enforced without hesitancy when courteous requests for cooperation are ignored.

Anderson (1) points out that the best way to obtain public cooperation is to definitely allocate responsibility for house sewer connections to the property owner, requiring him to pay for any maintenance work necessary on these lines. Many eastern cities have established a policy of accepting responsibility for all sewers outside the curb, which practice appears to have several advantages. The Atlantic City Sewerage Company (5) requires a trap on each house service at the curb and responsibility in each case is determined by examination of the trap. The company services all sewers outside the curb and local plumbers perform at the property owner's expense, any work needed from the curb to the house.

Among the more important items warranting inclusion in the sewer ordinance are:

1. Control over location of certain trees (poplar and willow) which might cause root stoppages, including authority to remove such trees found to cause trouble.
2. Prohibition of downspout and similar surface water connections from separate sanitary sewers.
3. Provision for detailed inspection by competent personnel of all house service installations. Also, rigid specifications covering workmanship and material in house services.
4. Requirement of suitable preliminary treatment facilities in commercial and industrial concerns to prevent damage to sewers. Wastes commonly controlled for this purpose are:
   (*a*) Greasy wastes from restaurants, packing plants, etc.
   (*b*) Oil and dirt from automobile filling stations and wash racks.
   (*c*) Inflammable and explosive wastes from cleaning establishments.
   (*d*) Wastes containing excessive solids, such as spent grain from breweries, paunch manure from packing plants, ashes, garbage, etc.
   (*e*) Corrosive wastes, as those from metal galvanizing and pickling plants.
5. Requirement of suitable preliminary treatment facilities in industries to prevent interference with sewage treatment plant operation.
6. Provision for stern penalties for malicious damage by vandals.

A combination grit and oil trap recommended by the South Dakota Board of Health (8) for use on sewers from garages, filling stations and automobile wash racks is shown in Fig. 10. The oil problem is successfully met at Baltimore (2) by requiring by ordinance that such waste be stored on the premises until collected periodically for disposal under direct control of municipal authorities. The provision of a convenient means of disposal of the oil eliminates need for policing garages and similar establishments.

After a bad fire caused by waste oil and gasoline dumped to sewers at Aurora, Illinois, Superintendent W. A. Sperry acted to prevent a recurrence by means of newspaper publicity and direct contact with industrial sources of volatile wastes. The latter was accomplished by a plant-to-plant canvass of 245 industrial and commercial establishments, during which a verbal notice was given a responsible representative of each concern, a poster epitomizing the sewer ordinance was left and a signed acknowledgement of each visit was obtained. The survey cost $100 and appears to be good insurance against future damage, although it must probably be repeated after several years.

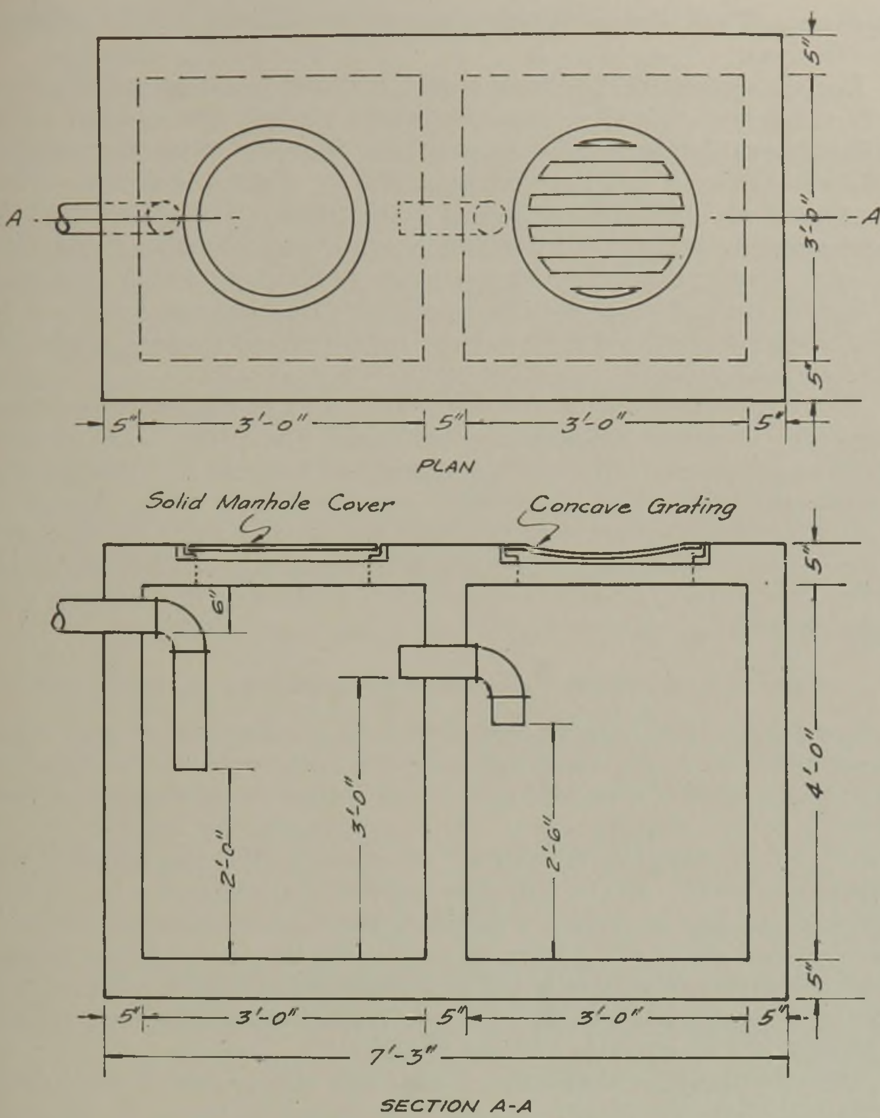

FIG. 10.—Combination oil trap and grit basin for garages and filling stations. Recommended by South Dakota State Board of Health.

SEWER VENTILATION

Ventilation in sewers is necessary to dilute and purge the system of gases which are inflammable, explosive, asphyxiant and toxic. In warm climates where hydrogen sulfide is often a problem, ventilation is also beneficial in controlling disintegration of concrete sewers and structures because (*a*) the concentration of H_2S in the atmosphere and (*b*) collection of moisture on exposed surfaces, are reduced.

The degree of effective ventilation in a sewer is usually dependent upon the amount of vent openings and the movement of air across the openings. Thus, it appears that natural ventilation is at a minimum on still days.

Forced ventilation has been found justified in large outfall sewers at Los Angeles (9) and several ventilation stations are in development. Ordinary ventilation practice is probably represented by the procedure at Lower Merion Twp., Pennsylvania (10). "Ventilating covers" having eight 1-in. openings are placed at the upper ends of all lines and approximately at each third manhole, with consideration being given to surface water drainage and proximity to points at which odor might be troublesome, when selecting locations. Buckets are hung beneath ventilating covers for the purpose of catching debris which might pass through the openings.

To guard against fires and explosions and to eliminate conditions dangerous to sewer maintenance personnel, the City of Los Angeles (9) has a gas survey crew which systematically checks the entire system, making observations at about 60,000 manholes per year. Results of various gas detector tests are recorded and used as basis for correction of dangerous conditions. When the presence of illuminating gas is suspected, the utility company is immediately notified so that any gas main leak may be repaired.

Design and Construction Items Facilitating Maintenance

Good design and careful construction of a sewer system will reduce maintenance to a minimum and expedite such work as is necessary. There has been sufficient experience at this time to substantiate present methods of ascertaining sewer sizes and grades, yet there is often a tendency to violate the limitations of good practice, particularly with respect to grades. Every effort to avoid capital and operating costs of pumping stations is certainly justified, but consideration must also be given the less satisfactory service and everlasting maintenance expense which accompany the installation of sewers on flat grades. Where moderate reductions in slope are logical, provision of adequate, suitable flushing facilities constitutes good practice.

The prevalence of difficulties from roots and ground water infiltration is ample proof that too much care cannot be taken in specifying and installing permanently tight joints. This fact, of course, is generally appreciated and modern jointing methods and materials are already demonstrating their superiority. Careful specification and performance of back-filling is also important in preventing crushing of pipe and movement which results in opening of joints. The use of especially suited pipe and construction methods in sections where foundation conditions are bad or where excessive ground water is present, has been proven to be good economy, even though more expensive in first cost.

Other design and construction details suggested by maintenance personnel as being of importance to their functions are the following:

1. Design of junction chambers so that back-water areas of low velocity, causing deposition of grit, are avoided.

2. Design of storm water overflows so that they are not accessible by vandals.
3. Catch basins of ample size at storm water inlets draining unpaved streets.
4. Complete consideration of local conditions when selecting the type of pipe used for sanitary and industrial sewers.
5. Spacing of manholes not more than 350 feet apart.
6. Lateral sanitary sewers of not less than eight inches diameter.
7. Smooth flow without splashing or turbulence at manholes or appurtenant structures. (Important where hydrogen sulfide might be a problem.)
8. Diversion and regulator devices of simple design and capable of convenient adjustment.

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OPERATORS' BREAKFAST DISCUSSION AT SECOND ANNUAL CONVENTION *

L. W. Van Kleeck and B. A. Poole, *Leaders*

Mr. Van Kleeck: The time has arrived, gentlemen, to push away the breakfast dishes, light up those pipes and cigars, and come down to earth, or to be more specific, discuss the elusive rascal of sewage treatment—grit.

Mr. Poole and I claim no credit for this discussion. We didn't even pick the subjects. The success of this hour depends on you. No operator has any priorities today with all respect to the Federal government's regulations. We are merely up here to ''encourage the timid'' and ''prevent the bold from making this session a riot.'' We ask that each speaker clearly announce his last name and locale before taking part in the discussions.

* Hotel Pennsylvania, New York City, October 11, 1941.

Grit: Conditioning, Handling and Disposal

Mr. Poole: It is no exaggeration to say that grit can be and has been a major operating problem at sewage treatment plants. It is, furthermore, a baffling problem for the designing engineer. How much grit will be received? How does grit get into a separate sewerage system? Have you considered such sources as canneries, wool scouring mills, and the cleanings from cesspools which may be dumped into sewer manholes? Should every plant, whether connected with a combined or separate sewerage system, whether large or small, whether in the east or west, be equipped with a grit collector? Does one grit chamber provide sufficient flexibility? Are hand-cleaned chambers satisfactory? What size should they be? When mechanical collectors are provided, what schedule of operation should be followed? How satisfactory are present-day grit washers? Does the grit smell? What is clean grit? Do you report the results of grit washing in terms of putrescibles or organic matter? How do you remove it? Where do you put it? Do you find that grit passing the grit chambers wears subsequent plant equipment like sludge pumps, or in some cases, sewage pumps? Does it clog plant piping? How often do you have to remove grit from your primary settling tanks? Is grit cutting down your effective digestion volume? What is your problem? How did you solve it?

Dr. Symons, you have had grit and more grit, what is the Buffalo situation to-day?

G. E. Symons (*Buffalo, N. Y.*): Am I one of the timid or the bold? Most of you fellows, particularly New Yorkers, will have heard this story before.

Grit is 50 per cent water. Of the dry solids, 40 per cent is volatile matter. We went to the trouble of itemizing the materials in the grit and found that the garbage and ash can matter was by far in the greater proportion. Corn led, followed by peas and beans.

The enormous amount of grit we have gathered at Buffalo during the past two years has resulted from a sewer cleaning program that was instituted when the interceptors went into service. The sewers had not been cleaned for practically ten years in any part of the city. There are about 700 miles of sewers in Buffalo, including the laterals. About 230 miles required cleaning and the amount of grit was tremendous. After one storm we had 200 cu. yd. of grit.

The way we get rid of grit is by burning. Greeley and Hansen made provision for this in the sludge incineration plant. During the first year, burning the grit was not very successful. The operators were advised that they might burn it but they were reluctant about doing it. We now find that this material can be burned with either one part grit to four parts sludge or one part grit to two parts sludge. I have seen incinerators operating on grit last eight years or more.

Grit which passes through grit chambers is fine sand. We have classified it, sieved it. Most of it is 60-mesh and runs down to 200-mesh.

It does not clog up digesters and flows out along with the sludge. It acts somewhat as a filter aid.

The amount of grit, as sand, in the sludge after digestion is about 30 per cent, and is mostly finer than 60-mesh. When it has been conditioned and dried and handled through the incinerator, you can realize we have abrasion problems. We have had blocking of the sludge lines from the primary tanks, due to the sand. In the incinerators themselves, the abrasion problem has been terrific. It has been superterrific on some parts. One of the schemes we have used to overcome abrasion is to use "wear backs," letting the grit wear out concrete instead of metal.

There has been abrasion in the incineration equipment proper and in the flues which handle the feed. We overcame that with some changes in the design. We changed the position of the draft vane so that it operates on the clean air side of the siphon and also used a special metal where abrasion was worst.

We are burning our grit at the present moment, using it as fuel. The grit does have an odor and this is the only odor problem in our plant. We can thank Mr. Hansen for providing a ventilation system which carries the odors up through a stack, and the fact that we have very little sulfide in our water. We have a relatively short time of flow and about 0.1 p.p.m. of hydrogen sulfide. Chloride of lime is used to keep down the odor.

A. L. Genter (*Baltimore, Md.*): How do you clean the sewers?

Dr. Symons: The Sewer Department does this work. We have used back flushing with water until we had one line so stopped up it had to be cleaned within a week. One of the largest sources of our grit is sand from streets, which is washed into the sewers by winter rains.

Mr. Wallace (*Delaware*): We handle a large amount of grit in our tanks. We framed in some false work to increase the velocity and pump at a uniform rate as much as possible, so that the velocity in the interceptor will not drop below 3 ft. per second. This has served to eliminate many of our troubles. Ordinarily, we burn our grit. We have very little odor and organic matter.

K. L. Mick (*Minneapolis-St. Paul, Minn.*): Our grit is 10 to 20 per cent of our total inorganic solids. We purposely admit some grit to the clarifiers. During dry weather flow we try to hold the velocity to 1 ft. per second, while during storms we strive for about 0.75 ft. per second. The purpose of this is to give us a heavier sludge so that it will burn better.

We have a total of eight grit chambers. The grit will vary from 65 per cent volatile matter to 2 or 3 per cent. Solids content varies from 40 per cent to 95 per cent. The grit amounts to about 7 cu. ft. per m.g. of sewage. The major portion is between 20- and 48-mesh and very little is smaller than 100-mesh. Any larger than that goes to the clarifiers.

We dispose of it by trucking to a dump where we have very little trouble with odor.

C. C. Larson (*Springfield, Illinois*): Our plant was originally designed with manually cleaned grit chambers which we operated for ten years. Last year we put in mechanical cleaning equipment. The mechanism was installed not for economy, but to insure cleaning of our chambers.

G. W. Magee (*Washington, D. C.*): I would like to ask how many operators of plants with combined or separate systems, who do not have grit chambers, wish they had them or plan to put them in?

G. Searls (*Rochester, N. Y.*): One of our small plants was originally planned to include a grit chamber but it was decided to omit it. The plant serves a separate system.

Last year I had to clean the tank and removed about 75 yards of grit from it. This grit came from a W.P.A. sewer project when water pumped from the trenches for the new sewers was pumped into our sewer system.

We put a crane alongside the tank and used a swing type of bucket to load the grit in bags. The bags were dumped out on the sludge beds to drain the grit.

F. W. Jones (*Cleveland, Ohio*): We forget something. It is a fact that there are some grit particles attached to sludge particles, which go through with the sludge and which would never come out in the grit chamber. They get into the digester, the carrying agent is digested and the grit falls to the bottom. Sooner or later it should be removed from the tank.

Wellington Donaldson (*New York City*): With the combined systems in New York City, grit is one of our most intensive problems.

First: Coney Island. Five years ago we did not have grit chambers. We have since had much reason to regret the omission of chambers. We have accumulated sand in the flocculators which caused them to shut down and to be cleaned. Sand has collected in the tanks and caused trouble there and in the pumps and the sludge lines. In the digesters, special protection has been effected.

Second: New plants. Grit chambers, mechanically cleaned, are being incorporated. We have had our troubles even with that. The amount of grit at Wards Island has been very excessive. I hesitate to quote quantities but it is something like 500 tons per day.

One of the sewers sent down avalanches of grit when we started the plant. We shut it down for cleaning. All sorts of things came out of it, including scrap iron. The washing and handling of grit has given a great deal of trouble. It is a very abrasive material and there is no entirely satisfactory mechanical means of handling it. Concrete is bound to suffer. Depreciation of the original grit chamber at Wards Island has been very heavy.

There is a great deal of dissatisfaction with the washers which have been available on the market. There is a distinct challenge to the equipment people to provide better washing equipment. Conveyors are not washers. It is difficult to find efficient washers and improvements can still be made.

Some of the grit in New York is used for building. The Bowery Bay Plant grit is used for fill on plant grounds. Grit from some of the other plants is not sufficiently clean to be used for fill.

WARREN J. SCOTT (*Connecticut*): I would like to ask Mr. Donaldson what he thinks of the idea of only one grit chamber at a small plant?

MR. DONALDSON: I know of few plants in which a single chamber is satisfactory.

D. E. BLOODGOOD (*Indianapolis, Ind.*): We were confronted with the problem of having a grit with a high content of organic matter and had difficulty with disposal. We started out with the assistance of the equipment people, to work out the problem of mechanical removal of grit from grit chambers.

We did not have time to have the chemists analyze the grit in the grit chamber section by section but one of my engineers got into the chamber and found very much more organic matter than grit. We put in a standard velocity weir. That gave us some segregation of the organic and inorganic material.

The drag net system is working very efficiently. We remove grit once every eight hours and all of it is put through a washer and adequately washed. The cleaned grit is piled and used for fill immediately adjacent to a public highway. We do not get all of the grain out but pigeons and sparrows take care of this.

Grit coming into the grit chamber in large quantities at low flows surprised us at first. It is our opinion now that grit moves in a sewer, not in suspension, but rolls along the bottom of the pipe. At the lower flows you are storing up a greater amount than when the sewer is full.

We have a type of grit washer on which the maintenance is very high.

ROY S. LANPHEAR (*Worcester, Mass.*): We do not have mechanical cleaning equipment. We found that one of our chambers got more of the material than the other; also that the outlet end of half of the grit chambers has a lot of organic matter in it. The grit is flushed out to an adjacent sand filter. We have no trouble with odor. One of the main troubles is to clean grit chambers without mechanical equipment. This job requires a good working crew. We clean them before they are full and have been very fortunate in having a little extra labor. Five or six men, in a day's time, can clean a 75-ft. grit chamber. Rubber boots are needed.

L. E. WEST (*Elizabeth, N. J.*): I rise in defense of baffles in grit chambers. They also assist in settling tanks. We have four grit chambers and have had trouble with organic material in the grit. Mr. Tark suggested that some fixed gates be placed where a head loss would be created near the incline. This created increased velocities. We worked out such a scheme and have hung gates made of steel plates so that they are suspended in the channel. They swing up in position and create a cross current. We get a much cleaner grit and have cut down organic matter.

C. C. AGAR (*Albany, N. Y.*): I believe I can say that our convictions are that a grit chamber is necessary and indispensable at every treatment plant. I think that will be the trend in the next few years. We will see more grit chambers and less need for that second digestion tank.

M. M. Cohn (*Schenectady, N. Y.*): At Schenectady we have a supposedly separate system but we have to get the relief force out every time it rains. We have no grit chambers. We have a trunk sewer one and one-half miles long in which the velocity is under 0.5 ft. per second. The grit accumulation becomes 6 ft. wide and 3.5 ft. deep. The drop is only 1.5 ft. in a mile. We now clean that trunk sewer. About 10,000 cu. yd. of material have been taken out.

Safety in Sewage Works

Mr. Van Kleeck: A stimulating feature of sewage treatment practice is the wide variety of engineering subjects which enter into its proper pursuit. To mechanics, electricity, chemistry, structural design and many other branches, safety engineering must be added.

The accident frequency at sewage treatment plants is greater than is generally realized. In fact insurance records show that the accident deaths and total disabilities per 1000 man-years are several hundred per cent more among sewage plant workers than among machine shop workers, the latter being a common standard for comparison in industry. Proper safety at sewage plants and in sewers boils down to (1) Prevention of physical injuries, (2) Prevention of infection, (3) Prevention of the hazards from gases and fumes, (4) Proper first-aid measures when an accident or injury occurs.

The designer of sewerage structures must do his part; the operation or maintenance of those structures must adhere to proper practices; and lastly, city officials must give operating crews the safety equipment needed for hazardous jobs. Lists of explosions at sewage treatment plants have been published and physical injury records are available. The infection record is a bit more obscure. This discussion can be of considerable profit to all of us, if actual personal safety experiences are related. For example, has anyone, when testing a sewer atmosphere, emptied digester, or other sewerage structure for gas, found an oxygen deficiency or a toxic or explosive gas in that structure which might have proved fatal? Data of that type are rare. What safety precautions do you take at your plant besides crossing your fingers? What is your personnel accident record? What questions do you have? Here is the time and the place to get your answer!

Mr. West, everybody knows that the Joint Meeting Plant in Elizabeth is safety-minded. How did you create such a desirable attitude?

L. E. West (*Elizabeth, N. J.*): We had an unfortunate experience at the Joint Meeting Plant some ten years ago when the largest chamber on one of the trunk line sewers blew up. Fortunately, no one was hurt. An investigation was started as to the cause and there were a great many suppositions but nothing definite was concluded. The Commissioners had to pay the bill and they decided to safeguard against a recurrence.

After this experience we went into an investigation of safety devices. We found many devices such as explosive gas indicators, hydrogen sulfide indicators, safety belts, rubber gloves, etc.

Safety is a matter of education. Our men take a course in first aid. We drive home the necessity for safety in sewer work and expand it to take in the treatment plant. We believe that the most important thing is constant prevention. We have had some experiences. We know what can happen with Workmen's Compensation. We list the men who are absent, and the loss and effect of accidents.

It is a fixed rule that every accident be reported. We have taken care. We provide equipment. The men must be familiar with the equipment. We have test trials. We know of an instance in Newark where a death occurred and had we been notified we could have saved the man's life.

Safety equipment must be available when needed. We carry our equipment in a special truck.

We do not allow a man to go into a deep manhole unless he has a safety belt attached. We have some manholes over 20 ft. deep. At points of extreme volumes of flow, where a slip can be hazardous, we use safety equipment. Also in the sludge tanks, where safety belts are always attached. We have telephones in the gas masks. Our men can go into a sewer for 200 ft. and be in connection with a man on the surface. You know how far a man is in the sewer and get a correct log of conditions in the sewer. There is not a great deal more I can add.

Mr. Van Kleeck: Do you test every sewer manhole before entering?

Mr. West: We try to use common sense. Testing can be overstressed. For ventilation we have a smokestack one hundred feet high connected to the main sewer line. Most of our sewers are relatively small. Our largest is 7 ft. in diameter and we have a great many branches, of which 90 per cent are less than 48 in. in diameter. Most of these are close to the surface although there are a few deep spots. Accidents in these lines are infrequent.

L. H. Enslow (*New York City*): What do you consider the first, second and third steps in the matter of safety?

Mr. West: I would start out as the first thing to give the men the best equipment they can use for the job. Sewer rods in themselves have not been found satisfactory in cleaning sewers. We have the flexible rods. For small sewers they are very effective. It is better for the men to work on the surface. If men have cuts on their hands we try to keep them from direct contact with the sewage. We insist on rubber gloves. We report every accident.

The second thing is personal cleanliness. We provide wash rooms and shower baths.

The third thing is to look for explosion hazards. Explosive gas indicators are more necessary where low velocities occur and deposits are suspected. All the men should be provided with gas masks for use on sewer systems. The voice power telephone is another item of equipment which is very important.

Mr. Enslow: What is the length of telephone service?

Mr. West: Most of our manholes are not over 250 ft. apart and the telephone is effective for this distance.

Another thing to watch is ventilation. We have a portable air blower and also provide ventilation by opening several manholes along the line we are working in. Hydrogen sulfide has never been found in dangerous concentrations.

Mr. Van Kleeck: This is the safety equipment list we recommend in Connecticut:

1. Safety belts.
2. Safety lantern.
3. Rubber boots and gloves.
4. Oxygen deficiency indicator. This is used on the surface (with rubber tubing) to detect oxygen deficiency and explosive gases in concentrations above one per cent by volume.
5. Lead acetate solution for detection of hydrogen sulfide.
6. Ampoules for carbon monoxide detection.

Mr. Enslow: You can also lower a dime into the sewer to detect hydrogen sulfide.

H. M. Matthews (*Georgia*): We have no necessity for going into the sewers but we do go into the digestion tanks. When 2 ft. of sludge or more is in the bottom we use a ventilator and mask. We always have three men on the top with one inside. As to cuts and abrasions, the State officers have advised us about germicidal solutions. The men are encouraged to use the solution. Our men are cautioned and all carry insurance. We do not have compensation.

C. C. Larsen (*Springfield, Illinois*): In the use of equipment, the training of the men is important. Last year, under the supervision of the American Red Cross, a complete course was given to our men. They cooperated very well. The American Red Cross is anxious to conduct these classes if you will contact them.

F. W. Jones (*Cleveland, Ohio*): I think of one thing we must try to drive home. You should not depend too much on the salvage value of sewage. We found one of our men using the soap he had taken from the sewage to wash his face!

As to the matter of health, do you know of any gang of men healthier than sewage plant operators? I had two men who came to work at the plant when it was thought they were about to die. They both got well!

W. A. Hansell (*Atlanta, Ga.*): How about smoking at the plant? This is the worst problem we have.

Mr. West: My plant is one where we do not have that worry. We have no sludge digestion. Our sludge is carried to sea in boats.

Mr. Donaldson: I do not agree with Mr. Hansell. Our men are not forbidden to smoke. At our plants they smoke except in particular locations where hazards exist. We confine our prohibitions to the parts of the plants where there are definite hazards. Smoking contributes to the comfort of the men.

R. W. Frazier (*Oshkosh, Wis.*): At our small plant we do not have a large crew. One man is on duty at night. We have installed a police alarm and the man reports every hour by a signal to the Police Department. If a signal is not received they call up or go out and investigate.

All men have been instructed to wear rubber heels. One day an Insurance Inspector, a woman, came in and wanted to see our first aid kit. I said, "You do not have rubber heels." She blushed and was quite embarrassed.

Regarding cuts and scratches, our men are instructed by signs posted in the plant. They are instructed to stop work immediately and get first aid. Bad accident cases go to a doctor. The result is that we have had a good safety record.

Mr. Searls: How many men have furnished their operators with rubber gloves? You can buy a cheap glove. By using them when tearing down pumps and handling machinery we save a lot of trouble.

Mr. Meyer (*Bakelite Co.*): There is a solution that can be prepared for the men to dip their hands in. To provide men with rubber gloves is a good investment. It is well to ask all who visit the plant to put on rubber gloves. One difficulty with wearing rubber gloves is that they cannot be kept clean.

Mr. Cohn: I have noticed cases of dermatitis around sewage plants because of too frequent washing of hands. This was recently described in a magazine article on safety. There is a solution known as "Calgon" which is applied to the hands twice a day. The solution enters the pores as it is allowed to dry. People who use this are free from effects of over-use of water.

Mr. Agar: At one plant it was necessary to enter the sludge digestion tank for the purpose of enlarging hand holes to enable scum to be broken up at these points. The tank was opened and the operator started to open the holes with a hand drill. This was slow work so the next day he took in a lag drill. There was a sheet of flame which shot out of the manhole, burning the drill operator severely. He is here at the meeting.

In this case there was a man with rope in attendance outside the manhole. However, the rope was attached to the drill so that it would not be lost—not to the man using it!

Sewage Plant Housekeeping: Inside and Out

Mr. Van Kleeck: Patient waiting for that badly needed new sewage treatment plant has led me to coin my own definition of a sanitary engineer: "He's the fellow that finally persuades people in a community to pay taxes for something they never see." The question: "Why make sewage plant sites attractive?" holds a challenge for that definition. A speaker at the New York State Municipal Training Institute in 1937 listed four good reasons for good housekeeping at sewage plants: (1) to foster good will, (2) to make the plant a better place in which to work, (3) to minimize maintenance costs, (4) for fun. We appreciate that under present conditions, it may be desirable to discourage plant visitors but we hope these conditions will not prevail forever, so let's discuss this topic from the standpoint of housekeeping chores which are always in good taste. Planting trees, shrubs and flowers, painting, keeping structures in good repair, neatness inside and out, and grass cutting are some of the matters to be considered. There are many here today who have done wonders with the old back-house of yesterday—what did it cost, what did you do, and how did you do it?

Mr. Cohn, will you give the lawn mower the first push?

MR. COHN: There is a close relation between safety and the question now before us: Plant Housekeeping. At Schenectady we sweep in the corners. I am reminded of the story of Calvin Coolidge attending church. When he came home his wife asked: "Did you go to church?"

"Yes."

"What did the minister preach about?"

"Sin."

"What did he say?"

"He was against it."

I am like the old maid who kissed a man. I like to talk about it.

Plant Housekeeping is being a good neighbor. Real cleaning is the thing. I like cleaning on the outside and the inside. A man came to our plant one day and immediately headed for the wash room. He came out and said he did not care to see the rest of the plant. In saloon keeping, the keeper was considered a good risk if he kept the back room clean. Keep the inside and outside of the plant clean.

One more thing: if your plant is clean it is going to function well. It raises plant morale. At no time as much as now has there been need for careful maintenance to protect equipment. If your plant's youth is gone, try to keep it running for another few years until this war is over. There is a direct relation between good plant housekeeping and efficient operation.

R. W. FRAZIER (*Oshkosh, Wis.*): I have a little philosophy. Many people have no noses and they smell with their eyes. Keep the grass in good shape. They forget about odors if the building and grounds are clean and neat. When they come inside it is good advertising to show the equipment is painted. We had one instance when a group came in with the idea they would have to wear rubbers. They went away with a better idea. Some people complain about the cost of the sewage plant but after going through the place, they are more satisfied to pay for sewerage service.

J. H. BROOKS (*Worcester, Mass.*): After many years with the Worcester sewer department, fighting the city officers for money, I was struck with the fact that the Finance Committee did not realize what sewage treatment meant. This Committee, on viewing the plant, asked: "What park is this?" They would never have had that impression had we not carried out good housekeeping.

R. W. WESTON (*Boston, Mass.*): The town water purification plant is likened to the town kitchen. The sewage treatment works is likened to the town water closet. A dirty one repels us. A clean one attracts us.

Mr. Scott: There is a case where a suit for damages was brought against a town where the sewage treatment plant was located in a very restricted area. The testimony showed no evidence of odor. A picture showing the landscaping was the main basis of defense.

WHAT NEW YORK CITY DOES ABOUT SCREENING SEWAGE *

By Wellington Donaldson
Director, Bureau of Sewage Disposal

The Bureau of Sewage Disposal of the City of New York is charged with the operation of four modern treatment plants and nine old ones, plus one detached pumping station. Some of the old plants are pretty much antiquated, but together with the new they exhibit a variety of screen equipment unlikely to be found in any other city. Besides the

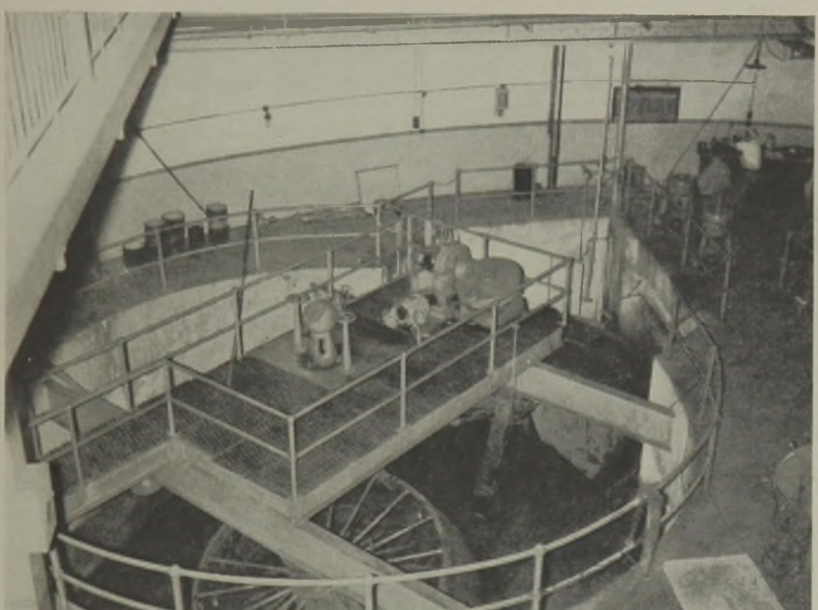

Fig. 1.—Jamaica fine screens.

manually cleaned trash racks with 2 in. to 4 in. openings, common to practically all sewage plants, there are a number of interesting types of mechanical screens in use.

Fine Screens.—During the period from 1917 to 1927 there were installed eight fine-screening plants as a corrective to the very serious

* Symposium on Control and Operation of Sewage Works, Second Annual Convention Federation of Sewage Works Assoc., New York City, October 10, 1941.

condition caused by the discharge of raw sewage into the water courses. These mechanical fine screens had slotted openings from 3/64 to 1/16 in. and comprised five disc screens of the Reinch-Wurl type, one band screen of the Rex type, one drum screen of the Tark type and one drum screen of the Dorr type. The installation at North Beach was discontinued in February, 1938, when the sewage from its tributary area was diverted to the new Bowery Bay Plant. The remaining seven fine-screening installations are still in service (Fig. 1). Very likely at the time the fine screens were installed they were considered adequate to combat the increasing pollution load on the harbor. They have, as a matter of fact,

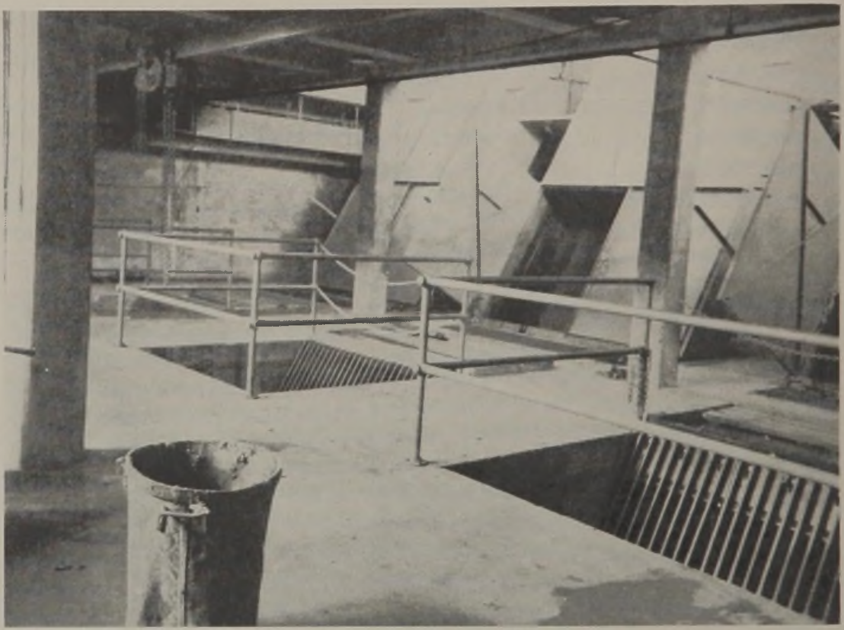

FIG. 2.—Bowery Bay—hand cleaned racks and mechanical bar screens.

served a useful purpose as a stop-gap between discharge of raw sewage and effective treatment. The efficiency of fine screens however, is only 10 to 15 per cent in removal of suspended solids, although their efficiency in removing nuisance aspects must be rated considerably higher. The maintenance of fine screens is high for the amount of work performed by them. All of the seven fine screens of the City are slated to be superseded as soon as modern treatment plants of high efficiency can be constructed. A single exception is Jamaica where the disc screens will be retained as preliminary treatment to the 65 m.g.d. activated sludge plant soon to be in service. Judging by the surprising amount of floating material which carries through many activated plant processes to the final tanks, some form of fine screens would be helpful in improving the sightliness of the activated sludge process.

Mechanical Bar Screens.—All new plants, except the original Coney Island installation, have been equipped with the usual type of mechanical screens of various makes, with ¾-inch to 1-inch spacing of bars (Fig. 2). In the new Coney Island Extension hand-cleaned bar screens have been discarded in favor of mechanical screens.

FIG. 3.—Debris from racks at Tallmans Is.

FIG. 4.—Manhattan grit chamber after a storm.

Our mechanical bar screen installations are provided with grinders for shredding the screenings and returning the shredded material to the sewage flow, later to be captured and treated as sludge. However, means are provided at the Wards Island grit chambers for removing the screenings by pneumatic ejectors or by cans. Both methods are practiced according to local circumstances, but experience indicates the bar screenings are more easily dealt with by shredding.

Mechanical Trash Racks.—Practically all of the drainage areas tributary to the existing sewage plants in New York City are on combined systems. On this account and because of the use of sewers for purposes for which they were never intended, a great deal of material reaching the treatment plants, particularly during storms, is of a nature entirely foreign to domestic or industrial wastes. It is composed of timber of all sizes, rags and fabrics of all description, stones, coal, bricks, concrete slabs and sometimes much larger objects, such as mattresses

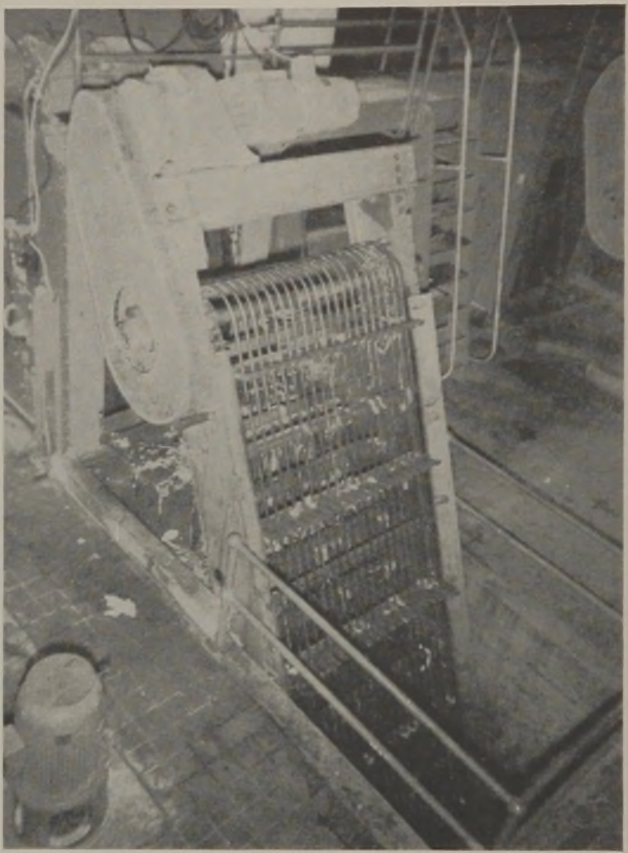

FIG. 5.—Bronx grit chamber—mechanical trash rack.

and hot water boilers. One wonders how people can go to so much trouble to put such objects into a public sewer (Figs. 3 and 4).

It has been painfully apparent to us that the trash racks at the large plants constitute a real "bottle neck." It has been very difficult to keep trash racks clean by hand and the hard work entailed on the operating personnel during storms has been very gruelling. In an effort to remove this "bottle neck" and thus provide greater safety and more comfortable operating conditions, substantial progress has been made in equipping trash racks with mechanical devices which are sufficiently rugged, powerful and dependable to deal effectively with the miscellaneous material which is brought down by storm flows. As a step in this direction, about two years ago a mechanical trash rack was installed at the Manhattan Grit Chamber for trial. Its performance proved so satisfactory that all hand-cleaned trash racks at both the Manhattan and Bronx Grit Chambers have been replaced by mechanical trash screens, with 2-inch spacing (Fig. 5). These screens differ from the usual mechanical screens in having the raking combs enter from the under or down-stream side of the screen. Also instead of rigid rectangular bars, the racks are formed of iron rods with some lateral play to prevent jamming by boards and sticks. The eight screens of this type now in use at the two Wards Island grit chambers are a development and improvement of the Laughlin type of screen.

At the new and enlarged Coney Island plant there are installed rugged mechanical trash screens of the Dorr make, with bar spacing 3¾ inches. In principle, this screen is much like a ponderous garden rake operating on the up-stream face of the screen. Experience with this screen so far has been good. During the first trials the screen brought up intact a wheelbarrow, unwittingly left in the sewer by the contractor.

From the foregoing will be indicated our present conviction that the large treatment plants of New York City should be provided with tandem mechanical screens—a rugged mechanical trash screen to take care of lumber and similar coarse material, followed by a conventional mechanical screen which will handle rags, paper, etc. No single screen seems able to handle equally well the wide assortment of floating material found in the combined sewers of large cities.

A list of existing operating plants, with pertinent data, as to equipment, quantities, etc. is given in the accompanying Table I.

Handling and Disposal of Screenings.—The handling of material caught on trash racks and mechanical bar screens is of course obvious. A certain amount of hand sorting and handling is necessary before the material can be hoisted out of the plant for final disposal. In the Manhattan and Bronx Grit Chambers the operating floors are served conveniently by travelling cranes so that any such material may be readily hoisted out to trucks. In other modern plants electric hoists are employed to raise material from the operating floor. The older and smaller plants employ hand methods.

In general all material caught on trash racks and mechanical bar screens, except where the latter is ground and returned to the sewage flow, is placed in standard 3 cu. ft. galvanized cans sprayed with a disinfectant such as "CN" or a mixture of orthodichlorbenzene mixed with sulfonated castor oil, and delivered to Department of Sanitation trucks which haul the material away for incineration, or fill according to the nature of the material. In other words, the responsibility for final disposal of such materials is not with the Department of Public Works, which operates the treatment plants.

At two of the rather isolated plants the small amount of material caught on the trash racks is disposed of locally on the plant grounds by burning or burial.

TABLE I.—*Sewage Screen Data, Bureau of Sewage Disposal—New York City*

Plant	Average Flow, M.G.D.	Daily Screenings, Cu. Ft.	Cu. Ft. / M.G.	Screen Openings, Inches	Type	Disposal
Canal Street	7	8	1.14	3	Rack	To city incinerator
		170	24.25	3/64	Fine*	To city incinerator
Dyckman Street	7	110	15.70	5/64	Fine*	To city incinerator
Wards Island						
Manh. Grit Ch.	88	83	0.95	2	Mech. bar	To city incinerator
		none	—	1	Mech. bar	Ground and returned to sewage
Bronx Grit Ch.	95	98	1.03	2	Mech. bar	To city incinerator
		none		1	Mech. bar	Ground and returned to sewage
26th Ward	46	40	0.87	2½	Rack	To city incinerator
		800	17.40	3/32	Fine*	Blown to plant grounds
Caisson No. 2	7	17	2.43	¾	Mech. bar	To city incinerator
Coney Island	50	34	0.68	3¾	Mech. bar	To city incinerator
		none		1	Mech. bar	Ground and returned to sewage
Neponsit	0.6	9	15.0	1½	Rack	To city incinerator
Hammels	4	4	1.0	2⅛	Rack	To city incinerator
		60	15.0	3/64	Fine*	To Jamaica for centrifuging and composting
Far Rockaway	2	3	1.50	1	Basket rack	Burned and buried at plant
Jamaica	32	20	0.62	2½	Rack	Covered with CN, dumped on plant grounds
		370	11.56	3/32	Fine*	Centrifuged and composted for soil conditioner
Tallmans Island	15	9	0.60	3	Rack	To city incinerator
		none		1	Mech. bar	Ground and returned to sewage
Bowery Bay	34	10	0.29	3	Rack	To city incinerator
		none		¾	Mech. bar	Ground and returned to sewage
Cromwell Avenue	3	1	0.33	2	Rack	To city incinerator
		10	3.33	1/16	Fine*	To city incinerator
Oakwood Beach	2	1	0.50	2½	Rack	To city incinerator
		25	12.50	3/64	Fine*	To city incinerator

* Slotted plate or ribbon screens, brush cleaned, except Cromwell Avenue, which is Dorr type.

The handling and disposal of material caught by the fine screens present a somewhat different problem because the fine screenings are voluminous, contain 85 to 90 per cent moisture, much putrescible matter, and in fact are very similar in their behavior to primary sludge.

At the Dyckman St. Plant, Manhattan, the fine screenings are collected in large cylindrical galvanized cans of 9 cu. ft. capacity, deodorized and removed by the Department of Sanitation for incineration. At the Canal Street Plant, which is entirely below the street level, fine screenings are delivered by pneumatic ejectors to special designed trucks at the street level and removed by the Department of Sanitation for incineration; at the Cromwell Avenue and Oakwood Beach Plants, Richmond, S. I., the fine screenings are collected in metal cans, deodorized and removed for incineration. At the sizeable 26th Ward Plant in Brooklyn, the fine screenings are ejected to a pile or mound on the station grounds as has been customary since the station was built. However, preparations have been made to utilize the accumulation of screenings by composting methods, later to be described. The fine screens at this plant will go out of commission when the new activated sludge plant is completed within a couple of years.

Composting of Fine Screenings.—We come now to a very interesting operation at the Jamaica Plant in Queens, where the fine screenings are dewatered and converted into a useful mulch much in demand by the Park Department. The Jamaica and Hammels Plants in Queens handle an average flow of 32 m.g.d. and 4 m.g.d. respectively and capture about 370 and 60 cu. ft. per day of fine screenings. The screenings from Hammels are ejected to tank trucks and transported to the Jamaica Plant where the combined screenings are centrifuged and composted.

About 1937 it was realized that the long standing practice of discharging the fine screenings at Jamaica by pneumatic ejectors to marshy areas adjacent to the plant was becoming too objectionable and required

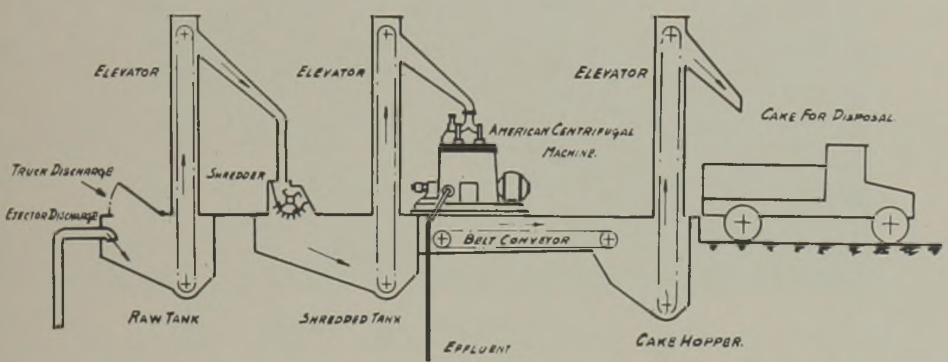

FIG. 6.—Jamaica centrifuge, diagram.

a remedy. Accordingly an American Centrifuge was installed to partially dewater the screenings from about 90 per cent moisture to a cake of some 70 per cent (Fig. 6). The yield of the centrifuge is approximately 700 lb. dry basis per hour. It proved unfeasible, on account of long trucking distance, to dispose of the centrifuge cake at city incinerators, hence, experiments were undertaken to convert a distinct liability into an asset.

The first attempts at composting were not particularly promising. It was easy to secure thermophilic digestion of the centrifuge cake in piles but apparently the putrescible matter "burned out," leaving cellulose and other easily identified sewage material little touched.

A method of composting was finally developed by Dr. Charlton of this Bureau which has furnished a satisfactory solution. As the disintegrated cake is being discharged by the centrifuge there are added approximately 2 per cent ground gypsum by weight and 2 per cent cut straw, by volume. These simple materials costing about 30 cents per ton of cake are effective in bringing about the desired change in the material. The disintegrated centrifuge cake is spread in layers approximately 18 in. deep and within a few hours the surface temperature rises to 60 degrees C. and a growth of white mould starts. The thermophilic action slowly advances into the interior of the pile and is accompanied by a marked shrinkage in cake and no offensive odor. In about 30 days the thermophilic action results in partial disintegration of the

FIG. 7.—Shredding compost at Jamaica.

cellulose and other sewage materials. The finished material has a brown chocolate color and is almost indistinguishable from good humus, which, in fact, it is. Most of the composting has been done on the concrete floor of an abandoned incinerator adjacent to the Jamaica plant, although considerable composting has been done out doors with substantially the same success (Fig. 7).

The finished material shows the following analysis:

	Per Cent
Total moisture of the material	35.2
Analysis of the Moisture-Free Material	
Total nitrogen	2.60
Water soluble nitrogen	.40
Available organic nitrogen	.77
Fat	3.10
Fibre	28.20
Phosphoric acid	1.21
Ash	19.80

The thermophilic digestion during the composting period has the effect of destroying insect life, tomato and other troublesome plant seeds, while bacteriological studies indicate almost complete removal of coliform bacteria.

All of the composted material produced at the Jamaica Plant has been used as a mulch around trees and shrubs in the city parks and as a stabilizing material for grass growth along some of the parkways, particularly where subject to erosion. During 1940 some 800 tons were distributed and in 1941, to September 30th, 775 tons were distributed.

This completes the story of screening and screenings disposal as practiced at the New York City plants.

Discussion

Mr. Pincus (*Dept. of Health, New York City*): Is there any health hazard in the use of composted screenings? Are the bacteria destroyed?

Mr. Donaldson: No, the bacteria are not completely destroyed but we do not allow the compost to be spread on play grounds. This method of disposal of screenings is better than incineration.

Dr. Heukelekian: What about composting? How long does it take, is it odorous? What is the temperature?

Mr. Donaldson: It takes about a month. The temperature is 60° C. The screenings should be stored in a deep pile. When 12 to 14 ft. deep, the mass was odorous and would not dry.

Mr. Enslow: Have you tried re-use of this material instead of straw?

Mr. Donaldson: The straw seems to be necessary to give porosity and to inoculate the mass with spore-forming organisms. Aeration is also essential. Gypsum furnishes calcium and seems to be necessary, although not as important as straw.

Dr. Heukelekian: Using composted material instead of straw would cut down time from a month to days.

Dr. Gehm: Have they incorporated pulverized limestone in this material?

Mr. Schroepfer: There is a need for flexibility in screenings disposal. We have found that the coarse bar racks are unnecessary in dry weather, so we raise them out of the sewage, and replace them only at times of storms. The bar screens with one-inch openings are used at all times.

Mr. Woltman (*Bloomington, Ill.*): Are round rods as good as bars? Do screenings work through?

Answer: No, they do not work through.

BARK FROM THE DAILY LOG *

By David Backmeyer
Guest Contributor,
Plant Superintendent, Marion, Indiana

Year 1940

July 5—First sewage enters plant from main interceptor.

July 8—Raw sewage pumped for first full day, aeration tanks and final settling tanks being filled.

* From First Annual Report on Sewage Treatment Plant, Marion, Indiana.

July 12—City officials make inspection trip through plant, forty people in entire group.

July 16—Members of Rotary Club visit and inspect plant at noon.

July 20—Hydrated lime being added to raw primary sludge before it is pumped to sludge digestor. Digestion tank being heated with gas fired boiler to increase temperature from 68 deg. to 85 deg. F.

July 23—Roots-Connersville blowers and Climax engines being serviced by factory men prior to initial operation.

July 25—Members of Marion Exchange Club inspect plant in evening.

July 28—Flow meters put in service by factory representatives.

August 1—Some sewage gas being produced in sludge digestors. Utility gas being burned in gas engines.

August 2—Complete survey made of all machinery for insurance company.

August 4—Sewage gas production increasing, 14,500 cu. ft. metered for day.

August 7—Raw sewage pump engine, 50 Hp., being operated on sewage gas.

August 17—Primary sludge digestor foaming, foam coming over edge of floating cover. Stopped pumping raw sludge to this tank.

August 22—Some sewage gas being wasted in waste burner, 60,000 cu. ft. per day being used in the three gas engines.

August 30—Primary sludge digestor back in use again, foaming condition subsided. Committee of six members of Greater Marion Association visit and inspect treatment plant in afternoon.

September 5—Three Hp. electric motor driving drainage pump became overloaded and burned up. Loss covered by insurance. Overload relay protector found not to be wired in circuit.

September 6—Total sewage gas production for day 85,200 cu. ft. Resident population of city 27,000.

September 9—Members of local Lions Club visit plant at noon.

September 11—Department heads, of Indiana General Service Utility Co., visit and inspect plant at noon.

September 13—Small shelter being constructed above raw sludge well to protect operators from weather while drawing raw sludge from primary settling tanks to well.

September 21—Plant final effluent diverted to stone quarry lake. Water level of lake raised about six feet.

September 22—Ground water coming through comminutor conduit pipes. Quarry water level lowered 39 inches to stop leakage.

September 26—Attended formal opening and dedication of Gary, Indiana, sewage treatment plant.

September 27—Garbage grinder given test run, 2580 lb. of green garbage ground in forty minutes with greatest of ease.

October 4—Lime waste from city water plant taken at sewage plant for first time. Daily solids load of lime sludge about one ton.

October 10—Final day of tomato waste from Snider Packing Company.

October 15—Booklet being prepared for formal opening and public inspection of treatment plant.

October 20—Open House, many visitors inspect plant, 750 registered and given booklets.

November 8—Supernatant liquor from secondary digestor becomes heavy with black solids for first time.

November 13—Digested sludge from bottom of secondary digestor lagooned to yard adjacent to plant buildings. This sludge was three months old and gave no offensive odor.

November 17—Lagooned sludge overflowed onto roadway, Sunday morning spent cleaning concrete driveway with brooms.

December 4—First sludge removed on Oliver vacuum filter, average total solids content of sludge was 6.93 per cent.

December 19—Oil burner replaces electric heaters at sewage lift station, saving in cost of heating building about 80 per cent.

December 20—General Electric Service man found seven overload relays in panel board "B" not wired in circuit.

Year 1941

January 6—Work begun on change of pump discharge lines at sewage lift station.

January 11—First ten ton shipment of ferric chloride (60 per cent crystals) unloaded in storage shed. Shipment made in 300 lb. bbls.

January 28—New bearing installed in comminutor gear box. Faulty lubrication was cause of failure.

February 7—Impeller frozen on vacuum filter filtrate pump, lime crust removed from pump impeller and casing.

February 21—Chemical feed rates changed for conditioning of digested sludge for filtration. Lime dosage increased and ferric chloride dosage decreased to reduce cost of removal.

March 22—New operator spent most of eight-hour shift drawing raw sludge through sight valve to sludge well. He did not return for second day's work.

March 24—Eight barrels of rancid oil from soybean plant dumped in sewer above plant as test for means of disposal of this type waste. It caused the treatment plant plenty of grief.

April 2—North section of State Sewage Works Association meets at local plant. New attendance record set, 73 present at noon luncheon.

April 20—Final effluent exceptionally clear, visibility good at depth of eight and ten feet.

April 26—Fourteen foot all-metal rowboat launched on quarry lake. Boat to be available to police and firemen for emergency use.

April 30—Eight large evergreens planted in front of service and compressor buildings.

May 2—Contract let for purchase and installation of 4,500 gallon capacity rubber lined ferric chloride tank.

May 5—Flock of 22 mallard ducks vacationing on quarry lake.

May 17—Chemist out for several days for tonsil operation, superintendent doing part of the laboratory test work.

May 29—Operator recovers upper set of false teeth from bottom of pre-aeration tank. Violent sneeze was cause of accident. The teeth were chlorinated, boiled, and back in use the following day.

June 6—Collection of garbage taken over by City Sanitation Department from private collector.

June 23—Special exhaust fan installed in filter room to remove lime dust and ammonia fumes. Fan removes 11,500 cu. ft. of air per minute.

July 7—New Ford V-8 pickup truck purchased for plant general use.

July 15—Number 3, Climax 75 Hp. gas engine dismantled for first complete inspection after 5600 hours operation.

July 16—Cast Iron Pipe News, national trade publication, carries story and pictures of Marion plant.

July 21—Mississinewa River black from paper waste discharged in stream several miles above city.

July 29—Sluice gate motor control wires shorted to ground, gate must be worked manually.

July 30—Sewage pump gas engine, 50 Hp., completely dismantled for inspection after 8500 hours operation. Insurance inspector recommends regular inspection at 5000 hours operation in future.

August 4—New garbage truck purchased, will go in operation following week. This is city's first garbage truck.

August 6—No. 4 blower engine, 75 Hp., dismantled for inspection after 5800 hours operation.

August 11—B.O.D. of corn waste from cannery tests as high as 5000 p.p.m. on grab samples taken at canning plant.

August 20—Tomato waste added to corn waste makes raw sewage B.O.D. run above 300 p.p.m. on some days. Difficulty experienced in maintaining sufficient D.O. in aeration tanks.

August 28—Mohlman sludge index increased from 80 to 275. Total sewage gas production for day was 85,100 cu. ft.

THE GADGET DEPARTMENT

The following devices were among the entries displayed in the Gadget Contest sponsored by the Central States Sewage Works Association at the Fort Wayne, Indiana, meeting held on October 6–7, 1941.

Pressure Differential Alarm

By C. K. Cornilsen

Chemist, Bloom Twp. (Illinois) Sanitary District

This alarm can be made to "sound-off" for either a decrease in pressure, an increase in pressure, or both, by the proper location of contact points. The principle of the alarm is that of a simple manometer, using mercury as the pressure seal, and as the medium to close the contacts that sound the alarm.

The platinum contacts are fused through the "U" tube at points predetermined as to the pressure at which the alarm is desired.

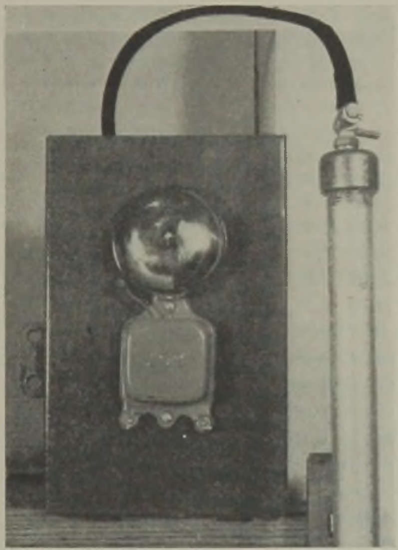

Fig. 1.—Pressure differential alarm. Submitted by C. K. Cornilsen.

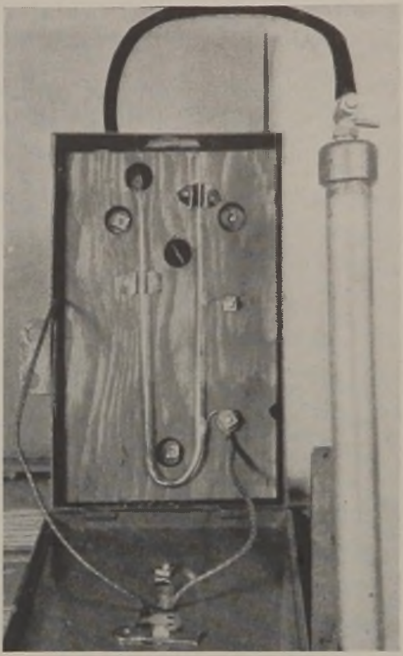

Fig. 2.—Pressure differential alarm opened to show construction.

The case used for the alarm was an old electric switch box. The batteries needed to energize the bell are located behind the panel that holds the manometer (making the alarm compact and portable).

The electric switch mounted in the top of the box cuts off the current to the bell when the contacts are closed and time is needed to correct the "alarm" condition, otherwise the alarm is automatic.

We have used several of these alarms in water and air lines for the last two years and have found them almost indispensible.

The alarm can be used (but is not recommended) in gas lines by installing an auxiliary mercury "U" tube without contacts ahead of the alarm "U" tube.

Vacuum Pump Control Switch

By P. L. Brunner and J. W. Patch

Operator and Electrician, Fort Wayne, Indiana

The laboratory at the Fort Wayne Sewage Treatment Works is fitted with a vacuum system with the vacuum pump located on the floor below. No control was provided to shut off the pump after maximum vacuum was established, and, as a result, the pump was overworked. No regulating device which would be reliable in a range of 2 to 4 in. of mercury was found available on the market, so the use of a tip-up mercoid switch on a mercury manometer was arranged as shown in the attached sketch. The manometer is made up of ⅛-in. black iron pipe with reservoirs of ⅜-in. black pipe on each end to reduce the fluctuations.

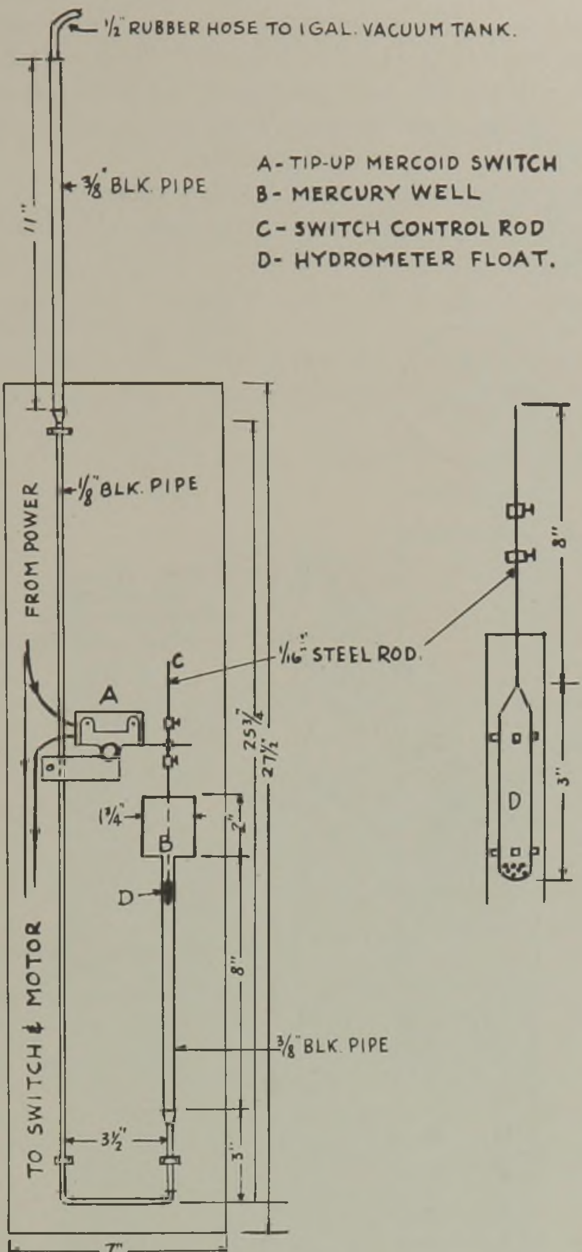

Fig. 3.—Control switch for vacuum pump. Submitted by P. L. Brunner and J. W. Patch, Fort Wayne, Indiana.

A carefully balanced hydrometer float is suspended in the ⅜-in. pipe and on the extended rod are two adjustable lugs which operate the tip-up switch as the mercury rises and falls. By careful adjustment, these lugs will trip the switch within a range of 1 in. of mercury, although in normal operation it is usually held between 2 and 4 in. of mercury. The actual time that the vacuum pump operates each day has been reduced from about an hour to about five minutes. The switch has operated very satisfactorily for the past year, and has required no attention or maintenance. The manometer and switch can be mounted on a panel or in a cabinet to protect it from dust and dirt.

The idea was conceived and construction was done by the plant electrician, James W. Patch. The device was entered in the Central States gadget competition by Paul L. Brunner.

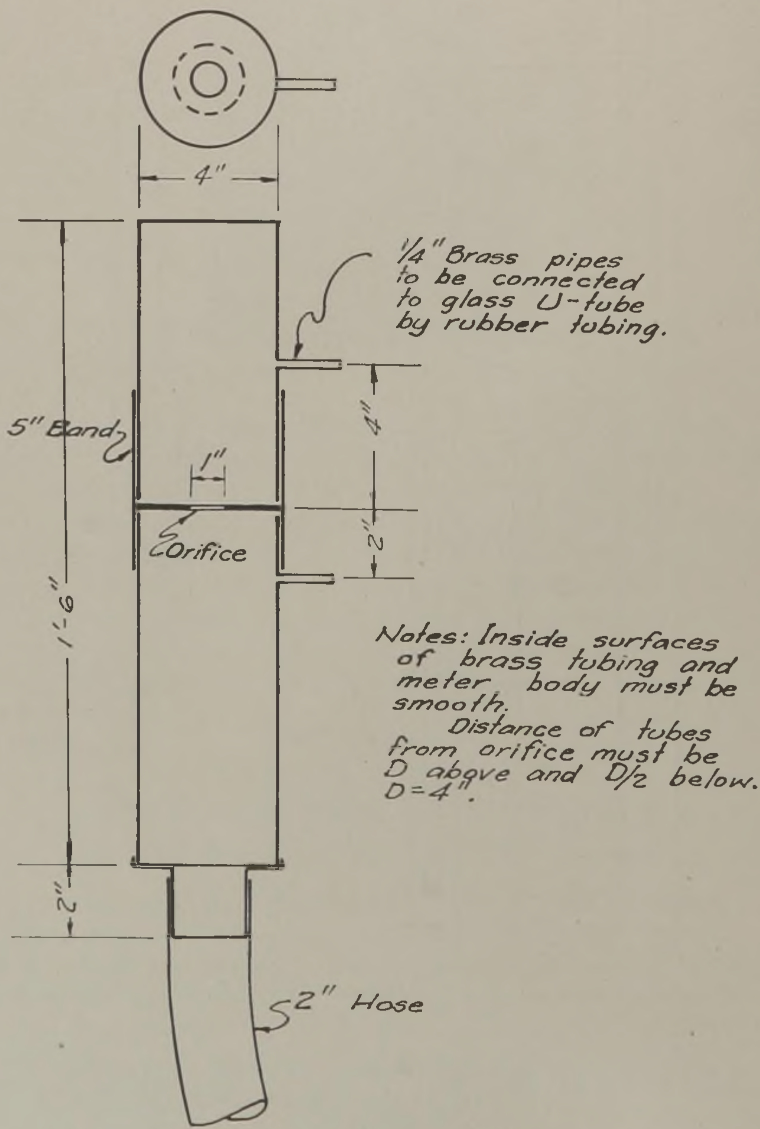

FIG. 4.—Section and plan of portable air meter. Submitted by W. E. Ross, Supt., Richmond, Ind.

Orifice Type Portable Air Meter

By W. E. Ross

Superintendent, Sewage Treatment Works, Richmond, Indiana

The portable air meter is used to secure the best possible adjustment of the gravity aerator units with which our plant is equipped. Readings of the meter readily tell us whether the gravity aerators are in need of cleaning and if they are adjusted to afford most efficient aeration at prevailing rates of sewage flow.

Details of construction of the meter are shown in Fig. 4. The meter body is designed to allow various orifice plates to be used. It was desired to secure the greatest differential at the "U" tube without changing the flow of air through the unit. The 1-in. orifice was found to give the best results for our use.

Fig. 5.—Orifice type portable air meter used in adjusting gravity aerators at Richmond, Indiana.

Calibration of the meter was accomplished by correlating readings at the "U" tube with anemometer measurements taken simultaneously. A curve of these observations was plotted and a "U" tube scale made which permitted the flow of air to be read directly in cu. ft. per minute.

It was originally thought that this same meter could be used to measure the flow of air into the air intake of our gas engine, but we have not yet used it for this purpose. With slight changes, the meter could also be used to measure small flows of gas.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Urbana-Champaign Sanitary District (Year Ended April 30, 1941)

W. H. Wisely, *Engineer-Manager*
C. G. Sidwell, *Chemist*

Summary of Operation Data

Item	1940 Average
Population (1940)	47,000
Estimated connected	43,000
Equivalent (by sewage analyses)	46,700
Design	45,000
Sewage flow—average daily	3.10 m.g.d.
Per capita daily	72.1 gallons
Unit loadings:	
Imhoff tanks—detention period	1.87 hours
Digestion temperature	66 degrees C.
Solids to digestion (lbs. per c.f. per mon.)	0.99
Vol. solids to digestion (lbs. per c.f. per mon.)	0.79
Trickling filters—area	1.6 acres
Application rate	2.02 m.g.a.d.
5-day B.O.D. (lbs. per acre per day)	3,274
5-day B.O.D. (lbs. per acre foot per day)	327
Final sedimentation tank—detention period	1.14 hours
Surface settling rate	1,330 g. sq. ft. d.
Sludge drying beds—solids loading	19.3 lb. sq. ft. yr.
Sewage analyses:	
5-day B.O.D. (p.p.m.):	
Raw sewage	314
Imhoff effluent	196
Removal-primary treatment	37.8%
Filter effluent	43
Final effluent	28
Removal—complete treatment	91.1%
Suspended solids (p.p.m.):	
Raw sewage	211
Imhoff effluent	106
Removal—primary treatment	49.7%
Filter effluent	51
Final effluent	33
Removal—complete treatment	84.4%

Digested sludge:	
Moisture content	94.8%
Volatile content	58.3%
Operation costs:	
Per m.g. treated	$16.11
Per capita per year	$ 0.415
Per 1000 lb. 5-day B.O.D. removed	$ 6.86

Buffalo Sewer Authority (1940–41)

Charles R. Velzy, *Works Superintendent*
G. E. Symons, *Chief Chemist*

Pumping.—The Main Pumping Station at the Treatment Works, as well as the two outlying pumping stations at South Buffalo and Hamburg Street, operated throughout the year without interruption and with a minimum of maintenance work. At the Main Pumping Station a procedure of frequent flushing was used successfully to prevent excessive deposits of grit and sludge in the wet well. The flushing was accomplished by pumping down the wet well to low water level several times a week. In cooperation with the Sewer Department, studies were made on the time of sewage flow from all parts of the City. A comprehensive report has been made by the Sewer Departments on this subject.

Screening and Grit Removal.—Screening and grit removal operations functioned well throughout the year. The amount of grit was considerably less than in the previous two years. This was probably due to the completion of the sewer cleaning program, which had removed old deposits from the sewers. Again large quantities of leaves were brought in during storms from September to November. The leaves were taken off the belts and stored in compost piles for landscape work.

Operation of equipment has been changed from continuous to intermittent, adapting the cycles to the load. This reduces wear on equipment and simplifies operation to some extent. Maintenance and improvements included some modification of equipment and normal overhauling of machines. New stub shafts, designed to be easily replaced, were installed on the screen rakes.

Washing of grit was improved by changes in weirs, and overflow pipes and installation of water jets. A new tail bearing for the conveyor screw of the grit machines was designed, and installed, and has shown considerably longer life than the old bearing. Regular maintenance included repair and replacement of parts subject to abrasion, and repainting of equipment and building interior. Light colors were used to maintain a clean and attractive appearance.

Chlorination.—A change in the personnel organization was made in this department with a man being assigned to maintenance and relief work. This afforded steady maintenance in the department, and with changes in the layout of the piping and valve work resulted in better control, remedial maintenance and safer operation. The amount of replacement parts installed was normal. Extensive study by the personnel has insured better understanding of the equipment by all operators and has tended to reduce maintenance costs.

Sedimentation.—The operation of the settling tanks proceeded normally throughout the year with only three tanks being operated during routine maintenance and inspection work. The per cent removal of suspended solids continued to be normal for flows up to the designed capacity. Study was continued on the inlet baffling arrangement for the purpose of obtaining better efficiency at higher flows. In the previous year, experiments had been conducted on two tanks and this year the baffle from the third tank was removed. Results of studies now indicate that a shallow center baffle, slotted, will be effective for tanks of this design.

For the first time since the plant has been in operation, the metal surfaces of the tank mechanisms were steam cleaned and painted in two of the tanks. Two types of paint were used, as an experiment, to determine which would give the best service for metal immersed in chlorinated sewage. Lubrication of the driving equipment of the tank mechanism was improved by the use of an oil which would not emulsify with the moisture from condensation.

Accumulation of deposits in the sludge discharge line re-occurred this year. Steaming operations on this line were again used with good results and a minimum of expenditure. Pumping of the sludge from the sedimentation tanks on an intermittent schedule resulted in a raw sludge averaging more than 7 per cent in dry solids content. The interior of the Sludge Pumping Station was completely painted and again the use of light colors resulted in an attractive and easily cleaned station. Plugging of sludge meters by the occasional excessive discharge pressures of sludge pumping was overcome by the installation of a booster pump and tank to maintain higher water pressures on the meters. Greater flexibility in operation has been obtained by the installation of cross-connections on the raw sludge suction lines.

Sludge Digestion Tanks.—The raw solids loading increased above previous years and again the gas production exceeded that which was anticipated. Formerly, when tanks were relieved of excess gas, no estimation of the amount could be made. Now the venting of this gas is controlled and estimations can be made. The maximum gas production has, on several occasions, reached one million cubic feet per day.

Better control of scum layers was made possible by the installation of recirculation lines through the station to the tanks. By means of these lines, it is now possible to recirculate supernatant liquor or light sludge through the gas dome on to the heavy scum layer. During the past winter a considerable portion of this scum or top sludge was removed for incineration after first being softened by this recirculation method.

Other developments included better sampling connections on sludge pumps, modifications to sludge and drainage piping, and construction of a sludge lagoon with necessary piping for drying of sludge for use in landscape work. During the year, the upper two floors of the Sludge Control Station were completely painted; concrete ceilings and concrete weir boxes received a semi-gloss finish and better housekeeping and cleanliness has been assured.

Sludge Disposal.—The fluctuation of incoming raw solids throughout the year made it necessary to vary the number of incinerators which were used. It was possible to use one incinerator for four months; two incinerators were required for seven and one-half months, and three incinerators were operated for a period of three weeks. Only sludge gas was used as an auxiliary fuel. The tonnage of sludge cake burned fell off at the end of the year due to high temperatures caused by increased volatile matter in the digested sludge. Grit disposal by incineration was carried on for 10 months without interruption. Variations in the grit made it possible to burn as high as 50 per cent grit with 50 per cent sludge for extended periods, and occasionally for short periods grit alone was burned.

Considerable development work was accomplished throughout the year. In the late winter, the incinerator manufacturer's representative spent some weeks at the Treatment Works and made changes in the mixer and flash dryer operation which have aided in reducing abrasive wear. The induced draft fan on one incinerator unit was relocated to operate on the clean air side of the cyclone, thus reducing abrasion of fan blades and liners. An experimental gunite lining was installed in the two cyclones of one incinerator unit in place of the original steel lining. The cost was considerably less than that of steel lining. The installation was reasonably successful and tests have been made to determine the most suitable aggregate and cement for this purpose. Gunite or other substitute for steel will probably be used for lining all cyclones. Interesting experiments were carried on with fan blades, leading to the use of arc welded narrow beads to effectively reduce abrasion. The use of sash cords in place of the original brass bars as a means of fastening the filter cloth to the filter drum has cut the time of reclothing by more than half.

Boiler Room.—Normal operation was maintained throughout the year. Efficiencies were increased by minor changes in the piping and valves in this department. Although the steam consumption was considerably above the previous year, 18,650 gallons less of fuel oil were used than in the year 1939–40. The increased steam consumption was caused by the use of the steam ejector for sludge ash removal from the incinerators and for the provision of hot water for the lime slacking machines.

Yards and Grounds.—The personnel assigned to the Yards and Grounds Department has included (both this year and last) a number of laborers working in other departments and the actual force attending the yards and grounds has been quite reasonable. With this force, it was possible to adequately care for the large planted area. The growth of the grass, trees and shrubs has continued to be excellent and the plant surroundings have become more parklike and attractive.

Miscellaneous.—A new sludge cake feeder with improved features and a drive of higher power was designed and installed, and has given excellent and anticipated results. Plans have been completed for the revision of the sewage conduit ventilation, and for the enlargement of the plant water supply well on the bank of the Niagara River. Building improvements included a much needed access door to the garage in the Main Building and enlargement of the shower and locker rooms in the Sludge Disposal Building. This installation has greatly improved temperature conditions in this department. Plans have also been made for additional ventilation for the Incinerator Building and the Boiler Room. For the convenience of the personnel, electric water coolers have been installed in various locations, and previous waste by continual operation of the old type of bubbler has been eliminated. During the year the wooden deck and wire screen on the surface of the vacuum filters were cleaned of calcium carbonate incrustation by means of an acid bath. Permission was obtained for the use of government property on the east side of the Island as a dumping area. Stone riprap walls paralleling the adjacent water have been built to confine this fill.

Summary of Operation Data (July 1, 1940 to June 30, 1941)

Item	1940–41 Average	
Sewage flow—average daily	140	m.g.d.
Per capita daily	233	g.c.d.
Suspended solids (p.p.m.)		
Raw sewage	168	
Grit chamber effluent	158	
Clarifier effluent	110	
Per cent removal—overall	34.8%	
Clarifiers only	28.5%	
Settleable solids—per cent removal by clarifiers	73.9%	
5-day B.O.D. (p.p.m.):		
Raw sewage	127	
Plant effluent	101	
Per cent removal	20.7%	
Chlorination:		
Chlorine demand—raw sewage	6.3	p.p.m.
Supernatant liquor	208	p.p.m.
Sewage—supernatant mixture	6.5	p.p.m.
Chlorine dosage	6,610	lb. per day
Coliform bacteria:		
Raw sewage	56,400	per ml.
Plant effluent	915	per ml.
Per cent kill	98.4%	
Grit removal	2.71	c.f. per m.g.
Moisture content	47.8%	
Volatile content	42.2%	
Raw sludge (wet)	172,000	g.p.d.
Solids content	7.23%	
Volatile content	62.9%	
pH	6.5	

Summary of Operation Data (July 1, 1940 to June 30, 1491)—Continued

Item	1940–41 Average
Sludge digestion:	
Digestion temperature	89.4° F.
Gas production	0.86 c.f. per cap.
Gas fuel value	641 B.t.u. per c.f.
Supernatant liquor	161,000 g.p.d.
Solids content	2.36%
Volatile content	50.2%
pH	7.3
Digested sludge (wet)	74,000 g.p.d.
Solids content	9.11%
Volatile content	47.5%
Specific gravity	1.03
Sludge dewatering:	
Quantity wet cake	79 tons per day
Solids content	36.9%
Volatile content	42.9%
Lime dosage *	11.21% CaO
Ferric chloride dosage *	2.93% $FeCl_3$
Fuel value sludge cake	4,320 B.t.u. per lb.
Incineration:	
Time operated	857 hr. per month
Wet cake	2,417 tons per mon.
Dry cake	1,781,000 lb. per mon.
Grit	154,000 lb. per mon.
Dry solids burned	1,935,000 lb. per mon.
Gas used	2,378,000 c.f. per mon.
Ash quantity (dry)	27,100 lb. per day
Volatile content	3.95%
Boiler operation	
Oil	277 g.p.d.
Gas	285,000 c.f. per day
Steam	162,000 lb. per day
Operation costs (including pumping)	$8.25 per m.g.
Operation costs (excluding pumping)	$7.80 per m.g.

* Pounds of chemical per 100 pounds dry sludge solids.

TIPS AND QUIPS

A method of preventing freezing in sludge digestion tank gas domes is suggested by Operator Justin Colsen, Grafton, North Dakota:

After having used furnace oil in our gas dome every winter, we always had 1 to 3 inches of ice form in the bottom and had to use hot water to thaw it out. This year we put in 2 gallons of Zerex and about one gallon of water, mixed these thoroughly, and then added the furnace oil. The Zerex and water stay in the bottom and the mixture is amply strong to prevent freezing.

North Dakota *Official Bulletin*, January, 1942

* * *

Members of the Western Section of the New York State Sewage Works Association, who attended the Section meeting at Lancaster, New York, on December 6, 1941, were fortunate in getting some practical tips on painting problems from Ivan W. Cadwell of Buffalo. Section Secretary G. E. Symons reports as follows from Mr. Cadwell's paper:

In the paper on paints, by Mr. Cadwell, the first point brought out concerned temperature and seasonal effects on paint. "Contrary to public opinion, the spring and fall are not the best times to paint," Mr. Cadwell pointed out, saying that at these seasons there might not be enough heat and, at the same time, there might be too much humidity for proper drying of the paint. "The best temperature range," said Cadwell, "is from 70 to 90° F., but painting should not be done in the late afternoon, even at these temperatures, if the nights are cold or humid. Furthermore, out-of-doors painting should be protected from the direct rays of the sun as long as possible, for direct sunlight affects not only the vehicle but also the thinner and may cause floating of the pigments."

Among several general points concerning painting discussed by Mr. Cadwell were the following:

1. Rapid drying may present difficulties that offset its usefulness; particularly, metallic driers in linseed oil may shorten the life of the oil.
2. All paints should be stirred or well mixed before use; the amount of stirring during use depends on the weight and rate of settling of the pigment in the vehicle.
3. Thin coats produce better bonding and better drying. In order to distinguish the coats, different shadings may be used for different coats. The prime coats should not have a high gloss.
4. Some paints require brushing out rather than thinner; other paints require flowing, *i.e.,* lay on heavy and brush out with a dry tip. Brushing consistency is a factor in manufacturing and may be opposed to storing quality which is another factor in the manufacture of paints.
5. On sash, it is advantageous to run the paint 1/32 of an inch on both sides of the glass as this protects the sash at the point of entry of deterioration agents.
6. The bonding of paint on surface differs with the material of the surface; on metal, bonding is by adhesion, on wood bonding is by penetration into the tiny spaces between the wood fibers. The use of metal paints containing aluminum and zinc prevents good penetration and, therefore, good bonding on wood.
7. In repainting, it is better to use both a prime coat and a finish coat than repeated finishing coats.
8. Discoloring of bright paints may be due to hydrogen sulfide or to fungus. Hydrogen sulfide discoloration may be prevented by using better paints and fungus discoloration may be prevented by adding a fungicide to the paint.

Mr. Cadwell continued with a short discussion of brushes, saying that since Japan invaded Manchuria brushes had been more expensive and that many brushes today were adulterated with horsehair. Generally, the longer the bristle the better the job, but the cost of brushes is disproportionate to the length of the bristle. Observation of splitting of the bristle is a means for determining adulteration with horsehair. Good bristles will split just ahead of the wear. Regarding the care of brushes, Mr. Cadwell said, "Don't place brushes in water, because it causes setting and don't set the brush on the tip. A brush may be suspended in the paint in which it is used, for a short period, but prompt cleaning pays in the long run."

By way of closing his paper, Mr. Cadwell stated that one of the most important factors in paint problems was the proper preparation of the surface. "No paint will hold on old scaling paint and rust should be removed because it creeps." As a final point, Mr. Cadwell said the cost of painting should not be calculated on the basis of the paint used, but the cost should include the preparation of the surface, the application of the paint and the paint cost. The best means of determining a basis for cost comparison was to calculate the cost per square foot per year for those three items.

Questions came thick and fast when Mr. Cadwell had completed his paper. Some of the answers which he gave were as follows: (1) to clean brushes use commercial products, benzol or water, not too hot, and the brush should not be left in the water too long; (2) blistered surfaces should be burned if bad or otherwise scraped; (3) liquid paint removers are expensive; (4) prime coats should be brushed; finish coats can be sprayed at less expense; (5) don't prime exterior surfaces with aluminum paint; (6) raw linseed oil is better if the weather could be forecast because it dries more elastic. Many boiled oils are boiled in name only and are treated with cobalt salts to accelerate oxidation. These tend to continue oxidation of oil after it is dry, thereby shortening the life of the paint.

* * *

The *Michigan Sewage Works Bulletin* cautions against waste of asbestos used in Gooch crucibles, this material being practically impossible to obtain at this time. The *Bulletin* reports that Superintendent Stanley Bower, at Ypsilanti, Michigan, contemplates experimental work with a filter crucible having a fixed, porous bottom.

* * *

Chemist C. G. Sidwell of the Urbana-Champaign Sanitary District, unable to replenish his stock of asbestos for Gooch mats, is experimenting with a reclamation procedure, suggested by chemists in the Dairy Chemistry laboratory of the University of Illinois. The method is given here but it is emphasized that it is still highly tentative and is in experimental status at this time.

The accumulation of used mats (which were ignited as part of the volatile solids determination) are placed in a wide mouth, glass-stoppered bottle. Add sufficient dilute hydrochloric acid (approximately 1 part acid to 6 parts distilled water) to dissolve the ash. Hydrochloric acid is preferred over sulfuric acid since the latter would precipitate calcium salts as the sulfate. Use of the mats without acid treatment is not advised because the carbon dioxide contained in the sewage would react with the calcium oxide of the ash to produce calcium bicarbonate. Finally, wash the acid treated asbestos in distilled water until it is free of chlorides. Washing is complete when the wash water gives no precipitate when treated with dilute silver nitrate solution.

It is not necessary to dry the asbestos. It can be left in a bottle with sufficient distilled water to be ready for use as a cream.

* * *

PRIORITY SHORT STORY

Do not condemn
  The O.P.M.
Don't gripe
  If it's denying.

Do best you can
  With what you've got
And help
  to Keep 'Em Flying!

Editorial

NEWS NOTES

The U. S. Public Health Service has announced an examination for appointment as Assistant Sanitary Engineer in the Regular Commissioned Corps of the U. S. P. H. S., to be held at 9 A.M. on May 11, 1942, in Washington, D. C., Cincinnati, New Orleans, Kansas City and San Francisco. Candidates must be not less than 23 years nor more than 32 years of age on that date, and must have had at least seven years (exclusive of high school) of educational plus professional training. They must hold a degree in engineering (sanitary engineering course) from a reputable professional school. In addition the applicant must pass physical, academic and professional examinations before a board of commissioned officers of the Regular Corps.

The written examination will comprise questions in chemistry, bacteriology and planktology, mathematics, physics, hydraulics, design and construction of sanitary projects, heating lighting and ventilation, water and sewage treatment, sanitary science and public health, and practical problems and laboratory demonstrations. The examinations will require approximately seven days for completion. Transportation and subsistence costs must be assumed by the candidate. Compensation varies from $2700 to $3160, with or without dependents.

For further information concerning these examinations, applicants are requested to write to the Surgeon General, U. S. Public Health Service, Washington, D. C.

* * *

U. S. Civil Service examinations are announced for chemical engineers, with positions ranging from assistant chemical engineer at $2,600 per year to principal chemical engineer at $5,600 per year. The lowest position requires a degree in engineering plus two years of responsible professional experience in chemical engineering, the highest, a degree plus seven years of broad, responsible professional experience. Candidates will not be required to report for examination at any place, but will be rated on sworn statements and corroborative evidence, ratings to be on a scale of 100. The Commission states that there is a shortage of eligibles qualified in the following specialized branches: plant layout, equipment design, market analysis, chemical economics, heavy chemicals, plastics, rubber, agricultural by-products, and strategic minerals.

Further details concerning these examinations are given in Announcement 163 of the U. S. Civil Service Commission, Washington, D. C.

Editor's Note: The chemical engineers seem to rate higher than the sanitary engineers.

* * *

A note has been received from the Committee on Aid to Libraries in War Areas, University of Rochester, Rochester, N. Y., requesting our subscribers to save stocks of *Journals,* rather than to dispose of them as waste paper, in order to have available copies to meet demands from foreign libraries in years to come. The Committee has purchased ten subscriptions as an initial supply. It would be thoughtful of those subscribers who do not save their *Journals* to offer them to Mr. Wayne M. Hartwell, at the above address.

* * *

A new book of considerable interest has just appeared—"Industrial Waste Treatment Practice" by E. F. Eldridge, published by McGraw-Hill Book Company, price $5.00. It will be reviewed in our next issue.

* * *

A letter from Dr. A. Parker of the British Water Pollution Research Laboratory, Langley Road, Watford, Herts., acknowledges his appreciation of the review of the work on alternating filters given in the Editorial in our November, 1941, issue. Dr. Parker forwarded, through the British Library of Information, 30 Rockefeller Plaza, N. Y., a copy of Research Paper No. 8, on treatment of milk products wastes, which refers especially to alternate filtration for treatment of such wastes. The volume has 125 pages and deals in great detail with the results of these interesting experiments. It will be reviewed in our next issue. It is sold by H. M. Stationery Office, York House, Kingsway, London, W. C. 2, for four shillings.

F. W. M.

Proceedings of Local Associations

PENNSYLVANIA SEWAGE WORKS ASSOCIATION

Fifteenth Annual Meeting,

Pennsylvania State College, State College, Pennsylvania, September 3–5, 1941

The fifteenth annual conference of the Pennsylvania Sewage Works Association opened in the auditorium of the Electrical Engineering Building at Pennsylvania State College on September 3, 1941.

The Conference was welcomed by Professor F. T. Mavis, head of the department of civil engineering at Penn State. W. H. Wisely, executive secretary of the Federation, spoke briefly concerning the reorganization of the Federation.

At the annual dinner, Colonel W. A. Hardenburgh, Sanitary Corps, U. S. Army, Washington, D. C., was the guest speaker.

The technical program was as follows:

"Demonstration of Plant Laboratory Control" by Harry W. Gehm.
"Laboratory Demonstration of Sewage Measuring Devices" by G. A. Rohlich.
"Sewage Treatment Plants in the National Defense Program."
1. "Design" by E. Sherman Chase.
2. "Operation" by Colonel W. A. Hardenburgh.
"Comparison of Various Types of Secondary Treatment" by Frank Woodbury Jones.
"Operation of the Butler Sewage Treatment Plant" by Harold I. Kurtz.
"Operation Results on Sewage Flocculation" by A. J. Fischer.
Symposium on Effect of Industrial Wastes Upon Sewage Treatment Plant Operation. Leader, C. L. Siebert.
I. "Milk Wastes" by W. R. Anderson.
II. "Steel Pickling Liquors" by L. E. Burnside.
III. "Cannery Wastes" by C. H. Young.
IV. "Brewery Wastes" by Harry A. Baber.
V. "Textile Wastes" by W. H. Corddry.

The business meeting was held at 11:15 A.M. on September 4, with President George P. Searight presiding. Approximately 90 attended the meeting.

Following adoption of a motion to dispense with a detailed reading of the minutes of the 1940 Conference, the secretary gave a brief resumé of these proceedings. The Annual Report of the Secretary-Treasurer covering a period from June 15, 1940 to August 15, 1941, showed a total membership of 268 which included a gain of 7 new members during the period and a loss of 2 through resignation, 2 through death and 6 having been dropped for non-payment of dues. Of the total 268 members, the dues of 180 were paid to date. The financial statement included in this report showed a balance of $27.17 in the Association's treasury. W. H. Eastburn, Chairman of the Auditing Committee, reported that the treasurer's books had been examined, the accounts audited and found to be correct. Upon a motion duly made and seconded, the secretary-treasurer's report was accepted.

Mr. F. B. Milligan, Chairman of the Resolutions Committee, presented his report.

At the request of R. O'Donnell, Chairman of the Correspondence Course Committee, President Searight announced that during the year the Committee had done nothing progressive toward a Correspondence Course, due partly to the illness of the chairman and largely to the fact that the Pennsylvania State College is so engrossed in the work of National Defense courses that it would be impossible to obtain any action from college authorities along this line. Under the circumstances, the Committee felt that this matter should be permanently tabled until after world conditions are more settled and an opportune time presents itself to continue the work. This brief statement was accepted by the members present and it was decided to have the Committee remain intact to pick up the work at some future date.

Under new business, the Chairman called for action on the amendments to the Association Constitution, which amendments were set forth in a form letter mailed to all members under date of August 1, 1941. On this subject, President Searight explained that subsequent to circularizing the membership with the amendments, the Federation of Sewage Works Associations had amended its By-Laws by letter ballot thereby making necessary further amendment to the Association's proposed amendment in order that we might become a member of the Federation.

This amendment has reference to Article 3, Section 1, Section 2(*a*) and Section 2(*g*) of the By-Laws of the Federation of Sewage Works Associations which creates a half pay membership. Since it was thought that some members might be lost through increased dues, it was deemed advisable to amend the Federation By-Laws so that a limited percentage of membership could be retained at the old rate. If an individual desires such membership, and approval is given, his annual dues, aside from the Pennsylvania Sewage Works Association fee of $1.00, will be $1.50 instead of $3.00 to the Federation and he would receive only alternate issues of the *Sewage Works Journal.*

In order that the matter could be clearly understood, W. H. Wisely, Secretary of the Federation of Sewage Works Associations, gave a very pleasing address explaining these matters and others in connection with the workings of the Federation and the plans which he, as well as the Board of Directors, have in mind for future development of the *Sewage Works Journal.* Following Mr. Wisely's talk, it was regularly moved, seconded and carried to adopt the Amendments to the Pennsylvania Sewage Works Association Constitution as set forth in the circular of August 1, 1941, and then it was regularly moved, seconded and carried to amend this amendment in order that our Constitution would conform with the By-Laws of the Federation.

Grant M. Olewiler, Chairman, presented the report of the Nominating Committee recommending the nomination of the following members as officers for the coming year:

President ....E. B. Swinehart
First Vice-President ....T. S. Bogardus
Second Vice-President ....Morrison N. Stiles
Secretary-Treasurer ....Bernard S. Bush
Editor ....J. R. Hoffert
Director as a member of the Board of Control
of the Federation until 1943 ....H. E. Moses

There being no other nominations, upon proper motion the secretary was authorized to cast a unanimous ballot for the election of those named by the Nominating Committee.

There being no further business, upon motion duly made, seconded and carried, the meeting adjourned at 12:15 P.M.

BERNARD S. BUSH, *Secretary*

CALIFORNIA SEWAGE WORKS ASSOCIATION

Fourteenth Annual Fall Convention,

Sacramento, California, October 12–14, 1941

Operators' Symposium.—President Harold F. Gray called the Convention to order at 2:30 P.M. in the Venetian Room of the Hotel Sacramento on Sunday, October 12, 1941. Fifty-two members were present. President Gray announced that the program for the afternoon was to be a symposium on various operating problems with open discussion after the particular subjects had been introduced by the various persons on the program. He then requested that each person taking part in the discussion announce his name and city so that the official reporter could prepare a transcript of all the discussion. As Mr. R. R. Sotter, Chairman of the Operators' Symposium, could not attend the Convention, President Gray turned the meeting over to F. Wayland Jones, Vice-Chairman of that Committee.

For the next two hours a very interesting and informative discussion was held on the following subjects: Plant records; methods used in disposing of rags and screenings; handling dry sludge from plant; beautification of plants and grounds; odor control of plant; personal safety; plant safety; and methods used in taking samples. (Note: An excellent transcription of the entire afternoon's program was made by Graeser-Meyer and Associates of Sacramento, and it will be published in whole or part in the forthcoming *California Sewage Works Journal.*) The meeting was adjourned at 5:45 P.M.

Operators' Buffet Dinner.—A very attractive and enjoyable buffet dinner was served to sixty-two operators, other members and guests, in the Mirror Room of Hotel Sacramento, following which President Gray announced that Mr. William T. "Bill" Ingram, Secretary-Treasurer of the Association for the past two years, had taken advantage of an opportunity to attend Johns Hopkins University for a year's study, and consequently was forced to resign on August 16, 1941. The Association certainly owes Bill a great deal of appreciation for his efficient and untiring work as Secretary-Treasurer. Mr. Gray then announced that the present Secretary-Treasurer had been appointed with approval of the Governing Board on August 20, 1941. As there was no entertainment for the evening President Gray thought that the new secretary should be properly initiated by a thorough introduction to all those present, and he thereupon proceeded around the room making the neophyte guess who's-who before making the introduction in his own humorous way.

Caravan.—On Monday, October 13, the Caravan was assembled on L Street at 9:15 A.M. by Carl M. Hoskinson, Chairman of the Local Arrangements Committee, with thirty-five cars in all. A very clever sketch map showing the route and time schedule to be followed by the Caravan and a mimeographed brochure of information relating to the sewage treatment plants to be visited were distributed to each member. The treatment plants for the cities of Roseville and Auburn were visited in the morning. The Caravan stopped for lunch at the historic Hotel Freeman in Auburn where the members so enjoyed the meal that they called for the cook and with the help of the waitresses finally coaxed Mr. Gee Fong to appear. The treatment plant for McClelland Field was the next stop. Before leaving the members were treated to a tour around the Field where they could see runways under construction, many types of airplanes under repair, and innumerable airplane engines and propellers stored around the grounds waiting for warehouse space. The Caravan then proceeded to the Dixon sewage plant where the Caravan was held up five minutes while a truck pulled Mr. Bowlus's car out of a camouflaged sludge bed. It then continued on to Sump No. 2, pumping plant of the City of Sacramento, where the Caravan disbanded at 5:30 P.M.

Annual Banquet.—Some 150 members and guests assembled in the Palm Court of the Hotel Senator at 7:30 P.M. with President Gray presiding. Members of the Department of Public Health Officials, League of California Cities, had been invited and a good number were in attendance. President Gray had as his personal guests Dr. Lee A. Stone, President of the Health Officials, and Mr. Louis Olsen, Health Officer, City of Palo Alto. The guest speaker of the evening was Dr. C. E.-A. Winslow, Professor of Public Health, Yale University. Dr. Winslow's subject, "The Past and Future of the Public Health Movement," was very much enjoyed by all those present as evidenced by the prolonged ovation at the end of his talk.

Joint Breakfast.—On Tuesday, October 14, a joint breakfast with the Public Works Officers' Department of the League of California Cities was held at 7:00 A.M. in the Empire Room of the Hotel Senator with a total of 39 in attendance. Ed. A. Hoffman, President of the Public Works Officers, presided. After a hearty breakfast Mr. Hoffman called on President Gray who presented a very humorous sequel to his paper "Sewage in Ancient and Mediaeval Times" which he had presented at the Twelfth Annual Spring Conference at Avalon in 1940. This additional data which President Gray had collected consisted of amusing incidences experienced by our ancestors while attempting to dispose of their household sewage.

Joint Meeting—Papers.—President Gray called the joint meeting with the Public Works Officers to order at 9:10 A.M. in the Little Theater of the Memorial Auditorium. The President then introduced the first speaker on the program, Roy E. Ramseier, Sanitary Engineer, City of Richmond, who presented a paper entitled "Methods of Evaluating the Industrial Wastes Problem of an Area, as Exemplified in the East Bay Sewage Disposal Survey." The following persons asked Mr. Ramseier several questions and participated in a very interesting discussion of his paper: Paul A. Shaw, Cedric L. Macabee, and A. A. Appel.

The next paper, "Sewage Disposal Practice at Military Establishments in California," prepared by E. A. Reinke, Senior Sanitary Engineer, and J. W. Pratt, Assistant Sanitary Engineer, Bureau of Sanitary Engineering, State Department of Public Health, was presented by Mr. Pratt.

In response to a question, Mr. Reinke stated that the information included in the paper had been obtained from plants constructed by the Quartermasters rather than by the U. S. Engineers Corps. He also stated that it was impossible to compare efficiencies of the various plants at the present time because the recirculation rates varied from 10 to 70 million gallons per acre per day, and that the B.O.D. loading varied from 0.1 to 3.0 pounds per cubic yard per day.

W. J. O'Connell, Jr. Research Engineer, Wallace and Tiernan Sales Corporation, presented the next paper, "The Evaluation of Sewage Treatment." The interest in this paper was evidenced by the discussion which followed.

F. Carlisle Roberts, Sanitary Engineer, presented the next paper, "The Design of Sewage Treatment Plants from the Standpoint of Defense Ratings and Materials Available." As many members present had various experiences on this subject a lively discussion followed, ending up with a dissertation by Mr. Phelps in his own inimical manner on the problems which have confronted San Diego in their sewer construction program.

The Joint meeting was adjourned at 12:00 noon.

President Gray reconvened the meeting at 1:30 P.M. and introduced Mr. Harvey F. Ludwig, Sanitary Engineer, who presented the last paper of the session entitled "Better Methods for the Determination of Grease in Sewage." Messrs. Baugh, Pomeroy and Parks participated in the discussion.

Business Meeting.—President Gray opened the meeting for business at 2:10 P.M., with forty-four members present, and called for the report of the Nominating Committee. R. D. Woodward submitted the following Nominations:

President ....Fred D. Bowlus
First Vice-President ....Carl M. Hoskinson
Second Vice-President ....Richard D. Pomeroy
Secretary-Treasurer ....Jack H. Kimball
Director—1946 ....Wm. J. O'Connell

As there were no other nominations it was moved, seconded and carried that the Secretary cast a unanimous ballot for all the officers as nominated.

The following Committee reports were called for and given:

Membership ....Jack H. Kimball
Financing Journal ....J. F. Smith
Publicity ....F. Wayland Jones
Secretary-Treasurer ....Wm. T. Ingram
(Read by present Secretary)
Auditing ....B. Benas
(Read by President)
Award ....A. J. Castro, Jr.
(Read by Harold L. May)
San Joaquin Local Section ....F. Wayland Jones
Certification ....R. L. Derby
(Read by President and discussed by R. D. Woodward)
School for Operators ....R. L. Derby
(Read by President)
Design Practice ....Richard D. Pomeroy
(Asked for continuance until next meeting)
Safety Standards ....F. S. Currie
(Read by President)
Industrial Wastes ....W. T. Knowlton
(Read by President)

W. A. Allen, Chairman of the Committee on Resolutions, read the resolutions.

It was moved, seconded and unanimously carried that the resolutions be adopted. Professor Reynolds then suggested that letters be sent to Charles G. Hyde, A. M. Rawn, R. R. Ribal, and to William T. Ingram to tell them that their absence at the Convention was very noticeable, and that we regret that they could not be present.

Mr. A. L. Frick, Jr., was then called upon to report on the activities of the second annual convention of Federation of Sewage Works Associations in New York City on October 11, 1941. Mr. Frick was alternate representative with Charles Gilman Hyde on the Board of Control and flew back just in time to attend this meeting. He briefly outlined the organization of the Federation and explained that even with the increase in dues the Manufacturer's Association was contributing a considerable amount to finance the Federation. The tendency towards activities of interest and value to the Operators was demonstrated by the Operators' Breakfast, which was a huge success according to Mr. Frick. He also announced that 1942 National convention will be held in Cleveland, Ohio.

Mr. Gray opened the meeting to discussion of the question of whether or not this Association should raise its dues from $2.00 to $4.00 per year, as set forth in the proposed amendments to the By-Laws, in order to retain its membership in the Federation. In response to a suggestion that dues for operators be kept at $2.00, President Gray read a letter from Mr. Rowntree, operator of the Carmel plant, in which he stated many reasons why every one should be willing to pay the full $4.00. Wayland Jones, Secretary of the San Joaquin local section, stated that at their last meeting their members had voted unanimously in favor of the proposed amendments. In answer to J. F. Smith's question, the President explained that the Federation had amended its By-Laws to permit member associations to determine their own class and status of members and that the Association had only one class of member. Mr. Woodward stated that in his plant having several operators only one membership would be used by all, and he feared a considerable loss in membership. Professor Reynolds stated that he understood that new issues of the *Journal* were intended to contain more material of interest and value to the operator.

President Gray then read a letter from A. M. Rawn, who was attending a meeting in Chicago, in which he expressed himself in favor of joining the Federation. Mr. Rawn regretted that he could not attend the convention as this was only the second meeting he has missed since this Association was formed.

President Gray then called for a vote on the proposed amendments to the By-Laws. There were 41 members present and 36 voted in favor of the amendments with five not voting.

President Gray then called for a vote to approve the Constitution and By-Laws of the Federation. Carried.

As there was no further business President Gray turned the meeting over to Mr. Bowlus, the newly elected President. After a brief greeting, President Bowlus adjourned the meeting at 4:15 P.M.

JACK H. KIMBALL, *Secretary*

GEORGIA WATER AND SEWAGE WORKS ASSOCIATION

Tenth Water and Sewage School, Georgia Tech., October 22–25, 1941

The tenth annual Georgia Water and Sewage School was held at Georgia Tech. on Oct. 22–25. Registration reached a new peak with more than 360 persons, exclusive of college students, in attendance.

Highlights of the School, other than the usual technical discussions, included the annual banquet and business meeting; an inspection trip to the Atlanta Water Works and the formal opening of the recent additions thereto; and attendance at the Tech.-Auburn football game.

The general session Wednesday morning opened with an address of welcome by Dr. M. L. Brittain, President, Georgia School of Technology, and a response by George Sparks, President, Georgia Water and Sewage Association.

A panel discussion on "Water Supply and Sewerage in the Defense Program" was opened by W. H. Weir, Georgia Department of Public Health, who gave a brief discussion of the situation as applied to Georgia. He mentioned the increased demands placed on existing plants and the necessity for new plants brought about by increased population in areas around defense projects and urged operators to exercise utmost vigilance in maintaining operation efficiency at a high level.

John B. Reeves, District Manager, O.P.M., Atlanta, explained "Priorities for Water Works and Sewage," pointing out the necessity for such a program in the face of a national shortage of certain materials. He stated that a preference rating of A–10 had been assigned to necessary maintenance and repair materials and urged all towns to execute and file Preference Rating Order Acceptance Form P–46.

L. H. Enslow, Editor of *Water Works and Sewerage,* Fred Stuart, President, Activated Alum Corp., and others discussed the subject and pointed out that certain materials are becoming more and more difficult to procure and that deliveries in the immediate future will be very slow.

Colonel R. C. Job, Georgia Defense Council, speaking on the subject of "Organizing for Defense of Public Utilities," outlined some experiences England has gone through and gave a resumé of the proposed set-up for defense organization in Georgia.

Wednesday afternoon two sessions were held dealing with water treatment.

The general session Thursday morning opened with a lecture by Dr. H. B. Friedman, Georgia Tech., on basic chemistry as applied to water and sewage treatment. Dr. Friedman discussed the more commonly used chemicals, explaining their reaction; the theory of ionization; indicators; and gave an explanation of the meaning of pH. In connection with the latter he pointed out that where colorimetric pH determinations are made it is important that proper indicator solutions be used and that these be kept free of contamination.

Malcolm E. Henley, Wallace and Tiernan Co., Atlanta, spoke on "Maintenance and Operation of Chlorinating Equipment." Mr. Henley had three types of chlorinators set up on the platform and using these, together with line drawings and blackboard sketches, explained the working principles of each type of machine. He gave detailed instructions for the care and maintenence of each and discussed the most likely points on each which may require attention.

The afternoon sessions on Thursday were divided into a Water Round Table and a Sewage Round Table.

H. E. Whelchel, College Park, led the discussion at the Sewage Round Table. He was followed by Wm. A. Hansell, Atlanta, who gave some pointers on construction and maintenance of sewers. L. H. Enslow discussed "Sludge Digestion" and other phases of sewage treatment. Additional topics covered at this session included "Pumping Raw Sewage," "Equipment Maintenance," and "Stream Pollution," the discussions being introduced by Van P. Enloe, Atlanta, L. W. Handley, La Grange, and G. R. Frith, State Health Department.

Friday afternoon those interested in sewage treatment visited the South River sewage disposal plant where they were given detailed instructions on the operation of a sewage treatment plant of this type.

The annual banquet and business meeting was held on Friday evening at the Henry Grady Hotel. The banquet was given with the compliments of H. M. Thompson, Manager of the Paper Makers Chemical Division of Hercules Powder Co., Atlanta. The following new officers were elected: *President*—H. E. Whelchel, superintendent Filtration, College Park; *First Vice-President*—W. H. Weaver, Director of Public Works, Decatur; *Second Vice-President*—T. A. Jones, superintendent Water Works, Fort Valley; *Secretary-Treasurer*—T. T. Gunter, Atlanta Filter Plant, Atlanta; and *Director,* Sewage Works Federation—Van P. Enloe, Sewer Department, Atlanta. The Committee on Awards presented certificates to the following men for outstanding work during the year: Fred M. Hull, superintendent Filtration, Columbus; D. H. Hurst, Sewer Department, Tifton; and George H. Sparks, superintendent Water and Light Department, East Point. Wm. A. Hansell, Construction Department, City of Atlanta, was given an honorary life membership in the Association. Clark W. Jones, superintendent, Dalton, speaking in behalf of the Membership, presented Paul Weir, superintendent Filtration, Atlanta, with a beautiful gold watch in appreciation of his faithful and efficient services as Secretary-Treasurer of the Association for the past eight years. Motion pictures were shown depicting the effects of modern warfare upon public utilities. These pictures were taken in London during recent months.

The session Saturday morning was divided into two parts. All candidates desiring to stand examinations for various class certificates were permitted to take these examinations. The remainder of the group held a question and answer session at which time the question box was opened and various members called upon to answer the questions which had been submitted during the School.

The School adjourned at noon and attended the Tech.-Auburn football game.

Paul Weir, *Secretary*

IOWA WASTES DISPOSAL ASSOCIATION

Seventeenth Annual Meeting,

Iowa State College, Ames, Iowa, November 20, 1941

The seventeenth annual meeting of the Iowa Wastes Disposal Association was held in the south ballroom of the Memorial Union, Iowa State College, on the evening of November 20, 1941, following the annual dinner. President George Ahrens presided.

The meeting opened with an address by W. H. Wisely, Executive Secretary of the Federation of Sewage Works Associations. He sketched the history of the Federation explaining the important financial aid of the Chemical Foundation in publishing the *Sewage Works Journal.* Funds from the Chemical Foundation are no longer available, hence a drastic reorganization of the structure and support of the Federation has been necessary. The manufacturers of equipment and products used in sewage treatment have agreed to cooperate with and financially support the Federation.

A new constitution has been drawn up and approved by the representatives of the State Associations. New officers have been elected and provision made for employing a full-time executive secretary to have charge of the actual handling of Federation business. Federation dues have had to be revised to make the *Journal* and business office of the Federation self-supporting.

An attempt is being made to make the *Journal* of increasing value to the small plant operator. The section on operation is being developed, and Mr. Wisely invited the cooperation of Iowa operators in sending material on operation, annual reports, new gadgets, etc. to him. He asked for member participation in the affairs of both State Association and National Federation.

A. H. Wieters reported on the National Meeting of the Federation which he attended in New York in October. He described the marvelous exhibits and the strong program mentioning particularly the interesting symposium on operators' problems. (The minutes were published in the January issue of the *Sewage Works Journal.*) He described briefly the report of the Policy Committee and the report of the Publications Committee. Mention was made of the request that member state associations reserve the first two weeks in October each year for the National Federation Meeting.

Rates for the *Sewage Works Journal* to non-members were set at \$5.00 per year with a 20 per cent reduction to institutions.

There followed a discussion by Dr. Max Levine, the 1941 Iowa representative to the Board of Control of the Federation, relative to the revised constitution and the changes needed in the Iowa Association Constitution and By-Laws.

The meeting was then thrown open for a discussion of Association business. After many diverse suggestions regarding the revision of the constitution, the amount of dues, and the question of who should receive the *Journal,* these questions were by common consent referred to the executive committee and constitutional committee for study and recommendations.

The report of the Secretary-Treasurer was then called for and presented.

Chairman Ahrens then raised the question of changing the place of meeting of the Association. He invited comments by those desiring a change. Several hours of discussion followed with Roberts Rules of Order barred; advantages of meeting at the College and away from the College were given with widely divergent views in evidence. Finally Dr. Max Levine introduced a motion that the executive committee be authorized to schedule occasional meetings of the Association away from the College. This motion was seconded and approved by a majority of those voting.

The chairman appointed a nominating committee composed of Pray, Hebig and McAllister. They nominated:

President .... T. R. Lovell, Marshalltown
Vice-President .... Paul Winfrey, Des Moines
Director .... R. G. Miller, Vinton
Director .... H. G. Spragg, Arnolds Park
Representative to the Board of Control
A. H. Wieters, Des Moines

Mr. Dye moved that nominations cease and that the secretary be instructed to cast the unanimous vote of the group for those nominated. The motion was seconded and carried.

The meeting adjourned.

L. J. Murphy, *Secretary*

NEW YORK STATE SEWAGE WORKS ASSOCIATION

Fourteenth Annual Meeting,

New York, N. Y., January 22–24, 1942

The fourteenth annual meeting of the New York State Sewage Works Association was held in New York City, January 22 through January 24, 1942, with headquarters at the Hotel McAlpin. About 235 members and guests registered. This number is somewhat less than the attendance at previous joint meetings but it was felt that this decrease was due to the war conditions, which have increased many fold the work of engineers.

Edward J. Smith, superintendent of the sewage treatment plant at Niagara Falls, N. Y., William H. Larkin, district sanitary engineer, New York State Department of Health, New York City, and William D. Denise, superintendent of the sewage treatment plant for the Town of Greece, were elected to the Executive Committee for a period of three years. Charles R. Velzy, works superintendent, Buffalo Sewer Authority, was elected President and Lawrence L. Luther, Commissioner of Sanitation, Freeport, N. Y., was elected Vice-President. A. S. Bedell of the New York State Department of Health, Albany, N. Y., was reappointed Secretary-Treasurer. J. C. Brigham and A. W. Eustance of the New York State Department of Health, Albany, N. Y., were reappointed Assistant Treasurer and Assistant Secretary, respectively, for the ensuing year.

The program was arranged as is our custom so that the members of the Sewage Works Association would be able to attend all the Thursday sessions of the Sanitary Engineering Division of the A. S. C. E. and likewise members of the A. S. C. E. could attend the technical sessions of the Sewage Works Association on Friday and the joint inspection trip on Saturday.

At the general business meeting on Friday, it was noted that the Association now has a membership of 747 and that at present there are five local sections in the State. Secretary Bedell pointed out that the membership is now entirely composed of active members because the Associate Membership classification was abolished so as to conform with the new Federation Constitution. The reports of the activities of the local sections and of the various standing committees were presented.

At the business meeting on Friday, Robert C. Wheeler, Chairman of the Legislation Committee, explained the two bills now before the Congress of the United States which were of interest to the organization. These bills are Senate Bill S–1617 and the corresponding House Bill which covers the Public Works Reserve plan, and the bill known as HR–5676 which covers the material in the old Barkley-Vinson bill. Resolutions were passed at this meeting recommending the approval of each of these bills by Congress.

At the technical sessions on Friday morning, W. R. Drury, Consulting Engineer, Ann Arbor, Michigan, presented a paper entitled "Varied Problems in Design and Construction of Sewers at Lockport, New York."

At the noon luncheon, which was attended by both members of the N. Y. S. S. W. A. and the A. S. C. E., Gordon M. Fair, Professor of Sanitary Engineering, Harvard Graduate School, Cambridge, Mass., was presented the Kenneth Allen Memorial Award for 1941 for the most meritorious paper of a technical and research nature. The bronze plaque was presented by Fred J. Biele, Chairman of the Award Committee. The title of the paper winning this award, which paper was given at the January, 1941 meeting of the Association, was "Natural Purification of River Muds and Pollutional Sediments."

The guest speaker at the Friday luncheon was Colonel W. A. Hardenburgh, Sanitary Corps, Office of the Surgeon General, U. S. Army, who gave a very inspiring "recruiting" talk.

Herbert H. Wagenhals, retiring president, was presented with a gold key bearing the emblem of the Association.

At the afternoon session, Charles H. Capen, Principal Sanitary and Hydraulic Engineer, Construction Quartermaster's Office, U. S. A., Zone II, New York City, gave a very interesting paper entitled "Special Sewage Problems at Army Cantonments." This was followed by a paper given by William L. Sylvester, Assistant Engineer, Office of the Commissioner, Department of Public Works, New York City, entitled "The Effect of War on Material Used in Sewerage and Sewage Treatment Works Operation and Construction." Professor R. G. Tyler, University of Washington, Seattle, Washington, presented the third paper of the afternoon entitled "Accelerated Re-Aeration."

In preparation for the inspection trip on Saturday, James R. Losee, Village Engineer of Tarrytown, N. Y., and Albert C. Kassay, superintendent of water and sewerage at North Tarrytown, gave a short description of their respective treatment plants, which were to be inspected the following day. James C. Harding, Consulting Engineer of New York City, gave a brief description of the main sewage treatment plant serving the village of Ossining which likewise was to be inspected.

On Friday evening the members of the N. Y. S. S. W. A. and the A. S. C. E. enjoyed the usual annual banquet and were greeted by Major E. B. Black, President-elect of the A. S. C. E. The guest speaker for the evening was Commander Robert Cobb, R.N. of the British Navy. Commander Cobb gave a very interesting talk on his life and experiences, which extended from World War I to and including World War II. Commander Cobb's boat which was damaged in action in the Mediterranean is at present in this country undergoing repairs.

On Saturday a joint inspection trip was made by approximately 50 persons in two chartered busses to the treatment plants serving Tarrytown, North Tarrytown and Ossining. A buffet luncheon was served to approximately 100 persons in the new Municipal Building at North Tarrytown. The inspection trip was very enjoyable as well as instructive in that three small modern sewage treatment plants were visited.

A. S. Bedell, *Secretary*

LOCAL ASSOCIATION MEETINGS IN 1942

Association	*Place*	*Date*
California Sewage Works Association	Bakersfield, Cal. (Motel Inn)	Apr. 26–28
Central States Sewage Works Association	Minneapolis, Minn. (Nicollet Hotel)	June 18–19
Florida Sewage Works Association	Gainesville, Fla. (Univ. of Florida)	Apr. 8–11
North Dakota Sewage Works Conference	Williston, N. D.	Oct., 1942
Kansas Water and Sewage Works Association	Lawrence, Kansas (Univ. of Kansas)	Mar. 26–28
Maryland-Delaware Water and Sewerage Association	Hagerstown, Md. (Alexander Hotel)	May 7–8
Michigan Sewage Works Association	East Lansing, Mich. (Mich. State College)	Mar. 25–27
Missouri Water and Sewerage Conference	Hannibal, Mo.	Sept. or Oct.
New England Sewage Works Association	Boston, Mass. (Bradford Hotel)	May 27–28
Ohio Sewage Works Conference	Cleveland, Ohio	Oct. 15–17
Pacific Northwest Sewage Works Association	Corvallis, Ore. (Marcus Whitman Hotel)	May 7–9
Pennsylvania Sewage Works Association	State College, Pa.	Aug. 24–26

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

Third Annual Meeting, Cleveland, Ohio, Oct. 15–17

Reviews and Abstracts

MAIN SEWAGE WORKS, BOROUGH OF SLOUGH

By M. A. Kershaw

Civil Engineering (London), 36, 539 (August, 1941)

Since 1879 the sewage of Slough has been pumped to a sewage farm at Dorney where disposal has been effected by irrigation methods. The original area of land was 25 acres. More land was acquired from time to time and by 1921 the area was 126 acres.

From 1921 to 1934 the farm was operated by a manager who was responsible for disposing of the sewage to the satisfaction of the Council. He received the use of the farm buildings and a fixed sum per annum, and was allowed to conduct general farming operations.

During 1930–31 the urban area was increased from 1684 acres to 6276 acres, and the population from 18,500 to 33,500. At the same time the Council acquired the Cippenham Sewage Works adjoining the farm, and a small district works at Langley from the Eton Rural District Council.

During the last war (1914–1918) a large mechanical transport depot was established in Slough by the War Office. After the war the depot was acquired by a private undertaking and since that time progressive development into a larger industrial trading estate has taken place. This has resulted in a considerable increase in the flow of sewage to be dealt with, most of which is trade waste effluents from a great variety of manufacturing establishments.

Increasing overload on the works and farm led to serious treatment difficulties. The Council had a thorough study made and in 1933 a comprehensive report was made which outlined a scheme of extensions. The scheme included the construction of a new treatment unit on a site adjoining the existing Cippenham Sewage Works and Farm at Dorney, so that the whole would be finally linked and operated as one complete disposal unit. The recommendations were adapted but construction work was not completed until October, 1938. As the load had increased to a greater extent than anticipated, an extension consisting of 6–100 ft. diameter filters and 3 humus tanks was added which was completed in December, 1940.

Description of Treatment Plant

Average daily volume of sewage,

1. At Main Works, Cippenham, 3½ million gallons daily, over 0.75 m.g.d. of which is trade wastes.
2. At District Works, Langley, 0.5 m.g.d. Area of treatment works, 43 acres. Area of the irrigation farm, 151 acres.

The eastern area of the town drains to the district works at Langley. Here the sewage is treated by screens, tanks, filters, and land irrigation.

The new works at Cippenham are linked with the original treatment plant and farm, so that the whole can function as one purification unit, or the farm areas can be operated independently of the artificial plant.

Sewage arriving at the plant is first passed through detritus tanks and screening chambers. The detritus tanks are hopper bottomed and are cleaned by an electrically operated chain and bucket dredger. This unit travels on fixed rails from tank to tank.

The screens are fitted with self-cleaning rakes. Screenings and detritus are discharged to an adjoining area of land and are later removed by local farmers.

After screening, the sewage is chlorinated; the average chlorine dose being in the nature of 5 parts per million. The following benefits have been proved at these works:

1. Aerial nuisance is almost completely eliminated throughout all stages of treatment.
2. The sewage is kept fresh throughout treatment.
3. Ponding on the filters, considerably overloaded, is avoided.

Between the screens and the sedimentation tanks the sewage passes through a channel, one side of which constitutes a storm water weir discharging into four rectangular tanks. The tanks are not full capacity for storm water requirements and they overflow to the irrigation lagoons which formed part of the old works and now function as storm water areas when necessary. Actually, due to the overload on the works, the storm water tanks are in operation daily as balancing tanks, the contents being pumped to the main inlet at night when the flows are lower.

Approximately a third of the flow following the storm water weir is diverted to the old treatment works. Here are provided three rectangular sedimentation tanks in parallel, five 60 ft. diameter filter beds, 4 ft. 6 in. deep, five small humus tanks, approximately 10 acres of irrigation lagoons, and 20 acres of rough grassland over which final effluent is discharged. Drainage from the grassland is discharged into a stream for eventual discharge into the River Thames.

The remainder of the screened sewage is passed into a battery of Dortmund type sedimentation tanks. There are six sets of tanks each containing three hoppers 20 ft. deep. Sludge is withdrawn hydrostatically and delivered by gravity to the sludge digestion unit or the main pumping station where it can be pumped to the farm for disposal on prepared land areas.

The tank effluent may be divided, discharging a portion to the irrigation areas on the farm and the remainder to the filters for final treatment. The filters are 12 in number, each 100 ft. diameter and 6 ft. deep. Six have metallurgical coke as media and the others, constructed later (as previously noted), use a clinker. All filters are constructed on a concrete floor. In the six original units land drains are laid on the floor, draining to one-third the perimeter of the filters. In the later units drainage is effected by patent tiles, and a much greater length of the perimeter is used for effluent discharge. The filter walls are constructed with the first three feet solid brickwork and the last three feet of large coke plums. Sewage is applied to the filters by rotary distributors.

The effluent from the filters is discharged to a battery of six rectangular humus tanks. Tank effluent is discharged to the stream. Humus sludge is discharged by gravity to the main pumping station where it is pumped either to the digestion tanks or to land areas on the farm.

Sedimentation tank effluent not treated on the filters is diverted to irrigation areas on the farm. As part of the reconstruction scheme the whole area of the farm is to be made available for either tank effluent or sludge treatment. The sludge disposal area is located at the center of the farm, and a pipe line bounds the area on three sides. Other pipe lines spread out Y fashion enable tank liquor to be easily distributed on prepared areas of land. Owing to the war this work is not complete, but is being incorporated in normal routine work.

There are six sludge digestion tanks, rectangular in shape. The floor slopes to the outlet end, the average depth being 18 ft. The raw sludge inlet is submerged some 8 ft. below the surface, and supernatant liquor drawoffs are located in the opposite end. The tanks were designed to treat only one-half the sludge from tank treatment, but up to the present time it has been possible to handle all the sedimentation and humus tank sludge.

Adjoining the digestion tanks are 24 sludge drying beds. They are constructed on concrete floors, with 6 in. of coarse clinker topped with 3 in. of ash. In normal weather digested sludge is dosed to a depth of about 15 inches. During the next 24 hours a considerable quantity of supernatant liquor is drawn off by means of decanting valves, and in four or five days the cake is ready for removal. Decanted liquor and water draining through the beds is discharged, along with liquor drawn from the digestion tanks, to the main pumping station.

When the works were completed various lines of experimental investigation were opened. Two questions of local importance were followed up on a large scale:

1. The possibility of utilizing gas produced during digestion for power purposes.
2. The possibility of treating the mixed sewage and trade wastes by the activated sludge process.

The present experimental plant is designed to treat up to 30,000 gal. of tank effluent per day, and is entirely operated on gas collected from a small section of two digestion tanks. The activated sludge unit consists of a re-aeration pocket, aeration tank and settling tank. Air is supplied by a blower driven by a 5 H.P. gas engine. A filter has also been constructed, 20 ft. in diameter. Thus a complete experimental treatment unit is available to test the possibilities of: (1) Utilizing gas for power purposes on the whole of the works. (2) Giving partial activated sludge treatment to the tank effluent. (3) Giving final treatment at high dosage rates on the filters.

T. L. Herrick

DESCRIPTION OF THE STRONGFORD AND HANLEY SEWAGE WORKS

By W. H. E. Makepeace

Civil Engineering (London), 36, 610 (November, 1941)

The city of Stoke-on-Trent is located on the River Trent, practically at its source. The stream, with a dry weather flow averaging as low as 4 million gallons daily, receives sewage and trade wastes amounting to 11 M.G.D. in dry weather. During the past 35 years plant extensions or entirely new works have been provided in six locations.

The Strongford Works serves a portion of the southern area of the city, the Borough of Newcastle-under-Lyme, and Barlaston parish of the Stone Rural District. The population served is 147,000. The Hanley works serves the central and northeastern area of the city.

Strongford Works.—All sewage handled at the works, except that from the village of Trentham, is pumped at the Trent Vale Pumping Station. The sewage first passes through one or more of three grit chambers. Grit is removed by means of a travelling dredger and discharged to a detritor where it is washed. A mechanically operated bar screen is located at the discharge end of each grit chamber.

Flows up to three times the dry weather flow are passed to the pump wells, and excess flows are discharged into storm tanks, four in number. These tanks fill consecutively during storm flows and excess flows during prolonged storms discharge from the tanks to the river. Storm water and sludge retained in the tanks are pumped to the treatment works during dry weather flows.

At the Strongford works the sewage is first passed into three detritus tanks, each 80 ft. by 28 ft. by 6 ft. 3 in. average depth. They have a total capacity of 262,000 gallons ($1\frac{1}{2}$ hours dry weather flow).

The detritus tank effluent passes by gravity to eight sedimentation tanks, each 200 ft. by 55 ft. by 6 ft. deep, having a total capacity of 3,460,000 gallons. They are so arranged that the effluent can pass to the bacteria beds or to the activated sludge plant interposed between the tanks and the beds.

The activated sludge unit is divided into 20 channels, each 210 ft. long, 8 ft. 6 in. wide, having a maximum depth of 11 ft. 6 in. and an average depth of 9 ft. The unit was designed to treat 3 M.G.D. with a detention period of 13.3 hours. There are 8 settling tanks, each 25 ft. square, with inverted pyramid sides.

The effluent from the sedimentation tanks, or the activated sludge unit, will pass to 3 bacteria beds. Each bed is 2 acres in area, 5 ft. 6 in. deep, and contains 51,000 cu. yd. of filtering material. This material consists of saggers, or broken gravel, varying in size from $\frac{3}{4}$ in. to 2 in. Sewage is applied by means of mechanically driven rectangular distributors, eight to each bed.

The humus tanks are rectangular, each 120 ft. by 70 ft. by 4 ft. 6 in. deep.

All sludge produced is screened and passed to the primary sludge digestion tank. The tank is 85 ft. in diameter and 28 ft. deep. It is equipped with mixing arms, and heating coils are fixed to the tank walls. A steel cover provides gas collecting facilities.

A portion of the gas produced is used in three 165 H.P. gas engines which drive an air compressor and two generators. Gas not needed for power purposes is wasted to the atmosphere. Engine cooling water is passed through exhaust gas heaters, then to the coils of the digestor. A gas fired boiler is interposed in the system which can be used if necessary. The average consumption of gas for power purposes is 51,000 cu. ft. per day.

The sludge from the digestor is pumped through a 15 in. main against a total head of 150 ft. to the secondary sludge digestion tanks at Newstead, about 1¼ miles away. Here are provided 8 open reinforced concrete tanks and an earth tank. The total capacity is 3,800,000 gallons. The earth tank serves also as a storage tank.

Sludge from these tanks is passed to the drying beds. The beds have an area of 48,000 square yards. They are covered by 18 to 24 in. of graded ashes and are underdrained. Drainage from the beds is returned to the works for treatment, and sludge is removed by hand labor.

Hanley Works.—The original works at Hanley were installed in 1880 and consisted of storage reservoirs, a steam pumping plant, and four sedimentation tanks. The plant was extended from time to time and since 1921 considerable alterations and additions have been made, including the provision of an activated sludge plant, washing and regrading of a portion of the filtration area, provision of humus tanks, and extensions to the sludge treatment plant. In 1937 further extensions were laid down which included a duplication of the activated sludge unit, settling tanks and other incidental work.

The present flow includes trade wastes, principally pottery wastes, brewery wastes, and a small proportion of waste gas liquor.

Sewage is first passed through 4 grit chambers from which grit is removed by means of a mechanical dredger. No screens are used at this plant.

A storm water weir is provided ahead of the primary tanks, all volumes in excess of 3 times the dry weather flow being discharged into tanks having a capacity equal to 10 hours dry weather flow. The primary tanks are five in number and have a total capacity of 600,000 gallons.

There are three sedimentation tanks having a capacity of 1,300,000 gal. on the low level, and a like number with a capacity of 1,700,000 gal. on the high level.

The activated sludge plant was designed for a flow of 2 M.G.D. There are 16 channels, each 200 ft. by 8 ft. 6 in. wide and 8 ft. average depth. Two circular settling tanks are provided, each 60 ft. in diameter. The rate of upward flow under dry weather flow conditions is 2.37 ft. per hour. Rotary sludge scrapers move deposited sludge to the center of the tank. Effluent from the settling tanks is passed directly to the river.

The bacteria beds cover an area of 9 acres and have a volume of approximately 85,000 cubic yards. Sewage is applied by power-driven rectangular distributors. Three humus tanks are provided. They are rectangular and have a total capacity of 600,000 gallons.

A portion of the effluent from these tanks is used for cooling purposes in the electrical works, and also as compensation water to the canal. Effluent for both purposes is chlorinated.

The sludge from the detritus tanks, sedimentation tanks, humus tanks, and a portion of the excess activated sludge is at present tanked, limed, and pressed. The present plant consists of 30 presses, each with 40 chambers.

T. L. Herrick

DETERMINATION OF GREASE IN SEWAGE, SLUDGE AND INDUSTRIAL WASTES

By Richard Pomeroy and C. M. Wakeman

Ind. and Eng. Chemistry, **13**, 795 (November, 1941)

The determination of grease in sewage and industrial wastes by prevailing methods permits error by (1) loss of part of the grease along with steam or evaporation to dryness; (2) resaponification of grease freed from insoluble soaps by hydrochloric acid on evaporation to dryness; (3) liberation of fats by hydrolysis of phospholipids; (4) insolubilizing of oil and grease by oxidation or polymerization; (5) extraction of non-greases.

The method described eliminates or greatly reduces most of the sources of error.

Two extraction procedures are suggested.

A study of various solvents which included hexane, petroleum ether, iso propyl ether, ethyl ether, benzene and chloroform led to the conclusion that hexane or petroleum ether extracted material more nearly like grease contained in sewage, sludge, or industrial wastes.

Results of analyses by the wet method are much less influenced by variations of technique and of solvent than is the case with the procedure given in " Standard Methods."

Wet Extraction, Procedure I.—It is generally desirable that the yield of grease be between 50 and 500 mg. Sewage samples of 800 to 2000 ml. have been found convenient, but where sample is heterogeneous 4000 ml. may be used. In the case of sewage sludges, samples containing 1.0 to 5.0 grams of dry solids are usually satisfactory.

The sample is acidified with 1:1 sulfuric acid, then transferred to a separatory funnel, and 75–150 ml. of the solvent is added. The funnel is shaken vigorously for 2 minutes. Connect the mouth of the funnel to a vertical condenser having a standard-taper ground-glass connection, and lower the assembly into a water bath maintained at a temperature of 90° to 100° C. (Cork connections may be substituted for ground-glass joints with introduction of scarcely appreciable errors.) Reflux briskly until the emulsoid mixture has separated into its component parts. This usually requires from 15 to 30 minutes. The funnel is disconnected and cooled for 5 to 10 minutes. Filter the clear solvent solution into a weighed conical flask of 125- to 250-ml. capacity.

Add 50 to 100 ml. of solvent to the funnel and repeat the extraction procedure. Make as many subsequent extractions as required to accomplish practically complete removal of the grease. For sewage, three of four extractions are sufficient, but sludges may require five or six extractions. After all solvent layers have been transferred to the flask, wash the filter thoroughly with fresh solvent. Separate the solvent from the fatty matter by heating (not over 100° C.). When no more liquid solvent is visibly present, introduce a jet of dry air or gas into the flask while it is still on the heating bath. This serves to displace the heavy vapor.

Dry the flask in an oven at 100° to 105° C. for 20 minutes, transfer to a desiccator, and weigh when cool.

Procedure II.—Follow same directions as previously given in (I) up to and including addition of the solvent. For sewages, which tend to form emulsions, the shaking must not be too vigorous. Allow the mixture to stand for 30 minutes, then draw off the lower layer of turbid water, which should separate into a second separatory funnel. Add 50 ml. of solvent to this second funnel and shake as before. Returning to the first funnel, a layer composed of an intimate mixture of water solvent and solids will be found, which may be covered with a clear grease-bearing layer of solvent. Shake the mixture vigorously. This will generally cause solvent to separate and the residue to become granular. If there is little separation, add 50 to 100 ml. more of solvent and again shake well. If at this stage a resistant emulsion remains, continue the test by Procedure I.

When the solvent layer has clarified sufficiently, transfer it to a tared conical flask as in Procedure I. When the second separatory funnel has stood for a suitable time, the aqueous layer is withdrawn and discarded. Transfer solvent and emulsoid layer to the first funnel, rinsing with a few ml. of fresh solvent. Shake the combined mixture again and allow it to stand until clear solvent can be transferred to the filter. Make subsequent extractions of the residue in the separatory funnel by adding quantities of solvent at least twice the volume of the emulsoid mixture and shaking as before. Withdraw progressively any water which separates and discard after each shaking. The number of extractions will vary with the volume of the residue and the nature of the sample. In the case of sewage, a total of three or four extractions is sufficient.

Conduct the remaining operations as in Procedure I.

The wet method was checked by using a mixture made to simulate sewage in which the grease content was known. A yield of 99.67 per cent of the grease was obtained. Averages of several series of determinations made on the same samples of sewages, sludges and industrial wastes gave results with differences from the means, averaging 2 per cent. The method extracts larger amounts of grease than the older A. P. H. A. method. Results comparing the wet method with the method of the A. P. H. A. are given in the table which has been condensed from the extensive tables of the original article:

Source	Grease Content, Average of Two or More Determinations		
	Wet Method		A.P.H.A.
	Extraction Procedure	P.P.M.	P.P.M.
Unscreened Sewage	II	130	105
Unscreened Sewage	I	197	135
Unscreened Sewage	I	127	108
Unscreened Sewage	I	82	59
Unscreened Sewage	I	92	57
Unscreened Sewage	I	127	101
Unscreened Sewage	I	48	32
Raw Screened Sludge	I	16,070	16,060
Unscreened Raw Sludge	I	6,940	6,505
Fish Cannery Waste	I	664	498

E. Hurwitz

SEWAGE DISPOSAL AND DRAINAGE IN WAR TIME

Treatment Difficulties: Design and Location of New Works

The Surveyor, **100**, 181 (Nov. 28, 1941)

This article is a discussion of a paper on the above subject presented by John T. Calvert, Minister of Health. The Ministry of Health in Great Britain has established a policy regarding extension of sewage works which comprises (1) sanctioning of projects necessary to protect water supplies and prevention of nuisance; (2) completion of projects under construction to the point necessary to prevent their protection from deterioration and loss. No work was to be sanctioned where the danger was merely the prevention of lowering the standard of purity of a receiving body of water.

The result of the war which most affected sewage treatment was the evacuation of people from urban into rural areas with the subsequent overloading of rural treatment works from 30 to 50 per cent. The Minister of Health stated that in such cases appeals to the Ministry of Health might be made for relief but he urged this only as a last resort, urging instead that experiments in operation be tried to absorb the additional load.

Activities of the military and war supply ministry had also created problems. In general, the policy had been to try to connect army camps and factories to existing sewage treatment works. Where none were available, as was the fact in many cases, new works were constructed. There was a serious shortage of filter media (gas works clinker). Use of brick bats from bombed buildings had been suggested. Army authorities were providing dry latrines at camps and separate treatment of liquids in chemical precipitation tanks (using lime and ferrous sulfate).

Use of sewage sludge for fertilizer as part of the general salvage effort was urged.

Regarding the reconstruction period after the war the Minister urged careful planning now on needed work which could be started quickly.

K. V. Hill

SEWAGE WORKS OPERATION IN WAR TIME

The Surveyor, 100, 201–202 (Dec. 12, 1941)

Further discussion of John T. Calvert's (Minister of Health) paper on Sewage Disposal in War Time by members of the Institute of Sewage Purification.

J. M. Wishart (Manchester) pointed out that increased efficiency of both settling tanks and filters could be secured by use of chemical precipitants. Some extension of sludge disposal facilities would usually be required. He knew of one large filter which contained a high proportion of broken bricks.

A. Kershaw (Slough) cited the tremendous difficulties involved in sewage plant operation due to the war particularly at smaller plants with few resources. He suggested that the Institute establish a clearing house committee for assembling data on difficulties at all plants and providing helpful suggestions to all members quarterly in a brief pamphlet.

A. R. Ward (Stockport), referring to clinker scarcity for drying beds and filters, stated that he had reduced the thickness of his clinker sludge drying beds from 14 to 7 in., and the beds were working just as well.

H. C. Whitehead (Birmingham) cited the results of higher rates of application on filters. On a quarter-acre bed which normally was dosed with 60–80 gal. of sedimented sewage per cu. yd. per 24 hr., 400 gal. per cu. yd. of sewage comprising 50 per cent sedimented sewage and 50 per cent settled effluent, had been applied all summer and produced an effluent which complied with the recommended standard of the Royal Commission.

Several members cited the need for more propagandic effort to promote the use of sludge as fertilizer.

K. V. Hill

SOME INVESTIGATIONS INTO THE DIGESTION AND DRYING OF HUMUS AND ACTIVATED SLUDGES

By C. Lumb

The Surveyor, 100, 191–192 (Dec. 5, 1941)

The sludges digested consisted of mixed humus and activated sludge in the ratio 3 to 1 of dry solids, respectively. Bottle digestors were used and thermostatically-controlled digestion temperatures of 15° C., 20° C., 30° C. (mesophilic zone), and 55° C. (thermophilic zone). Batches of one volume of raw sludge to three volumes of seed sludge were prepared and the mixtures digested until gas evolution decelerated considerably. Supernatant liquor was then removed, followed by sufficient digested sludge from the bottom of the bottle to total the volume of raw sludge added. The three volume units of digested sludge were then used to seed a new batch, and so on.

In general, sludge digested at 30° C. in 37 per cent of the time required at 20° C. with the production of 95 per cent of the gas produced at 20° C. and 96 per cent of the reduction in organic matter. Sludge digested at 55° C. in 24 per cent of the time required at 20° C. with the production of 83 per cent of the gas produced at 20° C. and the same percentage reduction of organic matter.

Sludge digested at mesophilic temperatures were much improved in odor compared with the undigested material: thermophilically digested sludges when cool had the same smell as the original sludge and worse odors when warm. Gas from the thermophilic digestor had a foul odor.

Filtering the thermophilically digested sludges (Buchner funnel technique) indicated that this digestion process would not aid dewatering by mechanical filtration.

Drying of digested (at 15° C.) humus and secondary sludge (5 to 10 per cent of activated sludge) on sand beds was slow and no improvement over that of the undigested sludge. Addition of ferric sulfate (0.75 per cent) increased the quantity which could be dried in a given time 83 per cent, but this procedure did not compare favorably economically with the cost for additional drying beds.

K. V. Hill

THE MECHANICAL FLOCCULATION OF SEWAGE

By J. Hurley

The Surveyor, 51, 15–16 (Jan. 9, 1942)

The writer remarks upon the comparatively little interest evinced in England for this adjunct to sewage treatment processes. He describes the mechanics of the process as a gentle, rolling agitation of the sewage by skeleton paddles which cause the finely divided particles to coalesce into flocs which settle more rapidly than their individual constituent particles, and which, in settling, carry down with them other fine solids present in the sewage.

The few experiments in England on flocculation without chemicals have not proved very conclusive. However, the author urges more extensive trials, and points to the benefits to be received from a cheap method of improved sedimentation. Among these are greater reduction of suspended matter loading upon trickling filters and more of the sludge removed as primary sludge. He also cites the possibilities of reducing the sedimentation period by including flocculation and at the same time securing a better effluent. Thus 30 min. flocculation followed by 30 min. sedimentation of a raw sewage containing 368 p.p.m. of suspended matter produced an effluent with 103 p.p.m. suspended matter. One hour's plain sedimentation of the same sewage produced an effluent having 166 p.p.m. of suspended matter.

Flocculation of raw sewage in the presence of waste activated sludge appears to be even more beneficial. Thus the effluent of a mixture of sewage and waste activated sludge containing 497 p.p.m. of suspended matter, contained 132 p.p.m. when settled for 1 hour; the effluent of the same sewage mixture when flocculated 30 min. and settled 30 min. contained only 44 p.p.m. suspended matter.

The author calls attention to the fact that flocculation may prove useful in later stages of the process as well as in primary sedimentation and states that at Hilversum, Holland, flocculation with returned humus sludge materially improved the settling properties of trickling filter effluent.

K. V. Hill

GARBAGE GRINDING AT GOSHEN

By Henry W. Taylor

Engineering News-Record, 127, 441 (Sept. 25, 1941)

The sewage treatment plant at Goshen, N. Y., included a preliminary settling tank, two heated sludge digestion tanks, a dosing tank and fan filters, together with a garbage grinding house and a Jeffrey hammermill grinder, having a rated capacity of six tons per hour. The ground garbage is made to discharge into a cylindrical ejector tank which delivers the material to a manhole on top of the sludge digestion tanks. Fresh sludge or freshly ground garbage can be delivered to either of the two digestion tanks but the principal method of operation is to utilize two-stage digestion, with sewage and garbage pumped into the primary tank. Each of the digesters has a fixed concrete cover with overflow elevations designed to submerge floating sludge beneath the roofs. Capacities are on the basis of 4 cu. ft. per capita for 3,000 people.

The author discusses some of the mechanical features which he has found desirable in the operation of garbage grinding plants. Among these is the design of the hammermill grinder. Design of hammers to suit any particular type of material is a matter of considerable importance and its construction may vary from the use of thin knives to the thick heavy hammer which can be utilized for coarse material. The hammers used at Goshen are about 1½ in. thick and about 2½ in. wide. The pressure plate, against which the hammers first throw the material to be ground, and the adjustment of this plate, are of primary importance. The clearance between these must be closely checked for a particular type of material. The screen of the grinder limits the size of the grinding, the larger size material being rejected and carried around again against the pressure plate for size reduction. The screen bars also may accomplish a limited amount of cutting of material. A ¾ in. screen was finally adopted after considerable experimental work. Present observations indicate that there is no reason to believe that the ¾ in. screen interferes with the success of the digestion process, although some people advocate smaller openings, although a ¼ in. screen was found to be too fine.

The material in the ejector tank had to be ejected rather promptly inasmuch as the ground garbage would float to the surface of the tank. If there is a long detention period, the first discharge of ground garbage is fairly thin, while the last discharge, representing the material originally at the top of the tank, is so thick that it requires additional air pressure and involves high frictional resistance in the pipe. The practice at Goshen is to empty the tank immediately after the grinding operation has been completed.

The density of the ground garbage depends on the quantity of water added in the grinding operation. With a relatively small amount of water 4.35 cu. yd. of garbage measured in a garbage truck were reduced to 3.55 cu. yd. in tank displacement after grinding. It was found desirable to use approximately 600 gal. of water per ton of garbage on the wet basis.

The sorting of the refuse is practised in order to eliminate the large amount of paper which requires a high power for grinding. Large bones, cans, metals, glass, and other objects which might injure the grinder are also sorted and disposed of differently. Some metal bottle tops will elude the screen of the grinder, and some evidences of ashes and coal are found in the digested sludge. None of this foreign matter, has involved any handling difficulties in either tank to any extent.

The fresh ground garbage has a tendency to float and form a considerable blanket of floating sludge in the primary digester. This action was corrected by jetting the floating sludge with hot supernatant liquor through a jetting pipe which extends through the cover of the gas dome and is equipped with a nozzle in horizontal position. The height of this nozzle can be adjusted so that it will be from 6 in. to 2 ft. 6 in. below the concrete cover and can be rotated to discharge along all the radii of the tank.

The treatment plant was operated for over a year handling sewage alone. It was not until after 18 months operation that the total garbage load of the city was ground. The supernatant liquor from secondary sludge digester had a B.O.D. of around 150 p.p.m. before the introduction of ground garbage; now it is about 1,000 p.p.m. Conditions have not reached equilibrium as yet, but the author expects that the supernatant B.O.D. will average 300 p.p.m. from present observations. The gas production increased from 1.2 cu. ft. per capita while digesting sludge to an average of 2.7 cu. ft. per capita in handling garbage and sludge. No loading figures are given in pounds to evaluate gas production in terms of organic matter. The author claims that the gas produced by the plant is more than sufficient to provide all of the electric service required by the village except that for street lighting. This would include the production of power needed for the water pumping station, the water filtration plant, and the sewage treatment works. This would involve a saving to the municipality of approximately $13,000 per year. The total power used in the sewage treatment plant, including the garbage grinder, has averaged only 600 K.W.H. per month since all the garbage has been ground. The total cost of this power, including the demand charge, has averaged only $40 per month.

Rolf Eliassen

SLUDGE GAS FOR MOTOR FUEL

Engineering News-Record, 127, 802 (Dec. 4, 1941)

Excess sludge gas formerly wasted at the Clayton sewage treatment plant at Atlanta, Ga., is now being used for fuel for heating boilers at the city's water pumping plant and is expected to yield an annual saving of $6,400. Additional studies reveal, however, that the gas could be used to operate all of the city's motor truck equipment at a net profit of $8,000 annually. Use of the sludge gas for boiler fuel is accomplished by piping the gas to the pumping station, which is less than one-half mile away, and is burned without being purified. The operating costs are negligible, and the 160,000 cu. ft. of gas formerly burned in waste gas burners in the treatment plant are now put to use.

In analyzing the use of sludge gases for motor fuel, the investigation revealed that the raw gas had to be cleaned of its carbon dioxide content and then compressed to at least 3,000 lb. per sq. in. In the compressed form, it could be transferred to cylinders 9 in. in diameter and 5 ft. long, which could be mounted on the sides of garbage collecting trucks. A garbage truck that would ordinarily travel 3.5 miles on a gallon of gasoline could go 8.5 miles on one cylinder of compressed gas. The fuel gas cylinders would have to be hauled back and forth between the sewage treatment plant and the incinerator where the garbage trucks are stored. It would not be practicable to transport the compressed gas in large storage cylinders and then fill the small cylinders without removing them from the truck. Fuel cylinder changes could be made at the incinerator. A recovery process based on the utilization of about one-half of the excess sludge gas as fuel for the municipal garbage collecting trucks could be installed for $34,520. The annual fixed charges and the operating costs would total $15,743. The annual value of the gasoline saved would amount to $19,350. If it were practicable to use the compressed gas as a motor fuel in enough of the other city trucks, so that all of the excess sludge gas could be employed, the net saving would probably be around $8,000 annually.

The process of taking the gas from the digesters to the final cylinders could be accomplished by taking the raw sludge gas and conducting it to the first stage of a compressor, where it is compressed to about 150 lb. per sq. inch. After water cooling, the gas would be led to the bottom of an absorbing tower, where it would meet a stream of water coming down the tower. Most of the carbon dioxide in the raw gas would be dissolved by the water. The clean gas, substantially pure methane, would rise to the top of the tower, whence it would proceed to a water entrainment catcher. Then the clean gas would be passed acceptably through the second, third, and fourth stages of compression. After each compressor stage the gas would have to be cooled in order to condense and remove the water vapor. From the last cooler the gas could leave at a minimum pressure of 3,200 lb. per sq. in. The high-pressure gas line leading from the compressor would connect with high-pressure storage tanks and with two charging manifolds. The author presents an interesting economic analysis of the installation costs, fixed charges, and operation costs, as well as comparative figures on the use of gasoline and compressed gas.

Rolf Eliassen

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Butterfield, C. T. Federal.
Byble, Duane. New York.
Byram, Arthur T. Canada.
Byxbee, J. F. California.

Cadwell, Ivan W. New York.
Cahill, William J., Jr. New York.
Caird, James M. New York.
Calderara Orall J. New England.
Caldwell, David H. Central States.
Caldwell, H. L. Central States.
Cale, Samuel L. New York.
Calkins, Lyle W. Ohio
Callen, Loy A. Central States.
Calvert, A. England (I. S. P.).
Calvert, C. K. Central States.
Cambridge Instrument Co. Associate.
Cameron, A. B. Ohio, Pennsylvania.
Cameron, Geo. New Jersey.
Camp, Thomas R. New England.
Campbell, Harry M. Central States.
Campbell, J. L. England (I. S. P.).
Campbell, John. Pennsylvania.
Campbell, Maxwellton S. Pacific Northwest.
Campbell, Wm., Jr. New Jersey.
Capen, Charles H., Jr. New York.
Carbone, Edward A. New York.
Cardwell, Edward C. Central States.
Carey, James L. California.
Carey, Wm. N. Central States.
Carl, Charles E. South Dakota.
Carlson, H. R. Federal.
Carmichael, David W. New York.
Carnahan, Charles T. Federal.
Carney, George. Michigan.
Carollo, John. Arizona.
Carpenter, Carl B. Central States.
Carpenter, George D. New York.
Carpenter, Harry C. New York.

Carpenter, Howard F. New England.
Carpenter, J. D. Pennsylvania.
Carpenter, William T. New York.
Carson, Caryl C. New England.
Carson-Cadillac Corp. Associate.
Carter Co., Ralph B. New York, New England, Associate.
Cary, Edmund S. California.
Cary, F. Arthur. New York.
Cary, William H., Jr. Michigan.
Cary, Willis E. New England.
Casey, Albert E. New England.
Casey, John J. California.
Casey, William. Canada.
Castello, W. O. California.
Caster, Arthur. Central States.
Castro A. J., Jr. California.
Cedar Rapids, City of. Iowa.
Cederberg, C. R. Rocky Mountain.
Ceriat, Eugene. California.
Cerny, Paul J. New York.
Chain Belt Co. Associate.
Chalmers, G. H. Canada.
Chamberlain, L. H. California, Central States.
Chamberlain, Wm. T. New York.
Chamberlin, Noel S. New Jersey.
Chambersburg, Boro of. Pennsylvania.
Chambers, Cecil W. Federal.
Chamier, Albert. Michigan.
Chapman, Clarke. California.
Chapman Valve Mfg. Co. Associate.
Charlton, David. Pacific Northwest.
Chase, E. Sherman. Pennsylvania, New England, New York.
Chase, H. W. Pacific Northwest.
Cheadle, Wilford G. Central States.
Check, Stephen. New York.
Chiarolla, Frank Vito. California.
Chicago Pump Company. Associate.
Chiode, Frank L. New York.
Chisholm, Colin B. New York.
Chisholm, Henry. New England.
Christian, J. A. England (I. S. P.).
Christian, James B. New York.
Casey, City of. Central States.
Chutter, H. W. (Jourdan Concrete & Pipe Co.). California.
Cipriano, Anthony G. New York.
City Water Dept. North Carolina.
Clapp, Milton Jr. North Carolina.
Clare, H. C. Pacific Northwest.
Clark, E. S. Central States.
Clark, H. W. England (I. S. E.).
Clark, H. W. New England.
Clark, J. C. California.
Clark, John A. California.
Clark, L. K. North Dakota.
Clark, M. S. Michigan.
Clark, Robert N. New York.
Clarke, Samuel M. Central States.
Clarke, V. B. New England.
Cleary, Edward J. New Jersey.
Cleland, R. R. Pennsylvania.
Clements, G. S. England (I. S. P.)
Clements, R. C. Maryland-Delaware.
Clementi, Paul T. New York.
Cleveland, E. A. Canada.
Clifford, W. England (I. S. P.).
Clift, M. A. New York.
Clouser, L. H. Pennsylvania.
Clover, I. N. Ohio.
Clusserath, Joseph A. Central States.
Coates, John J. New York.
Cobb, Edwin B. New England.
Coberly, Carroll H. Rocky Mountain.
Cobleigh, William. California.
Coblentz, J. M. Iowa.
Coburn, S. E. New England.
Cochrane, John C. New York.
Cohn, Morris M. New York, Central States.
Colahan, J. G. South Dakota.
Colbert, David. New York.
Cole, Charles W. Central States.
Cole, E. Shaw. New York.
Coles, Louis J. New York.
Colitz, Michael J. Pennsylvania.
Collard, A. E. England (I. S. E.).
Collier, H. England (I. S. E.).
Collier, James. Ohio.
Collins, A. Preston. California.
Collins, W. D. Federal.
Collins, W. H. Canada.
Collyer, Joseph C. New York.
Combs, H. F. Central States.
Compton, C. R. California.
Comstock, Walter C. New York.
Conger, Charles C. California.
Conklin, Chester A. New York.
Connell, C. H. Texas.
Consoer, Arthur W. Central States.
Cooke, P. N. Canada.
Cook, Horace J. New England.
Cook, Lawrence H. California.
Cook, Max E. California.
Cook, Rodney E. New York.
Cooley, E. C. California.
Coombs, E. P. England (I. S. E.)
Copeland, William R. New England, New York.
Copley, Charles H. New England.
Copple, Isaac. Pennsylvania.
Corbett, Walter E. New England.
Cordell, Miss Mona. New York.
Corey, R. H. Pacific Northwest.
Cornilsen, C. K. Central States.
Corrac, Joseph. California.
Corrington, Kingsley. Central States.
Corson, B. I. New Jersey.
Corson, H. C. Michigan.
Cortelyou, H. P. California.
Corwin, Raymond C. New York.
Costello, John J. New York.
Cotterell, G. T. England (I. S. E.).
Cottrell, H. S. New York.
Cottingham, W. P. Central States.

Cotton, Harry E. Central States.
Cousineau, A. Canada.
Coventry, F. L. Central States.
Covill, R. W. England (I. S. P.).
Cowden, Burney B. Florida.
Cowell, John E. New York.
Cowles, M. W. New Jersey, New York.
Cox, C. R. New York.
Coy, Arthur H. New England.
Coy, Burgis. Rocky Mountain.
Craemer, George H. New England.
Craig, Clifford. Central States.
Craig, Robt. H. Pennsylvania.
Crane Company. Associate.
Crane, H. R. California.
Crask, Rex. Central States.
Craun, J. M. Ohio.
Crawford, H. V. New York.
Crawley, George M. Pennsylvania.
Creears, T. H. California.
Critser, W. H. Ohio.
Crohurst, Harry R. Federal.
Cromer, Lyle. California.
Cropsey, W. H. Central States.
Cuddihy, Vincent. New York.
Cullison, Eugene F. New York.
Culp, King. Pacific Northwest.
Cummings, G. J. California.
Cummins, Walter. Ohio.
Cunningham, A. C. New England.
Cunningham, H. L. Pennsylvania.
Cunningham, John J. Arizona.
Cunningham, John W. Pacific Northwest.
Curfew, L. S. California.
Currie, C. H. Iowa.
Currie, David H. California.
Currie, Frank S. California.
Cushing, Robert. Arizona.
Cushman, S. P. Central States.
Cutting, Merritt. New England.
Cyr, Rene. Canada.

D'Aleo, A. R. New York.
Daley, E. W. Arizona.
Dallavia, Louis. Central States.
Damon, Nelson A. New England.
Damon, Wayne F. New England.
Damoose, N. G. Michigan.
Daniels, F. E. Pennsylvania.
Dappert, Anselmo F. New York.
Darby, George M. New England.
Darby, W. A. Pennsylvania.
Darcey, H. J. Oklahoma.
Darling, E. H. Canada.
Darling, O. M. Central States.
Davey, H. W. California.
Davids, E. M. California.
Davidson & Fulmor. California.
Davidson, F. G. New York.
Davidson, Philip. Central States.
Davies, A. T. England (I. S. E.).
Davis, Charles A. Rocky Mountain.
Davis, Clarence A. New York.
Davis, F. R., Jr. Central States.
Davis, H. F. North Carolina.
Davis, P. D. North Carolina.
Davis, R. L. Arizona.
Davis, Walter S. New York.
Dawson, F. M. Central States, Iowa.
Dawson, Lafayette Wm. Pennsylvania.
Dawson, Norman. Central States.
Dawson, Thomas T. Pennsylvania.
Dayton, Alfred E. New York.
Day, L. A. Central States.
DeBerard, W. W. Central States.
DeBrito, F. Saturnino, Jr. New York.
Debrun, John W., Jr. Central States.
Decker, E. P. New Jersey.
Deckert, Christ. Central States.
DeGroat, Frank N. New York.
De Haas, Nicholas. New England.
DeHooghe, Bernard A. Michigan.
DeJarnette, N. M. Georgia.
De Leon, Gregorio. California.
De Leuw, C. E. Central States.
Delisle, E. A. Canada.
Deming, Harold A. New York.
De Martini, Frank E. California.
DeMunn, E. M. New York.
Denise, Wm. D. New York.
Denison, W. R. Arizona.
Dennis, Carl. Michigan.
Denver Public Library, Rocky Mountain.
DePoy, A. G. Central States.
Derby, Ray L. California.
Deslauriers, A. J. Canada.
Desmarais, R. J. Canada.
Des Moines, City of. Iowa.
Deuchler, Walter E. Central States.
Devendorf, Earl. New York.
DeWolf, A. B. Florida.
Diamond Alkali Co. Central States.
Dick, Robert. Central States.
Dickman, Dorian H. Michigan.
Dickson, D. B. Texas.
Dickson, W. K. North Carolina.
Diefendorf, Fred G. Pennsylvania.
Dietrich, Paul. Central States.
Dietz, Jess C. Central States.
Dietz, John. Central States.
Dion, Clarence K. New England.
Disario, G. M. New England.
Division of San. Eng., Ill. Dept. of Pub. Health. Central States.
Dixon, G. Gale. Ohio.
Dixon, R. M. Texas.
Doane, Ercell J. Michigan.
Doane, Norman D. North Carolina.
Dobson, William T. New York.
Dobstaff, Robert, Jr. New York.
Dobstaff, Robert W., Sr. New York.
Dodge, H. P. Michigan.
Dodson, Roy E., Jr. Pacific Northwest.
Doerr, Earl. South Dakota.
Doman, Joseph. New York.
Domke, L. C. Central States.

Dommes, Sid F., Jr. California.
Domogalla, Bernhard. Central States.
Donaldson, Wellington. New York.
Donnell, Geo. M. Rocky Mountain.
Donnini, Frank L. New England.
Donohue, Jerry. Central States.
Dopmeyer, A. L. Federal.
Dorr Co., Inc. Rocky Mountain, Associate.
Dorr, Fred. Michigan.
Doubleday, Arnold R. Central States.
Doughan, Lee D., Jr. Canada.
Dougherty, James E., Jr. New York.
Dougherty, Lawrence J. New York.
Douglass, R. M. Pennsylvania.
Dowd, Ira. Michigan.
Downer, Wm. J. Central States.
Downes, John R. New York.
Dow Chemical Co. Associate.
Doyle, Thomas J. Michigan.
Drake, James A. Central States.
Dreier, D. E. Central States.
Dresselt, Edward L. New York.
Drew, Leland F. New York.
Drexel, Frederick. New York.
Driscoll, Timothy J. New York.
Drummond, A. H. England (I. S. P.)
Duane, John M. New York.
Dudley, Charles E. Central States.
Dudley, Richard E. New England.
Duerr, A. Ohio.
Duffey, R. K. Arizona.
Dufficy, Frank J. New York.
Duffy, John J. New York.
DuMounte, Robert. Ohio.
Duncan, Roland F. California.
Dundas, Wm. A. Central States.
Dunstan, Gilbert H. California.
Dunstan, James. Pacific Northwest.
Durand, Edwin M. Michigan.
Durham Water Dept. North Carolina.
Durrant, W. K. F. Canada.
Duvall, Arndt J. Central States.
Duxbury, S. England (I. S. P.).
Duy, C. Central States.
Dye, Elmer E. Iowa.
Dyckman, Warren W. New York.
Dyer, Samuel. New England.

Eager, Vernon. New York.
Early, Fred J., Jr. California.
Easdale, W. C. England (I. S. E.).
Eastburn, W. H. Pennsylvania.
Eastman, T. F. California.
Ebert, R. E. North Carolina.
Ecusta Paper Corp. North Carolina.
Eddy, Harrison P., Jr. New England.
Edge, L. C. Georgia.
Edgecomb, G. O. Michigan.
Edgehoffer, Albert. New York.
Edgerley, Edward. Pennsylvania.
Edmondson, J. H. England (I. S. P.).
Edwards, Gail P. New England, New York.
Edwards, Stacy W. Texas.
Edwards, William L. New York.
Egan, J. H. California.
Eggert, E. G. Georgia.
Eglof, Warren K. New York.
Ehle, Virgil. New York.
Ehler, John A. New York.
Ehlers, Ralph B. Michigan.
Eich, Henry F. New York.
Electro Rust-Proofing Co. Associate.
Elias, George A. Pennsylvania.
Eliassen, Rolf. New York.
Ellinger, Morris. California.
Elliot, S. F. Rocky Mountain.
Ellis, Albert. Central States.
Ellis, Norman T. Michigan.
Ellms, J. W. Ohio.
Ellsworth, Samuel M. New England.
Elnor, George E. Canada.
Eldridge, E. F. Michigan.
Eldson, G. D. England (I. S. P.).
Ely, E. H. England (I. S. E.).
Emerson, C. A. Pennsylvania.
Emigh, William C. Pennsylvania.
Engel, John H., Jr. Michigan.
Engineering News-Record. Associate.
English, C. C. Ohio.
English, James A. North Carolina.
Enloe, V. P. Georgia.
Enoch Pratt Free Library. Maryland-Delaware.
Enslow, L. H. New York, New England.
Epler, J. E. Central States.
Epstein, Harold. New York.
Erdle, Gardner F. New York.
Erdwurm, Emil. New York.
Erickson, Carl V. Central States.
Erickson, Una H. California.
Erzen, C. A. Central States.
Etheridge, W. England (I. S. P.).
Ettinger, M. B. Federal.
Eustance, Arthur W. New York.
Eustance, Harry W. New York.
Evans, David A. Pennsylvania, New York.
Evans, F. M. New Jersey.
Evans, H. W. Central States.
Evans, S. C. England (I. S. P.).
Evans, Wm. J. North Carolina.
Evansky, Frank J. New York.
Everson, Mfg. Co. Central States.
Everts, C. M., Jr. Pacific Northwest.
Everts, W. S. California.

Faber, Harry A. New York, Pennsylvania.
Faccinia, Frank. California.
Fah, C. Thum. England (I. S. E.).
Fairbanks, E. G. California.
Fairfield State Hospital. New England.
Fair, Gordon M. New England, New York.
Fales, Almon L. New England, Pennsylvania.
Falls, O. M. Canada.
Fargo Engineering Co. Michigan.
Farmer, J. E. England (I. S. E.).
Farnsworth, George L., Jr. Central States.

Farrant, James. New Jersey.
Farrar, J. H. California.
Farrell, Eugene J. New York.
Farrell, Michael. New York.
Fassnacht, George G. New York.
Faulkner, T. G. England (I. S. E.).
Feltz, Fred C. Central States.
Fenger, J. W. New York.
Fenton, John V. New York.
Ferebee, James L. Central States.
Ferguson, Gerald. New Jersey.
Ferguson, G. H. Canada.
Ferguson, W. S. Arizona.
Fernandez, John U. New York.
Ferris, James E. New England.
Fidler, G. C. England (I. S. P.).
Field, W. T. New York.
Filkins, D. A. Michigan.
Finch, Lewis, Central States.
Finch, J. England (I. S. P.).
Finck, G. E. Maryland-Delaware.
Findlay, Arthur. New York.
Firth, Elmer W. New York.
Fischer, Anthony J. New York.
Fischer, Philip C. New York.
Fishbeck, Kenneth. Michigan.
Fisher, Homer C. Central States.
Fisher, Lawrence M. Federal.
Fitch, T. A. California.
Fitzgerald, J. A. New York.
Fitzgerald, J. E., Jr. New England.
Fitzsimons, Richard H. New York.
Fiveash, Charles E. Florida.
Five, Helge. New York.
Fleet, Gerald A. New York.
Fleming, M. C. Pennsylvania.
Fleming, Paul V. New England.
Flexible Sewer-Rod Equipt. Co. Associate.
Flood, Frank L. New England.
Flower, G. E. Ohio.
Flowers, E. England (I. S. P.).
Foley, William M. New York.
Follett, John B. New York.
Fong, Paul. California.
Fontenelli, Louis. New Jersey.
Foote, Kenneth E. New England.
Forbes, Albert F. New York.
Ford, Curry E. Ohio.
Ford, Robert. Central States.
Foreman, Merle S. California.
Forsbeck, C. D. Pacific Northwest.
Forsberg, Ole. Central States.
Forster, M. H. New York.
Fort, Edwin J. New York.
Fortenbaugh, J. Warren. New York.
Forton, R. G. Michigan.
Foster, Herbert B., Jr. California.
Foster, Norman. Pennsylvania.
Foster, William Floyd. California.
Foth, Herbert I. Central States.
Fowler, G. England (I. S. P.).
Fowler, G. J. England (I. S. P.).
Fowler, H. D. Pacific Northwest.
Foxboro Company. Associate.
Francis, Geo. W. Michigan.
Francis, J. A. California.
Francis Hankin & Co., Ltd. Canada.
Franklin, W. M. North Carolina.
Franks, John T. Rocky Mountain.
Franzozo, Anthony. New Jersey.
Fraser, Charles E. Canada.
Fraschina, Keeno. California.
Fraser, Francis Ernest. England (I. S. E.)
Fraters, E. W. California.
Frazier, Leonard H. New York.
Frazier, R. W. Central States.
Fredson, Anthony. Central States.
Freeborn, W. F. England (I. S. P.).
Freeburn, H. M. Pennsylvania.
Freeman, A. B. Federal.
French, R. Del. Canada.
Freund, J. P. Pennsylvania.
Frick, A. L., Jr. California.
Frickstad, Walter N. California.
Friel, F. S. Pennsylvania.
Frith, Gilbert R. Georgia.
Froehde, F. C. California.
Fuchs, Abraham W. Federal.
Fuhrman, Ralph E. Federal.
Fuller, N. M. New York.
Fulmer, F. B. California.
Fulmer, Frank E. Central States.
Fulton, Noel W. Michigan.
Funk, John B. Maryland-Delaware.

Gabriel, Eugene L. New York.
Gadomski, Albert J. New Jersey.
Gail, A. L. Central States.
Ganschow, Elmer. New York.
Gard, Charles M. New York.
Gardiner, William E. Canada.
Gardner, George W. New York.
Gardner, R. T. California.
Garland, Chesley F. Maryland-Delaware, Florida.
Garner, J. H. England (I. S. P.).
Garrett, R. W. Canada.
Garrison, Peter L. Central States.
Garthe, E. C. Federal.
Gates, Justin F. New York.
Gauntt, W. C. Texas.
Gavett, Weston. New York.
Gearhart, John C. Pacific Northwest.
Gearhart, J. N. Pacific Northwest.
Gehm, Harry Willard. New Jersey.
Gelbke, Arthur W. New York.
Gelder, R. W. Rocky Mountain.
Gellon, Edmundo R. Argentine.
Genter, Albert L. Maryland-Delaware.
Gerard, F. A. Central States.
Gerdel, W. E. Ohio.
Gerecke, Edward R. New York.
Gere, William S. New York.
German, H. L. Kansas.
Germond, Earl. New York.
Geyer, John C. Maryland-Delaware.

Gibbing, Frank B. Michigan.
Gibbons, M. M. New Jersey.
Gibbs, R. C. England (I. S. P.).
Gibeau, H. A. Canada.
Gidley, H. K. Pennsylvania.
Giesey, J. K. Central States.
Gietz, Carlos E. Argentine.
Gifford, J. B. Central States.
Gilbert, A. J. Arizona.
Gilbert, J. J. Pennsylvania.
Gilbert, Joseph J. New England.
Gilbertson, W. E. North Dakota.
Gilcreas, F. Wellington. New York.
Gilcrest, R. V. Central States.
Giles, J. Henry L. New England.
Gilkey, A. E. California.
Gill, A. F. Canada.
Gill, J. Francis. New York.
Gill, Paul. Pennsylvania.
Gillard, J. E. England (I. S. P.).
Gillespie, C. G. California.
Gillespie, Wylie W. Florida.
Gillet, R. T. England (I. S. E.).
Gilman, Floyd. New York.
Gilman, N. A. Pacific Northwest.
Ginsberg, S. D. Central States.
Gisborne, Frank R. New England.
Glace, I. M. New York, Pennsylvania.
Glace, I. M., Jr. Pennsylvania.
Gladding, Charles. California.
Gladue, Donat J. New England.
Glamorgan Pipe & Foundry Co. Associate.
Glunz, Norman E. New York.
Glynn, William J. New York.
Goeke, Roscoe H. Pennsylvania.
Goff, James S. New England.
Goff, William A. Pennsylvania.
Goldenberg, Charles N. Rocky Mountain.
Goldthorpe, H. H. England (I. S. P.).
Golly, M. R. Central States.
Gooch, E. W. Pacific Northwest.
Goodenough, Frank H. New York.
Goodman, Arnold H. Central States.
Goodrich, Fletcher. Michigan.
Goodridge, Harry. California.
Goodwin, S. E. Canada.
Gordon, Arthur. Central States.
Gordon, J. B. Federal.
Gorman, Richard C., Jr. New York.
Gorman, William A. Pennsylvania.
Gotaas, Harold B. North Carolina.
Goudey, R. F. California.
Gould, Richard H. New York.
Grabbe Construction Co., H. A. Central States.
Grabowski, John J. Pennsylvania.
Gracenin, Sylvester. Pennsylvania.
Grady, Robert H. North Carolina.
Graemiger, Joseph A. New England.
Graham, Edward J. New York.
Graham, James E. Michigan.
Grand Forks, City of. North Dakota.
Grand Junction, City of. Rocky Mountain.
Granger, George M. Michigan.
Gran, Dr. John E. Georgia.
Grant, A. J. California.
Grantham, G. R. Central States.
Gray, D. M. Ohio.
Gray, Harold F. California.
Greek, Edward B. Central States.
Greeley, Richard F. New England.
Greeley, Samuel A. Central States.
Greeley & Hansen. Michigan.
Green, Carl E. Pacific Northwest.
Green, Herbert. New England.
Green, Howard R. Iowa.
Greendale, Village of. Central States.
Greenleaf, John W., Jr. New England.
Greenlee, J. L. North Carolina.
Greenwich Sewer Commission. New England.
Green, R. A. Michigan.
Gregory, L. L. England (I. S. E.).
Gregory Sanitary and Municipal Reference Library. California.
Gregory, Robert W. North Carolina.
Gregory, Ted R. California.
Greig, John M. New York.
Grelick, David. New York.
Grieff, Victor C. New York.
Griffin, A. E. New Jersey.
Griffen, F. T. New York.
Griffin, Guy E. New England.
Grinnell Co., Inc. North Carolina.
Groen, Michael A. Michigan.
Gross, Carl D. Central States.
Gross, Dwight D. Rocky Mountain.
Grossart, L. J. H. Pennsylvania.
Grosshans, Edward W. Central States.
Grover, Robert H. New York.
Growdon, Howard C. Ohio.
Gruendler Crusher & Pulverizer Co. Associate.
Grunsky, Eugene L. California.
Gruss, A. W. California.
Guastapalglia, S. Alberto. Argentine.
Gulden, H. B. Pennsylvania.
Gunderson, G. J. South Dakota.
Gustafson, Ivar. Michigan.
Gwin, Thomas. California.

Haberer, John C. New York.
Habermehl, C. A. Michigan.
Haddock, Fred R. Pennsylvania.
Haemmerlein, Victor E. New York.
Hager, Fred. Central States.
Hagerty, L. T. Ohio.
Hagestad, Herman T. Central States.
Hahl, Russell. New York.
Hale, Arnold H. New York.
Hale, Edward W. New York.
Halff, Albert H. Texas.
Hall, Frank H. New York.
Hall, Fred B. New York.
Hall, G. Albro. Ohio.
Hall, Harry R. Maryland.
Hall, Hilliard B. Arizona.
Hall, M. G. Iowa.

Hall, W. H. North Carolina.
Hallden, John T. Central States.
Hallock, Emerson C. New York.
Halm, Ernest W. New York.
Halpin, John. New York.
Halstead, Douglas M. New York.
Halverson, Gerry. Central States.
Hambleton, F. T. England (I. S. P.).
Hamilton, R. F. Pacific Northwest.
Hamlin, C. H. England (I. S. P.).
Hamm, William C. New York.
Hammond Board of Sanitary Commissioners. Central States.
Hammond, F. D. Central States.
Hammond, F. G. New York.
Hammond, George R. Pacific Northwest.
Handley, L. W. Georgia.
Hanenberg, A. L. Canada.
Haney, Joseph E. Central States.
Haney, Paul. Kansas.
Hanke, Carl C. Central States.
Hanrath, William J. New England.
Hansell, Wm. A. Georgia.
Hansen, Paul. Central States.
Hansford, Albert E. Canada.
Hanson, George I. New England.
Hanson, H. G. North Dakota.
Hapgood, E. P. California.
Hardenbergh, W. A. New York.
Harding, J. C. New York.
Hardman, Thomas T. Central States.
Hardy, W. R. Texas.
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.
Harr, Neal. Kansas.
Harrington, J. H. California.
Harrison, Louis B. Michigan.
Harris, George C. Central States.
Harris, J. F. Pennsylvania.
Harris, J. England (I. S. P.).
Harris, R. C. Canada.
Harris, T. R. Central States.
Harrison, Edward F. New York.
Harroun, F. E. Ohio.
Harroun, Norman W. Pacific Northwest.
Hartman, B. J. Central States.
Hartman, Byron K. Central States.
Hartom, R. A. New York.
Hart, Charles G. New York.
Hart, W. B. Pennsylvania.
Hartung, N. E. Central States.
Hartzell, E. F. Pennsylvania.
Harvey, Carl. New York.
Harvey, J. R. Pennsylvania.
Haseltine, T. R. Pennsylvania.
Hassfurther, William A. Central States.
Haskins, Chas. A. Missouri.
Hatch, B. F. Ohio.
Hatfield, W. D. Central States.
Hauck, Charles F. Ohio.
Hauer, Gerald. Michigan, Central States.
Havens, William L. Ohio.
Hawken, Dalton. Michigan.
Hawley, Arthur A. New York.
Haworth, W. D. England (I. S. E.).
Haydock, Chas. Pennsylvania.
Hayes, John A. New York.
Hayler, Geo. R. California.
Hayward, Homer. Michigan.
Hay, Julian. Central States.
Hay, T. T. Central States.
Hazen, Richard. New York.
Heaslit, Walter. Rocky Mountain.
Hechmer, C. A. Maryland-Delaware.
Hedgepeth, L. L. Pennsylvania, New York.
Hedges, Horace P. New York.
Heeg, H. H. Michigan.
Heffelfinger, D. D. Ohio.
Heger, Harold. Central States.
Heider, Robert W. Central States.
Heinemann, B. New Jersey.
Heiner, Roy. Pacific Northwest.
Heinrikson, J. J. Kansas.
Heiple, Loren R. Central States.
Heisig, H. M. Central States.
Heiss, Edward. Pacific Northwest.
Helland, H. R. F. Texas.
Heller, William. Central States.
Henderlite, J. H. North Carolina.
Henderson, Chas. F. New York.
Hendon, H. H. New York.
Hendrie & Bolthoff Mfg. and Supply Co. Rocky Mountain.
Henel, Wm. F. New York.
Henley, M. E. Georgia.
Henning, Clinton. California.
Henn, Donald E. Central States.
Henry, Augustine. New York.
Herberger, Arthur Henry. New York.
Herrick, T. L. Central States.
Herr, H. N. Pennsylvania.
Hersig, S. B. Central States.
Hervy, Elmer. Michigan.
Hesford, L. England (I. S. E.).
Hess, Daniel J., Jr. Pennsylvania.
Hess, Joseph C., Jr. Pennsylvania.
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.
Hickey, William. New York.
Hicks, Geo. W. Pacific Northwest.
Hicks, R. England (I. S. P.).
Higgins, William J. New York.
Highberger, W. W. New York.
Hiller, Paul W. New England.
Hill, Frank C. Rocky Mountain.
Hill, G. Everett. New England, New York.
Hill, K. V. Central States.
Hill, Milton T. New York.

Hill, R. F., Jr. North Carolina.
Hill, Theo. C. Pennsylvania.
Hill, W. R. Pacific Northwest.
Hilton, Elton M. California.
Hinkle, Ed. Kansas.
Hircock, Chas. W. Arizona.
Hirschel, Leslie. New York.
Hitchcock, Simon E. Canada.
Hitchner, A. H. California.
Hoad, W. C. Michigan.
Hoag, C. C. New York.
Hoak, Richard D. Pennsylvania.
Hobson, N. C. Canada.
Hodge, W. W. Pennsylvania.
Hodges, H. E. W. England (I. S. E.).
Hodgson, E. England (I. S. P.).
Hodgson, H. J. N. England (I. S. P.).
Hoeflich, G. C. Pennsylvania.
Hoefling, Wm. L. New York.
Hoey, John B. New York.
Hoff, Clarence W. Pennsylvania.
Hoffert, J. R. Pennsylvania.
Hogan, James W. T. New York.
Hogan, William J. New York.
Hoganson, Lester O. Central States.
Holden, E. G. Rocky Mountain.
Holderby, J. M. Central States.
Holderman, John S. Central States.
Holland, Frank H. New York.
Holloway, Frank M. New York.
Holmes, Glenn D. New York.
Holmes, Harry E. New England.
Holmgren, Richard F. New England.
Holmquist, Chas. A. New York.
Holroyd, A. England (I. S. E.).
Holst, J. S. South Dakota.
Holter, A. L. Pacific Northwest.
Holtkamp, Leo. Iowa.
Holway, O. C. Central States.
Homelite Corporation. Associate.
Hommon, H. B. Federal, California.
Honens, R. W. Central States.
Honigman, Elkono G. New York.
Hoot, Ralph A. Central States.
Hoover, C. B. Ohio.
Hoover, Charles R. New England.
Hopkins, L. S. R. New York.
Hopkins, Omar C. Federal.
Hopper, Allen O. New York.
Horgan, John J. New York.
Horn, A. John. New York.
Horne, Ralph W. New England.
Horton, F. C. California.
Horton, Robert K. North Carolina.
Horvath, George. New York.
Hoskins, J. K. Federal.
Hoskins, Nandy. England (I. S. E.).
Hoskinson, Carl M. California.
Hotchkiss, H. T., Jr. New York.
Hoth, Fred. Central States.
Houlihan, J. E. England (I. S. P.).
Houser, C. S. Ohio.
Houser, George C. New England.
Houston, W. J. Georgia.
Howard, C. M. Pacific Northwest.
Howard, N. J. Canada.
Howard, P. F. New England.
Howarth, J. P. England (I. S. P.).
Howe, Ben V. Rocky Mountain.
Howe, J. P. Canada.
Howell, Eugene. Rocky Mountain.
Howland, W. E. Central States.
Howson, J. T. New York.
Howson, L. R. Central States.
Hoyle, W. H. England (I. S. P.).
Hoy, J. R. Georgia, Florida.
Hromada, Frank M. Central States.
Hubbard, Winfred D. New York.
Hubbell, George. Michigan.
Hubel, J. H. Canada.
Huber, Harold J. New York.
Hudson, LaVerne D. Central States.
Huebner, Ludwig. California.
Hughes, W. P. Pacific Northwest.
Hulak, S. M. New York.
Hults, William S., Jr. New York.
Humboldt, City of. Iowa.
Humphries, J. T. Georgia.
Hundt, Edward L. Michigan.
Hunter, A. England (I. S. P.).
Hunter, Harry. Central States.
Hunt, L. W. Central States.
Hupp, John E., Jr. Central States.
Hurd, Charles H. Central States.
Hurd, Edwin C. Central States.
Hurley, J. England (I. S. P.).
Hurst, D. H. Georgia.
Hurst, William C. New York.
Hurwitz, Emanuel. Central States.
Hussong, Ernest W. Central States.
Hustead, Clarence P. California.
Hutcheson, H. D. New York.
Hutchins, Will A. Central States.
Huth, Norman A. California.
Hyde, Charles Gilman. California.

Illig, Louis. New York.
Imbt, M. Russell. Pennsylvania.
Indiana State Board of Health. Central States.
Ingols, Robert. New Jersey.
Ingram, Fred R. California.
Ingram, Wm. T. California.
International Filter Co. Associate, Central States.
Irwin, G. M. Pacific Northwest.
Iscol, George. New York.

Jack, D. Canada.
Jack, Grant R. Canada.
Jacka, S. C. Michigan.
Jacklin, T. W. Canada.
Jackson, James A. Central States.
Jackson, J. Frederick. New England.
Jackson, R. B. Michigan.
Jackson, T. L. Michigan.

Jacobs, L. L. Georgia.
Jacobson, John. California.
James, Norman S. Florida.
Jarlinski, Thaddeus T. New York.
Jarrett, J. M. North Carolina.
Jeffrey, H. H. California.
Jeffrey Mfg. Co. Associate.
Jellema, John F. Michigan.
Jenckes, J. Franklin, Jr. New England.
Jenks, Glen. Rocky Mountain.
Jenks, Harry N. California.
Jennings, A. E. Canada.
Jennings, L. R. Michigan.
Jensen, Emil C. Pacific Northwest.
Jepson, C. England (I. S. P.).
Jerge, Ray. New York.
Jeup, Bernard H. Central States.
Jewell, H. W. California.
Johns-Manville Corp. Associate.
Johnson, Arthur N. Central States.
Johnson, Clement. New York.
Johnson, E. M. North Carolina.
Johnson, Earle P. Pennsylvania.
Johnson, Eskil C. New England.
Johnson, Floyd E. Central States.
Johnson, F. M. North Carolina.
Johnson, Harold. New Jersey.
Johnson, H. B. Pennsylvania.
Johnson, Herbert O. New York.
Johnson, John W. New York.
Johnson, L. J. Central States.
Johnson, Lloyd M. Central States.
Johnson, R. J. Central States.
Johnson, Theodore S. North Carolina.
Johnson, Verner C. California.
Johnston, Roy N. Kansas.
Jonas, Milton R. Central States.
Jones, C. B. O. England (I. S. P.).
Jones, Daniel. New York.
Jones, E. M. New York, Pennsylvania.
Jones, Frank P. Michigan.
Jones, Frank Woodbury. Ohio, Pennsylvania.
Jones & Company, H. P. Ohio.
Jones, S. Leary. Federal.
Jones, T. A. Georgia.
Jones, Wayland. California.
Jordan, Edward C. New England.
Jordan, Harry B. New York.
Jorgensen, Homer W. California.
Joy, C. Fred, Jr. New England.

Kachmar, John F. Federal.
Kachorsky, M. S. New Jersey.
Kafka, John. Central States.
Kahn, J. M. Georgia.
Kaler, P. E. Kansas.
Kalste, Arthur. Central States.
Kammerling, Lane. Michigan.
Kampas, James. New York.
Kane, James I. Central States.
Kappe, S. E. Pennsylvania, New York.
Karalekas, Peter C. New England.
Karsa, William J. New York.
Kassay, Albert E. New York.
Kass, Nathan I. New York.
Kearney, E. W. North Carolina.
Kearney, John J. Central States.
Keatley, C. R. Pennsylvania.
Keefer, C. E. Maryland-Delaware.
Keefer, R. K. Pennsylvania.
Keeler, J. Harold. New York.
Kehoe, Daniel J. New York.
Kehr, Robert W. Federal.
Kehr, Wm. Q. Missouri.
Keirn, K. A. New York.
Kelleher, Joseph A. New York.
Keller, Jacob. New York.
Keller, Lyndon M. New York.
Keller, Perry. Kansas.
Kelley, R. E. Michigan.
Kellogg, Clarence E. New York.
Kellogg, James W. North Carolina.
Kelly, Clarence. New York.
Kelly, Earl M. California.
Keller, S. K. Florida.
Kelsey, Walter. Pennsylvania, New York.
Kempkey, A. California.
Kemp, Harold A. New York.
Kenna, Edward V. New York.
Kennedy, C. C. California.
Kennedy, D. R. California.
Kennedy, R. R. California.
Kennedy, S. J. Central States.
Kennedy, William. New York.
Kenney, Norman D. Maryland-Delaware.
Kepner, Dana E. Rocky Mountain.
Kershaw, Arnold. England (I. S. P.).
Kessler, Lewis H. Central States.
Ketcham, Joseph M. New York.
Kewer, J. F. Central States.
Kibler, Harry J. New York.
Kiker, John E., Jr. New York.
Kilcawley, Edw. J. New York.
Killam, E. T. New Jersey.
Kimball, Jack H. California.
Kimberly, A. E. Ohio.
Kimler, Alexander. New York.
King, Henry R. Central States.
King, Richard. Central States.
King, William B. North Carolina.
Kingsbury, Harold N. Central States.
Kingston, Paul S. Central States.
Kin, Stephen R. New York.
Kinney, E. F. Central States.
Kinney, J. B. Canada.
Kinsel, Harry L. Pennsylvania.
Kinsman, Frederick. California.
Kirchoffer, W. G. Central States.
Kirsner, Charles. New York.
Kivari, A. M. California.
Kivell, Wayne A. New York.
Kjellberg, G. California.
Klang, Marvin F. Michigan.
Klann, Martin C. Michigan.
Klegerman, M. H. New York.
Klein, L. England (I. S. P.).

Kleiser, Paul J. Central States.
Klemme, Wm. W. New York.
Klinck, Frank. New York.
Kline, H. S. Ohio.
Klippel, Floyd. Iowa.
Klippel, R. M. Michigan.
Knapp, Glenn. Michigan.
Knapp, H. A. Georgia.
Knechtges, O. Central States.
Knez, Cosmo M. New York.
Knight, Ray R. Canada.
Knittel, E. A. Pacific Northwest.
Knoedler, H. A. California.
Knowlton, Kenneth F. New England.
Knowlton, W. T. California.
Knox, Stuart K. New York.
Knox, W. H. Ohio.
Koch, Philip L. Central States.
Kochin, Milton. Pennsylvania.
Kochtitzky, O. W. Federal.
Koebig & Koebig. California.
Kolb, Fred W. California.
Koon, Ray E. Pacific Northwest.
Koplowitz, Sol. New York.
Korfmacher, John A. Central States.
Kozma, Albert B. New York.
Kramer, Harry P. Central States.
Kratz, Herman. Maryland-Delaware.
Krause, Ray. California.
Kraus, L. S. Central States.
Krell, A. J. New York.
Kremer, Robert W. Pennsylvania.
Kressly, Paul E. California.
Kretschmar, G. G. Pacific Northwest.
Kreutter, Clarence. New York.
Kriegel, Paul O. New York.
Krohn, William. California.
Kronbach, Allan. Michigan.
Krumm, Harry J. Pennsylvania.
Krunick, M. D. Ohio.
Kuhl, F. A. Central States.
Kuhner, Frank G. Central States.
Kulberg, Abraham J. New York.
Kulin, Harvey J. Central States.
Kunowski, Peter. New York.
Kunsch, Walter. New England.
Kunze, Albert T. Michigan.
Kupper, C. J. New Jersey.
Kurtz, Harold I. Pennsylvania.
Kuykendall, M. L. Texas.
Kyte, W. O. California.

La Croix, Louis. New England.
Lackey, James B. Federal.
Lacy, Ilbert O. New York.
Ladlow, John. Arizona.
Lafreniere, Theo. J. Canada.
Lakeside Engineering Corp. Central States, Associate.
Lamb, Clarence F. New England.
Lamb, Miles. Central States.
Lamb, P. England (I. S. P.).
Lambert, Carl F. Florida.
Lambert, Francis J. New York.
Lamoureux, Vincent B. Federal.
Lamson, B. F. Canada.
Lang, Lloyd. Central States.
Lang, William H. Pennsylvania.
Langdon, L. E. Central States.
Langdon, Paul E. Central States.
Langelier, W. F. California.
Langford, Leonard L. New York, Pennsylvania, New England.
Langton, Bernard. New Jersey.
Langwell, Louie. Central States.
Lannon, William. New England.
Lanphear, Roy S. New England.
Larkin, Donald G. New York.
Larkin, W. H. New York.
Larsen, Stanley J. Central States.
Larson, C. C. Central States.
Larson, John A. California.
Larson, Keith D. Central States.
Larson, L. L. Central States.
Lassiter, L. I. North Carolina.
Lauer, Charles N. Pennsylvania.
Laughlin, William G. New York.
Lauster, K. C. North Dakota.
Lautz, Harold L. Central States.
LaValley, Edward C. New York.
Laverty, Francis J. New York.
Lawlor, Jerome N. New York.
Lawlor, J. P. Iowa.
Lawrence, John. New York.
Lawrence, William H. New York.
Lawson, A. M. England (I. S. E.).
Lawson, W. S. Canada.
Lea, J. E. England (I. S. P.).
Lea, Wm. L. Central States.
Lea, W. S. Canada.
Leach, Walter L. Ohio.
Leahy, S. James. New York, Pennsylvania.
Leaver, Charles H. Canada.
Leaver, R. E., Jr. Pacific Northwest.
Lebetkin, George. New England.
LeClerc, Arthur B. North Carolina.
Ledford, George L. New York.
Ledwith, James J. New York.
Lee, Charles H. California.
Lee, David B. Florida.
Lee, Oliver. Central States.
Leemaster, J. F. Michigan.
LeFebvre, Fabian J. New York.
Leggett, John T. California.
Leh, Willard. Pennsylvania.
Lehmann, Arthur F. New Jersey.
Lehmker, William. Central States.
Lehr, Eugene L. New England.
Leigh, H. G. England (I. S. P.)
Leimbach, Harry. Pennsylvania.
Leist, Ervin F. Ohio.
Leitch, John C. Georgia.
Leland, Benn J. Central States.
Leland, Raymond I. Central States.
Lendall, Harry N. New Jersey.
Lenderink, Andrew. Michigan.

Lenert, Louva G. Georgia.
Lentfoehr, Charles E. Central States.
Leonard, W. V. Pacific Northwest.
Leonhard, Harold M. Michigan.
Lesher, Carl. Ohio, Pennsylvania.
Lesher, C. E. Michigan.
Lessig, D. H. Central States.
LeVan, J. H. Federal.
Levine, Max. Iowa.
Levy, Harry W. New York.
Lewis, John V. New York.
Lewis, R. K. Central States.
Ley, Charles H. Canada.
Liddle, E. G. Michigan.
Lieber, Maxim. New York.
Lind, A. Carlton. Central States.
Linders, Edward. Federal.
Lindsten, H. C. North Dakota.
Link-Belt Company. Central States, Associate, Pennsylvania, New York.
Linsley, Scott E. Central States.
Lippelt, Hans B. New York.
Littmann, M. L. New Jersey.
Lock, Daniel. New York.
Locke Joint Pipe Co. Rocky Mountain, Associate.
Locke, Edward A. New England.
Lockett, W. T. England (I. S. P.).
Loelkes, George L. Missouri.
Lonergan, Richard P. California.
Long, Frank V. California.
Long, George S. Pennsylvania.
Long, H. M., Limited. Canada.
Long, H. Maynard. Central States.
Long, James C. New Jersey.
Loomis, Harry E. New York.
Los Angeles Public Library. California
Lose, Charles, Jr. New York.
Lose, Charles, III. New York.
Losee, James R. New York.
Louis, Leo. Central States.
Lovell, M. L. North Dakota.
Lovell, Theodore R. Central States.
Lovett, M. England (I. S. P.).
Lowe, Thomas M. Georgia.
Lowe, Walter M. New York.
Lower, J. R. Ohio.
Lowther, Burton. California.
Lozier, William S. New York.
Lubow, Louis A. North Carolina.
Lubratovich, M. D. Central States.
Ludlow Valve Mfg. Co. Associate.
Ludwig, Harvey F. California.
Ludwig, Russell G. California.
Lueck, Bernard F. Central States.
Luff, Reginald. Pennsylvania.
Luippold, G. T. California.
Lumb, C. England (I. S. P.).
Lund, Ralph F. California.
Lusk, Charles W. New York.
Lustig, Joseph. Central States.
Luther, L. L. New York.
Luther, Robert W. North Carolina.
Luton, Max. Rocky Mountain.
Lutz, Howland C. Pennsylvania.
Lynchburg Foundry Co. Associate.
Lynch, Daniel E., Jr. New York.
Lynch, James T. New York.
Lyon, A. S. North Carolina.
Lyons, William. New York.

McAdoo & Allen Welting Co. Pennsylvania.
McAfee, H. D. Texas.
McAllister, Paul J. Pennsylvania.
McAllister, R. B. Iowa.
McAnlis, Chauncey R. Central States.
McArthur, Franklin, Canada.
McBride, J. L. California.
McCall, R. G. Central States.
McCallum, G. E. Federal.
McCannel, D. A. R. Canada.
McCarthy, J. J. Central States.
McCarthy, Justin J. New York.
McCleary, E. L. Pacific Northwest.
McClintock, H. C. Rocky Mountain.
McClenahan, W. J. Central States.
McClure, Ernest. Central States.
McCoy, M. H. Central States.
McCrae, K. C. England (I. S. E.).
McDill, Bruce M. Ohio.
McDonald, John. New England.
McDonald, Michael D. New York.
McDonald, N. G. Canada.
McDonald, Roland G. New York.
McDonnell, George H. New York.
McDuell, John W. California.
McFarlane, Walter D. Michigan.
McGough, James P. Pennsylvania.
McGrath, C. P. Michigan.
McGuire, C. D. Ohio.
McGuire, M. H. Pacific Northwest.
McHugh, Basil. Pacific Northwest.
McIlvaine, William D. Central States.
McInerney, Gerald J. New York.
McIntyre, F. J. Ohio.
McIntyre, John C. Central States.
McKay, R. Donald. Canada.
McKee, Frank J. Central States.
McKee, Jack E. New England.
McKeen, William H. California.
McKeeman, Edwin C. New York.
McKenna, Harold R. Michigan.
McKinlay, Daniel. California.
McLaughlin, Carroll W. New York.
McLaughlin, John. New Jersey.
McLean, R. F. Pacific Northwest.
McMahon, Walter A. New England.
McManamna, T. L. Canada.
McMenamin, C. B. New Jersey.
McMillan, Donald C. California.
McMorrow, Bernard J. California.
McNamara, W. P. Pacific Northwest.
McNamee, Paul D. Federal.
McNeal, Leonard. Ohio.
McNiece, L. G. Canada.
McPhail, James L. New York.

McWane Cast Iron Pipe Co. Associate.
McWilliams, D. B. Canada.
Macabee, Lloyd C. California.
Macauley, J. W. New York.
MacCallum, C. New York.
MacCrea, J. M. New York.
MacDonald, G. A. Canada.
MacDonald, J. C. Central States.
MacDowell, R. F. Ohio.
McFaul, W. L. Canada.
MacKenzie, C. J. Canada.
MacKenzie, Vernon G. Federal.
MacLachlan, Angus. Ohio.
MacLean, J. D. Canada.
MacLeod, Myron. New England.
MacMurray, L. C. Maryland-Delaware.
McLean, Clement. New York.
Mabbs, John W. Central States.
Mackin, John C. Central States.
Madison, James W. Central States.
Maga, John A. California.
Magee, George W. New York.
Maguire, Chas. C. New England.
Maier, F. J. Federal.
Makepeace, W. H. England (I. S. P.)
Malcolm, William L. Canada, New York.
Mallalieu, W. C. New Jersey.
Mallmann, W. L. Michigan.
Mallory, Edward B. New York, Pennsylvania.
Malloy, Howard. Michigan.
Malone, Carroll J. New York.
Malone, J. R. North Carolina.
Malony, W. L. Pacific Northwest.
Mannheim, Robert. New England.
Mann, Alfred H. New York.
Mann, Uhl T. New York.
Mannes, Arthur S. South Dakota.
Mansfield, M. G. Pennsylvania.
Manteufel, Lawrence A. Central States.
Mapelli, Herman. Central States.
Marchon, Seigmund S. New York.
Mariner, W. S. New England.
Marshall, E. A. New York.
Marshall, J. C. Michigan.
Marshall, Leslie S. New York.
Marshall, W. B. New York.
Marsh, H. M. Canada.
Martens, L. P. Central States.
Martin, A. E. New York.
Martin, Alexander G. New York.
Martin, Edward J., Jr. New York.
Martin, George C. Central States.
Martin, Phil J. Arizona.
Martin, Sylvan C. Central States.
Martin, Warren S. New York.
Martzell, Paul C. New England.
Marx, Frank. New York.
Marx, George W. Arizona.
Maryland State Dept. of Health. Maryland-Delaware.
Marzec, E. J. Iowa.
Mason, Clarence A. Central States.
Mather, Edward K. South Dakota.
Mathers, George. New York.
Matthew, R. P. California.
Matthews, C. K. Kansas.
Mathews, E. R. South Dakota.
Mathews, Frank E. Pacific Northwest.
Mathews, Henry M. Georgia.
Mathews, L. R. Central States.
Matthews, Richard. Michigan.
Mathews, W. W. Central States.
Mathieson Alkali Works, Inc. Associate.
Mathis, Alice. Arizona.
Matsumaru, Isao. California.
Matter, L. D. Pennsylvania.
Mattheis, Clarence. Central States.
Mattson, Walfrid T. Central States.
Maxwell, W. E. New York.
May, D. C. Michigan.
May, Harold L. California.
May, Ira C. California.
Meadors, L. B. Central States.
Meadows, Walter L., Jr. Rocky Mountain.
Meats, G. R. E. England (I. S. P.).
Mebus, George B. Pennsylvania.
Mechler, Louis W. California.
Medbery, H. Christopher. California.
Meeden, J. California.
Meiers, Walter W. New York.
Menantico Sand and Gravel Company. Pennsylvania.
Mendelsohn, I. W. New York.
Menzies, D. B. Canada.
Menzies, J. Ross. Canada.
Markel, Paul P. Pennsylvania.
Meron, L. A. New York.
Merrill, Walter E. New England.
Merryfield, Fred. Pacific Northwest.
Merwin, Willard. Central States.
Merz, H. Spencer. Central States.
Meserva, Charles. Michigan.
Mesner, Elmer C. New York.
Metz, Roy L. Central States.
Meyer, Louis P. H. California.
Michaels, A. P. Florida.
Michaels, John. New York.
Mick, K. L. Central States.
Mickle, Chas. T. Central States.
Middleton, Francis. Federal.
Miick, Fred E. California, Arizona.
Miles, Henry J. Florida, New Jersey.
Milinowski, Arthur S. Central States.
Miller, Fred M. New York.
Miljevic, Nicholas. New York.
Millard, Harrison. Michigan.
Miller, A. J. Central States.
Miller, A. P. Federal.
Miller, A. S. England (I. S. P.)
Miller, Alden W. Arizona.
Miller, J. John. Pennsylvania.
Miller, L. A. Central States.
Miller, Lester. Central States.
Miller, Paul E. Pennsylvania.
Miller, Robert G. Iowa.
Miller, Roy. Pennsylvania.

Miller, W. C. Canada.
Miller, Wallace T. New York.
Milligan, Francis B. Pennsylvania.
Milliken, Harold E. New York.
Milling, Martin A. Central States.
Mills, S. W. Canada.
Minneapolis-St. Paul San. Dist. Central States.
Mitchell, Ansel N. Kansas.
Mitchell, Louis. New York.
Mitchell, Robert D. South Dakota.
Mittelstaedt, R. E. California.
Moat, C. P. New England.
Mock, Alvin M. Ohio.
Modak, B. L. England (I. S. P.).
Modak, N. V. England (I. S. P.).
Mogelnicki, Stanley J. Michigan.
Moggio, William A. New Jersey.
Mohlman, F. W. Central States.
Molitor, Paul. California, Pennsylvania.
Monroe, Lowell W. Pennsylvania.
Monk, H. W. England (I. S. P.).
Monroe, S. G. Ohio.
Monsanto Chemical Co. Associate.
Monsell, Harry M. New York.
Montagna, S. D. Pennsylvania.
Montes, Jose Garcia, Jr. England (I. S. E.).
Montgomery, James M. California.
Montgomery, J. Robert. Michigan.
Montreal Sewers Comm. Canada.
Moor, Alex. New York.
Moor, W. C. Texas.
Moore, Charles A. Pennsylvania.
Moore, Edward W. New England.
Moore, F. Owen. England (I. S. E.).
Moore, George S. North Carolina.
Moore, George W. New York.
Moore, Herbert. Central States.
Moore, R. B. Central States.
Moore, R. L. England (I. S. P.).
Moore, W. A. Federal.
Morehouse, W. W. Ohio.
Morey, Burrows. New York.
Morgan, Edward F., Jr. New England.
Morgan, L. S. Pennsylvania.
Morgan, Philip F. Central States.
Morgenroth, Fritz. New York.
Morkert, Kenneth. Central States.
Morrill, Arthur. Michigan.
Morris, Arval. California.
Morris, Lee. South Dakota.
Morris, Paul J. Pennsylvania.
Morrison, William. Canada.
Morrow, Ben. Pacific Northwest.
Moseley, Harry H. Ohio.
Moses, H. E. Pennsylvania.
Moses, James E. North Carolina.
Moss, E. H. North Carolina.
Moss, F. J. Federal.
Mott, C. A. Canada.
Mountfort, L. F. England (I. S. P.).
Mount Penn, Borough of. Pennsylvania.
Mowbray, George A. New York.
Mower, Stanley E. New York.
Mowry, Robert B. Pennsylvania.
Mudgett, C. T. Michigan.
Muegge, O. J. Central States.
Mueller Company. Associate.
Muldoon, Joseph A. New England.
Mullinex, Charles D. Iowa.
Mulvaney, M. B. Central States.
Munding, Germaine G. New York.
Munford, Mrs. G. England (I. S. P.).
Munro, A. D. England (I. S. E.).
Munson, Laura A. California.
Murdock, Charles R. Canada.
Murdock, William. 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, Robert. Michigan.
Mutzberg, F. A. Georgia.
Myatt, R. England (I. S. P.).
Myers, Harry L. Central States.

Nadin, Joe W. Central States.
Nagel, W. B. Ohio.
Nance, E. L. North Carolina.
Nasi, Kaarlo W. California.
National Aluminate Corp. Central States.
National Water Main Cleaning Company. Associate.
Naylor, William. New England.
Nazareth Sewerage Company. Pennsylvania.
Necker, C. E. Canada.
Neiman, W. T. Central States.
Nelle, Richard S. Central States.
Nelson, Ben O. Pacific Northwest.
Nelson, C. L. Central States.
Nelson, Frederick G. Ohio.
Nemmers & Clark. Iowa.
Nesbit, George H. New York.
Nesheim, Arnold. Federal.
Nesin, Benj. C. New York.
Netto, J. P. De Lemos. New York.
Neves, Lourenco Baeta. New York.
Nevitt, I. H. New York.
New Eastern State Penitentiary. Pennsylvania.
Newell, Town of. Iowa.
Newlands, James A. New England.
Newman, Alfred C. Florida.
New Mexico Bureau of Public Health. Rocky Mountain.
Newsom, Reeves. New York.
Nichol, Gordon B. New Jersey.
Nicholson, C. P. New York.
Nicholas, Forrest A. Central States.
Nichols, Arthur E. New York.
Nichols Engineering and Research Corporation. Associate.
Nichols, M. Starr. Central States.
Nickel, Jack B. Central States.

Nicklin, H. S. Canada.
Nicoli, Frank A. New England.
Nielsen, A. F. New York.
Niemi, Arthur G. Central States.
Niles, A. H. Ohio.
Nisbet, George A. Rocky Mountain.
Nisnevitz, Oscar. New Jersey.
Nixon, J. England (I. S. P.).
Noguera, Gustavo S. England (I. S. E.).
Nolan, George H. New York.
Norcom, George D. New Jersey.
Nordell, Carl H. Central States.
Norgaard, John. Michigan.
Norris, Finlay J. California.
Norris, Francis I. Federal.
Norris, Harold E. Central States.
Noth, Melvin J. Central States.
Nugent, Franklin J. Pennsylvania.
Nugent, Harold F. New York.
Nugent, Lee M. California.
Nusbaum, I. Michigan.
Nussbaumer, Newell L. New York.
Nussberger, Fred. New York.

Obma, Chester A. Central States.
O'Brien, Earl F. New York.
O'Brien, James E. New York.
O'Connor, William F., Jr. New York.
Ocean City Sewer Service Co. New Jersey.
Ockershausen, Richard W. Central States.
O'Connell, Wm. J. California.
O'Dell, W. H. New York.
O'Donnell, Frank. New York.
O'Donnell, R. Pennsylvania.
Oeffler, W. A. Central States.
Oehlke, Henry E. Michigan.
Oelkers, Carl L. New York.
Oeming, L. F. Michigan.
O'Flaherty, Fred. Ohio.
Ogden, Henry N. New York.
Ogle, Harry B. California.
O'Hara, Franklin. New York.
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.
O'Leary, William A. New York.
Olewiler, Grant M. Pennsylvania.
Oliver, J. C. Texas.
Olmsted, C. Henry. New England.
Olney, H. Ross. California.
Olsen, W. C. North Carolina.
Olson, Frank W. Central States.
Olson, Herbert A. Michigan.
O'Mara, Richard. Central States.
O'Neill, Ralph W. California.
Ongerth, H. J. California.
Orchard, W. J. New York.
Orton, J. W. Michigan.
Osage, City of. Iowa.
Osborn, L. C. Rocky Mountain.
O'Toole, Matthew. New York.
Owen, Mark B. New York, Canada.
Owings, Noble L. Maryland-Delaware.

Pacific Flush Tank Co. Rocky Mountain, Central States, Associate.
Pacific Foundry Company, California.
Packard, O. E. Michigan.
Page, Ronald C. California.
Paige, Sam. Pacific Northwest.
Painter, Carl E. California.
Pallo, Peter E. New York.
Palmer, Benjamin M. New England.
Palmer, Fred C. Canada.
Palmer, Gilbert. Pennsylvania.
Palmer, G. L. Michigan.
Palmer, Harold K. California.
Palmer, I. Charles. Pennsylvania.
Palmer, John R. Central States.
Palocsay, Frank S. Ohio.
Parker, Charles F. New York.
Parker, J. C. North Carolina.
Parker, R. J. England (I. S. P.).
Parks, W. J. North Carolina.
Parr, James. California.
Parsons, F. W. California.
Parsons, Norman W. Central States.
Parsons, R. H. Canada.
Patriarche, John M. Michigan.
Patterson, Glenn G. Kansas.
Patterson, R. L. California.
Patterson, Roy K. New York.
Patterson, W. E. Canada.
Paul, Lewis C. New York.
Paulette, R. J. Kansas.
Payrow, Harry G. Pennsylvania.
Payton, Lyle. California.
Pearl, Emanuel H. Maryland-Delaware.
Pearse, Langdon. Central States.
Pearson, E. J. North Dakota.
Pearson, S. R. Pennsylvania.
Peart, Robt. Kansas.
Pease, Maxfield. Ohio.
Pecker, Joseph S. New York, Central States.
Peck, Lawrence J. New York.
Peirce, W. A. Central States.
Peirson, Henry C. California.
Pekin, City of. Central States.
Pelnar, William J. Michigan.
Pelz, William J. Canada.
Pene, A. J. California.
Pennsylvania Salt Manufacturing Company. Associate.
Perkins, J. L. North Carolina.
Perrine, J. Franklin. New York.
Perroni, Joseph. New York.
Perry, A. H. Canada.
Perry, Earl R. New England.
Perry, J. S. Central States.
Petersen, A. H. California.
Peterson, Earl L. New York.
Peterson, Ivan C. Central States.
Peterson, Myhren C. Central States.

Peterson, Ralph W. Central States.
Petrie, William P. New England.
Pettit, Charles. Ohio.
Peyton, James J. New York.
Pfeifer, Willard. Central States.
Pfeiler, L. F. Central States.
Phelps, B. D. California.
Phelps, E. B. New York.
Phelps, Geo. Canada.
Phelps, Tracy I. California.
Philadelphia Bureau of Engineering. Pennsylvania.
Philion, W. I. New York.
Phillips, Cornelius W. New England.
Phillips, H. N. New York.
Phillips, Roy L. Pennsylvania.
Phillips, R. S. North Carolina.
Piatt, Wm. M. North Carolina.
Pieczonka, Thaddeus. New York.
Pierce, C. L. California.
Pierce, George O. Central States.
Pierce, W. E. Michigan.
Pierron, Wm., Sr. Pacific Northwest.
Pierson, Otto J. Michigan.
Pieszczachowicz, Edward J. New York.
Pincus, Sol. New York.
Pinkney, Glenn E. New York.
Pinney, F. W. North Dakota.
Pintar, George. Pennsylvania.
Pitkin, Ward H. New York.
Pittsburgh-Des Moines Co. Associate.
Pittsburgh Equitable Meter Company. Associate.
Placek, O. R. Federal.
Plamondon, Sarto. Canada.
Pledger, A. England (I. S. P.).
Plummer, Raymond Benton. Central States.
Pohl, C. A. New York.
Poindexter, G. G. Central States.
Polakov, Nicholas N. New York.
Pollock, John M. North Carolina, New York.
Pomeroy, Richard. California.
Pontbriand, P. N. Canada.
Ponto, W. Michigan.
Pool, Charles L. New England.
Poole, B. A. Central States.
Poole, S. B. England (I. S. P.).
Pope, Lester. New Jersey.
Popp, W. L. California.
Porges, Ralph. New Jersey.
Porteous, W. K. England (I. S. E.).
Porter, H. California.
Porter, William, New York.
Post, Fred W. California.
Poston, R. F. South Dakota.
Potts, Clyde. New York.
Potts, Harry G. Michigan.
Powell, A. R. New York.
Powell, J. C. Central States.
Powell, S. T. Maryland-Delaware.
Powell, W. B. New York.
Powers, Leo. New York.
Pratt, Gilbert H. New England.
Pratt, Jack W. California.
Price, Charles R. South Dakota.
Price, R. C. Central States.
Primmer, B. J. California.
Pringle, H. L. Canada.
Proctor, J. W. England (I. S. P.).
Proportioneers, Inc. Associate.
Proudman, Chester F. New England.
Prough, Fred K. Central States.
Provost, Andrew J. New York.
Public Works Magazine. Associate.
Puffer, Stephen P. New England.
Purdie, David J. New York.
Purser, John R., Jr. North Carolina.

Quaely, Martin F. New York.
Quigley Company, Inc. Associate.
Quigley, T. T. New York.
Quinn, Francis T. New England.
Quinn, Thomas A. New England.

Racek, L., Jr. Central States.
Radcliffe, Jack C. New Jersey.
Raisch, William. New York, New England.
Raiter, Clifford R. Central States.
Ralston, Gerald E. Central States.
Ralston, Wilmer R. Pennsylvania.
Ramseier, Roy E. California.
Ranagan, Fred E. California.
Randall, C. C. North Carolina.
Randolph, Verdun. Central States.
Rankin, R. S. Central States.
Rantsma, W. F. California.
Ratcliffe, Clyde. North Carolina.
Rath, Henry M. New York.
Rawn, A. M. California.
Rawson, E. Otto. Canada.
Raymond, Herbert E. New England.
Raymond, N. I. Michigan.
Read, Homer V. Central States.
Reading, Lyle M. Michigan.
Reardon, Joseph F. New York.
Reardon, Wm. R. Central States.
Redding, Harry P. North Carolina.
Redfern, W. B. Canada.
Red Wing Sewer Pipe Corp. Central States.
Reed, Paul W. Central States.
Reed, Ralph. South Dakota.
Reedy, Timothy D. Michigan.
Rees, N. B. Central States.
Reeves, C. F. California.
Regedanz, Paul. Central States.
Regelsen, Alfred E. New York.
Regester, Robert T. Ohio.
Rehler, Joseph E. New York.
Reichheimer, Charles E. Florida.
Reid, G. Graham. Canada.
Reidell, Alfred G. California.
Reilly, John J. Pennsylvania.
Rein, L. E. Central States.
Reinke, Edward A. California.
Reinoehl, Don. California.
Reisch, Eugene A. New York.

Reisert, Michael J. New York.
Renshaw, Ted. New York.
Requardt, G. J. New York.
Reuning, Howard T. Pennsylvania.
Reville, James T. New York.
Reybold, D. C. Central States.
Reynolds, Leon B. California.
Reynolds, M. W. Michigan.
Rhoads, Edward J. Pennsylvania.
Ribal, Raymond Robt. California.
Ribner, Morris. New York.
Rice, John M. Pennsylvania.
Rice, Lawrence G. New York.
Rice, Palmer J. North Carolina.
Richards, G. H. Canada.
Richards, P. W. Central States.
Richardson, Charles G. New England.
Richardson, Charles S. New England.
Richgruber, Martin. Central States.
Richmen, W. F. Central States.
Richter, Paul O. Central States.
Rickard, Grover E. New York.
Ricker, W. H., Jr. Pennsylvania.
Riddick, Thomas M. New York.
Ridenour, G. M. New York.
Riedel, John C. New York.
Riedesel, Henry A. Central States.
Riehl, W. H. Canada.
Riffe, Norman T. California.
Riis-Cartensen, Erik. New York.
Riley, E. Pacific Northwest.
Riley, Harley M. New York.
Riordan, James T. New York.
Ritter, Bruce. Michigan.
Roab, F. H. Central States.
Robb, Charles G. New England.
Roberton, L. T. Canada.
Roberts, A. L. Arizona.
Roberts, C. R. New York.
Roberts, F. C., Jr. Arizona.
Roberts, Jack. New York.
Roberts, L. M. New Jersey.
Roberts, W. C. California.
Robinson, B. Canada.
Robinson, Carl H. New York.
Robinson, G. G. Canada.
Robinson, George L. New York.
Robinson, I. F. Canada.
Robinson, J. C. South Dakota.
Robinson, Willis S. California.
Robins, Maurice L. Central States.
Rock, Harold F. New York.
Rocker, Christian G. New York.
Rockne, T. B. Central States.
Roe, Frank C. New York, Central States, Canada.
Roetman, Edmond T. Pennsylvania.
Rogers, Allan H. New York.
Rogers, D. Paul. Pennsylvania.
Rogers, H. L. Pennsylvania.
Rogers, Harvey G. Central States.
Rogers, John A. New England.
Rogers, M. W. Canada.
Rogers, W. F. Centrals States.
Rohlick, Gerard A. Central States.
Roland, Robert J. Central States.
Romaine, Burr. Central States.
Romeiser, C. H. Central States.
Rooks, G. P. Michigan.
Rosemeyer, Alfred. Central States.
Rosengarten, W. E. Pennsylvania.
Ross, Edward J. Central States.
Ross, Herman M. Central States.
Ross, W. E. Central States.
Rostenbach, Royal Edwin. Iowa.
Roth, R. F. Ohio.
Rousseff, Christ M. Central States.
Rowen, R. W. Central States.
Rowinski, N. M. Central States.
Rowntree, Bernard. California.
Royer Foundry and Machine Co. Associate.
Roznoy, Louis W. New Jersey.
Ruble, E. H. Central States.
Ruchhoft, C. C. Federal.
Ruck, Franklin. Ohio.
Rudolf, R. L. California.
Rudolfs, Willem. New Jersey.
Rugdal, H. T. Central States.
Ruggles, M. H. Florida.
Rumble, George B. Canada.
Rumsey, James R. Michigan.
Rupp, Daniel H. Ohio.
Rush, DeWitt, New Jersey.
Rush, Frank O. Central States.
Russell, Don B. Iowa.
Russell, George. Missouri.
Russell, J. P. Canada.
Ruszczyk, Albert J. Central States.
Ruth, Leo. W., Jr. California.
Ryan, Joseph P. Central States.
Ryan, J. Samuel. New York.
Ryan, Wm. A. New York.
Ryon, Henry. New York.

Saetre, Leif. New York.
Sage, Howard D. New York.
Sageman, Norman. Michigan.
Sager, John C. Central States.
Sakellarian, Evans N. Central States.
Salle, Anthony. New York.
Salvato, Joseph. New York.
Sammis, L. A. New York.
Sampson, J. A. Iowa.
Samson, Channel. New York.
Sanborn, J. F. New York.
Sanchis, Joseph M. California.
Samuelson, Andy. New York.
Sanderson, W. W. New England, New York.
Sanders, M. D. Central States.
Sanford, Chester. New Jersey.
San Francisco, City and County. California.
Sargent, H. H. Central States.
Sauer, Victor W. California.
Savage, Edward. New York.
Savage, William T., Jr., Central States.
Saville, Thorndike. New York.

Sawyer, Clair N. New York.
Sawyer, Robert W., Jr. New England.
Scales, J. J. Michigan.
Schade, Willard F. Ohio.
Schaefer, Edward J. New York.
Schaetzle, T. C. Ohio.
Schaut, George C. Pennsylvania.
Scheak, H. M. Canada.
Scheffer, Louis K. Pennsylvania.
Scheidt, Burton A. Central States.
Schenk, E. E. Iowa.
Scherer, Paul. New York.
Schiele, Henry. New York.
Schier, Lester C. Central States.
Schildman, W. H. Central States.
Schiller, Bernard. Arizona.
Schlenz, H. E. Central States.
Schliekelman, R. J. Iowa.
Schlueter, William H. Central States.
Schmit, J. M. Rocky Mountain.
Schrack, Bert. Iowa.
Schreiner, W. R. New York.
Schriner, P. J. Central States.
Schroeder, A. W. Central States.
Schroeder, T. W. Central States.
Schroeder, W. L. South Dakota.
Schroepfer, George J. Central States.
Schuck, H. W. California.
Schwartz, H. L. Pennsylvania.
Schwartz, Louis. New York.
Schwartz, Oswald. Central States.
Schwob, Carl E. Central States.
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, Roy D. New York.
Scott, R. D. Ohio.
Scott, W. England (I. S. P.).
Scott, W. M. Canada.
Scott, Walter M. New York.
Scott, Warren J. New England.
Scovill, John R. New York.
Scudder, Aubrey P. New York.
Seaman, Henry. North Carolina.
Searight, Geo. P. Pennsylvania.
Searls, Glenn. New York.
Sedlacek, A. J. Iowa.
Seeley, George A. Arizona.
Segel, A. California.
Seid, Sol. New Jersey.
Seifert, William P. New York.
Seltzer, J. M. Pennsylvania.
Senseman, Wm. B. California.
Serba, Joseph S. New York.
Setter, Lloyd R. New Jersey, Pennsylvania.
Setzer, Aubrey James. North Carolina.
Seufer, Paul E. Pacific Northwest.
Sewage Works Engineering. Associate.
Seydel, Herman. New Jersey.
Shade, Earle. Central States.
Shannon, Francis T. New York.
Shapiro, Robert. New York.
Shaw, George H. Pennsylvania.
Shaw, Paul R. California.
Shea, Walter J. New England.
Shearer, A. B. California.
Sheen, Robert T. Pennsylvania.
Sheets, W. D. Ohio.
Shelley, Harry. Pennsylvania.
Shelton, E. N. Georgia.
Shelton, M. J. California.
Sheppard, Frederick. New England, New York.
Sheppard, W. F. Michigan.
Shera, Bryan. Pacific Northwest.
Sheridan, Thomas J. New York.
Sherman, Leslie K. New England.
Shertzer, J. H. Pennsylvania.
Shete, V. G. England (I. S. E.).
Shick, V. R. Ohio.
Shiffer, J. Paul. Pennsylvania.
Shirley, Donald L. Pacific Northwest.
Shockley, Homer G. New York.
Shook, H. E. California.
Shook, H. R. Canada.
Shupe, S. Canada.
Sibbald, Charles T. A. New York.
Sibila, Rocco. New Jersey.
Sibley, W. H. Georgia.
Sickler, Archie H. New York.
Sidle, R. S. England (I. S. P.).
Sidwell, Clarence G. Central States.
Siebert, Christian L. Pennsylvania.
Sieverding, O. C. New England.
Signor, C. V. Pacific Northwest.
Sigworth, E. A. New York.
Silberbauer, Walter R. California.
Simmerman, John S. New Jersey.
Simon, Samuel S. New York.
Simonton, Lewis. Georgia.
Simplex Ejector and Aerator Corp. Central States.
Simplex Valve and Meter Co. Associate.
Simpson, R. W. New York.
Simson, George, Jr. Rocky Mountain.
Simson, Paul W. New York.
Skinner, J. F. California, New York.
Skinner, W. V. California.
Sklarevski, Rimma. Maryland-Delaware.
Slagle, Elmer C. Central States.
Slee, Angus E. Rocky Mountain.
Sleeger, Warren H. Central States.
Slocum, Adelbert I. New York.
Slough, John. New York.
Smedberg, C. W. North Carolina.
Smigel, Walter A. Ohio.
Smiley, Paul E. Ohio.
Smith Manufacturing Company, A. P. Associate.
Smith, B. G. Pacific Northwest.
Smith, Benjamin L. New York.
Smith, C. A. California.
Smith, Charles E. Iowa.

Smith, David B. Florida.
Smith, E. A. Cappelen. New York.
Smith, E. E. Ohio.
Smith, Edward J. New York.
Smith, Frank E. California.
Smith, Fred J. Central States.
Smith, G. C. England (I. S. P.).
Smith, Harold. New York.
Smith, H. G. California, Pacific Northwest.
Smith, Harold L. Michigan.
Smith, J. F. California.
Smith, J. Irwin. Central States.
Smith, L. R. New York.
Smith, Paul L. Maryland-Delaware.
Smith, Marvin L. Pennsylvania.
Smith, Merlin D. Pennsylvania.
Smith, R. C. New Jersey.
Smith, Robert J. Michigan.
Smith, R. Trumbull. Central States.
Smith, Russell S. Federal.
Smith, S. H. Michigan.
Smith, Walter E. Michigan.
Smith, Walter R. New York.
Smith, Waymon, North Carolina.
Smith, Wendell H. Pacific Northwest.
Smith, W. T. E. Canada.
Smithson, Thomas. Pacific Northwest.
Smithwick, John J. New England.
Snapp, Russell G. Federal.
Snedeker, L. LaVerne Michigan.
Snell, J. R. New England.
Snook, W. F. A. England (I. S. P.).
Snow, Donald L. Central States.
Snow, Willis J. New England, New York.
Snyder, M. K. Pacific Northwest.
Snyder, N. S. New York.
Snyder, R. F. Ohio.
Solander, Arvo A. New England.
Solomon, G. R. New York.
Somers, Verne. Central States.
Sommerfeldt, Everett L. New York.
Sorbel, J. L. South Dakota.
Soreff, Joseph. New York.
Soroker, Sam. California.
Sorrell, W. H. Central States.
Sotter, R. R. California.
Soule, Ralph M. New England.
Souther, Fred L. California.
Sowdon, William K. New York.
Spacey, T. England (I. S. P.).
Spaeder, Harold J. Central States.
Spaeth, Julius. Kansas.
Sparks, Bert. Michigan.
Sparr, A. E. New York.
Spear, William B. Pennsylvania.
Speirs, George W. New York.
Spellman, W. A. Canada.
Speiden, H. W. Pennsylvania.
Spence, W. O. North Carolina.
Spencer, Albert M. New York.
Spencer, Henry. California.
Sperry, John R. Central States.
Sperry, Walter A. Central States.
Spiegel, Milton. Central States.
Spieker, Roy G. South Dakota.
Spier, Daniel R. New York.
Spies, Kenneth H. South Dakota.
Spiess, Reinhold. Central States.
Splitt, Howard A. New York.
Spragg, H. J. Iowa.
Spry, Fred J. New York.
Spuslock, R. Central States.
Stache, Paul. New York.
Stalbird, James A. New York.
Staley, H. H. Kansas.
Stalker, W. D. Canada.
Stanbridge, H. H. England (I. S. P.).
Stanley Engineering Company. Iowa.
Stanley, Stephen. England (I. S. E.).
Stanley, Wm. E. New York.
Stapley, E. R. Oklahoma.
Stark, Frank B. New York.
Starling, Charles H. North Carolina.
Stauff, Paul V. Central States.
Staynes, E. H. England (I. S. P.).
Stearns, Donald E. New England.
Steel, E. W. Texas.
Steffen, A. J. Central States.
Steffensen, S. W. New York.
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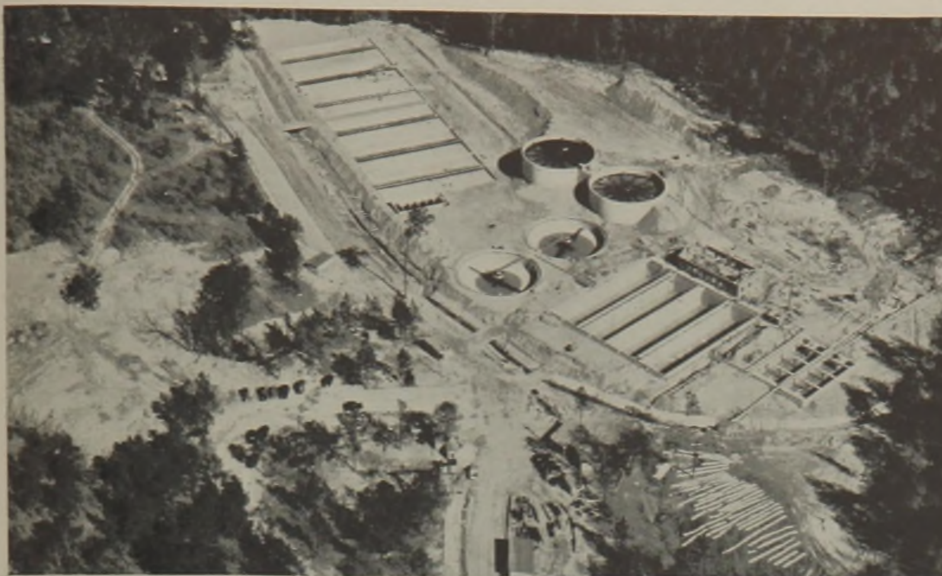

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