CLARIFICATION OF SEWAGE

BY

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CHEMNITZ

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In Germany, presumably because of local conditions, devices and processes for the clarification of sewage have been much more highly developed than in this country. Many of the rivers are large and the modification of the sewage to a non-putrescible state is quite frequently unnecessary. On this account there are many plants in Germany where screening devices and tanks of various kinds constitute the entire equipment of a sewage treatment plant.

The author of this book, Dr. Ing. Rudolf Schmeitzner, visited a number of the larger German clarification plants, prepared a detailed account of his trip and has presented, from an engineering standpoint, a critical review of the essential processes and devices now used in Germany in the preparatory treatment of sewage.

The literature in English relating to the design of screens of various types of sedimentation tanks, of towers and methods of sludge removal and disposal is apparently meagre, and it occurred to the translator that a translation of Schmeitzner's book might be of marked interest and profit to American engineers. This would appear especially to be true since many of our large water courses are fast becoming too polluted longer to serve for the inoffensive disposal of sewage. This condition may not mean a complete plant for the modification of the organic matter to a stable form, but rather the partial treatment of sewage and the development in this country of sewage clarification plants and an extensive use of just such devices as Dr. Schmeitzner describes in his book.

A. Elliott Kimberly.

Columbus, Ohio, June, 1910.

AUTHOR'S PREFACE

SEWAGE treatment plants are discussed in this book only with regard to engineering features of construction and of operation, and the chemical and bacterial phases of the question are, therefore, but briefly mentioned. The subject matter was obtained during an inspection trip to the following German cities where preparatory devices constitute the entire treatment of the sewage: Charlottenburg, Chemnitz, Dresden, Frankfort a. M., Spandau, Hamburg, Graudenz, Bromberg, Nakel, Weissensee, Goettingen, Cassel, Duesseldorf, Cologne, and Mannheim. Further information was obtained from circular letters of inquiry and from a study of current pertinent literature.

It is believed that the subjects discussed will be of great interest to city officials, especially since the disposal of sewage is an increasingly important problem and since there are no similar publications in existence.

For the further treatment of the clarified sewage, reference should be made to Dr. Ing. Imhoff's article in Vol. 7 of the Reports of the Royal Prussian Sewage Testing Institute at Berlin, and also to Dr. Dunbar's "Principles of Sewage Treatment."

RUDOLF SCHMEITZNER.

CHEMNITZ, *October, 1907.*

INTRODUCTION

In the larger cities the volume of sewage has gradually increased to such an extent that natural water courses, in many instances, cannot afford proper dilution, and the sewage gives rise to conditions objectionable from a hygienic, commercial and esthetic standpoint. Rivers are polluted and rendered unfit for water supply, fish life is destroyed and unsightly masses of sludge accumulate on the river banks, emitting disagreeable odors.

As a remedy for these conditions, health authorities require a more or less thorough treatment of the sewage. For example: Under the Royal Prussian Edict of 1901, the right to dispose of sewage by dilution in natural water courses is made dependent upon the volume and nature of the sewage and the flow and character of the stream. According to this Act, conditions favorable for the disposal of sewage by dilution comprise a large stream flow, a high current velocity, a rocky gravelly bottom, permanent banks, and the entrance of ground water. Conditions unfavorable for the disposal of sewage by dilution, are stagnant streams or running streams whose banks are frequently inundated.

In case the disposal of sewage by dilution is not feasible, health authorities prescribe a method of treatment by which there shall be obtained a certain degree of purification. Under Prussian conditions if official requirements are deemed too severe, a municipality may make an alternate proposition, based upon results obtained from an experimental purification plant.

When conditions are favorable for disposal by dilution, the Prussian health board requires only that there shall be removed from the sewage all suspended matter above a certain size. It is questionable whether the above requirement will prove satisfactory in the future, for it is evident that in order to fulfill this condition, it would be sufficient to reduce the coarser suspended particles to the desired size and separate out only those which cannot be so reduced. Such, moreover, appears to be the action of many sewage screens. In this way sludge-forming putrescible material reaches the stream and in sluggish streams it is quite possible that on account of their stickiness, the smaller particles coalesce after passing the screens.

Seaboard cities are often in the fortunate position of being able to discharge their sewage into the sea without treatment, but even then, on account of the tides, large storage reservoirs are necessary, as at Marseilles, Naples, and Boston. At seashore resorts, where the pollution of the bathing beach must be prevented at all costs, the discharge of sewage is hazardous and impossible in the absence of a strong current off shore.

The treatment of sewage may be said to comprise two distinct steps,—clarification and purification,—although in a number of publications there is made no sharp distinction between these two steps. In the following pages, *clarification* will be understood as the removal of the suspended matters in the sewage, exclusive of the bacteria, and *purification,* the treatment of dissolved organic matter and bacteria. Under German conditions, clarification is almost always necessary, while purification can at times be dispensed with. The author is aware that the expression *purification* as distinguished from *clarification* is not happily chosen and both of these terms should be abandoned if better ones can be found. However, both processes are distinctly separate, the two parts of a plant are often widely distant from each other, their supervision devolves upon different operators, and hence it is desirable that there should be a sharp distinction between them. Perhaps the terms *preparatory treatment* and *final treatment* would be better.

Clarification is not complete in itself, for a complete purification can be obtained only by a combination of chemical and biological processes, that is by treatment on sand filters, contact filters, or sprinkling filters.

In the following pages the subject of sewage treatment is discussed merely with reference to the design and operation of devices for preparatory treatment.

The removal of suspended matter from sewage may be effected in several ways:

1. Mechanically, by reducing the velocity of the flowing sewage and causing the sedimentation of matters whose specific gravity is greater than that of the sewage, or retaining the floating and suspended matters by baffles or screening devices.

2. Chemically, by the use of such chemicals as lime, alum and chloride of iron, whereby the sewage is coagulated and the suspended matters are precipitated.

3. Biologically, by passing the sewage through settling basins (so-called septic tanks) wherein the suspended matters deposit, putrefy, lose water and volume, and are in part destroyed.

Chemical precipitation plants are frequently used in manufacturing cities, in both England and Germany, as for example, at Bochum, Essen and Leipzig. The process is quite expensive on account of the constant application of chemicals, the volume of sludge is very great and its nature renders it unfit for profitable by-product recovery. Further, the dissolved mineral matters are partially precipitated and unless the excess of chemicals be removed by special filters or mixing basins, the clarified sewage often has an injurious effect upon the stream into which it is discharged. For these reasons, therefore, the process has gradually been abandoned in a number of places, for example, Frankfurt, Wiesbaden and Leipzig. The lignite process, however, has been successful in Potsdam and Spandau, and it will be briefly discussed in this book, since the clarification effected depends more upon mechanical than upon chemical features.

Septic tanks, so extensively used in England, are easily operated and yield a sludge which can be pressed and one which contains on an average, 10 per cent less water than sludge from settling tanks. Since the sewage must remain in the tanks for a considerable period (Hamburg, 15 hours) for large works large tank capacity is required, and this feature considerably increases the first cost of the plant. Other objections to the use of septic tanks are the feature of interrupted operation under severe winter conditions,* the necessity for further treatment to offset the injurious effect of the putrescent effluent upon fish life and the great possibility of a marked nuisance from odors.

Generally speaking, and particularly for large volumes of sewage, clarification processes are the most rational and, moreover, possess the great advantage that a plant can be built to secure a predetermined degree of clari-

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* This view is contrary to American experiences.

fication, since there are removed from the sewage only particles of a certain minimum size, or a determined minimum weight. This fact is of especial importance in conforming to the requirements of the Royal Prussian Board of Health, especially when purification is not deemed necessary, for it would, of course, be needless to exceed the official demands. Of course, complete purification is not possible by mechanical means, and the effluents from even the most efficient clarification plants still contain from 10 to 20 per cent of the suspended matters present in the raw sewage.

CLARIFICATION OF SEWAGE

CHAPTER I

GENERAL PRINCIPLES OF THE DESIGN OF CLARIFICATION PLANTS

A CLARIFICATION plant should be constructed in conformity with the following conditions:

1. The operation of devices for final treatment shall not be affected nor influenced in any way.

2. The efficiency of the plant must correspond to the requirements of the health authorities in case no after treatment is required.

3. The most advantageous arrangements shall be provided for the removal of sludge and for its treatment for by-product recovery. A sludge-disposal area should also be provided when it is not feasible to arrange for a continuous treatment of sludge.

4. The costs of installation, operation and maintenance shall be a minimum.

5. Ordinary repairs shall be possible without interrupting the operation of the entire plant, and in cases of emergency repairs shall be possible with a minimum delay.

6. Future extensions shall be possible without interrupting the operation of the plant.

7. Operators shall be protected while at work, and provision shall be made so that the plant does not create a nuisance in the immediate vicinity.

FACTORS CONCERNED IN REDUCING COSTS

There are a number of factors which govern the cost of installation, operation and maintenance, and it is of interest to consider briefly the more important ones.

Choice of Site. The most suitable site for a clarification plant is one located on low-priced land, situated in a part of the city which can never become a residential district and where there will be little likelihood of lawsuits because of daily or occasional odors. In the use of the site, for a maximum economy, advantage should be taken of the natural grades with a view to avoiding expensive pumping plants for delivering sewage at the plant, for pumping the sludge, or for pumping the treated sewage into the adjacent stream.

By uniting the plant with similar municipal works, such as garbage and refuse crematories, it is possible greatly to reduce the costs, especially as regards means for obtaining the best hygienic operation, and the construction of power plants and devices for the disposition of residues and by-products from the other processes.

It is further of advantage if the plant be located on a site inundated during high water in the adjacent stream. Land is then cheap and, as at Mannheim, can be used for sludge disposal purposes, and moreover, the plant is near the stream. The works themselves must, of course, be above high-water mark, and this is accomplished either by constructing levees, or by locating the plant on filled ground. The installation cost will, of course, be high if much ground water be found on the site, but unfortunately, such a site cannot always be avoided.

In choosing a site for the clarification plant operating expenses may be reduced if the plant is arranged to permit the cheapest handling of coal and the least expensive disposal of sludge. From this point of view, a plant can most favorably be located near a navigable stream. If the disposal of sludge and other waste material cannot be effected without incurring some operating charges, there should be provided a special area where the waste materials may be burned or coked, or may be worked for the recovery of fat or fertilizer base.

Constructional Details. To reduce renewal costs, only durable and acid proof material should be used in construction, and wood should be avoided in the more important parts of the plant. All iron work which comes in contact with water or is located near water, such as trapdoors, stairways and chains, should be galvanized or coated with asphalt. For finer work brass should be used for plates and copper for wiring. In case the wire is subject to considerable tension, steel is better, although it is more readily attacked by acids.

Walls can best be constructed of brick. Joints should be as small as possible and should be of cement mortar 1:3, enriched to 1:2 for bottom mortar. Concrete is much used, although it is not acid proof, and on this account it is advisable to face it with brick. Plastering with a stone grout, is practical, as at Frankfurt, but it is also very expensive. Preolite and fluoride washes afford good protection against acids, but if cracks appear in the concrete the wash breaks also, and the sewage comes into direct contact with the concrete.

There should be provided ample outlets for the gases which develop around the plant, and this may be accomplished by constructing air shafts. If such provisions are not made, roofs, elevators, conveyors, and even instruments, may suffer. It is important that all non-galvanized iron work be coated and that the coating be renewed when required. The most painstaking cleanliness should be observed everywhere. In power plants small moving parts should be avoided if possible, since they are so delicate and easy to get out of order.

Questions of economy, of course, govern the feature of continuous or intermittent operation, as well as that of mechanical as against hand operation.

UNINTERRUPTED OPERATION FOR REPAIRS AND SLUDGE DISPOSAL

In order to clean tanks or make repairs without interrupting the operation of the entire plant, it is very essential that certain parts of the plant be in duplicate, such, for example, as grit chambers, screens, settling basins and settling towers. These duplicate devices should be entirely separate and capable of being completely shut off from each other. For inspection purposes all parts of the plant should be readily accessible.

In case high water in the adjacent stream necessitates a complete shutdown, it is recommended to provide a special by-pass which is ordinarily closed. Such an arrangement is always desirable where the night sewage from perhaps 12 o'clock midnight to 6 o'clock A.M. is not treated, or in case, during heavy storms, the plant is by-passed entirely. In the latter case, as at Cologne, the by-pass can be operated automatically by means of a float-controlled valve placed in the sewage channel. In some cases when the crude sewage is rarely by-passed, and then only in case of necessity, German health authorities cause the by-pass valves to be kept under lock and key.

PROVISIONS TO MEET CHANGING CHARACTER OF CRUDE SEWAGE

In designing a plant, in choosing a clarification process and in cases where only occasional treatment is ordered by the health authorities, particular weight must be attached to the question of the future development of the community. The points to be considered are: (1) An increased sewage flow; (2) the changing character and quantity of the suspended matter; and (3) the changed concentration of the organic matters.

Increasing Sewage Flow. The volume of sewage is increased not only owing to the increase in population corresponding to the greater density of population in the city and in its various suburbs, but also because of the increased water consumption and the development of manufacturing. In the larger German cities it is sufficient to consider a per capita sewage flow of 29 to 40 gallons. Special districts in the larger cities, however, show a much higher flow. For example, Berlin 66 gallons; large manufacturing cities, such as Glasgow, 46 gallons. American figures are very much higher, ranging from 66 to 92 gallons per capita, and higher.

It may happen, as at Chemnitz, that small streams flowing through the city are used as sewers, and in this case such water also must be conducted to the plant, thereby creating a still further increase in sewage flow.

Character and Quantity of Suspended Matters. The character of the suspended matter in cities where there are no paved streets, where night soil is not regularly removed, and where there are few manufactories may change in case the streets are paved, the use of water closets made compulsory and new industries develop. Sewage from manufactories generally affects the dissolved matters in the city sewage, but some industrial sewages, especially from woolen mills, as at Leeds, carry thread fibres which clog screens. Wastes from grease and tallow-rendering plants (Manchester) contain fat which is especially disadvantageous in sludge pressing.

In case no provisions are made in the plant to handle the industrial sewage problem, regulations can be passed forbidding the larger establishments from discharging certain classes of sewage into the sewers.

PROTECTION OF OPERATORS

In the interest of the operators of the plant it is advisable to displace hand operation with mechanical devices wherever the men may come in contact with the sewage or solid matters, and also in the removal of screenings. If this appears inadvisable, on the grounds of limited space or economy, provisions are to be made in the original layout so that mechanical devices may be readily installed later.

Laborers, filter press and centrifugal machine operators in particular, are exposed to strong disagreeable odors. At the Chemnitz experimental station *faciloil* has been used to advantage for deodorizing. This is a thin brownish oil of a specific gravity of 0.79 and is obtained in Biebrich from the residue from the tar works. It is, of course, understood that an abundance of air is required in all parts of the plant where men are employed. Washrooms and bathrooms should also be provided.

FACTORS CONTROLLING NUISANCES

Factors which control the question of a nuisance from a clarification plant are:

1. Noxious gases;
2. Putrefaction of the sewage;
3. Extensive sludge disposal areas;
4. Flies;
5. Contamination of ground water;
6. Spread of disease germs during epidemics.

Noxious Gases. The foul odor from sewage is due chiefly to the hydrogen sulphide formed from the fecal matter. To avoid a nuisance from odors at houses near the plant, the entire plant should be under cover and in addition should be provided with a tall chimney. Settling tanks and channels in which the sewage remains for some time may be made almost odorless by means of oil.

Putrefaction of the Sewage. The fouling of the sewage in a clarification plant is especially in evidence when the clarified effluent is discharged into the stream without further treatment. The water of the stream is then deoxygenated and fish are destroyed. Moreover, it is of great advantage entirely to prevent septic action in clarification plants, since the putrefying sludge emits noxious gases of foul odor, and further, in quiet or in but slowly flowing sewage, particles of scum rise to the surface and foster the growth of insects. Septic action may be prevented by causing the sewage to reach the plant in a fresh condition, that is, by designing the sewerage system on substantial grades. By this means suspended matters are deposited only in their proper place and they may be removed before there is an opportunity for their decomposition. Clarification must be hastened in case the sewage strongly inclines toward putrefaction, and the sludge must be removed from the sludge sump during the operation of the tank.

In case the grades on which the sewers are laid do not permit the sewage to flow rapidly toward the plant, apparatus such as adopted in Ohrdruf may be used. It consists of devices for keeping the sewage flowing in the sewers in constant motion by means of compressed air. Naturally, its operation is quite expensive.

The tendency of sewage to septicize depends upon its composition, especially the relative quantity of fecal matter. Putrefaction is also favored by manufacturing wastes containing large quantities of organic matter and also by an extended system of trunk and lateral sewers. The works at Langensalza show that by sufficient flushing, even in long sewers, sewage in a fresh condition may be caused to reach the plant.

Sludge accumulation is especially to be avoided in grit chambers, diversion chambers or inlet channels, because these devices can rarely be cleaned without shutting down the entire plant. Moreover, the deposited suspended matters infect the fresh sewage as it reaches the plant. Although at Hannover the diversion channel is so designed that the deposited sludge may be washed into the settling basins by raising a gate, yet it is much better practice to make the deposition of the suspended matter impossible by providing a proper linear velocity, a suitable cross-section, and by avoiding dead corners. By these means the velocity of the sewage is maintained to the grit chambers. Beyond these the velocity may again be increased by reducing the cross-section of the channel.

Screens cause the deposition of considerable sludge, since they reduce the velocity of the sewage, especially if they be fine, as at Marburg, where, with a mesh of 1½ mm. ($\frac{1}{16}$ in.) the sewage backs up 25 cm. (10 in.). This decrease in velocity may be equalized by providing a heavier grade or by deepening the section.

The inverts of all the sewers reaching the plant should slope as much as possible, corresponding to the topography. This applies to closed, circular and egg-shaped sewers. With open channels right-angled sections are to be avoided, (Fig. 1). Trapezoidal sections are better (Fig. 2), while rounded inverts are best (Figs. 3 and 4).

Dead corners exist through the sudden increase in the cross-section, for example, where branch sewers leave the main conduit. To avoid these, the intersecting inverts are enlarged to full size up to the ordinary flow line.

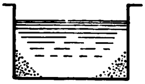

FIG. 1.

FIG. 2.

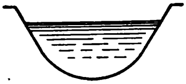

FIG. 3.

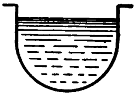

FIG. 4.

Sludge Disposal Areas. Emanations from sludge disposal areas may cause a decided nuisance in the vicinity of the plant and may involve a city in heavy damage suits. It is, therefore, best to dispense with a sludge drying area and treat the problem differently. By covering sludge disposal areas with peat dust or oil, it is, however, possible almost entirely to prevent objectionable odors, as has been the experience at Frankfurt-am-Main. The location of sludge beds is to be so chosen that the prevailing winds are directed as little as possible toward the inhabited sections of the city. Sludge beds are often a necessity, and if the solid matters removed from the sewage be immediately covered with peat dust, Düsseldorf experiences indicate that objectionable odors will be noted only in the immediate neighborhood.

Flies. In summer flies become objectionable to plant operators and to nearby dwellings. Their development is encouraged by sludge beds and by the particles of decomposing sludge which rise to the surface of the sewage in the settling basins. At Frankfurt *Faciloil* has been used with great success, both for sludge beds and for the surfaces of settling basins. It is sufficient to spray the cleaned, basins with the oil. It forms a thin covering upon the surface of the sewage and always reunites where broken by rising gas bubbles, so that insects can have access to neither scum nor sewage, and hence find no nourishment thereon.

The greatest cleanliness should prevail throughout the plant. All corners which insects can use as breeding places are to be cleaned regularly and exposed heaps of refuse must not be permitted.

Contamination of Ground Water. The ground water may become contaminated if there are used as settling basins open pools without tight bottoms or similarly open ditches as inlet channels. Many disagreeable features and lawsuits may thus arise if the ground water is contaminated at a point immediately below the plant. Under these conditions, according to circumstances, there are necessary deep and expensive drainage excavations.

Relation to Epidemics. One of the requirements of the health authorities for clarification and purification plants is that the sewage effluent shall be disinfected in case of epidemics (Prussian Ministerial order of 1901), and this applies to either the raw sewage or the effluent.

To treat the latter is certainly practical provided the non-disinfected sludge is burned or decomposed with chemicals and thus rendered harmless. In such cases the disinfectant, usually chloride of lime, is added at the main effluent drain.

In order to obtain a thorough mixing it is recommended to provide mechanical stirring apparatus or a special mixing channel at best so arranged that the sewage in a shallow stream flows slowly over a broad surface. By this means all portions of the effluent come into intimate contact with the disinfectant.

At Bernkastel the effluent is conducted into a special chamber where it is allowed to stand for a certain time in order to obtain a maximum disinfection. In the case of small volumes of weak sewage, according to English experiences in small plants, it is sufficient to float a perforated bell-shaped vessel containing the disinfectant as near mid depth of the sewage stream as possible. If the effluent flows into a stream which abounds in fish the excess of disinfectant must be removed by filtration or else be neutralized in a special basin.

Disinfection is very much more expensive if the raw sewage is treated. In this case, large quantities of disinfectant are required and simple stirring devices and mixing channels are no longer adequate. It is then best to provide one, or preferably two, special mixing tanks in order not to interrupt the operation of the entire plant. A slight loss of head is to be considered in the passage of the sewage through these mixing tanks.

Good mixing can also be obtained if the disinfectant is applied at the sewage pumping station, as at Mannheim. Suitable arrangements must be provided for storing the disinfectant. At Nakel, in Bromberg, there is a disinfecting plant which effects a very thorough mixing of the disinfectant and the sewage. At this place epidemics are more to be feared than elsewhere in Germany on account of the proximity of the Russian border. After the sewage is mixed with chloride of lime in a special tank equipped with stirring devices, it flows through four long tanks which contain staggered over and under baffles, which set up considerable wave action. Then by means of slanting submerged baffles, the sewage stream is forced to assume a rotary motion.

It is not clear what quantity of disinfectant shall be employed,* for the quantity to be used is dependent not only upon the concentration of the sewage, but also upon the character of the epidemic. In such cases the decision must always be left to the chemist or bacteriologist.

* See Dunbar, Leitfaden f. d. Abwasserreinigungsfrage. München, 1907. Principles of Sewage Treatment, J. B. Lippincott & Co., Phila., 1908.

CHAPTER II

THE COMPOSITION OF SEWAGE

THE substances present in municipal sewages are either of mineral or organic origin, and are either in solution or in suspension. The quantities present (usually expressed in parts per million) differ very widely in different cities. Dissolved mineral matters are unchanged by clarification plants. They are in part already contained in the water supply and cause no injury to streams. The reverse is true of the sewages of dye works and chemical works, especially where the wastes contain free acids. According to Lindley, the suspended mineral matters must be removed by the clarification plant, and under no circumstances should be allowed to reach the final treatment devices. In so far as practical the suspended organic matter must be removed in the clarification plant, because, according to Imhoff, it is cheaper to remove sludge from tanks, screens and settling channels than to wash filtering material.

The dissolved organic matters are converted to stable mineralized compounds by the oxygen introduced in the purification devices. For example, the nitrogen of the albumen is oxidized to nitrates and carbon to carbonic acid. The quantity of nitrates in the final effluent is, therefore, a measure of the resulting purification.

The composition of the sewage of a city is not always the same, but changes with the city's development. It is also different in different seasons; also on different days of the week, especially in case packing houses and manufacturing plants discharge their untreated wastes into the sewers. Results for the single day, however, show the greatest variations. For example: The night sewage from midnight to 6 o'clock A.M. often contains only one-fifth of the average suspended matter of the day sewage. The periodical variations in the composition of sewage are to be learned by tests. For example, if it is desired to compare the results of two clarification plants with basins operated with different lineal velocities it is necessary before each test to know the composition of the raw sewage. Moreover, the tests must be conducted preferably during the same periods of the day.

Another point in comparing the results of different plants, since the efficiency of a clarification plant expressed in percentage removal of suspended matters increases the greater the suspended matter present in the raw sewage, a comparison can be reliable only if the test is made when the strongest sewage is reaching the plant as opposed to samples covering the entire day period.

The small quantity of suspended matters in the night sewage can simplify the night operation of a plant. A more rapid clarification is then arranged or some parts of the plant are by-passed, such as fine screens and settling basins, and sufficient treatment is obtained by using the grit chambers and the coarse screens alone, or else the entire plant is by-passed. The latter procedure is, of course, permissible only in case the untreated night sewage contains less suspended matter than the treated day sewage. Such is the case at Cologne. In the experimental tanks at Cologne the clarified day effluent contained 88 parts per million of suspended matter, while the untreated night sewage contained only 55 parts.

The data in the following table illustrate the range in the quantity of suspended matter in different sewages, and the second table their composition.

SUSPENDED MATTER IN MUNICIPAL SEWAGES

(Parts per million.)

Merseburg	560	Breslau	405
Hannover	270	Halle	594
Frankfurt-am-Main	1300	Dortmund	430
Mannheim	717	Cologne	303
Mainz	480	Düsseldorf	545
Danzig	600	London	614
Berlin	1048	Paris	1515
Bremen	300	Columbus (U. S. A.)	215

ORGANIC AND MINERAL MATTER IN MUNICIPAL SEWAGES

	Per Cent.		Parts per Million.	
	Min.	Org	Min.	Org.
Bremen	40	60	120	180
Mainz	60	40	288	192
Cologne	29	71	88	215

The concentration of sewage is less when the water consumption is large, as at Columbus, O., where, with a water consumption of from 58 to 100 gallons, the suspended matters are only 215 parts per million. At Cologne, under the very high water consumption for German conditions, of 42 gallons per capita, the suspended matters are only 303 parts per million.

The quantity of organic matter varies but little, and averages perhaps 200 parts per million. On the other hand, the mineral matter varies widely and its quantity is largely controlled by the quantity of sand carried by the sewage. This is especially true of cities situated near large barren, sandy areas such as Berlin, Charlottenburg-Westend and Dresden-Neustadt.

Cities with a large working population are also to be included, such as Berlin, Mannheim and Paris. High concentration depends upon a low water consumption which, for example, in Berlin with but few modern water closets, averages only 4 gallons per capita. However, such cannot be said of manufacturing cities in which the sewages contain much free acid and iron salts, because the suspended matters to some extent pass into solution.

The suspended organic and mineral matters correspond to the following specific gravities:

Heavy sludge forming solids..........	$S > 1$
True suspended matter...............	$S = 1$
Floating matter.....................	$S < 1$

where S is the specific gravity of the water, or more exactly, that of the sewage containing only matters in solution.

Floating matters, matters in actual suspension, and the lighter sludge forming solids are chiefly of organic origin. These comprise feces, fatty matter, threads, food débris from man and beast, and sawdust.

The heavier matters, on the other hand, are chiefly of a mineral nature. To these belong sand, gravel, coal dust, (particularly in manufacturing cities and near coal mines such as at Könighütte) and also organic substances such as coffee grounds, coke and bones. All sewages contain also more or less large objects such as paper, straw, wood, entrails, corks, pieces of fruit and dead animals.

Because of the different composition of the suspended matters different devices are required for their removal. The heavier solids are separated by sedimentation, that is, by reducing the velocity of the sewage. Such is what takes place in the grit chambers. The lighter suspended matters are removed by means of settling tanks, sedimentation towers and the Kremer apparatus. Floating matters are intercepted by means of baffles submerged perhaps ten inches. The true suspended matters can be removed only by screens, which should be arranged to cover the entire cross section of the sewage stream. Refuse is generally retained by the coarse screen at the entrance to the plant. It is not possible, however, completely to separate the different classes of suspended matters by means of the devices just mentioned. Large lumps of organic matter already intercepted by the screens may become weighted by mineral matters and then deposited in the grit chambers. Finely divided mineral matters may cling to organic matter on account of its stickiness and thus pass through the grit chambers to the sedimentation devices.

Finally, in many instances no effort is made to remove the lighter sludge-forming substances by sedimentation, for they may be removed at the screens at a current velocity sufficient to keep them in suspension.

CHAPTER III

COMPONENT PARTS OF A CLARIFICATION PLANT

By the different devices in a plant there are removed:

1. Suspended matters of a certain size;
2. Suspended matters of a certain specific gravity, either greater or less than that of the sewage.

COARSE AND FINE SCREENS

Devices which remove suspended matters of a given size to some extent, fishing them or straining them out, are called screens. There are two types of screens, coarse and fine. The former consists of single bars or gratings, set at considerable distance apart. The latter are generally arranged in net shape; less frequently they are constructed as a harp.

The dividing line between coarse and fine screens lies at a clear mesh of about 15 mm. (0.6 inch). However, this figure is of no importance, since the characteristic difference of the two types of screens lies in the different uses to which they are put.

Coarse screens remove all refuse material which may injure the pumps, lower their efficiency or clog the force mains and suctions.

Fine screens are for the purpose of removing suspended organic matters as completely as practicable. In plants where no pumping is required the distinction between coarse and fine screens is not often made. In some cases a strong screen of coarse mesh takes the place of the grating. This removes the coarser floating and suspended débris besides coarse refuse material. In others a single grillage is used, with such a small clear opening as to take the place of the coarse screen.

Coarse screens are necessary before pumping stations and inlet piping. The upper limit of the clear opening depends upon the condition that no material shall pass that will injure the pumps. The lower limit, on the other hand, depends upon the effort to remove only what is necessary in order to keep as low as possible the operating costs in the screen plant, since pumping stations and suction pipes are often disadvantageously placed in this regard. At the plants visited the clear opening of screens ranged from 15 to 25 mm. (0.6 to 1 inch) (See Table No. I). It is not practical, however, to increase the opening much over 15 mm. (0.6 inch). For example, at the Tankgasse pumping station at Cologne an open space of 22.5 mm. (0.9 inch) has proved too large, since refuse materials such as threads, cloth, rags, animal entrails and the like, adhere to the axles and blades to such an extent as to lower the efficiency of the pumps and must be removed every five to eight days.

In some cases two screens are arranged, one in front of the other. The first has a large clear opening, as at Brühl, Eschweller, Hamburg, and Wiesbaden. Its purpose is merely to intercept very coarse substances which can easily injure the moving parts of the pumps. Such a device is of especial advantage if the water of any small stream in the city reaches the sewers, since under these conditions there may be encountered very large objects, such as limbs of trees. Such screens must be of specially strong construction and the clear opening should be from perhaps 12 to 16 cm. (4.8 to 6.4 inches). A smaller spacing is not advisable, for otherwise, there would be removed large quantities of material which can just as readily be intercepted by the 15 mm. (0.6 inch) screen. It is to be stated that double screens immensely complicate the operation of a plant, especially in case power is used. This fact has caused Mairich, in the works designed by him at Beuthen, Langensalza, Ohrdruf and Guben, to break up the suspended matters by compressed air in order that they may pass through the screens and be removed in the settling basins.

In general, such provisions are applicable only to small plants where, on account of the small quantity, it does not pay to work them for by-products separately from the sludge. For larger plants such a procedure is of less advantage for the following reasons:

1. Operating charges are lower when no compressed air is used.

2. The use of compressed air is impracticable because the screenings, on account of their nature and their slight water content, can be worked to better advantage for by-product apart from the sludge.

3. It is possible that the disintegrated screenings, on account of their small weight, will, in part, not settle in the settling tanks nor in the sedimentation towers, but will either pass out with the final effluent or will require special devices for their interception.

4. It is improbable that refuse such as animal débris, and rags, will be broken up by the air.

The high operating charges which arise with respect to the disposal of the screenings, especially when the location of the pumping plant is not the most advantageous is the reason why screens have been abandoned at pumping station No. 1 at Charlottenburg. This was done notwithstanding the fact that it is necessary to clean the pumps every 3 to 8 days, and at the same time shut down the plant. The saving in operating expense is, however, $1,250 per annum. Perhaps these inconvenient shutdowns of the pumping plant may be avoided by the use of membrane pumps instead of centrifugal or the single-plunger pumps. Membrane pumps have a membrane or screen in front of the plunger to protect it from actual contact with the flowing sewage.

THE DESIGN AND OPERATION OF COARSE SCREENS OR GRATINGS

The design of coarse screens, devices for scraping screens and for the removal of screenings has developed rapidly in recent years.

There are two kinds of coarse screens or gratings,—fixed or movable. Fixed gratings are constructed of:

1. Wooden grillage set upright;
2. Iron grillage set upright;
3. Iron grillage set horizontally;
4. Iron teeth set radially.

Movable gratings comprise:

1. Fixed rods with movable scrapers;
2. Movable rods with fixed scrapers;
3. Movable screens without mechanically operated scrapers;
4. Movable screens with movable scrapers.

These designs only partially correspond to requirements in the interest of rational, practical and hygienic operation.

In addition to the features already discussed, such as duplicate screens, accessibility and mechanical versus hand operation, there are still to be considered the following points:

1. In the case of interrupted operation of the pumps the necessity that the gratings can be cleaned without removing the sewage from the screen chamber.

2. In case pumping is not interrupted, the necessity that subsequent treatment shall also not be interrupted, neither in scraping nor in removing the screenings from the moving screens, which are, of course, required in such cases.

Disintegration of the refuse material is also to be avoided with continuously operated screening devices or in case there are fine screens or the Kremer apparatus beyond the coarse screens. This is requisite in order that the screenings may be removed as completely as possible above the sewage and that the relative lineal velocity of the sewage may be sufficiently low to retain the intercepted suspended matters on the screens.

Finally, emphasis is to be placed upon a rapid removal of the intercepted screenings, since by this means the efficiency of the screens is increased and the backing up of the sewage in front of the screens is lessened.

If the quantity of the screenings in the sewage varies widely, it is advisable in machine-operated screens, to provide a number of different speeds. In non-interrupted operation also, devices should be arranged so that the screens may be lifted out of the sewage for repairs. In a few plants it is possible to change the clear opening of the screen when the plant is shut down. This is accomplished by inserting rings of different thickness between the individual rods which rest on circular cross rods. These are easily arranged, but are more necessary for experimental plants than in practice. Of course, such devices cannot be used when the screens are cleaned mechanically. Fixed vertical rods are not adapted to the intermittent operation practiced in small plants.

If the sewage remains in the screen chamber so long that the latter is not emptied more often than once in four weeks for cleaning the grit chamber connected therewith, only a superficial cleaning is possible. In such cases the workman, standing upon a foot bridge, with an iron hand-rake or pole, scrapes the accumulations on to a drain or shelf which extends above and along the side of the screen chamber. This shelf is perforated with small holes so that the water may drain off, and has a tipping-bucket at one end for the reception of the screenings. With the rake the workman can with difficulty reach the lower part of the screen and control his operations. Deposits near the bottom of the chamber, therefore, often cannot be removed, and they putrefy and emit bad odors. Moreover, it is not possible to observe breaks in the screen. Extensive repairs require the removal of the sewage, and stairs are provided to make the screen accessible after the sewage is drawn off. Such simple arrangements are found in the old Berlin pumping station and in a few smaller plants in Rhineland, as at Pfaffendorf near Koblenz and at Bernkastel.

A suitable construction for intermittent operation is of iron radial screens, as at the Charlottenburg pumping station. (Fig. 5.) Here the screenings are raised by a rake whose teeth fit between the bars of an inclined screen. The screen is somewhat bent on top so that the screenings may slide into a waiting tip-wagon. The operator from time to time, cleans the exposed part of the screen with a brush or a stream of water.

When out of service, the entire rake may be raised by means of a chain or a windlass so that the material clinging to the teeth may be removed or repairs be made.

The rake is raised either in the plane of the screen or turning around the upper corner, as is the case of the dumping screens at Dresden (Fig. 2 on Plate II). Such a device before a fine screen may serve to prevent the clogging of the latter.

In order to drain the screenings as much as possible, a tip-wagon is used, as at Göttingen. On the side into which the screenings fall this is provided with coarse and fine screens so that there is removed a part of the water drawn up with the screenings. (Fig. 1, Plate I.*)

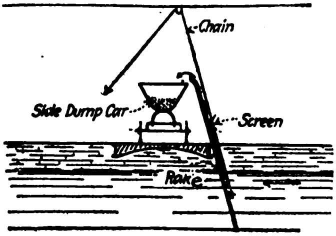

FIG. 5.

Fixed screens are placed beyond the grit chambers in intermittently operated plants. The grit chambers then serve as a storage basin during such times as the plant is out of service. Fixed screens would be permissible in front of the grit chambers only when the sewage flow is cut off and the sewage allowed to accumulate in the sewer during the raising and cleaning of the screens. This arrangement, however, is not advantageous on account of sludge deposits in the sewers, especially if they have a flat grade.

If the coarse screen is in front of the grit chambers there is the advantage that the coarse particles, which

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* Ztsch. f. Arch. und Ingenieurwesen. Jahrgang 51.

consist partly of heavy mineral matter and partly of light organic matter, are broken up in passing through the screen, and by this means there is reduced the quantity of putrescible matter deposited in the grit chambers. However, there is the greater disadvantage that in this arrangement the sand carried by the sewage will work in between the scrapers and the screen, hastening necessary repairs and interfering with its proper operation.

Fixed Horizontal Screens. If the operation of the pumps is strictly continuous, or at least if pumping follows screening, only fixed horizontal gratings are to be considered (Fig. 6). Such screens form a continuation of the invert of the main sewer and have at their upper end a perforated shelf from which the screenings are removed by a workman. The shelf has a detachable section at its lower end or else ends at a height sufficient to permit the screenings to be dumped into a tip-wagon or on to a belt conveyor.

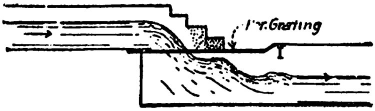


FIG. 6.

Screens with mechanical scrapers are more reliable than laborers, especially for night work. They are also recommended for hygienic reasons, and for large plants on the grounds of economy. Mechanical scrapers may be arranged as in Fig. 7 or Fig. 14. The screenings are not only removed, but they are raised as well. Scraping is effected by means of rakes whose teeth fit into the openings between the bars. These rakes are often fastened to an endless belt or to a loose chain which moves, in the direction of the sewage, over three drums. By this means the screenings are removed very rapidly. Small movable screens are usually arranged to remain about in a horizontal position during their upward movement, and to fall down on reaching the top. This, effected by the action of a small releasing device, causes the screenings to slide on to an inclined perforated chute or on to a belt conveyor, either directly or through the medium of a special metallic chute. If several small screens are arranged side by side, one belt conveyor may be used for all three. From the chute or the belt conveyor, the screenings pass to a tip-wagon or on to an elevator or a second conveyor which removes them to the dumping ground.

Horizontal coarse and fine screens require a certain fall, according to the velocity of the incoming sewage (compare Figs. 6, 14 and 1*a*, Plate II). Such screens are undesirable if the volume of sewage varies greatly, as is always the case when the sewers are on the combined plan. If the screening precedes pumping, horizontal screens may be completely submerged through the negligence of the pumping-station operators.

Inclined Screens. In the larger plants, as at Paris, Manchester and Cologne, inclined screens are used instead of horizontal screens. They require only a slight fall, depending upon the reduction of the cross-section of the sewage channel. These screens are either inclined in the direction of the current, as at Paris, (Fig. 8) or against it, as at Cologne (Fig. 14) and Manchester (Fig. 7).

In an exactly upright position there would be many constructional difficulties with regard to the automatic removal of the screenings.

Scraping is accomplished by movable rakes fixed to an endless chain which runs over two drums. Link chains are most practical, for they may be made of different lengths by inserting a link. If it is necessary to prevent the lateral motion of the scraper, teeth may be attached to the drum; these mesh into groove guides. If the screen is inclined with the current, the scraping rake is

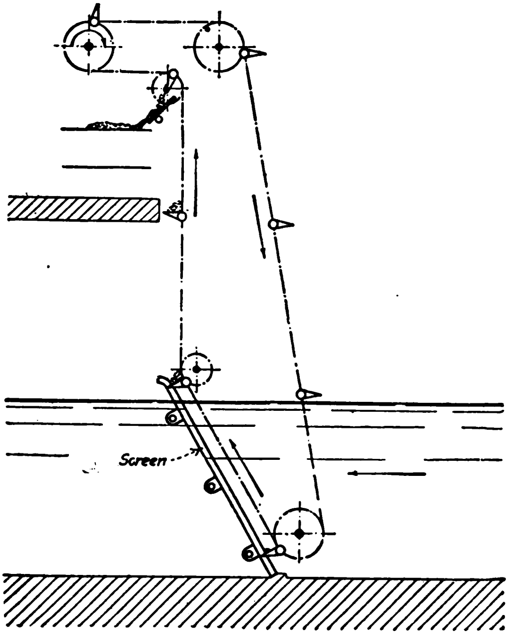


FIG. 7.

arranged to interlock at definite intervals, (Paris 17 cm., 6.8 inches) on the upstream side and move upward in a direction opposite to that of the current. Otherwise, the rakes on the down stream side move upward in the direction of the current and engage in the screen once only. In order to prevent the teeth from catching in the screen, the movable scraper is a simple shovel or brush, which moves between the screen rods. The shovel scraper generally is provided with a rubber or a leather strip on the bottom to allow an intimate contact with the screen at all points.

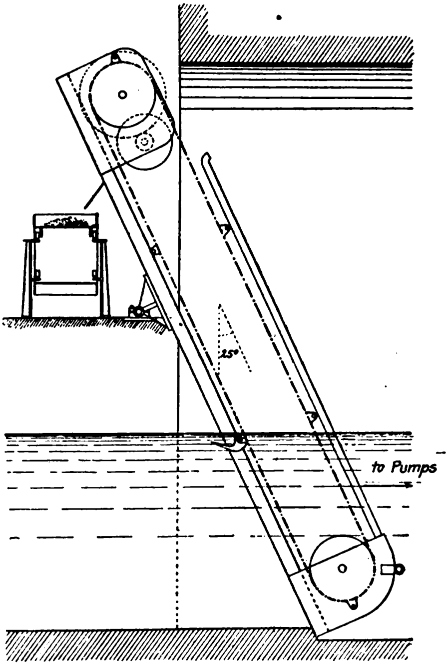


FIG. 8.

The advantage of the Paris construction lies in the fact that the screenings, especially entrails and rags, do not come in contact with the moving parts and cannot cause interruptions in the operation of the screens. Its disadvantage lies in the great possibility of the clogging of the engaging teeth of the rakes when angular hard substances are caught between the rods of the screens. The greater relative motion of the screenings during the upward movement of the screen against the sewage causes their partial disintegration.

This Paris design, therefore, is suitable only preceding clarification in basins or towers, before which gratings are indispensable.

The second design, which is found at the four-unit screening plant at Cologne, has the disadvantage that the lower end of the moving parts lies in the unscreened sewage. It is, therefore advantageous to provide a grating before it. Disintegration of the screenings is then lessened, and hence the device is more advantageous for automatically operated screens than fine screens or the Kremer apparatus. It is, however, in successful operation at the Hamburg plant described below.

Movable Screens and Fixed Scrapers. Another solution of the problem of the mechanical removal of screenings from sewage is movable screens with fixed scrapers, as developed at Hamburg and Schöneberg. Here the moving screen consists of a number of single rods which are connected together like the links of a chain (Figs. 9*a*, 9*b*, 9*c*). On account of the necessity for light-weight construction, a light metallic alloy is used instead of iron. The length of one link is about 35 cm. (14 in.). This belt screen, which is inclined against the current, moves with the current upward over two drums. In Hamburg the velocity is 2 cm. per second (4 ft. per min.).

The fixed scraper at first designed (Fig. 9*a*) threw the screenings on to a belt conveyor, but did not work well and was replaced by the design shown in Fig. 9*c*. Here the screenings are scraped off by means of a hard rubber comb whose teeth engage in the screen (Fig. 9*b*).

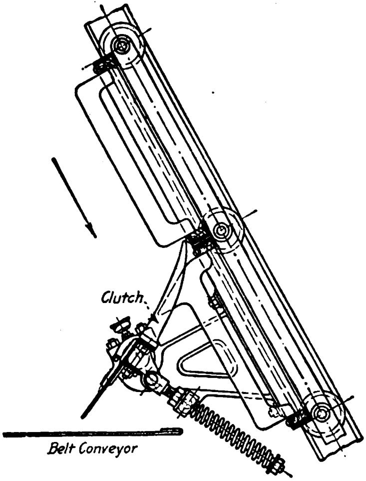


FIG. 9*a*.

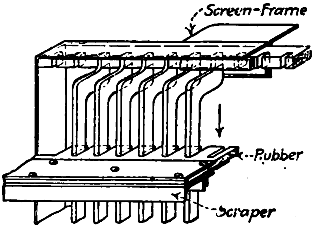


FIG. 9*b*.

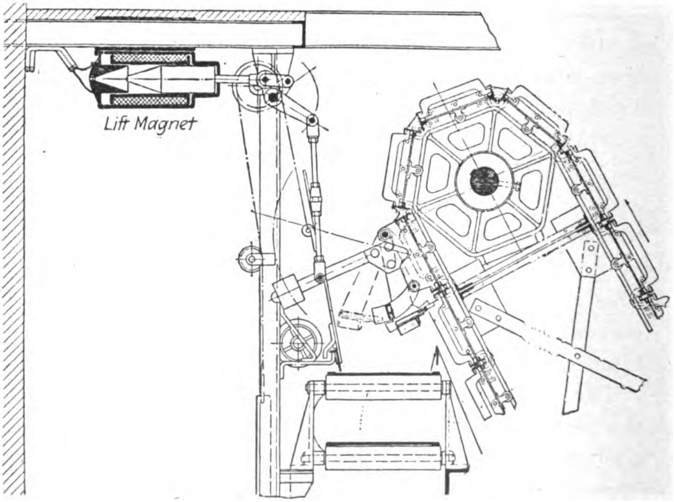


FIG. 9*c*.

By means of a second movable scraper the screenings are then carried to a belt conveyor. This moving scraper comes into action only at the moment when the trough passes the cam between two teeth.

Formerly in Hamburg the belt conveyor discharged on to a long conveyor. The land around the plant was subsequently built up and the long conveyor was replaced by the Lowren apparatus when the previous plan became unsatisfactory. According to Hamburg views such a plant is not so complicated as that at Cologne and Paris. The former possesses the great advantage that no part of the screen is constantly under water, and hence defects may readily be observed and repaired. The Cologne and the Paris screens, on the other hand, require special cranes for the removal of the screens for repairs. This consumes more time and necessitates greater labor expenditure. Further, the disintegration of the screenings is very much less at Hamburg, since the screen is scraped above the sewage line, and also since the screenings are thoroughly separated out. They fall off chiefly in the space over the links between each two moving rods (Fig. 9c). The disadvantages of the moving screen are its great weight and the fact that it cannot be stretched.

Screening devices similar to the Hamburg design are unconditionally preferable in automatically operated screening plants where as much as possible must be removed from the sewage, and also in case there follow fine screens and no settling tanks, a case where a disintegration of the screenings is to be avoided.

Wing Screens. The second type of moving screens is the so-called wing screen, as at Frankfurt, Düsseldorf and Wiesbaden. These screens comprise five or six sheets of screen rods which are arranged in a well like the wings of a windmill and turn in a direction opposite to that of the sewage (Fig. 10). In order that the flowing sewage may flow through the screen at each instant the invert of the sewage channel must have a cylindrical depression.

Screens of the wing type offer a number of advantages over fixed screens, as follows:

1. The condition of the screen can be under continuous supervision, since no part is continuously under water.

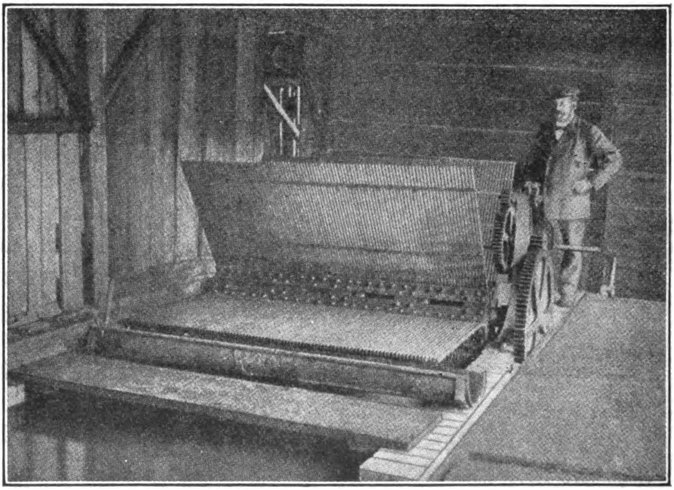


FIG. 10.

2. Scraping takes place out of the sewage, thereby lessening the disintegration of the screenings and increasing the efficiency of the screens.

3. The work of the screen can be noted at a glance.

The disadvantages of the wing screen are that the screenings are forced directly against the sewage and are thus broken up, and hence the advantage mentioned under (2) does not obtain. A wing screen, therefore, is feasible only preceding clarification in basins and towers; not as an independent plant or preceding fine screens. Wing screens may be hand-operated by means of a crank which is turned as soon as one sheet is sufficiently loaded. At rest, one sheet always lies at right angles to the sewage current and the loaded sheet is then cleaned by a workman who brushes the screenings into a wagon which stands upon a platform above the screens.

Such a screen would be satisfactory only for small plants or where the clear opening between the bars is large and where the quantity of intercepted matter is small. Düsseldorf clear opening is 155 mm. (6.2 in.).* The Scheppendahl design (Fig. 10) with hand drive is to be compared with the machine driven Uhlfelder screen at Frankfurt. (Fig. 1*a*, Plate II). Here the screenings are scraped off on to a platform by the lower half of an eccentrically moving wheel hung above the screen. A revolving brush placed behind the screen and cleaned from time to time by a stream of water, provides for a thorough cleaning between the screen rods. When the wheel reaches the periphery of the screen, released by a special device, it falls on to the next screen sheet. The uppermost sheet is tipped by the movement of the screen, and the screenings are caused to fall onto a conveyor.

The Frankfurt screens fulfill the requirements of hand operation ideally; likewise devices in use at Hamburg, Cologne and Paris. Unfortunately, on account of their motion, all the important parts are not free from liability of breakage.

Clear Opening. The following table shows a few data regarding the clear opening of screens at different places:

*Gesundheitsingenieur, Jahrgang 25 (1902), p. 398.

TABLE NO. 1

SCREENS BEFORE PUMPING STATIONS

Place.	Clear Opening.	
	m.m.	Inches.
Charlottenburg	15	0.6
Cologne	22.5[*]	0.9
Mannheim	20	0.8
Paris	25	1.0
Hannover	10	0.4

SCREENS BEFORE CLARIFICATION PLANTS

Place.	Clear Opening.	
	m.m.	Inches.
Brühl at Cologne	100 and 50	4.0 and 2.0
Cologne	15	0.6
Düsseldorf	155	6.2
Hamburg	150 and 15[†]	6.0 and 0.6
Marburg	15	0.6
Leipzig	8	0.32
Frankfort	10	0.4
Wiesbaden	40 and 15	1.60 and 0.6
München-Gladbach	45	1.8
Pffafendorf b. Koblenz	25	1.0
Aachen	20	0.8
Boltrop	15	0.6

[*] Has proved too large.

[†] The new Hamburg plant provides only a 10 mm. (0.4 inch) clear opening.

DESIGN AND OPERATION OF FINE SCREENS OR SIEVES

Fine screens are fixed or moving, and are independent or in combination with grit chambers. Independent fine screens which are recently in favor in Germany where ample dilution is available, are intended to replace settling tanks or settling towers. They should remove as much as possible of the suspended matters which ordinarily pass the grit chambers and the coarse screens.

Several conditions are necessary in order that fine screens shall operate successfully:

1. That no disintegration of the screenings takes place on the screens;
2. That no backing up ensues in the sewage channel to produce objectionable deposits of sludge;
3. That the screens be easily interchangeable;
4. That the screens be quickly adaptable to variations in the sewage flow.

The first condition is not satisfactorily fulfilled in any of the plants so far built, excepting perhaps, the plant at Göttingen, and this plant should really not be considered on account of the large open space (11 mm.) (0.44 in.).

To prevent the disintegration of the screenings it is necessary:

1. That the sewage does not become stale before it reaches the screens. Otherwise the screens will be ineffective, since angular pieces of sludge readily break up and pass through.
2. That the intercepted screenings are removed above the sewage and are not forced back into it by the brushes.
3. That the intercepted matters are removed from the sewage as soon as possible, that is, before they are forced through the screens by the current.
4. That in order to avoid the disintegrating effect of water pressure, the relative velocity of the screenings be as low as possible whilst the screen is being raised.

It is also to be noted that as soon as the screens are heavily clogged, sewage backs up in the screen chamber aside from the effect of the cross-sectional change itself.

Fixed screens, especially vertical or inclined screens, do not satisfy the above requirements. Horizontal screens are better in so far as the screenings are forced out of the sewage by the current and can be removed from above. However, the cleaning of such screens is a disagreeable task. The disintegration of the screenings is considerable on account of the high current velocity, and a fall of at least 20 cm. (8.0 in.) is necessary, a quantity not always available.

In the design shown in Fig. 11, where the fine screen forms a continuation of the invert of the main sewage channel, both of the last-made criticisms obtain less than in that shown in Fig. 12. It is advantageous to bend up the screen at the lower end to prevent its being flooded with sewage.

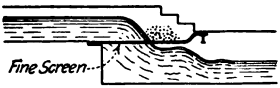


FIG. 11.

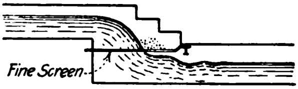


FIG. 12.

Plants visited where there are moving fine screens are not wholly without objectionable features. The screen is either fixed and the scraper moves, or vice versa, or the scraper and the screen both move. The first-mentioned design is not to be recommended except for horizontal screens, because in that case the screenings are scraped off under water. A screen of this type is at the Wiesbaden plant described by Forbat. Here brushes which move on endless chains lift the screenings on to a perforated band which deposits them into a cart (Fig. 13).

A decided improvement over this screen is that at Bromberg and Insterburg, designed by Metzger. Here, the sewage flows into a semi-circular channel where it piles up until it flows over one side into a fine horizontally placed screen with meshes 3 mm. ($\frac{1}{8}$ in.) apart. Scraping is effected mechanically by brushes arranged similarly to those shown in Fig. 13. The brushes discharge into a wheelbarrow, whence the screenings are removed to the point of disposal. It must be added that with such a design, the fine suspended matters are broken up on the screen by their own velocity. Further, the channel in front of the fine screen must be so designed that there will occur no objectionable deposition of suspended matter.

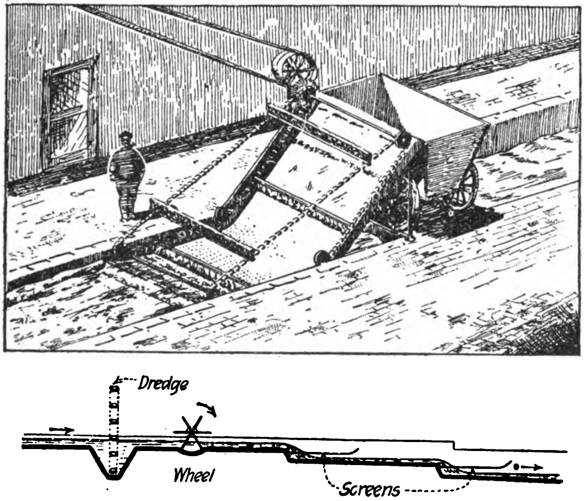


Fig. 13.

An example of a fixed fine screen with a moving scraper is that patented by Riensch and in use at the plant at Düsseldorf (Fig. 15). This consists of four fine screens,

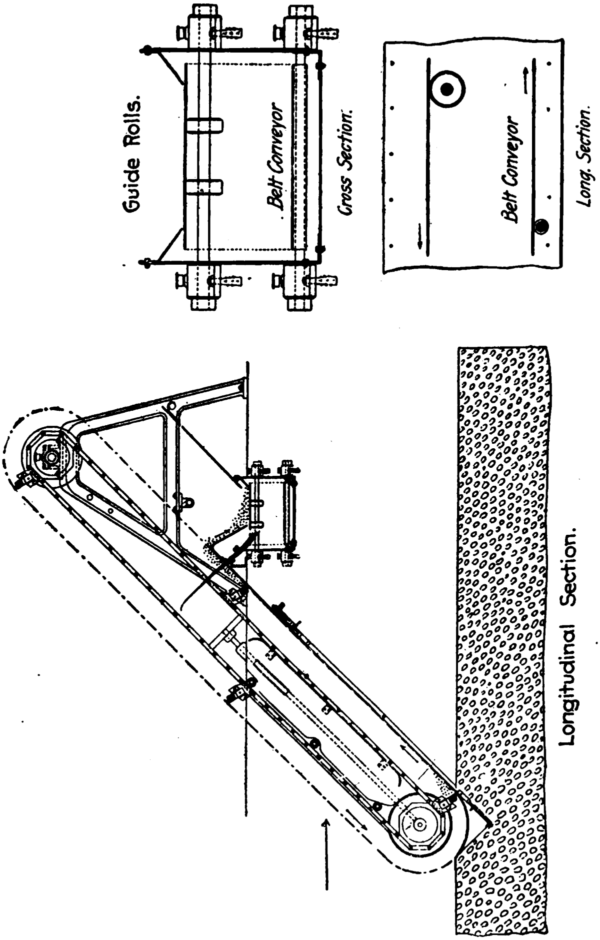
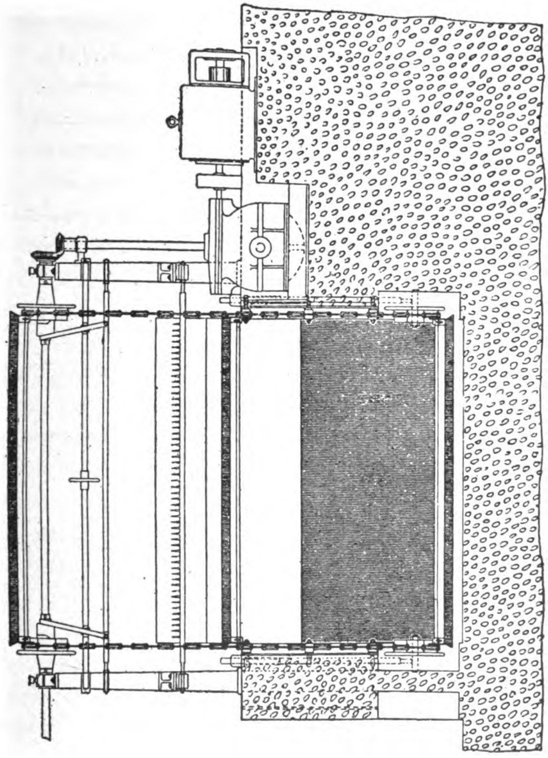


FIG. 14.

so-called harp screens, constructed of steel wire spaced 3 mm. (⅛ in.) apart. The wires are under a tension of 500 kilograms per square centimeter (7100 lbs. per sq. in.) in order that they may not be forced apart sidewise.



Cross Section.

FIG. 14.

For this reason steel wires were selected, although they must be renewed every four years. Copper wire cannot withstand this high tension. The cleaning of this screen is effected by four combs whose teeth are formed of thin vertically placed steel plates which move upwards between the wires. Formerly, brass and steel wire brushes were used, but they proved much too expensive. The four combs are placed on the spokes of a wheel which moves in the direction of the sewage current. The length of these spokes is telescopically varied by sharp dogs which run in check rails on the walls of the channel. By this arrangement there is effected the movement of the combs over the entire length, top to bottom, of the somewhat curved hoop-shaped screen. Above the screen the screenings are thrown on to a conveyor by an automatic scraper. The action of the Düsseldorf harp screen is interfered with by wool fibres from the wastes of the woolen mills and by pig bristles from packing-house sewage.

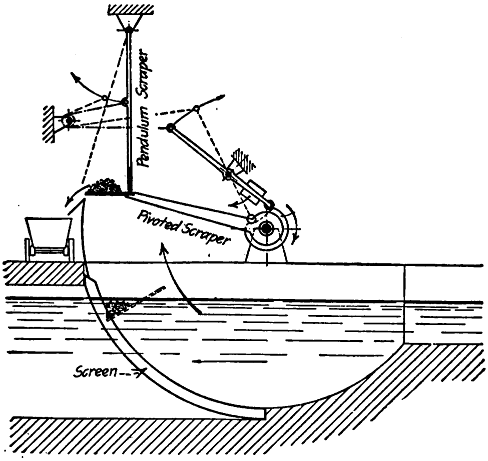


Fig. 15.

A similar harp screen, as is also in use in Mainz, fulfills completely, however, the official requirement that matters of a certain size shall not be allowed to enter the stream. These harp screens possess the further advantage that parts, such as the wires and combs, subjected to wear and tear are comparatively inexpensive and can easily be replaced. They afford, also, an example of the disintegration of the coarser suspended matters carried by the sewage. These substances are practically not removed at all, since those which are not broken up by the wire of the nearest vertical string are cut by the vertically placed comb and pass out with the effluent.

In Cologne a grid with bars spaced 3 mm. (⅛ in.) apart has been constructed instead of a fine screen. Its construction is the same as that of the previously described screen with 15 mm. (⅝ in.) open space (Fig. 14). A fine screen of this kind causes a decided backing up of the sewage, because the bars are the same size as the clear opening and because the spaces between the bars cannot be cleaned completely by scraping with brushes. To overcome this difficulty, at Cologne, the channel is widened between the coarse and fine screens. The disintegration of the organic matters is, however, less at Cologne than at Düsseldorf, for the cutting effect of the fine wires and steel combs is absent. The author noted that there were removed a large quantity of sludge-forming matters, such as solid feces, but with due justice it is to be stated that the Cologne plant was visited at 10 o'clock in the morning, an hour when the sewage is especially strong.

BELT SCREENS

By the use of moving screens either in the form of belts or bands, sheets or perforated drums, it has been the endeavor, with partial success, to overcome the common fault of the fixed screens just described,—that is, their tendency to disintegrate the coarse suspended organic matters.

A plant with an endless belt screen of small mesh is at Göttingen (Fig. 1, Plate I). The screen is a netting of braised copper wire 1½ mm. ($\frac{1}{16}$ in.) in diameter and with a clear opening of 11 mm. (0.44 in.). A belt of perforated brass sheet did not prove successful, since it burst under the heavy tension sustained. A belt of copper wire also stretched out of shape and had to be continually shortened.

The 17-m. (56-ft.) belt moves with a velocity of 2.48 m. (8.1 ft.) per minute in a direction opposite to that of the sewage, over two drums 50 cm. (20 in.) in diameter, the upper one of which is belt-driven. In order that there may be no depression in the flow line of the sewage, the carrier is sumped about 70 cm. (28 in.) just beneath the lower drum (Fig. 1, Plate I). To cause the suspended matters to pass on to the screens as much as possible and to prevent them from slipping through near the walls of the channel or becoming lodged under the lower drum, a so-called moving boat is arranged in the lengthened channel, and this somewhat contracts the cross-section of the stream of sewage.

A uniform movement of the screen belt is effected by suitable devices, such as rubber-coated slide rolls. The belt screen is inclined 45 degrees toward the current so that the relative velocity of the enmeshed matters, when moving upward, is very slight compared to that of the sewage, and no disintegration is noticeable. The relative velocity may be reduced still more by making the angular inclination of the screen more acute. However, the angle must not be too small, especially when it is a question of dealing with very changeable sewage flows.

At intervals of 1 m. (3 ft. 3 in.) small pieces of brass are placed on the screen belt to prevent the loose screenings from falling back into the sewage.

The cleaning of the screen belt is effected by means of a belt-driven, revolving brush which is arranged below the driving drum and on the side of the screen opposite to that which contains the screenings. In addition, the screen is cleaned by a stream of water under heavy pressure. The screenings then fall into the previously mentioned tip-wagon which has sides constructed of coarse and fine screens so that the water brought up with the screenings and that used in cleaning the screens, may flow back into the sewer. The entire screen may be removed for repairs by means of a block and tackle.

The screen is also lifted at night, and the night sewage, which contains less suspended matter and screenings, flows only through a coarse fixed screen placed above the belt screen. The matters caught during the night are removed the next morning by the belt screen. The Göttingen design is the only one in actual operation, experimental plants excepted, in which there is no appreciable disintegration of the intercepted fecal matter.

Unfortunately, it is improbable that it will be found practical to obtain results with screens of this type, that is, with clear openings as small as 1½ mm. ($\frac{1}{16}$ in.). In construction there are a number of difficulties to be overcome. The smaller the clear opening, the finer must be the wire used, and the more serious becomes the effect of stretching. Perhaps, however, it is possible to design a net screen of wide mesh and sufficiently strong wire to permit interweaving a fine screen of fine wire. If the screen-belt were composed of a number of sheets arranged similarly to the coarse screens at Hamburg, strains could then be made of no moment. These Hamburg screens are wire gauzes which are surrounded by rectangular iron frames connected together like the links of a chain. A similar device is in use at Bromberg in Nakel, where the frames consist of upright pieces of iron, which prevent the screenings from sliding off.

The feature to be avoided in screens of this type is the passage of the sewage between the links connecting two screens. In Nakel the problem was easily solved because there the belt is not built in the sewage channel, as in Göttingen, but the sewage falls down onto the screen from a channel which is directly above the same. It is, therefore, sufficient to provide each joint with a small metal plate which covers the link in the direction of the motion. The development of the inlet cannot be carried out when the flow of sewage is great, since, on account of the greater velocity, there would then result a disintegration of the screened material. The difficulty of fitting a tight cover over the links, as well as the disadvantage that the moving parts of the screen-belt come in contact with the sewage and may therefore be corroded, cause the omission of a screen belt in the new plant in Bromberg and the substitution of a drum screen, which is entirely above the sewage and has no moving parts like the above-mentioned links. A more complete description of the drum screen cannot be given, since the design is not settled in all its details.

The clarification plant at Nakel is of special interest in that the screenings are neither scraped nor brushed from the screens, but are blown off by compressed air. The advantage of this method is apparent. It is exceptional for the intercepted screenings to be disintegrated on the screen, the screen is very thoroughly cleaned, and, of the greatest importance, the screenings are obtained in a very dry condition. Of course, the use of compressed air makes the operation of the screening devices more expensive. It is therefore a question of constructing a blower which will use as little air as possible. For supplying the air, a pipe with bottom perforations is very satisfactory. This is caused to move back and forth over the screen in a direction at right angles to the same.

A third method, which makes possible the immediate removal of the screenings from the sewage and outside scraping, is the fine screen disc or separator of Riensch, as used in the testing station at Dresden (Fig. 2, Plate II). Here the sewage flows through a circular rotating perforated brass plate with openings 2 mm. (0.08 in.) wide. The screen is inclined at an angle of 15° so that one half of it is above the sewage. The screenings are removed by brushes which revolve in a plane parallel to the screen, and cause the screenings to fall onto a conveyor.

Riensch has further improved this device at the Graudenz plant. At this plant the screen disc carries a small screen concentrically placed, and a frustrum of a cone in shape. This small screen is cleaned by a special brush. To make the device more rigid braces are attached to the sides of the central cone screen. It is not desirable that the sewage flows directly upon the screen and it is much better if the screen is built within the sewage channel so designed that the sewage reaches the screen under a velocity not more than about 0.1 m. per second (20 ft. per min.).

Such a screen also possesses the theoretical disadvantage that the screenings which are deposited on the side where the cleaned surface dips below the sewage are exposed to the full pressure of the sewage, so that they are appreciably disintegrated. Furthermore, the screen is very rapidly clogged at certain points. This objection can be eliminated by increasing the velocity at which the screen moves.

On the other hand, fine disc screens possess the advantage that they require the sewage channels to have an elliptical form, which conforms better to egg-shaped trunk sewers than the right-angle section which is required for a band screen. The removal of the intercepted screenings by brushes is not advantageous if the sewage contains considerable fecal matter, for this is broken up on the screen, passes through the openings, and in part escapes with the effluent. It is more difficult to arrange for the compressed-air cleaning of disc screens than band or drum screens. Compressed air is very satisfactory, but of course, increases operating expenses.

Experiments with screens of fine mesh have been carried out by Metzger in Bromburg. These, however, have not yet been completed.* The present results of Metzger's experiments may be summarized as follows:

1. The screen surface must be larger for equal volumes of sewage the more concentrated the sewage, that is, with reference to the relative quantity of suspended matter the average diameter of which exceeds that of the meshes of the screen. Therefore, the screen area is either to be based upon the size of the largest suspended particles or else arrangements should be such that the velocity of the moving screen may be varied.
2. The quantity of screenings retained and hence the efficiency of the screen is not influenced by the speed with which the screen moves. This latter fact is very important, for it permits a considerable economy in the area of the screen by increasing the velocity. According to Metzger, at a screen velocity of from 2 to 3 mm. per second (0.4 to 0.6 ft. per min.) the required area of fine screens is only one per cent of that necessary for fixed screens.

In experiments with fine screens constructed in Hamburg, the sewage was sprayed onto the screens. Naturally, under these conditions, the screenings were broken

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* Techn. Gemeindeblatt.Jahrgang 9.

up; the experiments were, therefore, not satisfactory and, moreover, the process is decidedly dirty. All screening plants hitherto constructed have but incompletely solved the problem of removing sludge-forming material, partly because the intercepted matters are greatly disintegrated on the screens, and partly because the mesh of the screens has been too large. The smallest mesh used to date is that at Wiesbaden, which is 1¼ mm. (0.05 in.). As Bredtschneider has shown, the average diameter of the sludge-forming matters is generally less than 1 mm. (0.04 in.). If, therefore, the suspended matters are not massed together in the sewage, but reach the screens in a finely divided condition as, for example, in the case of very long sewerage systems with considerable fall and many bends, and also following pumping stations, or in case water closets with narrow outlets are used (diam. < 10 cm. [4 in.]), then no satisfactory results can be obtained even with the finest screen yet built. It is, of course, possible to construct screens with still smaller open spaces than the above mentioned, but it is uncertain whether they will prove practicable, as the fine wires or sheets of which they must be constructed would offer but little resistance to the acids in the sewage and would be quickly broken by the cleansing brushes.

Of course screens may be cleaned by a jet of water instead of brushes. By this means, however, the water content of the sludge is increased and one of the principal advantages of the moving screen would be removed. The satisfactory removal of screenings under such conditions would be possibly only by means of air under heavy pressure. A fine screen constructed of strong metal plates with a greater space between the perforations could not be used without greatly increasing the backing up of the sewage, which is in any event, a large factor with screens of small mesh.

The fear that the fatty matters in the sewage would lower the efficiency of the screens, the author found to be nowhere justified. Screens with $1\frac{1}{2}$ mm. ($\frac{1}{16}$ in.) perforations retain only a part of the fatty matters; the larger part, however, pass through such fine screens as has been noted in Marburg and Mannheim, where fatty matters carried into the stream by the sewage are very rapidly devoured by the fish. On the other hand, hair, wool fibres and pig's bristles greatly interfere with the efficiency of the screens, since they make the cleaning of the screen more difficult.

With a view to increasing the efficiency of screens of fine mesh, it is necessary to construct in front of them a coarse screen with an open space not greater than 15 mm. (0.6 in.) and to provide a grit chamber in case the sewage carries considerable sand. Otherwise the backing up of the sewage, caused by the coarse suspended matter retained, bends the fine plates or the wires, and particles of sand force apart the sheets when the screens are cleaned with brushes, clog the screens and bend the wires sidewise, especially if the screenings are removed by combs.

Fine screens used in conjunction with a sludge sump are placed either in the inlet or within the sludge basin itself. In a few plants only are such screens to be found as in Marburg. The advantage of such a plant is the fact that a portion of the sludge is obtained with a comparatively low water content, but of course, the fact that the sludge is deposited at more than one point increases the cost of operation.

Fine screens are further disadvantageous preceding settling basins, particularly if they break up the suspended solids and render more difficult the subsidence of the finer suspended matter. Further, by the use of a fine screen there is to be expected no reduction in the number of settling tanks, since it is the office of the settling tanks to remove just the fine particles passed by the fine screen. Depending upon the cross-section of the tanks, the lineal velocity must be as low as possible and the length of the tank as great as possible. The fine screen merely reduces the quantity of sludge which is deposited in the settling tanks. It has not been shown that it is cheaper to clean screens than to remove sludge from basins, but, on the contrary, the proper design of settling basins and sludge drains, as will be described presently, makes possible the automatic removal of the sludge. On the other hand, fine screens are often built in the inlets of septic tanks. However, screens on the inlets possess the same disadvantages as when they precede the basins. They require, for example, the uniform distribution of the sewage over the entire width of the tank and they must not be cleaned so frequently as to interfere with its operation.

Fine screens with clear opening from 1½ to 3 mm. (1/16 to ⅛ in.) are, however, practicable immediately in front of the outlet. These remove all floating matters, and especially rising sludge in the state of active fermentation. Since the quantity of such matter is small, the screen rarely requires cleaning during a run of the settling basin. On this account the fact that the screen is constructed as a harp with wires under a high tension, makes it necessary materially to limit the backing up of the sewage, a feature which is undesirable with reference to the uniform velocity in the tank. In Manheim fine and coarse screens of other types have been abandoned at the outlets of the settling basins just on account of their retarding effect; moving screens are, of course, out of the question in such cases.

SEDIMENTATION PROCESSES

Devices by which there are removed from the sewage substances of a specific gravity greater than that of the sewage, are called settling tanks.

The operation of a clarification plant and the recovery of by-products from the sludge make it advantageous to separate the sludge according to its nature. The heavier portion, which is chiefly mineral matter, is first intercepted in grit chambers; while the remainder, which is chiefly organic matter, is removed in settling basins, settling channels, settling towers, or by the Kremer apparatus. In a few small plants, or where the sewage contains but little sand, as in Cologne, Düsseldorf and Bonn, the above separation is not carried out.

DESIGN AND OPERATION OF GRIT CHAMBERS

When no separation of sludge is attempted, the settling tanks generally comprise a single chamber in which the sewage is stored for a definite time, and on the bottom of which the sludge is deposited.

The cleaning of these tanks is difficult whilst they are in operation, since the sludge cannot be removed completely by a dredge. Some putrescible matter remains and eventually develops objectionable odors. Another possibility is to make the bottom conical with a slope of 1 to 1 and to cause the sludge to flow out while the plant is in service by means of a sludge drain on the bottom. In such cases the presence of sand is objectionable since it clogs the sludge drain; hence this arrangement is feasible only when there is but little sand in the sewage.

It might be possible to suck up the sludge to the point of a cone by means of a steam jet. However, a device of this character did not prove successful when used in Düsseldorf. Its chief disadvantage lay in the fact that too much water is drawn up and that it is not practical to use it while the tank is in service. In small plants it is best to cause the sludge to deposit in a bucket placed on the bottom of the tank. When cleaning is necessary the inlet is closed, the sewage is drawn off and the bucket is removed and emptied. At the sludge sump in the Bonn plant there is a removable screen basket which takes the place of settling tank, grit chamber, coarse screens and settling channel.

Grit chambers are of special advantage in the larger plants and where the sewage carries considerable sand. They are also desirable where the sludge from the clarification plant is burned or coked, where fine screens are used, and when the removal of sludge from the tanks or channels is effected without placing the settling devices out of service. They are also advisable before sewage pumps in order to prevent stoppages. If the sewerage system of a city is quite extensive and the sewer grades are small, as at Paris, and at Cologne it is also desirable to construct grit chambers at several suitable points in the system. From these, deposits may be easily and cheaply removed.

The deposition of mineral matters is effected by diminishing the velocity of the sewage. In the plants visited, this velocity varies widely. For example, Hamburg, (old plant) 100 cm. per second (200 ft. per min.); Aachen, only 1.7 cm. per second (3.4 ft. per min.); Wiesbaden, 50 cm. per second (100 ft. per min.); Elberfeld-Barmen, 5 cm. per second (10 ft. per min.). Since putrescible matters cause bad odors if they deposit in grit chambers, their deposition must be prevented, or in other words, the velocity must not be too low. It is recommended to provide a velocity of 30 cm. per second (60 ft. per min.), a figure which, in the light of previous experiences, has been chosen for the new Hamburg plant. Of course, the above figures are only average values, since the velocity varies with the changing sewage flow, and too much weight must not be attached to them. To allow for these variations, in Aachen the grit chamber is divided into several compartments only .57 m. (1.87 ft.) in width, of which one or more are in service at one time, depending upon the sewage flow.

The velocity of the sewage in the sewer ranges from 1 to 1.5 meters per second (3.28 to 4.92 ft. per second). One meter per second (3.28 ft. per second) is the lowest permissible limit if the deposition of sand is to be prevented. The velocity in the grit chamber is perhaps one-fifth of this and the cross-section of the tank is, therefore, required to be only 5 times that of the sewer. If a large number of compartments were arranged side by side they would prove to be too narrow, the design would be complicated by the necessary partition walls and would be too expensive. Besides, narrow channels, under 70 cm. (28 in.) are difficult to clean. A grit chamber with three or four compartments is sufficient even for a large plant. A further division of the sewage for subsequent clarification by fine screens or in settling tanks when necessary, takes place preferably beyond the grit chamber and the coarse screens (See Fig. 2, Plate I.).

Single compartment grit chambers, as at the old Hamburg plant and that at Wilmersdorfer, are not to be recommended for reasons previously mentioned in discussing general features of clarification plants. On account of the great width of the tanks in such plants where no sufficient fall is available, special dividing walls are necessary to cause the sewage to flow uniformly over the cross-section and the sludge dredge, to operate not only at the deepest point in the tank, but on the entire width of the cross-section and at different depths. It is obvious that this entails a very complicated design.

In computing the cross-sectional area for grit chambers it must be borne in mind that it is necessary that the putrescible matters do not deposit under the average dry weather sewage flow. On the other hand, if the mineral matters are to be removed as completely as possible, the maximum storm-water flow reaching the plant is the controlling factor. In general, grit chambers should be rectangular save for a few special shapes mentioned below. Grit chambers, circular in form, having radial partitions, can, of course, effect a much greater economy of space, but sedimentation is prevented by cross currents, and the difficulties attending cleaning are increased.

Grit chambers generally contain a depression in which the intercepted matters are deposited. The longitudinal section of the depression may be designed in a number of ways, but symmetrical forms with level depressions are chiefly used, as sketched in Fig. 16.

Designs shown in Fig. 17 are not practical because tanks of this form can with difficulty be cleaned with a brush, and because they tend to cause a nuisance from odors. Grit chambers on this plan, once used in Dresden and Wiesbaden, have since been remodeled. It is the best practice to design the bottom of the grit chamber with a circular cross-section, as in the case of sewers. Rectangular sections are not advisable, since the sludge which collects in the corners can with difficulty be removed by a dredge. In order to prevent the deposition of putrescible organic matter of low specific gravity, it is recommended to make the longitudinal section as shown in Fig. 18. The suspended matter which reaches the bottom of the tank passes from the section *aa* in a curve which is flatter than the sewage depression curve, on account of the resistance which the suspended matter

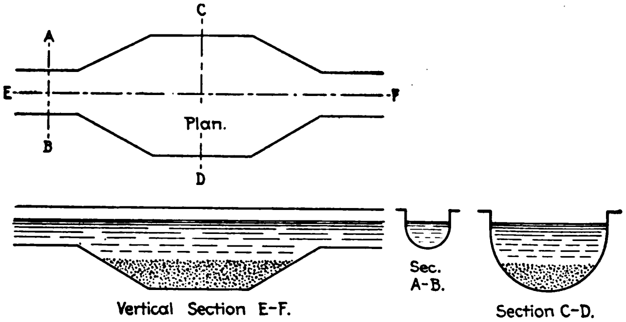

FIG. 16.

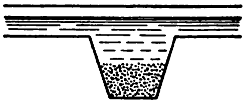

FIG. 17.

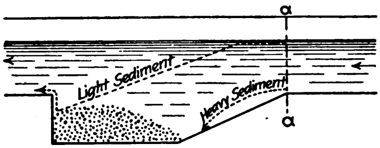

FIG. 18.

meets in falling through the sewage. The heaviest matters have already deposited on the first part of the sloping bottom and, owing to their weight, slide down to the bottom of the grit chamber. The lighter putrescible matters, on the other hand, which would still deposit on the lower part of the sloping surface, are prevented from so doing by a vertical wall and are carried along by the increased current velocity thus induced. A grit chamber with a longitudinal section of this character is provided at the new Charlottenburg pumping station. For the new Hamburg plant, on the other hand, a non-curved longitudinal section is used because it is desired that the heavy solids deposit as much as possible at the base of the coarse screens in order that they and the screens may be cleaned at the same time—a feature which is cheaper under Hamburg conditions (Fig. 19).

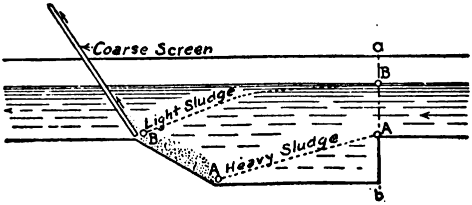

FIG. 19.

The cleaning of grit chambers which have rectangular cross-sections which consist of several parallel compartments, is best effected by means of a bucket dredge which can be lifted out of the sewage and moved across the current. The deposits may be caught on a belt conveyor or caused to fall onto a chute. A dredge should be used to clean the inside of all the compartments. In small plants grab buckets or hinged lifting buckets are sufficient. Masonry on the bottom of the tanks should be protected by wrought-iron plates, since it may easily be injured, especially when grab buckets are used.

In some cities there are used grit chambers circular in plan and with conical sumps. Cleaning, however, is difficult and it is not advisable to collect the sludge at the deepest point because, owing to the sand it contains, it flows with difficulty. To remove the deposit with a steam siphon or to pump it out with a rotary pump is likewise disadvantageous, since so much sewage must also be removed and since a special sand separator is required. A sand separator is generally a pipe of gradually increasing cross-section which causes the mineral matter to separate out, owing to its weight and on account of the lowering of the velocity. A sand separator of this kind used at Düsseldorf has proved as successful as an air blast. The power required for this method of cleaning grit chambers is considerable and the efficiency of the method is variable.

A peculiar design said, however, to operate successfully, is at the experimental plant at Dresden (Fig. 2, Plate II). Here a second grit chamber concentrically placed and with a deeper bottom, is built within a circular tank with a flat bottom. This is flooded by the sewage and is open at the bottom where the sewage streams meet, so that the heavy solids which settle out, owing to the reduced velocity, slide into the small inner compartment, whence they can be removed by a dredge.

Conveyors. Belt conveyors are chiefly used to remove the deposits from coarse and fine screens and grit chambers. They generally consist of hinged iron plates. Conveyors of this kind in Hamburg and in Cologne have not given satisfaction because the hinges require frequent repairs, since in passing the drums, particles of solid matter lodge in the openings and prevent a complete stretching of the hinges on the upward movement, thereby giving rise to strains sufficient to burst them. Moreover, the sludge does not slide off automatically as is desired, but requires the constant attention of a laborer. In Cologne it has been the endeavor to overcome these objectionable features by the use of leather laces. However, it is an advantage, where possible, to replace the belt conveyor by a truck running on rails. It is worthy of note that the fats in the sewage make unnecessary the oiling of the moving parts of the apparatus with which the sewage comes in contact.

DESIGN AND OPERATION OF SEDIMENTATION DEVICES

Settling tanks are best adapted to the removal of the organic suspended matters from sewage. These are level basins through which the sewage flows at a very low velocity, or in which it stands quiescent for a certain length of time. The latter method of operation is, however, used only in small plants.

By the greatly reduced velocity it is possible to remove the larger part of the suspended matter. In Frankfurt-a.-M., with a very strong sewage (suspended matter 1300 parts per million) a removal of 90 per cent is possible.

On the other hand, at the Cologne experiment station, even after 12 hours' sedimentation, there remain 17 per cent of the suspended matter, and in Chemnitz with a 24-hour period, 26 per cent. In both of these experimental tanks the true percentage of removal was naturally still greater. Both sewages are relatively weak for German conditions, and contain perhaps 300 parts per million of suspended matter. Moreover, both in Cologne and Chemnitz the suspended matters were low in the effluents from the tanks because the tanks were well designed.

On an average, the effluents contain the following quantities of suspended matter: Cologne 88, Chemnitz 100–120, Frankfurt-a.-M. 120–160 parts per million.

Theory of Sedimentation

The theory of sedimentation is as follows (see Fig. 20): A particle *A*, which enters the tank as it precipitates, traverses a curved path due to the combined effect of the velocity *V* and gravity *G*. This curve is approximately a parabola which gradually approaches a straight line and finally becomes one when the retardation due to the upward pressure of the sewage, which increases with the vertical velocity component of the particle, equals the velocity due to gravity. Sedimentation is more rapid the shorter the path of the particle *A* to the bottom of the basin, and also when the following conditions prevail (see Fig. 20):

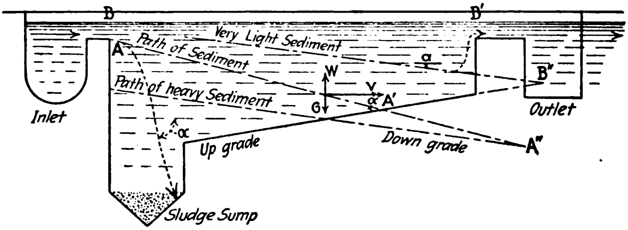

FIG. 20.

1. The angle *a* is as large as possible, while *v* is as small as possible.
2. The depth of the sewage is small.
3. The bottom rises toward the outlet.
4. Disturbing eddies are avoided.

It is evident also that the lighter the particle, and therefore the smaller the angle, so much longer must the basin be, for otherwise the particle will not reach the bottom and will be borne along by the sewage. Settling tanks are to be designed and figured in accordance with these principles..

Design. With the exception of the tanks at the experiment station at Chemnitz, bottoms of basins are made rectangular in form. The proportion of length to width which was formerly generally taken as 2½ : 1, according to English practice, is not sufficient if the sewage flows through the basins, as is usually the case. It is more advisable to make the basins from 6 to 10 times as long as they are wide, partly to equalize the harmful effect of eddies at the inlet, although these can scarcely be prevented, and partly to cause the finer matters to settle.

Figures for the most important plants are as follows:

RATIO WIDTH TO LENGTH OF SETTLING TANKS IN REPRESENTATIVE GERMAN PLANTS

Frankfurt,	8 : 41.4	=1:5⅛
Kassel,	4.2: 40	=1:9.4
Mannheim,	5 : 48	=1: 9.6
Hannover,	6.5: 40	=1: 7.7
Bremen,	20:160	=1: 8
Salingen,	7 : 45	=1: 6³⁄₇
Trier,	6 :100	=1:17
Giessen,	2.5: 40	=1:16

The cross-sections of the tanks which, in the earlier plants were simple right angles (see the English plants, Figs. 26 and 33 *a* and *b*), in the later plants are similar to the section of the hull of a ship. By means of the depressed section toward the center, the sludge is caused to flow through a central sludge drain. This bottom slope must be very great (Frankfurt 1 : 3) hence the narrow form of the later plants. With small slope the frictional resistance between the thin sludge layer and the bottom of the tank is too great compared to that unsettled sewage layer above.

The fact that in all modern German plants there is a slope in the longitudinal section, causing a variable cross-section in a rectangular tank, prevents there being a uniform velocity through the tank. The Chemnitz plant overcomes this objection by providing, through a trapezoidal plan, a constant section of the rising bottom. Such a design is practical when the sewage enters the tank across the entire section. Otherwise, as shown in Fig. 21, there would form dead corners near the inlet, and the sewage would actually flow only on the cross-hatched trapezoidal portion, and in this case a wider section toward the outlet is unnecessary. In the older plants, the bottom of the tank was sloped toward the outlet. The experiments at Cologne and Chemnitz have shown, however, that the reverse sloping is more advantageous because the sludge, for the most part, deposits immediately in front of the inlet, so that with a descending slope to the outlet, the available cross-section would be diminished. Inlet to outlet, the quantity of sludge deposited decreases very rapidly; the deposit becomes finer and contains a greater percentage of water.

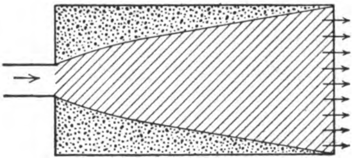

Fig. 21.

The curve of sedimentation devised by Steurnagel shows the progress of the sedimentation which takes place when in a rectangular system of coördinates, the abscissæ are the time and the quantity of sludge deposited the ordinates. (Compare Die Mittheil. a. d. Königl. Prufungsanstalt f. Wasserbesorgung u. Abwasserbeseitigung, Vol. 6, Fig. 31, p. 43). Sedimentation curves which are naturally different for every sewage, make it possible to design the bottom of a tank so that the upper surface of the sludge deposit is a horizontal plane and the available cross-section of the tank remains a constant. This condition naturally involves a curved shape for the bottom of the tank. An approximation is sufficient. At Cologne there was adopted an upward slope of 1 : 50; at the new plant at Heinersdorf in Chemnitz the slope was made 1 : 33.

In order to cause the sludge to deposit most advantageously with respect to its independent discharge through sludge drains, still other provisions are made in some plants. For example, the gravity removal of sludge which contains 90 per cent of water is effected by providing a large longitudinal slope. In Frankfurt-a.-M. the tanks have a serrated longitudinal section with a slope of 1: 10 and the flow of sludge is facilitated by covering the bottom of the tanks with glazed tile. When required, water from a hose may be employed. At the deepest points of the tank are the suctions of two pumps for pumping the sludge. Such an arrangement is planned for the plant at Münich-Gladbach. (Fig. 22.)

A design of this kind is recommended when it is a question of the most advantageous removal of the sludge as possible. Of less significance in this respect are Steurnagel's experiments. On this account in the settling tanks at Elberfeld which, as at Frankfurt, contain two sludge sumps, the former is made very much larger than the second, because in the latter there deposits only comparatively little sludge and this is fine and contains a large percentage of water. If principal stress is laid upon a maximum clarification effect, as is generally the case when dilution facilities are poor, then the sludge sump should be placed directly in front of the inlet. For otherwise the heavy sludge which necessarily precipitates at this point, would be obliged to pass to another part of the tank and would interfere with the deposition of the finer suspended matters.

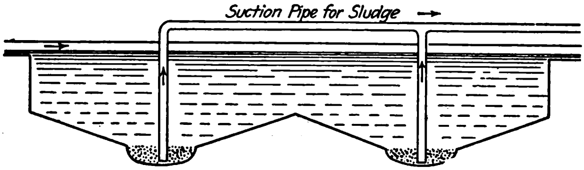

FIG. 22.

A bottom slope of 1 : 10, which always makes possible the removal of the sludge by gravity, is of course impracticable with long tanks and it is often necessary to hasten the flowage of the sludge by means of wooden or of rubber pushers. To minimize the labor entailed in using these pushers, in Merzig (Rhineland) a sludge sweeper wagon is used. This is provided with a hard rubber plate in front which pushes along the sludge. The plate has the same shape as the section of the tank. It is further of advantage to depress the bottom of the tank to a central drain in which the sludge flows to the sump. This is especially recommended in very long tanks which have only a slight fall outlet to inlet. In such cases the bottom of the channel merges with that of the tank at the outlet and ends at the inlet at about one-half the depth of the bottom of the tank and the sludge sump. In such a channel the stream of sludge concentrated in a solid mass flows better than when it is spread over the breadth of the bottom of the tank. (On this account the design sketched in Fig. 23 is better than that in Fig. 24.)

The downward movement of the sludge in the sludge channel of course interferes with the uniform velocity of the flowing sewage, the broader the plane of contact. The tank patented by Imhoff avoids this feature and at the same time possesses other advantages. In this tank the channel is separated from the current of sewage by two small inclined walls. Through a narrow opening between the two partitions, the sludge falls down into the channel. The channel must be made quite large, since the sludge may remain there a long time and may putrefy, and thus cause a 10 per cent reduction in its volume. The rise of particles of sludge in an active state of fermentation is prevented by the narrow opening between the inclined partitions. On this account the flow of sewage in the upper part of the tank is not interfered with and the process of putrefaction cannot contaminate the incoming sewage.

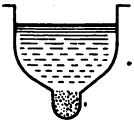

FIG. 23.

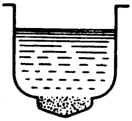

FIG 24.

In order to confine the deposition of the sludge in the front part of the tank at the experiment station at Chemnitz, submerged baffles have been used to advantage on the bottom of the tank. In the sketch, almost no deposition is observed behind the first baffle. Of course when the tank is cleaned the baffles are raised. (Fig. 25.)

If the sludge is to be removed during the operation of the tank, the sludge sump at the inlet must be provided with steep sloping sides, at best 1:1, for otherwise the sludge will contain too much water. The bottom of the sump must be from 1.5 to 2.5 meters (4.92 to 8.20 ft.) deeper than that of the main tank and, in case of the gravity removal of the sludge, must slope also toward the sludge drain pipe or the outlet valve.

Continuous operation of the tank, that is, the removal of the sludge during the operation of the same, is provided by the plan proposed by Knipping (Deutsche Bauzeitung, 1906). Knipping provides no sludge outlet at the inlet of the tank and no upward slope to the bottom as at Cologne, but forms the bottom of the tank, which is only 8 to 10 meters (26.2 to 32.8 ft.) long as a pyramid with steeply sloping sides, from the deepest part of which the thin watery sludge flows into a channel in which, with a view to avoid pumping, it stands as high as the sewage in the tank. From the sludge tank the supernatant sewage, if sufficiently clear, can be discharged into the outlet, or better, into the inlet again to pass through the tank. Tanks designed according to Knipping have the disadvantage that the sludge which separates out at the inlet reduces the effective cross-section of the tank and is forced to flow through half

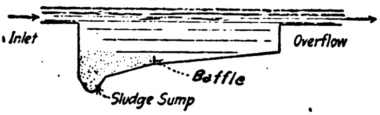

FIG. 25.

the length of the tank and thus this part of the tank is then not available for sedimentation.

Floating pipes described below, Figs. 26 and 33, *a* and *b*, are much used in England for the removal of the supernatant sewage from a settling tank. They could be employed for the removal of sludge while the tank is in service if the floating arms were made heavier so that they would sink almost to the bottom of the tank. However, the sludge would contain a high percentage of water, and further, the movement of the arms would interfere with the sedimentation. The same is true of the devices in use at Heywood (Mittheilungen der kgl. Versuch station, Heft 3), where the sludge is sucked up through a perforated horizontal pipe which moves over the bottom of the tank by means of gears and a track. (Fig. 26.)

Continuous operation possesses the great disadvantage that the sludge obtained contains a very large percentage of water. With few exceptions, where the sludge is pumped to a sludge-disposal field, as in Mannheim and Birmingham, it is very important to obtain a sludge with as low a percentage of water as possible. The sludge produced under continuous operation of the tanks must be dried on special sludge areas, for the cost of drying will be very high if this is undertaken in sludge presses, centrifugal machines or by evaporation. This disadvantage appears to offset the advantage of continuous operation which permits a longer time to elapse between successive cleanings of the tanks. Of the newer more important plants in Germany, only in the settling tanks at Elberfeld-Barmen is the sludge removed while the tanks are in service.

Of greatest importance for a rational operation of the tanks is a uniform velocity of the sewage and the avoidance

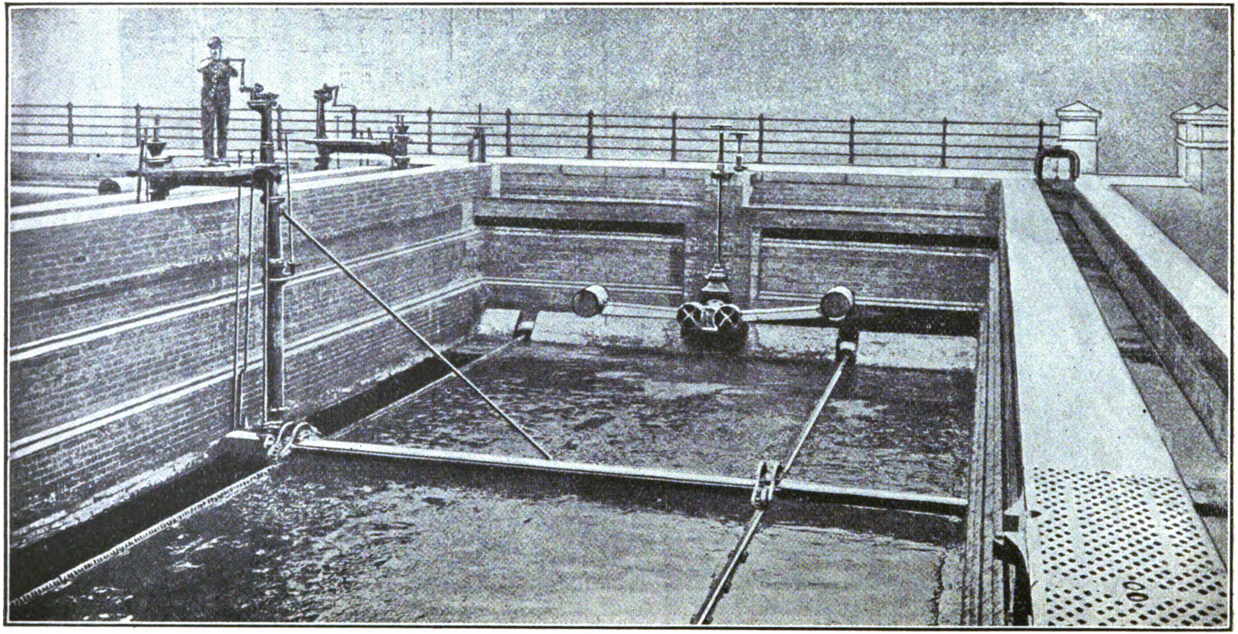

FIG. 26.

of any feature that may interfere with the same. In this connection, there are to be considered eddies which form at both the inlet and outlet if the sewage does not enter and leave the tank across the entire cross-section. The best design for inlets and outlets is therefore adjustable weirs. Siphons at the outlet are less desirable. Of further harmful effect is the influence of wind on uncovered tanks. To prevent this there is recommended the use of baffles extending about 25 cm. (10 in.) below the normal flow line (Bremen). A uniform velocity is also disturbed by rising particles of decomposing sludge due to the disengagement of gas. As soon as such conditions arise, the tank should be cleaned, a feature which of course is necessary for other reasons.

Of marked significance with respect to the efficiency of the sedimentation is the relative temperature of the entering sewage and that in the tank. In the colder months of the year where, particularly in uncovered tanks, the influent is warmer than the sewage in the tanks, the sedimentation curve is not the same as represented in Fig. 20, but as the investigations by Schmidt in Oppeln show, the warmer incoming sewage flows over the colder sewage in the tank and by this means the efficiency of the plant is greatly reduced.

In order to cause the sewage to spread over the entire cross-section of the tank, and to equalize the velocity, in Cologne behind the sludge sumps there are constructed wooden flow regulators whereby the sewage stream may be choked. It is advisable to have a continuous record of the sewage flow in the tanks and this may be accomplished by means of floats with adjustable depths of submergence and provided with self-registering devices connected with a bell alarm. It is also desirable to arrange adjustable weir plates at the inlet and at the outlet in order that the height of the weirs may be varied and the velocity controlled.

SLUDGE REMOVAL METHODS

Sludge may be removed from settling tanks by the following means: *a*, pumps; *b*, gravity discharge: *c*, dredges; *d*, special devices.

Pumping. To remove sludge from the sludge sump by pumping, ordinary pitcher pumps and centrifugal pumps have proved less adaptable than vacuum pumps. These last require considerable space, however, and also considerable attention. On this account in Hanover, Frankfurt and Mannheim, membrane pumps have been installed and have given very satisfactory results.

The removal of sludge is effected either by pumping from a sludge tank or well to which the sludge flows by gravity, or directly from a sludge sump in the settling tank. A very large saving in operating charges is effected if there is a gravity flow of sludge from the settling tanks. The gravity discharge of sludge is, however, satisfactory only when the sludge is free from sand. The sludge drains may be closed pipes laid in open channels or in drains provided with inspection manholes. An interruption in the flow of the sludge must always be expected. This feature may cause an interruption in the operation of the settling tanks, especially with closed sludge drains, and also in such closed devices as centrifugal pumps by which the sludge is further handled. It is therefore advisable in such cases, either to have a suction pump in readiness or to provide water connections for flushing purposes. Flushing is of special advantage when large closed pipes terminate at inspection manholes, as in Elberfeld. Of course these features entail relatively high costs. If the removal of sludge takes place in drains with inspection manholes or in open channels, the danger is less to be feared, for occasional stoppages can then be easily removed.

Gravity Sludge Discharge. The slope required for the gravity discharge of sludge depends upon the percentage of water in the sludge and the relative quantity of sand it contains, and also upon the roughness of the sludge drain, especially the bottom and sides. Since a cylindrical mass of sludge flows more readily than a rectangular mass, sludge drains should be built as in Fig. 28, rather than as shown in Fig. 27.

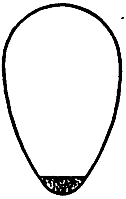

FIG. 27.

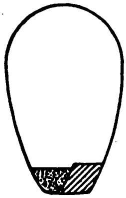

FIG 28.

In Bremen the roughness of the sludge drain has been avoided by constructing a channel of smooth planks rather than of masonry. In the case of the thin sludge obtained from sedimentation towers (Dortmund tanks) or from a settling tank under continuous operation a grade of 1 : 100 is sufficient. Such a sludge drain is used at Ohrdruf and requires flushing only when sand deposits in the drains after rains. On the other hand, for the removal of the sludge produced in settling tanks under intermittent operation—a sludge which contains from 83 to 90 per cent. of water—there must be provided a fall of at least 1 : 50. This figure is used for the bottom of the sludge channel at Mannheim and also in several plants recently proposed. The closed sludge drains at the Elberfeld plant have a grade of 1 : 30. Since conditions are different at each plant, it is advisable to determine the suitable grade by experiment.

Dredges. The removal of sludge by dredges is not desirable because it is not possible to clean the tank with sufficient thoroughness to prevent putrefaction of the remaining sludge. Moreover, dredging operations are very dirty.

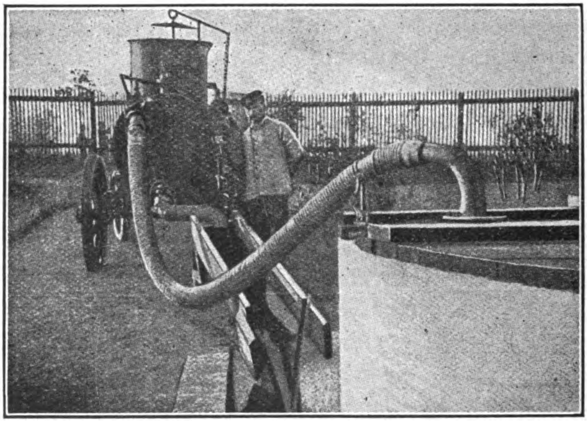

FIG. 29

Special Devices. A special device for sludge removal is the wagon patented by Wegner. This is a movable vacuum apparatus with which, by means of a hose, the sludge is sucked up from the tank and can then be transported to the point of sludge recovery or drying. By its use special sludge drains are avoided. (Fig. 29).

SETTLING TANKS IN SERIES

In a few rare cases a number of settling basins have been arranged in series. By this means, as in the Elberfeld plant, there is obtained a separation of the coarse and fine sludge. This advantage is slight, however, for a separate treatment of coarse and fine sludge would be profitable only when handling large quantities. The disadvantages of such an arrangement, namely, high construction costs and high operating expenses, are so apparent that the settling tank plants which are already of considerable size in the larger cities cannot justly be further enlarged to correspond to operation in series. Moreover, such a plant as exists in Sheffield, where three tanks of equal size and depth are arranged in series, does not offer the advantage of a greater clarification. The Sheffield plant shows a suspended matter removal of only 49.3 per cent.

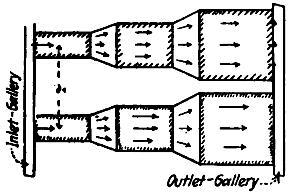

FIG. 30*a*.

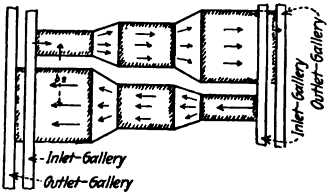

FIG. 30*b*.

The efficiency of the plant at Viersen is greater. In this plant the velocity is reduced by successively widening the cross-section of the three tanks in series. The removal of suspended matter by this plant is significant, namely, 82 per cent. It has, however, the disadvantage of very poor economy of space. (Compare Fig. 30*a*.) On the other hand, in order to avoid this disadvantage, if the tanks are arranged as in Fig. 30*b*, the construction of the inlet and outlet galleries would be difficult and the plant would be unsightly.

PRINCIPLES UNDERLYING THE DESIGN OF SETTLING TANKS

There are several features which control the design of settling tanks, as follows:

1. A certain definite efficiency which is dependent particularly upon the dilution afforded by the stream into which the settled sewage is to be admitted.
2. The average dry weather sewage flow.
3. The linear velocity.
4. A limited depth.
5. The character of the sewage.
6. The proportion of width to length.
7. The treatment of night sewage and storm flows.

Average Dry Weather Sewage Flow. The tank capacity is to be based upon the highest hourly flow, which is to be learned by measurement or by assuming it to be from one-eighth to one-tenth of the daily average. Large variations during periods of less than one hour will be equalized by the tank since the period of flow is generally greater than one hour. Thus for example, at the relatively high velocity of 12 mm. per second (2.4 ft. per minute) theoretically the sewage would flow through a tank 43.2 m. (144 ft.) long in exactly one hour.

Linear Velocity. While in practice the linear velocity varies widely in small plants and some very low velocities are used (Kingston, England, only 0.5 mm. per second [0.1 ft. per minute]), in the larger plants, on the ground of economy, the velocity is never lower than 4 mm. per second (0.8 ft. per minute). This is to be considered the figure usually employed. Steurnagel shows that by increasing the linear velocity from 4 to 20 mm. per second (0.8 to 4.0 ft. per minute), the removal of suspended matter is reduced only from 72.3 to 68.1 per cent, a very insignificant reduction. A velocity of 20 mm. per second (4.0 ft. per minute) would require a tank only one-fifth as large as 4 mm. per second (0.8 ft. per minute), a very important reduction in first cost.

At the higher velocities the sludge is thicker, the cost of drying is less, and the actual volume of sludge is likewise less. However, experiments at Chemnitz have indicated that it is not desirable to exceed a velocity of 12 mm. per second (2.4 ft. per minute) because too much finely divided suspended matter escapes with the effluent. This feature will, of course, lower the efficiency of the final treatment devices.

The author considers a velocity of 20 mm. per second (4.0 ft. per minute) too high if the suspended matter is broken up before reaching the plant, a fact which always obtains when the sewage is pumped. Thus at Mannheim, the tank effluent contains a very large quantity of suspended matter. At this plant subsidence of the suspended matter is also retarded by the presence in the sewage of large quantities of fat.

Depth. The depth of the tank must not be too great, for otherwise, as previously mentioned, conditions will be unfavorable for sedimentation. The plants visited showed a range in depth of tanks from 0.6 to 3 m. (1.97 to 9.84 ft.). Representative data in this regard are shown in the next table. This table shows that chiefly the smaller plants have the less flow-line depths, although very much deeper tanks are allowable to reduce the required tank areas.

In view of the very satisfactory results at Cologne, a flow-line depth of 2m. (6.56 ft.) should still be considered permissible. It is, however, desirable so to construct tanks that their normal flow-line depths may be increased if conditions require it.

FLOW-LINE DEPTHS OF DIFFERENT SETTLING TANKS

Place.	Population.*	Depth.	
		Meters.	Feet.
Giessen	25,000	1.5	4.82
Cologne	372,500	2.0	6.56
Bremen	214,000	0.7	2.30
Borbeck	57,500	1.0	3.28
Bottrop	31,000	0.85	2.79
Kempen	6,300	0.8	2.63
Cassel	120,500	3.0	9.84
Neuwied	11,000	2.0	6.56
Solingen	45,300	1.5	4.82
Elberfeld-Barmen	299,000	2.5	8.31

* From Dr. Solomon's Encyclopedia of German Sewage Plants.

Character of Sewage. The character of the sewage and its relation to sedimentation is determined by experiments, the results of which are plotted in Steurnagel's sedimentation curve (see Fig. 31.)

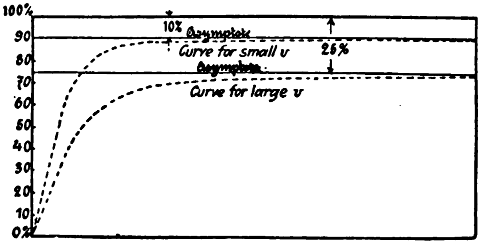

FIG. 31.

The form of the curve varies at different velocities and at different flow-line depths. This is especially true of the parallelization to the axis of the abscissæ. To this axis the curve approaches assymptotically under greater velocities since there exists for each particle a limiting velocity, under which it will not subside in a basin of unlimited depth.

The flow-line depth is also of influence with respect to sedimentation. It will readily be seen that if the tank is first filled to the line *AB–CD* (Fig. 32) and at the same time *n* particles settle out in the section *a–a*, if the tank be filled to twice this depth *A′B′–C′–D′*, on the section *a–a*, not 2 *n* particles will subside but less, since the upper particles must travel a greater distance before they reach the bottom of the tank.

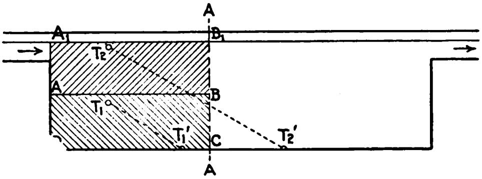

FIG. 32.

Proportion of Breadth and Length. The proportion of breadth to length should be from one-sixth to one-tenth, as already mentioned.

Treatment of Night Sewage and Storm Flow. The question whether the night sewage during certain hours shall not be treated or whether it shall be treated at a greater rate, is also a feature which controls the tank capacity of the plant. Also the question of by-passing during storms when the absolute quantity of organic matter does not increase in proportion to the tremendous increase in the sewage flow, or operating the tanks at a greater rate by increasing the flow line or by changing the rate controllers on the inlets and outlets.

Number of Tanks Required. After deciding upon the required degree of removal of suspended matter, the period of subsidence may readily be determined by developing a sedimentation curve. The following is a method of computing the required number of tanks.

Let m = hourly volume of sewage;
v = lineal velocity;
t = time read from sedimentation curve:
l = length of tank;
b = breadth of tank;
h = flow-line depth;
B = total width of sewage stream;
x = number of basins required.

Then 1. $Q=\frac{m}{v}$;

2. $l=vt$;

Since $n=\frac{b}{l}=\frac{1}{6}$ to $\frac{1}{10}$;

3. $b=nl$,

4. $B=\frac{Q}{h}$;

5. $x=\frac{B}{b}$ = number of tanks required.

This calculated figure is to be increased so that tanks may be placed out of service for cleaning or for repairs.

Since under the most unfavorable conditions one tank must be cleaned every five days, requiring perhaps one day's time, it is advisable to increase the value of x at least 20 per cent.

A numerical example of the above computation may be of interest:

Sewage flow, 4,200,000 gals. in 24 hours;
175,000 gals. per hour;
23,400 cu.ft. per hour.

$A =$ cross section;
$m = 23{,}400$;
$v = 2$ ft. per mm.;
$t = 1$ hr.;
$l = vt = 2 \times 60 = 120$ ft.;
$b = \frac{1}{10} = 12$ ft.;
$h = 4$ ft.;
$B = \frac{A}{h} =$ total width of sewage stream;
$x =$ number of basins required;

Then

$$A = \frac{23{,}400}{2 \times 60} = 195 \text{ sq. ft.};$$

$$B = \frac{195}{4.0} = 48.75;$$

$$x = \frac{B}{b} = \frac{48.75}{12} = 4.$$

4 plus 20 per cent increase $= 5$ tanks.
Dimensions $12 \times 120 \times 4$ feet to flow line.

If the night sewage is not treated, cleaning may take place at night and even for the larger plants but one reserve tank will be necessary. Opinion differs as to the time which shall intervene between cleanings when the tanks are not operated continuously. This is due in part to the fact that conditions are different at each plant.

While in Hannover in the summer months the tanks are cleaned every two or three days, according to Bredtschneider, cleaning is not necessary oftener than perhaps every four weeks when solid masses of sludge begin to appear in the effluent.

However, for the reason already advanced it is advisable to clean the basins when there is evidence of septic action. According to conditions, this may take place every two or three days as in Hannover, but more generally in summer every 5 or 6 days, in winter 8 to 10 days.

In order to obtain sludge with as low a percentage of water as possible, in Sheffield the sewage in the tanks is treated with lime after the influent is shut off. The supernatant sewage must then of course be treated on land and not applied to filters.

The withdrawal of sewage is effected best, layer by layer, by means of an adjustable weir, or, as more general in England, by means of floating arms. (Fig. 33.)

Floating arms are pipes which lead to a horizontally placed sludge drain. In order that they may be turned around in a vertical plane, they. are arranged like the spokes of a wheel around a solid hub. On the upper end there is a small floating compartment so that the opening is always at the surface of the sewage in the tank (Figs. 26 and 33). Similarly to outlet pipes which may be lowered into the sewage, floating arms possess the disadvantage that they interfere with the progress of the sedimentation.

As soon as the clear supernatant layer is removed the turbid sewage is drawn off into a pump sump from which it is raised by a pump and again enters the tank.

Movable outlet pipes can also be used for the removal of the turbid sewage if there is a valve in the sludge drain which leads to the sump of the pump. Otherwise, under the inlet or the outlet there is provided a sluice

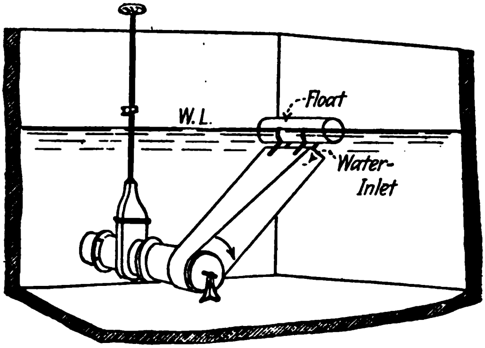

FIG. 33*a*.

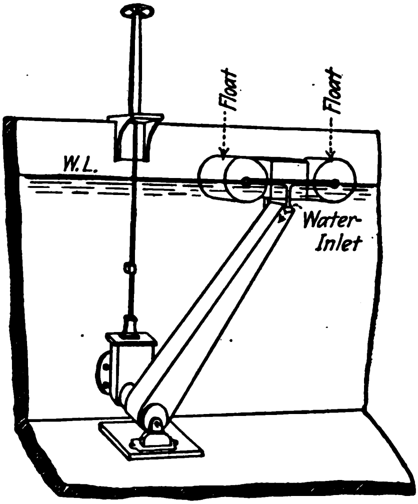

FIG. 33*b*.

gate which controls a special turbid sewage drain. If the flow line depth of the tank is greater than one meter (3 ft. 3 in.) then it is recommended to draw off the supernatant sewage, a little at a time (Elberfeld), in order to avoid the disturbance of the sludge due to the currents set up.

The period of pumping may be lessened if the turbid sewage be pumped out of the tank to be cleaned into a tank which has just been cleaned, until the water level in the two tanks is the same.

To retain the floating matters, it is practical to arrange a scumboard which extends below the flow line perhaps 25 cm. (10 in.). The material which here collects is from time to time removed by the operator. This labor has been saved in Cassel, where the sewage has a relatively high velocity at the entrance to the influent gallery, by constructing quite deep baffles by which the floating matters are intercepted. By this means they become completely saturated with sewage and eventually fall to the bottom of the tank because of their increased weight.

The fact that it is practical to retain the floating matters at the end of the tank by means of a harp screen has already been mentioned. The tension of the wires must be great, 250 to 500 kg. per sq. cm. (3550 to 7100 lbs. per sq. in.) in order that the adhering particles of scum do not force the wires apart and pass through the screen.

In English and in a few German cities, for example, in Weissensee at Berlin, there are tanks in operation in which the sewage is subjected to quiescent subsidence for a certain time. The supernatant liquid is then drawn off after a sufficient sedimentation has been effected. The turbid sewage is pumped back to the inlet channel and the sludge is removed. Such plants require considerable tank capacity and cannot be considered for the larger cities.

The construction of these intermittently operated settling tanks is slightly different from that of ordinary tanks, since the sewage is spread over the entire surface as uniformly as possible. This is best effected by a Stoddard channel, a corrugated metal sheet, or by staggered wooden channels which are arranged side by side. At mid depth this channel contains a series of holes (*cf.* Fig. 34).

The supernatant sewage may be drawn off by means of adjustable weirs, floating arms, funnel-shaped or cylindrical sluices. Both of these last can also serve for the removal of the turbid sewage. Otherwise, for this purpose special sluice gates must be arranged at the proper depth. For the ready removal of the sludge, the bottom of the tank consists of a number of pyramids arranged side by side, with very steep sides. There is a valve for the removal of the sludge at the point of each pyramid.

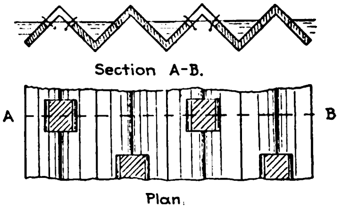

FIG. 34.

The tanks at Weissensee have recently been operated continuously and are an example of a plant operated according to the previously mentioned Knipping process.

SEDIMENTATION TOWERS

Sedimentation towers are used particularly in the previously mentioned plants designed by Mairich. The efficiency of the towers in general is not so great as that of tanks. In Remscheid there was obtained a removal of organic matter of 60 per cent after the mineral matter had previously been separated out in the grit chamber. The efficiency of this plant is particularly high, due to the fact that the sewage which enters from below rises with a very slight velocity, $v \overset{=}{<} 1$ mm. per second (0.2 ft. per minute) and passes out above after filtering through a sludge filter formed by the heavy matters which have subsided to the bottom of the tower. In this way finer suspended matters are also retained. The sludge collects below the water inlet; it is very much more dilute than that in settling tanks and never contains under 95 per cent of water. This fact favors its gravity discharge. The removal of sludge during the operation of the tower is much more readily accomplished than is true of settling tanks.

The lowest part of the tower is in form practically a pyramid or a cone, at the deepest part of which the sludge can be removed through a drain. The slope of the side walls, with respect to the coping, is best made 1 to 1 because otherwise the sludge drain is easily clogged and septic action will be set up. The high percentage of water contained in the sludge unfortunately increases the volume of sludge and makes the removal of water more expensive, so that in some cases special sludge areas have been constructed, as for example, in Merseburg.

The requirement that the entrance and the exit of the sewage shall not interfere with the uniform velocity can scarcely be fulfilled by a settling tower.

The inlet may be an iron pipe with a funnel at the end leading to the center of the tower (Fig. 35). This, however, requires expensive iron construction and, moreover, the change of a velocity through the sudden widening of the cross-section is so great as to cause the sludge to roll up from the bottom. It is still less advisable to introduce the sewage sidewise at several points along the periphery. Moreover, this construction is difficult, especially since the inlet piping must be built so that it may be removed for cleaning to prevent stoppages in this comparatively narrow pipe.

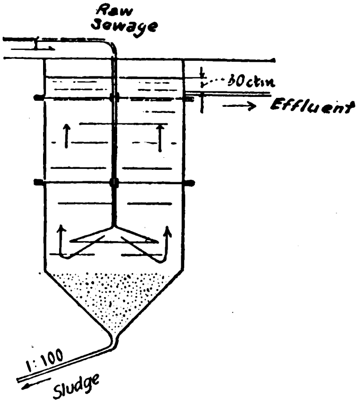

FIG. 35.

In order to overcome the harmful effect of eddy currents the outlet is effected at several points along the periphery, chiefly by gravity discharge; less often by pumping. The outtake pipe is generally submerged about 30 cm. (12 in.), so that it will not be choked up with scum or rising sludge particles. Moreover, it is advisable to arrange a fine screen in front of each outlet. The author doubts whether it is desirable to arrange under the water level a special outlet for fatty matters in the form of a funnel open at the top, as in the Merten sedimentation tower (Fig. 36), since a very dilute fat is obtained in the fat tank. If importance is attached to recovering the fat, the best arrangement would be to remove the fat directly from the surface of the sewage in the tower. In order to preserve the fat as pure as possible, the undesirable masses of scum must be removed previously by screens and also there must be prevented the rise of particles of putrefying sludge.

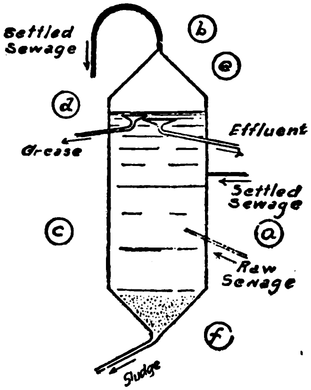

FIG. 36.

Detrimental to the operation of the sedimentation tower is the rise of gas which takes place with great violence as a result of the septicization of the sludge. This results in breaking up the sludge filter and in carrying upward masses of sludge. However, in towers such features are more readily avoided than in tanks because the sludge can be removed at will during the operation of the tower. A disadvantage in this respect is the construction of the iron inlet devices above mentioned. Under the low velocity the sticky matters readily cling to the inlet piping and there become septic.

Generally speaking, the relative constructional cost of towers is greater than that of tanks. When the volume of sewage is large there are required a great number of towers, which necessitate a very extensive network of influent piping. Settling towers, however, require very little space, and when the ground water level is high can be constructed at a lesser cost, because they may be built after the manner of a driven well. For clarification processes for pure mechanical sedimentation, towers are not used. For it is generally true that the previously operated chemical treatment devices have been abandoned on economic grounds and the towers are now operated on a sedimentation basis.

The Degener lignite process, which is used in Spandau and Potsdam, is not to be considered a purely chemical process. On the contrary, the particles of coke and sludge undergo a very thorough mechanical mixture and this conglomerate, weighted by the addition of sulphate of alumina, rapidly settles out. On account of the chemicals and the extensive mechanical devices required, this process is more expensive. Its use is, therefore, to be recommended in only very special cases (see ch. 4).

A Degener lignite process plant consists of the following parts:

1. Coke mill.
2. Stirring apparatus by which the ground-up coke is mixed with water.
3. Stirring apparatus for the solution of the chemicals, sulphate of alumina and sulphate of iron.

4. Pumps for supplying water for the solution tanks.

5. Mixing tanks in which the sewage is treated with the ground coke and the chemicals, in case of epidemics also chloride of lime for the purpose of disinfection.

6. Sedimentation towers in which the mixture from the mixing tanks, as a result of the action of a siphon, rises with a velocity of 5 mm. per second (1 ft. per minute). A stirring apparatus in the tower increases the intimacy of the mixture.

7. Sludge pump by which the sludge deposited in the lower part of the tower is pumped to the sludge drier.

8. Sludge drier.

9. Air pump for filling the apparatus for the removal of the water from the sludge through the sludge dryer.

10. Filter presses for the removal of water from the sludge.

In Spandau with a sewage of medium strength there is added to each cubic meter 1122 grams (65.6 grains per gallon) of powdered coke and 142 grams (8.25 grains per gallon) of sulphate of alumina. It is unnecessary to further treat the clarified sewage since the effluent from this plant contains very much less suspended matter than that from settling tanks or settling towers. This is all the more possible since the lignite process removes a part of the dissolved organic matter, and produces a non-putrescible effluent. In cold weather the efficiency of the process is somewhat less, but under favorable conditions the effluent is scarcely to be distinguished from drinking water.

An example of sedimentation towers operated on a purely mechanical basis, is the tower designed by Merten, which was built at the Spandau plant for experimental purposes (Fig. 36). The entrance of the sewage and the removal of the effluent is effected by a siphon which is started when clarified sewage enters at *a* and is drawn off at *b*. If the tower is full and the siphon in action, *a* is closed and *b* is opened so that the sewage may enter; if it rises above the upper funnel *b* is also closed. The tower has three outlets. The highest at *d* for fatty matters, at *e* for the settled sewage and at *f* for the thin sludge. Although in operation for some time, the apparatus has not given satisfactory results, and its efficiency is very much less than the lignite process, a fact which has caused Merten to construct a special filter beyond the tower.

The assumption that the sludge would be very low in water because it is under pressure is not correct. In every sedimentation tower the sludge which collects at the bottom is under the pressure of a high column of water, but nevertheless the sludge is very mobile, even when the tower is not in continuous operation. In the sludge chamber, which is constructed below the apparatus, there forms on the surface a putrefying compact sticky mass of sludge, while on the bottom there gathers a very heavy sludge. Between the two, however, there is a deep layer of turbid sewage (Fig. 37). This phenomenon appears everywhere where watery sludge is allowed to stand in a tank and is no special feature of the Merten apparatus.

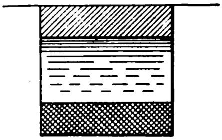

FIG. 37.

There is still to be considered a purely mechanical clarification process which has been introduced in the last few years, and one which was first received with much distrust. This is the Kremer system of sewage clarification. (See Techn. Gemeindeblatt, 6. Jahrgang; Gesundheitsingenieur, 28. Jahrgang.)

In this process the sewage enters a tank in which, by means of baffles, it is forced to move up and down whereby the fatty matters are separated at the top and the sludge at the bottom. Since the entire apparatus operates as a continuous series of pipe, the outlet is approximately at the same height as the inlet, so that the plant requires only a slight loss of head (40 cm. [16 in.] for 100,000 people).

This apparatus is in use in Charlottenburg, Osdorf, Lichtenberg at Berlin and in the experiment stations at Chemnitz and Dresden, and has given such satisfactory results that in Chemnitz it has been decided to use the Kremer apparatus in the new plant to be built at Heinersdorf.*

An improvement in this apparatus was effected in Chemnitz and Dresden by providing a sloping bottom by which the sludge which collects thereon flows sidewise into a chamber where heat can be applied through an oven or a steam pipe. The result of this is that there remain on the bottom of the chamber only mineral matter, sand and gravel in an exceptionally pure condition, while the organic portion of the sludge rises to the surface and can there be removed. This separation is aided by the previous removal of the fatty matters. The company which controls the Kremer patent has developed a further improvement by constructing the apparatus of masonry or of concrete, abandoning the use of wood, and by providing a sloping bottom and causing the sludge to flow to a common chamber for several towers. This

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* The feasibility of this plan has recently again been questioned.

chamber may be closed by a valve so that particles of the sludge in an active state of fermentation cannot pass back into the apparatus itself.

The time required for the sewage to pass through the apparatus is very short (only 15 minutes), and hence putrefaction is thus prevented. The operation is simple and one workman can take charge of from 2 to 12 towers. In the earlier design the apparatus was so arranged that the sloping baffle boards on which the sludge is deposited must be removed by the workmen from time to time and be cleaned. By means of a watchman's clock it was possible to learn of the faithfulness of the workmen.

In the later design, fat and scum are merely skimmed off for the purpose of further treatment and when the apparatus is out of service the mineral sludge is removed by a dredge. The efficiency of these plants is much greater under continuous than under intermittent operation. In the first case the removal of suspended matter is as great as 78.5 per cent, an efficiency which is not less than that of settling basins. However, the nature of the different by-products is quite different. In the Kremer process there is produced more fat, and there settles out less finer sludge-forming matters, so that the Kremer apparatus and settling tanks, to a certain extent, are not to be considered on the same basis. Under continuous operation larger floating and suspended matters over 1 mm. (0.04 in.) in size are also removed. This method of operation, of course, requires twice the number of machines. A still greater advantage of the Kremer apparatus is the fact that the by-products, the fat and scum contain such a small quantity of water that they can immediately be pressed; the maximum quantity of water is only 85 per cent.

CHAPTER IV

SLUDGE REMOVAL AND TREATMENT FOR THE RECOVERY OF BY-PRODUCTS

SLUDGE as it is formed in the different parts of a mechanical clarification plant differs greatly in composition, and hence its treatment for by-products recovery likewise varies. The percentage of water in sludge from settling tanks under continuous operation ranges from 83 to 90 per cent; that from settling towers and basins under intermittent operation, 95 per cent. The fatty sludge in the Kremer apparatus contains from 81 to 86 per cent of water, while the bottom sludge averages about 85 per cent. The organic and mineral sludge as is obtained in the later Kremer machines contains still less water. The organic sludge is a sticky semi-solid mass which contains from about 70 to 75 per cent of water. The mineral portion which remains on the bottom of the machine contains 65 per cent of water, as is true of the mineral residue in grit chambers where only mineral matter is deposited, that is where the velocity in the grit chamber is more than 30 cm. per second (60 ft. per minute) as in Hamburg. The material removed by coarse and fine screens with fixed scrapers and movable coarse or fine screens contain about 83 per cent of water, (Hamburg); still less with movable scrapers and fixed screens (Cologne, Düsseldorf, Paris).

The purely mineral sludge from grit chambers and from the Kremer apparatus can with advantage be used as fill. On the other hand, the mixture of organic and mineral matter which is obtained from grit chambers operated under low velocity is too liquid to be so used. At best it is composted with peat, but on account of the large quantity of sand it contains its fertilizing value is slight. The combustible matters are scarcely 33 per cent. The screenings from both coarse and fine screens have a high fertilizing value since they contain both nitrogen and phosphorus. It is almost always possible to sell them, or at least dispose of them without cost. In Mannheim the profits of one cubic meter was 0.5 mark (about 10 cents per cubic yard). These matters are often mixed with peat and composted.

If such simple methods of removal as the above are not possible, then the only available procedure is to burn the screenings after the addition of rubbish or coal, as is done in Göttingen.

Cities near the sea make use of sludge steamers with movable bottoms, in which these matters are transported to a proper point and there thrown into the sea. In general, sludge from settling basins or settling towers is difficult to handle. In many English and in a few German cities this matter may be spoken of as a sludge nuisance. Only a few cities, such as Mannheim and Birmingham, can dispose of sludge as it flows from the tanks by pumping it on to land. At Mannheim, by means of a network of pipes it is conducted to vertical pipes from which it is sprayed. At Birmingham the sludge is caused to flow into a series of ditches in porous soil where it dries and is then covered with earth. The Mannheim practice is, of course, very dirty but cheap. The sludge fields are sludged every three years, necessitating high operating costs. The Birmingham practice is not recommended for sludge which contains a large quantity of fat, because drying is very protracted, as is also true where the sludge contains considerable water. It is generally to be recommended, therefore, to remove fatty matters from the sludge, for otherwise, directly on the surface of the sludge field there forms a tenacious layer impervious to air and moisture, which prevents the growth of plants. Other English cities pump the 90 per cent sludge into sludge steamers and ship it to sea. This is, however, expensive, costing .65 to .70 mark per cubic meter (12 to 13 cents per cubic yard). The sludge obtained in Cassel is worked for by-product recovery in a very satisfactory manner. The settling basin sludge which contains 90 per cent of water is composted with peat and finds a ready sale at a relatively high price, although it is necessary to ship the same 50 km. (31 miles) by railroad. Of course local conditions are there very favorable, and this is not always true. In many cases the sludge is used for soil enrichment because it contains nitrogen, phosphoric acid and potash. However, farmers are willing to take it away only at certain times of the year. For the remainder of the time, after drying, it must be piled up until it will adhere. The drying of the sludge is effected by evaporation and seepage on either special sludge-drying areas of coarse porous soil or in filter presses or centrifugal machines. Many bad reports have been made with reference to areas set apart for drying sludge, since a very great nuisance is caused in the neighborhood from odor. Drying is usually continued until the water in the sludge is reduced to 60 per cent. Areas for drying sludge are entirely impracticable if the sewage contains a large quantity of fat, for in such cases the sludge will not dry at all (Mannheim). Filter presses are operated only at very high cost. At Frankfurt 1 cu.m. of pressed sludge costs from 3 to 5.5 marks ($0.57 to $1.05 per cu.yd.). In order that the sludge may be pressed it is necessary to add 5 per cent of milk of lime to the fluid sludge. The effect is to reduce the water to from 50 to 60 per cent. On account of the high cost of sludge-pressing this practice can hardly be considered for new plants, and is therefore not further described.

Centrifugal machines are much cheaper and more rapid. An experimental machine in Chemnitz, built by the Haubold Machine Works, reduced the water from 2.5 cu.m. (3.3 cu.yds.) of sludge containing 90 per cent water in about ten minutes to 45 to 60 per cent, requiring an electric motor of 6 H.P. One cubic meter of centrifugalized sludge at Chemnitz therefore entails a cost of from .37 to .60 mark (11 to 20 cents per cu.yd.). These figures are much more favorable on a larger scale. In Frankfurt in from 3 to 5 minutes the water content of the sludge was reduced to 65 per cent.

Fatty matters in the sewage have a marked influence upon the action of the centrifuge, for an impervious layer of fat forms on the surface of the sludge and will not permit water to pass out. On this account experiments with centrifugal machines carried out in Mannheim, Cologne and Spandau were very unsatisfactory. Results obtained in Hannover and Chemnitz were quite favorable. The Mannheim sewage contains an exceptionally large quantity of fat since there are several oil refineries at that place. In Cologne also the nature of the sludge was the cause of the poor results, for when there was used sludge which was mixed with some which consisted chiefly of coffee grounds the results were excellent. The Chemnitz sewage on the other hand is very low in fat. At times, moreover, it contains almost no solid fecal matter. For experimental purposes, however, a certain quantity was added which was equivalent to what would be anticipated as a maximum were the device subsequently adopted for the entire plant. The efficiency of the experimental centrifuge used at Chemnitz was very high. Perhaps the relative quantity of fat ought not alone to be considered as influence in the efficiency of the machines. In Mannheim the sewage flows through the pumps and travels a considerable distance to the plant, and hence there takes place a much more thorough mixture of the particles of fat with the other suspended matter than is the case at Chemnitz, where the sewage reaches the plant in a very fresh condition and with little opportunity for the breaking up of the coarse organic matters.

All things considered, centrifugal machines are the best means at present available for drying sludge. To insure success it is only necessary to reduce the fat content of the sewage, since fatty matters have such a marked influence upon the efficiency of centrifuges. Fatty matters can be thoroughly removed by the Kremer process.

Sludge dried in centrifuges is either removed in its natural form or is pressed into special cakes or briquettes. If these sludge cakes still contain considerable fat it is advisable not to use them for fertilizing purposes since, as already mentioned, the fatty layer which forms on the surface of the ground will be a great disadvantage. If it is not possible to remove the pressed sludge to a dumping ground, other means for sludge disposal are to be provided. There is to be considered:

1. Incineration;
2. Coking for gas production;
3. Recovery of fat and of artificial fertilizer base.

Incineration. The incineration of the sludge is the best method to be used with the lignite process. The water content of the sludge is first reduced to 60 per cent by filter presses and by exposure to the air in heaps, and then is formed into briquettes in simple brick presses and burnt. At Spandau it has been possible to obtain a product which is entirely odorless and which burns, of course, with a tremendous development of smoke, also without odor, and finds ready sale at .35 mark per cwt. ($1.75 per ton). The sludge obtained from ordinary settling tanks is very difficult to burn. A number of experiments have been made, for example in Charlottenburg, where the sludge is burned with coal; this has proved too expensive. Only in the vicinity of coal mines where coal is very cheap and where the sludge already contains particles of coal dust, would this process be satisfactory. There is still to be considered for certain localities the proposition of obtaining a satisfactory disposal of the sludge by the addition of peat. In Frankfurt-a.-M., the dried sludge has been pressed into briquettes without the addition of coal; the heat of combustion, however, was slight.

If there are no other means for disposing of the sludge than by fire, then, generally speaking, the incineration with slack coal is to be preferred. The combustion of the mixed screenings and sludge is cheaper than a separate incineration, in spite of the fact that the large amount of heat required increases the first cost of the plant and also operating expenses.

At Frankfurt-a.-M. experiments were carried out in Schuppmann's garbage crematory. A mixture of one part moist sludge and three parts of rubbish were incinerated at a temperature from 600 to 900° C. (1212° to 1652° F.). The heat of combustion is greater, the more combustible matters the sludge contains, especially hydrogen and carbon. It is reduced by fat which is decomposed or becomes gaseous below its ignition temperature. The developed energy is generally lost.

Coking or Gas Making. Coking of sludge or the manufacture of gas is really feasible only when the lignite process is used in the treatment of the sewage. Experiments with ordinarily settling tank sludge have given some poor results, as for example, in Stuttgart, Chemnitz and Frankfurt-a.-M. The gas obtained in Chemnitz was valued at .3 mark per cu.m. ($2.13 per 1000 cu.ft.), but it had so little illuminating power and contained so many impurities that it soon stopped up the pipes. At Frankfurt it was found more advantageous to coke the previously mentioned briquettes than to burn them. Satisfactory results were not obtained at Frankfurt also, since the candle power of the gas was very low. One disadvantage of incineration and coking is that the water in the sludge is first converted into steam with the development of a vast amount of energy, which, however, is not made use of since the steam again condenses. Koschmieder's process overcomes this by conducting the tarry vapor and the steam, which, as above mentioned, is produced below the ignition temperature over glowing coal, whereby carbon monoxid and water gas are obtained.

Among the methods for obtaining fat from sludge, perhaps the best known is the tank process of the firm of Beck & Henkel (compare Gesundheitsingenieur, 26. Jahrgang; Mitt. d. Kgl. Versuchsanst f. Wasserversorgung u. Abwasserbeseitigung). In this process the sludge from which the coarser matters, garbage, rags, etc., have been removed, is treated with sulphuric acid to obtain a better drying, and is pressed in filter presses and then extracted with benzene or carbon bisulphide for the removal of the fat. The end products are:

1. Distilled fat which is made into soap.
2. A tarry mass which remains after the distillation of the fat.
3. The residue from the fat extraction, which is worked up into fertilizer base.

The process was not even salable, and was given up. The cause of the poor result is, first the fact that the plant was initially of too small capacity, and second that the drying machines were unsatisfactory and had to be replaced, necessitating a heavy captial outlay and ruining the company financially. According to the views of the author the poor commercial possibilities in the process were in part due to the fact that the separation of the sludge, because of its nature and especially the extraction of the fat, was too expensive. In clarification plants both can be effected without the use of chemicals or heat. Of course, even in the Kremer apparatus the fat cannot be entirely removed from the sludge, but so much is removed that the organic residue can readily be used directly for fertilizing purposes or can be worked up into artificial fertilizer. Moreover, the fat obtained is in a condition which really makes possible the profitable recovery of a marketable by-product. This has been shown by experiments at Chemnitz and at Osdorf near Berlin. Except when the sewage is low in fatty matter the recovery of fat is profitable.

Experiments made up to the present time relative to the recovery of by-products from sludge have shown:

1. The recovery of a marketable by-product is cheaper the better the sludge is separated into fatty matters, mineral matters and organic substances in the clarifica-

tion plant itself; that is, without the application of outside energy.

2. Valuable by-products are in general not to be expected.

3. The type of process to be adopted and the profits to be derived from a given process vary widely under different local conditions. Sludge should be used for agricultural purposes where it is possible so to do. However, in cases where the sewage contains considerable fat, fat and fertilizer may be recovered by the Kremer apparatus, a process which covers, as a rule, the cost of operation. If this is also not possible, then the sludge must be burned or coked after the addition of combustible material such as coal, or it can be incinerated together with garbage. If it is decided to burn the sludge with the addition of coal, then according to conditions it is exceedingly more advantageous to add the coal before the sewage enters the sedimentation tanks than to use the lignite process, because the former plan makes unnecessary the otherwise required lignite treatment plant.

In order that the cost of the process may be reduced, experiments on the incineration of sludge must be particularly directed towards the use of the cheapest possible material which at the same time will make the sludge easy to press.

CHAPTER V

PRACTICAL ARRANGEMENT OF CLARIFICATION AND PURIFICATION PLANTS

THE most complete and the simplest purification of sewage as regards operation is effected by treatment on land which affords a source of revenue if used also for raising crops. Broad irrigation is to be adopted therefore, when there is available outside of the city, low priced land properly placed and of suitable character, sandy and not loamy. In order to save operating expenses the devices for preparatory treatment should be placed upon a site adjacent to the irrigation area. In a number of cities, such as Berlin, Darmstadt and Paris, the sewage flows to irrigation fields only after being previously treated in grit chambers and after passing coarse screens.

Generally speaking, the process has not proved at all successful. The irrigation fields become overloaded, sludge up and require, moreover, a very large area. On this account clarification of the sewage is unconditionally to be recommended antecedent to broad irrigation.

Clarification is effected chiefly in settling tanks, rarely in towers. In the opinion of the writer, however, the Kremer apparatus ought to be recommended especially for irrigation fields because it retains more fat than settling tanks and settling towers, and, as already mentioned, fat reduces the fruitfulness of the land. Furthermore, the Kremer process reduces the quantity of very fine suspended matters which ordinarily reach the irrigation fields. Fine screens are not to be recommended because they remove but little sludge, nor do they retain all the particles of fat; but, of course, fine screens are better than none at all.

In case irrigation fields are unpracticable, purification must be effected in artificial filters constructed of gravel, or in water-tight basins filled with a hard material, so-called contact filters or sprinkling filters. In this process of purification there is necessary the most complete preliminary removal of suspended matter; otherwise the filters rapidly clog and the filtering material must be cleaned. Fine screens are in these cases not suitable. Kremer apparatus following settling tanks and settling towers is, however, satisfactory for coarse-grain filters.

In the case of artificial sand filtration it is not only a question of the removal of the fine matters which will form a coating on the filtering material, but also that of preventing the formation of a fatty layer which will interfere with the entrance of the air necessary to support the biological action which takes place in the filters. On this account neither the Kremer apparatus nor settling basins alone are entirely satisfactory. It is advisable, however, to unite both plants and provide the Kremer apparatus following the basins. According to the Chemnitz experiments the decrease of oxygen consumed in the effluent is greater the lower the velocity in the settling basins. For example, with a velocity of 10 to 12 mm. per second (2 to 2.4 ft. per minute) the reduction in oxygen consumed was 80 per cent; at greater velocities the reduction was less.

If the sewage is clarified in towers, no Kremer apparatus should be necessary because, in this case, the fats are generally removed.

If no purification of the sewage is necessary on account of sufficient dilution in the nearby stream, then, generally speaking, settling tanks are to be preferred to settling towers. One of the largest clarification plants in which settling tanks are used is that at Frankfurt-a.-M. (Fig. 2 on Plate I). The sewage flows through a grit chamber, a three-compartment screen set transversely to the current, and then passes into the inlet gallery of the settling basin. During high water the ordinary outlet is closed and the effluent is pumped through a special outlet pipe. The pump is also used when the sewage is to be treated with a disinfectant, and in this case the treated sewage is pumped to special filters where the excess of disinfectant is removed.

The matters caught in the grit chambers and on the coarse screens are removed by means of a belt conveyor which carries them to a dumping ground. The sludge in the settling tanks is pumped with a suction pump to a tank from which it is forced to sludge disposal areas or to centrifugal machines.

If conditions are more favorable, then the cheaper Kremer apparatus is sufficient. Only in especially favorable conditions should fine screens or even coarse screens be used alone.

Plants of this kind are shown in Figs. 1 and 2, Plate II. Fig. 2 has already been fully discussed Fig. 1 shows Forbat's design for the city of Griesheim. The sewage here passes through a grit chamber, coarse winged screens and two fine screens horizontally placed. The material caught in the grit chamber and on the screens is removed mechanically by three belt-conveyors, one each for the grit chambers, the coarse and fine screens respectively. The material is then carried on a long conveyor which throws it into a sludge tank. The plant consists of two adjacent symmetrical parts, each of which can be cut off from the other completely. Evidence that automatic coarse and fine screens as a complete plant are to be used with caution is that fact that in Hamburg it has been decided to undertake a thorough clarification in settling tanks followed by purification on sprinkling filters with rotary distributors. This plan was deemed wise because the adjacent stream is small, the fall is slight and because the ebb and flood tides interfere with the operation of the plant.

Before all clarification plants should be placed a coarse screen to intercept the coarse débris carried by the sewage. If the sewage contains considerable quantities of coarse sand, a grit chamber is also required. As to movable screens, preference is to be given generally speaking, to the devices in use at Frankfurt or at Paris. The Hamburg design is to be considered only when decomposition of the organic matter is to be avoided before the sewage reaches the coarse screens; hence in cases where coarse and fine screens are operated automatically, and when the Kremer apparatus is used without being followed by treatment in settling tanks.

If, on account of insufficient grades, it is necessary to pump the sewage, then coarse screens, grit chambers and fine screens are to be placed before the pumps.

Irrigation fields possess the disadvantage that on account of the long distance which the sewage has to flow, and because of their very large area, decided loss of head is effected, thereby generally necessitating pumping. Under certain circumstances it may be possible to overcome this by conducting the sewage by the shortest route and causing it to flow into the stream after treatment in sedimentation and purification devices designed with minimum losses of head.

In such cases it is to be considered whether the advantages of irrigation fields justify the high construction and operating expenses of a pumping plant, including the removal of the material intercepted by the screens, a procedure which in these cases is generally expensive.

There are cases where there is some doubt whether settling tanks, settling towers, Kremer apparatus or fine screens are to be recommended. On this account the advantages and disadvantages of these devices are set forth as follows:

A. Towers are more advantageous than basins for the following reasons:

1. They are cheaper to build when the ground water is high. 2. The fatty matters may be more readily removed. 3. The area required is less. 4. Cleaning during the operation of the towers is more easily accomplished than is the case with basins, and they are therefore to be preferred when the sewage is very stale. 5. More finely divided suspended matter is intercepted on account of the fact that the heavy suspended matters fall to the bottom and form a sludge filter.

Compared to settling tanks, they possess, however, the following disadvantages:

1. They are more expensive, with the exception of the case mentioned, where the ground water is high. 2. The construction of a satisfactory inlet is difficult. 3. A large number of towers are necessary when the quantity of sewage is large, and these require a complicated network of pipes and necessitate more labor in their

operation. 4. The sludge contains more water than that in basins. 5. The evolution of gas has a much more deleterious effect.

B. Kremer apparatus possesses the following advantages over settling tanks:

1. Operating expenses are less; operation is simple and depreciation is very small. 2. Less space is required. 3. Clarification is effected in 15 minutes and thus septicization is prevented. 4. A cheap recovery of fat is made possible. 5. The production of odors is not to be feared. 6. There is made possible the separation of suspended matters, according to their nature.

On the other hand, with the Kremer apparatus less finely divided matter is removed than is true of either settling tanks or settling towers.

In comparison with the above-named processes, fine screens as a complete plant possess the advantages that:

1. The material intercepted is at once removed from the sewage and can easily be examined. 2. The screenings need not be raised to so great a height. 3. The intercepted material contains less water. 4. Putrefaction is prevented. 5. A slight space is required.

On the other hand, fine screens possess great disadvantages, namely:

1. Their efficiency is very low. 2. They permit no regulation with respect to the volume of the sewage. 3. They are almost entirely ineffective when the sewage is stale or when the organic matters tend to break up.

The fact that the operation of fine screens is cheaper than settling basins, the author did not find to be justified. For example, the operation of the Cologne plant, which contains both fine and coarse screens, cost 32,000 marks ($8000) annually, while at the settling tank plant at Mannheim, the yearly operating expenses were 28,000 marks ($7000). Although in Cologne the population is greater, in Mannheim the sewage contains more industrial wastes. To be sure conditions in Cologne where the sewage is weak and free from sand, are scarcely more unfavorable than in Mannheim.

As regards the first cost of the plant and also the construction costs of the fine screens, the necessary machinery can scarcely be less than the concrete or masonry basins, unless there are unfavorable conditions, such as high ground water pressure. The cost of repairs is likewise less in the case of settling tanks than fine screens.

Finally, stress is to be laid upon a thorough distribution of the effluent as it discharges into the nearby stream. This is best effected by conducting the effluent to the middle of the stream and discharging it at the bottom, corresponding to the Hamburg design.* If the bed of the stream is wide it is preferable to cause the effluent to discharge at different points in the cross-section. If the plant is on low land the water must be pumped into the adjacent stream.

In the interest of the community, it is desirable to ascertain the efficiency of the plant by the periodic collection of samples of river water below the plant, and in case of poor results immediately to undertake the necessary improvements before cities below the outlet institute lawsuits, or before the state forces costly measures for rectifying nuisances, expenditures which are, in such cases, far in excess of those that would have been required had attention been given to the necessary improvements in the plant when the analytical evidence first gave indication of its low efficiency.

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* Zeitsch. des Vereins deutscher Ingenieure, Jahrgang 1906.

ADDENDUM

LIST OF PUBLICATIONS RELATING TO SEWAGE PLANTS MENTIONED

In the following list, references to the literature are given by numbers corresponding to those assigned to the different publications as follows:

(1) Dr. Salomon, Abwasserlexikon, Vol. I.
(2) Reports of Royal Prussian Testing Institute.
(3) Techn. Gemeindeblatt.
(4) Gesundheitsingenieur.
(5) Deutsche Bauzeitung.
(6) Deutsche Technikerzeitung.
(7) Zeitschr. f. Arch. u. Ing.-Wesen.
(8) Zeitschr. d. Vereins deutsch. Ing.

Aachen	(1); (3) 8; (4) I. 29
Andernach	(1)
Barmen	(see Elberfeld)
Berlin	(4) I. 29
Bernkastel	(1)
Beuthen (O. S.)	(3) 6
Bielefeld	(1)
Bonn	(1)
Borbeck	(1)
Bradford (England)	(4) I. 29

Birmingham	(2) (Heft 3)
Brühl (Rheinland)	(1)
Bremen	(3) 5; (3) 6
Cassel	(2); (3) 5; (3) 6; (4) I. 26
Cologne	(1); (2); (3) 5; (3) 6; (3) 7; (4) I. 26
Columbus (N.-A)	(3) 9
Darmstadt	(1)
Dresden	(3) 8; (5) 1906
Düsseldorf	(1); (5) 1904
Duisburg	(1)
Elberfeld	(1); (4) I. 26
Eschweiler (Rheinland)	(1)
Frankfurt am Main	(1); (6) 21 Jahrgang
Giessen	(1)
Göttingen	(7) 51; (4) I. 28
Guben	(3) 9
Hamburg	(3) 7; (8) 1906; (5) 1907
Hannover	(2) (see Cologne); (3) 6
Kempen (Rheinland)	(1)
Kiel	(3) 5
Königstein im Taunus	(1)
Langensalza	(2)
Lichtenberg bei Berlin	(4) I. 28; (3) 6
Manchester	(3) 5; (2) (Heft 3)
Mannheim	(1); (3) 9; (4) I. 29
Marburg	(1)
Merseburg	(3) 8
Merzig (Rheinland)	(1)
Ohrdruf	(4) I. 25
Oppau (Rheinpfalz)	(4) I. 29
Osdorf bei Berlin	(4) I. 28
Paris	(3) 5
Pfaffendorf bei Coblenz	(1)

Posen	(3) 9
Remscheid	(1)
Rheyd	(1)
Silbey (England)	(4) I. 29
Solingen	(1)
Stuttgart	(1); (2)
Trier	(1)
Viersen (Rheinland)	(1)
Weissensee	(3) 6
Wiesbaden	(1); (3) 6; (3) 7; (4) I. 25 (4) I. 28
Wilmersdorf	(8) 1907
Worcester (Severn)	(3) 8

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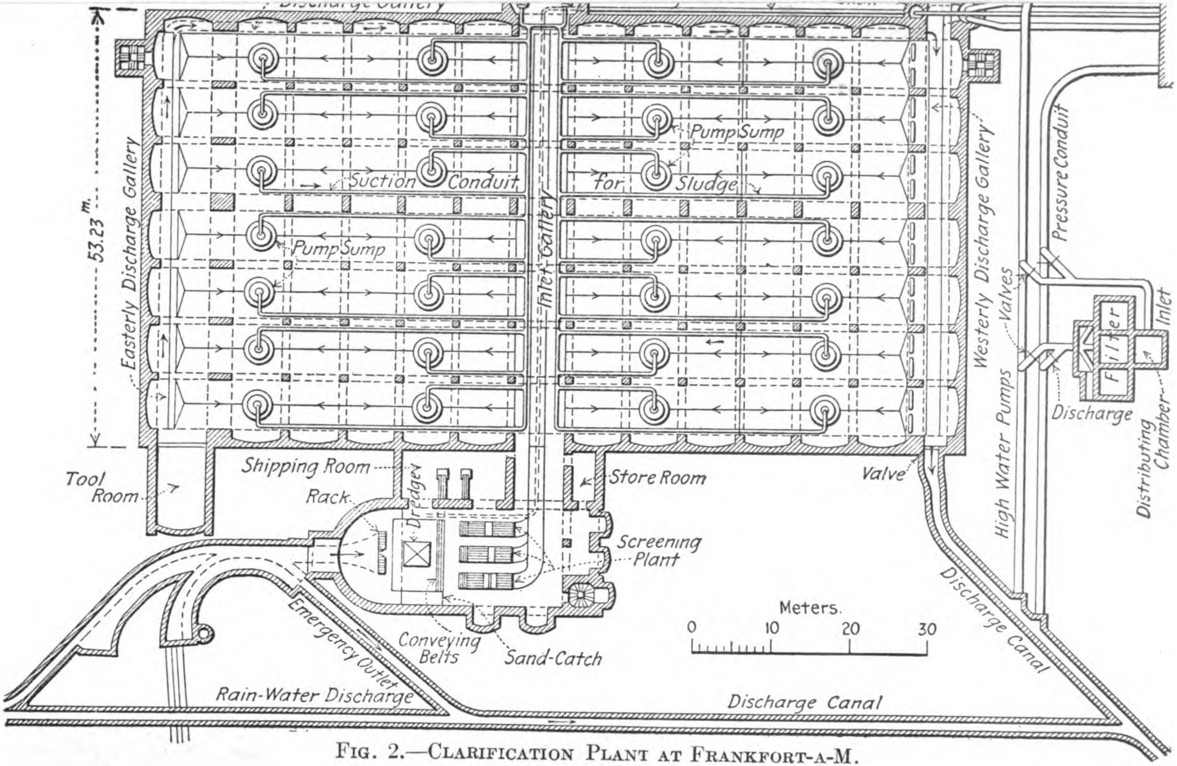


Engine

FIG. 2.—CLARIFICATION PLANT AT FRANKFORT-A-M.

PLATE I.


Discharge Gallery
Discharge Conduit
Discharge Pump
Shaft
200

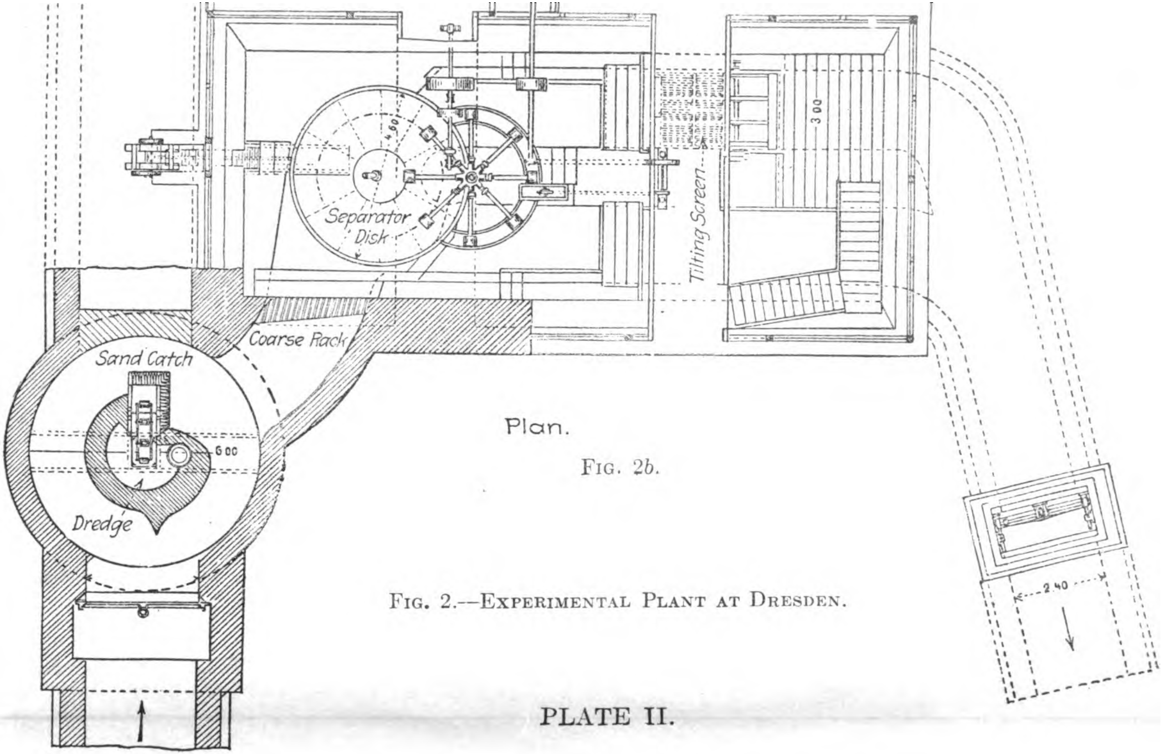


FIG. 2b.

FIG. 2.—EXPERIMENTAL PLANT AT DRESDEN.

PLATE II.

Fig. 1a.

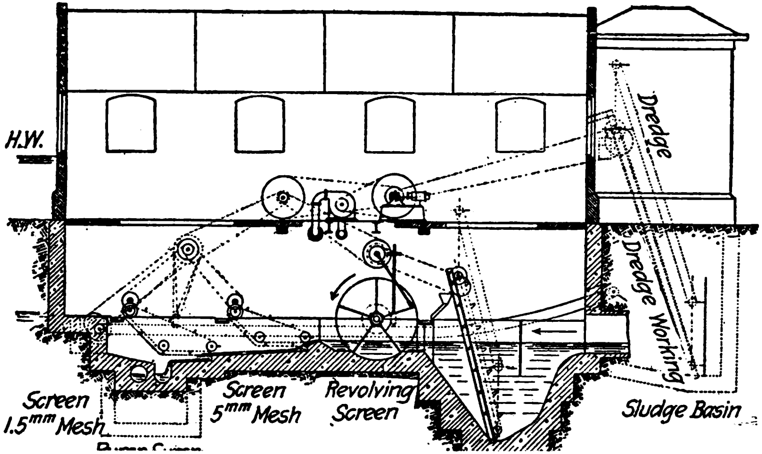
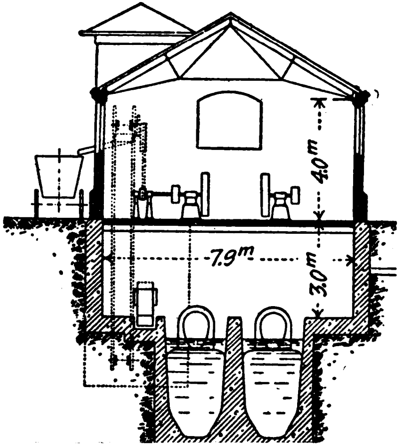

H.W.
Dredge
Dredge Working
Screen
1.5mm Mesh
Screen
5mm Mesh
Revolving
Screen
Sludge Basin

Fig. 1c.


4.0m
7.9m
3.0m


Discharge Gallery
Discharae Conduit
Shaft