18.

MAIN SEWERAGE

AND

SEWAGE DISPOSAL

BY

T. AIRD MURRAY, C.E.

(Consulting Engineer, Toronto)

Author of "Improved House Drainage,"
"Sewage Disposal for Isolated Buildings,"
&c., &c.

(Reprint from The Canadian Engineer)

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CONTENTS

PREFACE

"By means of this treatise it is my endeavor to bring the whole question of town drainage and the purification of sewage in a terse and concrete manner before those authorities, engineers and others to whom the subject is a new one. It is not pretended that the information given is by any means conclusive. There are many variations and features which can be found described in more pretentious works on the subject. I am indebted for much information on American sewage disposal to Messrs. Rafter and Baker in their extensive work on 'Sewage Disposal in the United States.'

"The principal information which I give is based on an experience of over twenty years' connection with this work in Great Britain, and I recognize that certain precautions will have to be taken in a country such as Canada to guard against severe frost.

"I shall be glad to give any further information at any time and answer enquiries arising out of these pages upon receipt of a letter addressed to the offices of the 'Canadian Engineer.'"

T. AIRD MURRAY, C.E.,

TORONTO,

(Formerly Consulting Engineer to the North Eastern Sanitary Association, England.)
(Engineer to the Sheffield Board and Sheply and Shelley Joint Sewage Boards, England), etc., etc

MAIN SEWERAGE AND SEWAGE DISPOSAL

T. AIRD MURRAY, C. E.
Consulting Engineer, Toronto

CHAPTER I.

The term "sewerage" as used applies to the process of the removal of sewage by water carriage by means of pipes or other conduits.

The term "sewage disposal" applies only to some process by means of which the sewage delivered by the "sewerage system is dealt with in order to render it innocuous to human beings."

Although a sewerage system in every town is recognized as an early necessity, the application of some system of sewage disposal is only very tardily recognized. The practical application of sewage disposal is in fact a new subject in Canada.

The author's chief aim will be, to lay stress on the necessity of some method of sewage disposal. To describe as simply as possible the leading features appertaining to an up-to-date disposal plant, the evolved result of the experience of both Europe and America. In order to obtain satisfactory results from sewage disposal it is necessary to broadly consider the subject of main sewerage.

Haphazard Sewerage Systems.

Much money is at present being thrown away in Canada by laying out sewerage systems without any consideration of how such systems will meet certain requirements, if at any time sewage disposal is found necessary. The City of Toronto is very much to the point. Here the sewers have been laid in any haphazard manner, each discharging locally at the nearest point to the lake from which the city's water supply is obtained. No care has been takeñ to separate storm and subsoil water from the sewage proper, hence it is now found that a large sum of money must be expended to first collect and arrange the general outfall of the system, and provide storm overflows, before any scheme of sewage purification can be adopted. While there may be some excuse for lack of forethought in the case of older towns such as Toronto, there can be no excuse for towns, which are at present springing, as it were, into municipal existence, adopting haphazard sewerage systems. It is now quite apparent to those who have watched the progress of city hygiene that sooner or later every community will be called upon to deal with the question of sewage disposal.

Canada as at Present.

Throughout Canada generally there has been up to the present no attempt of a serious nature to deal with the question of sewage purification. Throughout the Province of Ontario it is the common practice to discharge the raw sewage from towns into rivers and lakes, otherwise of a pure water character, which form the only source from which drinking water can be obtained.

Town after town on the banks of the St. Lawrence pours its raw sewage into the river, while these towns pump back the river water and use it for drinking purposes without any attempt even at filtration.

At the head of Rainy River the town of Fort Frances contaminates the water, and the various towns below drink the diluted sewage.

Niagara by the Lake drinks the unfiltered water from the river, receiving the whole of the sewage of Buffalo and other towns on both sides of the river. The intake being above the Falls.

The Grand River, the Thames, and, in fact, all the rivers on which towns are situated, are sewage contaminated and totally unfit as water supplies for domestic purposes. The serious aspect of such a state of things is being brought more and more before the people every day. As populations along the river banks increase, and as people become more educated to the fact that the health of a community depends to a great extent upon a pure and unadulterated water supply, so we are beginning to understand that the problem of sewage purification is very much with us. It is a problem which must be faced by every community in the near future.

Legislative Power.

The Ontario Provincial Board of Health, with Dr. Hodgett's as the secretary, is doing a good work in bringing before communities this serious and disgusting state of matters. In several of the most glaring cases they have been able to bring sufficient pressure to bear to cause the authorities to act. But it is generally admitted that the laws on the subject require strengthening and more rigidly put in force. The Provincial Board of Health is ridiculously understaffed. Sewerage works and other works of a like character over which the Provincial Board have certain powers of administration are carried out practically without their knowledge and in many cases entirely against the principles of good hygiene recognized by that authority.

Some administrative system such as that adopted in Great Britain, where the Local Government Board are empowered to hold public enquiries into questions relating to sewerage, sewage disposal, and water supply, and insist on communities adopting certain standards is much required in Canada. Again, in Great Britain the powers granted to River Boards are extremely useful in preventing river pollution. They have the power to obtain in the law courts an injunction against any municipality or private person, who contaminates a water course, and inflict a fine sometimes amounting to $1,000 a month until such time as the pollution complained of ceases.

The addition to the staff of the Board of Health of an engineer expert in public works problems with a staff of competent inspectors would tend to make the Board of Health more of a power for useful work in advising authorities, and keeping some check upon the work done. A systematic report upon the rivers of Ontario and the amount and degree of pollution from the various towns would be useful to the Board as a basis upon which much good work of a propagandist character could be effected.

The Excuse for Neglect.

Some will here say, "You cannot expect Canada to be on a line with Great Britain, Canada is a new country." We may ask the question, When is Canada going to cease to be a new country? Or because it is a new country, is that any reason why it should not be a clean country? Canada at some time or another will have to toe the line of civilization. Canada is no longer represented by isolated wood cabins. It has huge cities, prosperous and modern built towns, fed with electricity and every scientific improvement of a utilitarian character. Canada must also recognize that it has duties to perform in fathering its population, in providing every care for its good health, physical development and consequent happiness. This is where the principles of hygiene come in

Sewage Disposal an Essential Duty.

It has been held in Great Britain, in Germany, in France and in other civilized communities that it is the duty of every community borrowing water for domestic purposes to return it in as pure a condition as it is possible to do so. In fact, that no town has the right, simply because it exists on a river bank, to pollute that river with sewage to the detriment of its own inhabitants, and especially to the inhabitants below who in turn receive the water at their doorsteps.

The Results of Neglect.

The acknowledgment of this duty sixty years ago in Great Britain, brought the community face to face with a great expenditure of money. The rivers once clear and full of fish, even at such towns as Leeds, Huddersfield and Sheffield had become stygian ferments, fruitful beds of disease, most objectionable and nauseous. The evil had been done slowly and gradually. Rivers once beautiful turned into hideous sewers, their banks impossible to walk along, places to be shunned. Now the experience of other countries is writ large before us. The Rhine, the Danube, the Rhone, the Thames at London, the Clyde at Glasgow, the Forth above Edinburgh, the Tyne at Newcastle, the Mersey at Liverpool all turned into open sewers costing millions of gold to re-purify.

Where Canada May Profit.

Is Canada going to profit by this knowledge? And, at the commencement, even granting the new country excuse, is it going to put its foot down at once, adopt principles and rules of government which will make such a state of things impossible? Is it going to preserve its rivers and lakes, things of joy and beauty for ever? Is it going to adopt a policy for which its children will praise it and be thankful? A new country! Why the benefit of being a new country is that there is all the experience of the sad mistakes of the old to figure from. The extent of Canada, its scattered populations are no excuses for delay. Everyone with faith in Canada, faith in its future, and with the knowledge of its wonderful development in the near past and present, expects it to go on increasing, expects populations to arise and rivers and lakes become, even more so, highways of commerce and prosperity.

Now is the Opportunity.

Surely now is the fit and proper time when the country must recognize it as a duty to cease to pollute the beautiful lakes and water courses, to retain them as fit and proper sources of water supply.

If legislation is necessary, then legislation must be put in force. Boards of health must insist upon a standard of purification. Communities and peoples must be educated to the subject, and our children taught in school that it is a crime to pollute God's water supply, sent for the benefit of His people for not only this but other ages.

Typhoid and Water Supply.

Epidemics of typhoid fever are generally the result of drinking sewage contaminated water. Wherever such water is provided, typhoid is generally found to be endemic. The typhoid infection is carried by a specific germ or bacillus which is given off from the patient. The disease may be of a mild character in the first instance, the person having it being unaware of its presence. Such a patient may even undertake and continue his daily avocations and yet sow the germs of disease broadcast with every direction.

The bacilli of typhoid, which are given off with the excreta find ready access by means of sewers to water supply sources. They continue to multiply in the water or in the organic matter of the sewage, from which they ultimately find their way into pure water. Although such water may appear pure enough, as soon as it is taken into a slightly disordered stomach or intestinal canal, the bacillus gains a foothold, and another patient is attacked or a general epidemic may occur. This may happen simply through the rinsing out of a milk pail by water from a stream which has received sewage contamination.

Milk and Typhoid.

The germs propagate at a great rate in milk, and many causes of epidemic may be traced to a milk supply, but in the first instance the infection is almost always obtained by the milk utensils coming in contact with sewage polluted water.

Other Diseases Common.

Typhoid fever is perhaps the most important of water-borne diseases, but diarrhoea, dysentery and cholera are often carried by water, and all frequently result from sewage contaminated sources.

Details of enquiries into epidemics of the above diseases are numerous, and many of an interesting character might be given, conclusively proving how hundreds of lives have been sacrificed, and are still being so, by providing water for drinking purposes known to be polluted by sewage.

In a comprehensive volume entitled "Sewage Disposal in the United States," * a large amount of evidence is collected of a most instructive nature, showing conclusively that zymotic diseases and epidemics are peculiar only to those towns in America which are supplied with sewage contaminated drinking water. And, that on the institution of water filtration and by cutting off the sources of contamination the proportion of such diseases at once fell to a low rate, and that epidemics practically ceased to occur. An interesting quotation from the above is as follows: "In 1880 a number of large hotels were constructed on the lake beach not far from the mouth of the Genesee River. Numerous cottages were erected, and these soon gathered about and near the river's mouth a considerable summer population, consisting almost entirely of citizens of Rochester. On Sundays and holidays it is no uncommon thing for from 25,000 to 30,000 people to visit the lake beach. Drinking water is supplied through pipes which lead a short distance into the lake, and through which at times the sewage polluted water of the Genesee River, mixed with lake water, is drawn.

The growth of the summer resorts at Lake Ontario and the consequent drinking by a large number of citizens of a seriously polluted water, has directly contributed to nearly double the typhoid rate in the City of Rochester. As the matter stands a warm May is followed by an increase in the typhoid death rate, either in the latter part of the month or in the following month of June." The authors conclude: "From the consideration of a large number of cases similar to the foregoing we derive the conclusion that crude sewage should never be discharged into any body of water used as a water supply at any point within the influence of the sewage. This statement may be considered the fundamental proposition of modern sewage disposal."

"Scepticism to be Overcome."

An adequate treatment of the systematic work and discussion on the subject of stream pollution is however impossible in the limits of a single chapter. Enough, however, may have been said to convince those who have not given the matter much consideration that the subject is one worthy of deep consideration. There are no doubt many who maintain a sceptical attitude with regard to the importance of

* Authors: Messrs. Rafter & Baker. Published 1894.

the matter. But such scepticism is generally the result of ignorance or lassitude of interest. But whatever the result of, it is the one prick which the sewage engineer finds it hard to kick against. The spirit of ignorance is to domineer. Many an honest engineer who in his heart knows exactly what the advice is he should give, finds it diplomacy to play the role of the silent guest, and quietly takes his orders and pockets his fees, rather than suffer the strain of attempting to persuade a corporation that they should be paying for advice and not paying in order to give it.

An engineer of repute in Canada only lately informed the author in accents sad and pathetic: "Once I had hope in bringing the subject of sewage disposal to the fore, but now I have almost given up. I visited the Old Country to see what they were doing there, and came back with tons of information. But, if you want to make dollars you must give the advice the people want, not the advice they should have."

A fitting close to this chapter is the well-known quotation from Sir Spencer Wells: "Typhoid fever, scarlatina, diphtheria, smallpox, whooping cough, can no longer be looked upon as natural, providential, or unavoidable. The existence of such 'preventable diseases' is a proof of ignorance or negligence, and a disgrace to the country, to the town, to the family."

CHAPTER II.

MAIN SEWERAGE

The question of main sewerage is perhaps, one of the most important ones affecting the health of any community. Sewage in its composition consists of most of the waste products of humanity. The human body is constantly taking in forms of poison which it has to deal with and discharge in the form of effete matter. Upon the ability of the constitution to handle and combat with these various poisons depends its health state.

Human Waste.

There is a constant flux or change going on in the tissues and frame of the body. It is held that in ten years the whole body has undergone an entire change, has been, in fact, renewed with fresh tissue and new cell formations. Thus in ten years the material part of a whole population has either passed as refuse into the atmosphere or down the town sewers. The waste is represented to a large degree by the carbonic acid the body is giving off by expiration to the atmosphere and by the organic particles absorbed by clothing, removed by washing and by the ordinary digestive processes. This waste has properties of a toxic ptomaine character, which, if they re-enter the human system, act as poisons.

When the air in a room is vitiated, it is not the presence of the carbonic acid gas which affects those present. The consequent lassitude, sickness, and headache are due to re-breathing and swallowing particles of effete organic matter of a p[illegible]ous character. The measure of the carbonic gas is on[illegible] indication of the presence of organic impurities. Now, just as it is necessary to remove a vitiated air as quickly as possible, so is it necessary to remove a vitiated volume of water containing waste products, such as sewage.

What is Sewage?

Sewage represents the total amount of water supplied for domestic purposes after it has passed through the human body, removing with it the internal waste products; also the dirt from surfaces of the body, from clothing, house-cleaning, street-washing, grease, etc., from cooking utensils, and, in fact, all the discarded waste which the water supply in passing through the town carries with it. With the sewage is carried all the effete discharges and resultants from disease. Skin scales from scarlet fever and small pox, bacilli from typhoid and diarrhœa, etc. The whole sum total of the sewage, consisting of a liquid containing a large amount of organic matter charged with poisons and disease germs, in a condition unstable in its chemical combination and most liable to putrefaction. Sewage forms a suitable nidus for the rapid growth of disease germs; it will absorb them, whenever it comes in contact with them. In its midst they will grow by the million.

Sewage undergoing putrefaction produces a dangerous gas, called sewer gas, which may be charged with the germs or spores of disease and carry the infection of disease on its wings.

Sewage coming into contact with milk, milk utensils, food and water poisons them and renders them dangerous. Sewage is a necessary factor in the economy of existence. It has, however, to be dealt with firmly and scientifically—removed, totally removed, by the quickest and cleanest method possible to the wit of man.

The Careless Mind.

When a municipality approaches the question of sewerage (or the getting rid of sewage) there is apt to be engendered a feeling of carelessness, resulting from a common idea that "anyone can lay a sewer." "There can be no difficulty in laying pipes under ground with a fall so that water runs." So we hear it said, the result being that many sewerage systems have been put in roughly, improperly, leaky, without sufficient falls, no flushing, no proper supervision, and, it is said, "We never had smells till we got a sewerage system." "Our death rate is now higher since we got the sewerage system." The end of many of these so-called sewerage systems is certainly worse than the beginning.

What can be said of a sewerage system which is practically a disposal system in itself. That is, by means of careless jointing, defective laying, and, perhaps, broken pipes, most of the liquid sewage is escaping into the soil near the houses, near water mains, which may also be leaking, and into which the sewage is drawn when the water is turned off and the mains emptied. A town built upon a sewage contaminated soil, the ground air to the buildings supplied from a sewage contaminated source, the liquid escaping, leaving the solids stranded in the sewers to putrefy, forming elongated cesspools in the streets, supplying sewer gas in abundance at manhole gratings and into dwellings by means of plumbing defects. There is no exaggeration here. Thousands of dollars have been expended to obtain the above results. Plans, complete plans, carefully designed by competent engineers, have been handed over and botched by careless contractors, supervised, if at all, in many cases by some local person with no real experience of good work, but pushed into position by some local influence. In other cases no proper plans have been made, all being left to piecemeal hazard—odd bits done at odd times, no regulated plan, no complete scheme, no specification, and practically no knowledge of good work of any kind relating to sewerage. Every engineer can point to plenty of instances of the above. Many a community in its heart of hearts knows it is so. No one really to blame, no real culpable negligence, but just carelessness and want of real knowledge of the seriousness and importance of the subject, and, perhaps, just a little tendency to sacrifice good work in order to guard the sacred dollar in the safe.

Approaching the Subject.

When an engineer or an authority has to approach the problem of main sewerage there are certain defined points which must be kept in mind. The author will endeavor to deal with these points as concisely as possible.

The Main Principle.

Sewage must be completely removed from the vicinity of the town as rapidly as possible and before time is given for putrefactic to commence. Any structure or appliance retaining sewage is against every good principle of sanitation. Retention of sewage means formation of sewer gas and an admittance that the sewers are not capable of doing their duty.

A Complete System.

No matter whether it is the intention to only lay a short length of sewer, or sewer only part of a town, every such length should be a part of a general system, schemed and laid out on a plan to deal not only with the town's present limits, but also comprising and taking in districts over which the town may have a tendency to extend. As far as possible, before laying out a sewerage system, a common point of discharge should be fixed upon, a point to which the whole of the sewage can be taken by gravitation if possible. Such a point should be well away from the inhabited part of the town, where sufficient land can be easily obtained for disposal purposes in the event of such being required at any time, if not at present contemplated. By the use of judicious foresight in this instance much money can be eventually saved. Every community may take it for granted that at some period or another sewage purification will become a necessity to them.

The Separate and Combined Systems.

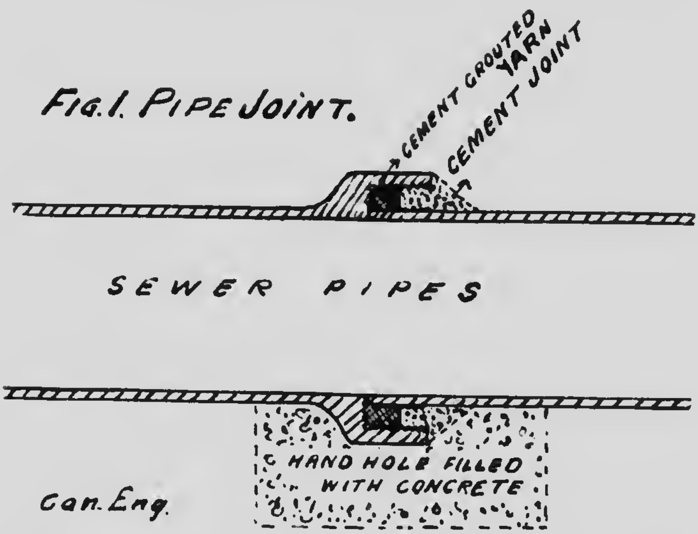
A "combined system" of sewerage is one which takes not only domestic sewage, but also all the storm road water and sub-soil water which it is necessary to remove from a town. The "separate system" of sewerage is when there are two systems laid down, one for domestic sewage, including roof water and another for road and subsoil water. The separate system presents the more up-to-date and by far the better plan. By the combined system it is necessary to lay down large diameter pipe sewers, capable of taking excessive torrential rains, and so prevent roadways and cellars from flooding. These large sewers during dry weather are much too large for the flow of domestic sewage, the result being that the mean hydraulic depth is so small and the liquid spread over so great a surface, it is incapable of carrying forward solid matter. Such sewers present channels of piled-up filth, through which the liquid simply oozes, the filth not being removed until some rainstorm comes along capable of flushing the conduits.

The natural objection to the separate system is that at first sight it appears more costly, apparently providing for two systems of sewerage. However, the cost is very little more, if any, than in the combined. The two lines of pipes can be laid in the same trench when open and smaller diameter pipes are required.

The great advantage of the separate system is, however, that if at any time sewage disposal is required, definite amount of sewage at the point of discharge can be figured on. The amount in dry weather simply represents the water supply per capita, and in wet weather the water supply, plus the rainfall on the roof area of the town, which at no time amounts to more than three times the dry weather flow. On the other hand, if storm road and sub-soil water be admitted to the main sewerage system, it is necessary to spend almost four times the amount on disposal works and build works on a scale totally much too large to deal with the real sewage of the town.

Sewers Should be Self-cleansing.

By self-cleansing it is meant that whenever possible gradients and sizes of sewers should be so arranged that the depth and velocity of the flowing liquid should be sufficient to carry all solid matter with it. It is apparent that only by the adoption of the separate system can this object be attained. In main collecting trunk sewers little difficulty is found in obtaining a volume of sewage with a sufficient velocity. But in sectional sewers, where the volume is small and often intermittent, there is sometimes difficulty. Mistakes are often made in putting in sewers for branch work of too large a capacity. The velocity aimed at for branch sewers should not be less than two feet per second when running half full. The following falls, given to 9-inch and 12-inch circular sewers, running half full, will produce the



following velocities in feet per second:—9-inch, 1 in 450 = 2 ft.; 1 in 200 = 3 ft.; 1 in 120 = 4 ft.; 1 in 75 = 5 ft. 12-inch, 1 in 600 = 2 ft.; 1 in 200 = 3 ft.; 1 in 160 = 4 ft.; 1 in 100 = 5 ft.

Whenever it is necessary to lay a branch sewer, 9-inch diameter at a gradient less than 1 in 450, or a 12-inch at less than 1 in 600, producing a velocity of less than 2 ft. per second, some method of extra flushing should be resorted to.

Flushing Sewers.

A good method of flushing for branch sewers is to erect at the head of the sewer an automatic discharging tank, fed either from the water main or by collecting bath waste water. The amount of the discharge should not be less than 700 gallons for a 9-inch pipe and 1,000 for a 12-inch pipe. The discharging syphon should be capable of three-quarter filling the sewer to be flushed.

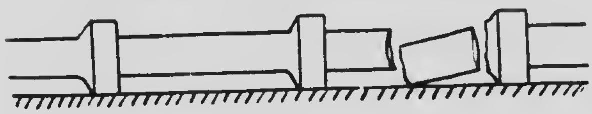
Materials for Sewers.

For all conduits up to 2 ft. 6 in. diameter, stoneware salt-glazed pipes are the best; for over 2 ft. 6 in. diameter the conduits should be built in culvert of the egg-shape section of either brickwork or reinforced concrete. Stoneware pipes should have a thickness of crust equal to 1-10th their diameter and the spiggot ends threaded externally while the sockets are threaded internally. There should never be less than 2½-inch depth of socket room, and width space of at least ½-inch clear all round.

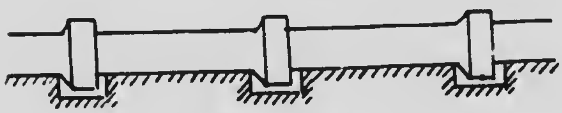
Jointing in Sewers.

Fig. 1. shows a good sound sewer pipe joint, made with grouted yarn stemmed into about half the socket space, the

FIG. 2. LAYING PIPES.



SEWER LAID WITH SOCKETS ON HARD BED



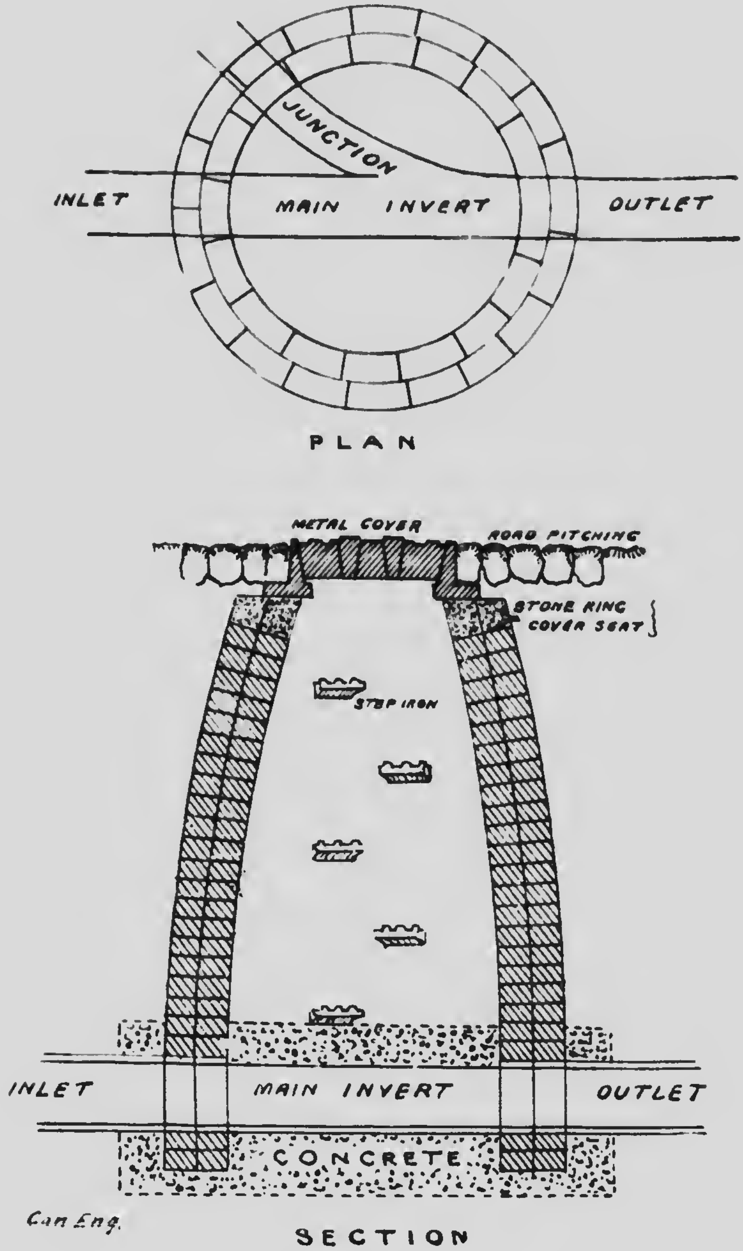
SEWER LAID ON HARD BED WITH SOCKET CAVITIES

remaining space being occupied with cement neatly finished. The purpose of the grouted yarn is to keep the pipe in position, so that the alignment is true and an equal socket space maintained all round the pipe. It also serves the double purpose of preventing cement from running into the pipes. The yarn is first dipped in liquid cement and then stemmed into the socket. The cement finish should be in parts of one of cement to one of sand. Pure cement is apt to crack when setting.

Laying the Pipes.

Great care should be taken that the body of all pipes rests evenly on the surface of the trench, and that holes be

FIG. 3. MANHOLE



excavated at the sockets. No pipe must rest on its socket, or the result shown on Fig. 2 will be obtained. This commonly happens, especially when sewers are laid in rock or concrete, or other hard surface. The handholes should be filled with concrete. (See Fig. 1.)

Testing Pipe Jointing.

It is extremely important that all pipes be tested as to their jointing before and after they are filled in. The proper and only satisfactory test is the water test. The length of sewer as laid is plugged at the lower end and the whole length filled with water, the natural gradient providing a head of pressure. At the top end a curved elbow pipe should be temporarily fixed so as to obtain pressure on the upper joints of the length. The length of drain must be capable of holding the water without the least sign of leak. This is the natural test the sewer will be put to it at any time the length becomes choked in practice. The reason for testing a second time after the trench is filled is that there is a chance of the pipes being disturbed, and even broken, by careless filling in.

The man who says it is not necessary to test sewer joints is the man to be careful of. He either suffers from a mental or moral twist, or perhaps both. The contractor who takes it as an insult to have his work tested, and says, "So and So has always found his work all right without testing," is the sort of man who cannot take a threshing standing up, and is really afraid of his work.

Filling in Trenches.

The filling of the trenches requires great care and most careful supervision. Many lengths of sewer are ruined by careless filling, throwing in large stones immediately over the pipes, treading on the pipes, and ramming the earth before there is sufficient cover to protect them. It should always be borne in mind that a length of sewer jointed with cement forms a rigid tube. In filling, loose earth should first be carefully packed around and over the pipes, and no ramming should commence till there are at least two feet of covering.

Manholes.

Manholes should be built on the line of sewer at every change of gradient and direction, and at distances of not more than 300 feet apart. These will allow the sewer to be examined at any time, as a clear view through the sewer must be presented between each manhole. They also allow of any choke being removed by the use of drain rods. A well-arranged manhole system is a saving of money, and guards against the future breaking up of the road for examination purposes. Fig. 3 gives a useful and cheap form of manhole. Built circular, it is very strong, and will stand any weight of traffic. Such can be built of 9-inch brickwork with radiated bricks, or in concrete rings, either reinforced or otherwise.

Ventilation.

A common practice is to ventilate the sewers by means of open gratings over the manholes. In a first-class system of drainage, where the sewers are self-cleansing, there is not much objection to this, as the sewer gas is seldom of a character causing any nuisance. The better plan, however, is to provide close covers on the road surface, and provide separate vent-pipes from the manholes to the sides of roadways, and carry up 6-inch iron pipes up the sides of buildings clear of all windows and chimneys. The vent-pipes may be carried in connection with gas lamps, and the organic impurities in the sewer gas destroyed by combustion. Special vent-pipes are often required at the head of sewers. Sewer gas, being generally warm, has a tendency to rise and become more concentrated in the higher reaches of a town. Ventilation to sewers is always necessary, relieving house fittings from any undue pressure.

Much more in detail may be stated, but the object here is simply to show what should generally be insisted on in connection with a good, honest and serviceable system of sewerage. Special circumstances are always arising, such as waterlogged land, running sand, etc., which may require special pipes and special joints. If, however, sufficient has been said to make it clear that a sound and durable system of sewerage is within the reach of every municipality, the author will feel that his object has been achieved in this chapter.

CHAPTER III.

THE HISTORY OF SEWAGE DISPOSAL

In Great Britain in the year 1876 an Act of Parliament came into force, called the "Rivers Pollution Prevention Act." Part I., par. 2, enacts:

"Every person who puts, or causes to put or to fall, or knowingly permits to be put in, to fall or to be carried into any main, so as to interfere with its due flow, or to pollute its waters, the solid refuse of any manufacturing process or quarry, or any rubbish or cinders, or any other waste, or any putrid solid matter, shall be deemed to have committed an offence against this Act."

Part II., par. 3: "Every person who causes to fall or flow, or knowingly permits to fall or flow or to be carried into any stream any solid or liquid sewage matter shall be deemed to have committed an offence aginst this Act."

Part IV., par. 10: "The county court having jurisdiction in the place where any offence against this Act is committed may by summary order require any person to abstain from the commission of such offence." The penalty for default in not complying with such an order is fixed at not more than £50 (or $250) a day for every day during which such person is in default, as the court may order."

This Act had become a public necessity, as the rivers of Great Britain were gradually becoming simply open sewers. Previous Acts of Parliament of a local character, such as "The Thames Conservancy Act, 1857," had been enacted. Other Acts also existed by which an injunction could be obtained against any person or persons polluting a stream and causing a nuisance. The above Act of 1876, however, was a bona fide attempt to put in force the recommendation of a Royal Commission, called "The Rivers Pollution Commission," which had made extensive enquiries into existing methods of sewage disposal up to that date, and fixed certain standards to determine impurity in waters discharged into streams and rivers.

Broad Irrigation.

The earliest method of sewage disposal was naturally its application to land. Large tracts of land were either leased or purchased. At Birmingham (England) the sewage for every 560 persons was purified on an acre of land. Thus large sewage farms came into existence, it being more often found that an acre of land was only sufficient for every 100 persons. These have, however, been almost universally abandoned. By this method the sewage was allowed to simply irrigate by means of ridge and furrow beds, the land being used for cropping.

Intermittent Land Filtration.

An improvement in broad irrigation was highly recommended by the "Rivers Pollution Commission," called "Intermittent land filtration." By this method much of the solid matter was precipitated in settling tanks, the land divided into plots, so that each plot received a discharge of sewage in turn, thus giving the land periods of rest. The land was well underdrained, and the purpose of obtaining crops was made subservient to the principals of filtration. It w found that this form of treatment allowed of an acre of ..d for each 1,000 of population. This method also is generally being abandoned, although, where labor is furnished without expense, as in connection with public institutions, as asylums, reformatories, etc., it may still be accepted as an economical and useful form of sewage disposal.

Objections to Land Treatment.

There are several reasons why the above systems have proved a failure. The principal ones are: The large amount of labor required; the fact that sewage requires daily treatment, unless accompanied by extremely large storage, which is most objectionable in the case of sewage. The sewage should be treated fresh. It is, therefore, necessary that the land shall continue to receive the sewage in both dry and wet weather. This means that at times of great rainfall, when the land is saturated, it is called upon to deal with the maximum flow of sewage.

It has been found that land continuously treated with sewage becomes "sewage sick." The best of land becomes non-absorbent, and will only produce the rankest vegetation. Such land requires over one and two years for recovery.

The tillage properties of sewage have also been much exaggerated. Many people suffer from a most extraordinary idea of the value of water-carried sewage as a manure. The fertilizing properties in sewage are nitrogen, phosphoric acid and potash. A net ton of London sewage contains:—

	Pound.
Nitrogen	0.10
Phosphoric acid	0.052
Potash	0.020

Now, with nitrogen at 17 cents, phosphoric acid 7 cents and potash 5 cents per pound, the value of the fertilizing ingredients in a ton of sewage is thus less than 4 cents. If we take into account the loss of nitrogen, the most valuable element, the value when applied to the best advantage is not more than from 1 to 2 cents per ton. When flooded on land the value is practically nil.

The above sewage represents a daily water consumption of about forty gallons per capita per day. As in Canada the average water consumption is about double this amount, the value of the sewage in this country is even less.

Chemical Precipitation.

Sewage disposal has passed through an age of chemical treatment. It having been found that if raw sewage was allowed to stand in settling tanks, much of the solid matter settled by gravity, and was retained in the tanks. Consequently it was felt that if reagents of a precipitating character could be added to the sewage a larger proportion of the organic solids might be retained and the land treatment relieved of its most troublesome duty. This stage of sewage disposal may aptly be called "the sludge-making epoch." The reagents chiefly used are lime, sulphate of alumina, and ferrous sulphate. These chemicals combine with certain constitutents in the sewage, and in precipitating drag down the major part of the suspended matter in the sewage in the form of sludge.

In many cases in England large chemical precipitating plants have been installed, notably in Sheffield, where some years ago over $5,000,000 were expended in lime-precipitating tanks. These and other such plants now stand condemned, and are giving way to more improved methods.

Objections to Chemical Precipitation.

The chief objections to chemical precipitation are, an enormous amount of sludge is created, which has still to be dealt with. At one time it was thought that if this sludge was dried and pressed it would be useful as a manure. This, however, has proved a fallacy. Sheffield has been face to face for years with the problem of either finding huge dumping grounds for its sludge or carrying it right out to sea, a distance of eighty miles. The treatment of sewage by precipitants tends to remove from the sewage the necessary organisms conducive to the process of nitrification, this being the process by which sewage is purified by filtration, either through land or artificial filters. Chemical treatment, while precipitating much of the organic matter in suspension, leaves the organic matter in solution in the effluent. Hence, sewage, after chemical treatment, although it may appear clarified, after it is allowed to stand, becomes turbid, undergoes putrefaction, and is still a favorable nidus for the growth and propagation of disease germs.

Nitrification.

Until the year 1877 the process by which the organic compounds in sewage were rendered harmless was not understood. It was known that by the aid of soil, nitrogenous compounds were broken up and rendered harmless and reduced to their more primary forms of nitrates and nitrites. It was thought that this process was one of oxidation, performed by the action of the atmosphere.

In 1882 Robert Warrington read a paper before the Society of Arts, part of which is here quoted:—

"The purifying action of soil on sewage is probably due to three distinct actions: 1. Simple filtration, or the separation of suspended matter. 2. The precipitation and retention of ammonia and various organic substances previously in solution. 3. The oxidation of ammonia and organic matter by the agency of living organisms. The last mode of action is undoubtedly the most important, as without oxidation the sewage matter must accumulate and the filter bed lose its efficacy. It was formerly supposed that the oxidizing power of soil depended solely upon its porosity, oxidation being assumed to occur by simple contact with the air in the pores of the soil. We now know that nitrification of sewage will take place when passing it over the surface of polished pebbles."

This discovery that the nitrification of sewage is due to the presence of living organisms of the family of bacteria has entirely revolutionized methods of sewage disposal. It is now found that by a clear understanding of Nature's method of work, and by following the principles which Nature teaches, not only can the whole of the solid organic matter of sewage be destroyed, but a liquid effluent can be obtained entirely free from organic constituents, and, therefore, not liable to putrefaction.

Bacteria must be looked upon as being governed by much the same laws which govern other plants and animals. They are composed of protoplasm. The differences in protoplasm are differences in degree rather than in kind, and the laws which govern the protoplasm of bacteria govern animal and other vegetable protoplasm. Many of the processes of everyday life are intimately associated with the specific activities of micro organisms; we are constantly meeting with these organisms, and it is now proved beyond dispute that their presence is not merely accidental, but is absolutely essential to the most commonplace operations. Bacteria, in fact, serve to transform inert organic matter into inorganic substances. The whole of the stable manure placed upon land, and which at length disappears, would be of no use whatever to plant life, in fact, could not possibly be absorbed by the plants unless first reduced to their mineral component parts by the action of myriads of bacteria.

The leaves which fall in autumn and disappear in spring are, as it were, digested by bacteria, and their products form fresh nutriment for new growth, and so give back to the soil that which was taken from it.

Fermentation, putrefaction, and nitrification are all very similar processes, being the result of organisms. All organic compounds, whether in sewage or otherwise, are simply composed of a few mineral elements, held together in combination by the energy of heat. The decomposition or rearrangement of the elements is spoken of as a process of nitrification when there is a conversion of the nitrogenous elements with ammonia, nitrous and nitric acid, carbonic acid and water, or, speaking more generally, it may be said to be a process of mineralization of the organic forms of nitrogen, phosphorus, carbon, and hydrogen, during which they become finally oxidized or mineralized to nitric acid (HNO_3), phosphoric acid (H_3PO_4), carbonic acid (CO_2), and water (H_2O). In nature this process goes on in the superficial layers of the earth. [illegible]dern sewage works, in properly constructed filtration [illegible] built and constructed so as to provide the most ideal ho[illegible] in which the [illegible]ifying organisms may exist and do the greatest amount of work.

Bacteriological Sewage Disposal.

The construction of special filter beds on bacteriological principles first became a matter of experiment in the year 1872. At that time the Massachusetts Legislature directed that experiments of a definite character should be made. To the report then published sewage disposal owes a deep sense of gratitude. The results of experiments of an exhaustive nature became public property, and the whole subject received an added interest throughout Europe. The experiments were mostly carried out with tanks containing various filtering media, including coarse gravel and fine sand. The most interesting and useful experiments are those by filtration through clean gravel, as the rougher forms of filtering media are better suited to sewage filtration, such being not so easily choked. The results of two tank experiments are here given:—

Average quality of the effluents form a gravel filter in comparison with the original sewage when filtering at the rate of 108,500 gallons per acre per day (sewage applied fourteen times a day for six days in the week).

1889.		Ammonia.		Chlorine	Nitrogen as		Bacteria per cub. C.C.
		Free	Albuminoid		Nitrates	Nitrites	
Sept. 24-Oct. 24	Sewage	2.0559	0.6453	5.55	0.0	0.0	3,031,000
	Effluent	[illegible]68	0.0325	6.42	1.5700	0.0003	11,592
	Per cent	[illegible]of 1	5.				0.4 of 1

Average quality of the effluent from a gravel filter in comoarison with the original sewage after filtration had taken place at the rate of 70,000 gallons per acre per day for seven months. Sewage applied nine times a day for six days in the week.

(Parts in 100,000.)

1889.		Ammonia		Chlorine	Nitrogen as		Bacteria per cub. c.c.
		Free	Albuminoid		Nitrates	Nitrites	
May 23-June 22	Sewage	1.9910	0.6031	5.16	0.0	0.0	......
	Effluent	0.0031	0.0375	6.[illegible]0	2.0700	0.0002	10,305
	Per Cent.	0.2 of 1	6	...	....	....	
June 23-July 22	Sewage	2.5000	0.7255	7.40	0.0	0.0	1,813,500
	Effluent	0.0050	0.0354	9.01	2.2500	0.0004	13,523
	Per Cent	0.2 of 1	5.	...	....	......	0.7 of 1

We see from the above that it is not a straining process. The liquid starting at the top reached the bottom with the organic matter nearly all burned out. The removal of the organic matter is in no sense a mechanical one of holding back material between the stones. After twelve months' continued use the filters were as clean as at the commencement. The liquid flowing out at the bottom is a clear, bright water, comparing favorably in every respect by both chemical and biological examination with many drinking waters. The above tanks were protected from snow and severe frost during winter months.

The System in Practice.

Since the Massachusetts enquiry into the subject and their report, dated 1891, the principle of nitrification as applied to sewage has become the general basis on which the problem has rested. Many plants of an extensive character have been put down, and the problem, like all new problems, has shown some marked improvement in the practice of construction, and we appear to have now arrived at a point where sewage disposal has taken up the position of an exact science.

Given an analysis of the constituents of a sewage and the amount to be dealt with, there remains no difficulty in the way of an engineer acquainted with the various data collected on the subject guaranteeing a plant to any municipality which is bound to give permanent satisfaction and give good value for the money spent thereon.

Snow and Frost.

A difficulty which has been felt in Canada is the effect the extreme cold of the winters may have upon such a plant. That parts of the plant must be guarded against severe frosts appears necessary Such parts, however, occupy so small an area of land that the problem of protecting them is simplicity itself. An up-to-date system was installed for one of the large suburbs near Berlin (Europe) lately. Here the winters are often very severe. During last winter the temperature reached 7 degrees below zero Fahr., and, although the plant had no protective covering, it was unaffected in its working, and continued to give first-class results. The Massachusetts State Board of Health reported on the question of cold as follows:—

"When sand is frozen solidly after draining there still remain open pores through which the sewage easily finds its way, thawing to some extent the frost as it proceeds. After the sewage has drained away the portion which remains in the filter again freezes, but open pores are still left which allow the passage of the next portion of sewage. If snow is upon the surface of the filter and sewage is applied uniformly to it, it is at once chilled to the freezing point, and has then no power of thawing the frost in the upper layers of sand, and if the weather is very cold the whole will solidify on the surface, effectually closing the filter. The two essential conditions to the passage of sewage through filters in winter are that sewage shall never be put into snow, and that the filtering material shall be open enough to absorb its dose rapidly."

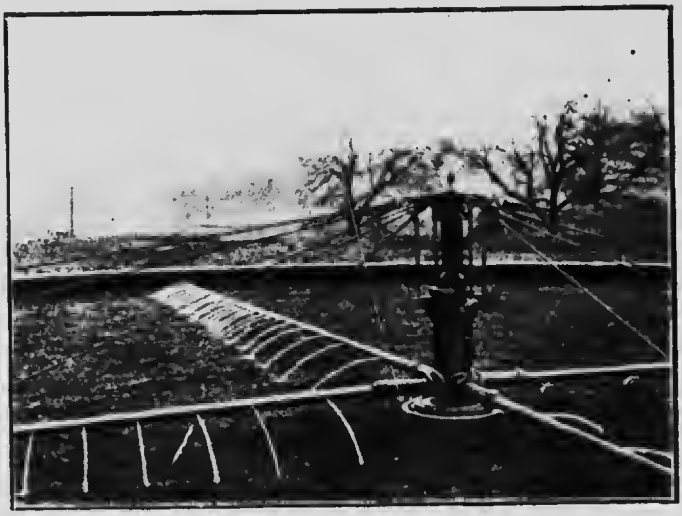
The average temperature of sewage in winter as delivered to works is from 44 to 46° Fahr

CHAPTER IV.

AN UP-TO-DATE "BACTERIOLOGICAL TREATMENT" SYSTEM

Naturally, it took a considerable time before large cities could see their way to accept a new system of sewage disposal. A system so directly opposite in its principles to the chemical method of treatment, generally in vogue.

At many towns large sums of money had been laid out on systems which at the time were practically guaranteed to be final solutions of the problem. People began to loose confidence and ask "when is this going to end?" For a time all theories of sewage disposal were received in a spirit of scepticism. Especially in Great Britain is it difficult to install any plant of an experimental character. There, before a municipality can obtain the consent of the Local Government Board to borrow money on the security of the rates, a perfected scheme on paper, showing every detail, must be submitted to this central authority. This authority is naturally conservative in its institution and practice, and one of its duties



Sprinkler at Work, Bradford, England.

is to guard against, local municipalities throwing money away on what may result in profitless experiments.

We, therefore, find that the bacteriological system for a long period was confined to small efforts, made by those who were able either to carry out works by aid of their own funds, or out of current rate, without a loan consent being required.

This phase of the problem has now, however, passed. We find the Local Government Board on every hand encouraging the adoption of this, the most modern system. Large towns in England and Europe have either adopted the bacteriological system, or they are in the process of adoption. Leeds, Manchester, Sheffield, Bradford, and scores of other large towns, with even complex sewage discharges, owing to manufacturing waste, have carried out valuable experiments, and are now asking or have obtained powers for the installation of complete systems.

Processes.

Bacterial sewage disposal may be divided into two systems: (a) "The Contact System;" and (b) "The Continuous System."

By the contact system, the liquid sewage is fed into rectangular tanks containing filtering media. A series of these tanks being adopted, each tank is filled in turn to the point of saturation with sewage. Allowed to remain quiescent for a period of time, and then drawn off. This period is regulated so as to give the nitrifying organisms, growing on the surface of the media, sufficient time to attack and destroy the organic matter in the sewage. These tanks can be on the simple or multiple system. In the first the tank is undivided, in the second each tank is sub-divided, and the sewage syphoned from one division to the other, coming into contact with a finer grade of media in each division. The great advantage of the multiple contact system lies in the fact that several contacts are obtained in the depth of a single contact bed, and practically on the same area. Constructional cost is thus reduced considerably when there is insufficient fall and great purification is required. The whole apparatus for working beds of the above character can be obtained of automatic construction by makers who make a specialty of such plant.

By the continuous system, the liquid sewage is not held back in contact for any quiescent period in the filter. It is supplied (uniformly) to the surface of the filter in small doses or discharges, and allowed to percolate slowly from one particle of media to the other by its own gravity, there never being a sufficiently large discharge allowed, which would cause any hydraulic head or weight of sewage in the filter. This system, both from practice and observation, the author claims as the best; although in dealing with certain forms of strong sewage, especially in manufacturing districts, he has found that a combination of both the contact and continuous systems are at times advisable.

The purpose of this article is, however, to describe in more detail a continuous filtration plant dealing with the domestic sewage of a small town on the most economical lines consistent with obtaining satisfaction.

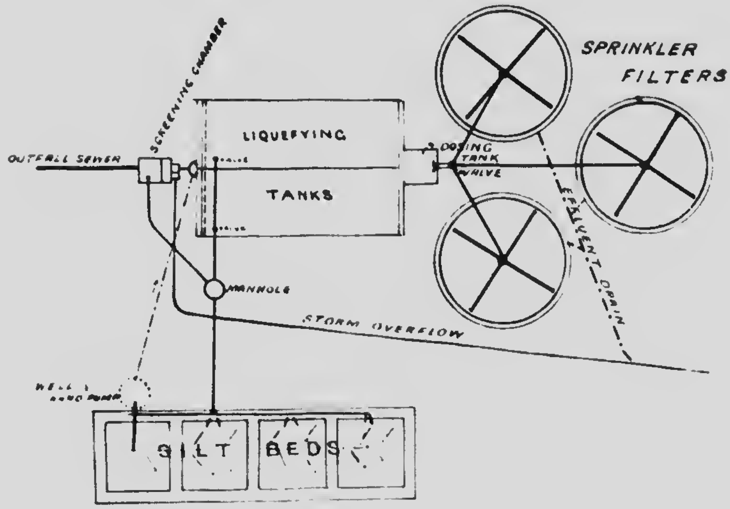
A System for 2,000 Inhabitants.

We will deal with a town of 2,000 inhabitants with a supposed daily water consumption of 60 gallons per head; giving 120,000 gallons of sewage in dry weather every 24 hours. The system will be capable of taking this amount diluted to five times during rain periods, any overplus being treated as storm water.

The system may be divided as follows:—

1. Outfall sewer.
2. Screening chamber.
3. Storm overflow.

FIG 4. BACTERIAL DISPOSAL SYSTEM.



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4. Duplicate liquefying tanks.
5. Dosing chamber.
6. Continuous filters.
7. Effluent.
8. Silt beds, (Fig. 4 shows general arrangement).

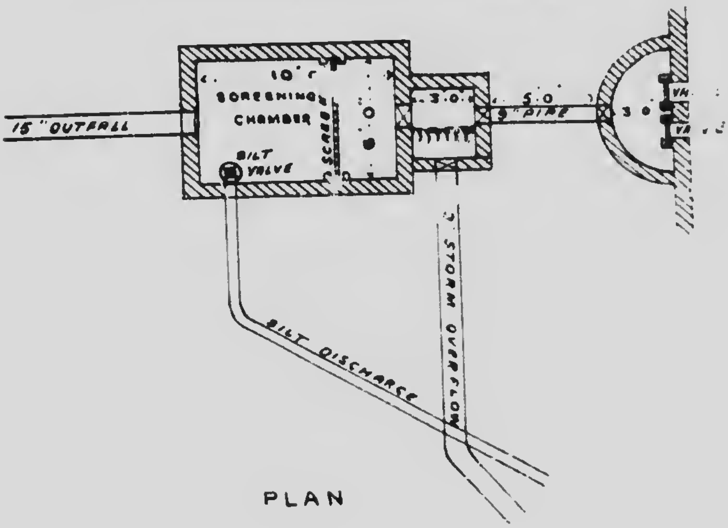
Outfall Sewer.

We will take it that the sewage is carried to a plot of land by means of an outfall sewer capable of taking not only the dry weather flow but also storm water dilution. The size of this sewer is, of course, a sewerage question depending upon the amount of surface water taken. If not more than from ten times the dry weather flow, it will probably be represented by a 15-inch pipe at a gradient of not less than 1 in 500 capable of discharging running half full 530 gallons per minute. This sewer should enter the land at its highest level, and the land should at least present a fall of about 10 feet 6 inches for working purposes from inlet of sewage to outlet effluent.

Screening Chamber.

Figures 5 and 6 show plan and section of screening chamber with storm overflow arrangement attached. In this chamber 10′ 0″ × 6′ 0″ × 8′ 0″ deep, a wrought-iron screen is placed of ⅜-inch mesh. The purpose being to keep back such solids as tin cans, scrubbing brushes, etc., which are

FIG. 5. SCREENING CHAMBER.



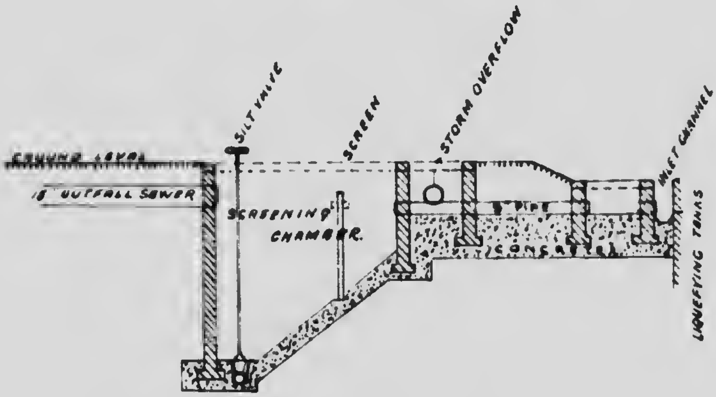
not easily digested by bacteria, but are often the accompaniment of domestic sewage. There is no standard size for this chamber; but in no case should it be larger than necessary, as it is desirous to produce a boiling or swirling action in the sewage, thus helping to break up the solids into finer particles.

Storm Overflow.

The storm overflow immediately following the screening apparatus is a simple, but reliable arrangement, by which only five times the dry weather flow is allowed to enter the works. The overplus passing over a concrete weir, (see Fig 7), and into a separate sewer either direct to the stream or for partial treatment in a rough stone filter if necessary.

The pipe leading to the works is shown 9-inch diameter, and must only be capable of taking 600,000 gallons in 24

FIG 6. SCREENING CHAMBER



Con. Eng.

SECTION

hours, or 416 gallons per minute, it must therefore have a gradient of not less than 1 in 290.

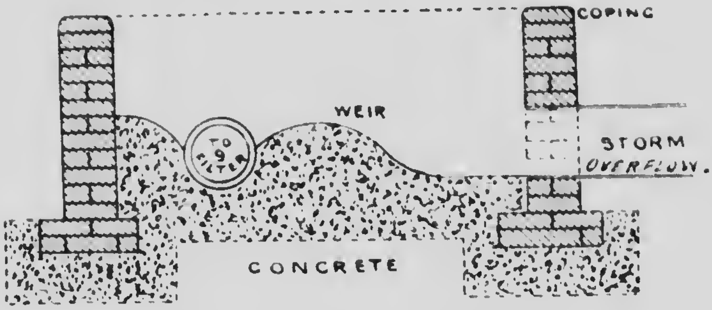
The size of the verflow pipe and gradient must be arranged to take the whole of the overplus, and the length of the weir with a hydraulic depth of ½-inch, also represent this amount. The top of the " being kept ½-inch below the top of pipe leading to the wo so as to prevent a head acting upon this pipe and so incr natural flow by pressure.

Liquefying Tanks.

These tanks are sometimes called "Septic" Tanks, being a trade name applied to a covered-in cesspool, in which the solid sewage is allowed to precipitate by natural methods without the aid of any precipitant. These tanks are very necessary to a bacterial disposal system, as they serve to break up and liquefy the solids and so make the work of the filters much easier and prevent them from choking. Experiments of treating new sewage by direct filtration have not been a success. It is not only the question of the organic solids, but also of mineral solids, such as the sand silt from the tear and wear of roadways, pathways and stone work. These mineral solids always form a proportion of the sewage matter and settling tanks of some nature are necessary in order to retain them. The tanks are shown in figures 8 and 9. They are in duplicate, to allow of repairs and cleaning. The size of each being [illegible] x [illegible] x 8' 0" deep. The two being capable of holding 120,000 gallons of sewage or 24 hours' dry weather flow.

The sewage enters over a weir, the full breadth of the tank, in the form of a thin film. It then meets with a scum

FIG. 7 STORM-OVERFLOW



CROSS SECTION THROUGH STORM OVERFLOW

plate fixed about 3 inches from the weir, this stands about 6 inches above the water-level and dips about 2 feet into the body of the tank. It serves the double purpose of preventing any disturbance of the surface of the tank, while the sewage entering at a level above the bottom of the tank, the lower layers of precipitated matter are also undisturbed. The method of outlet is arranged in precisely similar lines.

The main principal in these tanks, is to prevent as far as possible any undue disturbance of the sewage. The process which the sewage undergoes is that of putrefaction. All putrefaction is of a septic nature, that is it is brought about by the aid of bacteria in their effort to break up effete organic

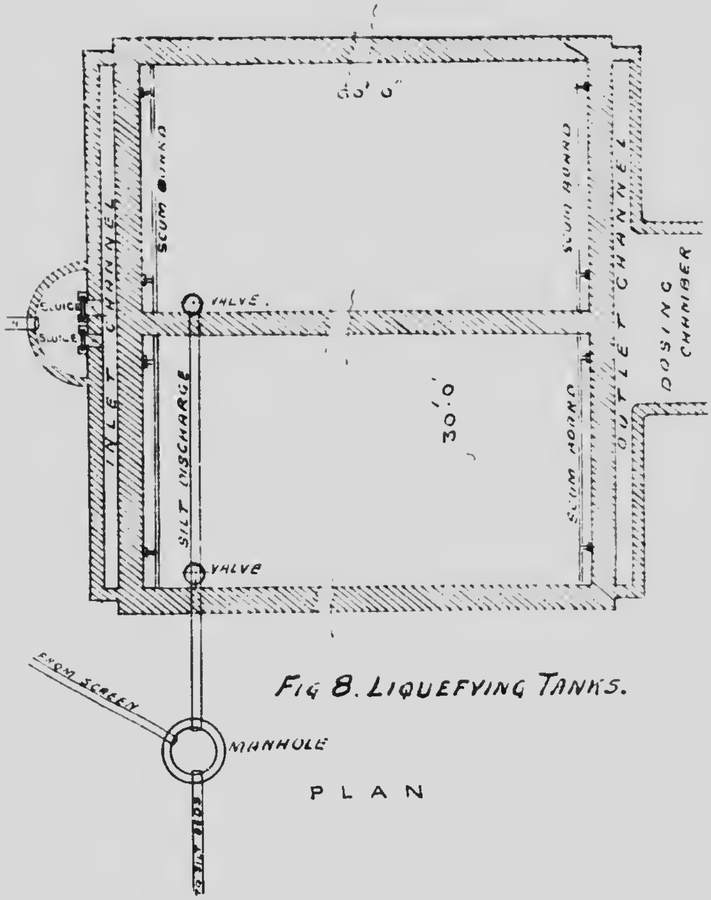


Fig 8. Liquefying Tanks.

PLAN

compounds. Consequently we gain from these tanks a more liquefied form of sewage. But it must be borne in mind, that no nitrification has taken place. And the effluent from these tanks is still sewage, though presenting a more desirable appearance than when it first entered.

An opinion exists in some quarters that such tanks provide all that is necessary for sewage purification. They accomplish no such desirable end. All that they effect is to prepare the sewage for purification by nitrification. In fact the work done is nothing more nor less than that of the old-fashioned, neglected cesspool; in which it was found that organic solids dissolved, and were then absorbed in their liquid state into the soil, there to undergo nitrification. To Mr. Cameron, of Exeter, however, great credit is due for having put this action definitely on a scientifically practical basis.

He himself, however, does not claim that this septic action will provide a purified sewage effluent, without the addition of nitrification. At the Exeter works the effluent from the septic tank is treated on bacterial contact beds.

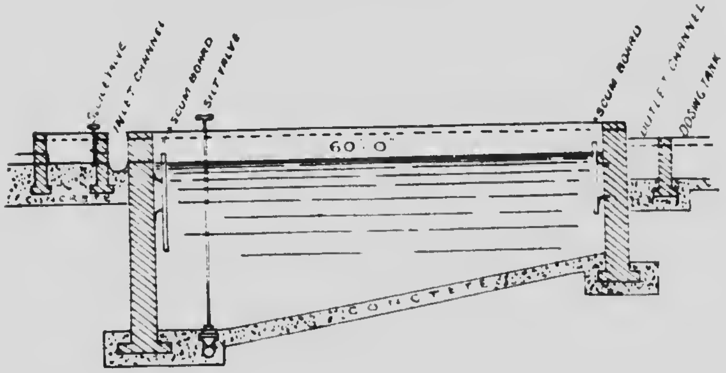
It would be as safe to discharge the effluent from septic or liquefying tanks into a clear water source, as to feed upon a dead carcass in a septic state of putrefaction.

Dosing Chamber.

The dosing chamber, or intermittent discharge chamber, forms an extremely important feature in the continuous bacterial system, on its capacity largely depends the success of the filter.

The capacity is entirely based upon the super area of filtering media to be dosed; and should not represent more

FIG. 9 LIQUEFYING TANKS



Con. Eng. SECTION

than 2 gallons per super yard of filtering area. In other words, should not exceed a ½-inch of rain fall over the surface. Fig. 10 shows a simple form of measuring value by means of which the discharge can be regulated.* The size of the tank shown, 28′ 0″ × 14′ 0″ × 1′ 6″, together with the outlet channel from liquefying tank 30′ × 2′ 0″ × 1′ 6″ will give a capacity of 678 gallons, capable of dosing the area of filtering media required.

Continuous Filters.

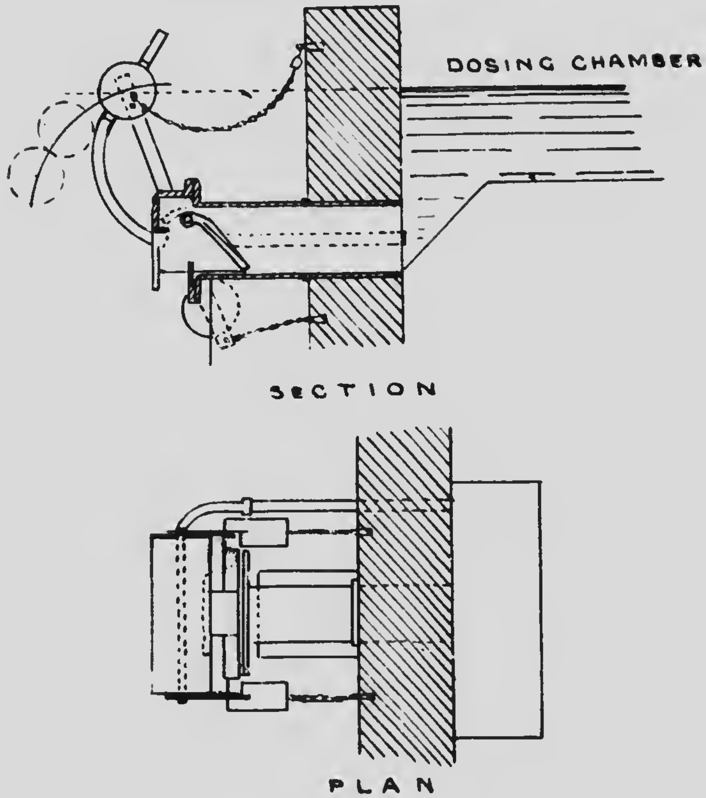
Figures 11 and 12 show plan and section of the usual type of continuous filter supplied. Their total filter capacity shoud bear the proportion of a cubic yard of media to every

*Messrs. Mather & Potts' patent, Manchester, England

168 gallons of sewage per 24 hours. In this case with 120,000 gallons of sewage per day divided by 168 equalling 715 gives the cubic capacity required in cubic yards.

Three filters 36 feet diameter with 7′ 6″ depth of media would equal 840 cubic yards. As it is well to be over the mark, these are the sizes here advised. The filtering media should be of any hard indissoluble matter graded so that the

FIG. 10. DOSING CHAMBER.



AUTOMATIC MEASURING VALVE

top layer may consist of cubes from 4 to 5 inches, the centre layer of finer material of about 1-inch cubes, while the lower or draining layer should be of about 3-inch cubes. The author has found these grades of media to give splendid results with domestic sewage. The floor of the filter should be underdrained with ordinary tile sub-soil pipes made on the concrete

FIG. 11.

FILTER

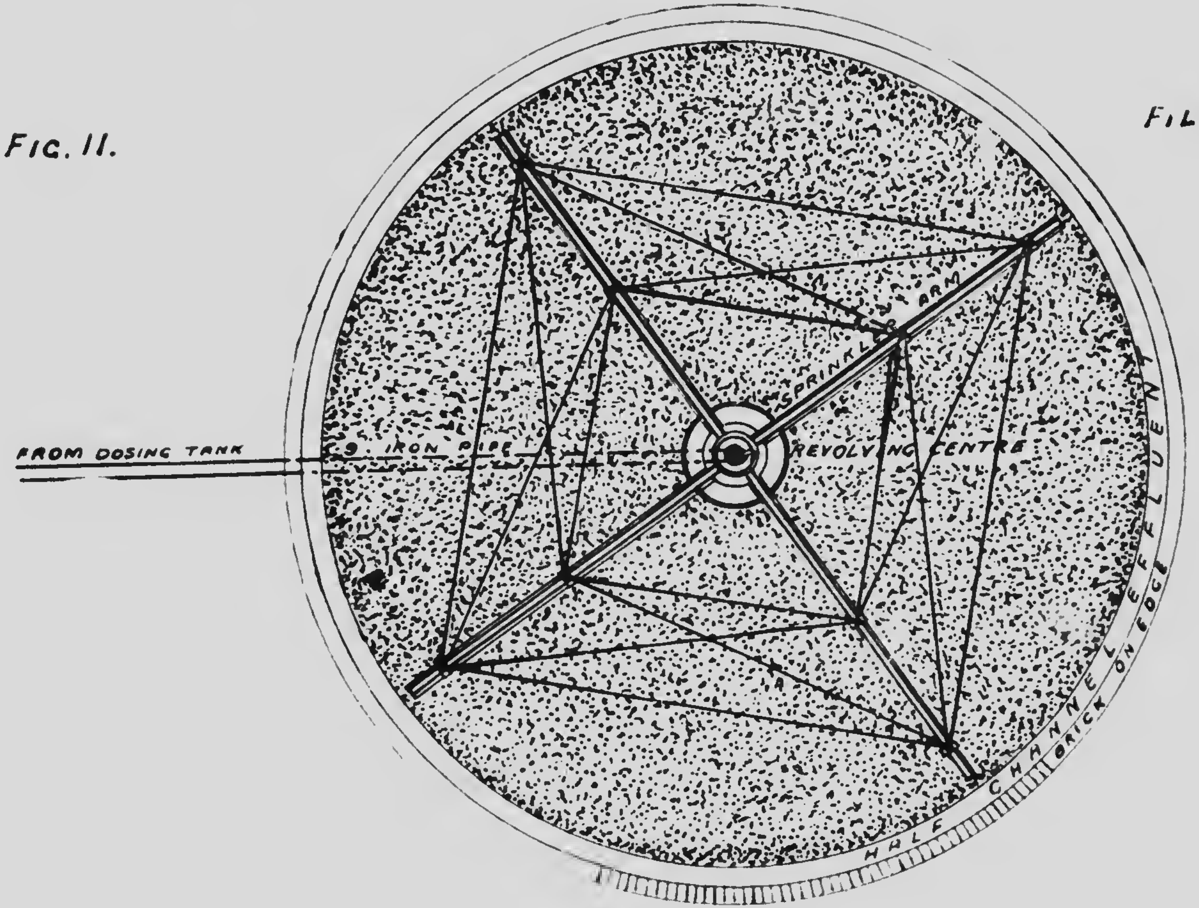


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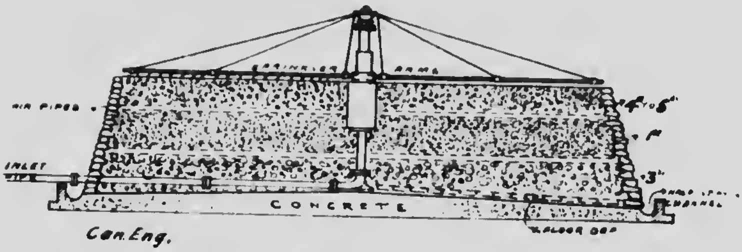
Fig 12. FILTER.



SECTION

base; special drain pipes can be obtained for this purpose at a slightly greater expense than ordinary tiles.

Pipes are provided radiating from the centre of each bed to the outside, giving free access of oxygen to the body of the media. The circumference walls may be built of honey combed hit and miss brickwork. If economy is desired, then by means of rough rubble walls, built up with large cubes of the filtering media itself. As many open air spaces in the walls as possible should be provided consistent with strength. It should be noted that the walls have no water pressure upon them whatever, and have merely to support the media, which is practically self-supporting once it has settled.

The method of distributing the sewage, is by means of automatic sprinklers. The sewage is discharged from the dosing tank by means of iron pipe arms fitted with valves, so that any filter may be put out of use on occasion. The dosing tank outlet being above the level of the sprinkler, the head of sewage is exerted on a turbine centre, through which it passes and is carried into perforated arms, which revolving, spray the sewage in fine particles over the whole surface of the filter bed in an even manner. The outlet channel surrounding the filter at the base receives the nitrified effluent.

Effluent.

The effluent from the above may either be discharged direct into a stream, or if desired used for irrigation purposes. Such an effluent will be incapable of causing any nuisance or undergoing further putrefaction. But if it is desired to obtain absolute purity from a biological point of view, that is to make it immediately safe to mix with a drinking water supply; it should be further treated by means of fine sand filters, as are in vogue for water supply filtration.

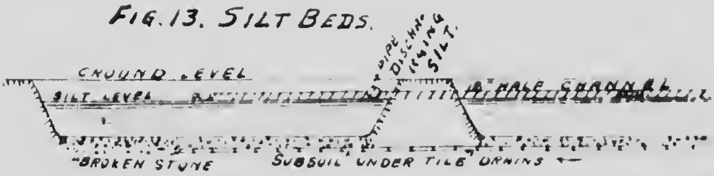
Silt Beds.

There is still the silt from the screening chamber and liquefying tanks to be dealt with. This consisting principally of mineral, indissoluble matter will be necessarily mixed with a proportion of organic matter.

The general plan and section, Fig. 13, shows silt beds simply dug out of the ground with a layer of broken stone for the foundations and under drains. The silt sludge is discharged by means of hand valves to a channel running alongside the beds, and is turned into the beds in turn by means of hand penstocks, where it is allowed to drain and dry. The dried sludge being dug out and dug into land as tillage. The amount of sludge made is extremely small by this process and gives little or no trouble. The liquid draining from the sludge should be led back to a well, and from thence pumped by a small hand pump back to the liquefying tanks for treatment.

This then completes a small bacterial filtration scheme which is well within the reach of any small municipality, and should not cost more than $5 per head of population when

FIG. 13. SILT BEDS.



SECTION

completed. The proportions and data above given are practically the same for a less or greater population. It, however, should be borne in mind that the characteristics of all sewage are not the same, and before any settled scheme is adopted, consideration should be given to the particular sewage to be dealt with, especially with regard to manufacturing wastes, if any.

CHAPTER V.

ADMINISTRATIVE SUGGESTIONS

No matter how necessary a scheme of sewerage or sewage disposal may be, no matter how carefully such a scheme may be thought out, no matter how well the engineering plans may be made and specification carefully drawn, it must be granted that in the administration of such a scheme its success greatly depends. This practically applies to all affairs. The ideal may be in our mind, but how to approach it in practice is always the difficulty.

It is our purpose, therefore, to tabulate a few suggestions which may be of use to communities who have matters of public works in contemplation.

Obtaining a By-law.

The first effort of a corporation in connection with a sewerage or sewage disposal scheme, (this, of course, applies to almost all schemes of public works in which loans are required), is to obtain the consent of the citizens. How often does it happen that the people are asked to vote upon a scheme, which is only put before them in the vaguest possible manner?

The author has in mind a by-law only recently submitted by a corporation in Canada for extensive main sewerage and sewage disposal, upon the details of which it was impossible for any citizen to obtain any information whatever, beyond the fact that the scheme contemplated lengths of collecting sewers, and some form or another of sewage disposal in a certain vague locality, no other information was forthcoming.

Is it remarkable that by-laws are often defeated when the citizens are not taken into confidence? Or it may even be that no proper matured scheme has even been settled upon by the authorities upon which the people may vote.

It is suggested that before a by-law is asked for, that complete plans of any scheme should be first drawn out. That such plans should be on exhibit at the City Hall, so that everyone who takes an interest in the matter should have the opportunity of knowing exactly on what proposal his vote is asked.

In Great Britain such plans must be on exhibit for at least three weeks previous to a public enquiry, at which any objections raised may be heard.

The cost of such plans is small. And the fact that they provide every member of a corporation with the ability to answer any question that may arise, inspires the public with confidence.

In the case of main sewerage, the plan should show every line of sewer with the names of the streets proposed to be sewered. In the case of sewage disposal the land to be occupied, and the character and extent of the scheme should be shown. It is well also that the corporation, (if it is necessary to purchase any land), should have a provisional agreement of purchase, so that no after difficulty may arise in obtaining the land.

The Appointment of an Engineer.

An engineer may be either appointed to act simply as a consulting engineer along with the permanent engineer of the municipality, or he may be given separate and full control over the work from commencement to finish. The arrangement greatly depends upon the ability and skill of the permanent official, and whether his ordinary duties will allow of him attending to extra work over and above the usual routine.

In all cases, however, a proper agreement should be drawn up between the municipality and the engineer, defining both his duties and method of payment. This is satisfactory to both parties and prevents disputes upon what may or may not be the custom, tends to smooth working, and mutual understanding.

The appointment of an engineer to have full charge over the works he has designed, generally proves the most satisfactory solution. It throws the responsibility on to one person's shoulders, on to that person who knows his own scheme best, and is most anxious of all others that it be a success.

The old saying that too many cooks spoil the broth is very applicable to engineering work.

Payment to engineers may either be made by a commission sum being a per centage on the cost of the works, or in the form of a lump sum by arrangement, based upon the amount of his own estimate of the total cost. The latter method of payment is the best, as the engineer has no interest in the amounts he may have from time to time, to certify due to the contractors. His efforts are engaged in keeping the cost within the limits of his own estimate.

Further, an engineer is not tempted to underestimate the work in the first instance, which may be done in order to get work commenced at any cost. The eventual cost amounting to much more than the preliminary estimate. A denouement requiring careful explanation, as a rule.

The Duties of the Engineer.

The engineer should engage to make all preliminary plans, profiles, specifications, etc., to the satisfaction of the "Board of Health" or other authority having jurisdiction.

He should be prepared to attend all meetings of the council, to discuss and advise with the corporation in arranging for carrying on the work and obtaining contracts.

He, or his representative, should test and examine all work carried out, and be able from time to time to certify that such work is done satisfactorily.

The number of working visits an engineer should put in, is an open question, depending upon whether there is a resident engineer fully employed on the work or not. However, whether there is a resident engineer or not, it is the duty of the engineer to see personally all lines of sewers and other work tested before certifying.

Sewers can be and should be tested after they are covered up by means of the hydraulic test.

No extra work or any alterations to the work should in any case be made without the written authority of the engineer. The engineer should in all cases obtain the consent of the corporation before ordering alterations causing excess of expenditure.

The Duties of the Corporation

Are not to unduly interfere with the engineer and make his life a burden. If an engineer cannot be trusted with work in which he is a specialist, he should be got rid of. It is better for both parties and better for the work in hand.

Members of a corporation should not act singly. They should remember as individuals they have no locus standi. When a corporation wishes to instruct or advise with their engineer, it should be by properly convened meetings, at which they have power to act. The alderman or councillor who buttonholes an engineer, and would like this or that done, is not acting in an official capacity unless deputed by the council. He should be content to air his feelings before his brother members, where they may or may not be listened to; and not as a private member of society, take upon himself the functions of a full grown corporation.

Instructions to the contractor should always be given through the engineer. When instructions are given direct it may have the effect of belittling the engineer in the eyes of the contractor. Especially is this the case when alterations are desired by the council. When a corporation orders alterations or deviations direct, they must remember that they remove all responsibility from the engineer and create in the mind of the contractor an opinion that he may trespass from the lines of the specification without the engineer's authority.

Diplomacy on Both Sides.

A corporation should always bear in mind that an engineer may be more or less of what is popularly called a crank, that is he has decided leanings to one line of thought, and as such should be treated tenderly. Care should be taken of his professional corns. You can always convince a good sound engineer, but you cannot bully him. The man you can bully you may be sure is not a sound engineer and deserves no respect. An engineer should always remember that nothing is gained in being unwisely dogmatic. The golden rule is that there is no rule. What is meant by this is that special circumstances and environment often require special treatment. Useful information may be gained by listening patiently to the opinions and expressions of information from people who know and are apt to continue to know more about the locality in which they have lived for years than the engineer will ever find out for himself. Common sense, as it is called, is very apt to be very common, and leagued with ignorance. But a common sense expression of opinion has at times been of valuable assistance to an engineer in either completely altering his thought-out design or in bringing it clear out of the eddies of probabilities.

The axiom which must be kept in mind is, "That cheap work is generally of a cheap nature." "Good work will always command its price in the market." There are two usual methods by which a contract price may be obtained. They are (a) "The lump sum contract"; (b) "The quantity based contract."

"The Lump Sum Contract."

In this case it is the custom for the engineer to prepare plans and profiles together with a description of the character of the work called "specification." He gives no measurements as to amount of material required. The contractors view and study the documents, take their own measurements and arrive at what they consider the amount of material and labor required to complete the work. The advantage of this system is that it saves the engineer a large amount of trouble and responsibility. The objections to the system, however, are many. When a corporation receives bids or tenders, they can never be sure that such are based on the same amount of work and material. When there is a wide discrepancy in the tenders, it is impossible to say that the result is caused by one man being able to do cheaper work than the other, or is simply the result of a false estimate of the amount of work required. The tenders do not therefore stand on the same basis. The higher tender may be for the actual amount of work required, based on an experienced and intelligent estimate of the quantities required. The lower tender may be the result of inexperience and ignorance of a proper method of taking out quantities.

Again, when it is left to the contractor to take his own quantities from the plans, he is apt to be left with the unsatisfactory feeling that items may be left out, and he generally adds a sum to cover any such errors of judgment.

The argument is used, that if the contractor makes a mistake, and puts in too low an estimate, it is his own fault, and he consequently suffers. However, the contractor not only suffers, but the character of the work suffers considerably. Half way through a contract, the contractor can tell whether the work is going to pay or not. If he finds that it is going to loose him money, then his whole efforts will be centred on cutting down expenses, even at the cost of good work, whenever and wherever he can possibly escape the vigilance of the engineer. Nothing is more unsatisfactory than the struggle to obtain first-class work from a man who knows that he is losing so many dollars each day. "The laborer is worthy of his hire."

"The Quantity Based Contract."

In this case the engineer as well as preparing plans, specification, etc., also prepares a full list of the quantities of material required throughout the work. This Bill of Quantities, as it is called, itemizes every detail of the work. Against each item the contractor has simply to put his price, including an estimated sum for the labor required. The addition of the sums forming the total contract price. Every contractor wishing to tender is supplied with a full sheet of these quantities. Every tender is therefore based on exactly the same estimate of material. Each tender may therefore be compared not as a whole, but in detail. The corporation have the advantage of knowing what they are paying for every item of the work. Any extra work, or diminution of work, can be correctly and easily audited. This is the system which is now generally being adopted in Great Britain. It is advantageous to all parties concerned. It brings work out of chaos into the plane of business exactitude. It is good for the engineer, as in taking out exact quantities, he familiarizes himself with every detail of his own general proposition. He can see the whole of the work in his mind's eye in every detail even before it is commenced.

It may be here objected that the engineer may make a mistake in taking out the quantities. Certainly! He is not infallible. But rather the engineer make a mistake than the contractor. Any error in the quantities is rectified as the work proceeds. Every completed item is measured and if less or more than given in the quantities is deducted from or added to as the case may be. As a rule it will be found that an engineer will prepare his estimate of quantities on the full side. He has no inducement to underestimate. It often, therefore, happens that the completed work costs less after being measured up than the original contract sum. The corporation getting, of course, the benefit of the difference.

The Resident Engineer.

The resident engineer, or clerk of works, as he is often called, is an essential in works of any magnitude. His business is never to be away from the works while there are men working. He should have a good understanding of the practical trades employed. Should be a competent judge of material and workmanship. He must have the plans and specifications in his mind. Be able to set out work, check levels, and measure up. Above all things he must have a back-bone and an individuality not liable to be absorbed in the human personality of the contractor. His wage should be of a sufficiency, to prevent him relying upon the philanthropy of the contractor for ordinary comforts.

Although there may be times when a clerk of the works may be justified in considering himself a much more able man than the chief engineer who has designed the work, as a simple form of etiquette, it is due to the engineer that his instructions be carried out.

Payment of salary to the clerk of works may either be made by the engineer or the council. This being a matter of arrangement between the council and the engineer.

On Completion.

On completion of the work the engineer should furnish the council with a complete bill of quantities, showing clearly every item for which the contractor has been paid with the price of the same, together with the original bill of quantities in corresponding columns, so that any diminution or addition may clearly stand out, and be audited.

Complete Plan.

The engineer should provide a complete plan showing the whole of the work as carried out. In the case of sewers the plan must show the correct position of each manhole with its depth, the gradient of each line of sewer as laid, with all junctions for future connections correctly marked with measurement of distances from manholes.

This now concludes what can only be looked upon as a very scant and general survey of a big subject. The author feels that he has gone over much ground which is by no means new to the engineer experienced in public works. The object however has been to put the whole subject in a concrete form, of some value to municipalities and others who may be contemplating works as described, as a new venture.