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SOME RECENT DEVELOPMENTS IN THE PURIFICATION OF PUBLIC WATER SUPPLIES.

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(To be read before the General Section, 28th April, 1910.)

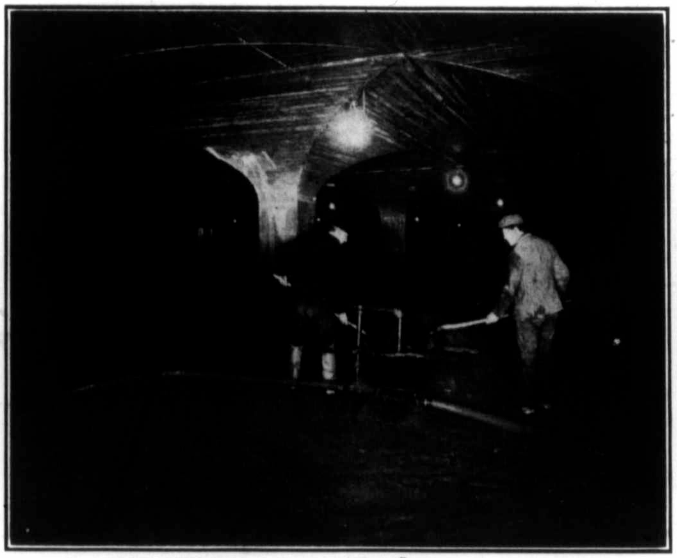
In January, 1899, the writer read a paper before this Society on "Sand Filtration of Public Water Supplies," covering methods of construction, cost, operation, and accepted theories of the nature of the process. This involved a more or less extended discussion of two of the three great advances which had taken place in the science of water purification up to that time. The first was the conception of the idea of sand filtration and its practical application, by Simpson in 1892. The discovery by Dr. Koch of the plate culture method of studying bacteria marks the beginning of a period, since when it has been possible to deal with the purification of water in a rational and scientific way. This discovery, which took place in the year 1880, constitutes the second advance in the art. A third advance soon followed in the discovery of the utility of coagulation, or rather its adaption to a useful purpose in the field of water purification; this development is associated with the introduction of mechanical filters, but as this system was then in the evolutionary stage it did not receive more than passing notice in the previous paper.

Since that time such developments as have taken place in either system have been confined chiefly to improvements in materials of construction and in appliances for operation and control. Apart from this, however, a much better idea now prevails of the importance of the characteristics of the water as factors in the selection of the type of system best adapted for its purification. As a result plants of recent date seldom fail to accomplish the purpose contemplated in their construction, and, though the last decade has not been productive of any fundamental changes with respect to either system, such improvements as have taken place may, perhaps, on account of their great practical worth, be of interest on the eve of what promises to be a permanent filtration movement in this country.

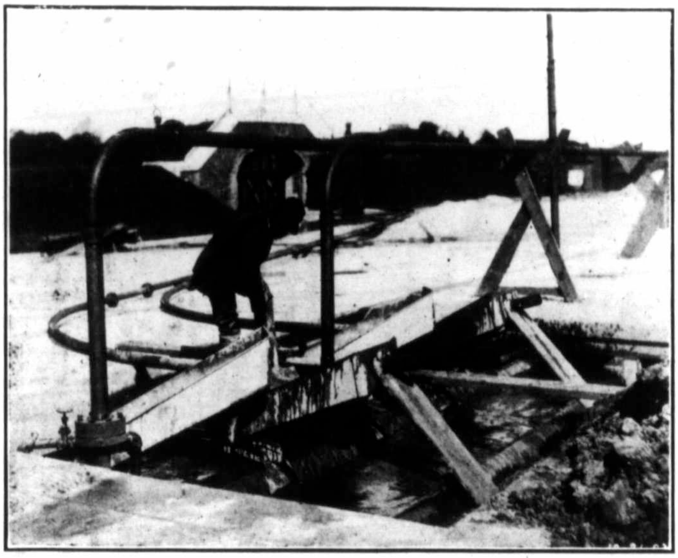
As might be expected of a system, which from its inherent simplicity was susceptible of but little improvement since its first appearance, there is not very much to record in the recent development of slow sand filters. In this familiar type the raw water after preliminary sedimentation, where necessary, is applied to beds consisting of horizontal layers of rather fine sand supported by gravel, and underdrained, the whole being enclosed in a suitable tank or basin. The efficiency of this system to some extent depends upon, and is improved by, the fineness and depth of the sand employed, and on the lowness and uniformity of the rate adopted. As filtration proceeds, the friction of accumulated suspended matter retained on the surface of the bed gradually reduces the quantity of the water passing through, below the allowable uniform rate controlled by a regulator on the outlet pipe, and the filter must then be thrown out of commission to permit the removal of this surface layer deposit to a depth of from ½ in. to 1 in.; when the bed becomes reduced to some minimum thickness, the sand so removed is either replaced by new material or used again after washing. The quantity of the water filtered between scrapings depends on the character of the raw water, the grain size of sand, and the maximum loss of head allowed.

The accompanying sketch of a small plant installed at the Nova Scotia Hospital, Dartmouth, N.S., is here introduced for the purpose of illustrating the main features of a filter of this type. In this two unit plant the raw water enters the filters, by gravity maintained at a constant level by a float valve in the common inlet chamber. An overflow from the filters provides an outlet for the water in case of its failure to act. The main drain from both beds is led to a regulating chamber, and has also a branch connection to a common waste pipe. Either filter can be thrown entirely out of commission, or its effluent can be turned to the regulating chamber, or diverted to the under-drainage system of the other filter, when required for filling from below after washing, or it can be let run to waste. The filtered water passes from the regulating chamber to the clear water basin through a regulator. The type here installed was an ordinary float pipe with an orifice at the free end. There is no necessity for venting as the outlet of the regulator is never entirely submerged. The high water overflow from the clear water storage basin permits of a maximum loss of head of four feet. The discharge can be varied either by changing the size of the orifice or the extent of its submergence below the surface of the water in the regulating chamber.

The plan and section of the filter shows the under-drainage system with the sand and gravel in place; it will be noted, that provision against the passage of the water through the bed at undesirable rates down the faces of the walls and piers is guarded



Sand Ejector in Operation.



Ejector Sand Washer.

against by terminating the sub-drains and gravel at a point some distance from the base of the wall; the piers and interior face of the walls are battered for the same purpose.

Recent practice in slow sand filter design does not show much variation from the old. The excessive depths of sand and gravel, particularly of the latter, common in many of the earlier filters now, seldom exceeds four feet, and much greater uniformity is apparent in this respect. More attention is given to the grade of sand used, and in general a sand of lower "uniformity coefficient" is now called for. The maximum loss of head provided for in many modern plants is much greater than previously allowed.

Probably the most notable advance of recent years in connection with slow sand filters has been the introduction of much improved machinery and methods for washing and preparing filter sand and for handling it cheaply.

The earlier method consisted in scraping the bed and removing the sand by manual labour; crude appliances were used for washing.

Practically all the modern methods for cleaning filters have been applied at the Philadelphia Filtration Plant, some views of which are here given. The following description of these methods is taken with some omissions from a Report of the Water Bureau of the Philadelphia Public Works Department in 1909:

"At the time the filters were first put in operation, the method followed in cleaning was practically the same as that employed in Continental European cities and London, and for slow sand filters in this country. It consisted in taking the filter out of service and allowing the water above the sand level to slowly filter through until the level had subsided to a depth of about one foot below the surface of the sand bed. Labourers then entered the filter and scraped off the upper dirty layer of sand containing mud and other suspended matter. The depth of this scraping was regulated by the depth of the layer of discoloured sand and varied, from one-half to one inch, although at times a much greater depth has been removed. The dirt thus scraped from the sand layer was placed in piles at convenient distances apart, and was then shovelled into a portable ejector.

"The sand ejector consists of the well-known 'Korting' ejector with nozzle and throat extensions connected by two lines of fire hose, one of which supplies water under pressure to operate the ejector, and the other to conduct the mixed sand and water from the ejector to the washer located in the court outside the filter. The ejector not only transports the sand from the filter, but it was found that it did about one-half of the work of cleaning. The sand was then delivered into the first hopper of the sand washer, which is of the same general type as the ejector, and then passed again to a second hopper from which it was discharged into piles on the court in front of the filters. The only manual work connected with the transportation and washing of the sand was represented by the scraping and the shovelling of the sand into the ejector, and once a year placing the same back into the filters.

"The quantity of sand handled to each ejector averaged approximately ten cubic yards per hour, requiring about 2,800 gallons of water per cubic yard.

"In point of efficiency the method was satisfactory, but it was thought that more economical methods could be obtained, and it has the objection of keeping a considerable portion of the plant out of service during periods of re-sanding which, as stated, occur annually.

"Methods whereby the sand could be cleaned in the filters without removal to the courts were investigated, and resulted in trying what is known as the 'Brooklyn' method. This method obviates the necessity of removing the dirty sand scraped from the surface of the filters and storing it in the courts, as the entire work is accomplished without removing the sand from the beds. The water is drained to a depth of a few inches above the sand surface, and outlets, which permit the water remaining above the surface of the sand to flow off, are then opened. The wash water is applied at one end of the bed and is allowed to flow over the surface of the sand at the rate of about one-half foot per second velocity. The direction of the flow is guided by boards set on edge, thus forming channels of the width of a bay or, approximately, 15 feet. As the water flows over the sand the layer is raked by men standing on the surface of the bed, which is continued until the water flowing from the surface is practically clear. Water is then applied through the usual inlets and filtration resumed.

"When the Brooklyn method was first tried the results were not always entirely satisfactory, and another method which involves the separating of the sand from the dirty wash water in the filter, and immediately restoring it in place without removal to the courts, was tried. It is known as the 'Nichols' method (after the name of the inventor of the separator) and consists of ejecting dirty sand and water by an ordinary sand ejector into a separator which is moved into the filter during the process of cleaning. The separator consists of a closed steel cylinder 42 inches in diameter, 3 feet high, having a cone shaped bottom in which is placed a valve and hose connections, through which the sand is forced from the separator.

"The interior of the separator is arranged with a system of baffles and a disc, so that there is a down-flowing stream of sand and an up-flowing stream of wash water, and they are so proportioned that practically no sand is carried away in the wash water, which passes out at the top of the separator, and is carried out of the filters to the sewers. The clean sand is discharged from the separator through a two-inch hose and distributed in the filters in small piles on the surface of the sand bed and then spread and leveled by hand.

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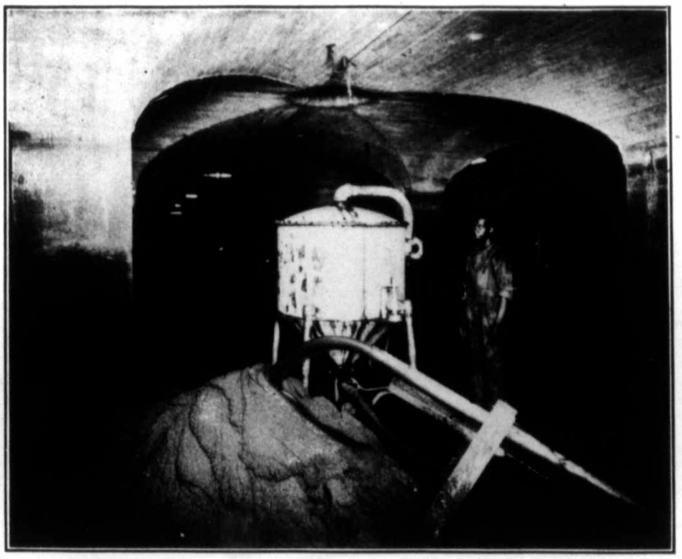

"Nichols" Sand Separator in Operation.

Cleaning Filters, "Brooklyn" Method.

"The apparatus weighs about 700 pounds, and is mounted on wheels so that it can be readily moved. It has a capacity for handling about ten cubic yards of sand per hour, using about 1,200 gallons of wash water per cubic yard of sand, and works under a pressure of 65 pounds.

"In point of efficiency, there is little that can be urged in favour of any one of the methods over the others, that is, where pre-filtered water is used or where the applied water has received a long period of sedimentation. In point of economy, however, the 'Nichols' method has the advantage over washing in the courts inasmuch as it saves the cost of restoring the sand, otherwise, the cost is about the same.

"The 'Brooklyn' method is found to be much cheaper, but how much cannot at this time be stated, as it is believed it will be necessary to remove at least five or six inches of the sand bed and put it through an ejector and separator and replace the same about on an average, every eighteen months. This method has not been in operation for a sufficient length of time to ascertain how much should be added to the present cost for this item. While it uses more water than the other methods, it requires no re-pumpage as the water is not required to be under pressure, as is the case with the other methods, and has a lower cost in this respect,"

Preliminary filters form a part of four of the five installations which comprise the Philadelphia plant, the usual method employed in cleaning being the same as that followed in ordinary mechanical filters. In one case, however, the Blaisdell washing machine was installed, and is described in the Report as follows:

"The Blaisdell machine consists of an inverted box about four feet square and two feet deep, which is sunk under the water in the filter to the filtering surface and is held in position and operated from a movable platform supported on the filter walls. The box contains a revolving hollow axle and head from which perforated teeth project into the filter any desired distance. The box can be raised or lowered, and the platform moved longitudinally or laterally, all electrically operated by one man. The box is moved over the surface of the filter while at the same time the teeth are made to revolve slowly. Water under a pressure of twenty pounds per square inch is introduced through the axle, head, and teeth, passing in fine streams into the bed through the holes in the teeth.

"A centrifugal pump connected with the top of the box draws away a little more water than is supplied through the teeth and discharges it to the sewer. The machine is constructed so that it can be transferred easily from one filter tank to another."

As a result of these improved appliances for handling and washing sand it is now possible to secure a much better grade of filter sand in localities where it does not naturally exist, while the cost of cleaning filters has been reduced in some instances from two and three dollars to fifty and sixty cents per million gallons filtered. This reduction in operating charges has been accompanied by some economy in first cost effected by keeping the total depth of the basin, that is, of filtering medium and head room, within reasonable minimum limits. The recently constructed Queen Lane filters at Philadelphia present a novel feature from the point of view of economy of space required. In this plant the filters are placed over the clear water basin, the floors forming the roof of the latter. The applied water is here subjected to preliminary filtration; which has permitted the adoption in the final filters of a sand layer, only 20 inches deep, covering 16 inches of gravel.

Mechanical Filters.—About the year 1884 the late J. W. Hyatt patented a process for the purification of water known to the present day as Mechanical Filtration. The essential feature of this system as distinctive from its forerunner, the Continuous or English method, is in the use of some soluble chemical salt as alum, sulphate of iron, but usually sulphate of alumina, to coagulate the raw water before reaching the sand filters. The subdrains were so arranged and connected that the beds could be washed quickly and easily by a reverse current of water aided by appliances for stirring the sand.

By coagulation is meant the formation of an inorganic precipitate in the water, the presence of which has a physical action on suspended matters, facilitating their removal by subsidence or filtration; where sulphate of alumina is used, the chemical reactions result in the formation of hydrate of alumina, an insoluble gelatinous compound of greater specific gravity than the matters in suspension, which along with the bacteria, it draws together and surrounds, forming a flaky precipitate in the settling basin, and to a lesser degree on the surface of the filter beds, where this spread of entangled suspended impurities, adhering to the sand grains, has through its absorption of dissolved organic matter, a marked effect in reducing the colour, and accomplishing the chemical purification of the water, besides increasing the efficiency of the straining action of the filter, by offering to the flowing treated water a closer and more compact surface.

It is to be noted that the complete decomposition of the alumina salt will only take place in the presence of an excess of calcium carbonate, and in the absence of sufficient natural alkalinity it must be artificially added to the raw water by the introduction of some such alkali as soda ash. The effect of this treatment on the water is a slight change in the nature of the lime salts, owing to an increase in the proportion of sulphate of lime, and the diminution to a corresponding extent of the carbonate of lime, while the carbonate acid displaced, passes off or is absorbed by the water.

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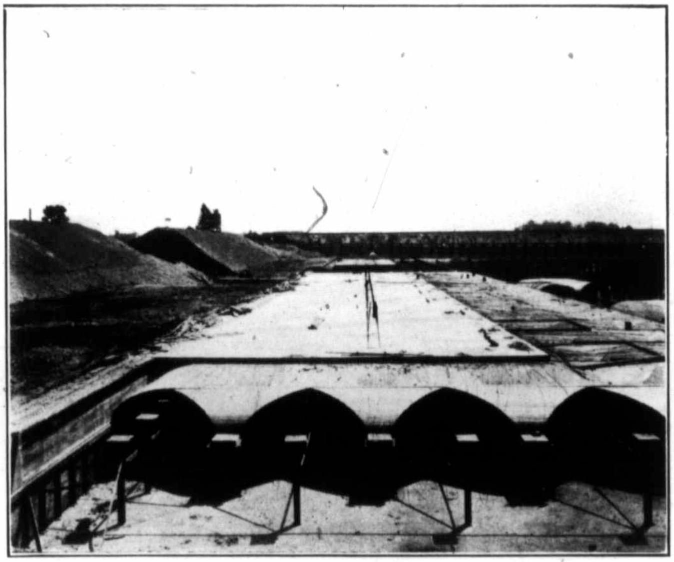
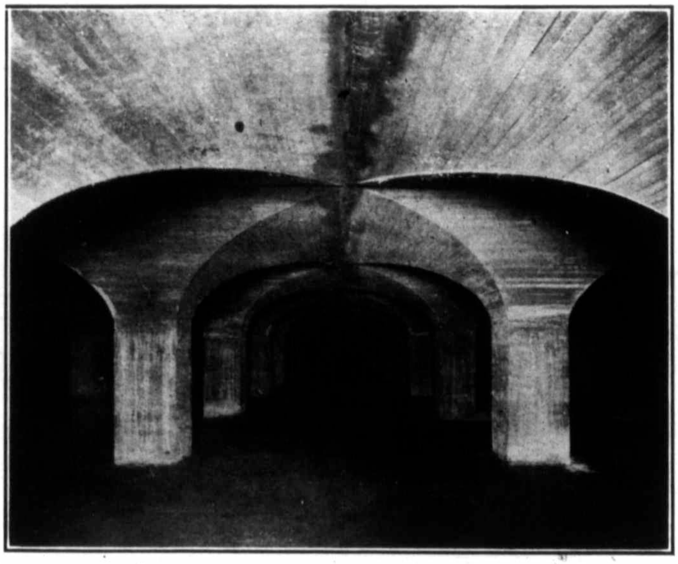


Queen Lane Filters, Philadelphia.



Queen Lane Filters.
Filtered Water Basin (under final filters).

There are two varieties of mechanical filters known as Gravity and Pressure Filters. In the latter the filtering medium and the drainage system are placed in an enclosed steel tank, through which the water is forced under pressure, directly from its source, to the mains, and thus it has the distinct advantage that it can be easily connected into existing systems without requiring additional pumping machinery. It is a cheap installation, and has been extensively used for industrial plants requiring a clear water. It is further claimed to give good results in the treatment of domestic supplies, which it probably does under favourable conditions; but for obvious reasons it cannot be expected to compare in efficiency with gravity or open filters.

The accompanying sectional view shows a somewhat improved filter of this type. The open wooden tank contains the filter sand overlying a subdrainage system through which the water passes to a rate controller. When clogged the filter is quickly and easily cleaned by a reverse flow of water under pressure overflowing to waste above the beds. This washing is accompanied or preceded by a loosening of the bed through the operation of mechanical agitators. The coagulent was mixed with the raw water in advance of its admission to the bed with more or less preliminary sedimentation.

These filters met with some success in the decade that followed their introduction, and quite a number of small plants were installed. The conditions of successful operation were not, however, clearly understood at that time and, consequently, while some of these earlier installations undoubtedly gave good service, there were many instances of failure to accomplish desired results. In 1895 experiments were commenced at Louisville with the excessively turbid water of the Ohio River; where at times the clay in suspension is in a very finely divided state, smaller even than the bacteria. The tests here carried out served to show the inadequacy of slow sand filtration when applied to such a water, the physical characteristics of which, like many American waters, presented a problem in water purification which had not been encountered to any extent in European practice.

The next five years witnessed a great development in the process of mechanical filtration; in fact, the scientific basis for the working of this system may be said to date from the inception of these investigations. It was only another example of "necessity being the mother of invention." Experiments were later undertaken by Pittsburg, Cincinnati, and other interested corporations. A free interchange of experiences soon resulted in the development of methods of treatment capable of purifying a great range of waters. The mechanical filters installed since that time show a marked improvement over the earlier plants. Better appliances for the application and control of the chemical were devised. The importance of regulating the period of coagulation to suit the condition of the raw water was now understood, and led in many cases to the use of larger coagulation basins to allow the chemical changes to become complete before the water passed to the filters.

Without tracing in detail the changes in construction which have kept pace with more enlightened methods of operation, it can be said that the plant of the East Jersey Water Co. at Little Falls, N.J., put in service in September, 1902, was the first to embody those features which distinguish the mechanical filter plants of to-day from the early installations. Concrete construction is employed wherever possible and with the rectangular filter unit mechanical agitation gave place to the air wash. There are thirty-two filter units, each having a capacity of 1,000,000 gallons per day. All of the valves required for working the filter are controlled by hydraulic cylinders, which are operated from a floor on a level with the tops of the filters over the pipe gallery. The accompanying plan and sections of the Fredericton, N.B., filter plant, built in 1906 and 1907, represents the layout of a smaller installation on the same lines, and is in a general way typical of modern design. It will be seen that the side and rear walls near one end of the clear water basin are extended above the usual height to form in the one case a side of the end filter tanks, and in the other a common end wall to the five filter units and side wall to the coagulating basin. The excavation for this basin was utilized for forming its own covering and the embankment over and around the coagulating basin. The front wall of the filters is supported by concrete piers. The rear walls of the building rest on the division walls between the filter plants; this permits of inspection of the filter from within and access from the outside for removing or replacing sand and gravel. Two main rooms run the whole length of the building. The lower, known as the pipe gallery, contains the filter piping; above this is the operating floor where the loss of head gauges and the operating tables and their appliances for controlling and working the filters are located. The plant for the preparation and application of coagulant is located on a tower (not shown) sufficiently above the subsidence basin to allow of its introduction to the raw water by gravity. The rate of discha ge from the filters is regulated by a Weston controller, a plan and section of which is shown. A constant head is maintained over its annular orifice by attaching the disc to a large copper float which also opens and closes two inlet valves and automatically adjusts itself to such a height varying with the pressure in the effluent pipe as will admit the quantity the controller is set to discharge. It will be noted that this controller and the float pipe described above work on the same principle in maintaining a uniform discharge; the throttling valves of the Weston, however, obviate the necessity of having the top of the regulating tank on a level with the water on the filters.

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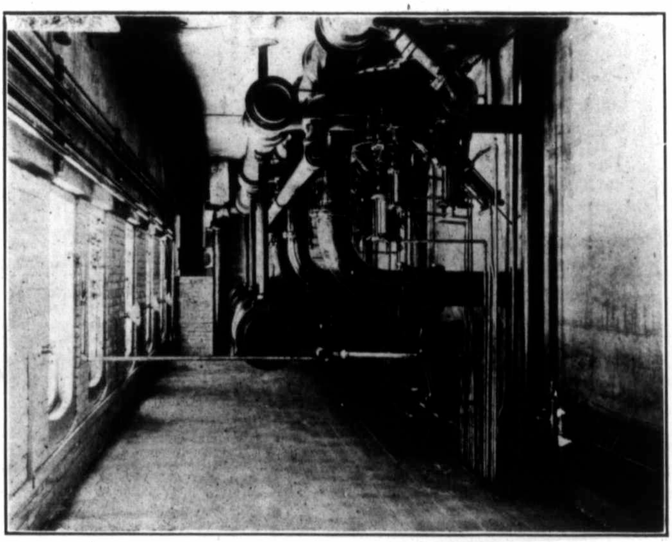
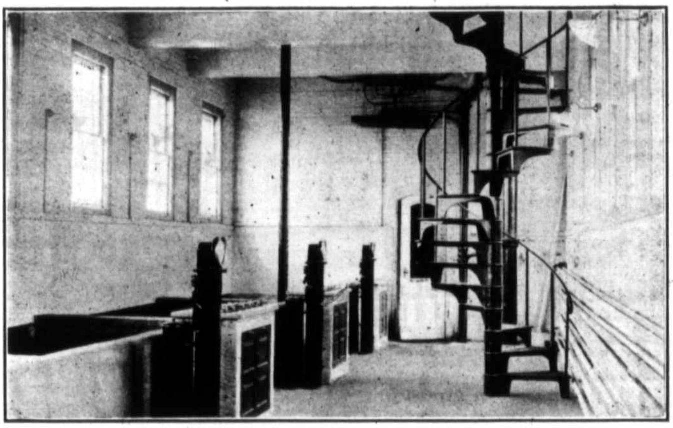
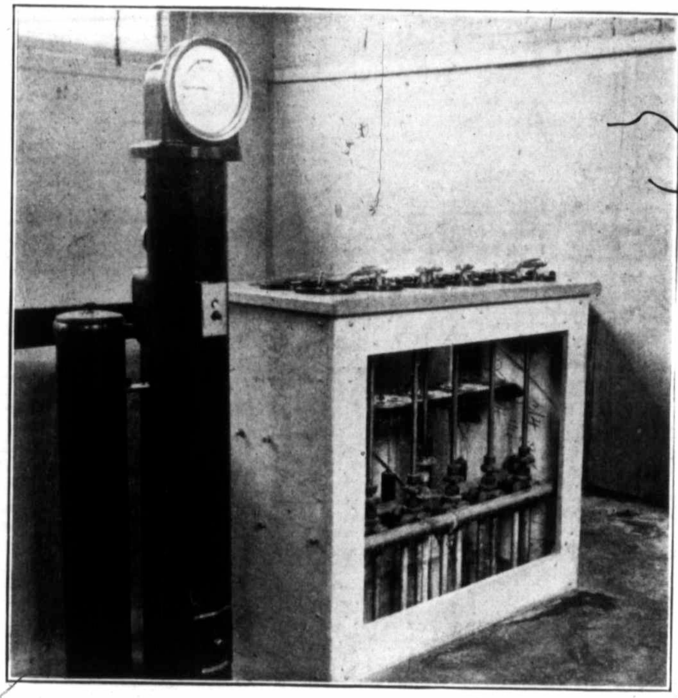


Pipe Gallery, Fredericton Filters.



Operating Room, Fredericton Filters.



Operating Table, Fredericton Filters.

The elevation of the pipe gallery floor on which the controller is placed is 12 feet below H.W. on the filters, and admits of a loss of head of about 10 feet.

Each of the five filter units has an area of 145 square feet and a capacity of over 400,000 U.S. gallons per day, when operating at a rate of 120,000,000 gallons per acre per day.

As has been already stated no material change has taken place during the last decade in the established methods of filtration. The past eighteen months, however, has witnessed what promises to merit recognition as a very decided advance in the science of Water Purification. This advance may be described as a demonstration of the feasibility of accomplishing the bacterial purification of water at a low cost by treatment with an oxidizing agent, and in such small quantities as to eliminate any apparent risk incidental to its reaction.

Although several oxidizing agents had been previously experimented with or used as temporary expedients for this purpose, it was not until after the disinfecting plant of the East Jersey Water Company was put into commission in September, 1908, that the actual capabilities of the process were fully appreciated and understood. The oxidizing agent here used was chloride of lime or "bleach." The theory of the process is as follows: when added to the water the bleach splits up into the inert calcium chloride and calcium hypochlorite; the hypochlorite when acted upon by the carbonic acid in the water forms calcium carbonate and the oxidizing agent, hypochlorous acid; in the presence of oxidizable matter the oxygen of this compound is released, leaving hydrochloric acid, which displaces the carbonic acid of the carbonates forming an inert chloride, while the atomic oxygen, which is the agent that actually does the work, and accomplishes the bacterial purification, combines with any oxidizable organic matter present. Its effects are said to be practically instantaneous. The treatment removes the colour slightly, but not materially, and does not affect suspended matter except the bacteria. From the point of view of bacterial purification, the results obtained in Jersey City, using only five pounds of bleach per million gallons of water treated, would rank this process with the best filtration plant now in operation. To quote from a report of Dr. Leal, who recommended this treatment: "For weeks at a time the water taken three-fourths of a mile below the works has been practically sterile, and the count at Jersey City has been from sterile to an average of 20 or 30 per c.c. with bacillus coli present in 10 c.c. only three times up to April 27th, 1909. The bacteria in the raw water has been from 300 to 20,000 per c.c. with B. Coli frequently present in one-tenth c.c."

Litigation which followed the use of "hypochlorite" in the Jersey City Supply brought the process prominently to public notice, and the bleach treatment has consequently been later applied for purposes of bacterial purification to several large water supplies. The uniform success which has attended its use under varying conditions with respect to the character of the raw water and to the nature of associated purification processes, is really remarkable when we consider that in its application as an adjunct to water filtration it has scarcely passed the experimental stage.

At Nashville, Tennessee, a highly turbid river water has been satisfactorily clarified and has shown over 95 per cent. removal of bacteria, by the combined application of sulphate of alumina and bleach without subsequent filtration. 14,000,000 gallons per day have been there treated in this way since August, 1909.

At about this same time the hypochlorite treatment was introduced at Harrisburg, Pa., in connection with their mechanical filtration plant. The supply from the Susquehanna River had proved a difficult water to secure good results with at all times, owing to great variation in the colour, turbidity, and other characteristics of the water. The use of 10 pounds or less of hypochlorite per 1,000,000 gallons has effected a marked improvement in the uniformity of the bacterial purification, besides permitting the reduction of coagulant to only such quantities as are necessary to remove colour and turbidity. The operation of the plant under the combined treatment continues to give the best of satisfaction as shown by a recent statement of the Superintendent of the Plant. "The operation of our plant during the months of January and February (1910), ordinarily the worst months of the year, has been made easier; and the results bacterially and in the quantity of chemicals used are remarkable. The bacteria in the river water averaged 23,117 per c.c., and in the filtered water only 6 in January, while in February the river water contained 9,015 and the filtered 3 bacteria per c.c., both remarkable averages when it is considered that these months are the ones when all the shortcomings of mechanical filters are present."

The use of hypochlorite with the otherwise untreated supplies of Minneapolis, Toronto, Montreal, and Montreal Municipalities as an emergency measure afforded relief from threatened typhoid epidemics during the past winter. Probably in no instance has the value of "disinfection" as an adjunct to established processes of water filtration been more conspicuously shown than at Poughkeepsie, N.Y. To this city belongs the distinction of building and operating the first filter plant on the continent; in 1896 and in 1905 the works were improved and enlarged, nevertheless it was found expedient to construct a sedimentation basin for preliminary treatment of the water with a coagulant after the manner of mechanical filters. This method of treatment gave good results with the Hudson River Water during its turbid stages. The severe drought during the summer of 1908 added to the pollution of the Hudson River supply by concentration in the reduced flow of the river, and in the absence of any turbidity in the raw water no results were obtained from coagulation and sedimentation. The plant operating as a slow sand filter failed to produce a safe effluent. Under these circumstances which represent in a sense an example of the inability of both types of filters to handle the water, the hypochlorite treatment introduced in February 12th, 1909, has so far overcome the difficulties previously experienced with this plant, and, to quote from a paper by Dr. Otis (*Journal New. E. W. W.*, September, 1909), "they believe that when used in quantities from 8 lbs. to 10 lbs. per 1,000,000 gals. it will reduce the bacteria over 99 per cent. and will practically eliminate the B. Coli and presumably the typhoid germs." The bleach used in the cases cited contained about 35 per cent. of available chlorine, and was applied in very small quantities, ranging from five to ten pounds per million gallons. In almost every instance the treated water has shown a bacterial count of an order that is hard to maintain in the effluent from the best filters of either type in practical operation. The cost of the treatment is merely nominal. Fifteen cents to thirty cents per million U.S. gallons covers the cost of chemicals and operation.

While the value of the "Bleach" or any other oxidizing agent as a treatment for water in cases of emergencies, is duly recognized, it is perhaps too early to predict to what degree disinfection will be productive of economy and efficiency in the science of water purification. As a complete treatment in itself it is applicable to only a special class of waters, but results from its use to date, point strongly to the conclusion that as an adjunct to both types of filters it will permit of the adoption of higher rates and possibly less reserve area with a corresponding reduction in first cost. This would appear to be particularly the case where the rate is governed by the degree of bacterial purification required rather than the physical improvement of the water.

In the judgment of those who from their experience are best qualified to pronounce on the matter, it is believed that from the point of view of economy and certainty in operation the use of disinfectants will give the best results as an aid to filters of the mechanical type. Over two years ago experiments were undertaken at Lawrence, Mass., on the Merrimac River water by mechanical filters using sulphate of alumina as a coagulant and bleach as a disinfectant. Soda was used when the alkalinity of the water demanded it. The following extract from a paper on these tests is of interest in this connection. "When bleach is used in combination with sulphate of alumina in mechanical filtration, a satisfactory bacterial removal may be obtained at much less expense for chemicals than when sulphate of alumina is used alone. In such a process the disinfection occurs in the coagulation basin before the water reaches the filter and subsequent filtration introduces a factor of safety which greatly adds to the effective purification of the water and greatly reduces the chances of the occasional failure of the process. In the experiments quoted, an effluent of better quality bacterially was obtained by the use of about 0.9 grain sulphate of alumina and about 0.7 grain of soda per gal. in combination with bleaching powder equivalent to 0.11 part per 100,000 available chlorine, than when nearly double the amounts of sulphate of alumina and soda were used without disinfectant."

The first cost of purification plants will depend primarily on the quality of the water to be dealt with. When the appropriate method of purification has been decided upon the cost will depend for each case on the price of materials and the local conditions which usually affect the cost of engineering works. Manifestly, then, it is impossible to make any statement as to cost which would be generally applicable; but, speaking broadly, it may be said that for plants of from one to four or five million gallons per day capacity, the first cost will range from $15,000 to $30,000 per million gallons for filtration alone. In some cases where the circumstances are unusual the cost may be higher than this. For large plants the cost will range from $12,000 to $25,000 per million gallons. As has been stated above, each case should be separately studied so that both economy and efficiency may be advantageously combined. Generally speaking, what have been referred to as mechanical filtration plants will cost less to install than slow sand filters; but with a water which can be handled by either system the reverse is usually the case, when the initial, operating, and maintenance costs are jointly considered.

It may be said that with present methods of purification the total cost including interest, sinking fund, operation and maintenance for treating water of average turbidity will not often be greater than one cent per thousand gallons of water purified. This means that for a consumption of one hundred gallons per capita per day the cost to each consumer will be less than forty cents per year.

It may not be out of place to add a word concerning the relative merits of slow sand and mechanical filters. It is a question that has received considerable unprofitable and not entirely disinterested and fair discussion; as a result both systems have been the subject of some unmerited claims and much unjustifiable criticism.

Such a controversy is neither necessary nor desirable; the two systems do not in fact admit of a rational comparison in the abstract. Both are wonderfully efficient machines in the accomplishment of the work legitimately required of them; and the varying conditions encountered in the field of water purification presents a variety of problems in the solution of which both systems are a necessity.

The distinguishing feature of mechanical filtration does not commend this system to the popular mind which is disposed to regard with suspicion the use of a chemical in a drinking water; to those who hold strong convictions on this subject it may be well to point out that after twenty years of experience, the indictment against coagulants with respect to effects prejudicial to the potability of the water, has never yet taken any more definite form than a suspicion.

Coagulants are moreover a necessity in the efficient and economical treatment of many turbid and highly coloured supplies. The waters to which slow sand filters are inapplicable as a complete treatment are the most costly to handle, and the cost of operations of systems using a coagulant considered as a class is naturally higher than in the case of slow sand filters.

The installation of rapid coarse grained filters for preliminary treatment has permitted the adoption of final filters of the slow sand type in some recently constructed plants; these preliminary filters, known as "Roughing Filters," effect the clarification of the water in some cases as at Philadelphia without the aid of coagulants. A description of some of the largest plants recently put in operation on this continent has lately appeared in the daily press; and it has no doubt been noted with regard to these plants that scarcely any two of them follow the same course of treatment; this is perhaps one of the reasons why all are giving such splendid results. Novel features and methods have been introduced to meet varying conditions arising from the characteristics of the raw water, the availability of space and structural material, and any peculiar circumstances anticipated in the operation of the plants.

The success of these installations from the point of view of both economy and efficiency, is in no small measure to be attributed to the thoroughness of preliminary investigations.

An interesting and remarkable example of the value of careful study of local conditions, in advance of the selection of a method for the purification of a water supply, is to be found in the small plant put in operation in September, 1908, for the treatment of the Susquehanna River water at Steelton, Pa.

Here the designer had the benefit of an experience gained in the design and operation of the Harrisburg Filters on the same river. Some idea of the difficulties presented may be gathered from the following description given of the river water at Steelton:

"High bacterial counts sometimes accompany very low, as well as very high, turbidities, and similarly relatively low turbidities are sometimes found at very high stages of the river; further, the colour of the turbidity is no indication of its total amount, as a comparison of the records of ten samples of water, each with a turbidity of one thousand parts per million, collected at different times, and at different parts of the river, shows all gradations of colours between bright yellow, red, dark brown, and black. As a result of these complex conditions, the water in the river may change quickly from a moderately hard, clear water to a soft water carrying several thousand parts per million of turbidity, which, on occasions, may intermittently come down coagulated to a more or less slimy or flocculent condition with hydrated oxide or iron and hydrate of alumina. On the other hand, the river from bank to bank may be carrying its maximum load of yellow clay from the Conodoguinet and Juniata, or reddish brown mud from the West Branch. During a general flood from the entire water shed all these conditions may prevail at the same time.

The plant here installed has a nominal capacity of 3,000,000 gallons per day; and consists of preliminary coarse grained filters working at a rate of 170,000,000 gallons per acre per day. These filters are operated both as simple roughing filters and also as mechanical filters using a coagulant when it is found necessary to produce an effluent which can be handled by final filters of the slow sand type.

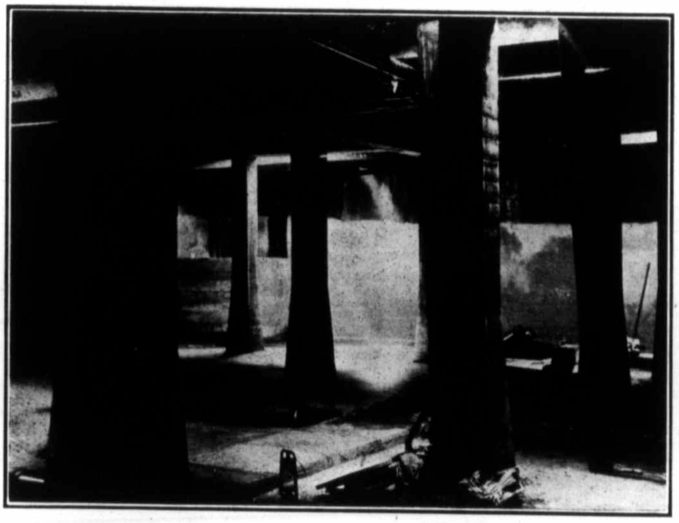
As a result of careful control of the preliminary filters it is estimated that the final filters will have a capacity of 9,000,000 gallons per acre per day.

This plant has been most efficient in accomplishing the bacterial and physical improvement of the water.

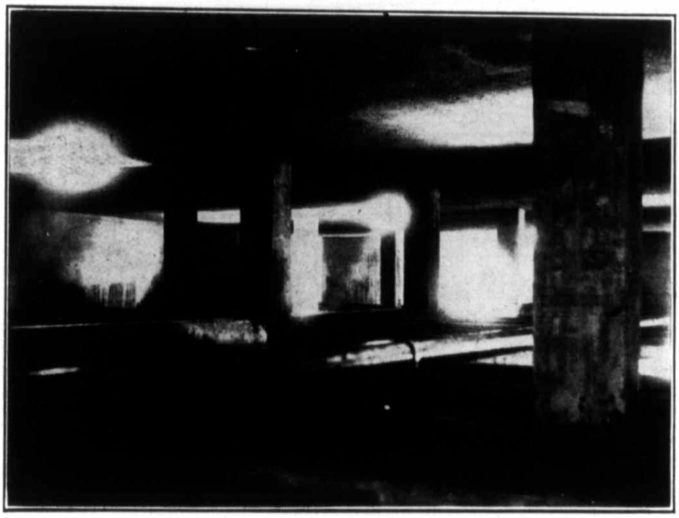
The initial cost exclusive of exterior conduits was less than $60,000.00, that is, about $20,000.00 per million gallons estimated capacity. The cost of operation is in the vicinity of three dollars per million gallons, so that placing interest and depreciation at 10 per cent. on the cost of the plant, it will be seen that the total cost is within ten dollars per million gallons filtered.

This is a remarkable performance under such unusual circumstances; and the moral points forcibly to the expediency of giving to those entrusted with the design of water purification plants, ample opportunities and facilities for familiarizing themselves with all local conditions.

It will not be necessary to refer in detail to the many advantages possessed by filtered water when used for drinking and other domestic purposes. One of the most serious and at the same time unnecessary diseases which affect humanity is typhoid fever. This is a disease of the human intestines, and is now generally admitted to be caused only by the specific germ of typhoid, the typhoid bacillus. This germ is found in enormous numbers in the urine and feces of persons afflicted with typhoid fever. Hence it is that sewage is at all times liable to contain large numbers of these germs, and is of all impurities in water the one most to be feared. The water courses of a country, the rivers and streams, are the natural drainage channels, and it is, therefore, practically impossible



Steelton, Slow Sand Filter Basin.



Steelton Filters.

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when their watersheds are inhabited to prevent sewage in some form or other from entering them; so that it may be generally stated that except for the smaller streams whose watersheds may be thoroughly protected, no river water is safe to drink without purification. This statement must of course be greatly modified as to degree. Large streams and sparsely inhabited watersheds constitute safer conditions because of a high dilution; but the universal and constant use of water demands that its purity should be jealously guarded at all times and under all circumstances. If, for example, it was known that a public water supply was ever, rarely, liable to contain a poisonous substance like lead in such quantities as to be sufficient to cause serious disease and sometimes death, there would be no hesitation in condemning it. Rivers flowing through populous districts will always receive a certain proportion of sewage which will occasionally contain that which will cause disease and death just as surely as if they were contaminated with a deadly poison in some other form. We do not need examinations of the water to tell us this. As a matter of fact no analysis has as yet been able to furnish positive evidence of infection. In all the thousands of sanitary analyses of water which have been made the typhoid bacillus has been identified less than a dozen times, so that a favourab'e analysis of a surface water is no guarantee as to its safety for drinking purposes.

The important fact is that rivers have other uses than furnishing supplies of drinking water, and even if all our sewerage systems were equipped with efficient disposal plants, which they are not now, and will not be for a long time, there are still many ways that impurities may enter. Fortunately the tendency is for typhoid germs to die rapidly in water; but the hardy forms at least, which are probably the dangerous ones, can live in river water for days.

Typhoid can be transmitted by other media than water, but a large proportion of the deaths from this disease is caused by water-borne germs, as is shown by the records of places whose water supplies have been improved either by filtration or the substitution of a purer source; and also by a comparison of the typhoid death rates of different cities with supplies of varying degrees of purity. An illustration of this is given in the diagram, and also by the following typhoid rate of Jersey City from 1889 to 1909:

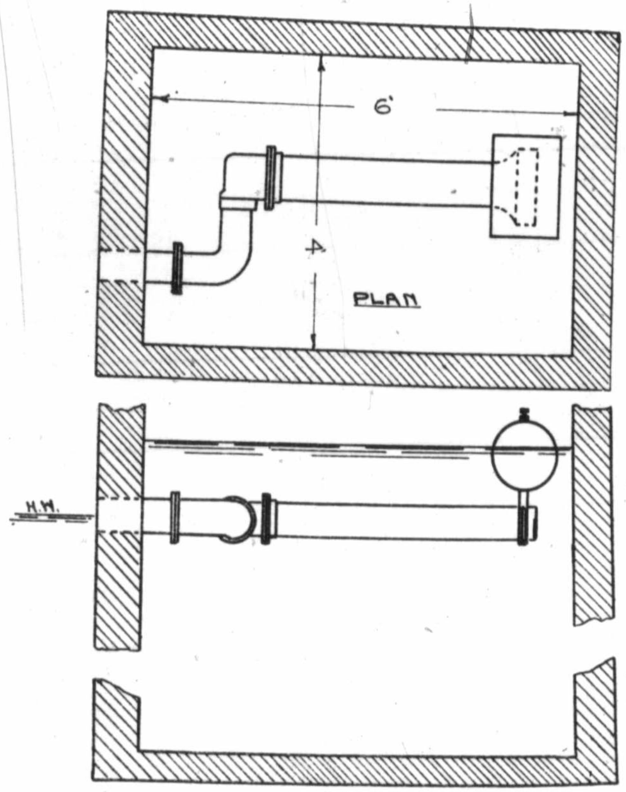
Year.	Typhoid death rate per 100,000 population.
1889	81
1890	95
1891	98
1892	90
1893	65
1894	52
1895	95
1896	84

Change to a purer supply.

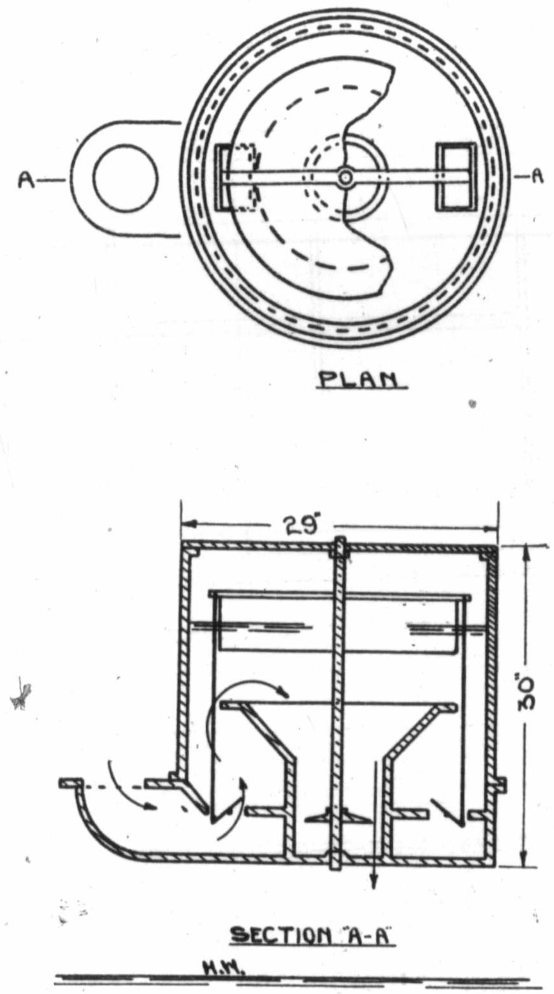
1897	20
1898	40
1899	19
1900	21
1901	11
1902	16
1903	16
1904	20
1905	19
1906	21
1907	13
1908	10

It is now considered that with purification plants properly designed and operated the typhoid rate should be kept down to from fifteen to twenty per 100,000, and probably in many cases to less than this. The water supply of Montreal is taken from a large river, where the dilution is unusually great, yet the average typhoid fever rate for the last thirty years has been over forty; and for the last ten years about thirty-five. Probably half of these might have been prevented by properly purifying the water. This means, on the basis of the population of Greater Montreal, the prevention of 100 deaths a year, and at least 1,000 other cases. Last year forty lives were lost in the whole Dominion by accidents at railway crossings, towards the prevention of which the Federal Government is itself devoting $200,000 per year for the next five years. Probably from two to three times as many lives are lost by typhoid fever in the City of Montreal alone.

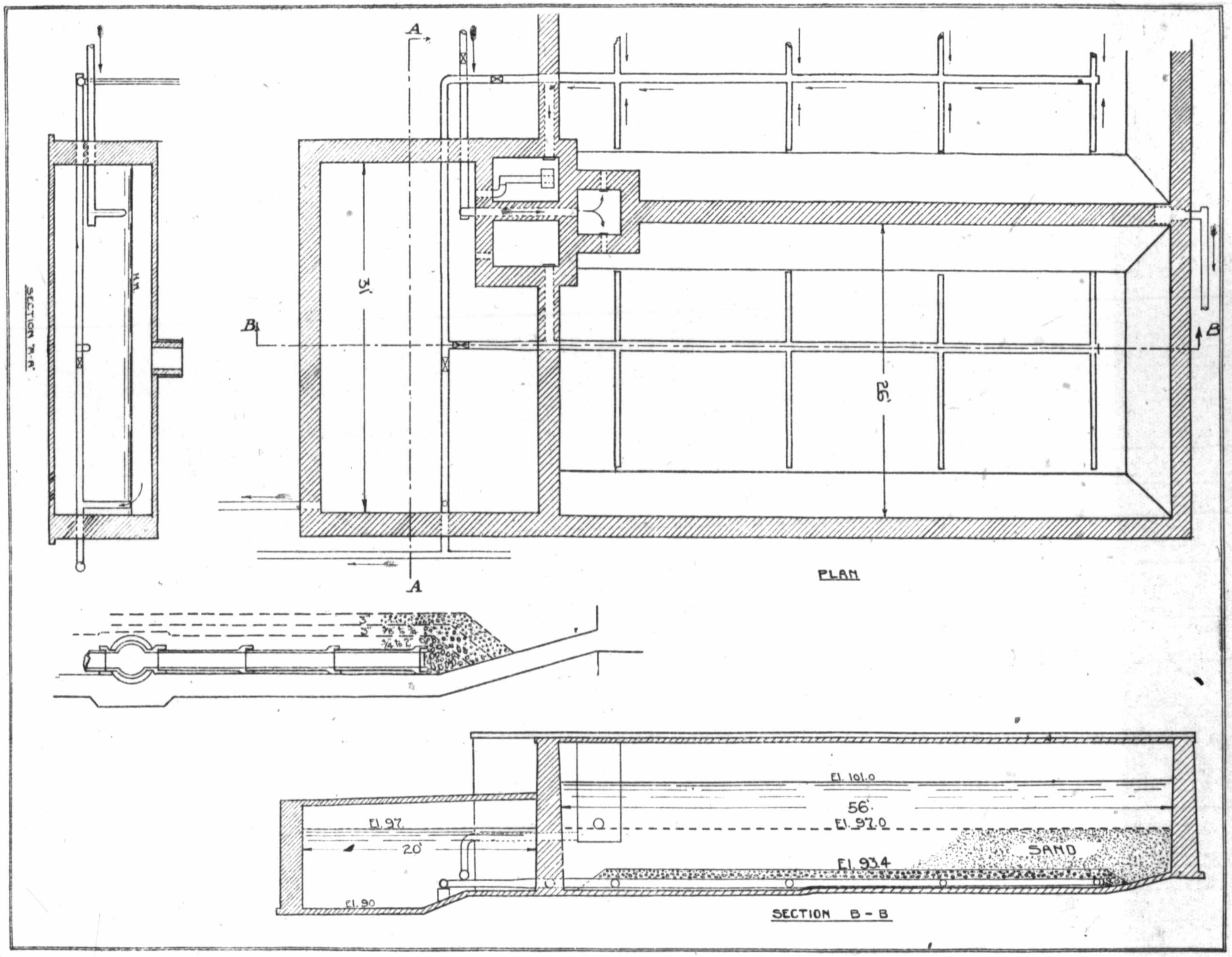
From a financial standpoint the average value of a human life is generally given by statisticians as $5,000.00, which will give some idea of the actual preventable loss to the community from this disease alone, particularly when we remember that the victims of typhoid fever are largely of the age when their life value is greatest. Considering, however, only the cases which recover, with the loss of time and incidental expense we would probably be underestimating the average cost as at least $100.00 per patient. This in itself means a loss of $100,000.00 a year to this community, which somebody has to pay for. But it is from the point of view of the individual that the cost of placing water beyond suspicion appears in its real relation to the results obtained. When the facts of the case are clearly realized no one would risk his health or life, or those of the members of his family for the sake of an expenditure of less than one cent per week; and this will cover the entire cost of purifying most water supplies.



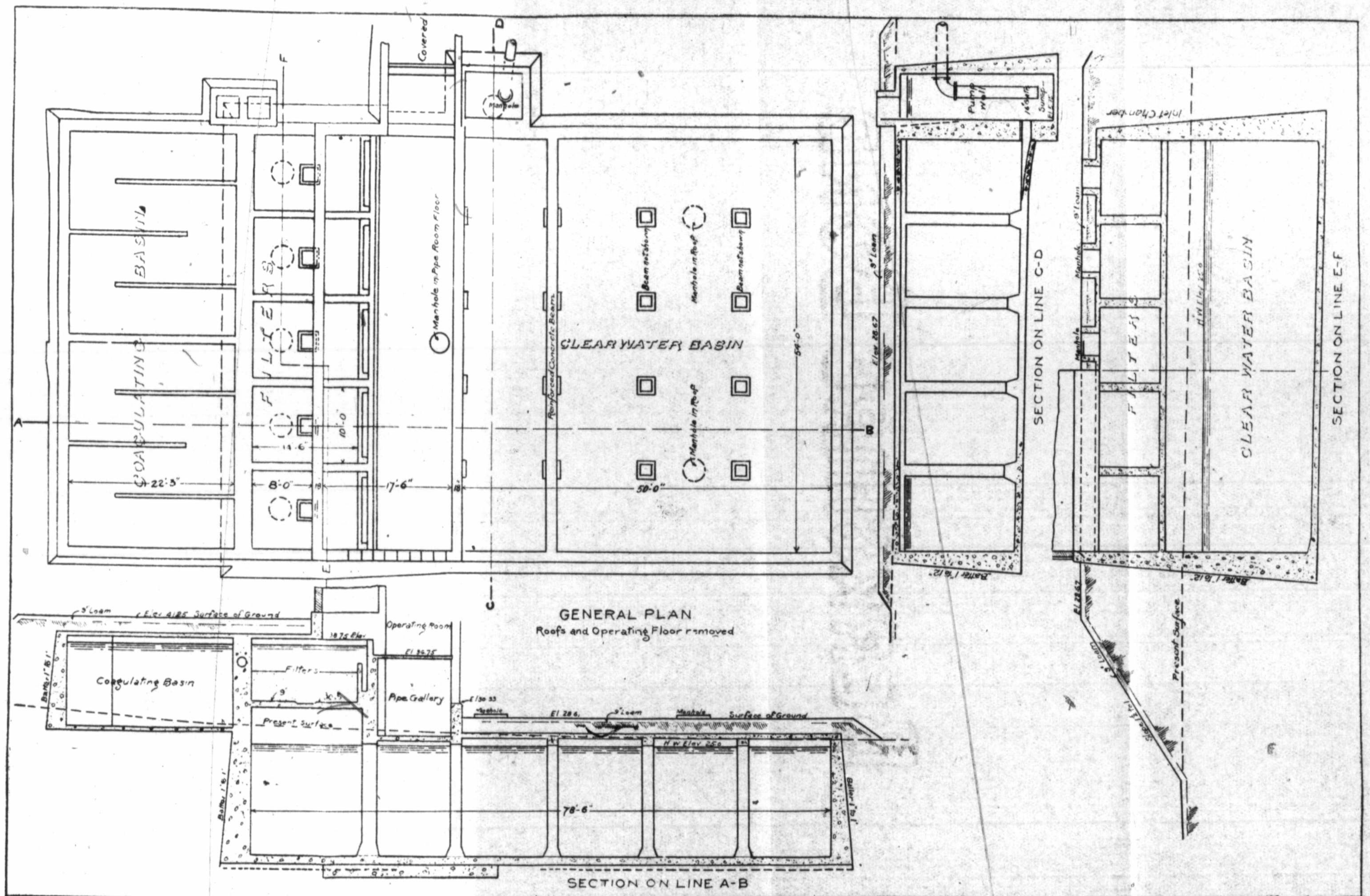
Elevation.
Float Pipe Controller.



WESTON CONTROLLER



Nova Scotia Hospital Filter.



Fredericton Filter Plant.