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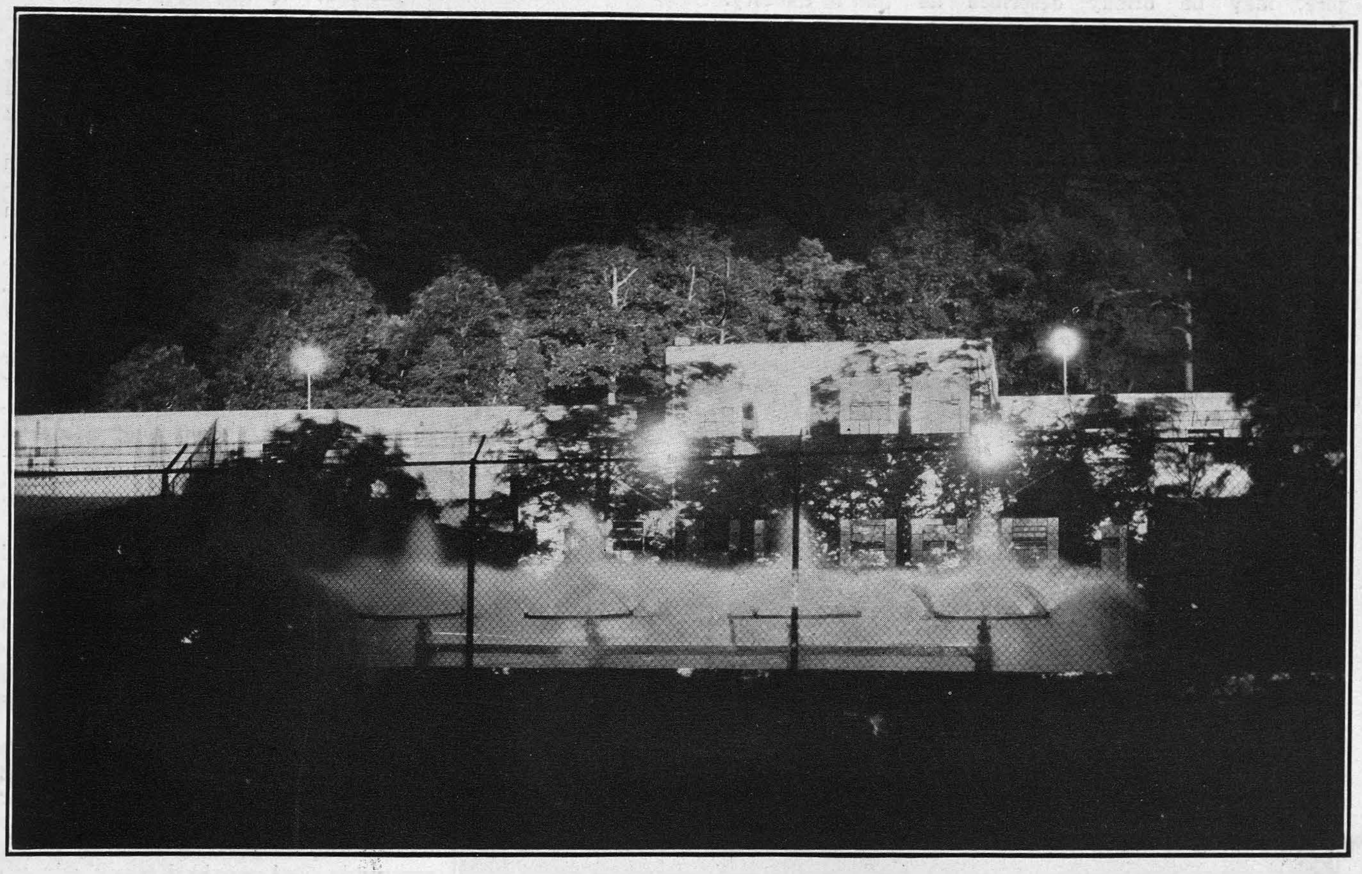

Night View of Plant Showing It Illuminated with Monticello Search Light. The Secondary Aerators are in the Foreground

Slow Sand Filtration at Charlottesville, Va.

The Development and Results of Operation

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AN historical summary of the development of the Charlottesville Water System is essential to complete understanding of the treatment problem as is a description of the physical elements of the system.

Prior to 1925, Charlottesville's water supply was from two impounding reservoirs, located in the "Ragged" mountains about three miles southwest of the town. In elevation the reservoirs are deficient for adequate pressures in the western part of the city and at the University of Virginia.

This supply demonstrated its inadequacy as early as 1918. During the late spring, summer and early fall the water had an intensely disagreeable odor, taste and color, resulting principally from algae. Copper sulphate treatment was resorted to, but with little success.

In 1922 a pumping station was constructed on Maury Creek, a small stream flowing from the drainage area below the reservoirs, pumping back into the reservoirs for storage, a means of augmentation which not only did not improve the stored water but which was expensive due to high heads.

During the summer of 1921 the situation, both as regards inadequacy of the supply and the repellant physical characteristics of the water, became unbearable and the city officials began investigations of additional sources simultaneously with studies of treatment requirements. Surveys were made of all available sources including the Rivanna River, with the result that a gravity supply from Moorman's River was clearly demonstrated as the logical addition to the supply.

On Nov. 11, 1921, George W. Fuller of New York, Dr. M. G. Perrow of Lynchburg, Major R. Messer, Chief Engineer of the Virginia Board of Health, and myself reported unanimously in favor of a slow sand filter with preaeration, located on the Observatory Mountain, as sufficient and most economical treatment of both existing and proposed supplies. Construction was immediately begun and operation commenced in the Fall of 1922.

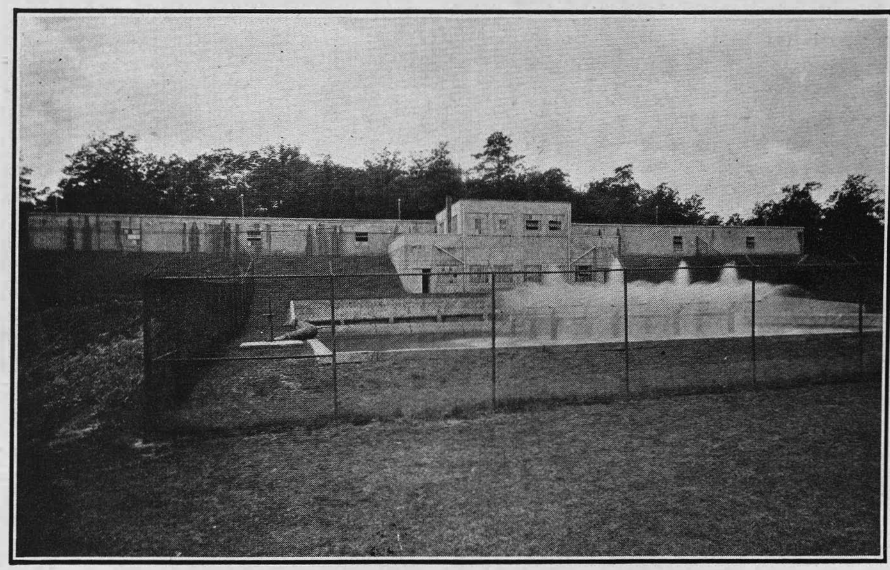
In 1922 and 1923, there were again acute shortages which were temporarily relieved by the installation of modern pumping equipment at Maury's Creek, so connected as to pump direct to the new filter plant. Early in 1924 the development of the Moorman's River source was begun and the water turned into the mains on March 30, 1925.

The Completed System.—The completed system at Charlottesville, therefore, may be briefly described as follows:

The intake, consisting of simply a diversion weir, is situated in Jarman's Gap developing a total drainage area of approximately 23 sq. mi. of rough, mountainous, heavily forested land. Just below the intake is situated the grit chamber and from this an 18 in. cast iron conduit leads to the storage reservoirs near the city. This conduit is designed for pressure on the hydraulic gradient so that the only cut off is at the intake. Topography, however, allows short lengths to be drained in case of emergency repairs. The 18 in. line connects into the old 18 in. and 10 in. mains from the storage reservoirs to the filter plant, so cross connected that water may be drawn from either the reservoirs or direct from Moorman's River through either the 18 in. or 10 in. main.

With this system of connection it was necessary to prevent static pressure on the pipe line by closing valves at the filter plant or at the cross connection. Moreover, the Moorman's River conduit has a far greater capacity than present requirements and it as desired to store Moorman's River water in the reservoirs whenever possible. An open control chamber was, therefore, constructed on the hydraulic gradient so that in case of a shut down below this point all water flowed to storage in the reservoirs through the control chamber or under normal conditions the excess supply from Moorman's River, over the demand at the filter plant, flows through the control chamber to storage.

A booster station for use when drawing from the reservoirs is located near the filter plant with suitable connections to allow combined use of Moorman's River water by gravity and boosted water from the reservoir. Eighteen, 10 and 6 in. mains lead from the clear-water reservoir to the distributing system in the city.



General View of Plant, Showing Secondary Aerators in Foreground

Basic Elements in Selecting Treatment Plant.—The 1921 survey of purification requirements discovered the following elements as basic in selecting the location, type size and extent of treatment plant.

1. Two sites were available, (a) at the Impounding reservoirs and (b) on the Observatory Mountain near the University.

2. The location in elevation should be such that delivery by gravity to all parts of the city then developed or or likely to be developed in the future could be accomplished. This required the correction of notable pressure deficiencies in the western part of the city and at the university. The location was further qualified by the requirement that a supply from Moorman's River could be economically brought in by gravity, without seriously curtailing its drainage area.

3. The situation demanded a location lending its self to economical and speedy construction, with due regard for facility of operation.

1. Treatment of the existing supply required:

(a) Removal of some pollution though the water shed was municipally owned.

(b) The removal of color, taste and odor of a marked degree.

(c) The reduction of iron.

(d) The removal of very slight turbidity.

2. Treatment of the proposed new supply from Moorman's required:

(a) Removal of possible pollution. No part of the shed being owned by the city, the drainage area being 25 sq. mi., impossible of acquisition and difficult to patrol if acquired.

(b) The removal of fairly large suspended matter during the periods of flood flows.

(c) The reduction of iron.

Water from both supplies was very soft, moderately high in iron and it was evident that large volumes of fresh, clear water from Moorman's River added to the impounded supply, would vitalize the latter and greatly improve its quality.

Capacity.—1. A Pitometer survey in 1920 showed the average daily consumption as approximately 1 Mg. with the per capita consumption about normal.

2. Provision for a service supply, situated by physical necessity well away from the points of demand and the desirability of a uniform rate of filter operation dictated a large clear water reservoir. Peak rates were then secondary in the determination of the total plant capacity though they further influenced selection of a large clear well capacity as an investment economy over increased plant capacity.

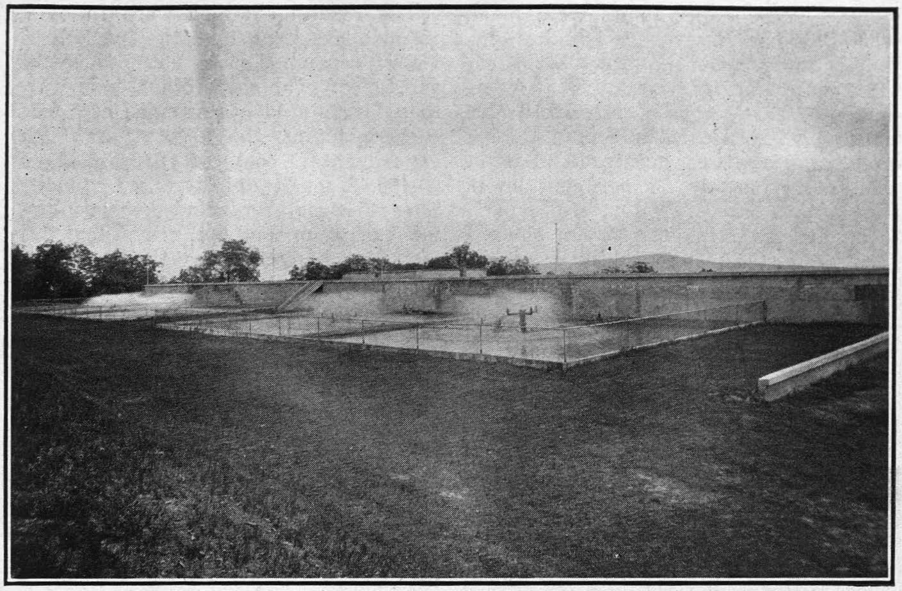
Consideration of these principal, and numerous other secondary, elements, together with careful study as to the ultimate economy to be gained, led to unanimous recommendation of the slow sand type of filter with aeration, with the following thoughts uppermost as regards location, type and size.

The location at the old reservoirs was very inaccessible, served by no improved roads, and requiring a 5-mile haul for construction materials. Conversely, the observatory location was close, easily accessible, and provided many advantages and economies, both of construction and operation.

The turbidity to be removed was well within the proven ability of slow sand filters without coagulation or pre-treatment. The taste and odor being principally due to various forms of algae, were capable of adequate treatment by aeration, as was reasonable reduction of iron. The color, though high, was not beyond the capacity of the slow sand type, whose high bacterial efficiency has been undeniably demonstrated.

Simplicity of operation and consequent lower labor costs, the elimination of chemicals, lower wash water requirements, and the small size of the plant presented marked economies, in this particular case, even in the face of greater investment per unit of capacity for the slow sand filters over that for mechanical. In short, the situation was ideal for the slow sand filter with no single feature demanding mechanical filter treatment. Selection of the slow sand filter, in this instance, is as obviously correct as is the selection of the mechanical filters for the city of Richmond, for instance.

With an average demand of 1 Mgd. and clear well capacity of 1 Mg., this capacity being selected primarily in



Primary Aerators at Rear of Plant

deference to its distance from the point of demand, the desirability of a uniform operating rate and economy of Filter Construction, it seemed amply sufficient to provide 2 Mg. of Filter capacity.

Basic Data for Design.—Accordingly, the design was developed from the following basic data:

Capacity 2 Mgd.

Rate: 5 Mg. per acre per day.

115 gal. per sq. ft. per day.

08 gal. per sq. ft. per minute.

This determined the total area as .4 of an acre which was divided into 4 beds of .1 acre each.

Gravel was 12 in. deep as below.

7 in. retained by 1 in. mesh, none over 2 in.

2½ in. passing 1 in. mesh retained by ⅜ in. mesh.

2½ in. passing ⅜ in. mesh with effective size of 2 to 3 MM.

Sand was 36 in. deep as follows:

Maximum turbidity 200 p.p.m. Silica sbd.

Effection size .36 MM.

Uniformity coefficient 2.00.

The under drains were 12 in. split tile with joints laid ¾ in. open.

The area drained by each line of tile was 1,089 sq. ft. as against 1,200 sq. ft. maximum area for efficient velocity.

Friction in drainage system .09 ft.

All piping was amply large with the express purpose of conserving friction resulting in the following velocities:

Under drains, .55 ft. per sec.

Main Collector Lines, .90 ft. per sec.

Effluent Lines, .99 ft. per sec.

Troubles Operating and Their Correction.—During the first few weeks of operation the effluent had a milky color due probably, to silacious material in the sand bed. This cleared nicely, however, and at about the same time the bacterial efficiency began to pick up.

During the first summer the water from the reservoirs was at its worst due to drought and stagnation. The beds clogged rapidly and for several weeks had to be cleaned once a week. Then a red slime appeared in the clear water reservoir, having the appearance of red mud, in which small red worms bred. Experiments were at once started to determine the cause and it was found that the water was abnormally high in iron in the ferrous state which thus passed the filters in solution, was oxidized by aeration and precipitated as ferric iron in the clear well.

The remedy was the installation of aerators ahead of the filters with sufficient detention for the floc to form. The installation of this equipment relieved the clogging of the filters so that a minimum period of two weeks was maintained between scrapings when bad weather prevailed.

Enlargement.—After this correction, the effluent was excellent and in spite of the rapid installation of meters the consumption increased perceptibly. Moreover, certain industries who had previously maintained private supplies asked to be supplied from the municipal system. Since their demands totalled several hundred thousand gallons daily it became necessary to study means of increasing the filter capacity.

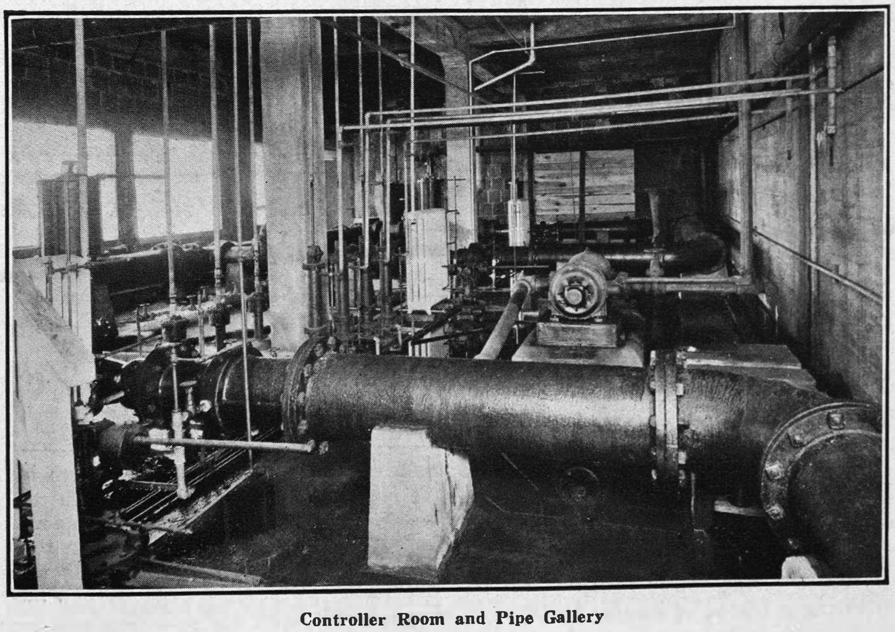
Studies were made on the basis of additional 3 Mgd. per acre rate filters with estimates of cost and found to be beyond the then financial ability of the city.

In studying the troubles encountered during early operation, an experimental filter was constructed and the results obtained indicated the possibility of using a higher rate of filtration, especially since the Moorman's River supply was assured and improvement of the raw water, even during the summer months was confidently expected. With completion of the new supply, better water was an accomplished fact, therefore the city council subsidized a series of experiments during the summer of 1925. These covered operation of a small experimental plant at various rates with studies of the water during all stages of the processes, together with studies of the water in its passage through the slow sand plant.

These experiments were made under conditions which were as adverse as can be expected, that is, when most of the water was being furnished from the storage reservoirs during an exceedingly dry season and before the Moorman's River supply had time to reach its maximum effectiveness in the improvement of the impounded supply.

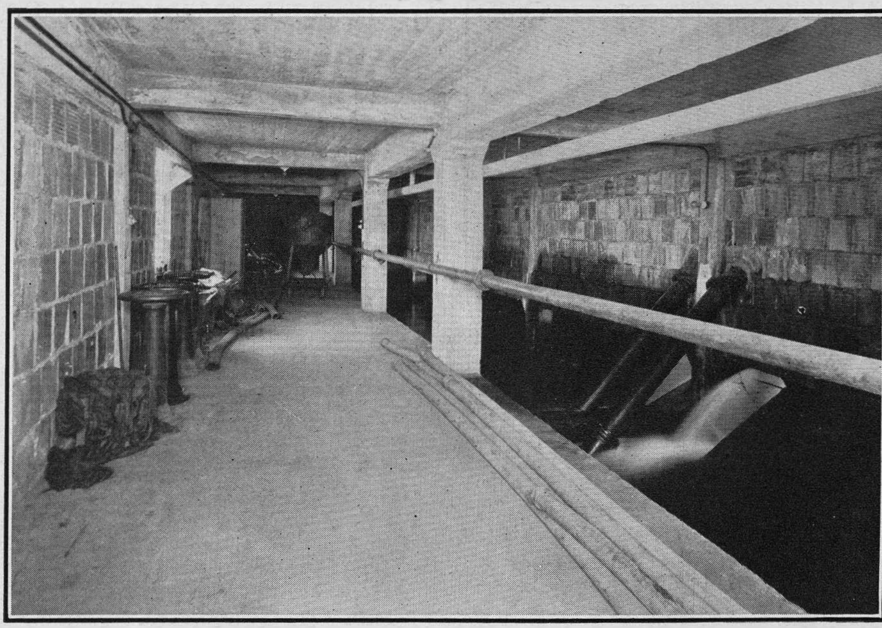
The results may be summarized briefly as follows:

This water had no characteristics which would preclude an increase of rate to 10 Mg. per acre per day. Both color and turbidity ranged between 20 and 27 parts per million. In was found, however, that the water was very high



Controller Room and Pipe Gallery

in iron and the importance of preliminary aeration was clearly demonstrated. That is, it was necessary to remove as much of the iron carried in solution as possible, as otherwise it so passed the filters and was precipitated by the secondary aeration. Since preliminary aeration causes the formation of a floc the question of providing settling basins ahead of the filters was studied carefully with the idea that the load on the filters might be materially reduced by allowing the floc formed to precipitate out before the water was applied to the filters. It was found, however, that due to the nature of the floc, a period of about 15 minutes was all that was justified, since over a six hour period, only 17 per cent settled out and 65 per cent of this was settled out during the first 15 minutes.



Operating Gallery and Nichols Sand Washing Machine

The experimental filter was rigged with a pre-aerator and 15 minutes sedimentation ahead of the filter, with a secondary aerator after filtration. Operating at a 10 million gallon rate the effluent was excellent, the following tabulation showing the condition of the water at various stages of the process:

	Raw Water	First Aeration	After Filtration	Secondary Aeration
Temperature OC	23.5	23.5	23.5	23.5
Turbidity	27.0	25	5.0	5.0
Taste	Faint, Earthy	Faint, Earthy	0	0
Color (apparent)	21	20	3	3
Alkalinity	0	0	0	0
Hydroxide (OH)				
Carbonate (CO_3)	0	0	0	0
Bicarbonate (HCo_3)	18.5	17.9	18.1	17.5
(In terms of $CaCo_3$)				
Iron	0.76	0.70	.04	.04
Free Carbon Dioxide	9.30	3.7	6.1	1.6
Dissolved Oxygen	1.54	6.01	2.04	8.07
Per Cent of Saturation	17.9	69.8	23.7	93.8

Practically rates as high as 10 Mg. per day had been used only in an experimental way in this country, the most noteworthy experiment having been carried out at the Washington filter plant during 1908 to 1910, inclusive, covering a period of approximately 1½ years. These experiments were made with Potomac River water at best infinitely more turbid than the Charlottesville supply at its worst. They demonstrated that up to a rate of 10 Mg. the loss in bacterial efficiency was very small and that the cost of filtration was approximately 33 per cent lower than with a rate of 5 Mg.; also experiments at the Lawrence filters showed practically the same results, that is, that bacterial efficiency was very slightly decreased between rates of 5 and 10 Mg. per acre.

Both experiments, however, demonstrated the importance of the cleaning method used, as uniformly better results were obtained when the filters were cleaned by scraping, as is the usual method for cleaning this type of bed, than was the case when they were cleaned by the reverse flow method.

As a result, one filter was revamped to operate at the new rate of 10 Mg. per acre per day by increasing the aerator capacity ahead of the filter and providing 15 minutes sedimentation; reconstructing the drainage system by installing two 10-in. by 12-in main collectors and 6-in. split tile laterals; and installing new controller equipment of increased capacity. Thus a filter which previously had 5 Mgd. capacity new has been doubled.

The results obtained were in every respect excellent and the period between scrapings was not perceptibly shortened. The three other beds were, therefore, similarly revamped at a total cost, including the absorption of the experimental cost of $16,936.84 or $8,468.42 per Mg. of increased capacity. These figures also included the replacement of some sand and gravel lost during the change. Also the new sand was carefully selected and carefully mixed with the old sand so as to reduce the effective size to .34 mm. and to somewhat improve the uniformity coefficient. The mixing was accomplished by repeated washings with the Nichols machine.

The cost of $8,468 per 1,000,000 gal. of increase may be compared with $51,000, the estimated cost per 1,000,000 gal. of capacity of additional filters operating on a 5,000,000 gal. per acre rate.

No major troubles, either of operation or sufficiency of treatment, have been encountered since the revamped plant was put into operation in the summer of 1926 but, as will be later shown, the cost of operation has been steadily lowered. The average time between scrapings for 2½ years' operation on the 10 Mg. rate approximates 50 days, or only 10 per cent less than the period obtained when the lower rate was used. The sanitary and physical characteristics of the water have equaled in every respect the effluent obtained with the 5 Mg. per acre rate.

During summer months when the iron precipitate was heavy it was found that the installation of a coke screen over the outlet from the preliminary aeration basins relieved the filters of considerable load. These were so arranged as to be readily cleaned and cost only a few dollars each.

Cost of Operation.—In determining the cost of operation only the actual cost of treatment and purification functions are included. Similarly the fixed charges represent only actual investment in treatment and purification works. This method of cost determination is based on the theory that booster pumping and service water storage should have been provided whether or not treatment was necessary.

Thusly, the average yearly cost of water treatment, exclusive of fixed charges, has been as shown in Table I.

The high costs of 1922 and to 1924 are caused by treatment of Maury's Creek water in part and to the generally poor condition of the impounded water during the period immediately preceding completion of the Moorman's River supply. The principal element of cost being labor for scraping and washing during the summer and early fall months.

The plant has been in operation since November, 1922, and this time is log-

Table I

	'22-'23	'23-'24	'24-'25	'25-'26	'26-'27	'27-'28	'28-'29*
Aver. cost of treatment per 1,000,000 gal...	$14.28	$16.78	$7.23	$7.42	$7.90	$5.95	$5.99

*Seven months only.

ically divided into three periods: First, November, 1922 to April, 1925, during which all water came from the impounding reservoirs and Maury's Creek. This water represents the most adverse conditions and covers the starting up and shake down period. The average cost for the period was $8.94 per Mg. Rate of filtration was 5 Mg. per acre per day. Second, April, 1925, to June, 1926, during which Moorman's River water was available, causing a constant improvement of the raw water operation at the 5 Mg. per acre rate, during which water was as under the second phase, but the rate of filtration was 10 Mg. per acre per day, average cost $6.65, or 10 per cent lower than under the same conditions with a 5 Mg. rate.

The average cost over the entire period of operation is $8.94 per Mg. Over the period covering the 5 Mg. rate $11.68 per Mg. and over the 10 Mg. rate period $6.61 per Mg.

These costs include all labor, supplies, maintenance and repairs, together with light and power for washing sand.

The fixed charges over the entire period of operation average $13.53 per 1,000,000 gal., and include a sinking fund for retirement of the outstanding bonds, making a total cost at present of $20.18 per Mg. or .02018 ct. per 1,000 gal.

Acknowledgment.—The foregoing is a paper presented at the First Virginia Conference on Water Purification and Sewage Treatment, held April 25 and 26 at Richmond. Va.

Laying a Reinforced Concrete Outfall Sewer

Steps in the laying of the new San Rafael, Calif., outfall sewer are shown in the accompanying photographs. Sewage is pumped through this line from San Rafael to an outlet in San Francisco Bay. The sewer is built of centrifugally-spun reinforced-concrete pipe of 21-in. internal diameter. Pressures in the line are relatively high, sections of the pipe being reinforced to with-

At the End of the Pipe in Place. The Horse Moves Along on Rollers to Handle the Next Section

stand a 100-ft. head. The design was based upon the estimated population in 1948.

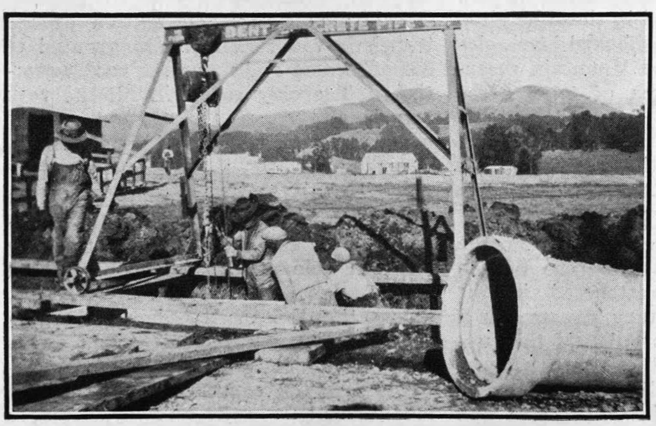
The pipe, which was supplied by the Bent Concrete Pipe Co., was transported from the Oakland plant of that company to San Rafael on barges. At San Rafael it was loaded on trucks and carried to various points along the line where it was unloaded. One of the illustrations shows a derrick unloading pipe from a barge to the pier. A chain hoist, suspended from a heavy steel horse, was used to lower the sections of pipe into the trench. Planks were placed across the trench beneath the hoist, and the sections were rolled over the trench. They were then picked up by the hoist and the planks were removed, allowing the pipe to be lowered into the trench. Redwood cradles were installed in the bottom of the trench to carry the pipe. The horse is provided with small wheels so that it may be moved along the trench on planks laid at the sides. For a wider trench, the wheels may be changed and the horse turned the other way.

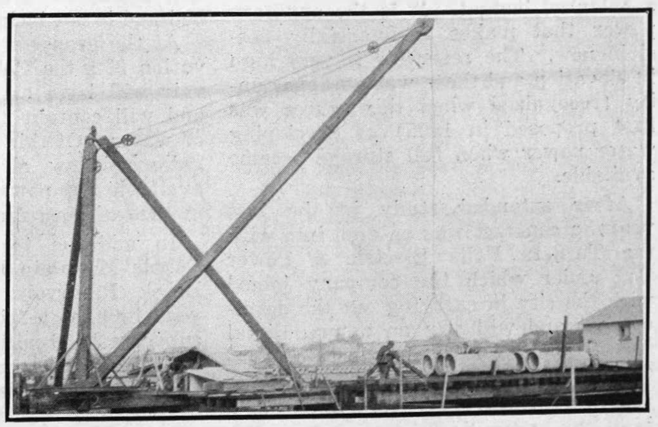
City's Powers Defined

Authority of a city to delegate administrative powers and authority for the enforcement of health regulations was sustained in a recent decision of the Ohio Supreme Court in the case of the State ex rel. George Moock, et al, vs. the City of Cincinnati, et al, on appeal from the Court of Appeals of Hamilton County, according to Ohio Health News of June 1. This was a case growing out of denial of a permit to Moock to collect garbage after a contract had been entered into with another contractor for garbage collection and disposal. The opinion was by Judge Jones. The syllabus follows:

The city of Cincinnati advertised for and received bids and entered into a contract with a single contractor who for a consideration paid by the city, engaged to collect and remove garbage therefrom in accordance with the city's specifications. A permit was thereupon issued to the city's contractor but denied to the relator who had contracts for garbage removal with various hospitals and restaurants in the city. This garbage, consisting of animal, vegetable and other products, had a commercial value, much of which being adaptable for the feeding of swine.

Held: Neither the city ordinance nor the refusal of the city manager to issue relator a permit for the collection and removal of garbage contravened any provision of the state or federal constitution.





Left—Lowering a Section of Pipe. The Planks Have Been Removed and the Pipe Is on Its Way Down. Right—The Sections of Pipe Were Carried from Oakland to San Rafael on Barges