serted in the feeder flue to exclude the cold air when the oven is open while coke is being drawn.

The general design of these flues is the result of the experience of the company at several of its plants. It has been found at these plants that the cost of maintenance of the flues is unexpectedly high, and the present design is expected to reduce this charge. The whole flue system is practically a combustion chamber, and the temperatures in the flues are very high.

Mine Buildings.—The mine buildings at the various plants have been made as nearly uniform as possible. The repair shop, boiler, engine and power houses are built of common, hard-burned brick laid in lime mortar tempered with cement. The roofs are all supported on steel Fink trusses designed to carry calculated concentrated loads on the lower chord, representing shafting, steam lines, and so forth, and in the engine house the hoisting drums. The latter provision is believed to be of considerable economy, owing to the difficulty in repair work of blocking up the drums and other parts of the hoisting apparatus, and the consequent loss due to longer shutting down of the plant during such repairs. The roofs are all covered with No. 1 ribbon Bangor slates nailed with copper nails and flashed with 16-oz. copper.

Boiler Houses.—The boiler houses have doors at each end large enough to admit a car for the removal of ashes produced from the occasional use of coal. A glazed door, forming part of a triple window effect, is opened to allow the larry to chute coal to the floor, the front wall of the house being proportioned as a retaining wall, carrying the fill, on which the larry track is laid 5 ft. above the boiler house floor. The floors are of 12x12x3-in. clay oven tile, laid on a 6-in. foundation of fine coke ash, the joints being grouted with cement mortar. The interiors are given two coats of white cold-water paint, which adds greatly to their appearance and improves the light.

Power Houses.—The power houses are similar to the boiler houses, except that the appearance of the interior is improved by making the roof sheathing of beaded yellow pine, nailed to yellow pine rafters, surfaced four sides, which are dapped over yellow pine stop chamfered purlines. All of this woodwork is treated with a good coat of grain alcohol shellac and one of Murphy's No. 1 spar varnish.

Repair Shops.—The repair shops are located close to the mine openings so as to be convenient for repairing mine cars, motors, tools and the like. The shops are each provided with a brick and concrete wheel pit, drill presses, fans and other apparatus, all of which is driven by motors hung from the roof trusses.

Stables.—The stables are of wood construction and are of two sizes. One accommodates twenty head of stock, the other thirty. They also contain box stalls, harness rooms and similar divisions. Instead of using wooden floors, as is generally the custom in the coke region, the floors are made of tile and brick, laid in the same manner as in the boiler houses. The stall floors are graded toward the backs, where they are drained by concrete gutters. As the tile is too hard for the stock to stand upon continuously, each stall has a top floor of 2x2-in. W. O. slats spaced ⅝ in. apart. These can be removed for cleaning. So far this floor has proven very satisfactory. It is also more sanitary than a wooden floor, since it is easily cleaned.

The second stories are used for storing feed and supplies. Hay tracks extend from end to end, and bins of three carloads' capacity are provided for oats. The stables are framed entirely of white oak, sided with yellow pine and roofed with slate. Each is provided with a detached saddlery shop, where harness repairs are made.

A corn crib of 1½ carloads' capacity and a wagon shed large enough to shelter the wagons and carts in use at the plants are near the stable.

Tenements.—There are four different classes of tenement houses at each of these plants. The lowest in the scale are double houses of four rooms to the side, 28 ft. front by 30 ft. deep, with front porches, 6x28 ft., and two rear porches per house, 6 ft. square. The stairs to the second story are in the kitchen and are not enclosed in the room above. The kitchen has a closet under the stairs. The houses in the next class are double houses of four rooms to the side, 32x30 ft., with porches the same size as the last described. The stairs are enclosed between the front and rear rooms, thus making each room private. Each room has a closet, a rather unusual feature in this class of tenements. The houses of the next class are exactly like those just described, with a kitchen addition in the rear. The highest class of dwellings consists of single houses of six rooms and bath each. They are provided with kitchen sinks, hot and cold water, electric light, spacious porches, cellars and similar conveniences.

The superintendents' houses are of nine rooms each, consisting of reception hall, parlor and dining room and kitchen on the first floor, and four bedrooms and bath on second floor. Each room has a spacious closet. The house is heated by a hot-air furnace and lighted by electricity.

All the houses are built on stone foundations, have hemlock framing, slate roofs and all except the last two mentioned, have yellow pine siding. They are all plastered with Colonial wall plaster, with a hard skim. They have yellow pine floors, bases, trim, chair rail and other trim. All woodwork usually painted is given three coats of white lead and linseed oil paint. The hearths are of concrete instead of the usual rough brick. All window and door openings are provided with weather strips. The last two houses mentioned above are sided with white pine and finished inside with "clear" yellow pine. The outside has three coats of paint, as above, the body being French gray, the trimmings cream white.

Water Systems.—Water is used to quench the coke in the ovens, about 1,000 gal. being required per oven per day. This is applied by hand, with a hose attached to a special "coke oven" valve on a 1-in. pipe riser at every second oven. These risers connect to a 4-in. main under the yard in front of the ovens, which draws its supply from a main line coming from a reservoir located on high ground nearby. These reservoirs are steel plate tanks of 500,000 capacity each at Collier, Phillips and Ronco, and 300,000 gal. at Dearth.

Outside hydrants are provided for the tenements. Water is also delivered to the two better classes of dwellings mentioned above; to the stables, the boiler houses and other buildings and to a system of fire plugs. In the stables connected hose reels are provided, and at a convenient point hose reels on wheels are stationed in small buildings erected for the purpose. Hose drying towers are also provided.

These plants have been designed under the immediate supervision of Mr. W. R. Elliott, construction engineer, and the buildings were designed by Mr. H. C. Frank, architect for the H. C. Frick Coke Company.

THE WATER SUPPLY of Rio de Janeiro, Brazil, is being increased from a present capacity of approximately 38,300,000 gal. a day to substantially 53,550,000 gal. a day by extensive improvements involving an expenditure of nearly $9,000,000. Rio de Janeiro is in a district similar to the District of Columbia, and the water supply is provided by the Federal Government. The present works include eleven separate stations, in the hills near the city. The additional supply is also to be obtained from these hills, which are controlled by the Government and insure a large quantity of water quite satisfactory for domestic purposes.

Operating Results of the Water Purification Plant at Ithaca, N. Y.

By E. M. Chamot, Ph. D., Asst. Professor of Sanitary Chemistry and Toxicology, Cornell University.

Continued requests for information relative to the results and operation of the mechanical filters installed at Ithaca, N. Y., as a result of the typhoid epidemic of 1903, have been made on the authorities in charge of the plant, but a combination of circumstances has heretofore prevented the publication of any data. Soon after placing the purification plant in service, the city of Ithaca acquired the entire water-works system under condemnation proceedings, following a vote for municipal ownership. During the litigation of many months which followed it was impossible to edit the data which had been collected. In the meantime the city had been developing a ground-water supply, on which work was first begun immediately following the typhoid epidemic. Before the hearing was closed the municipality found it possible to abandon the filters and supply ground water to all consumers. Moreover, part of the record books and all of the copies of reports were placed in evidence, and when the hearing closed, the return of these papers being refused and the filters being no longer in service, the task of recalculating all the results from the meagre data in note books seemed so discouragingly great that all thought of publication was abandoned. Persistent demands, however, from engineers and water analysts for data soon showed that it was necessary to attempt the recalculation of the lost data. As a further incentive the ground-water supply has proved inadequate and it has been found necessary to again place the filter plant in service. The data therefore no longer deals with an abandoned system, but one in actual service at the time of writing.

An extended account of the construction, with plans, of the Ithaca water purification plant appeared in The Engineering Record of Aug. 29, 1903, to which the reader is referred for details. The present article deals merely with the results obtained, and only a very brief résumé of the arrangement of the plant is therefore necessary.

The source of the water is a small stream locally known as Six Mile Creek, having a catchment area of about 50 square miles, with a population of about 40 persons per square mile. An impounding reservoir has been formed in the stream by a 30-ft. reinforced concrete dam constructed a little over a mile from the purification plant at a point where the stream bed forms a narrow gorge through the rocks. This dam backs up the water into an amphitheater, forming a pond of some twenty acres with a capacity of 72,000,000 gal. From the bottom of this reservoir the water flows through a 24-in. line to the pump house, whence it is raised by steam or water power to the purification plant through a 20-in. pipe.

The purification plant is the design of Mr. Allen Hazen, with the co-operation of Prof. Gardner S. Williams and the New York Continental Jewell Filtration Co. It consists of two coagulation basins arranged in parallel, each of 218,500 gal. capacity, when filled to the normal height for use; six rapid-sand filters of 500,000 gal. each and a pure-water basin of 500,000 gal. capacity.

The coagulant is dissolved in two tanks each holding 1,700 gal., whence it is raised to a small distributing or orifice tank through hard-rubber pipes by bronze centrifugal pumps run by Pelton water motors, the shafts of motors and pumps being coupled. The distributing tank consists of two sections, each with a separate discharge orifice; weirs at the center allow the excess of coagulant solution to flow back into the solution tank from which it is being pumped and at the same time maintain a constant head upon the discharge orifices. These orifices consist of hard-rubber plates with semi-circular slots, over the top of which play hard rubber disks, fastened to a vertical spindle provided with a graduated head. The coagulant is introduced into the raw water just after it enters the filter house; thus treated, the water flows through a vertical pipe provided with a sharp-edged circular weir 20-in. in diameter, set in the hub of the pipe. A horizontal 1-in. pipe is tapped into the vertical 20-in. pipe and is attached to a glass water-level gauge provided with a scale whose zero point is at the same elevation as the edge of the weir, thus enabling the filter attendants to learn the rate of pumping. The weir discharges into a mixing tank through a series of five baffles, and from the mixing tank the water passes into the coagulation basins through large gates. In the basins the water takes the course indicated by the arrows in the accompanying drawing, passing around the baffles and eventually reaching the influent tank in the filter house, whence it flows to the filters.

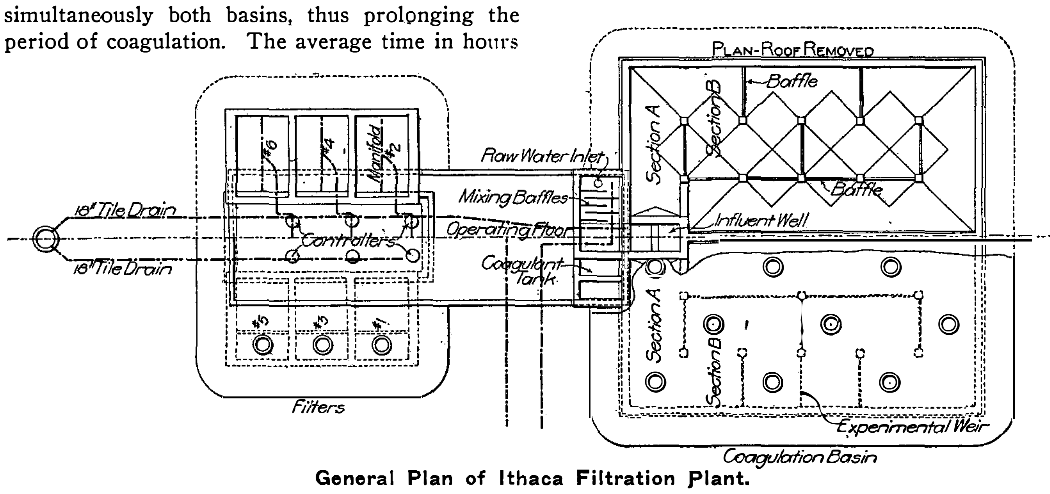
Coagulation Basins.—The coagulation basins are of reinforced concrete, covered and placed completely underground. Board baffles, arranged as shown in the illustration, serve to retard the flow of the coagulated water and to increase the deposition of sediment and sludge. As the result of many tests it was found best to always use simultaneously both basins, thus prolonging the period of coagulation. The average time in hours that the coagulated water remained in the basins before reaching the filters will be found in the fourth column of Table 1. The period could of course be varied by changing the number of filters in service or by using one basin or both basins.

Under normal conditions the best results were obtained when the basins were cleaned monthly. This was done by opening the waste gates of the basins and, after all the water had drained away, washing out the sludge by means of a fire hose. One basin was cleaned at a time, the work occupying three to five hours. Runs of even three months, however, can be made with excellent results unless a sudden change in the temperature of the entering water causes a rise in its density, when vertical convection currents result and the very fine sediment lying on the surface of the sludge is sure to be distributed throughout the whole basin. In such an event the bacterial content of the filter influent becomes higher than that of the raw water. In the control of the plant when the temperature of the raw water indicated a marked increase in density of the incoming raw water the filter influent was carefully watched, particularly when dealing with dirty basins. At the first appearance of an overturning, the filters were thrown out of commission and the basins run to waste until equilibrium had again been established, a matter of a very short time. This plan was found to be much more economical than attempting to handle unsatisfactory influents, and if not done the bacterial efficiency of the filters usually fell very rapidly.

During the freshets of Spring and Fall the quantity of sediment removed daily by the coagulation basins is very large. It has reached as high as 35 tons per twenty-four hours, calculated from determinations of the total solids in suspension in the raw water.

By far the greatest quantity of sediment is deposited near the entrance to the basins, in the sections marked Sections A and B in the drawing. If we call the quantity of sediment deposited at the outlet of the basins, where they discharge into the influent tank, one, then the quantity of sediment deposited in Section B appears to be at least six to ten times as great. This estimate is based upon measurements taken each time the basins were cleaned. Because of the relatively greater deposition in Section B, the experiment was tried of still further slowing down the flow of the water by placing a weir between piers in the south basin as shown by the dotted line in the figure. The two basins were run thus for many months and the results compared, but the increase in the amount of sludge deposited was so slight as to be practically negligible.

The monthly averages of the bacteria per cubic centimeter remaining in the water after subsidence are given in Table 1. The high counts of January, March and May show the result of running the basins without monthly cleaning. That the efficiency of the basins may be made very high is readily seen by comparing the average bacterial content of the raw water as given in Table 2, with that of the influent in the corresponding months. The plant was not considered to be doing good work unless the basins were removing at least from 80 to 90 per cent. of the bacteria.



General Plan of Ithaca Filtration Plant.

TABLE 1.—GRAINS PER GALLON COAGULANT USED.

	Average	Maximum.	Minimum.	Avg. Period in Coag. Basin.	Avg. Bact. per CC. in Filter Influent.
1903					
October	2.20	8.0	1.00	6.1	680
November ..	1.60	4.5	0.90	6.5	960
December ...	1.10	1.2	1.00	6.2	870
1904					
January	1.20	3.0	0.60	6.3	1900
February	1.25	3.0	0.75	5.4	500
March	1.75	4.0	0.50	5.4	3300
April	1.45	3.6	0.90	5.1	690
May	1.10	2.5	0.70	6.5	1300
June	1.60	3.0	0.75	6.3	630
July	1.60	2.2	0.95	6.6	220
August	2.00	3.3	1.20	6.1	164
September ...	1.40	3.6	1.05	6.1	129
October	1.46	2.7	1.00	6.6	430
November ...	1.33	1.9	1.20	6.6	330
December ...	1.39	2.6	1.10	6.5	400
1905					
January	0.92	1.10	0.70	—	315
February	1.20	1.90	1.05	—	195
March	1.74	3.7	1.05	—	990
April	1.44	1.9	1.05	—	285
May	1.07	1.4	0.95	24.0	175
June	1.73	2.8	0.95	24.0	470
July	2.58	9.0	1.40	13.4	785
August	1.78	2.5	1.30	15.5	175
September ...	2.03	4.3	1.20	16.3	115
October	2.73	6.4	0.90	13.6	295
November ...	1.20	2.7	0.70	13.0	325
December ...	2.80	4.5	1.30	20.0	540
Average ..	1.60	9.0	0.50	—	635

The quantity of coagulant used is also given in Table 1. It was rarely possible to reduce the rate to less than 1 gr. per gallon, while as high as 8 to 10 gr. per gallon has been found necessary for a few hours at a time to properly handle turbidities ranging from 2,500 to 4,500. If these few exceptionally high quantities are excluded in the averaging it is found that the average amount of coagulant used is approximately 1.3 gr. per gallon. Rates as low as the minimum, 0.5 grain per gallon, could never be maintained for more than a few hours at a time.

The coagulant employed has always been basic aluminum sulphate, "Filter Alum," having an average content of about 17 per cent. of water soluble alumina. The coagulant solution is prepared by placing a weighed quantity in a loose-bottomed box at the top of the rectangular, concrete dissolving tanks, allowing filtered water to slowly flow through until the tank is filled and the undissolved "alum" completely submerged. A current of compressed air forced into one corner of the tank, assures complete mixing. When the plant was first placed in commission solutions of definite percentage strengths were employed, and this system was adhered to, the amount of coagulant added in grains per gallon being calculated from curves, plotted for the number of filters in service. Under normal conditions the coagulant was made so as to contain 3 per cent. of the filter alum as weighed out; but during periods of high turbidity solutions of 6 per cent. were employed. In order to learn if possible the most convenient and effective strength, under the conditions which obtained at this plant, runs were made at different seasons and under variable conditions with solution strengths of 1, 2, 3, 4, 6, 8 and 10 per cent. The most satisfactory results appeared to follow the use of solutions of 3 per cent. This strength was therefore adopted by the writer in all of the subsequent working of the plant. When dealing with high turbidities, however, the necessity of applying large quantities of coagulant caused such a rapid consumption of the coagulant solution that a tank would be emptied before a fresh supply could be prepared. It was necessary therefore to make use of much stronger solutions, usually 5 per cent. or 6 per cent. As soon, however, as the turbidity began to fall, the solutions in the tanks were again diluted to 3 per cent.

The power of the coagulant to rapidly clarify the water and yield a satisfactory filter influent seemed to be dependent at times on the character of the precipitate of aluminum hydroxide formed. During very cold weather and moderately clear water, the decomposition of the aluminum sulphate was very slow, the resulting precipitate separated in very fine flocs, and refused to agglutinate and settle in the basins, thus throwing more work upon the filters and causing more frequent washing and an increased percentage waste through wash water. In no case was this change due to a deficiency of alkalinity, nor was it possible to cause any appreciable change by the application of lime, soda ash or ammoniacal liquors, but the introduction of muddy water (obtained by stirring clay in water) to the raw water just after the application of the coagulant would almost invariably start agglutination of the particles, this once started curiously enough would rapidly spread throughout the entire coagulation basin. Rarely this phenomenon of the change, from a slowly subsiding very finely divided precipitate to a large, flocculent, rapidly subsiding one, would start spontaneously. In practice, as soon as the fine difficulty handled precipitate appeared, the filters were thrown out of commission, the influent run to waste and a few parts of muddy water added; the reaction once properly started, the plant was placed in service under normal conditions. Another interesting fact which is probably pure chance is that our records show that the best coagulation took place when the raw water stood at about 8° Cent.

Some difficulty was at first experienced in properly checking the accuracy and care of the filter house attendants in the making up of the coagulant of proper percentage strength. It is, of course, obvious that failure to weigh out the proper amount or the filling of the dissolving tanks to overflowing would materially change the figures expressing the quantity applied in grains per gallon, and it was evident that such checking was imperative, since in a number of instances, the calculations did not accord with the character of the water. The plan finally adopted consisted of taking the specific gravity of the solution in the orifice tank. A large number of samples of filter alums of the type used in the plant were taken and careful determinations were made of the density of solutions of known percentage strength. From the results a curve showing the relation between percentage strength and specific gravity was plotted. A small hydrometer (of such a size as easily to be carried in the pocket) was then constructed with a scale from 1.00 to 1.06 specific gravity at 22° Cent. The corresponding percentages could then be etched upon the stem and it became merely necessary to immerse the hydrometer in the discharge tank or a sample taken from it to learn whether the solution was of the strength recorded in the day-book.

The amount of coagulant to be applied was determined in the usual manner by inspection of the amount, character and rapidity of formation and rapidity of settling of the flocs of aluminum hydroxide. For this purpose, samples of the raw water, immediately after the application of the coagulant, were taken at intervals in tall beakers or glasses and set aside for ten to fifteen minutes. With the waters of the character treated it was found easy to estimate the proper quantity of coagulant within a few tenths of a grain per gallon. A curve was also plotted with grains per gallon as ordinates and turbidities as abcissas according to the data from the best results obtained, to serve as a guide in estimating the proper quantity of coagulant for any given turbidity when both sedimentation basins were in service. The results given by this curve were found reliable for all save very low or very high turbidities. In most cases the addition of a trifle too much coagulant proved more objectionable than too little; the number of bacteria in the effluent increased more rapidly, the filters clogged faster and the amount of wash water required was greatly increased. The alkalinity of the raw water was at all times more than sufficient to take care of the coagulant required and at no time could undecomposed aluminum sulphate be detected in the filter effluents or filter influents, save in the case of experimental runs made with the view of learning the results of over-coagulation on filters and effluents. A number of attempts were made to learn the reduction in alkalinity due to the addition of exactly one grain per gallon, with a view of checking in this way the hourly records kept by the filter attendants. To our surprise this reduction appeared to be a variable quantity, the decomposition of the aluminum sulphate being dependent upon other conditions than alkalinity alone.

The Raw Water.—Six Mile Creek is a torrential stream due to a run off exceptionally rapid; as a result the water is "catchy" to a remarkable degree. The character of the water is well shown by the analyses summarized in Tables 2 and 3. In Table 2 turbidities are expressed in terms of the silica standard; colors, in terms of the platinum cobalt standard, using the U. S. Geological Survey tubes and standard glasses; alkalinities are given as parts per million of calcium carbonate, and the bacteria as colonies per cubic centimeter on standard + 10 gelatine incubated at 20° Cent. for 48 hours. In Table 3 all results are expressed in parts per million.

During periods of drought or light rains the turbidity is very low, the bacterial content also low, the alkalinity relatively high, and fecal and putrefactive organisms are absent and the water is doubtless potable. A moderate rain, however, gives an almost immediate wash of road sides, dairy farms and several small villages; the turbidity rises with astonishing rapidity usually accompanied by a corresponding rise in bacterial counts, fecal and putrefactive organisms appear and the water becomes unsafe for household use. The turbidity of this stream ranges from none to over 4,000, the rising being very rapid and the fall almost equally so.

TABLE 2. Raw Water From Six-Mile Creek.

Date.	Bacteria per cc. Avg.	Max.	Min.	Turbidity. Avg.	Max.	Min.	Color. Avg.	Max.	Min.	Alkalinity. Avg.	Max.	Min.
1903												
Oct.	7,220	36,000	850	80	1800	Trace	45	128	3	81	134	45
Nov.	5,460	23,000	800	31	160	1	63	160	18	82	93	60
Dec.	2,900	8,600	900	8	35	1	33	85	14	89	98	80
1904												
Jan.	6,200	520,000	1000	13	2500	5	14	40	10	76	100	45
Feb.	13,400	97,000	1500	46	400	6	11	24	4	72	85	35
Mar.	28,600	115,000	2500	220	3000	5	13	24	5	57	88	40
Apr.	7,330	50,500	1500	104	400	40	11	20	5	54	68	38
May	7,300	35,000	450	40	500	10	13	24	5	72	95	55
June	7,500	62,000	450	47	250	7	15	34	5	94	125	60
July	1,050	6,500	350	57	95	28	9	27	3	127	130	120
Aug.	2,400	18,000	400	76	200	45	20	45	1	127	140	110
Sept.	1,200	2,800	500	57	80	18	9	20	3	131	140	125
Oct.	3,100	15,000	250	15	70	5	30	118	9	117	150	75
Nov.	1,600	3,000	350	3	8	1	18	30	10	107	115	95
Dec.	3,160	20,500	125	18	200	2	15	35	10	105	130	45
1905												
Jan.	3,600	12,000	150	25	93	4	11	18	5	70	85	45
Feb.	1,000	7,900	190	10	30	2	8	20	2	103	115	90
Mar.	30,000	175,000	550	125	1200	6	23	72	5	74	115	20
Apr.	4,380	20,500	400	37	110	8	19	45	8	57	70	45
May	1,600	3,000	500	16	25	5	9	25	4	96	110	75
June	4,840	20,000	500	54	200	13	23	90	5	96	125	70
July	7,200	36,000	1000	170	1000	22	26	65	6	128	180	95
Aug.	1,480	3,500	450	37	157	8	13	25	8	151	175	125
Sept.	16,740	180,000	220	110	500	6	10	20	3	123	150	97
Oct.	12,250	73,000	1200	316	1500	35	23	65	9	112	160	85
Nov.	4,340	49,000	250	76	260	3	23	60	10	112	127	100
Dec.	8,220	26,000	1500	174	300	100	18	20	10	93	110	76
For 27 mos.	7,150	520,000	220	72	3,000	Trace	20	160	1	96	180	20

TABLE 3.

Averages of Partial Analyses of Water from Six-Mile Creek.

	Parts per million.
Nitrogen as free ammonia	0.019
Nitrogen as albuminoid ammonia	0.065
Nitrogen as nitrites	Trace.
Nitrogen at nitrates	1.170
Oxygen consumed	1.710
Chlorine	3.200

Frequently the turbidity rises from less than 100 to over 3,000 in less than five hours. The maximum turbidity usually persists for a few hours only, often one hour or less, it then falls gradually for a few hours, after which the fall is apt to be very rapid. A coefficient of fineness greater than unity has not yet been observed.

These waters are most interesting to handle owing to their sudden and complete change in character. The setting in of a heavy shower is marked at first by a gradual rise in the turbidity of the raw water as it enters the filter house; should the storm prove to be a violent one, there is, in about two hours, a sudden and striking clearing up of the entering water, followed in less than an hour by great and rapidly increasing turbidity. It would appear that the first rush of the run off carries into the impounding reservoir weathered clay which acts as a coagulant. The appearance and character of the water at such times seems to justify such a hypothesis. This well marked period of lowering in turbidity before a very sudden rise was so constant that it became a matter of custom to watch for it so as to learn whether an increase in the quantity of coagulant would be necessary.

The most difficult waters to treat in a satisfactory manner have invariably been those after a sudden drop in temperature following a thaw in winter and spring. Under these conditions coagulation usually is slow and the resulting flocs exceedingly finely divided. Sometimes, as already stated above, it has been almost impossible to start the reaction. Should a heavy shower be followed by a second shower the turbidity of the water rises to a value higher than before, but the bacterial content is, as might be expected, much lower than the water resulting from the first run-off. On the other hand a storm giving rise to a slow run-off followed by a heavy shower will first give a high turbidity and high bacterial count followed by a bacterial count considerably higher than that in the more turbid water. As representative examples of the character of the water and the working of the plant under these conditions the following cases may be cited:

	Raw Water. Turbidity.	Bacteria.	Coagulated Water. Bacteria.	Per cent Bact. removed.	Filtered Water. Bacteria.	Per cent Effic. of Plant.
Mar. 23	140	65,000	1,200	98.1	12	99.98
Mar. 24	500	175,000	1,200	99.3	45	99.97
Mar. 25	1,200	56,000	500	99.1	14	99.97
Mar. 27	200	21,600	800	96.3	45	99.79
Oct. 2	35	4,500	30	99.3	6	99.93
Oct. 3	1,200	14,500	450	96.6	12	99.91
Oct. 4	500	73,000	1,080	98.5	90	99.88
Oct. 5	200	2,000	725	63.7	65	96.75
Oct. 7	77	10,500	450	95.7	40	99.52

Filters.—The filters are rectangular concrete tanks, 11 by 17 ft., with a sand surface 11 by 16 ft., equivalent to 0.004 acre and planned to yield at the rate of 131,000,000 gal. per acre per day. The under drains consist of a 6-in. leader 16 ft. long, in the center line, tapped on both sides at intervals of 6.14 in. by latterals of 1½-in. wrought-iron pipe. Each latteral carries 11 Continental strainers, 5.9 in. center to center, with the end strainers 3 in. from the tank walls. Each filter therefore has 682 of these brass strainers. The concrete in which the under drains are imbedded is laid up to the shoulder or flange of the strainers. Above the strainers are placed 7 in. of graded gravel ranging from 1/12 in. to ¼ in. The sand bed consists of 30 in. of sand from Felts Mills, N. Y. This sand, which has been neither sized nor screened, has an effective size of 0.39 mm., and a uniformity coefficient of 1.50. The under drains discharge through Weston controllers having a rate of 525,000 gal. per twenty-four hours. These controllers have proved satisfactory and repeated measurements have shown that their constant is substantially correct. However, the fact that their discharge is a fixed quantity has frequently proved uneconomical since three filters in service would at times cause a constant flow of the pure water basin, while only two in service would prove insufficient to supply the immediate needs. The controller of each filter is connected with a Jewell loss-of-head gauge provided with electric bell and contacts so arranged as to ring automatically when the loss-of-head of the filter reaches 9 ft., the point set for the washing of the filters.

In the washing of the filters it was found, after experimental runs extending over a period of several months, that the best results were obtained by first slowly turning on the wash water so as to lift the film of deposit lying chiefly upon the surface of the sand, and float this material off; then increase the force of the wash water to its full power. As soon as the filter showed signs of clearing, the wash water was turned off and compressed air turned on at a pressure of 3 to 5 lb. for three minutes under normal conditions, but occasionally for five minutes. After closing the air valve, washing with water was again practiced until the sand bed could easily be seen and the wash water flowing in the gutters was substantially clear. The average time required for the clearing of the filters by wash water was about seven minutes. No effort was made for many months to economize in the wash water, the only orders being "wash until the filter is as clean as it can be made." The figures for wash water used, as given in the table, are therefore maximum values.

When the air was applied first, the amount of wash water required for satisfactory cleaning was almost invariably greatly increased and the bacteriological efficiency of a filter thus washed was subsequently uniformly lower than by the method of first applying wash water, due probably to the fact that the bacteria removed by the upper layers of the filter were distributed throughout the sand bed and gravel.

The usual practice has been to place the filters on one side in service for a week, then shift to the other side; that is, filters 1, 3 and 5 would be in service while 2, 4 and 6 were lying idle, and vice versa. For several months the shifts from one set of filters to the other set, were always made on Sunday mornings, irrespective of the loss-of-head. This was done in order that certain data might be obtained and also to permit of supervising the washing. After it was found that the filter house attendants were sufficiently skilled and careful, the practice of shifting only when the filter showed a loss-of-head of 9 ft. was adopted as the normal method of procedure. Thus it happens that the percentages of wash water used, as given in Table 4, are, for the first six months, somewhat greater than that actually required.

TABLE 4. OPERATING RESULTS, ITHACA FILTERS.
MONTHLY AVERAGES OF ALL FILTERS.

	Avg. per cent. bacteria removed by all filters	Avg. bacteria per c.c. in filter effluents	Avg. quant. water filtered daily, per filter	Avg. per cent. wash water used	Avg. per cent. total waste	Avg. hours run between washings per filter	Average quantity water filtered daily in thousand gallons
1903—							
October...	99.8	26	458.2	3.2	3.6	17.1	1,550.0
November.	99.5	19	433.0	3.7	4.4	21.8	1,532.2
December.	98.9	37	452.9	3.3	4.1	19.8	1,501.6
1904—							
January...	98.1	112	427.5	3.9	4.3	22.4	1,586.6
February..	97.9	168	424.9	4.0	4.8	18.3	1,795.7
March....	99.1	153	386.1	4.3	5.4	18.7	1,815.2
April.....	99.0	34	417.9	4.1	4.8	21.2	1,556.1
May......	98.3	50	446.7	3.4	4.0	22.4	1,621.2
June......	98.7	22	406.1	3.3	3.8	26.4	1,658.7
July......	96.7	30	414.0	2.7	3.3	23.7	1,582.2
August....	97.8	24	421.0	2.7	3.3	21.2	1,681.8
September.	97.9	20	373.8	4.7	5.6	12.3	1,674.5
October...	98.3	33	430.4	2.6	3.6	20.2	1,580.2
November.	97.8	32	450.9	2.6	3.0	24.6	1,553.3
December.	97.8	27	428.9	2.9	3.4	23.5	1,618.3
1905—							
January...	98.8	28	236.9	3.9	5.3	28.4	606.0
February..	99.0	7	271.0	2.3	3.6	24.4	636.7
March....	98.9	53	192.6	3.9	4.7	35.6	588.1
April.....	99.4	10	193.5	5.3	6.2		489.2
May......	99.3	11	200.7	3.5	4.4		490.9
June......	99.1	35	248.4	3.4	4.3	36.0?	571.5
July......	98.3	64	284.8	2.3	3.5	37.5	736.2
August....	96.5	42	310.8	2.0	2.7	63.3	650.7
September.	99.1	5	349.4	1.2	1.6	64.1	637.9
October...	99.4	22	288.6	1.8	2.2	46.5	689.6
November.	98.8	18	287.2	2.0	2.3	38.6	735.5
December.	98.6	56	217.6				470.9

In order to learn whether the use of air in washing was essential or desirable in this plant and with waters of the type of Six Mile Creek, no air was used during the first fifteen months in the washing of either filter 3 or filter 4. At intervals the sand beds of these filters were drained and the sand removed down to the strainers for examination. At no time was there any discoloration of the sand or formation of "mud balls" or of masses of vegetable matter. No difference in the appearance or character of the sand beds as compared with the air treated beds could be detected. During this period a very noticeably less amount of wash water was required for the proper cleaning of these two filters; their bacterial efficiency was not at all impaired (as a matter of fact, their efficiencies average about one-tenth of one per cent. higher) and the average run between washings was noticeably longer. During the last six and one-half months of service, covered by Table 4, no air was used in the washing of any of the six filters owing to the fact that the power house was damaged by a June freshet and the air compressor placed out of commission. The absence of all "mud balls" and discoloration, in spite of the fact that the raw water contains, when the turbidity is high, much blue clay and dead leaves in suspension, is doubtless due to the fact that there is a moderately long period of subsidence in the coagulating basins.

As stated above, the normal method of procedure for the greater part of the first year was to keep all even or all odd numbered filters in service for a week at a time. During this period as soon as the loss-of-head of any filter of the series in service reached 9 ft., the filter was washed and again placed in service at once.

Upon studying the efficiency of the filters it was found after some months that the effluents gave high bacterial counts immediately after the filters were washed, after an influent high in bacteria, although until the filter was washed, the bacteria in the effluent were few in number. It seemed probable, therefore, that the bacteria were not passing through the sand bed, but that during the washing the bacteria penetrated to the lower parts of the bed and into the gravel between the strainers, then when the filter was again placed in service they would slowly be forced into the under drains and thus into the effluent. These high counts in such effluents would often persist for several days and would be out of all proportion to the number of bacteria in the constantly improving influent.

It was also noticed that a filter which had been lying idle and was placed in service to handle a poor influent gave a much higher efficiency than one which had been in service with such influents, washed and again placed in service. It was evident that an entirely new system should be tried and compared very carefully with the older one. As a result of this study, whenever the raw water gave a very high turbidity and corresponding high bacterial count, and the influent would in all likelihood also soon increase in bacterial content, all filters washed were allowed to stand idle for at least one day after washing, and when possible two or even three days were allowed to elapse before again placing them in service. The results more than met our expectations. Many experimental runs were again made to learn whether such a system was always desirable. These experiments gave substantially agreeing results, in that the bacterial efficiencies were better if a very dirty filter was allowed to stand idle for twenty-four hours or more after washing, instead of being again placed at once in service. This practice was therefore followed during the last months covered in the table. When dealing with waters of average bacterial count and turbidity there appeared to be no gain in efficiency by this system, while on the other hand there was of course an increased waste due to the necessity of a longer period of rewash necessitated because of placing in service a filter which had been standing idle for some time.

During the first few months of service the time for filtering to waste (rewash) following washing was set at five minutes. After tests showed that the maximum efficiency appeared to be reached by filtering to waste for a period between one and two minutes, the plan of filtering to waste three minutes was adopted. When, however, a filter had been standing idle for several days after washing, the period of filtering to waste for from ten to fifteen minutes was always adopted, in order that all the water in the bed should be completely displaced before discharging the effluent into the pure water basin. In the summer months this was essential to prevent a bad odor or taste due to the growth of algae in the filters not in service.

There were times when it was found necessary to place a filter in service for from eight to twelve hours a day only. The question therefore arose as to whether it was necessary to wash such a filter before again placing it in service or whether, on the other hand, the filter could be used intermittently until a loss-of-head of 9 ft. was reached, as under normal conditions for washing. Experimental runs were therefore made, from which it was learned that unless the period of subsidence in the coagulating basin was 10 hr. or more the bacteria in the filter effluents rapidly rose in numbers, from day to day, e. g., with a clean filter, Mar. 8, the effluent contained 9 bacteria per cubic centimeter, idle 12 hr. and again in service, 50 bacteria per cubic centimeter, idle for another 12 hr. and again in service, 135 per cubic centimeter, then 215 next day. Washing appeared to be essential to high efficiencies under these conditions. When, however, the period in the coagulating basin could be prolonged to 10 hr. or more, very different results were obtained, for under these conditions a filter could be successfully operated intermittently without washing until the normal loss of head was reached. With care a filter could be made to filter water for even 90 hr. before reaching a loss of head of 9 ft. In computing these runs between washings, the period is not included during which a filter was lying idle and not actually filtering water. The omission of the data for hours of service between washings for the months of April and May, 1905, is necessitated because of the impossibility of obtaining the return of one of the record books loaned during the litigation already referred to.

The shortest runs between washings occurred in September, 1904, due to a remarkable growth of an unidentified species of organism. In the last week of August it was noticed that the filters clogged rapidly and that the aluminum hydroxide appeared in the filter influents in large flakes. An examination of these flakes of hydroxide showed that they consisted of a mass of colorless filaments of an organism resembling Crenothrix. Day by day this organism multipled in the coagulation basins and in the influent pipes. Any change in the rate of flow would dislodge at times felted masses as large as one's hand, the period of run between washings became shorter and shorter until within less than three weeks the filters would clog so as to give a loss of head of 9 ft. in a little over an hour or less, the initial loss of head being a little less than 3 ft. When washed the filters presented a most interesting sight, for as the wash water rose through the sand, the felted mass collected on the surface of the sand bed rose in an unbroken sheet until the gutters were reached when it would become torn into huge pieces and float away. One to three minutes was sufficient to clean a filter and the amount of water wasted was therefore not large considering the number of filters washed. For three days the plant was sorely tried, then the development of the organism appeared to be suddenly checked, and in about a week the filters were again working under normal conditions. No attempt was made to destroy the organism, as it was thought desirable to learn whether it would persist or would disappear as rapidly as it had come, and the information obtained would doubtless prove of value in the future operating of the plant. It was also thought desirable to learn the possibilities of the plant under such adverse and abnormal conditions. Had the conditions become critical it was only necessary to empty and clean the coagulation basins, since it was here that the growth took place, the impounding reservoir in the creek showing no such growth. In spite of the strain placed on the filters, owing to the rapid clogging, their bacterial efficiencies remained satisfactory, the average number of colonies in the effluents being 20, the efficiencies calculated in per cent. are low (97.9 per cent.), owing to the fact that, as will be seen in Table 2, the number of colonies in the raw water was below the average, there being a period of drought. The organism has not again apeared, although a watch has been maintained in the hope that its positive identification would be possible.

The filters have given results that more than met our expectations; during only January, February and March, 1903, have the effluents averaged over 100 bacteria per cubic centimeter, and here the high counts were the result of an insufficient knowledge of the conditions affecting the plant. Abnormally cold weather, below zero for days at a time, caught us with dirty basins and snow and ice so thick on the manholes that attempts to open them were abandoned. During a period of several hours, while shut down for freeing ice from a race way and pumps at the pump house, ice formed in the coagulation basins, and short circuits were established over the surface. The period of subsidence was thus greatly shortened, with the inevitable result of throwing too much work on the filters. The true cause of the high bacterial counts was not discovered until the arrival of sufficiently moderate weather in March allowed the inspection and cleaning of the coagulation basins and revealed ice 8 and 10 in. thick. In conclusion it may be pointed out that the average efficiencies of the filters during the entire period of the service was over 98 per cent. and that if we exclude from our averages such periods, where the number of bacteria in the raw water falls below 1000 per cubic centimeter, the average efficiencies will be over 99 per cent. The removal of turbidity has been complete and the color has also been substantially completely removed, no more than a trace having been found. The per cent. of wash water and of total waste has been also very satisfactory.

Only a few chemical analyses of both raw and filtered water were made; in these the removal by the purification plant was as follows: N. as free ammonia removed, 50 to 60 per cent.; N. as albuminoid ammonia removed, 50 to 60 per cent.; N. as nitrates removed, 0; oxygen consumed removed, 50 to 70 per cent.; chlorine, increased to about 5 per cent.; total hardness removed, 1 to 3 per cent.; alkalinity removed, 3 to 25 per cent.

There remains only to record the improvement in the health of the community due to the introduction of a safe and clean water supply.

In the records kept by the City Clerk it appears that the deaths in the city of Ithaca have been as shown in the table presented herewith.

In explanation of the summary of deaths from water-borne diseases, it should be said that typhoid, all diarrhœal diseases and cholera infantum have been included; although doubtless the latter is probably almost wholly borne by the milk supply.

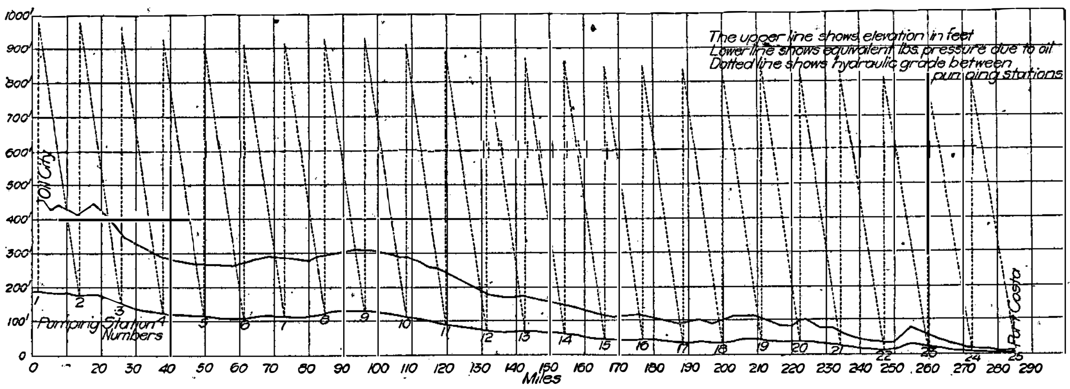
	Avg. for 5 years 1898-1902.	Typhoid year 1903.	Avg. for 3 years 1904-1906 Improved Supply.
Total deaths from all causes..	203	269	184
Deaths of infants under five years	32	32	27
Deaths from diseases which might be directly or indirectly attributable to water supply	15	62	9

Presumably, therefore, the introduction of a clean water supply has been followed by a very material reduction in the death rate of the community.

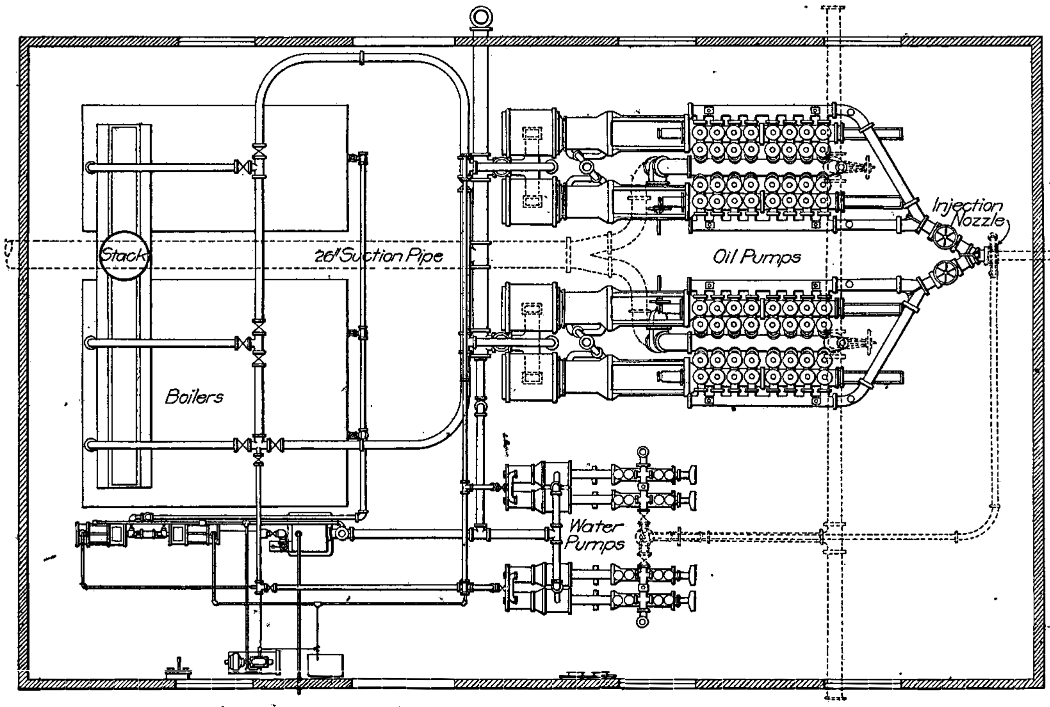
The city of Ithaca has a population of between 14,000 and 15,000. In the typhoid epidemic of 1903 there were 1,350 cases and 85 deaths known to have resulted from an infected water supply. The writer estimates the loss to the community to have been not less than $900,000.

A Long Rifled-Pipe Line for Pumping Heavy Oils.

The construction for the Associated Pipe Line Co., of San Francisco, of an 8-in. rifle-pipe line extending from the Kern River oil fields in California to tide water, with a total length of 282 miles, is now approaching completion. A section of this line 31.17 miles long from Volcan, a station on the Southern Pacific R. R. in the central part of those oil fields, to Delano, another station to the north on the same railroad, was placed in operation about two years ago. Based on the satisfactory results obtained in operating this section, the construction of the remainder of the present line from Delano to Porta Costa, the latter being on an arm of San Francisco Bay, was started in September, last, and will be ready to be put into service during the coming summer.

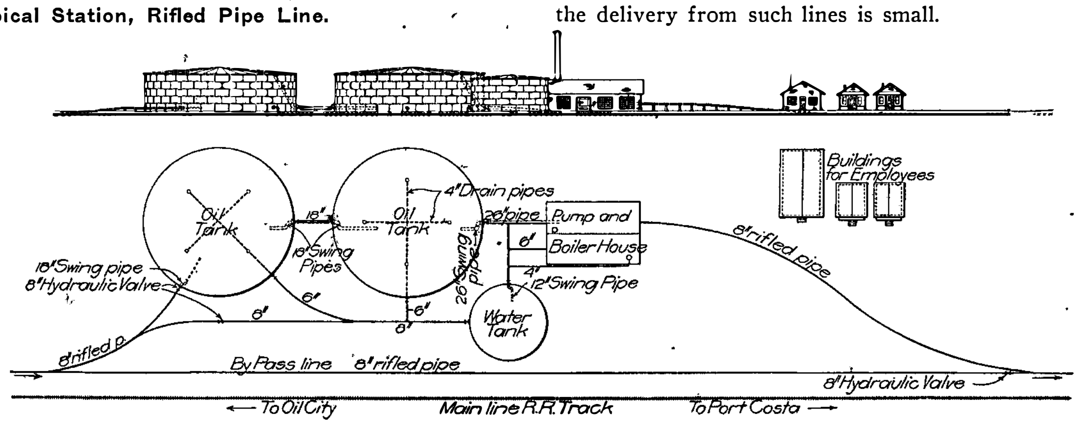


Profile of Rifled Pipe Line for Pumping Heavy Oils.



Plan of Pump House of a Typical Station, Rifled Pipe Line.

The oil from practically all of the California fields is a thick, heavy, viscous fluid, with an asphalt base, the output from the Kern River fields being particularly heavy, with a density averaging about 14 deg. Baume. The oil from these fields is so dense, in fact, that until recently it has been transported almost entirely in tank cars. Various attempts to handle it in long pipe lines of the ordinary type have been made, however, but these lines have not been practically successful for various reasons. In the first place, very high pumping pressures are required to push the heavy oil through such lines, resulting in large expense for pipe and for pumping equipment. Even when these high pressures are used under the most favorable operating circumstances the delivery from such lines is small.



Arrangement of a Typical One of Twenty-three Pumping Stations.

Of the numerous means devised to overcome the difficulties of operating the pipe lines which have been built, the most successful has been to heat the oil. The heated oil flows much more readily than oil at normal temperatures, but so much heat must be applied, to render the process sufficiently effective to permit the location of pumping stations at practical distances apart as to cause a portion of the asphalt base to be deposited, with a consequent stoppage of the line. In some cases water is also added to the crude oil, in order to thin the latter. Since nearly 30 per cent. of water is required to produce good