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MOUNT PROSPECT LABORATORY.*

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THE practical value of the sciences in our modern civilization is strikingly attested by the increase in the number of laboratories connected with various departments of nation, state and municipality. This is emphatically true in the domain of sanitary science, where the advances in chemistry, microscopy and bacteriology have wrought revolutionary changes. With the knowledge that many diseases are caused by living organisms and that some of them are transmitted by water came the need of more careful supervision of public water supplies, which resulted in the establishment of laboratories devoted to water analysis. The pioneer work of the Massachusetts State Board of Health has been followed by the installation of laboratories in most of our large American cities. In many instances these are operated in connection with the departments of health, but in Boston, Lynn, Louisville, Cincinnati, Pittsburgh, Albany, Washington, Philadelphia and elsewhere, laboratories have been organized in connection with the departments of water supply, either for the purpose of experimental work or because the character of the water supply was such that proper management depended upon analytical as well as engineering data. Departments of water supply should be justly held responsible for the quality as well as the quantity of the water supplied to the public. This involves a constant knowledge of the sanitary condition of the water, which can be obtained only by frequent analysis and inspection.

The complicated character of the water supply of Brooklyn made the need of a laboratory apparent to the department of water supply several years ago, but it was not until 1897 that an appropriation for the purpose was obtained. In May of that year the writer was appointed Biologist and Director of the Laboratory and instructed by Mr. I. M. DeVarona, engineer of water supply, to prepare plans for the installation and equipment of a complete chemical and biological laboratory. Mount Prospect Reservoir, near the entrance to Prospect Park, was selected as the most available site, and the gate-house of the reservoir was found to have ample accommodations. Contracts were let during the summer, and the laboratory was in complete operation on the first of October, though regular microscopic examinations of the water were begun early in July.

Mount Prospect laboratory has a fortunate location. It is conveniently near the Long Island depot, where the samples from the watershed are received; Ridgewood Reservoir, the chief distribution reservoir; and the office of the department of the Municipal Building. Its isolation and elevation make it comparatively free from noise and dust, while the building is well lighted by large windows, heated by hot water, provided with

gas, electricity and telephone. The upper portion of the building contains three rooms, besides the keeper's office and a corridor from which visitors may ascend to an observatory on the roof. The three rooms are known as the General Laboratory or Preparation Room, the Biological Laboratory, and the Chemical Laboratory. In the basement are the Physical Laboratory, the General Store Room and the Furnace Room.

The General Laboratory is devoted to the shipment of bottles and reception of samples, the washing of glass-ware, the sterilization of apparatus, the preparation of culture media, and to such chemical operations as might charge the air with ammonia and the fumes of strong acids. The room contains a well ventilated

water that are being analyzed; three work tables; two work shelves with windows in front; a weighing room, with balance in front of window and with a wide desiccator shelf and a drying closet; a hood, under which are two steam baths; a battery of twelve stills for ammonia distillations; a still for obtaining redistilled water; an apparatus for gas analysis; a battery of twelve Sedgwick-Rafter filters used in the microscopical examination of water; an apparatus case; a case for chemicals; a Richards pump; and various pieces of specially designed apparatus that facilitate the work of analysis. The room also contains a combustion furnace and a Mahler bomb calorimeter for the analysis of coal and the determination of its heating power. A storage room opens from the chemical laboratory, and there is a small dark room under the stairs. The three laboratories have marble tiled floors, and the work tables and shelves are covered with white tiles throughout. The partitions between the rooms are largely of glass.

The physical laboratory in the basement is not fully completed. At present it contains a crusher, a coal sampler, sieves for sand analysis, and a cement testing machine with its accessories. Much of the room is devoted to storage and to shop work.

The laboratory force consists of one biologist and director, one chemist, one assistant chemist, and three assistants.

The work of the laboratory may be divided into three parts: Water analyses, miscellaneous analyses and experimental work.

WATER ANALYSES.

The routine work consists of the regular examination of samples of water received from all parts of the watershed and distribution system, i. e., from the driven wells, streams, ponds, aqueducts, reservoirs, and service taps. The complicated and varied character of the water supply requires the examination of an unusually large number of samples, and it is safe to say that no water supply in this country is examined more thoroughly and minutely than that of Brooklyn.

The regular routine includes the bacteriological examination of three samples of water from the Ridgewood pumping stations and from a tap in the city collected daily; the complete physical, chemical, and biological examination of nine samples from the distribution system collected weekly; the physical, biological, and partial chemical examination of twenty-four samples from the supply ponds collected weekly, with complete chemical analyses monthly; the complete examination of nineteen samples from driven wells collected monthly; and the complete examination of twenty-one samples from the private water supply companies of Brooklyn and from the water supplies of the Borough of Queens collected quarterly. In addition to these regular samples, many extra samples are taken at various times and places as occasion requires.

During the two and a half years that the laboratory has been in operation, this schedule has resulted

THE MOUNT PROSPECT LABORATORY, BROOKLYN, N. Y.

hood; a work table, under which are closets and drawers; a shipping desk; a large sink, with draining boards on the sides; a drying oven; a hot-air sterilizer; a steam sterilizer; an autoclav; an automatic still and a distilled water-tank lined with block tin and having delivery tubes that extend to the other rooms.

The biological laboratory is devoted to the bacteriological and microscopical examinations of water and to the study of the various organisms found. It also forms the office of the director. It contains a work table; a long work shelf with three windows in front; three incubators; an ice chest for the storage of culture media; a case for sterilized apparatus; a book case, with a good working library; a desk; a typewriter; and cabinets for report blanks, biological specimens, etc. Electric bells connect with the different laboratories and with the telephone in the office of the keeper of the reservoir.

The chemical laboratory is the largest of the three rooms. Its atmosphere is kept free from ammonia and from the fumes of strong acids, in order not to vitiate the results of the water analyses there carried on. It contains a table for holding the samples of

THE BIOLOGICAL LABORATORY.

CORNER OF THE CHEMICAL LABORATORY.

* A paper read before the Brooklyn Engineers' Club, April 12, 1900.

in the analysis of more than six thousand samples, as follows :

Number of samples received from July 12, 1897, to April 1, 1900.....	6,471
Number of physical examinations.....	5,925
Number of complete chemical analyses.....	2,562
Number of partial chemical analyses.....	1,049
Number of microscopical examinations.....	4,688
Number of bacteriological examinations.....	5,230
Number of tests for <i>Bacillus coli communis</i>	2,639

The samples of water from the watershed are collected in the forenoon during the early part of each week and sent to the laboratory by express. The average time that elapses between the collection of a sample and the beginning of its analysis is about four hours, but this time varies from ten minutes to eight hours. Samples are collected in large bottles for chemical analysis, and in small sterilized bottles for bacteriological examination. The large bottles have a capacity of one gallon, are made of heavy, clear, white

The apparatus used for collecting samples from beneath the surface, when necessary, is shown in Fig. 3. The frame consists of a brass wire, *A*, attached to a weight, *B*, with clips for holding the bottle, *C*. The frame is supported by the spring, *F*, joined to the sinking rope, *E*. A flexible cord, *G*, extends from the top of the spring to the stopper of the bottle. The length of this cord and the length and stiffness of the spring are so adjusted that when the apparatus is suspended in the water by the sinking rope the cord will be just a little slack. In this condition it is lowered to the desired depth. A sudden jerk given to the rope stretches the spring and produces sufficient tension on the cord, *G*, to pull out the stopper.

The apparatus for collecting bacteria samples from beneath the surface is similar in principle. The bottle is replaced by a sterilized vacuum tube, with end turned outward and backward and drawn to a point.

sults are expressed according to the following scale of intensity and with the following abbreviations :

Scale of Intensity.	Abbreviations.
0. None.	v. Vegetable.
1. Very faint.	e. Earthy.
2. Faint.	a. Aromatic.
3. Distinct.	g. Grassy.
4. Decided.	f. Fishy.
	m. Mouldy, etc.

CHEMICAL ANALYSIS.

The sanitary chemical analysis ordinarily includes the determination of the nitrogen as albuminoid ammonia, free ammonia, nitrites, and nitrates ; total residue on evaporation ; loss on ignition ; chlorine ; iron ; and hardness. In addition to these, the following de-

PLAN OF LABORATORY.

glass, and have glass "Hood" stoppers. They are not sterilized, but are carefully cleaned with chromic acid before leaving the laboratory. Brown paper is tied over the stoppers to prevent contamination from dust, and the bottles are packed in boxes that have separate compartments lined with indented fiber paper and that are provided with tight fitting covers. The breakage of bottles packed in this way is very small.

The bottles for the bacteria samples hold two ounces, and are made of clear, white glass, and have wide mouths with glass stoppers. They are known to the trade as "Chemical salt-mouths." These bottles are sterilized each time before use. The stoppers of the bottles are covered with pieces of tin foil, and each bottle is then placed in a tin box just large enough to receive it and that has a screw cap. The tin boxes are painted to keep them from rusting. The bacteria samples are shipped in portable ice boxes, sections of which are shown in Fig. 1. There is an outer box with asbestos packing and a copper lining, and an inner copper tray, divided into compartments to hold the tin boxes just mentioned, and between the outer box and the tray is a large space for ice. The box holds sufficient ice to last eight hours in hot weather, and the samples almost invariably are received in good condition.

The samples from the supply ponds are collected at a depth of one foot below the surface. The shallowness of the ponds makes it unnecessary to collect sam-

The pull of the cord breaks off the tip of the tube, and the pressure of the water causes the tube to fill. The end may be then sealed with an alcohol lamp or closed with a bit of sterilized wax. The frame for holding the tube consists of a short piece of lead pipe, which also serves as a weight.

The temperature of each sample is taken at the time of collection and recorded on a certificate, together with the locality of the sample, the date of collection, the name of the collector, etc. Temperature readings below the surface are obtained with the thermophone.*

When the samples reach the laboratory each is given a serial number and entered in an index book, and throughout all the examinations each sample is known by its number rather than by the name or the locality from which it was collected.

It would be out of place in this paper to describe in detail all the methods used in the analysis of the samples, but, inasmuch as methods differ considerably in different laboratories, it seems desirable to give at least an outline of the methods used, and to describe those that differ materially from those practised elsewhere.

PHYSICAL EXAMINATION.

The physical examination includes the observation of the temperature of the water, its general appearance, its turbidity, its color, and its odor.

Temperature.—The temperature of the sample is ob-

FIG. 1.—PORTABLE ICE CHEST FOR TRANSPORTING BACTERIA SAMPLES.

ples at greater depths. The samples from the distribution reservoirs are collected just outside the gate-houses, where the flowing water gives a representative mixture of the water entering or leaving the reservoirs. Special precautions are taken to avoid contamination in the collection of samples, and to this end special forms of collecting apparatus have been devised.

The apparatus for collecting the bacteria samples is shown in Fig. 2. The sterilized bottle is placed in a metal frame, *F*, *G*, attached to the lower end of a small brass tube, *B*, and is held in position by spring clips, *E*. A small rod, *A*, extends through the brass tube, and at the lower end is provided with a clutch, *C*, *D*, for grasping the stopper of the bottle. By means of this rod the bottle may be opened and closed under water.

served at the time of collection as mentioned above.

Appearance.—The amount of sediment and the turbidity after standing twelve hours are estimated by inspection and recorded numerically according to the following scale :

Turbidity.	Sediment.
0. None.	0. None.
1. Very slight.	1. Very slight.
2. Slight.	2. Slight.
3. Distinct.	3. Considerable.
4. Decided.	4. Heavy.

Turbidity.—The actual turbidity is determined by comparison of the sample with silica standards of turbidity, as described by Whipple and Jackson in *The Technology Quarterly* for December, 1899. According to these standards, a turbidity of 100 is equal to that produced by adding 100 mg. of finely divided diatomaceous earth to 1 liter of water. Comparisons are made in gallon bottles or in Nessler jars held toward the light or placed over a series of black lines.

Color.—The color is determined by comparison with the Platinum-Cobalt Standard described by Hazen in *The American Chemical Journal*, vol. xiv., page 300. The comparisons are made in 100 c.c. Nessler jars 1 inch in diameter and 12 inches long.

Odor.—The "cold odor" is observed after vigorously shaking the bottle in which the sample is contained. The "hot odor" is observed by heating about 200 c.c. of the sample in a beaker covered with a watch glass to a point just short of boiling, and applying the nose as soon as the water has sufficiently cooled. The re-

* Henry E. Warren and George C. Whipple, "The Thermophone," *Technology Quarterly*, July, 1895.

FIG. 2.—APPARATUS FOR COLLECTING BACTERIA SAMPLES.

terminations are sometimes made : Oxygen consumed ; alkalinity ; incrusting constituents ; dissolved oxygen ; carbonic acid, etc.

Form of Expression.—The results of the chemical analyses are expressed in Parts per Million.

Nitrogen as Albuminoid Ammonia.—The method of Wanklyn is used according to the practice of the Massachusetts State Board of Health, described in the two special reports on Water Supply and Sewerage, published in 1890. The total albuminoid ammonia is determined on the unfiltered water. The dissolved albuminoid ammonia is determined after filtering the sample through filter paper. The suspended albuminoid ammonia is found by subtracting the dissolved albuminoid ammonia from the total albuminoid ammonia. In the case of ground waters, only the total albuminoid ammonia is determined.

Nitrogen as Free Ammonia.—The free ammonia is determined by Wanklyn's method, referred to under albuminoid ammonia. 500 c.c. of the sample serves for the determination of both the free and albuminoid ammonia.

Nitrogen as Nitrites.—Warington's modification of the Griess method is used.

Nitrogen as Nitrates.—The phenolsulphonic acid method of Grandval and Lajoux is used, but with certain modifications tending to refinement. The quantities operated upon vary from 2 c.c. to 50 c.c., according

FIG. 3.—APPARATUS FOR COLLECTING SAMPLES FROM BENEATH THE SURFACE.

to the amount of nitrogen present as nitrates. Permanent standards are used instead of preparing fresh standards for every set of comparisons. Comparisons are made in 100 c.c. Nessler jars.

Residue on Evaporation.—For the determination of the residue on evaporation, 200 c.c. of the sample are evaporated to dryness on a water bath in a platinum dish of known weight, dried for half an hour in a steam oven, cooled in a desiccator, and weighed. Where it is necessary to determine the amount of suspended matter, the residue is determined both before and after filtering the sample through a Pasteur filter, and the difference obtained.

Loss on Ignition.—After the determination of the total residue on evaporation the platinum dish is placed in a larger platinum dish that serves as a radiator, ignited for seven minutes at a low red heat, treated with a small amount of distilled water to restore any loss of

water of crystallization that may have been driven off by the ignition, evaporated to dryness on the water bath, and dried, cooled and weighed as before. The difference of weight before and after the ignition gives the loss on ignition. The loss on ignition is not determined for the ground waters or for the waters of the distribution system.

Chlorine.—The chlorine is determined by titration with silver nitrate, using potassium chromate as an indicator, according to Hazen's modification of Mohr's method described in The American Chemical Journal, vol. xi., page 409.

Hardness.—The hardness is determined by Clark's Soap Method, substantially as described in Sutton's Volumetric Analysis, but with certain modifications in the preparation of the soap solution. No attempt is made to separate the "temporary hardness" from the "permanent hardness" by the method of boiling. The information covered by these terms is obtained when necessary by the determination of the alkalinity and the incrusting constituents.

Alkalinity.—The alkalinity of a water is a measure of the carbonates and bicarbonates present. It is ordinarily determined by titrating 100 c.c. of the sample with N/50 H₂SO₄, using methyl-orange as an indicator; but it is sometimes desirable to substitute lacmoid for methyl-orange as an indicator, making the titration after heating the sample to the boiling point. It has been found that when the true end-points are known, and the proper corrections for the indicators are applied, methyl-orange and lacmoid give practically the same results. These indicators differ in their power of showing the presence of sulphate of alumina, and methyl-orange should not be used in determining the alkalinity of a water that has been treated with that coagulant.

Incrusting Constituents.—The incrusting constituents are the salts that give to water its "permanent hardness." The determination is made according to Hehner's Method as described by Leffman in his "Examination of Water." The sum of the alkalinity and incrusting constituents is approximately equal to the hardness as determined by the Soap Method.

Iron.—The iron is determined from the residue in the platinum dish according to Thompson's Method as described in Sutton's Volumetric Analysis, but with certain changes in technique that tend to greater accuracy.

Oxygen Consumed.—The Kubel Method is used substantially as described in the special reports of the Massachusetts State Board of Health above referred to. The period of boiling is five minutes. This determination is seldom made on the regular samples.

Dissolved Oxygen.—Winkler's Method is used according to the modifications of Drown and Hazen described in the special reports of the Massachusetts State Board of Health above referred to.

Carbonic Acid.—Pettenkofer's method is used according to the modifications of Trillich, described in Ohlmüller's Untersuchung des Wassers, edition of 1896.

MICROSCOPICAL EXAMINATION.

The microscopical examination of water determines the number and kind of microscopic organisms present.

The Sedgwick-Rafter method is used with the modifications described in the author's "Microscopy of Drinking Water." The results are expressed in number of standard units of organisms per cubic centimeter.

BACTERIOLOGICAL EXAMINATION.

The bacteriological examination consists of the determination of the number of bacteria present in a sample of water, and tests for the presence of *Bacillus coli communis*. No general qualitative work is undertaken in connection with the regular routine.

Quantitative Examination.—One cubic centimeter of the sample (diluted 1-10 or 1-100, if necessary) is mixed with 5 c. c. of sterilized nutrient gelatine in a Petri dish, and allowed to cool on a level surface. When hard, the culture is placed in an incubator and kept at a temperature of 20° C. in an atmosphere saturated with moisture for 48 hours, after which the number of developed colonies is counted. It is then returned to the incubator and kept 24 hours longer, after which a second count is made. The 72-hour count is the one reported. All determinations are made in duplicate. The gelatine used as the culture medium is prepared substantially as recommended in the report of the Bacteriological Committee of the American Public Health Association, published in 1898. It is given an acidity of 1.5 per cent.

Test for *Bacillus Coli Communis*.—Smith's fermentation method is used as the basis of the test, isolation of the colon bacillus, according to ordinary qualitative methods, being attempted only when a positive test is obtained in the fermentation tube. If the amount of gas in the fermentation tube after 48 hours incubation at 37° C. is above 30 per cent, and below 70 per cent, of the closed arm, a portion of the sediment is plated on lactose-litmus agar. If red colonies develop after 12 hours incubation, transfers are made from them to glucose gelatine, milk, nitrate solution, sugar-free broth (for indol), and glucose broth in a fermentation tube. If these tests give positive results, the presence of the colon bacillus is considered as proved.

It is not within the province of this paper to discuss the quality of the water supply of Brooklyn; that belongs more properly to the annual reports of the Department of Water Supply; but, an account of the growths of microscopic organisms in the supply may be of general scientific interest.

MICROSCOPIC ORGANISMS.

The troubles of the Brooklyn Water Supply during the past few years have been occasioned by the growth of odor-producing organisms in the distribution reservoirs. The growth of *Asterionella* in Ridgewood and Mt. Prospect reservoirs and its effect upon the quality of the water have been so fully described (Report of Dr. Albert R. Leeds to the Department of City Works, Division of Water Supply, Brooklyn, 1897) that it is not necessary to again relate the details of its occurrence. That the growths of *Asterionella* continued to occur periodically is shown by the profiles on Fig. 4.

Asterionella is not the only odor-producing organism that develops in the distribution reservoirs. *Anabaena*, *Synedra*, *Cyclotella*, and other forms are sometimes present in great abundance. The character of the

water collected from the watershed of the Brooklyn supply is such as to furnish abundant nourishment for microscopic plant life, and organisms that in many water supplies appear in small numbers without having any noticeable effect on the character of the water, develop in Brooklyn to an enormous extent.

This is emphatically true in the case of *Synedra pulchella*, a diatom that until recently has not been classed as an odor-producing organism. Like *Asterionella*, this diatom contains oil-globules, but the oily substance has not the same strong odor as the oil of *Asterionella*. Nevertheless, *Synedra* is capable of imparting an odor to water if present in sufficient numbers. The odor is not a characteristic one like that of *Asterionella*, *Uroglena*, *Dinobryon*, etc., and can be described by no more exact term than "vegetable." The taste imparted to water by *Synedra* is perhaps more noticeable than the odor, being somewhat "earthy" as well as "vegetable."

In few water supplies in this country is *Synedra pulchella* ever present in numbers greater than 5,000 per c.c., and although a smaller number than this will make a water turbid, it requires about this number to produce a noticeable odor. In Brooklyn, however, the growths of *Synedra* have been much heavier, as may be seen from Fig. 4. On several occasions the numbers have reached 15,000 per c.c., and once as many as 20,000 per c.c. were observed. The water at such times has been very turbid, and has had the vegetable and earthy taste and odor just referred to.

Cyclotella is another diatom that, because of its limited occurrence, has been seldom known to cause trouble in water supplies. Yet in Ridgewood Reservoir it is sometimes present in large numbers. Its growth has been usually of short duration, but when present in numbers equal to 5,000 standard units per c.c. its aromatic odor could be distinctly recognized.

Two species of *Melosira* occur in the Brooklyn supply. *Melosira granulata*, the common free-floating form, is seldom present in sufficient numbers to cause trouble, though two or three thousand per c.c. are sometimes found. *Melosira varians* grows luxuriantly on the shores of Ridgewood Reservoir, and constant scraping is required during the summer to keep the

sphaerium, *Eudorina*, *Panderina*, and *Volvax* are often present in numbers of 500 standard units per c.c. *Clathrocystis* is not often found in Ridgewood Reservoir, but in Mt. Prospect Reservoir it has been as high as 1,440 standard units per c.c. As a rule the Brooklyn water contains comparatively few protozoa, but *Mallomonas* has been observed as high as 660 per c.c. in Ridgewood Reservoir, and *Cryptomonas* has been as high as 2,000 per c.c. in Mt. Prospect Reservoir. *Chlamydomonas* has been found occasionally.

To the water consumers of Brooklyn, however, the important fact is not the number of organisms in the distribution reservoirs, but the number present in the tap water in the city. Prior to the construction of the by-pass at Ridgewood, the organisms that developed in the reservoir found their way as a matter of course to the service taps of the consumers. But by using the by-pass it has been found possible to so regulate the distribution of the water that very few organisms reach the consumers. Guided by the frequent and regular microscopical examinations made at Mt. Prospect Laboratory, the Engineer of Water Supply has directed one or more basins to be isolated whenever it was found that odor-producing organisms were developing in them, the water meanwhile being delivered through the by-pass direct from the force mains to the distribution pipes.

MISCELLANEOUS WORK.

The miscellaneous work of the laboratory includes analyses of coal, lubricating oil, boiler scales, boiler compounds, cements, deposits from driven wells, etc. These are all problems of engineering chemistry and need not be described at length. The most important part of this work is the analysis of coal, and a brief description of the methods used may be of interest to some of the members of the club.

The specifications under which coal is purchased by the department require that each bid shall be accompanied by a sample of the coal offered, and provide that no bid shall be accepted unless the sample contains a certain number of heat units. Bituminous coals must contain not less than 13,500 B. T. U. per pound, and anthracite coals not less than 12,500 per

FIG. 4.—VARIATIONS IN NUMBERS OF MICROSCOPIC ORGANISMS IN THE BROOKLYN RESERVOIRS, NOVEMBER, 1897, TO FEBRUARY, 1900.

banks clean. During severe storms the filaments of *Melosira* become detached from the shores and are scattered through the water, and on one occasion the amount of vegetable matter so detached was sufficient to impart a distinct taste to the water. Like *Synedra pulchella*, *Melosira* produces simply a vegetable, earthy and somewhat oily taste and odor, very different from the aromatic fishy odor of *Asterionella* and *Cyclotella*.

Next to *Asterionella*, *Anabaena* has probably caused more trouble in the Brooklyn water supply than any other organism. During the past two years it has appeared but once, but there are good reasons to believe that in the summer of 1896, prior to the investigations of Dr. Leeds, the disagreeable odor of the tap water was due not so much to *Asterionella* as to *Anabaena*.

In July, 1898, *Anabaena* appeared in all the Ridgewood basins. In Basin 3 it did not develop to any extent. In Basin 1 it attained a maximum growth of 1,720 standard units per c.c. on August 19, and gave to the water its characteristic odor of mouldy grass. In Basin 2, however, it developed to an enormous extent. On August 3, there were 24,000 standard units per c.c. From the last of July until early in September the water in the basin was densely turbid and had a green color. On quiet days a scum collected on the surface and drifted about with the wind. The water was entirely unfit for use, and the gates of the reservoir were kept closed. As soon as the organisms disappeared in the fall and the water had again assumed its normal condition, Basin 2 was emptied and cleaned, with the hope of preventing recurrence of such growth in the future. An examination of the deposit at the bottom of the reservoir showed that it was well seeded with the spores of *Anabaena*. Since that time there has been no further development of this organism.

In September, 1898, a phenomenally large growth of *Scenedesmus* occurred in Mt. Prospect Reservoir, the water at one time containing 25,800 standard units per c.c. This organism in the numbers ordinarily found causes no odor, but on this occasion the water had a distinct vegetable and aromatic odor and taste. The growth continued for several weeks.

There are several other organisms that deserve mention, because they occur in larger numbers in the Brooklyn water than in most water supplies. *Dictyo-*

pound, the calculations to be made in both cases on dry coal by the method of ultimate analysis. The amount of sulphur must not exceed 1 per cent.

The samples of coal that accompany bids are analyzed by the method of ultimate analysis and are also tested in the Mahler Bomb Calorimeter; but in the case of samples taken from each consignment, the ash is determined in the combustion furnace, and the heating power in the calorimeter.

The method of ultimate analysis was described by Mr. D. D. Jackson, chemist of the laboratory, at one of the library talks of the club in 1898. The sample of coal—usually about ten pounds—is reduced by successive divisions to a small representative sample, which is powdered to such a degree of fineness that it will pass a sieve that has 60 meshes to the inch. The moisture is determined by ascertaining the loss in weight when dried for one hour at 110° C. This determination is made, not for the purpose of obtaining the moisture in the coal as used, but in order that the results of the analysis may be calculated on the basis of dry coal. The amounts of carbon, hydrogen and ash are determined in a combustion furnace in the usual manner. The nitrogen is sometimes determined by the Kjeldahl method, but the determination is omitted on the regular work. The sulphur is determined by Eschka's method. The volatile sulphur, when required, is determined from the water left in the bomb of the calorimeter after the combustion. The oxygen is determined by difference.

All of the determinations of the ultimate analysis are made in duplicate.

The heating power is calculated from the ultimate analysis according to the following formula:

$$\text{Number of B. T. U. per pound of coal} = 14,544 C + 62,032 \left(H - \frac{O+N}{8} \right) + 4,500 S$$

where C, H, O, N and S represent the percentages of carbon, hydrogen, oxygen, nitrogen and sulphur.

Expressed in terms of calories, this formula becomes

$$H = 8,080 C + 34,462 \left(H - \frac{O+N}{8} \right) + 2,500 S.$$

The heating power of the coal is determined directly by combustion in the Mahler bomb calorimeter. A good description of this apparatus may be found in Gill's "Gas and Fuel Analysis for Engineers." About one gramme of the powdered coal is weighed out in a shallow platinum pan and placed in the steel bomb of the calorimeter, after which oxygen is admitted until the pressure in the bomb reaches 25 atmospheres. The bomb is then immersed in the water cylinder and the charge ignited by means of an electric current, which is passed through a fine iron wire embedded in the coal. The heat produced by the combustion of the coal causes an increase in the temperature of the surrounding water, and from the observed rise in temperature, the heating power of the coal is calculated.

An examination of the results of about fifty analyses, made by the method of ultimate analysis, shows that duplicate samples usually differ by about 1 per cent., or approximately 120 B. T. U., while with the calorimeter duplicates usually agree within 50 B. T. U. Comparisons of determinations of heating power made by direct determination and by calculation from the ultimate analysis show an average difference of about 200 B. T. U.

In conclusion, the author wishes to express his thanks to Mr. Robert Van Buren, Engineer-in-charge, Department of Water Supply, Brooklyn, for permission to quote from unpublished laboratory records, and to Mr. I. M. De Varona, Engineer of Water Supply, under whose general direction the laboratory was established and the system of work inaugurated, and to whom belongs the credit for its existence and success. The photographs of the laboratory that accompany this article were taken and kindly furnished by Mr. P. Schuyler Miller, the assistant chemist in the laboratory.

THE DUDELL OSCILLOGRAPH.

THE determination of the actual relation between the potential difference of an alternating current and the current itself in different circuit conditions has for long been a matter of considerable difficulty. In certain simple cases the problem could be solved from theoretical considerations without much difficulty, the more especially if the generator was such as to give a sine curve for the wave of potential, but with the types of wave curve common in commercial machines matters become more complicated. Further, as in the case of an alternate-current arc, data were wanting to permit of any satisfactory prediction of the current wave, even when the wave of potential was of the simplest character; and in other cases where the nature of the circuit was better understood, it was at least highly desirable to make an experimental comparison between the theoretical deductions and the actual facts of the case. The only methods available up to quite a recent date were highly laborious. These involved the determination of the curves concerned point by point; and though much valuable research work had thus been accomplished by different observers, the time needed to complete a research was enormous,

English engineer to overcome the practical difficulties involved, and to devise an instrument which seems capable of meeting the severest of requirements. Mr. W. Duddell, the gentleman in question, in addition to his theoretical knowledge, is at the same time endowed with considerable manipulative skill, which enabled him to construct the first of the instruments made with his own hands, though much of the work was of an exceedingly delicate character, and the instruments

condenses the line of light to a point, and this point falling on a mirror vibrated by the motor is thrown up on to the curved screen above, as shown in Fig. 1. A piece of tracing paper can be secured above this screen, and the curve penciled in. The curtains shown keep out stray light, and enable the experimenter to follow the curve more easily.

The galvanometer constitutes the most important part of the instrument. Its magnetic circuit is satu-

FIG. 2.—THE DUDELL OSCILLOGRAPH.

are now being made by the Cambridge Scientific Instrument Company.

The instrument consists essentially of a modified D'Arsonval galvanometer, combined with a rotating or vibrating mirror. In this instrument, the strength of a current is measured by the angular displacement of a beam of light reflected from a mirror mounted on a coil suspended in a strong magnetic field. The beam of light in question being received on a screen, the strength of a current is proportional to the linear displacement of the resultant spot of light. With alternating currents the spot of light reflected from the mirror of this galvanometer oscillates to and fro as the current through its coil varies, and would thus trace a straight line on a screen interposed in its path. In the oscillograph, however, a second mirror is interposed in the path of the beam, and this mirror is caused to vibrate by a cam driven by a synchronous motor, and there is thus added to the beam of light a vibration at right angles to its original plane of motion, and it now traces on the screen a curve of potential or current as

rated with a comparatively small energizing current, so that considerable changes in the latter have little influence on the strength of the magnetic field in which the moving coil or coils are placed. In the instrument shown there are two such coils, enabling simultaneous observations to be made on both current and potential. The coil in each case consists of a simple loop of phosphor bronze, arranged as indicated in Fig. 4. The upper end of the loop passes round a pulley which is attached to a light spring balance, as shown in Fig. 3. By altering the tension of this spring, the periodicity of the instrument can be varied at will. In the instrument shown, these loops are but 7 mils wide by $\frac{3}{16}$ mil thick. Each leg of a loop passes through a slot in a soft iron armature, the clearance between the sides of the slots and the moving strip being but 1.5 mils, and these slots are then filled with a viscous oil, over which is placed a small lens, which is held in position entirely by the surface tension of the oil, and at the same time serves in its turn to keep this oil in place. The object of the oil is to damp the oscillations of the coil. A

FIG. 1.—THE DUDELL OSCILLOGRAPH.

ous, and in certain cases led to the abandonment of the attempt after the full magnitude of the undertaking was completely appreciated. Some few years back Prof. Blondel succeeded in substituting, by means of an instrument he named an oscillograph, an autographic arrangement for the point-by-point method of curve tracing them in vogue; but though he did obtain some interesting results, his instruments did not come into general use, and it remained for a young

the case may be. The apparatus is shown complete in Fig. 1, while in Figs. 2 and 3 we show separately its principal components. As will be seen, the galvanometer and the motor are placed in a wooden case. A lamp fitted with a condenser of the usual type is placed outside the case to the right, and its light passing through a vertical slot, is reflected back from the galvanometer mirrors, and passes through a cylindrical lens clearly shown in front of the motor in Figs. 1 and 2. This

small mirror marked *M*, Fig. 4, is attached to the loop, as shown. The effect of passing a current through one of these loops is to cause one leg of it to advance while the other goes back, and the mirror is thus oscillated round a vertical axis. In the instrument shown, the natural period of vibration of the loop is $\frac{1}{10000}$ of a second, and the clearances being, as stated, extremely small, the damping effect of the oil is very great, so that the instrument can be relied upon to give good