Thesis:—

On the Relative Efficiency of Certain Filters for Removing Micro-Organisms from Water, with special reference to the Nordtmeyer – Berkefeld and Pasteur – Chamberland Filters.

Preface.

The experiments forming the subject of this Thesis were made in the Public Health Laboratory of Professor Sir Douglas Maclagan, in the University of Edinburgh, between October 1893 and June 1894. They were carried out at the suggestion and under the direction of Dr. Hunter Stewart, to whom I am indebted for much valuable advice and universal courtesy. I am also indebted to my brother, Mr. Charles S. S. Johnston, Architect, Edinburgh, for the drawings of the filters and autoclave. The experiments were made for the purpose of testing the relative efficiency of the different filters experimented with for removing micro-organisms from water, with special reference to the selection of the best filter for sterilizing drinking water. The results of the experiments have conclusively proved that the Pasteur-Chamberland Filter (cylinders stamped "B") is undoubtedly the best and the only one on which reliance can be placed for permanently sterilizing drinking water.

Henry Halcro Johnston.

Leith Fort,
Scotland,
29th June 1894.

Bibliography

Maignen's "Filtre Rapide".

Laveran, Des Filtres Maignen, Archives de Médicine Militaire, No. 15, 1886. In this article the filter is described by Laveran.

The Pasteur-Chamberland Filter.

Chamberland, Comptes Rendus, Tome 99, p. 247, 1884. The filter is first described in a note by Chamberland.

Miquel, Revue d'Hygiene, p. 536, 1884, experimented with the unfiltered Seine water at $\frac{1}{3}$ atmospheric pressure and with the water of the Vanne at 3 to 4 atmospheres. His experiments extended over one week, and all the cultures made with the filtered water were sterile. He does not state which kind of cylinder he used.

Kübler, Zeitschrift für Hygiene, Band 8, 1890, sterilized the cylinders for 1 hour in steam at 100°C. He experimented with unfiltered Berlin water without pressure, and the results of his experiments were that the cylinders only sterilized the filtered water for 4 days of continuous filtration. He does not mention the kind of cylinders he used, but from the rate of filtration — 183 cubic centimetres per hour on the first day of filtration for each cylinder — he appears to have used the same kind as those used in the experiments forming the subject of this Thesis, viz., those stamped "B", in which the rate of filtration is only one-third of that in the cylinders stamped "F". If he used the slow filtering cylinders stamped "B", the results of his experiments are entirely

antagonistic to those obtained by the method adopted in this Thesis, in which the chances of accidental contamination of the filtered water and the cultures made with it were reduced to a minimum. If he and the fast-filtering cylinders stamped "F," his results are also antagonistic to those obtained by Guinochet, who experimented with "F" cylinders and came to the conclusion that the few bacterial colonies occasionally found in some of the cultures made with filtered water were due to accidental contamination during the process of making the cultures.

Guinochet, Archives de Médicine Expérimentale, Tome 5, p. 646, 1893, working in the Laboratory of Professor Straus, Paris, with cylinders stamped "F" for rapid filtration, at pressures of 10 to 40 Metres, for periods extending over several weeks of continuous filtration, obtained results which are very satisfactory considering that he did not sterilize the cylinders. He came to the conclusion that the few bacterial colonies and moulds occasionally found in some of his cultures made with the filtered water were due to accidental contamination during the process of making the cultures.

It is very important that experimenters, in publishing their results, should mention the particular kind of cylinder used, the method of preparation for experiment, and the pressure and rate of filtration of the water at the time of making the experiments; because the different results obtained by different experimenters may be due to the use of different kinds of cylinders, or to the different methods adopted of preventing accidental contamination of the cultures.

Method of Preparing and Sterilizing the Nutrient Jelly and Apparatus used in making the Cultures.

The nutrient jelly was made by the well known process of Koch. It contained 10 per cent of gelatine, 1 per cent of peptone and ½ per cent of sodium chloride. The reaction of the broth from which the jelly was prepared was, through all stages of its preparation, alkaline to litmus and turmeric paper. This was necessary on account of the amphoteric reaction of animal fluids. The test-tubes containing 10 cubic centimetres each of the nutrient gelatine jelly were sterilized by steam at 100°C. in Hunter Stewart's autoclave (Plate V) for 1 hours on three consecutive days. The plugs of cotton wool were then scorched in a Bunsen flame and the mouths of the test-tubes covered with india rubber caps, which had been previously sterilized by immersion in corrosive sublimate solution, 1–1000, for 2 hours, and allowed to dry between folds of filter paper. Several gross of these tubes were prepared, and in every tube the nutrient jelly remained permanently sterile. Esmarch's roll culture tubes containing 7 cubic centimetres each of nutrient gelatine jelly were prepared in the same manner as the test-tubes.

The following glass apparatus, after having been well washed in distilled water, was sterilized by dry heat at 160°–180°C. for 1½ hour:– Petri's capsules; collecting flasks plugged with cotton wool; and dropping tubes plugged with cotton wool at the upper end. The collecting

flasks were 200 cc - Bohemian glass vessels having mouths $\frac{3}{4}$ inch in diameter; and the dropping tubes were made of pieces of $\frac{5}{16}$ inch glass tubing, 11 inches long and tapered at the lower or dropping end. Fifteen drops of water from each of three dropping tubes measured 1 cubic centimetre.

Forster's boxes were well moistened inside with corrosive sublimate solution, 1-200, the day before they were used, and at the same time three shuts of filter paper moistened with the corrosive sublimate solution were placed in each box. One shut was placed at the bottom of the box, and the other two shuts were placed, in the experiments, above the first and second pairs of Petri's capsules respectively, to prevent the entrance of micro-organisms from the air during the period of incubation of the plate cultures.

During the short time occupied in pouring the melted jelly from the test tubes into Petri's capsules, the latter were placed on a glass slab moistened with corrosive sublimate solution 1-200.

The nutrient jelly in the test-tubes and in Esmarch's tubes was melted by placing the lower ends of the tubes in a beaker containing some warm corrosive sublimate solution, 1-200.

Before making the cultures the hands were well washed in distilled water and then in corrosive sublimate solution, 1-200, after which they were allowed to dry.

The iron tongs used for removing the cotton wool covering the lower ends of the filter nozzles at the beginning of each series of experiments was sterilized by heating to redness in a Bunsen flame.

The Atkins Patent Water Filter.
6 — Gallons.

Manufacturers:—

The Atkins Filter and Engineering Company, Ld.,
33, Bowerie Street, London, E.C.

Description and Method of Preparation for Experiment.

This filter is made of stoneware, and consists of two parts, an upper and a lower, separated from each other by a stoneware diaphragm, in the centre of which is an aperture filled with a cork containing a metal tube. The lower portion consists of a reservoir capable of holding about 2½ gallons of filtered water, and it is provided with a metal tap near the bottom. The upper portion contains the filtering material, which consists of a block of wood charcoal 6 inches high and 5¾ inches in diameter, and fits on to the metal tube; this block being surrounded with granulated animal charcoal. The filter has a small aperture at the back of the upper rim connected with an air passage reaching to the lower part of the filter. As it was impracticable to sterilize the lower reservoir and make cultures with the filtered water at any particular time, I employed Messrs. John Ford & Co, Flint-glass Manufacturers, Edinburgh, to make a cylindrical glass vessel (Plate I), open at the upper end and closed at the lower end with a flat bottom, perforated at the centre by a 1⅝-inch circular aperture. The internal dimensions are height 11½ inches and diameter 11 inches. This vessel corresponds to the upper reservoir and perforated diaphragm of the Atkins Filter, and it is supported on a wooden bench, through which a circular aperture is bored opposite

the aperture in the bottom of the glass vessel. The block of wood charcoal is a cylinder, 6 inches high, and 5 3/4 inches in diameter, and it contains a central cylindrical cavity, 3 1/2 inches long and 1 1/4 inch in diameter, which is closed at the top and open at the bottom. The lower 1 1/4 inch of this cavity is firmly plugged with a perforated cork containing a metal tube. The thickness of the wood charcoal, between the outer surface and internal cavity of the block, is 2 1/4 inches. The superficial filtering area of the external surface of the block is 160 square inches, and that of the wall of the internal cavity 10 square inches, so that, in a given time, the quantity of water filtering through one square inch of the wall of the internal cavity is equivalent to the quantity of water filtering through sixteen square inches of the external surface of the block. The metal tube, referred to, has an internal diameter of 1/12 inch, and has a 7/8-inch flange situated 1 1/2 inch from the upper end and 2 inches from the lower end. The upper portion of this tube is pushed through the perforated cork in the block of wood charcoal, and the lower portion through a perforated cork, for which was substituted a perforated india rubber stopper, and the flange on the tube is in contact with the cork above and india rubber stopper below. In the first series of experiments the lower end of the metal tube, which projects 3/4 inch beyond the india rubber stopper, was connected to a glass nozzle by means of a piece of 3/8 inch india rubber tube. Before sterilizing the block of wood charcoal, the lower end of the glass nozzle was covered with cotton wool secured with cord, and a screw-

clip was applied to the india rubber tube, without compressing it. The block of wood charcoal, thus prepared, was placed in distilled water, contained in an earthenware jar covered with white paper, and boiled at 100° C. in the autoclave for 1 hour on three different occasions, viz., 23rd, 24th and 28th Nov. 1893. Between the first and last boilings the prepared block was left immersed in the boiled distilled water in the earthenware jar covered with sterilized paper. After the third boiling on 28th Nov. the india rubber tube was compressed by means of the screw-clip, to prevent the entrance of air through the nozzle during cooling, and the prepared block of wood charcoal, held by the right hand between several folds of sterilized paper, was quickly transferred, while hot, to the glass vessel, and the india rubber stopper inserted into the aperture in the bottom of the vessel. The block of wood charcoal was then surrounded with 14 lbs of granulated animal charcoal, which with the lid and interior of the glass vessel had previously been well washed with distilled water, but not sterilized. On 30th Nov. the filter was filled with Edinburgh Main Water, and the first series of experiments were made between that date and 8th Dec. 1893, after which the filter was allowed to stand full of water, containing innumerable micro-organisms, until 15th May 1894, when it was prepared for the second series of experiments.

In the second series of experiments the same block of wood charcoal and granulated animal charcoal were used as in the first series. The block of wood charcoal was prepared in the

same manner, except that for the glass nozzle was substituted one of gun-metal, $\frac{1}{4}$ inch in diameter, $4\frac{1}{2}$ inches long, and tapered at the lower end, with a terminal bore of $\frac{1}{16}$ inch. The india rubber tube connecting the gun-metal nozzle with the metal tube of the filter is secured at both ends with silked copper wire. The block was partly surrounded with a piece of folded calico secured with an india rubber band, to prevent the block becoming contaminated when lifted in the hand. On 15th May 1894 the granulated animal charcoal was placed in distilled water, contained in two tin pails covered with tin lids, and boiled at 120°C. (15 lbs steam pressure to the square inch) in the autoclave for 1 hour. The steam was then turned off and the charcoal allowed to cool in the closed auto-clave until the following day, when the prepared block of wood charcoal was boiled in the same manner at 120°C. for 1 hour, and, while hot, quickly transferred to the glass vessel, the lid and interior of which had been previously well washed several times with distilled water, sterilized by boiling at 120°C. for 1 hour in the autoclave. The india rubber band and calico were then removed from the block of wood charcoal, after which the block was surrounded with the cool granulated animal charcoal, and the mouth of the glass vessel was covered with the lid of the Pasteur Filter. The second series of experiments with Bacillus violaceus were made between 17th and 23rd May 1894.

Maignen's Table "Filtre Rapide."
3 — Pints.

Manufacturers:—

Maignen's "Filtre Rapide" + "Anti-Calcaire" Co., Limited, 43, Commercial Street, London, E. C.

Description and Method of Preparation for Experiment.

Plate II represents this filter as prepared for use in the experiments. The glazed porcelain filtering frame is nearly cylindrical, 3 inches high, 3 inches in diameter at the lower end and 2½ inches at the upper end. The side of the filtering frame is perforated with seventy 5/16 inch holes, which in the aggregate occupy a superficial area of 5.37 square inches. The filtering frame is enclosed in a cylindrical jacket of asbestos cloth secured at each end with asbestos cords, which are lodged in circular grooves at each end of the filtering frame. The superficial filtering area of the asbestos cloth is 21 square inches. The top of the filtering frame is flat, entire and uncovered with asbestos cloth. The bottom of the frame is provided at the centre with a wide obconical porcelain nozzle, 1¼ inch long, fitted into the upper end of a piece of ⅜ inch india rubber tube, and secured to the glass vessel by means of a perforated india rubber stopper, which is inserted into a short cylindrical aperture at the centre of the bottom of the glass vessel. This india rubber stopper takes the place of the asbestos washer supplied with the filter. The glass vessel is supported on a wooden bench, through which

A circular aperture is bored to receive the short cylindrical tube at the bottom of the vessel. The lower end of the india rubber tube was connected to glass and gun-metal nozzles in the first and second series of experiments respectively, in exactly the same manner as described for the Adkins Filter. The lower ends of the nozzles were covered with cotton wool secured with cord, and a screw-clip was applied to the india rubber tube, without compressing it. On 24th Nov. 1893 the filtering frame, thus prepared, was sterilized by steam at 100°C. for 1 hour in the autoclave, and then quickly transferred, while hot, by means of sterilized iron tongs, to the glass vessel. A charge of powdered Carbo-calcis, which had been previously boiled with a litre of distilled water in a sterilized glass flask plugged with cotton wool for ½ hour in the autoclave at 120°C. (15 lbs steam pressure to the square inch), and allowed to cool, was then allowed to filter rapidly through the asbestos cloth, on which the powdered Carbo-calcis was deposited in a thin film. The filtering frame was surrounded with granular Carbo-calcis, which with the porcelain screen, glass cover and interior of the glass vessel had previously been well washed with distilled water, but not sterilized. The india rubber tube was then closed by means of the screw-clip.

On 30th Nov the filter was filled with Edinburgh main water, and the first series of experiments was made between that date and 8th Dec. 1893, after which the filter was allowed to stand full of water containing innumerable micro-organisms until 15th May 1894, when it was

prepared for the second series of experiments. In the second series of experiments the powdered carbo-calcis was washed off the asbestos cloth and a fresh charge used. On 16th May 1894 the prepared filtering frame, provided with a gun-metal nozzle, and the powdered and granular carbo-calcis were sterilized by boiling at 120°C for 1 hour in the autoclave, and, while hot, they were transferred to the glass vessel, which with its cover and the screen had previously been well washed several times with distilled water, sterilized by boiling at 120°C. for 1 hour in the autoclave. The second series of experiments with Bacillus violaceus was made between 17th and 23rd May 1894.

First Series of Experiments with the Atkins Patent Water Filter and Maignen's Table "Filtre Rapide". Tables I & III.

On 30th Nov. 1893 these two filters, after having been prepared in the manner described, were filled with Edinburgh main water, containing 160 micro-organisms in each cubic centimetre, and, by means of the screw-clips compressing the india rubber tubes, were allowed to filter slowly through the cotton wool covering the lower ends of the glass nozzles. On the following day, after 24 hours' continuous slow filtration, the cotton wool was removed from the nozzles with sterilized iron tongs, and some of the filtered water was received into sterilized

collecting flasks, the cotton wool plugs and necks of the flasks having been previously scorched in a Bunsen flame. Two plate cultures were then made with the filtered water from each filter, in the following manner:— Two test tubes containing each 10 cc of sterilized gelatine jelly were placed in a becker of warm corrosive sublimate solution 1—200 until the jelly was melted. The india rubber caps were then removed, and the cotton wool plugs and mouths of the test tubes scorched in a Bunsen flame. By means of a sterilized dropping tube 10 and 20 drops of the filtered water were transferred from the collecting flask to the two test tubes respectively, and after mixing the water and melted jelly together by shaking, two cultures were made in sterilized Petri's capsules, which were then placed in a sterilized Forster's box and transferred to the incubator at 19° C.

Both filters were then allowed to filter slowly continuously until 8th Dec, when fresh sterilized glass nozzles were inserted into the india rubber tubes, and plate cultures made in the same manner as in the first experiment. During the week's filtration the total quantity of water that passed through the Atkins Filter was 12 litres and Maignen's Filter 4½ litres. In the Atkins Filter, when the filter was nearly full, the rate of filtration was 17 litres per hour, which is at the rate of 106 cc per hour for each square inch of the outer filtering surface of the block of wood charcoal, and 1700 cc per hour for each square inch of the inner filtering surface of the block. In Maignen's

Filter, the rate of filtration, when the filter was full, was 9 litres per hour, which is at the rate of 428 cc per hour for each square inch of filtering surface of the asbestos cloth. The rate of filtration was calculated from the time taken to fill a ½ litre flask. The extreme porosity of these filters is, therefore, very evident, since they filter without any pressure, except that of the column of water in the filters themselves.

In No 1 experiment the cultures were examined at the end of 4 days' incubation, and in No 2 experiment at the end of 3 days.

Results. In all the cultures from both filters the number of colonies of micro-organisms was so enormous as to be quite uncountable, and the jelly was quickly liquefied.

Conclusions. In this series of experiments the granulated animal charcoal in both filters was not sterilized, but merely washed in distilled water, and if the block of wood charcoal in the Atkins Filter, and asbestos cloth covered with powdered carbo-calcis in Maignen's Filter were properly sterilized, it is evident that these filtering materials alone, exclusive of the granulated animal charcoal, were not only useless in removing micro-organisms from the water, but that they formed a suitable medium for the rapid growth and multiplication of micro-organisms. As the Edinburgh main water placed in the filters only contained 160 micro-organisms in each cubic centimetre, it is probable that the large numbers of micro-organisms found in the filtered water were derived from the multiplication of the micro-

organisms in the pores of the unsterilized granulated animal charcoal, as well as from the micro-organisms present in the Edinburgh main water. As will be noticed in the second series of experiments, it is also doubtful whether boiling at 100°C. for 1 hour on three different occasions was sufficient to sterilize the whole thickness of the block of wood charcoal in the Atkins Filter.

Second Series of Experiments with the Atkins Patent Water Filter and Maignen's Table "Filtre Rapide". Tables II & IV.

On 17th May 1894 5 cc of a somewhat old broth culture of Bacillus violaceus made on 27th March 1894 was added to a large pailful of distilled water, which had been previously boiled at 120°C in the autoclave for 1 hour and allowed to cool to 21°C. The water was then well stirred with a sterilized metal spoon, and a plate culture made with 1 cc of the water in sterilized gelatine jelly, from which it was ascertained that each cubic centimetre of the water contained 12 Bacilli violacei and 33 other micro-organisms. Both filters, after having been prepared in the manner described, were then filled with this water, and as soon as filtration was established the cotton wool covering the lower ends of the gun-metal nozzles was removed with sterilized iron tongs. The lower ends of the nozzles were sterilized in

a Bunsen flame, and immediately after the rapid filtration of 2 litres of water from the Atkins Filter and ½ litre from Maignen's Filter, the india rubber tubes were compressed by the screw-clips until the filtered water fell in drops from the nozzles. 1cc (19 drops) of the filtered water from each filter was then received direct from the nozzles into test-tubes containing sterilized gelatine jelly, with which plate cultures were made in sterilized Petri's capsules and placed in a sterilized Forster's box in the incubator at 19°C. The india rubber tubes were then still more compressed by the screw-clips until just sufficient water was allowed to flow to keep the nozzles full of water. On the following day, 18th May, plate cultures were made in the same manner, immediately after the rapid filtration of 1 litre of water from the Atkins Filter and ½ litre from Maignen's Filter. Plate cultures were again made in the same manner on 23rd May. In experiments Nos 1 and 2 the cultures were examined at the end of 4 days' incubation, and in experiment No 3 at the end of 2 days.

Results. In the case of the Atkins Filter, in experiment No 1, in which the culture was made after the rapid filtration of 2 litres of water immediately after placing the unfiltered water in the filter, there were no B. coli-violaceus, but there were 3150 other micro-organisms in 1cc of the filtered water. In this series of experiments the whole of the filtering material had been previously boiled at 120°C. for 1 hour, and as the unfiltered water only contained 33 other micro-organisms in 1cc at the time the experiment was made, it is evident

that, during boiling, sufficient heat did not penetrate the charcoal to kill all the micro-organisms lodged in its deeper pores during and after the first series of experiments. In experiment No 2 made at the end of one day, and in experiment No 3 made at the end of six days, the number of colonies of Bacillus violaceus and especially of other micro-organisms was so enormous as to be quite uncountable, and the jelly quickly liquefied.

In the case of Maignen's Filter sterilization was more easily accomplished. In experiment No 1, made after the rapid filtration of ½ litre of water immediately after placing the unfiltered water in the filter, the plate culture contained no Bacilli violacei and only 4 colonies of other micro-organisms in 1cc of the filtered water. In experiment No 2, made on the following day, immediately after the rapid filtration of ½ litre of water, there were 7 colonies of Bacillus violacei and 26 colonies of other micro-organisms in the plate culture made with 1cc of the filtered water. In experiment No 3, made at the end of six days, the number of colonies of Bacillus violacei and other micro-organisms was so enormous as to be quite uncountable, and the jelly quickly liquefied.

Conclusions. Although the Atkins Filter was not sterilized by boiling for 1 hour at 120°C, still the enormous number of Bacilli violacei and other micro-organisms found in the filtered water, after one days filtration, conclusively proves that this filter not only allows micro-organisms to pass through its pores, but the

Charcoal forms a suitable medium for the growth and multiplication of micro-organisms, which are found in much greater numbers in the filtered water than in the unfiltered. Maignen's Filter is of some service in removing micro-organisms from water on the first and second days of filtration, but after that it forms a suitable medium for the growth and multiplication of micro-organisms, which are found in much greater numbers in the filtered water than in the unfiltered. These filters are, therefore, useless for sterilizing water, and no reliance can be placed on them for removing pathogenic micro-organisms from drinking water.

The Nordtmeyer-Berkefeld Filter.

Manufacturers:-

The Berkefeld Filter Company, Limited, 121, Oxford Street, London, W.

Description:-

This filter (Plate III) is composed of diatomaceous earth called "Kieselguhr", and it consists of a hollow cylinder, 7½ inches long and 1 inch in diameter, which is open at the lower end only, where it is provided with a glazed porcelain nozzle. At the junction of the cylinder with the nozzle, the latter is provided with a circular flange, 1½ inch in diameter, on which is supported a circular india rubber washer. The internal cavity of the cylinder is cylindrical in shape, 6⅞ inches long and ⅜ inch in diameter, and opens into the porcelain nozzle at its lower end. The filtering material is 5/16 inch thick between the outer surface and internal cavity of the cylinder. The superficial filtering area of the outer surface of the cylinder is 24.34 square inches and that of the wall of the internal cavity 8.1 square inches, so that the quantity of water filtering through 1 square inch of the wall of the internal cavity is equivalent to the quantity of water filtering through 3 square inches of the outer surface of the cylinder. The cylinder is enclosed in a metal case, and is retained in position by means of a metal cap, which is screwed on to the lower end of the case and provided at its centre with a circular aperture, through which projects the nozzle of the cylinder. The upper end of the metal case is provided with

a stop-cock, which, when the filter is in use, is screwed on to a water supply-pipe, from which the water enters the metal case, filters through the cylinder into its internal cavity, and escapes through the nozzle at the lower end of the cylinder.

The Pasteur-Chamberland Filter.

Manufacturers:-

The Pasteur-Chamberland Filter Company, 58, Rue Notre-Dame-de-Lorette, Paris.

Agents:-

Messrs. J. Defries & Sons, 147, Hounds-ditch, London, E.C.

Description.

This filter (Plate III) is composed of very fine grained unglazed porcelain; and it is constructed and used in the same manner as the Nordtmeyer-Berkefeld Filter. The cylinder, stamped "B" is 8 inches long and 1 inch in diameter. The internal cavity is $7\frac{7}{8}$ inches long and $\frac{10}{12}$ inch in diameter. The filtering material is $\frac{1}{12}$ inch thick between the outer surface and internal cavity of the cylinder. The superficial filtering area of the outer surface of the cylinder is 25.92 square inches and that of the wall of the internal cavity 21.15 square inches, so that the quantity of water filtering through 1 square inch of the wall of the internal cavity is equivalent to the quantity of water filtering through 1.22 square inch of the outer surface of the cylinder. The two cylinders experimented with were stamped "B" on the upper end.

Method of Preparation for Experiment.

Both filters were prepared in exactly the same manner and used under the same conditions in each series of experiments. The porcelain nozzle of each filter is connected to a gun-metal nozzle by means of a short piece of $\frac{3}{8}$ inch india rubber tube secured at each end with silked copper wire. The gun-metal nozzles are $4\frac{1}{2}$ inches long, $\frac{1}{4}$ inch in diameter, tapered at the lower end with a terminal bore of $\frac{1}{16}$ inch, and, except in the first series of experiments, provided with a circular flange $\frac{7}{8}$ inch in diameter, 1 inch from the lower end of the nozzle. 19 drops from each of these gun-metal nozzles measure 1 cubic centimetre respectively. Before sterilizing the cylinders, the india rubber tubes were placed on them and the lower ends of the gun-metal nozzles were covered with cotton wool secured with cord, to prevent the entrance of air micro-organisms during cooling of the cylinders, before filtration was established. The two cylinders, thus prepared, were placed in distilled water in a tin trough and sterilized by boiling in the autoclave. In the first series of experiments both prepared cylinders were boiled at 115°C. ($12\frac{1}{2}$ lbs steam pressure to the square inch) for $\frac{1}{4}$ hour; in the second series of experiments at 120°C. (15 lbs steam pressure to the square inch for $\frac{1}{2}$ hour); in the third series with the Nordtmeyer-Berkefeld Filter at 120°C. for 1 hour; and in the last series with both filters at 115°C. for 1 hour. In all the series of experiments the sterilized prepared cylinders were transferred to their metal cases while hot, and as soon as they were cool the stop-cocks were turned full on, and the water allowed to filter continuously

day and night until the end of each series of experiments.

Plate IV shows the method adopted of fixing up the filters for experiment in the laboratory. A metal water-pipe soldered to the end of a main water-tap is fixed along the top of a range of shelves for bottles. This supply-pipe is provided with (1) a gun-metal tap for supplying unfiltered water, (2) a water pressure gauge, (3) a short branch to which is fixed the Nordtmeyer-Berkefeld Filter, and (4) a terminal arm to which is fixed the Pasteur-Chamberland Filter.

Method of Making the Experiments.

As soon as filtration was established in both filters, after having been prepared and fixed up in the manner described, the cotton wool covering the lower ends of the gun-metal nozzles was removed with sterilized iron tongs. The gun-metal tap for unfiltered water and the gun-metal nozzles of the filters were invariably sterilized in a Bunsen flame and allowed to cool before collecting water for making cultures with in each experiment. After sterilizing the nozzles, ten minutes' filtration was allowed before collecting the filtered water for making cultures with, so as to ensure the escape of all water heated in the Bunsen flame during sterilization of the nozzles. Only the lower ends of the nozzles, including the flanges, were heated in the Bunsen flame, and the subsequent ten minutes' filtration was ample for the purpose of allowing all heated

water to escape from the nozzles.
In the first series of experiments and in the first ten experiments of the second series with both filters, collecting flasks and dropping tubes were used in the same manner as described for the Aitkins and Maignen's Filters; but in all the other experiments with both filters, 1 cubic centimetre (19 drops) of filtered water was received direct from the gun-metal nozzles into each tube of sterilized gelatin jelly. This method considerably lessened the chance of air micro-organisms accidentally entering the cultures, especially in the experiments made before the gun-metal nozzles were provided with flanges. The diameter of the mouths of the collecting flasks is $\frac{3}{4}$ inch; and in the case of the Pasteur-Chamberland Filter, after three days' filtration, the mouth of the collecting flask had to be left uncovered for 1 minute until sufficient water was received to fill the dropping tube; after a week's filtration for 2 minutes; after a fortnight's filtration for 3 minutes; and after three weeks' filtration for 4 or 5 minutes. On referring to Table X, second series of experiments with the Pasteur—Chamberland Filter, it will be observed that out of the first ten experiments, in which collecting flasks and dropping tubes were used, 4 of the 10 plate cultures contained in all 7 bacterial colonies; but that in the remaining 15 experiments, the 6 plate cultures and 12 of the 13 roll cultures were absolutely sterile. In the one exception the roll culture contained only 1 bacterial colony. In the third series of experiments (Table XI), made with the same

cylinder, stamped "B", that was used in the second series, 28 roll cultures, made on 28 consecutive days of continuous filtration were absolutely sterile. In the case of the Nordtmeyer-Berkefeld Filter, in which the rate of filtration is greater than in the Pasteur-Chamberland Filter, the mouths of the collecting flasks were not left uncovered so long as in the case of the latter filter. In every experiment, with each filter, in which 10-drop and 20-drop plate cultures were made, the filtered water was allowed to fall into each test-tube of sterilized gelatine jelly respectively from the same dropping tube, without filling the dropping tube a second time. If, therefore, the filtered water contained micro-organisms in any number, it is very improbable that bacterial colonies would occur in only one of the two cultures made with filtered water from the same dropping tube. On referring to Table V, first series of experiments with the Nordtmeyer-Berkefeld Filter, it will be observed that when micro-organisms once appeared in the plate cultures they were present in considerable numbers in both the 10-drop and 20-drop cultures in each experiment, and continued to occur in large numbers in every subsequent culture; whereas, on referring to Table IX, first series of experiments with the Pasteur-Chamberland Filter, it will be observed that out of 56 plate cultures only 7 cultures contained 1 bacterial colony each, the remaining 49 cultures being absolutely sterile, but that in no instance did the 10-drop and 20-drop cultures, made with filtered water from the same dropping tube, both contain bacterial colonies. It is, therefore, pretty certain that the few bacterial colonies found in the cultures of the first and second series of experiments with the Pasteur-Chamberland Filter were due to air micro-organisms having accidentally fallen into the cultures during the time the cultures were being made. The plate cultures were made with sterilized

gelatine jelly in the same manner as described for the Aitken's and Maignen's Filters. The roll cultures were made in Esmarch's tubes, which were rotated in Houston's frame until the jelly solidified, after which the mouths of the tubes were covered with sterilized india rubber caps.

In the first and second series of experiments with both filters and in the third series with the Nordtmeyer-Berkefeld Filter (Tables V, VI, VII, IX and X), the plate and roll cultures were incubated at 19°C. In the last series of experiments with both filters (Tables VIII and XI) the cultures were incubated at 21°C.

The plate cultures of Edinburgh main water (Table XII), made simultaneously with the first series of experiments with both filters, were incubated at 19°C.

In counting the bacterial colonies in the plate cultures, Petri's capsules containing the cultures were placed on a black slab divided into squares, and the number of colonies in each square was counted with the aid of a lens. The actual number of colonies in each plate culture was counted, except when the number exceeded 3000, when it was estimated approximately from the number of colonies counted in part of the culture. The number of bacterial colonies in the roll cultures was counted by means of the ingenious apparatus designed by Dr. J. Buchanan Young, and figured and described by him in the Proceedings of the Royal Society of Edinburgh, Vol. XX, p. 28, 1892-93.

In Tables V, IX and XII the number of bacterial colonies in 1 cubic centimetre of water is

calculated from the number of colonies actually present in the 10-drop and 20-drop cultures respectively, 15 drops from each of the dropping tubes used being equivalent to 1 cubic centimeter of water. In Table XII, however, the number of moulds actually present in the 10-drop and 20-drop cultures with unfiltered Edinburgh main water is recorded, instead of the calculated number in 1 cubic centimeter of the water. Each colony is held to represent one microorganism in the water at the time of making the cultures. The rate of filtration of each filter was calculated on the first day from the time taken to fill a ½-litre flask, and after that from the time taken to fill a 100-cc flask. In the second series of experiments with the Nordtmeyer-Berkefeld Filter (Table VI) the rate of filtration, immediately after turning on the water at a pressure of 21 lbs to the square inch, was 30 litres per hour, which is at the rate of 1.233 litre per hour for each square inch of the outer filtering surface of the cylinder, and 3.703 litres per hour for each square inch of the inner filtering surface of the cylinder. At the end of 24 hours' continuous filtration, the rate of filtration at 20 lbs pressure was only 1.333 litre per hour, which is at the rate of 0.055 litre per hour for each square inch of the outer filtering surface and 0.165 litre per hour for each square inch of the inner filtering surface. In the second series of experiments with the Pasteur-Chamberland Filter (Table X), the rate of filtration, immediately after turning on the water at a pressure of 21 lbs to the square inch, was 6 litres per hour, which is at the rate of 0.231 litre per hour for

each square inch of the outer filtering surface of the cylinder, and 0.284 litre per hour for each square inch of the inner filtering surface of the cylinder. At the end of 24 hours' continuous filtration, the rate of filtration at 20 lbs pressure was 1.143 litre, which is at the rate of 0.044 litre per hour for each square inch of the outer filtering surface, and 0.054 litre per hour for each square inch of the inner filtering surface. In comparing the rates of filtration through each square inch of the outer filtering surfaces of these two filters, it will be observed that, immediately after turning on the water, the rate of filtration through the Nordtmeyer-Berkefeld Filter is 5 1/3 times greater than that through the Pasteur-Chamberland Filter; but that at the end of 24 hours' continuous filtration, the rate of filtration is only 1 1/4 time greater than that through the Pasteur-Chamberland Filter.

In the first series of experiments (Tables V and IX), during 31 days' continuous filtration at pressures varying between 17 lbs and 46 lbs to the square inch, the Nordtmeyer-Berkefeld Filter maintained a slight superiority over the Pasteur-Chamberland Filter in the rate of filtration; but after the first day's filtration, the difference between the rates of filtration through the two filters was steadily diminished. This diminution is caused by the greater deposit of sediment, in a given time, on the Nordtmeyer-Berkefeld Filter than on the Pasteur-Chamberland Filter, when both filters are used under the same conditions of pressure and continuous filtration, without cleansing the filters.

First Series of Experiments with the Nordtmeyer-Berkefeld and Pasteur-Chamberland Filters and Edinburgh Main Water. Tables V, IX & XII.

This series of experiments was commenced simultaneously with both filters on 29th January 1894. The Pasteur-Chamberland cylinder was stamped "F", and it had a narrow flange supporting the india rubber washer, in consequence of which the india rubber washer was forced down over the flange by the increased water pressure (40 lbs to the square inch) during the first night, and on the following morning the unfiltered water was discovered escaping from the lower end of the metal case and flowing down over the india rubber tube and gun-metal nozzle. The cylinder was removed from the metal case and another cylinder stamped "B" with a broader flange, after having been prepared and sterilized in the same manner, was substituted for it. The experiments with the Pasteur-Chamberland Filter were, therefore, one day behind the corresponding experiments with the Nordtmeyer-Berkefeld Filter. In each experiment 10-drop and 20-drop cultures were made in sterilized Petri's capsules with unfiltered Edinburgh main water drawn from the nozzle for the purpose and with filtered water from each of the two filters. The filters were never cleaned throughout the whole series of experiments. The plate cultures made with filtered water were examined and the number of bacterial colonies counted at the end of 7 days' incubation. The bacterial colonies in the plate cultures made with unfiltered Edinburgh main

water were counted at the end of 7 days' incubation, except when the cultures showed signs of liquefying before the expiration of that time.
Results. In the case of the Nordtmeyer-Berkefeld Filter (Table V), although micro-organisms were constantly present in considerable numbers in the unfiltered water, all the plate cultures made daily with the filtered water during the first ten days' continuous filtration were absolutely sterile; but in the eleventh day's culture there were 590 micro-organisms per cubic centimetre of filtered water in the 10-drop culture, and 770 in the 20-drop culture. In the next four days' cultures the numbers varied between 101 and 941. After the 15th experiment the filter was allowed to filter continuously day and night for 16 days longer, after which the last experiment was made on 1st March. In this experiment the 10-drop culture contained 147 micro-organisms per cubic centimetre of filtered water, and the 20-drop culture 165. The number of micro-organisms in the plate cultures made with filtered water do not bear any relation to that in the plate cultures made simultaneously with unfiltered water. When micro-organisms first appeared in the plate cultures made with filtered water on the eleventh day of continuous filtration, there had accumulated eleven days' deposit of micro-organisms on the outer surface of the filter from the water which had passed through the filter in that period. It is not, therefore, to be expected that there should be any relation between the numbers of micro-organisms present in the filtered and unfiltered water at any particular time; but

it is most probable that the micro-organisms gradually grow through the pores of the filter from the bacterial mud deposited on the outer surface of the cylinder.

In the case of the Pasteur-Chamberland Filter (Table IX), the 10-drop and 20-drop plate cultures were made daily during the first 14 days' continuous filtration, and then on every other day during the next 28 days' continuous filtration. Of the total 56 plate cultures made with filtered water in 28 experiments extending over a period of six weeks' continuous filtration, only 7 cultures contained 1 micro-organism each, the remaining 49 cultures being absolutely sterile. The 7 cultures containing micro-organisms occurred in experiments Nos 1, 10, 14, 17, 21, 25 and 26 On removing the filtering cylinders from their metal cases at the end of the series of experiments, both cylinders were coated on the outer surface with a copious deposit of brown slimy mud. By means of a sterilized platinum wire a little quantity of this mud was transferred to a test-tube of sterilized nutrient-gelatine jelly and a plate culture made. The number of micro-organisms in this culture was uncountable, and the jelly was liquified at the end of 5 days' incubation at 19°C. Some moulds were also present in the culture.

Conclusions. The Nordtmeyer-Berkefeld Filter sterilized the filtered water during the first ten days' continuous filtration, but after that the filtered water invariably contained large numbers of micro-organisms which had grown through the pores of the filter.

In the case of the Pasteur-Chamberland Filter

it is pretty certain, for the reasons previously mentioned, that the filtered water was absolutely sterilized during six weeks' continuous filtration under pressures varying between 17 lbs and 39 lbs to the square inch, and that the 7 plate cultures containing 1 bacterial colony each were accidentally contaminated during the process of making the cultures.

Second Series of Experiments with the Nordtmeyer-Berkefeld and Pasteur-Chamberland Filters and Bacillus violaceus and Edinburgh Main Water. Tables VI and X.

This series of experiments was commenced simultaneously with both filters on 9th April 1894, and extended over a period of 3 weeks continuous filtration in the case of the Nordtmeyer-Berkefeld Filter and 6 weeks in the case of the Pasteur-Chamberland Filter. New cylinders were used in both filters of the same pattern as those used in the first series of experiments, viz., the cylinder stamped "B" in the case of the Pasteur-Chamberland Filter. The space between the sterilized cylinder and its metal case, in each filter, was filled with water containing approximately 20,000 Bacilli violacei in each cubic centimetre. The metal case was then screwed on to the Edinburgh main water supply-pipe, and the stop-cock turned full on. The first 100 cubic centimetres of filtered water from each filter was received into a sterilized collecting-

~~collecting~~ flask, and by means of sterilized dropping tubes 10-drop and 20-drop plate cultures were made with the filtered water.
In the case of the Nordtmeyer-Berkefeld Filter 20 plate cultures were made, each with 1 cubic centimetre of filtered water. The first 19 experiments were made on the first 19 days of continuous filtration; and the last experiment at the end of 21 days' continuous filtration. 8 roll cultures were also made with 1 cubic centimetre of filtered water simultaneously with the last 8 plate cultures.
In the case of the Pasteur-Chamberland Filter 25 experiments were made, the first 16 daily, the next 8 every other day, and the last experiment 11 days after the previous one. One plate culture was made with 1 cubic centimetre of the filtered water in each of the first 16 experiments, and one roll culture was made with the same quantity of filtered water in each of the last 13 experiments.
Both filters were allowed to filter continuously day and night, without cleansing, throughout the whole series of experiments; and the cultures were made at pressures varying between 18 lbs and 36 lbs to the square inch; but at night the pressure was greater, usually between 40 lbs and 46 lbs.
The water, containing Bacillus violaceus, which was placed in the filters at the beginning of this series of experiments, was prepared in the following manner:— On 9th April 1894, to a litre of distilled water, which had been previously sterilized by boiling at 120°C. in a sterilized glass flask plugged with cotton wool for ½ hour in the

autoclave and allowed to cool, 1 cubic centimetre of a broth culture of Bacillus violaceus made on 27th March 1894 was added by means of a sterilized dropping tube. The Bacilli violacei were then well mixed with the water by shaking the flask. 10-drop and 20-drop plate cultures in sterilized gelatine jelly were made with this water, and at the end of 3 days' incubation at 19°C. the mean of the two cultures was approximately 20,000 Bacilli violacei in each cubic centimetre of the water.

The number of micro-organisms in the Edinburgh main water was not ascertained in this series of experiments, but a reference to Table XII will show that they are always present in considerable numbers.

In the first 8 experiments with both filters the cultures were incubated at 19°C. for 7 days before they were examined and the number of bacterial colonies counted. In all the remaining cultures, with both filters, the cultures were incubated at the same temperature and the bacterial colonies were counted at the end of 14 days' incubation.

Results. In the case of the Nordtmeyer-Berkefeld Filter no Bacilli violacei occurred in any of the cultures. The first 3 plate cultures were sterile, but in the remaining 17 plate cultures the number of other species of micro-organisms in 1 cubic centimetre of the filtered water varied from 4 to 172. All the roll cultures contained other species of micro-organisms, but the number of bacterial colonies was not counted, except in the last culture, which contained 17 colonies. At the end of 3 weeks' continuous filtration, two

plate cultures in sterilized gelatine jelly were made with some of the mud deposited on the outer surface of the cylinder, but no Bacilli violacei occurred in either culture at the end of 10 days' incubation at 10°C. Other species of micro-organisms, however, were present in these cultures in large numbers. In the case of the Pasteur-Chamberland Filter no Bacilli violacei occurred in any of the cultures. Of the 16 plate cultures 12 were sterile and 4 contained from 1 to 3 bacterial colonies each, but these 4 non-sterile cultures occurred in the first 10 experiments in which collecting flasks and dropping tubes were used. In the remaining 15 experiments, in which the filtered water was received direct from the gun-metal nozzles into the test-tubes and Esmarch's roll culture tubes, all the plate cultures and 12 of the 13 roll cultures were sterile. The 1 non-sterile roll culture contained only 1 bacterial colony. At the end of 6 weeks' continuous filtration the cylinder was washed in a litre of distilled water by means of a soft nail brush. A plate culture in sterilized gelatine jelly was made with $\frac{1}{15}$ cubic centimetre of the muddy water in which the cylinder had been washed, and at the end of 2 days' incubation at 19°C. the number of colonies of other species of micro-organisms was uncountable and the jelly quickly liquified. No Bacilli violacei were observed in this culture.

Conclusions. No Bacilli violacei occurred in any of the cultures made with the filtered water from both filters; but as no colonies of this species of Bacillus occurred in the

plate cultures made with the bacterial mud deposited on the outer surfaces of the cylinders of both filters, it is possible that these Bacilli may have been killed out by the hosts of other species of micro-organisms deposited on the cylinders from the Edinburgh Main water, before the Bacilli violacei had time to grow through the pores of the Nordtmeyer-Berkefeld Filter. It is not improbable, however, that this filter may prevent the larger species of micro-organisms from passing through its pores, while the smaller species are allowed to grow or pass through. The advantage, therefore, of using ordinary Edinburgh main water for testing the sterilizing power of filters is very apparent, because it always contains considerable numbers of different species of micro-organisms of different sizes.

With reference to the other species of micro-organisms derived from the Edinburgh main water, they occurred, in the case of the Nordtmeyer-Berkefeld Filter, in every culture made with the filtered water, after the second day of continuous filtration, in numbers varying from 4 to 172 micro-organisms in each cubic centimetre of filtered water.

In the case of the Pasteur-Chamberland Filter, it is pretty certain, for the reasons previously mentioned, that the 5 non-sterile cultures, containing from 1 to 3 bacterial colonies each, were accidentally contaminated during the process of making the cultures; and that the filtered water was absolutely sterilized during six weeks' continuous filtration at pressures varying between 18 lbs and 36 lbs to the square inch.

Third Series of Experiments with the Nordtmeyer-Berkefeld Filter and Edinburgh Main Water. Table VII.

This series of experiments was commenced on 1st May 1894, and extended over a period of 3 weeks' continuous filtration without cleansing the filter. The experiments were made simultaneously with those of the latter part of the second series with the Pasteur-Chamberland Filter. The cylinder used in the second series of experiments was also used in the third series. 14 experiments were made, the first 13 daily, and the last experiment 8 days after the previous one. One plate culture was made with 1 cubic centimetre of the filtered water in each experiment, and one roll culture was made with the same quantity of filtered water in each of the first 8 experiments. The filtered water was received direct from the gun-metal nozzles into the test-tubes and Esmarch's roll culture tubes, and the chance of air micro-organisms accidentally falling into these tubes, during the time the filtered water was being received, was reduced to a minimum by means of the circular flange, 7/8 inch in diameter, on the gun-metal nozzle, 1 inch from its lower or dropping end. This flange covered the mouths of the tubes, without touching them, during the time the filtered water was being received from the lower end of the nozzle, which was inside the mouths of the tubes.

The cultures were made at pressures varying from 14 lbs to 34 lbs to the square inch, and

they were all incubated at 19°C. for 14 days before the bacterial colonies were counted.

Results. In the first 3 experiments all the plate and roll cultures were sterile. In experiment No 4, made at the end of 3 days' continuous filtration, there were 220 colonies in the plate culture and 7 colonies in the roll culture. The remaining 10 plate cultures contained from 3 to 776 colonies each, with the exception of experiment No 11 in which the plate culture was sterile. In No 5 experiment the roll culture was sterile, but in the remaining 3 experiments the roll cultures contained from 2 to 80 colonies in each culture.

Conclusions. In this series of experiments the Nordtmeyer Berkefeld Filter sterilized the filtered water during 2 days' continuous filtration, at pressures varying between 15 lbs and 20 lbs to the square inch; but in all the subsequent experiments, with one exception, there were from 3 to 776 micro-organisms in each cubic centimetre of the filtered water. These micro-organisms were undoubtedly derived from the Edinburgh main water with which the filter was constantly supplied, and they undoubtedly passed through the pores of the filter.

Fourth and Third Series of Experiments with the Nordtmeyer-Berkefeld and Pasteur-Chamberland Filters respectively and Micrococcus sp. and Edinburgh Main Water. Tables VIII & XI.

These two series of experiments were commenced simultaneously on 25th May 1894, and in the case of the Nordtmeyer-Berkefeld Filter extended over 10 days' continuous filtration, and in the case of the Pasteur-Chamberland Filter over 28 days' continuous filtration, without cleansing the filters in either case. The cylinder used in the second and third series of experiments with the Nordtmeyer-Berkefeld Filter, and the cylinder used in the second series with the Pasteur-Chamberland Filter, were also used in the present series of experiments with both filters respectively.

On 25th May 1894 the space between the sterilized cylinder and its metal case, in each filter, was filled with a diluted broth culture containing approximately 47,250 Micrococci sp. in each cubic centimetre. The metal case was then screwed on to the Edinburgh main water supply-pipe, and the stop-cock turned full on. After 50 cubic centimetres of water had passed through the filter, the stop-cock was screwed down until the filtered water fell in drops from the gun-metal nozzles. In the case of the Nordtmeyer-Berkefeld Filter, one plate culture and one roll culture were then made with 1 cubic

Centimetre (19 drops) of filtered water received direct from the gun-metal nozzle into the test-tube and Esmarch's tube respectively. In the case of the Pasteur-Chamberland Filter, one roll culture was made in the same manner. The stop-cocks of both filters were then turned full on, and both filters were allowed to filter continuously day and night until the end of the series of experiments.

In the case of the Nordtmeyer-Berkefeld Filter, 10 experiments were made on 10 consecutive days at pressures varying between 14 lbs and 46 lbs to the square inch. One plate culture was made with 1 cubic centimetre of filtered water in each experiment; and one roll culture was made with the same quantity of filtered water in experiments Nos. 1 and 8.

In the case of the Pasteur-Chamberland Filter, 28 experiments were made on 28 consecutive days at pressures varying between 12 lbs and 46 lbs to the square inch. One roll culture was made with 1 cubic centimetre of filtered water in each of the 28 experiments.

The diluted broth, containing Micrococcus sp. , which was placed in the filters at the beginning of the series of experiments, was prepared in the following manner:— On 19th May 1894 100cc of sterilized broth were inoculated by means of a sterilized platinum wire with part of a colony of Micrococcus sp. taken from the roll culture made on 30th

April 1894, in experiment No 20 of the second series of experiments with the filtered water from the Nordtmeyer-Berkefeld Filter. After 6 days' incubation at 21°C. the 100 cc of broth were mixed with an equal quantity of distilled water. A plate culture in sterilized gelatine jelly made with 1 cc of the diluted broth culture, after 7 days' incubation at 21°C., contained approximately 47,250 Micro-cocci sp. This Micro-coccus was easily recognised by its occurring in yellow globose slow-growing nonliquefying colonies in the plate and roll cultures made with the filtered Edinburgh main water taken from the Nordtmeyer-Berkefeld Filter. The species was not identified. The cultures made with the filtered water from both filters were incubated at 21°C. In the case of the Nordtmeyer-Berkefeld Filter the cultures in the first 4 experiments were incubated for 14 days, but in the remaining 6 experiments the cultures had to be examined at the end of from 2½ to 7 days, on account of the enormous numbers of micro-organisms liquefying the jelly. In the case of the Pasteur-Chamberland Filter the cultures were examined at the end of 14 days' incubation.

Results. In the case of the Nordtmeyer-Berkefeld Filter the plate and roll cultures in the first 4 experiments were sterile, except in experiment No 2 in which the plate culture contained 1 colony of another species of micro-organism. In this experiment the culture was probably accidentally contaminated during the process of making the culture.

In experiment No 5, made after 4 days' continuous filtration, there were 40 colonies of Micrococcus sp. and 1 colony of another species of micro-organism in the plate culture. In the next experiment the plate culture contained 254 colonies of Micrococcus sp. and 3 colonies of other species of micro-organisms. In the remaining 4 plate cultures and in the roll culture made in experiment No 8 the number of colonies of Micrococcus sp. and other species of micro-organisms was uncountable and the jelly was more or less liquefied.

In the case of the Pasteur-Chamberland Filter the 28 roll cultures, made on 28 consecutive days of continuous filtration, were all absolutely sterile, notwithstanding that plate cultures made with the mud deposited on the cylinder during 27 days of continuous filtration contained enormous numbers of micrococci sp.? In this series of experiments both filters were put to a very severe test, because the dilute broth culture with which the filters were filled contained approximately 47,250 micro-organisms of Micrococcus sp. which had passed through the Nordtmeyer-Berkefeld Filter in the second series of experiments with that filter. The enormous number of Micrococci sp. and other species of micro-organisms in the filtered water from the Nordtmeyer-Berkefeld Filter, after the third day of continuous filtration, conclusively proves that this filter cannot permanently sterilize water, whereas the entire absence of micro-organisms from the filtered water from the Pasteur-Chamberland Filter, when subjected

to precisely the same conditions, conclusively proves that the Pasteur filter can permanently sterilize water containing micro-organisms.

General Conclusions.

The Pasteur-Chamberland Filter is the best and the only one on which reliance can be placed for permanently sterilizing water. Its use is, therefore, recommended for sterilizing drinking water, water used for surgical dressings, and wherever sterilized water is required for any particular purpose.

This filter is most likely to prove of valuable service in reducing the number of cases of such diseases as Cholera and enteric fever, in countries in which the drinking water is contaminated with the pathogenic micro-organisms of these diseases.

These conclusions have been arrived at from the results of the three series of experiments made with the Pasteur-Chamberland cylinders stamped "B", which are suitable for slow filtration. The cylinders stamped "F" for rapid filtration were not experimented with, on account of the flange being too narrow to support the india rubber washer when exposed to high water-pressure in the filter.

The Atkins' Patent Water Filter.

Tables I & II.

The Atkins Patent Water Filter.

Table I. Results of the First Series of Experiments with Edinburgh Main Water.

Number of Experiment.	Date of Culture.	Temperature of Water. °C.	Rate of Filtration. Litres per hour.	Date of Counting Micro-organisms.	Micro-organisms in 1cc of Filtered Water. Plate Culture. 10-Drops Culture.	Micro-organisms in 1cc of Filtered Water. Plate Culture. 20-Drops Culture.	Micro-organisms in 1cc of unfiltered Water. Plate Culture. 10-Drops Culture.	Micro-organisms in 1cc of unfiltered Water. Plate Culture. 20-Drops Culture.	Micro-organisms in 1cc of unfiltered Water. Mean.	Remarks.
1	1st Dec. 1893	Not recorded	Not recorded	5th Dec. 1893	Uncountable ~~Innumerable~~	Uncountable ~~Innumerable~~	237	83	160	Culture made after 1 days slow filtration.
2	8th Dec. 1893	Not recorded	17.000	11th Dec. 1893	Uncountable ~~Innumerable~~	Uncountable ~~Innumerable~~	Not recorded.			Culture made after the continuous slow filtration of 12 litres of water between 1st and 8th Dec. 1893.

Table II. Results of the Second Series of Experiments with Bacillus violaceus.

Number of Experiment.	Date of Culture.	Temperature of Water. °C.	Rate of Filtration. Litres per hour.	Date of Counting Micro-organisms.	Micro-organisms in 1cc of Filtered Water. Plate Culture. Bacillus violaceus	Micro-organisms in 1cc of Filtered Water. Plate Culture. Other Micro-organisms.	Micro-organisms in 1cc of unfiltered Water. Plate Culture. Bacillus violaceus	Micro-organisms in 1cc of unfiltered Water. Plate Culture. Other Micro-organisms.	Remarks.
1	17th May 1894	21.0	20.000	21st May 1894	0	3150	12	33	Culture made after the filtration of 2 litres of water immediately after placing the unfiltered water in the filter.
2	18th May 1894	18.5	20.000	22nd May 1894	Uncountable ~~Innumerable~~	Uncountable ~~Innumerable~~	Not recorded		Culture made after the filtration of 1 litre of water.
3	23rd May 1894	20.0	19.000	25th May 1894	Uncountable ~~Innumerable~~	Uncountable ~~Innumerable~~	Not recorded.		Culture made after the filtration of 2 litres of water.

Maignen's Table "Filtre Rapide".

Tables III. & IV.

Maignen's Table "Filtre Rapide".

Table III. Results of the First Series of Experiments with Edinburgh Main Water.

Number of Experiment.	Date of Culture.	Temperature of Water. °C.	Rate of Filtration. Litres per hour.	Date of Counting Micro-organisms.	Micro-organisms in 1 cc of Filtered Water. 10-drops Plate Culture.	Micro-organisms in 1 cc of Filtered Water. 20-drops Plate Culture.	Micro-organisms in 1 cc of Unfiltered Water. 10-drops Plate Culture.	Micro-organisms in 1 cc of Unfiltered Water. 20-drops Plate Culture.	Mean.	Remarks.
1	1st Dec. 1893	Not recorded	Not recorded	5th Dec. 1893	Uncountable ~~Innumerable~~	Uncountable ~~Innumerable~~	237	83	160	Culture made after 1 days slow filtration.
2	8th Dec. 1893	Not recorded	9.000	11th Dec. 1893	Uncountable ~~Innumerable~~	Uncountable ~~Innumerable~~	Not recorded.			Culture made after the continuous slow filtration of 4.250 litres of water between 1st and 8th Dec. 1893.

Table IV. Results of the Second Series of Experiments with Bacillus violaceus.

Number of Experiment.	Date of Culture.	Temperature of Water. °C.	Rate of Filtration. Litres per hour.	Date of Counting Micro-organisms.	Micro-organisms in 1 cc of Filtered Water. Plate Culture. Bacillus violaceus.	Micro-organisms in 1 cc of Filtered Water. Plate Culture. Other Micro-organisms.	Micro-organisms in 1 cc of Unfiltered Water. Plate Culture. Bacillus violaceus.	Micro-organisms in 1 cc of Unfiltered Water. Plate Culture. Other Micro-organisms.	Remarks.
1	17th May 1894	21.0	9.000	21st May 1894	0	4	12	33	Culture made after the filtration of ½ litre of water, immediately after placing the unfiltered water in the filter.
2	18th May 1894	18.5	9.000	22nd May 1894	7	26	Not recorded		Culture made after the filtration of ½ litre of water.
3	23rd May 1894	20.0	8.200	25th May 1894	Uncountable ~~Innumerable~~	Uncountable ~~Innumerable~~	Not recorded		Culture made after the filtration of ½ litre of water

The Nordtmeyer-Berkefeld Filter.

Table V.

The Nordtmeyer — Berkefeld Filter.

Table V. Results of the First Series of Experiments with Edinburgh Main Water.

Number of Experiment.	Date of Culture at 1 p.m.	Temperature of Water at 1 p.m. C.	Pressure of Water in Main and Rate of Filtration. 1 p.m. lbs per square inch	1 p.m. Litres per hour	Midnight. lbs per square inch	Midnight. Litres per hour
	29th Jan. 1894	Not recorded	20	25.714	40	2.377
1	30th	6.0	22	0.714	42	1.111
2	31st	4.5	19	0.454	40	0.705
3	1st Feb. 1894	5.0	18	0.308	41	0.500
4	2nd	6.5	18	0.278	44	0.444
5	3rd	8.0	17	0.208	46	0.414
6	4th	7.5	29	0.304	44	0.400
7	5th	6.3	17	0.214	42	0.380
8	6th	7.0	17	0.193	---	---
9	7th	8.0	18	0.189		
10	8th	7.5	18	0.170		
11	9th	7.0	20	0.176		
12	10th	9.0	18	0.132		
13	11th	7.3	25	0.165		
14	12th	7.1	20	0.141		
15	13th	6.8	20	0.130		
	14th	6.9	22	0.129		
	15th	7.7	22	0.138		
	16th	6.4	22	0.133		
	17th	7.1	20	0.114		
	18th	6.0	31	0.174		
	19th	6.8	21	0.116		
	20th	6.1	18	0.101		
	21st	5.5	21	0.108		
	22nd	5.8	22	0.115		
	23rd	6.6	23	0.120		
	24th	6.4	19	0.090		
	25th	6.7	39	0.150		
	26th	5.6	18	0.080		
	27th	7.1	21	0.092		
	28th	6.0	21	0.088		
16	1st March 1894	6.5	23	0.097		

Date of Counting Micro-organisms.	Micro-organisms in 1 cc of Filtered Water. 10-days Culture.	20-days Culture.	Micro-organisms in 1 cc of unfiltered Water.	Remarks.
				No cultures made.
6th Feb. 1894	0	0	242	
7th	0	0	17	
8th	0	0	4	
9th	0	0	17	
10th	0	0	39	
11th	0	0	15	
12th	0	0	646	
13th	0	0	1528	
14th	0	0	158	
15th	0	0	302	
16th	590	770	156	
17th	356	384	485	
18th	131	101	316	
19th	941	831	2420	
20th	437	481	4372	
			1345	
			1124	
			[illegible]	
			5927	
				No cultures made with the filtered water
			699	
			841	
			11340	
			379	
8th March 1894	147	165	1290	

The Nordtmeyer-Berkefeld Filter.

Table VI.

The Nordtmeyer — Berkefeld Filter.

Table VI. Results of the Second Series of Experiments with Bacillus violaceus and Edinburgh Main Water.

Number of Experiment.	Date of Culture at 2 p.m.	Temperature of Water °C.	Pressure of Water in Main Lbs per square inch.	Rate of Filtration. Litres per hour.	Date of Counting Micro-organisms.	Micro-organisms in 1 cc of Filtered Water. Plate Culture. Bacillus violaceus.	Plate Culture. Other Micro-organisms.	Roll Culture. Bacillus violaceus	Roll Culture. Other Micro-organisms.	Bacilli violacei in 1 cc of unfiltered Water.	Remarks.
1	9th April 1894	10.0	21	30.000	16th April 1894	0	0			20,000	Culture made with 1 cc from first 100 cc of filtered water.
2	10th	10.3	20	1.333	17th	0	0				
3	11th	10.7	21	0.923	18th	0	0				
4	12th	11.4	21	0.727	19th	0	4				
5	13th	10.6	21	0.585	20th	0	4				
6	14th	10.0	25	0.616	21st	0	10				
7	15th	8.8	36	0.666	22nd	0	14				
8	16th	9.4	32	0.600	23rd	0	15				
9	17th	9.8	21	0.363	1st May 1894	0	30				
10	18th	10.0	23	0.387	2nd	0	51				
11	19th	10.1	19	0.308	3rd	0	172				
12	20th	10.0	20	0.300	4th	0	102				
13	21st	10.0	27	0.338	5th	0	43	0	Present ~~100~~		Number of micro-organisms in roll cultures not counted.
14	22nd	9.6	35	0.381	6th	0	70	0	Present ~~100~~		
15	23rd	10.1	21	0.246	7th	0	12	0	Present ~~100~~		
16	24th	10.4	20	0.224	8th	0	12	0	Present ~~100~~		
17	25th	10.0	21	0.228	9th	0	27	0	Present ~~100~~		
18	26th	10.3	22	0.231	10th	0	27	0	Present ~~100~~		
19	27th	10.5	23	0.238	11th	0	9	0	Present ~~100~~		
	28th	9.8	23	0.235							No cultures made.
	29th	10.3	36	0.292							
20	30th	11.0	22	0.212	14th	0	19	0	17		2 Micrococci sps.. in the roll culture, from one colony of which the unfiltered water, containing 47,250 Micrococci sps. and used in the Fourth Series of Nordtmeyer — Berkefeld and Third Series of Pasteur — Chamberland Experiments, derived its micro-organisms.

The Nordtmeyer–Berkefeld Filter.

Table VII.

Table VII. Results of the Third Series of Experiments with Edinburgh Main Water.

Number of Experiment	Date of Culture at 1 p.m.	Temperature of Water °C.	Pressure of Water in Main lbs per square inch	Rate of Filtration Litres per hour.	Date of Counting Micro-organisms.	Micro-organisms in 1cc of Filtered Water. Plate Culture.	Roll Culture.	Remarks.
1	1st May 1894	11.1	15	24.000	15th May 1894	0	0	Cultures made after the filtration of 1 litre of water, immediately after placing the unfiltered water in the filter.
2	2nd	10.8	19	1.538	16th	0	0	
3	3rd	10.7	20	0.882	17th	0	0	
4	4th	10.1	19	0.674	18th	220	7	
5	5th midday	10.5	14	0.500	19th	8	0	3 Micrococci s/p. in plate culture.
6	6th	10.0	34	0.685	20th	3	80	
7	7th	11.1	22	0.468	21st	22	2	1 Micrococcus s/p. in plate culture.
8	8th	10.8	20	0.421	22nd	8	4	
9	9th	10.5	18	0.358	23rd	352	—	
10	10th	10.6	20	0.375	24th	36	—	
11	11th	11.3	18	0.338	25th	0	—	
12	12th	11.7	18	0.315	26th	34	—	
13	13th	10.4	34	0.444	27th	776	—	
14	21st	11.7	22	0.200	4th June 1894	102	—	

The Nordtmeyer–Berkefeld Filter.

Table VIII.

The Nordtmeyer—

Berkefeld Filter.

Table VIII. Results of the Fourth Series of Experiments with Micrococcus sp. and Edinburgh Main Water.

Number of Experiment.	Date of Culture at 2 p.m.	Temperature of Water. °C.	Pressure of Water in Main. lbs per square inch.	Rate of Filtration. Litres per hour.	Date of Counting Micro-organisms.	Micro-organisms in 1 cc of Filtered Water. Plate Cultures. Micrococcus sp.	Plate Cultures. Other Micro-organisms	Roll Cultures. Micrococcus sp.	Roll Cultures. Other Micro-organisms	Micrococci in 1 cc of Unfiltered Water.	Remarks
1	25th May 1894	11·4	21	27.272	8th June 1894	0	0	0	0	47,250	Culture made after the filtration of 50 cc of water, immediately after replacing the unfiltered water in the filter.
2	26th	11·6	21	2.182	9th	0	1				
3	27th	10·8	36	1.463	10th	0	0				
4	28th	11·6	19	0.760	11th	0	0				
5	29th	10·9	17	0.631	5th	40	1				
6	30th	10·8	20	0.540	6th	254	3				
7	31st	11.3	21	0.472	5th	Uncountable	Uncountable				All the cultures partly liquefied.
8	1st June 1894	11·0	16	0.353	5th	Uncountable	Uncountable	Uncountable	Uncountable		
9	2nd midday	11·7	14	0.308	5th	Uncountable	Uncountable				
10	3rd midnight	11·8	46	0.600	6th	Uncountable	Uncountable				

The Pasteur – Chamberland Filter.

Table IX.

The Pasteur—Chamberland Filter.

Table IX. Results of the First Series of Experiments with Edinburgh Main Water.

Number of Experiment	Date of Culture at 1 p.m.	Temperature of Water at 1 p.m. °C.	Pressure of Water in Main and Rate of Filtration: 1 p.m. — lbs per square inch	1 p.m. — Litres per hour	Midnight. — lbs per square inch	Midnight. — Litres per hour
	30th Jan. 1894	6.0	22	5.000	42	2.000
1	31st	4.5	19	0.600	40	0.800
2	1st Feb. 1894	5.0	18	0.333	41	0.600
3	2nd	6.5	18	0.286	44	0.444
4	3rd	8.0	17	0.205	46	0.400
5	4th	7.5	29	0.285	44	0.353
6	5th	6.3	17	0.191	42	0.333
7	6th	7.0	17	0.176		
8	7th	8.0	18	0.176		
9	8th	7.5	18	0.154		
10	9th	7.0	20	0.160		
11	10th	9.0	18	0.117		
12	11th	7.3	25	0.149		
13	12th	7.1	20	0.125		
14	13th	6.8	20	0.114		
	14th	6.9	22	0.110		
15	15th	7.7	22	0.120		
	16th	6.4	22	0.118		
16	17th	7.1	20	0.103		
	18th	6.0	31	0.140		
17	19th	6.8	21	0.104		
	20th	6.1	18	0.091		
18	21st	5.5	21	0.097		
	22nd	5.8	22	0.103		
19	23rd	6.6	23	0.106		
	24th	6.4	19	0.080		
20	25th	6.7	39	0.131		
	26th	5.6	18	0.070		
21	27th	7.1	21	0.082		
	28th	6.0	21	0.079		
22	1st March 1894	6.5	23	0.089		
	2nd	6.7	20	0.068		
23	3rd	7.2	22	0.082		
	4th	6.3	34	0.103		
24	5th	6.2	23	0.075		
	6th	6.4	20	0.068		
25	7th	7.1	23	0.088		
	8th	6.4	23	0.084		
26	9th	6.7	24	0.090		
	10th	7.0	20	0.063		
27	11th	6.2	38	0.100		
	12th	5.8	20	0.059		
28	13th	6.2	21	0.065		

Date of Counting Micro-organisms	Micro-organisms in 1cc of Filtered Water. 10 days Culture.	20 days Culture.	Micro-organisms in 1cc of unfiltered Water.	Remarks
6th Feb. 1894			242	No culture made with the filtered water.
7th	0	1	17	
8th	0	0	4	
9th	0	0	17	
10th	0	0	39	
11th	0	0	15	
12th	0	0	646	
13th	0	0	1528	
14th	0	0	158	
15th	0	0	302	
16th	1	0	156	
17th	0	0	485	
18th	0	0	316	
19th	0	0	2420	
20th	1	0	4372	
22nd	0	0	1345	
24th	0	0	1124	
26th	1	0	5927	
28th	0	0	699	
2nd March 1894	0	0	841	
4th	0	0	11340	
6th	0	1	379	
8th	0	0	1290	
10th	0	0	7480	
12th	0	0	3591	
14th	0	1	1619	
16th	1	0	971	
18th	0	0	159	
20th	0	0	126	

The Pasteur-Chamberland Filter.

Table X.

The Pasteur—Chamberland Filter.

Table X. Results of the Second Series of Experiments with Bacillus violaceus and Edinburgh Main Water

Number of Experiment	Date of Culture at 2 p.m.	Temperature of Water. °C.	Pressure of Water in Main. lbs per square inch.	Rate of Filtration. Litres per hour.	Date of Counting Micro-organisms.	Micro-organisms in 1 cc of Filtered Water. Plate Culture. Bacillus violaceus	Plate Culture. other Micro-organisms.	Roll Culture. Bacillus violaceus	Roll Culture. other Micro-organisms.	Bacilli violacei in 1 cc of unfiltered Water.	Remarks.
1	9th April 1894	10.0	21	6.000	16th April 1894.	0	0			20,000	Culture made with 1 cc from first 100 cc of filtered water.
2	10th	10.3	20	1.143	17th	0	0				
3	11th	10.7	21	0.846	18th	0	0				
4	12th	11.4	21	0.666	19th	0	2				
5	13th	10.6	21	0.534	20th	0	3				Collecting flasks and dropping tubes used in making the cultures.
6	14th	10.0	25	0.559	21st	0	1				
7	15th	8.8	36	0.615	22nd	0	0				
8	16th	9.4	32	0.566	23rd	0	0				
9	17th	9.8	21	0.342	1st May 1894.	0	1				
10	18th	10.0	23	0.363	2nd	0	0				
11	19th	10.1	19	0.289	3rd	0	0				
12	20th	10.0	20	0.283	4th	0	0				
13	21st	10.0	27	0.328	5th	0	0	0	0		
14	22nd	9.6	35	0.363	6th	0	0	0	0		
15	23rd	10.1	21	0.231	7th	0	0	0	0		
16	24th	10.4	20	0.214	8th	0	0	0	0		
	25th	10.0	21	0.216							
17	26th	10.3	22	0.218	10th			0	1		
	27th	10.5	23	0.229							
18	28th	9.8	23	0.224	12th			0	0		
	29th	10.3	36	0.275							Cultures made by running 1 cc (19 drops) of water direct into the test-tubes containing the gelatine jelly from the filter-nozzle without the use of collecting flasks and dropping tubes thereby considerably lessening the risk of air micro-organisms accidentally entering the cultures.
19	30th	11.0	22	0.205	14th			0	0		
	1st May 1894	11.1	18	0.162							
20	2nd	10.8	20	0.165	16th			0	0		
	3rd	10.7	20	0.155							
21	4th	10.1	19	0.153	18th			0	0		
	5th-Midday.	10.5	13	0.120							
22	6th	10.0	33	0.218	20th			0	0		
	7th	11.1	22	0.153							
23	8th	10.8	20	0.146	22nd			0	0		
	9th	10.5	18	0.129							
24	10th	10.6	20	0.144	24th			0	0		
25	21st	11.7	22	0.113	4th June 1894			0	0		

The Pasteur-Chamberland Filter.

Table XI.

The Pasteur–Chamberland Filter.

Table XI. Results of the Third Series of Experiments with Micrococcus sp. and Edinburgh Main Water

Number of Experiment.	Date of Culture at 2 p.m.	Temperature of Water °C.	Pressure of Water in Main. Lbs per square inch.	Rate of Filtration. Litres per hour.	Date of Counting Micro-organisms.	Micro-organisms in 1cc of Filtered Water. Roll Culture. Micrococcus sp.	Micro-organisms in 1cc of Filtered Water. Roll Culture. Other Micro-organisms	Micrococci sp. in 1cc of Unfiltered Water.	Remarks.
1	25th May 1894	11.4	21	4.615	8th June 1894	0	0	47,250	Culture made after the filtration of 50 cc of water, immediately after placing the unfiltered water in the filter.
2	26th	11.6	21	0.909	9th	0	0		
3	27th	10.8	36	0.759	10th	0	0		
4	28th	11.6	19	0.438	11th	0	0		
5	29th	10.9	17	0.400	12th	0	0		
6	30th	10.8	20	0.361	13th	0	0		
7	31st	11.3	21	0.348	14th	0	0		
8	1st June 1894	11.0	16	0.261	15th	0	0		
9	2nd midday.	11.7	14	0.235	16th	0	0		
10	3rd midnight.	11.8	46	0.430	17th	0	0		
11	4th	11.3	19	0.240	18th	0	0		
12	5th	11.3	21	0.261	19th	0	0		
13	6th	11.6	19	0.235	20th	0	0		
14	7th	12.8	20	0.244	21st	0	0		
15	8th	11.7	19	0.222	22nd	0	0		
16	9th 7 p.m.	11.9	31	0.279	23rd	0	0		
17	10th 9 p.m.	12.0	42	0.333	24th	0	0		
18	11th	11.6	22	0.210	25th	0	0		
19	12th	13.3	19	0.200	26th	0	0		
20	13th	15.0	23	0.218	27th	0	0		
21	14th	13.8	23	0.218	28th	0	0		
22	15th	13.0	18	0.179	29th	0	0		
23	16th midday	14.0	12	0.132	30th	0	0		
24	17th 10 p.m.	12.4	41	0.285	1st July 1894	0	0		
25	18th	13.0	14	0.138	2nd	0	0		
26	19th	12.9	15	0.143	3rd	0	0		
27	20th 6 p.m.	15.5	22	0.190	4th	0	0		
28	21st	15.1	20	0.182	5th	0	0		

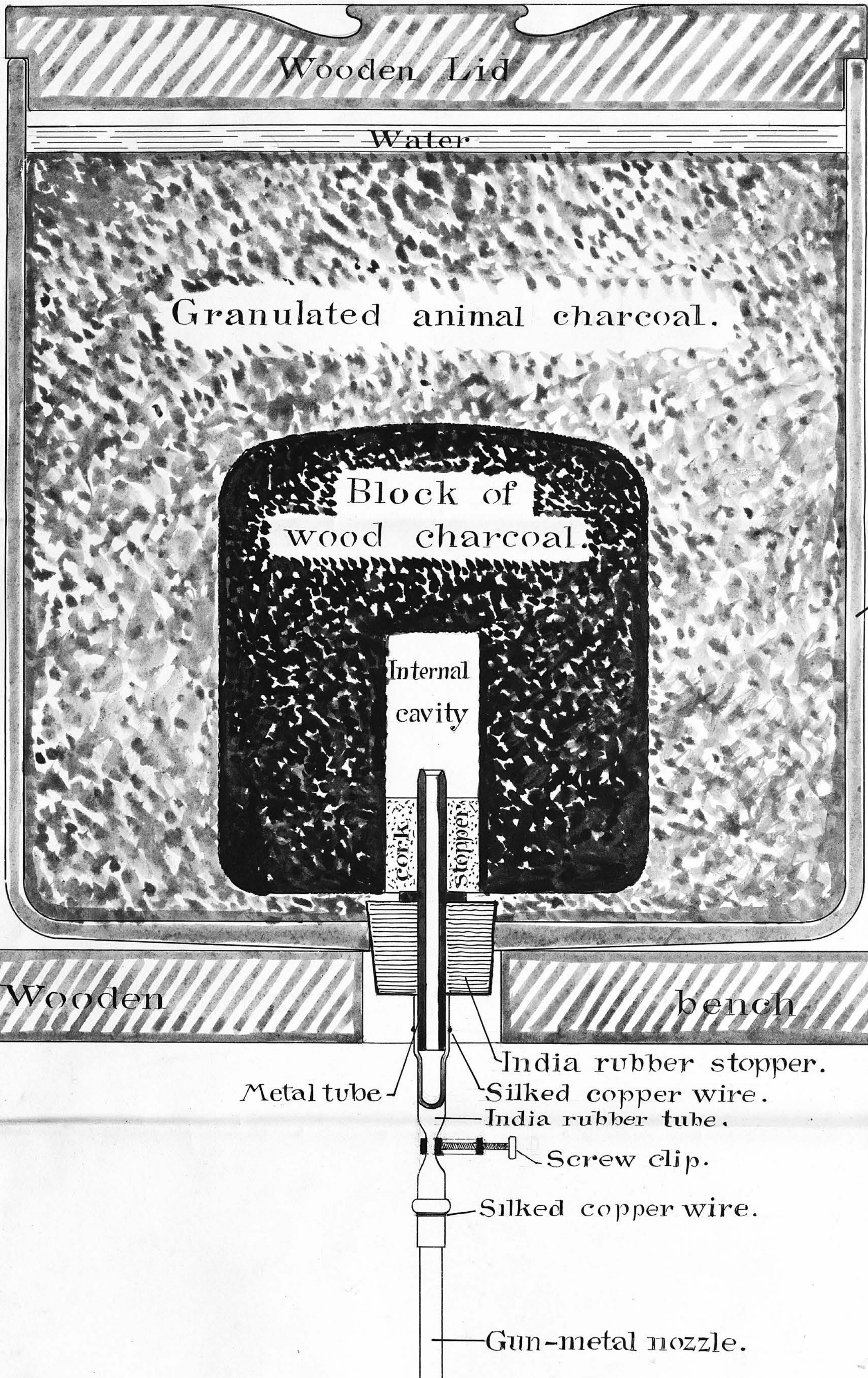
Micro-organisms in Edinburgh Main Water.

Table XII.

Table XII. Micro-organisms in Edinburgh Main Water.

Number of Experiment	Corresponding Number of Experiment in First Series of Experiments: Nordtmeyer-Berkefeld Filter.	Pasteur-Chamberland Filter.	Date of Culture at 1 p.m.	Temperature of Water. °C.	Pressure of Water in Main. Lbs per square inch.	Date of Counting Micro-organisms.	Micro-organisms, including Moulds in 1 cc of Edinburgh Main Water: 10-drop Plate Culture.	20-drop Plate Culture.	Mean.	Moulds in Edinburgh Main Water: 10-drop Plate Culture.	20-drop Plate Culture.	Remarks.
1	1		30th Jan. 1894	6.0	22	4th Feb. 1894	209	275	242	0	0	20-drop culture liquefied on 5th Feb.
2	2	1	31st	4.5	19	7th	19	15	17	0	0	
3	3	2	1st Feb. 1894	5.0	18	8th	5	3	4	1	2	
4	4	3	2nd	6.5	18	9th	17	17	17	2	1	
5	5	4	3rd	8.0	17	10th	46	32	39	3	5	3 Bacilli violacei in 20-drop culture from one colony of which were derived the Bacilli violacei used in the second series of ~~all the~~ Experiments with all the filters. Both cultures liquefied on 11th Feb.
6	6	5	4th	7.5	29	11th	8	22	15	1	0	
7	7	6	5th	6.3	17	10th	662	630	646	0	0	
8	8	7	6th	7.0	17	13th	1530	1526	1528	1	0	
9	9	8	7th	8.0	18	14th	115	201	158	4	4	
10	10	9	8th	7.5	18	15th	276	328	302	0	4	
11	11	10	9th	7.0	20	16th	134	178	156	1	2	
12	12	11	10th	9.0	18	17th	472	498	485	1	0	
13	13	12	11th	7.3	25	18th	250	382	316	0	0	
14	14	13	12th	7.1	20	18th	2420	Liquefied	2420	0	0	20-drop culture liquefied on 17th Feb.
15	15	14	13th	6.8	20	20th	4224	4320	4372	0	2	
16		15	15th	7.7	22	22nd	920	1770	1345	1	4	
17		16	17th	7.1	20	22nd	1101	1147	1124	0	0	Both cultures liquefied on 23rd Feb.
18		17	19th	6.8	21	26th	6885	4969	5927	6	5	
19		18	21st	5.5	21	28th	699	Liquefied	699	14	0	20-drop culture liquefied on 25th Feb.
20		19	23rd	6.6	23	2nd March 1894	1058	624	841	3	11	
21		20	25th	6.7	39	4th	11160	11520	11340	17	32	1 Bacillus violaceus in 20-drop culture.
22		21	27th	7.1	21	6th	349	409	379	4	5	
23	16	22	1st March 1894	6.5	23	8th	855	1725	1290	10	24	1 Bacillus violaceus in 20-drop culture.
24		23	3rd	7.2	22	10th	7235	7725	7480	0	0	
25		24	5th	6.2	23	12th	3780	3402	3591	2	6	
26		25	7th	7.1	23	14th	1227	2011	1619	1	1	
27		26	9th	6.7	24	16th	756	1186	971	4	4	1 Bacillus violaceus in 20-drop culture.
28		27	11th	6.2	38	18th	110	208	159	2	4	1 Bacillus violaceus in 20-drop culture.
29		28	13th	6.2	21	20th	87	165	126	11	0	Culture made after running off 300 litres of water from the main.

PLATE I.



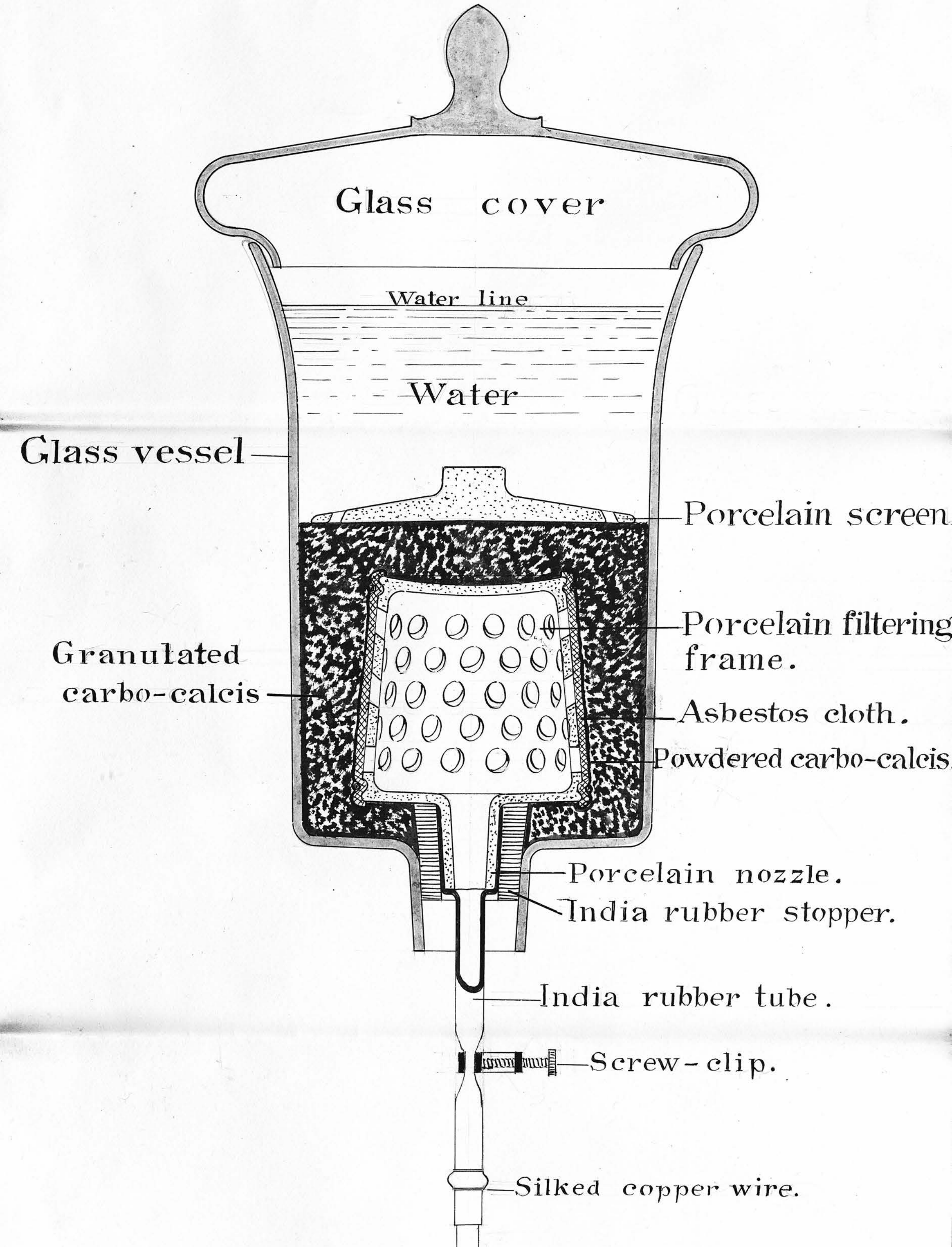
Vertical Section of the
ATKINS PATENT WATER FILTER.

(Full size)

Inches.

1 2 3 4 5 6 7 8 9 10 11 12

PLATE II

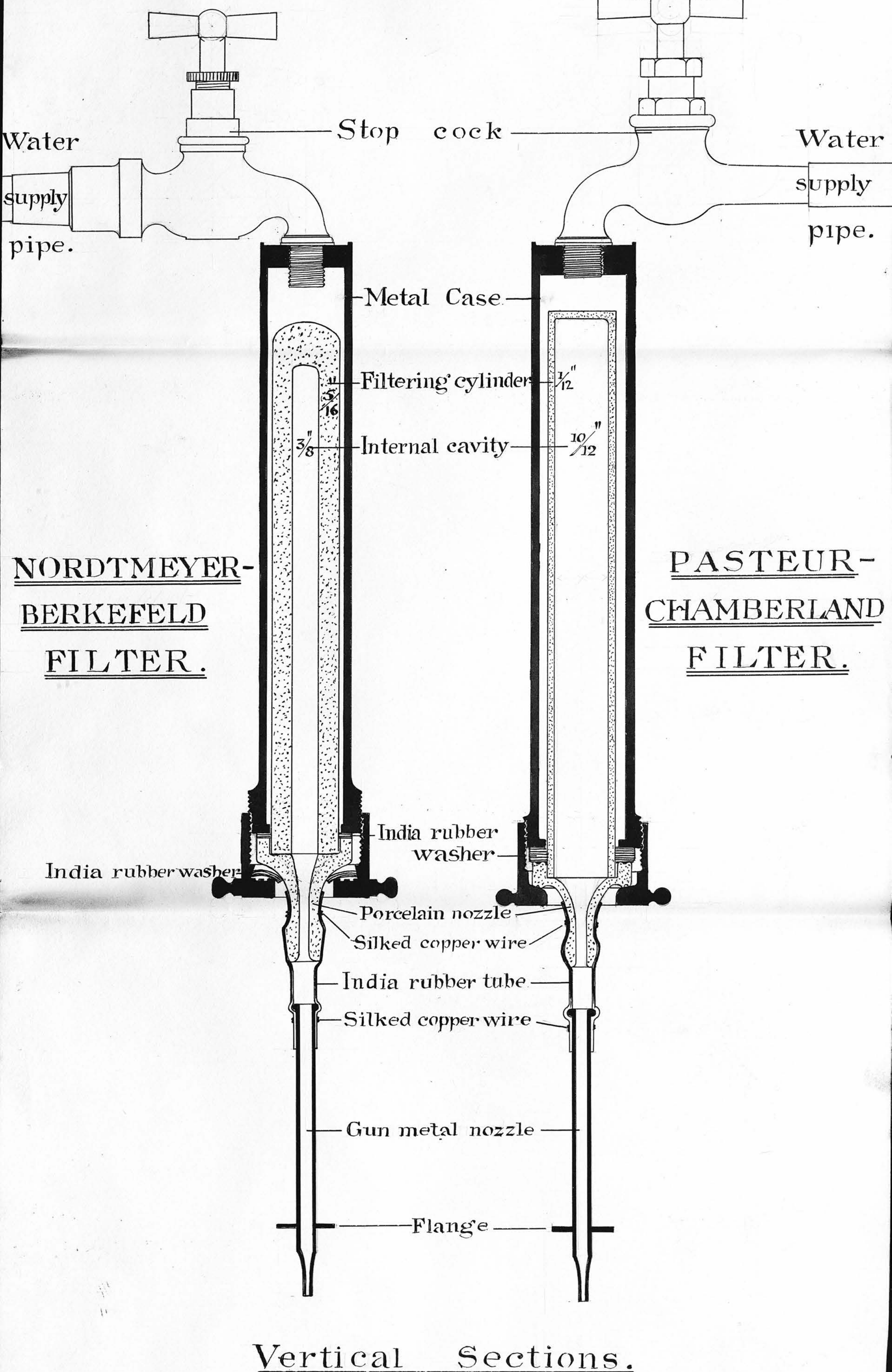


Vertical section of

MAIGNEN'S TABLE "FILTRE RAPIDE."

(Full size)

PLATE III



NORDTMEYER-BERKEFELD FILTER.

PASTEUR-CHAMBERLAND FILTER.

Vertical Sections.

(Full size)

Inches 0 1 2 3 4 5 6 7 8 9 10 11 12

PLATE IV.

GENERAL VIEW of the Pasteur-Chamberland and Nordtmeyer-Berkefeld Filters, as arranged for experiment.

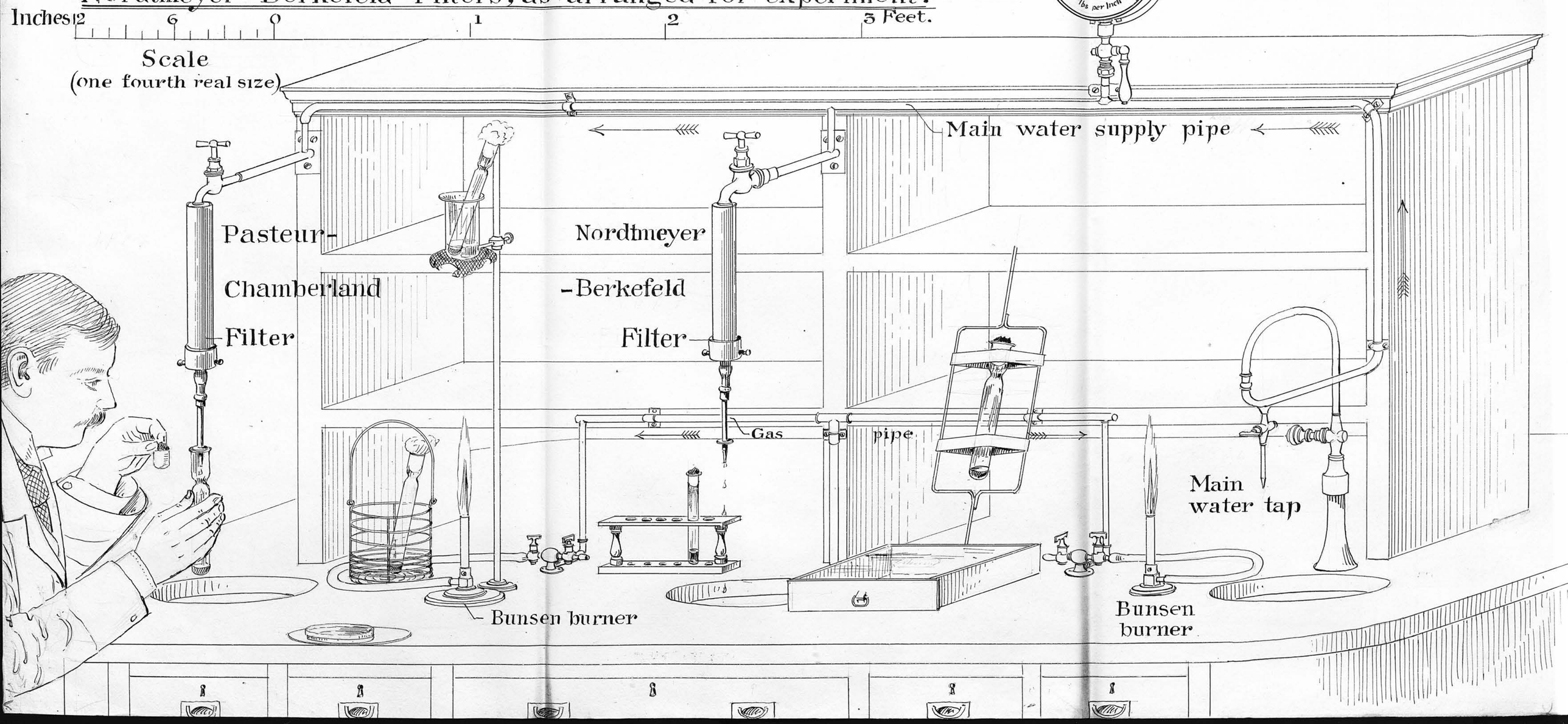
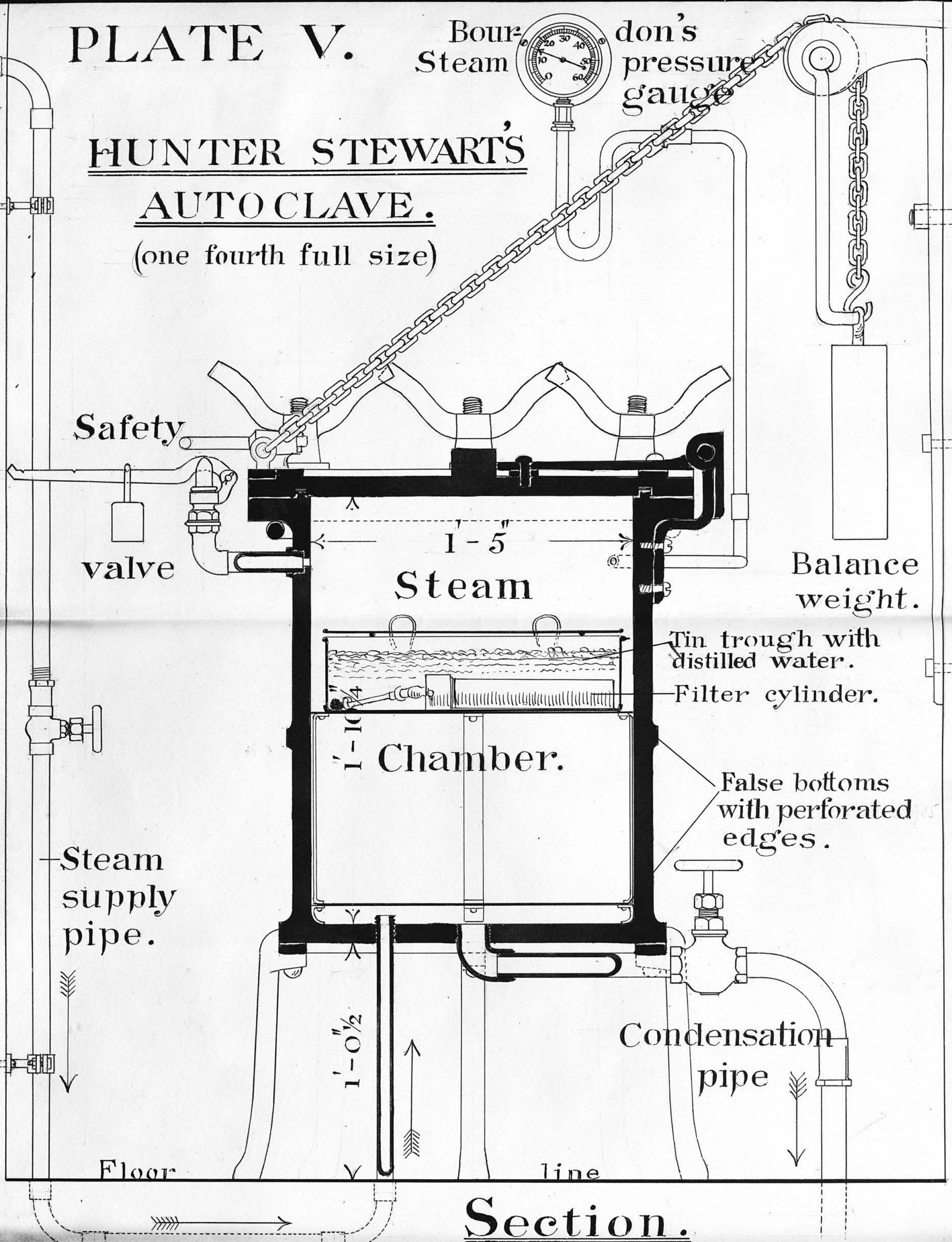


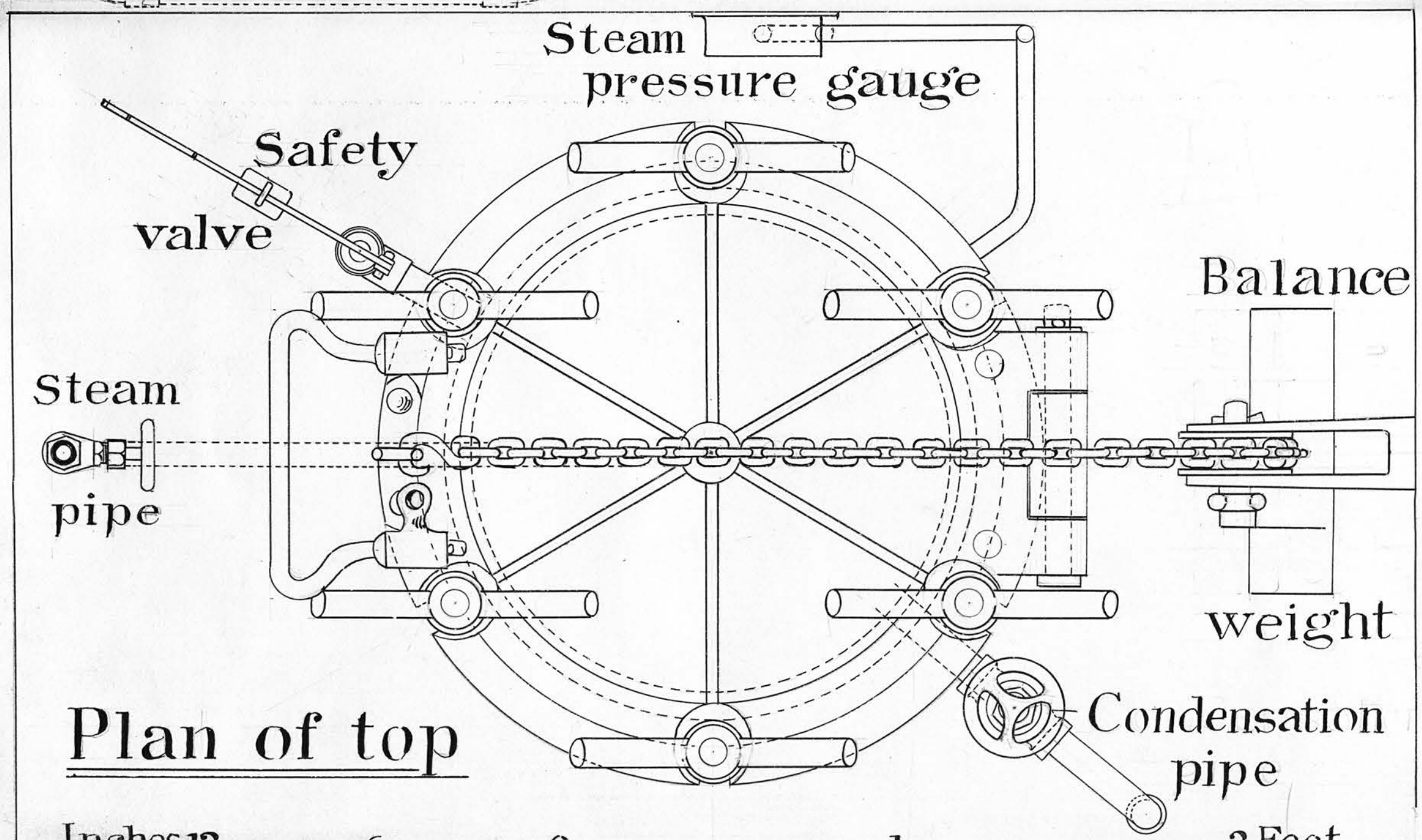
PLATE V.

HUNTER STEWART'S AUTOCLAVE.

(one fourth full size)



Section.



Plan of top

Inches 12 6 0 1 2 Feet