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Some of the Characters of Coagulated and Mechanically-Filtered Water.

BY

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SOME OF THE CHARACTERS OF COAGULATED AND MECHANICALLY-FILTERED WATER.

By Prof. SHERIDAN DELÉPINE, M.B., C.M., M.Sc., of the University of Manchester.

THE effects of the treatment of water by means of coagulants and pressure mechanical filters do not appear to have been fully understood in the past. Since 1901, when the author had for the first time the opportunity of observing on a large scale the action of pressure filters, he has had several opportunities of testing the action of important installations, and has more than once noticed that, although the results obtained were highly satisfactory, the conditions of guarantee suggested by, or imposed upon, the contractors, had not been fulfilled, because the effects of filtration had been different from what had been expected. From a hygienic point of view, many of the requirements were valueless, and a consideration of what could be expected to take place in a mechanical filter would have been sufficient to show that some of the conditions could not be realised, and that among those capable of realization there were several which were not of material importance.

To make this clear, the author will briefly discuss the conditions of guarantee included in a contract which came under his notice about four years ago. The water to be treated was a very soft water. The only conditions to which reference need be made for the present were included in 12 clauses which, in the form finally agreed to by both sides, read as follows :—

"The contractors to guarantee purification to the following extent :

(1) The removal of 95 per cent. of the discoloration present in the raw water.

(2) The removal of 95 per cent. of the suspended matter and 45 per cent. of the organic matter in solution in the raw water.

(3) The filtered water not to take up more than ·035 grains of lead in solution per gallon (0·05 per 100,000) after being in contact continuously with new lead during a period of 24 hours.

(4) The filtered water to have no odour when heated to 100 degrees Fahr.

(5) The filtered water in appearance on examination in a 2 feet tube to be clear and bright.

(6) The filtered water not to contain any alumina in excess of that present in the raw water previous to treatment and filtration.

(7) The filtered water not to contain :—

(*a*) any bacillus coli communis in quantities not exceeding 10 c.c. of water.

(*b*) more than 100 bacteria growing at 20°C. on peptone gelatine (plus 10) in 3 days in 1 c.c. of water.

(8) The free ammonia present in the raw water to be reduced by at least 25 per cent. after treatment and filtration.

(9) The albuminoid ammonia in the filtered water not to exceed ·003 grains per gallon (0·0042 per 100,000).

(10) The oxygen absorbed from permanganate in four hours not exceed ·035 grains per gallon (0·05 per 100,000).

(11) The permanent hardness of the filtered water to be increased not less than ten per cent. above the raw water.

(12) The filtered water to have no deleterious action whatever on wrought iron, steel or cast-iron pipes."

In another contract which came under the author's notice at about the same time, some of the conditions were stated differently. Only five of these need be mentioned, viz. :—

(1) The colour of the filtered water shall not exceed 10 degrees of the platinum cobalt scale, when one degree corresponds to one part of platinum per million.

(3) The filtered water shall be tested for its action on lead in the following manner : A length of new lead pipe ½ inch internal diameter and three feet long, bent into the form of a U tube, shall be filled with water from the sample to be tested. The ends of the tube shall be sealed, and the whole left standing for 24 hours. At the end of this period the tube shall be emptied, rinsed with the filtered water, and then refilled from the sample. The whole shall be sealed and again left for 24 hours, and the water then run off and tested for dissolved lead.

The lead found in solution shall not exceed 0·05 parts per 100,000.

(5) The filtered water shall be free from turbidity as measured by the immersion of a platinum wire, one m.m. in diameter, which shall be visible at a depth of 50 inches.

(7) Bacteria.—When the unfiltered water contains less than 500 per c.c., the bacteria present in the filtered water shall not exceed 20.

When the unfiltered water contains more than 500 and less than 1,000 per c.c., the bacteria removed shall, on the average, be not less than 97 per cent. of the whole, within a minimum for each sample of 96 per cent.

When the unfiltered water contains more than 1,000 per c.c., the bacteria removed shall not be less than 98 per cent.

ACIDITY.—The filtered water shall in no case be acid, and the alkalinity shall not exceed $1\frac{1}{2}$ degrees.

The test for acidity shall be made by evaporating 500 c.cs. to a small bulk and titrating with N/10 caustic soda solution.

The test for alkalinity shall be made by adding an excess of N/10 sulphuric acid solution, boiling to expel the carbon-dioxide, and determining the excess of acid. The indicator used shall be phenolphthalein, and each degree of acidity or alkalinity respectively shall be equal to 1 c.c. of the corresponding N/10 solution used to neutralise 500 c.cs. of the water."

The conditions enumerated above indicate fairly completely the characters which successfully treated water was expected to have. It will be noticed that some of these are indicated in absolute terms, while others are stated in terms relative to the characters of the raw water.

The object in view in imposing conditions on a contractor is that the water should, after treatment, be free from any objectionable property, that is, so far as its *essential properties* are concerned.

A properly treated water intended for ordinary drinking and domestic purposes should be free from :—

1. Discoloration.
2. Appreciable turbidity.
3. Any product capable of imparting to it an unpleasant taste or smell.
4. Any excess of bacteria and more specially of bacteria indicating dangerous, or possibly dangerous, pollution.
5. Any material power to act on metals, and more specially on lead.
6. Any product imparting to the water an unusual physiological action.*

* This applies to products which can be removed by precipitation and filtration, such as compounds of lime, magnesia, iron, etc., removed

7. An excess of mineral matter capable of imparting to the water excessive hardness.

It is quite possible to state in absolute terms the characteristics of a water satisfying these desiderata, and there are methods by which one can accurately ascertain whether a treated water meets these necessary requirements; it is therefore unnecessary to rely upon the percentage improvement which has taken place as a result of treatment, this method of estimation may even lead to gross errors, seeing that the fulfilment of such conditions would not be proof that the water was fit for domestic purposes, and *vice versa*. For example, a water so polluted that it contained before treatment 10,000,000 bacteria and associated products of decomposition, would not be rendered satisfactory by treatment, even if the number of bacteria removed amounted to 98 per cent., for this would still leave 200,000 bacteria in the treated water. Similarly a reduction in the free ammonia by at least 25 per cent. would not in such a case be proof that soluble objectionable products of decomposition were not present in the water.

On the other hand, no constant material reduction in number of bacteria could be expected from the treatment of a water usually containing less than 10 bacteria per cubic centimetre, and a 50 per cent. increase in number would not be an indication that the water was unsuitable for domestic purposes. Neither is the absence of any reduction in the amount of free ammonia material when the quantity is originally very low. As a matter of fact, the quantities of free or saline ammonia usually present in drinking water are quite negligible from a hygienic point of

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by precipitation. This condition is almost superfluous for it is covered more or less completely by 1, 3 and 7. An excessive amount of chloride of sodium, sulphate of magnesium, or other soluble salts giving a taste or special physiological properties to the original water would render that water incapable of being made suitable for domestic purposes by mechanical filtration.

view even when the water is distinctly polluted. The ammonia figure is of use only as an indicator of pollution when other more direct methods are not available for the purpose of ascertaining whether pathogenic or fæcal bacteria are possibly present.

The author now proposes to discuss some actual results obtained in connection with two installations of pressure mechanical filters of different types (erected by two of the leading firms in this country) which may be designated by the letters A. and B.

Both installations yielded excellent results, and for the purpose of this discussion we will suppose that the conditions enumerated at the beginning of this paper had to be met in each case. In both cases the waters to be treated were derived from peaty moorlands, were therefore liable to discoloration, soft, had a marked action on lead, and required nearly the same kind of chemical and mechanical treatment. There were, however, some differences between them.

Filters A. had to deal with the water of four reservoirs. The water from each of these reservoirs was examined in the author's Laboratory both bacteriologically and chemically before and after treatment at short intervals during a period of over $1\frac{1}{2}$ years, but it will suffice to deal with only one set of observations in each case. Some of the observations relate, in the case of A., to the initial period when the working of the filters had not been fully adjusted. The author will deal seriatim with the conditions of guarantee in the light of the analytical results obtained in the laboratory. Tables giving the results of two short series of tests, carried out lately in connection with both installations, are given in an appendix.

Condition 1.—*Removal of* 95 *per cent. of the discoloration present in the raw water.*

The water of the four reservoirs was examined 32 times and found to be when examined in good day-light in a two foot tube :—

	Before Treatment.	After Treatment.
Dark or dull brown	14 times.	0 times.
Brown	5 ,,	0 ,,
Yellow or Brownish yellow.	8 ,,	0 ,,
Yellowish green	5 ,,	0 ,,
Greenish blue	0 ,,	12 ,,
Pale blue	0 ,,	20 ,,

On attempting to estimate colorimetrically the amount of yellow or brown discoloration which had been removed by treatment, it was found that more than 95 per cent. of the discoloration had been removed in the 12 cases in which the colour of the treated water was greenish blue. It is obvious that when the water had a pure blue colour no trace of original discoloration could be detected.

In the case of Installation B. the water of a reservoir was examined six times and found to be :—

	Before Treatment.	After Treatment.
Dull brown	4 times.	0 times.
Yellowish brown or dull brown.	2 ,,	0 ,,
Greenish blue	0 ,,	4 ,,
Pale blue	0 ,,	2 ,,

These remarks indicate that, as far as the colour is concerned, the treatment can be considered as satisfactory when the colour of the treated water is either pale blue or greenish blue, and a statement to that effect is far more likely to be correct and to be clearly understood than a figure indicating the percentage of discoloration removed, as may be done by the platinum cobalt or other colorimetric methods.

Condition 2.—*Removal of* 95 *per cent. of the suspended matter and* 45 *per cent. of the organic matter in solution in the raw water.*

The second part of this clause is, in the author's opinion, entirely unnecessary. The figures relating to oxygen absorbed and to various nitrogenous products would, if information were needed regarding organic products, give most of the data required. The estimation of volatile and organic matter as usually conducted does not give results capable of simple interpretation.

The first part of the clause which relates to suspended matter is one which offers certain difficulties of interpretation. The coarse suspended matter which was present in most of the samples of raw water was invariably removed by treatment, and in ordinary day-light, the treated water appeared to be quite clear ; a platinum wire 1 m.m. thick could invariably be seen through 50 inches of water, but when the treated water was strongly illuminated and examined against a dark ground, a slight turbidity or opalescence was usually recognisable. This turbidity was not due to the suspended matter originally present in the raw water, but to the presence of superadded extremely fine particles. This slight turbidity was generally more marked when the quantities of chemicals had not been completely adjusted. Before this was done it was possible by gravimetric method to show that there was slightly more insoluble suspended matter in the treated than in the untreated water ; after adjustment the reverse was true, but in both cases, it was clear that the suspended matter which caused turbidity in the raw water had been replaced, in the treated water, by another kind of material. This suspended matter was composed almost entirely of minute particles, many of which were almost ultramicroscopic. It had, therefore, nothing in common with the coarse particles which caused the turbidity of the untreated water.*

When the treated water was made to pass through a sedimentation tank, a dark gelatinous layer was, in the course of several months, deposited on the sides and bottom

* This point was illustrated by lantern slides which have been reproduced with further explanation in the Addendum (see p. 20).

of the tank. This deposit was due to the separation of the fine particles contained in the water. Through Mr. Molyneux's kindness the author has had an opportunity of investigating the nature of this deposit. By a process of elutriation it was possible to separate from it five types of constituents :—

1. Fine, heavy, brownish, greyish and white sandy particles, which separated easily from water in about one minute (that is, after they had been freed from the surrounding gelatinous mass). These particles had to the naked eye the characters of fine sand grains and siliceous debris. This part of the sediment was very scanty.
2. Much finer heavy particles of a dark grey colour, which separated from the water almost as rapidly as the coarser particles.
3. Extremely fine dark brown particles forming semi-gelatinous flakes, which separated from the water in about half-an-hour in the form of a semi-gelatinous mass. This contracted in the course of 24 hours to about half of its original bulk.
4 A greyish-white sediment difficult to separate from the previous parts and composed of very light flakes. In the course of several hours these formed a very light flocculent sediment, which continued to contract for several days.
5. After separation of these various deposits, the water still retained a slight whitish opalescent appearance, due to the presence of extremely minute particles, which in the course of a month formed an extremely thin whitish film on the bottom of the vessel to which it adhered. This layer could be separated from the vessel as a very soft whitish pellicle.

Mr. Heap, at the author's request, has kindly analysed these various constituents with the results given in the following table :—

ANALYSES OF DEPOSIT FROM FILTERED WATER IN SEDEMENTATION TANK (C.B. 1527).

No.	A. General Composition of Dry Solids.			B. Mineral Matter.						
	Organic Matter.	Mineral Matter.	Total.	Iron, Fe_2O_3	Aluminium Al_2O_3	Silicon, SiO_2.	Calcium, CaO.	Magnesium, Mg O.	Unaccounted for.	Total.
I. .. .. (Heavy coarser particles sand like).	0·249	1·360	1·609	0·198	0·075	0·923	0·139	0·011	0·014	1·360
II. .. .. (Heavy fine particles dark sand like).	0·091	0·247	0·338	0·045	0·036	0·090	0·023	0·017	0·036	0·247
III. .. .. .. (Dark brown gelatinous deposit).	1·804	4·843	6·647	1·405	0·2078	2·179	0·526	0·137	0·3882	4·843
IV. .. .. .. (Greyish white gelatinous deposit).	0·094	0·224	0·318	0·026	0·055	0·071	0·044	0·004	0·024	0·224
V. .. .. (Water separated from sediment).	0·039	0·062	0·101	0·001	0·002	0·004	0·023	0·003	0·029	0·062
Totals	2·277	6·736	9·013	1·675	0·3758	3·267	0·755	0·172	0·4912	6·736

This table gives the actual weights found in the amount of material available for examination. The percentage total amounts of each of the solid components of the sediment as well as the percentage of the same constituents found in the water unfiltered and filtered and in another sediment, are given in tables 2 and 3 at the end of the paper.

The composition of this sediment indicates that it is partly composed of material derived from :—

1. The sand or broken quartz.
2. The walls and other parts of the filter which are composed of iron.
3. Precipitates resulting from the addition of chemicals and from the rearrangement of the constituents of the water during treatment. It will be noticed that this alteration in the composition of the water is one of the desired effects of treatment, and that, when a soft water is dealt with, it is reasonable to expect an increase in the amount of soluble mineral constituents.

The finer particles of iron and silica are probably produced by attrition during the washing of the filters when the grains of sand, or broken quartz, are thrown into a state of active motion.*

The suspended matter just described might, by deposition in the mains, form very slowly a thin coating, which, for a long time, would be incapable of reducing materially the carrying capacity of the mains, and would probably have a protecting action. Such a coating, if it ever became too thick, should be easily removed by simple mechanical means.

Very different effects are observed when untreated moorland waters are conveyed by iron pipes ; in such cases the inner surface of the pipes is rapidly incrusted with organic matter mixed with mineral deposits. This incrustation is associated with more or less rapid erosion, more specially when the deposit scales off or is removed. The author has seen pipes lined in this way with rough nodulated

* This interpretation is supported by the following fact. Some time ago the author noticed that the water from filters under Mr. Dixon's charge had become much freer from the fine suspended matter, and, in reply to enquiries, Mr. Dixon stated that the only change which had been made in the method of treatment had been a considerable reduction in the rate of motion during the cleaning of the filters.

deposits more than half-an-inch in thickness, firmly adherent and very hard, which diminished considerably the carrying capacity of the mains.

The nature of the suspended matter which is found in treated water, is interesting chiefly from this point of view, for, as previously explained, this matter does not affect either the appearance or the hygienic value of the water.

Condition 3.—*The treated water not to take more than* 0·035 *grains of lead in solution per gallon* (i.e. 0·05 *parts per* 100,000).

The results obtained at installations A. and B. showed that this important condition was easily met, even in the case of waters having considerable action on lead before treatment.

The author has, in another place,* explained that, in order to obtain comparable results, it is necessary to use pure bright lead under very definite conditions for the purpose of testing the action of water on that metal. The method described in the second set of conditions enumerated at the beginning of this paper, does not appear satisfactory, for the author has found that the action of the same water on several new lead pipes obtained from the same source varied considerably. Some pipes yield much more lead than others. Lead pipes which have been exposed to air containing traces of sulphuretted hydrogen yield much less lead, even after several washings, than pipes which have always been kept in air free from that gas. The action of water is modified by many other factors which cannot be controlled when lead pipes are used for the purpose of this test.

Conditions 4 and 5 need not be discussed. It is sufficient to say that the treated water was always found free from odour. The question of clearness has already been discussed under clause 2.

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* Journal of the Royal Sanitary Institute XXXV., p. 117, 1914.

Condition 6.—*The filtered water not to contain any alumina in excess of that in the raw water previous to treatment and filtration.*

The accurate estimation of the amount of alumina in the raw and in the treated water was found to involve an expenditure of time which the results did not justify. Both before and after treatment the amount found was very small, and, with very few exceptions, no excess of alumina was discovered in the treated water. The slight turbidity and the increase in the amount of solids previously alluded to, cannot, therefore, be attributed to an increase of that product during the passage of the water through the filter.

The results of 40 analyses made in the author's laboratory by Mr. Heap may be tabulated as follows :—

INSTALLATION A.—ALUMINA IN WATER.

RESERVOIR 1		RESERVOIR 2		RESERVOIR 3		RESERVOIR 4	
Before treatment	After treatment	Before treatment	After treatment.	Before treatment.	After treatment.	Before treatment.	After treatment.
0·05	0·05	0·20	0·10	0·20	0·20	0·40	0·20
0·17	0·05	0·42	0·02	0·14	0·05	0·29	0·24
0·08	0·05	0·33	0·23	0·33	Traces	0·27	Traces
0·02	0·02	0·03	0·03	0·65	0·10	0·75	0·80
0·60	0·95	0·50	0·90	0·35	0·10	0·30	0·20

Condition 7.—*The filtered water not to contain :—*

(a) *Any bacillus coli communis in quantities not exceeding* 10 *c.c. of water.*

(b) *More than* 100 *bacteria growing at* 20°*C. on peptone gelatine in* 3 *days in* 1*c.c. of water.*

With regard to Installation A., quantities of raw water exceeding 10 c.c. were tested 62 times, and the *bacillus coli communis* was found to be present on seven different occasions. The treated water was tested the same number of times and never found to contain this bacillus in 10 c.c. Over 100 c.c. of each sample was used in each test. Installation B. yielded equally good results.

With regard to the *total number of bacteria*, some details will be found in the table at the end of this paper. In the case of Installation A., the number of bacteria found in the treated water rose above 10 on 7 occasions out of 32, and above 20 only once out of the same number of observations, when the total reached 47. The results were, therefore, eminently satisfactory, yet on 4 occasions on which there were only 1, 2, 5 and 5 bacteria respectively in the untreated water, there was an increase after treatment, but this increase was quite immaterial. If the condition as regards the number of bacteria had been stated in the form of a percentage improvement, as in the second set of conditions (No. 7), the treated water would have been condemned on those 4 occasions, and yet on each of them the treated water would have been of great bacterial purity. The number of bacteria in the raw water before treatment was generally low, but it reached 1,400 once, 385 once, and was about 50 or more on 9 occasions.

Installation B. also yielded excellent results as regards the reduction in the number of bacteria.

Condition 8.—*The free ammonia present in the raw water to be reduced by at least 25 per cent. after treatment and filtration.*

The author has already stated that this condition is of no importance and should never be insisted upon. As a matter of fact, it does not appear to be capable of realisation.

In the case of Installation A., the results obtained in connection with each of the 4 reservoirs were as follows :—

FREE AMMONIA IN TREATED WATER AS COMPARED WITH RAW WATER.

	Increased.	Unchanged.	Reduced
Reservoir 1 ..	1 occasion.	2 occasions.	5 occasions.
,, 2 ..	1 ,,	5 ,,	2 ,,
,, 3 ..	2 occasions.	1 occasion	5 ,,
,, 4 ..	1 occasion.	3 occasions.	4 ,,
Totals ..	5 occasions.	11 occasions.	16 occasions.

With regard to Installation B, the free ammonia was increased twice, unchanged once, and reduced once.

Condition 9.—*The albuminoid ammonia in the filtered water not to exceed* 0·003 *grains per gallon* (0·0042 *parts per* 100,000).

Installation A. gave very good results. The albuminoid ammonia was reduced, sometimes considerably, on 32 occasions out of 32. Once only was the reduction so slight as to be doubtful. The amount found in the treated water was well below the limit indicated, except on 3 occasions when the amounts found in the treated water were respectively 0·0048, 0·0044, 0·0044, *i.e.*, 0·0006, 0·0002, 0·0002 above the amount allowed which are insignificant quantities well within the limits of experimental error.

Installation B. yielded similar results.

Condition 10.—*The oxygen absorbed from permanganate in four hours not to exceed* 0.035 *grains per gallon* (0·05 *parts per* 100,000).

This condition was amply fulfilled by filters A. and B. on 34 out of 36 occasions, and the two failures were due to exceptional and accidental circumstances. The amount of oxygen absorbed by permanganate of potash indicates the amount of oxidisable matter which is chiefly organic matter. The removal of this oxidisable matter is of importance, and this was very thoroughly effected by the filters.

Condition 11.—*The permanent hardness of the water to be increased not less than* 10 *per cent. above that of the raw water.*

When dealing with hard water it might be convenient to indicate in percentage terms how much the hardness should be reduced, but in the case of a soft water, when the increase of the hardness has for object the removal of the action which the water has on lead, it is useless to demand a percentage increase. What is wanted is that the water should not act on lead and this can be tested directly. It is also obvious that, when a water is exceedingly soft, a 10 per cent. increase may be quite insufficient to render the water inactive as regards lead. This is actually what happened in one instance. The hardness had been increased by treatment to the extent of 30 per cent. and yet the water had still a marked action on lead.

The reaction of the water is a better indicator of its probable action on lead, but even the reaction cannot always be depended upon, and it appears to the author safer to rely on a direct estimation of the actual action of water upon pure lead than to trust to the indications given by hardness or reaction. The reaction is, however, a valuable indicator in the practical working of filters. When one knows the average composition of the water to be tested and the extent of its action on lead, the reaction may be generally used with advantage for the purpose of determining the quantity of chemicals to be used.

The tests for reaction given in the second set of conditions quoted at the beginning of this paper, do not, however, seem to the author so suitable in current work as the combined use of 3 indicators. Mr. Heap, who has charge of chemical water analyses in the author's laboratory, has paid special attention to this point, and has supplied the following short statement of the way in which he estimates the reaction in ordinary routine work.

Indicators—

Methyl Orange.—2 grammes dissolved in 1 litre of water.

Lacmoid.—2 grammes dissolved in 1 litre of 75 per cent. alcohol and water.

Phenolphthalein.—2 grammes dissolved in 1 litre of 75 per cent. alcohol.

TITRATION.—In the case of waters showing an alkaline reaction with an indicator, they are titrated with centinormal sulphuric acid, and in the case of an acid reaction, the titration is made with centinormal caustic soda. The quantities taken are 100 c.cs. of the water and 1 c.c. of Indicator.

The results are expressed in cubic centimetres of normal acid or alkali in 100,000 cubic centimetres of the water.

For the purpose in view the data given by the indicators may be interpreted as follows:—

Methyl Orange.—This gives the bicarbonates of calcium and magnesium.

Phenolphthalein. Lacmoid.—When no colour is given in the cold with Phenolphthalein and the water is alkaline to lacmoid, it means that no normal carbonates are present and that the alkalinity is due entirely to acid carbonates.

GENERAL CONCLUSIONS.

The facts recorded in this communication show that the results of treatment by coagulants and mechanical filtration of soft moorland water are eminently satisfactory when reliable plants are used. The author has also had the opportunity of observing the effects of treatment of hard waters by analogous filters and these have also been satisfactory. The seven essential desiderata indicated at the beginning of this paper can easily be met when the best types of pressure mechanical filters are properly worked. As to the conditions to which the author attaches little or no importance, some have been satisfied, while others have remained unsatisfied. He would, therefore, suggest, whether hard or soft water are in question, they should when treated satisfy the following conditions:—

Essential conditions—

1. The water viewed in a 2 ft. tube shall be of a pale blue colour, or retain not more of any original yellow or brown discoloration than an amount capable of giving to the water a greenish blue colour.
2. The water viewed in a 2 ft. tube shall be clear.
3. The water when heated to 30° C. and to 100° C. shall be free from any appreciable smell.
4. One cubic centimeter of filtered water shall not contain more than 100 bacteria, capable of growing in three days on peptone bouillon gelatine (+ 10) incubated at 20° C.
5. Any quantity less than 10 c.cs. of the filtered water shall not contain the bacillus coli communis.
6. The filtered water shall have no material action on bright pure lead after being in contact continuously for 24 hours at a temperature of 20° C. (By material action is meant an action causing the taking up by the water of more than one part of lead in 2,000,000 parts of water, when the lead is completely immersed, the water is protected from access of air or other gases while the test is carried out, and the ratio between the surface of lead and the volume of water is as one to four).
7. The amount of alumina in the filtered water sh ll

not exceed the amount of alumina in the raw water.

8. The filtered water shall contain no appreciable quantity of copper, lead, zinc, or more than traces of iron.

Conditions regarding which the scientific referee may exercise his discretion.

9. 100,000 parts of filtered water should not take more than 0·05 parts of oxygen from permanganate of potash in acid solution in 4 hours at 27° C.

10. Free ammonia in the filtered water should not exceed 0·02 parts in 100,000.

11. The albuminoid ammonia in the filtered water should not exceed 0·005 parts per 100,000.

12. The hardness of the filtered water as tested by Clarke's method should not exceed 20 per 100,000 except in special cases.

The author cannot conclude these remarks without expressing grateful thanks to Mr. T. Molyneux and to Mr. F. J. Dixon for the trouble they have taken to make certain observations and in forwarding to the author some special samples needed to complete the work. He also desires to thank the representatives of Messrs. Mather and Platt and of Messrs. Bell Brothers for the very ready manner in which they have replied to enquiries. The waters treated had different characters, useful comparison could be made only if the same water had been treated by both methods. The small number of examples selected for the purpose of this paper (out of a considerable number of observations) is sufficient to show that both installations have worked very satisfactorily. Finally the author wishes to acknowledge the very great help received from Dr. E. J. Sidebotham and Mr. H. Heap, who respectively have charge of the Bacteriological and of the Chemical analyses of water in the author's laboratory.

Addendum.

The statement relating to the characters of the suspended matter observable in filtered water were illustrated by several photographs which were thrown upon the screen; some of these are reproduced here.

The apparatus devised by the author for comparing the turbidity of filtered and unfiltered water consists, in its simplest form, of a rectangular flat trough, the sides of which are made of colourless plate glass. This trough is surrounded by an opaque case dull black inside and provided with three windows.

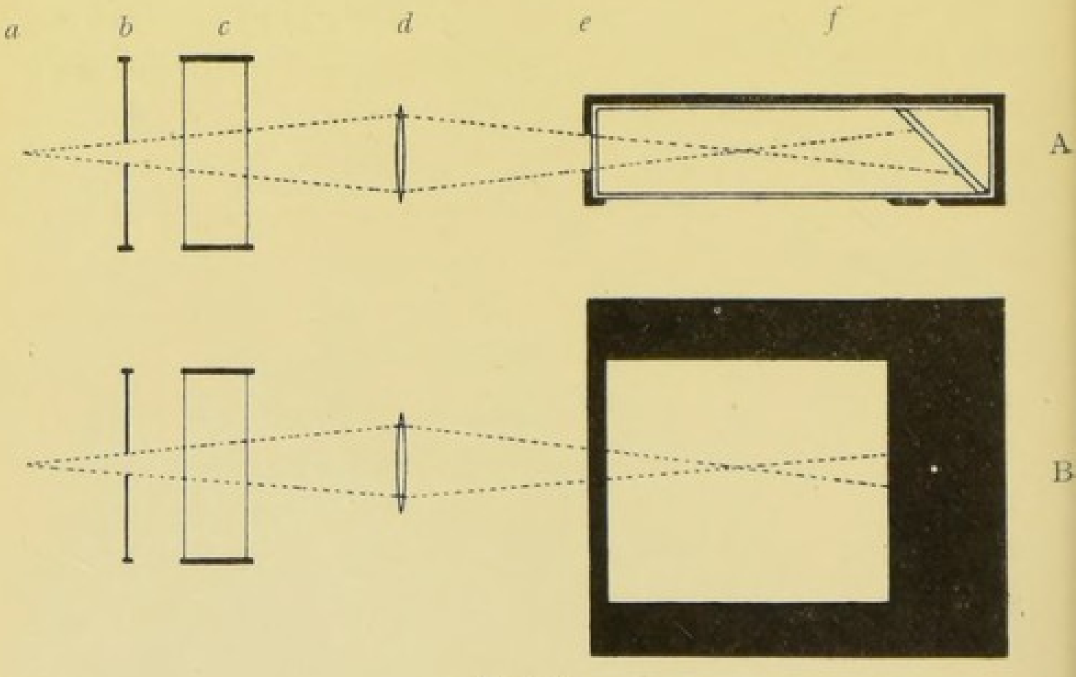


Fig. 1.

a. Arc light. *b*. Diaphragm. *c*. Cooling trough. *d*. Bi-convex lens. *e*. End of trough with narrow window. *f*. White reflector and round opening.

A. Transverse horizontal section. B. Front elevation.

Fig. 1 shows in a diagrammatic fashion, a horizontal section (A) and a front elevation (B) of the apparatus.* On one of the narrow sides there is in the opaque case a

* A more convenient but more complicated form of this apparatus will be described in a later communication.

rectangular window $\frac{1}{4}$ in. wide corresponding in height to the wider window shown in the front elevation. On the right side of the broad window there is a small round opening measuring about $\frac{1}{8}$ in. in diameter, behind that opening a white reflecting surface is fixed at an angle of 45°. This surface, therefore, reflects through the small opening horizontal rays of light admitted into the trough through the narrow lateral window at the level of the round opening. To use this simplified form of the apparatus which I have devised for estimating the amount and character of turbidity and of colour in fluids, two arrangements may be adopted.

A. After removal of the white reflector a wide beam of parallel rays of light normal to the glass surface, is thrown into the fluid through the large window in front. The fluid is observed through the narrow window and is seen to be more or less luminous. The amount of light reflected from the fluid depends on the colour and amount of suspended matter. Pure water, theoretically, should not be visible at all, that is to say, that even when a strong beam of light is thrown into it, the fluid contained in the trough should remain dark. But even pure distilled water, which has been protected from dust and allowed to stand for several days, is slightly luminous under these circumstances.

In Fig. 2, three sets of photographs are arranged so as to show the difference of turbidity between unfiltered and filtered water in the case of 3 different mechanical filters, A, B, and C, of two different types. In each case clear distilled water is used as a standard of comparison. In each group the unfiltered water is on the left (1) the filtered on the right (3), and the distilled water in the middle (2). Negative pictures have been preferred as being more suitable for reproduction, so that the waters which were most brightly illuminated appear in the photographs as producing a darker shade than the waters which were less illuminated. It will be noticed that in all cases the

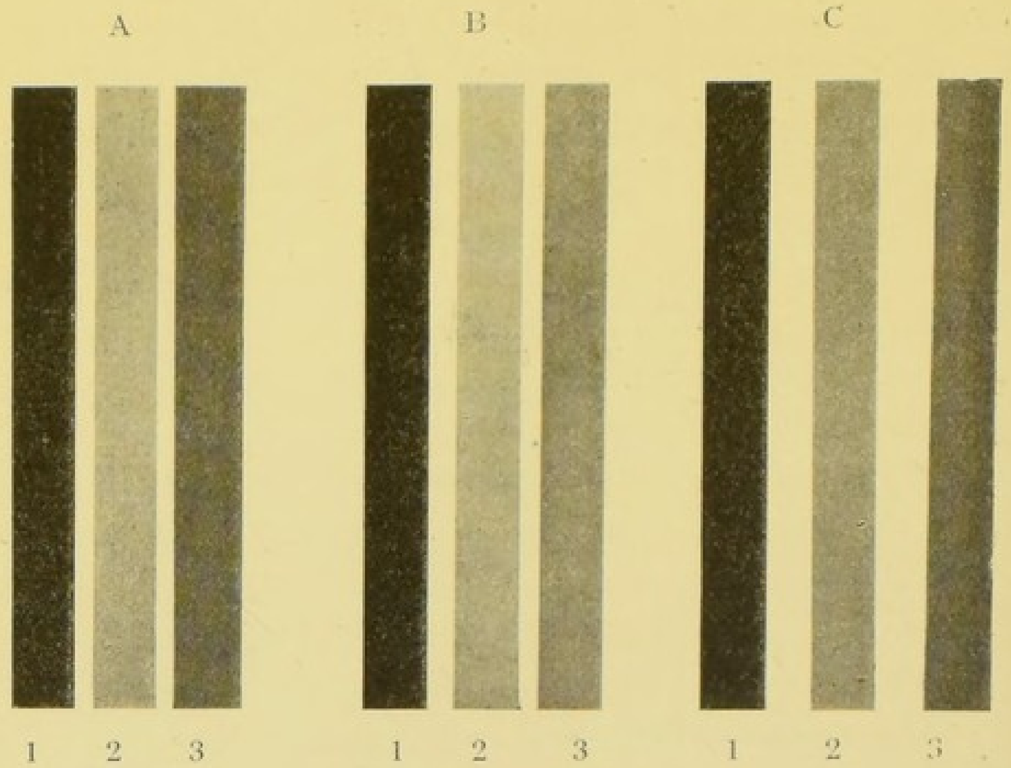


FIG. 2.

A. B. C. Effects of mechanical filtration of three different waters by three filters of two types.

1. Unfiltered water. 2. Distilled water. 3. Filtered water.

Photographic negatives untouched. The most luminous water appears darkest. The depth of the shade indicates the amount of turbidity.

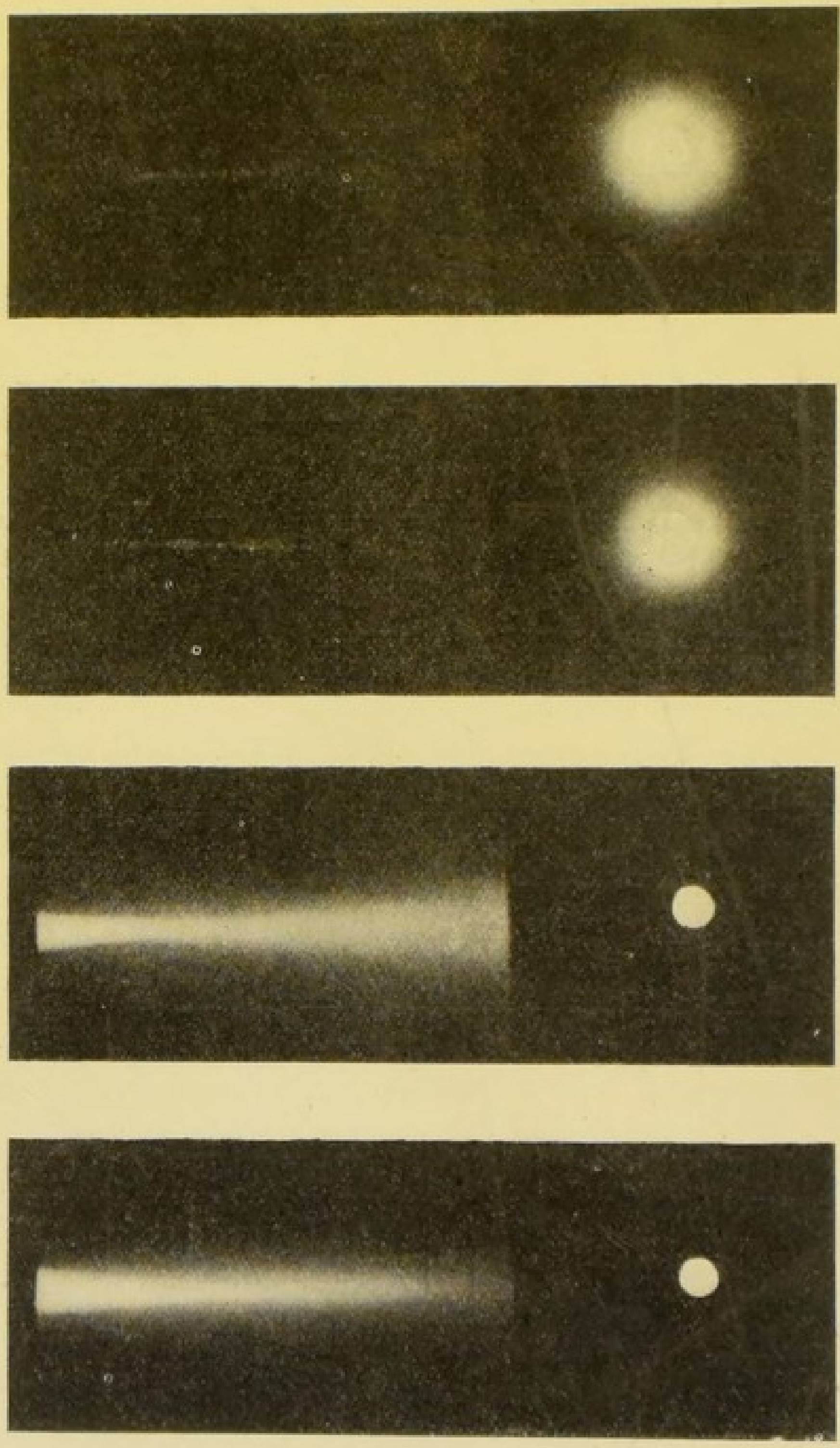
filtered water contained much less suspended matter than the unfiltered, but distinctly more than pure distilled water.

B. The second arrangement is more instructive, but the effects observed are more complicated. This arrangement is made clear by diagram 1. The white reflecting surface (Fig. 1 f.) being in its place, a narrow pencil of light is admitted through the narrow side window, the axis of this beam being horizontal and parallel to the long axis of the trough (Fig. 1 e.). The rays are made to converge to a point corresponding to about the middle of the large window, and to fall on the white surface at the level of the small round opening. Part of the rays falling upon the white reflector are, therefore, reflected through the small round window and as these rays are divergent on reaching the reflector, those passing through the round opening form a cone, the apex of which is in the trough and the basis towards the observer. (To prevent the disturbing currents which would be produced by the heating of the fluid, the heat rays are absorbed by a trough (*c*) before the light passes through the biconvex lens (*d*) used to focus the light in the fluid.)

When very pure water is examined in this way, only a few bright particles are visible along the tract of the beam of light (more specially at the place where the light is focussed). The surface of the reflector is brilliantly illuminated, and a *bright corona* is seen outside the margin of the opening (fig. 3A).

So long as the number of particles is not great enough to prevent direct transmission of a part at least of the radiant light, the white reflector is directly illuminated, and a corona is produced by the divergent reflected rays. The size and brightness of the corona depend on the number of rays that reach the reflecting surface. When mechanical filtration has been efficiently carried out, a corona nearly as wide and bright as that obtained with clear distilled water is observed (fig. 3 B), but the number of suspended particles visible along the tract of the beam is distinctly greater.

When the number of suspended particles is sufficiently great to break all the direct rays, light becomes diffused through the fluid, all the rays being reflected at various angles by the particles. If the suspended particles are not too numerous, the fluid is illuminated along the whole tract of this beam of light, and also in the neighbourhood of it. If the fluid and suspended particles are colourless, the illumination is brilliant and a considerable part of the fluid is lighted, but as only diffused light reaches the reflector, no corona is visible round the small window (fig. 3 D.).



A

B

C

D

Fig. 3.

A. Distilled water. B. Mechanically filtered water. C. Water with coarse white precipitate. D. Water with very fine yellow precipitate. Photographic positives untouched.

When the suspended particles are coloured, and more especially if their colour is red, brown, yellow or green, they cause not only diffusion but also considerable absorption of light, and the beam of light becomes considerably reduced in width and intensity as it penetrates through the fluid. The amount of light reaching the white reflector is reduced, there is no corona, and the part of the reflector seen through the small round window is not so bright as in the previous cases (fig. 3 D.).

All these appearances can be easily photographed (the illustrations are reproductions of untouched photographs). When a powerful arc light is used, instantaneous photographs can be taken, and it is then possible to form an idea of the number and size of the suspended particles. When a less intense source of light is used, e.g., an incandescent electric or gas lamp, a longer time is needed to obtain a picture such as is shown in fig. 3, and, owing to their movements, the particles are not individually distinct. It will be seen that the new apparatus is based partly on Tyndall's method for revealing the presence of dust in air, and partly on what the author believes to be a new method, *i.e.*, the one used to distinguish between radiant and diffused light. Photographs showing the effects on pure lead of the action of moorland waters before and after mechanical filtration, proved that the results of ordinary chemical examination could be confirmed by direct observation of the passage of lead into waters acting on lead. A full account of this method would occupy too much space and will be given elsewhere.

THE CHARACTERS OF MECHANICALLY FILTERED WATER.—APPENDIX.

Table Ia.—Giving the Results of the Analyses of 2 Sets of Samples.

Date.	Reference L.B.	Kind of Water.	Total Bacteria per 1c.c growing on gelatine in 3 days at 20°C.		IN PARTS PER 100,000. Oxygen absorbed.		Albuminoid Ammonia.		Free Ammonia.		Nitrites.		Nitrates.	
			Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.
Filter A.—														
1913, Jan. ..	5758	Reservoir 1.—Soft water (Moorland)	11	0	0·1156	0·0136	0·0094	0·0044	0·0130	0·0130	0·	slight	0·100	0·125
Mar. ..	5847	,,	34	5	0·0936	0·0260	0·0042	0·0030	0·0100	0·0086	0·	traces	0·100	0·100
June ..	5988	,,	2	6	0·0980	0·0420	0·0062	0·0032	0·0084	0·0084	0·	0·	0·125	0·125
July ..	6081	,,	25	17	0·0660	0·0080	0·0050	0·0022	0·0130	0·0110	0·	0·	0·115	0·115
Sept. ..	6177	,,	13	2	0·0480	0·0240	0·0030	0·0014	0·0088	0·0076	0·	0·	0·120	0·120
Nov. ..	6333	,,	145	3	0·0128	0·0128	0·0020	0·0010	0·0102	0·0094	0·	0·	0·125	0·125
Dec. ..	6425	,,	190	4	0·0176	0·0044	0·0030	0·0030	0·0170	0·0170	0·	0·	0·125	0·125
Filter B.—														
1913, Dec. ..	6438	Soft water (Moorland)	115	4	0·156	0·028	0·0076	0·0014	0·0040	0·0044	0·	0·	0·175	0·175
1914, Jan. ..	6506	,,	51	1	0·152	0·032	0·0046	0·0020	0·0014	0·0016	0·	Traces	0·125	0·125
Feb. ..	6592		66	4	0·152	0·020	0·0050	0·0014	0·0010	0·0022	0·	0·	0·040	0·060
Mar. ..	6678	,,	41	0	0·148	0·020	0·0046	0·0046	0·0038	0·0038	Traces	Traces	0·115	0·115
Apr. ..	6741	,,	21	0	0·160	0·028	0·0054	0·0024	0·0040	0·0026	Traces	Traces	0·14	0·10
May ..	6834		20	1	0·120	0·052	0·0076	0·0024	0·0002	0·0004	0·	0·	0·100	0·100

Table Ib.—Giving the Results of the Analyses of 2 Sets of Samples.

IN PARTS PER 100,000.

Date.	References L.B.	Kind of Water.	SOLIDS.		Insoluble.		Soluble.				Reaction to						Hardness.				Action on Lead.	
			Total.		Suspended matter.		Non-Volatile.		Volatile.		Lacmoid.		Methyl-orange.		Phenol-phthalein.		Total.		Temporary.			
			Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	Afte
Filter A.—																						
1913, Jan. ..	5758	Reservoir 1.—Soft water (Moorland	7·80	9·50	Traces	Traces	5·56	7·20	2·24	2·30	+3	—7	—	—	+	+	3·5	4·5	0·	0·5	0·36	0·
Mar. ..	5847	,,	8·20	7·90	0·50	0·10	5·40	5·80	2·30	2·00	+4	—1	—	—	+	+	4·0	4·5	0·	0·5	0·40	0·
June ..	5988	,,	7·80	9·10	0·30	0·30	5·50	6·40	2·00	2·40	+3	—4	—	—	+	+	3·5	4·0	Traces	0·5	0·40	0·
July ..	6081	,,	10·00	10·0	0·80	0·	6·40	6·40	2·80	3·60	+6	—11	—	—	+	+	3·5	4·0	0·	0·	2·00	0·
Sept. ..	6177	,,	12·40	11·44	1·20	0·24	6·00	6·64	5·20	4·56	+4	—5	—	—	+	+	3·0	3·5	0·	0·5	0·50	0·
Nov. ..	6333	,,	10·00	10·0	0·40	0·	5·60	6·00	4·00	4·00	+7	—4	—	—	+	+	3·5	3·5	0·	0·	0·50	0·
Dec. ..	6425	,,	11·6	9·32	0·	0·	6·8	6·72	4·80	2·60	+10	—4	—	—	+	+	3·0	4·	0·	0·5	0·50	0·
Filter B.—																						
1913, Dec. ..	6438	Soft Water (Moorland)	—	—	—	—	—	—	—	—	—5	—8	—	—	+	+	3·5	4·5	1·	1·	0·	0·
1914, Jan. ..	6506	,,	8·80	10·56	Traces	Traces	5·44	7·20	3·36	3·36	—3	—16	—	—	+	+	3·5	3·5	1·	1·	0·06	0·
Feb. ..	6592	,,	8·80	9·84	—	—	5·60	7·20	—	—	—10	—15	—	—	+	+	3·	3·5	1·	1·5	0·12	0·
Mar. ..	6678	,,	8·88	9·36	0·08	Traces	5·28	6·16	3·52	3·20	—18	—22	—	—	+	+	3·	3·5	0·	0·5	0·08	0·
April ..	6741	,,	10·96	13·00	Traces	Traces	4·40	6·00	6·56	7·00	—12	—25	—	—	+	+	2·	2·5	1·	1·5	0·06	0·
May ..	6834	,,	8·00	9·76	0·16	0·16	4·44	5·6	3·44	4·00	—15	—30	—	—	+	+	3·0	4·5	1·	1·5	0·10	0·0

TABLE 2.—SOLUBLE MATTER.

PROPORTIONS OF VOLATILE MATTER (ORGANIC AND INORGANIC) AND OF NON-VOLATILE MINERAL MATTER, IN THE UNFILTERED AND THE FILTERED WATER.

Averages based upon 12 analyses of water from four reservoirs. Expressed in part per 100 parts of dry solid matter.

	Volatile (organic and inorganic).	Non-volatile matter. Mineral matter.
Unfiltered water	27·9	71·8
Filtered water	24·6	75·4

TABLE 3.

PROPORTION OF CERTAIN CONSTITUENTS IN DEPOSITS OBTAINED FROM CHEMICALLY TREATED WATER BEFORE AND AFTER FILTRATION. Expressed in parts per 100 parts of dry (non-volatile) mineral matter.

	Iron Fe_2O_3	Aluminium Al_2O_3	Silicon SiO_2	Calcium CaO	Magnesium MgO	Undetermined
A. Sludge from wash water (from a single washing (C.B. 1541)	14	31	31	—	—	24
B. Deposit in sedimentation tank near filters formed in six weeks corresponding to a large amount of water. (C.B. 1527)	24	5	48	11	2·5	9·5
C. Deposit in Disley Reservoir formed in 18 months and corresponding to a very large amount of water.(C.B. 1486) ...	17·4	7·97	65·45	5·1	0·79	3·29

Discussion.

Mr. F. J. Dixon (Ashton-under-Lyne) in opening the discussion said he would have liked, before he discussed the paper, to have heard some remarks from the scientific men present. He could only speak from experience which he had gained from association with Prof. Delépine—an association which had been very instructive to both of them. The paper was a very interesting one, dealing, as it did, with two installations of a different type treating similar classes of water. Prof. Delépine had criticised the conditions of guarantee included in installation " A," and as he (Mr. Dixon) was the unfortunate gentleman who formulated these conditions, he wished to explain that they were drawn up some four years ago, and he was ready to admit that some of the conditions were severe, but if anything, they erred on the right side from the engineer's point of view. His only regret was that when he framed his specification and conditions of guarantee, he had not more knowledge of chemistry which would have assisted him in excluding those conditions which Prof. Delépine had criticised. Another thing he regretted was that he did not call in the advice of eminent scientists such as Prof. Delépine. He had, however, to work at a very low cost, and his Committee always raised objections to calling in outside experts. He did the very best he could under the circumstances to safeguard his Committee, and he felt, especially after hearing the paper, that he had attained that object, as they would notice in the concluding remarks of Prof. Delépine that the results came out fairly satisfactorily when compared with the original conditions which he (Mr. Dixon) had laid down. The conditions for installation " B " were he believed laid down by a very eminent man—Prof. Franklin—and he noticed in clause 7 the Professor paid great attention to the reduction of the percentage of bacteria, but in his opinion that was not a very satisfactory clause, and in his case he did not include the results in percentages, but in the number of bacteria allowable in so many cubic centimetres of water, which he thought was more satisfactory when comparing the results. The results as to the colour of the water, which Prof. Delépine showed, were very satisfactory, as in the case of 32 samples examined the water was practically colourless, 95% of the discolouration being removed. The references to suspended matter were undoubtedly very interesting. In the original samples sent to the Professor about 18 months or two years ago, he was at a loss to understand why there was such a large increase of suspended matter. He had feared that the contractors would not be able to comply with the original conditions, and he was very pleased to find that the increase of suspended matter in the treated water was due to fine particles of the filtering medium which had evidently passed through the filter and got into the filtered water. He thought it was only fair to the contractors who put down his plant to say that the filtering medium when first put in contained a large amount of dust caused by the granulating of the quartz, and that by constant washing, those fine particles had undoubtedly increased. The medium used in installation "A," after washing, showed that if anything, the result of the attrition was greater in the installation which he controlled than in the one which they visited the previous day at Kinder. Having observed that after washing some of the filters, the whole of the medium was not thoroughly washed, he drew the attention of the contractors to this and suggested that it was due to the high velocity of the propellers which forced the sand through the central tube. This was something like 650 revolutions per minute, which was of course a very high speed, and such that the life of the propeller section of the jets would be very short. The contractors then reduced the speed to something like 350 revolutions per minute with excellent results. The Professor, not being acquainted with those conditions, very naturally could not understand why the suspended matter was not as large in amount as it had hitherto been.

Referring to the sediment which Prof. Delépine found in the clear-water well at Kinder he (the speaker) was wondering how long after treatment the Professor discovered this sediment. In the sample which the Professor had passed round and which he had had for three weeks, he (Mr. Dixon) could not detect any sediment with the naked eye. He had samples which had been kept for 3 months and 6 months respectively and had never seen any sediment. Moreover, he had inspected the water in the new 24 inch mains on the outlet of the installation, an inspection cover having been inserted for the purpose, and although there was a certain amount of small green slime, he had never up to the present found any deposit such as was found in the clear-water well at Kinder. He was wondering whether the absence of this fine suspended matter was due to the velocity with which the water passed through the pipes. They were greatly indebted to the Professor for giving them the constituent parts of this sediment, as it proved it to be due to the action of the medium on the pipes. They would notice that the proportion of iron was very pronounced. In his specification he required that the interior of the filters should have three coats of "siderostin" paint. While, in the case of the filters at Kinder, the paint on the interior might remain intact, in his case it was undoubtedly removed by the scouring action of the medium while being driven through the central tube. The result was that the iron was exposed, and no doubt the contact of the water with the exposed iron accounted for the presence of the small particles of iron which the Professor discovered in the sediment. He would like to know whether the Professor had found the same quantity of iron in subsequent samples.

He thought they would all agree that the Professor had adopted a very excellent way of arriving at the action of the water on lead. A good many experts, including those in America and Germany, tested with three feet of lead pipe. Now, in making lead pipe there was a kind of greasy solution put round the mandril which was deposited on the inner walls of the pipe. There was no chance of this being removed, as the pipe was delivered in coils, with the result that the pipe would certainly have a protective coating which would prevent the immediate contact of the water with the lead. He thought they would agree that the results obtained by the Professor were excellent, and that his test was a very severe one and far more reliable than the methods usually adopted. They could hardly realise the difference between the lead foil before and after contact. The test was undoubtedly the most severe which could be applied, and if water came out satisfactorily under it, he thought it was water as to which they might be well satisfied.

With regard to bacteria, at the works under his (the speaker's) control it was very curious that in one or two cases after water had been passed through the filters, the bacteria increased. The number of bacteria in the original water was so small that it did not affect the results, but as he had said, it was very strange that the number in the filtrate should be increased, and he would like to hear from Prof. Delépine what was the cause of the increase.

The indicators which the Professor enumerated in his paper were very useful to the man in charge. As he (Mr. Dixon) explained in a paper which he read in London, a simple method by which the man in charge could readily ascertain the condition of his water for the purpose of knowing the quantity of chemicals required to deal with it was much wanted. The Professor had been good enough to prepare those indicators and they had proved very helpful except in one case. The reaction of lacmoid with acid water could be readily obtained by the man in charge when he compared the filtered with the unfiltered water. However, in the case of a supply at Greenfield valley, which was obtained partly from an impounding reservoir, and partly from springs, the reservoir (which held 200 million gallons) unfortunately had no waste-water channel to take flood-water and consequently, in times of heavy rain, the whole of the water from the gathering ground flowed direct into the reservoir. The suspended matter thus brought down made the water very turbid and if much of the reservoir water were used at such times it necessitated washing the filters every 12 hours, so he had been in the habit of using a good deal of the hard spring water. He had never had the waters separately analysed. On one occasion, after a drought, the man in charge used an excessive quantity of spring water which had a hardness equal to 16 degrees Clarke's scale. When the man tested the water with lacmoid he found that it showed a neutral reaction, and when he (Mr. Dixon) sent a sample to Prof. Delépine, he got a very bad report. The plumbo-solvent action in the unfiltered water equalled .36 parts per 100,000 while the filtered water showed .26. He could not understand such a result, and upon investigation Prof. Delépine found that it was due to the excessive alkilinity which was present in the spring water.

If they looked at Table " B " and compared the two waters, he thought the results were extremely satisfactory for installation " A." They would notice that the action on lead before filtration was what he would call very excessive, .36 parts per 100,000 being the minimum. In one case in July it was as high as 2, and in every case after filtration and treatment with the very small amount of chemicals (not more than .3 grain per gallon)—it was neutral. If they compared the two waters he thought the results of installation " A " were far more satisfactory than those of installation " B," because the unfiltered water in installation " B " was practically neutral. In no case was the action on lead before filtration above .12, so it was evident that the work which installation " B " was called upon to do was not nearly as severe as in the case of installation " A."

Mr. W. T. BURGESS (London) said that Prof. Delépine had given them some very valuable information concerning mechanical filters and the reasonable conditions that might be formulated for makers. He quite supported Prof. Delépine in his criticisms of some conditions, which were clearly unreasonable. For instance, when the water had but few microbes in it, it was absolutely unreasonable to insist that a definite percentage should be taken out by the filters. In fact, as the Professor had told them, it was quite possible that water that had but few bacteria in it should come out of the filters with a larger number. With reference to the action on lead he noticed that in one of the installations it was specified that the water should not be capable of taking up lead to a greater extent than 0.05 per 100,000. He had come across specifications which demanded even a lower proportion of lead. He certainly thought the Professor had not erred on the side of unreasonableness in insisting that the water should take up not more than .05 per 100,000 after treatment. He had tried all sorts of methods for testing waters for their action on lead. He had tried the " shot " method adopted by Dr. Houston in connection with his researches for the Metropolitan Water Board, and he had used pure sheets of lead, but he still pinned his faith to trials with lead pipes and he believed he would continue to do so. Whenever he was testing the action of water on lead pipes, knowing the difficulty that there was in always getting the same sort of pipe, it was his habit to test with a standard water which he knew something about, and if he was making a series of experiments he always had his pipes cut from the same (new) coil of lead. It was important to see that the interiors of the test pipes were clean, and that could only be done by rubbing with a clean cloth,—it was unsafe to use chemicals. He was quite satisfied that he would stick to lead pipes for his testing. Condition 7, referring to the hardness of filtered water was unimportant. He did not see that that condition was one that could be insisted upon. Hardness of the filtered water as tested by Clarke's method was not to exceed 10 per 100,000, but anybody who had anything to do with mechanical filtration and the treatment of water with chemicals knew that in some cases the hardness was untouched, whilst with certain soft waters, the hardness might be increased, the increase depending on the proportion of chemicals used. He would like to see the reference to the hardness of the water omitted altogether from the conditions.

Mr. F. W. HODSON (Loughborough) said he thought it would be an advantage if Prof. Delépine would add a few words to the tables in the body of the paper explaining the nature of the figures relating to the sludge taken out of the tank at Kinder. He took it to be the direct result in grains of the total sample analysed. Also in the table of alumina found, it was not stated whether the results were in parts per 100,000 or otherwise. It would also add materially to the value of the tabulated results if it could be stated whether the sample analysed represented the whole deposit in the sedimentation tank from the first erection of the plant, or whether the tanks had been cleaned out at any time prior to the sample being taken. Something like 75% of the total mineral matter deposited appeared to be fine particles from the filtering material and from the walls of the filter. If the results were from the start they included all the original fine particles in the sand as delivered, but if the tank had been cleaned a reasonable time after the preliminary working commenced, they represented attrition due to washing, which was a matter of much greater importance as being a continuing source of trouble.

THE PRESIDENT said that as time was getting short he would have to ask those who wished to ask any questions to send them in writing to Prof. Delépine who would reply to them in the "Transactions." His works at Kinder had been referred to, and he had got some very interesting analyses of the water immediately it left the filters, and also from a consumer's tap in a house nine miles away from the filters, the water having passed through the filtered water tank at Kinder and the Jacksonsedge service reservoir which held 400 million gallons; it will be seen that the two analyses were almost identical.

	Water as it left Filters.	*Water from House Tap.*
Bacteria	1 ...	1
Oxygen absorbed	0.052 ...	0.052
Free and saline ammonia ...	0.0004 ...	0.0004
Albuminoid ammonia ...	0.0024 ...	0.0036
Nitrous nitrogen	None. ...	None.
Nitric nitrogen	0.100 ...	0.100
Chlorides	1.40 ...	1.40
Hardness—		
Temporary	1.50 ...	1.50
Permanent	3.00 ...	3.00
Plumbo solvent action ...	0.04 ...	0.04

It was very remarkable that the analysis of the water as delivered to the consumer, which had left the filters probably 36 hours earlier, came out almost identical with that of the water taken direct from the filters. He had pleasure in proposing a vote of thanks to Prof. Delépine for his interesting and instructive paper. Mechanical filtration was the development of a process which had long been used for manufacturing purposes. Mechanical filters had been in use for 50 or 60 years for clearing river water for manufacturing purposes, and it was owing to the thought and ability which gentlemen like Prof. Delépine had brought to bear upon the subject that the mechanical filter had been so perfected.

Mr. E. J. SILCOCK (Westminster) seconded the vote which was carried unanimously.

CORRESPONDENCE.

Mr. WILLIAM PATERSON, being unable to attend personally, sent the following remarks on Professor Delépine's paper: Professor Delépine is to be heartily congratulated upon his timely paper, as the facts he brings out will undoubtedly receive careful consideration by the members of council, who, our esteemed President advises, are engaged upon the framing of satisfactory contract guarantee clauses. The title of the paper might perhaps more precisely indicate its contents were it to read "Characters of Pressure-filtered Moorland Waters," because it refers exclusively to experience of pressure filters, and the special nature of the filtrate, to which the author calls our particular attention, may, as we see, be exclusively characteristic of pressure, and not gravity filtration; further, they particularly apply to the mechanical filtration of soft, artificially hardened moorland waters and not turbid and calcareous supplies. The author remarks that, "although the results obtained were highly satisfactory, the condition of guarantee had not been fulfilled, because the effects of filtration have not turned out what might have been expected" and later says that "a consideration of what could be expected would have been sufficient to say that some of the conditions could not be realised." Consider the position of two contractors "X" and "Y" tendering to a specification containing such a guarantee clause. Let us suppose contractor "X" takes the specification seriously, and, after elaborate and costly analytical tests on the crude water before and after treatment with various reagents, próves conclusively that the guarantee required is impossible of attainment. Contractor "Y," on the other hand, swallows the guarantee clause whole and trusts to luck. Most probably he will receive the contract on the ground that he alone is prepared to guarantee fulfilment of all the clauses in the guarantee form. Obviously those responsible for the framing of the specification unwittingly inflict a grave injustice on contractor "X," who has at much expense proved by tests that the conditions required were impossible of attainment. For this reason it must be obvious that it is urgently necessary for an independent authoritative body like the Institution of Water Engineers to establish some form of guarantee which, if fulfilled, will comply with all the essential conditions of a pure potable water without calling for conditions to be complied with, which no responsible contractor could conscientiously undertake. I am in entire agreement with all that Professor Delépine has to say in criticism of the guarantee clauses. There is no precision in the term "removal of 95 per cent. of the discoloration," and the requirement that 45 per cent. of the organic matter in solution must be removed might lead to serious misunderstanding unless it is agreed as to how this must be estimated. In one case that came under my experience the reduction of organic matter when estimated by the albuminoid ammonia test was 63 per cent. while the "oxygen absorbed" test showed only 31 per cent. reduction. Again, the free ammonia in a treated water may quite as frequently be increased as diminished, as the treatment more or less shows traces of ammonia in commercial aluminia. The condition No. 10, "The oxygen absorbed from permanganate in four hours not to exceed 0.035 grains per gallon," is, in some cases, practically impossible of attainment. In one simple case that came under my notice lately the oxygen absorbed by the crude water was no less than .8, while this was reduced to 0.15, or 81 per cent., an excellent case, but far from complying with the figure called for by the specification. This proves the necessity, as far as possible, for making tests of samples of water obtained before giving a binding guarantee as to the official figures to be obtained. The author draws attention to the fact that, whilst under normal working conditions the water was apparently cleared, when viewed in a strong light there was a slight turbidity or opalescence due to suspended matter, composed almost entirely of minute particles which were practically ultra-microscopic, and goes on to say that when the treated water was made to pass through a sedimentation tank a dark gelatinous layer was deposited on the sides and bottom of the tank. The deposit was due to the separation of the fine particles contained in the water. From the interesting analysis given he concludes that this is composed of (1) filtering material, (2) iron from the filter walls, (3) precipitation resulting from the lime salts, and says it is reasonable to expect an increase in the soluble mineral constituents; but I venture to suggest that, while the analysis shows that results are exceedingly good, they would have been better had this insoluble precipitate been removed by the filtration process, and see no reason why this should not be effected by allowing time for the chemical reaction to complete before filtration. It is claimed that on the addition of a coagulant the reaction is instantaneous. My experience is that, while its effect in clearing the water from discoloration would lead one to imagine that this was so, time is essential for the completion of the reaction, and the slight, exceedingly minute precipitate described by the author is due to the completion of the reaction if the water has been freed from discoloration and gross suspended matter. The remedy, in my opinion, is the provision of a storage tank to allow a completion of the chemical reaction before the water passes on to the filter. The excellent summary of the essential conditions which the author has given appears to be very fair, and should be acceptable to any responsible contractor. The only suggestion that I should make is that Clause 3 might read : " The filtered water and vapour therefrom shall be free from odour at all temperatures up to 100 deg. Cent." Clause 7 seems hardly essential, as with a soft moorland water a licence to increase the hardness to 10 parts per 100,000 is too sweeping. The requirements desired could be obtained by specifying that the hardness is not to be increased more than 2 or 3 parts per 100,000. My experience is that it is generally desirable to insert a clause guaranteeing the weight and cost of the reagents required per 100,000 gallons purified. Professor Delépine is to be congratulated upon his excellent paper, which doubtless will lead to the framing of satisfactory standard guarantee clauses.

Mr. R. A. Blakeborough (Brighouse) wrote as follows :—

Prof. Delépine's paper is extremely interesting to anyone connected with the filtration of water by means of Mechanical Filters.

In regard to the Author's comments on Condition No. 1 relating to discoloration, I understand that in both the cases cited, namely " A " and " B " that these raw waters were comparatively good ones, containing only a slight amount of peat stain. I think it is agreed that the yellow and brown colours in the raw waters are the objectionable ones, and those which one wishes to get rid of, whereas the blue or greenish colours are not objectionable, and may possibly be produced by the chemical treatment. For this reason I would submit that a colour test for the brown, red, and yellow colours measured either by Hazen or Lovibond standard methods is advisable. In my experience, when dealing with a highly peat-stained water, the removal of 95% of the brown colour is by no means a simple task, whereas with comparatively good waters, with only a slight peat stain, 95% of the colour can be much more easily removed. It is extremely important that this colour measurement should be taken on an average number of samples of the filtered water taken at regular intervals over the whole period the filters run between the times of cleansing. It will be found very much more difficult to fulfil this guarantee if this is done. As a general guarantee, I do not consider that any contractor should be asked to agree to a binding contract without some latitude, and the removal of 90% to 95% of the colour is, I consider, as much as should be reasonably expected.

As to Condition 2, namely, the percentage reduction of organic matter, I am glad the Author has pointed out the advisability of using the measure of "oxygen absorbed" as an indication of the reduction of the organic matter contained in the water. I think, however, that owing to the great difference in the amount of oxygen absorbed by different waters, it is absolutely necessary that the amount should be specified as a percentage reduction.

With regard to the Author's examination of suspended matter in the filtered water, it will be observed that the greater part of the suspended matter is of a silicious nature. The Author explains that this sediment indicates that it is derived from the filtering material produced possibly by attrition during washing. I am of the opinion that there would have been practically none of this silicious matter had best quality quartz been used as a filtering media. There is no doubt the best filtering media is mechanically crushed and riddled pure white quartz crystals. No natural sand can be procured that does not contain more or less soft material. The other suspended matter referred to in the filtered water is undoubtedly caused by the chemical treatment. There are several possible reasons which can be given for this suspended matter finding its way past the filters, and a very important one is—that often sufficient time is not given for the complete chemical action. In this respect I have always maintained that proper time for the chemical action and for coagulation should be given. Another possible reason I submit is that the precipitate caught in the bed is apt to be forced through or disturbed when working filters under high heads and when the speed of filtration in each filter is not kept constant by the use of controllers.

The Author is to be congratulated in bringing before the Institution of Water Engineers this subject, for there is no doubt that the guarantee clauses relating to the chemical improvements of the water require careful consideration, as numbers of instances can be quoted where contractors who conscientiously considered certain guarantees could not be fulfilled, have been placed at a very great disadvantage.

Professor Delépine in the first instance expressed his thanks to the President for the kind words of introduction which he had given him and the members for the very kind reception they had accorded his paper. Mr. Molyneux's reference to what occurred in Bolton in 1903 was particularly generous, for at the meeting which took place in that town, his advocacy of the advantages of protection of gathering grounds combined with sedimentation and mechanical filtration was not received with favour by most of the engineers there present.

The advantages which these methods offered had been pointed out by him (Prof. Delépine) as far back as 1895 or 1896 when he advised the Bury Corporation to adopt protection, sedimentation and mechanical filtration in preference to sand filtration. His views were, however, strongly opposed by the Local Government Board, who insisted upon sand filtration. Prof. Delépine added that he had been led to suggest the use of mechanical filters (or strainers, as he preferred to call them in those days) for the purpose of removing suspended matter, owing to the fact that this method had been used with success for industrial purposes. It was hardly necessary to say that since 1897 the process of mechanical filtration had been considerably improved. In the early days it could not have been relied upon for any other purpose than that of removing comparatively coarse suspended matter and was only applicable to waters not liable to dangerous pollution. By combining the use of coagulents with mechanical filtration a very efficient process of purification had been evolved.

The author proceeded to assure Mr. Dixon that in criticising the conditions of guarantee which had been inserted in a certain contract, he did not suggest that Mr. Dixon was responsible for the conditions criticised. Mr. Dixon was only responsible for putting together the views of various experts. It was really the chemical and bacteriological experts who were responsible for these conditions, and immediately he (Prof. Delépine) saw them, he told Mr. Dixon that he thought some of them would never be fulfilled and that if he acted Shylock he would be able by means of such conditions to break through any contract. Mr. Dixon did not consult him in his capacity as an *expensive expert,* but they had many friendly conversations and he was glad at the time to find that there was no difficulty in convincing Mr. Dixon regarding bacteriological Standards.

The advantage of careful observations both by the engineer and the scientific expert was well shown by the fact that, without knowing the nature of Mr. Dixon's experiment on the rate of washing, he (Prof. Delépine) detected at once a difference in the amount of suspended matter when the method of washing had been modified, and was led to ask Mr. Dixon what alteration he had made in the treatment, and when he learnt that Mr. Dixon had reduced the velocity of the washing stream, he felt satisfied that this was sufficient to cause a reduction in the amount of suspended matter. This was a very clear justification of the attrition theory he had previously advanced to explain the presence of the fine suspended matter (composed chiefly of silica and iron) in the treated water.

The information asked for regarding the time during which the sediment had been allowed to form in the Kinder clear-water well is given in Table III. of percentage composition of suspended matter (A) in the wash water, (B) in the tank near filters and (C) in Disley Service reservoir. The last sediment was collected after 18 months, the second after 6 weeks, and the first immediately after a single washing.

Except in the case of the wash water, no turbidity or sediment could be observed by the naked eye in a small amount of water such as was contained in a jar, even after it had stood several weeks, yet the suspended matter could be demonstrated by the optical method which had been described, and by the slow formation of sediment as the result of the passage of many thousand gallons through a tank or a reservoir, and possibly at some bends in the pipes. Separation takes place when the movement of the water is reduced to a slow speed or the flow is sharply diverted from its original direction.

As regards the presence of iron in the sediment, there did not seem to have been any diminution since an attempt was made to estimate it, but during the first 6 months no such attempt was made.

An increase of bacteria during filtration is of no moment when the increase is very slight and the original number is very small, a minute flake of organic matter is sufficient to account for such an increase. If the increase was constant and material, this would of course indicate imperfect washing of filters and possibly multiplication of some bacteria in the plant.

He (Prof. Delépine) would like to say that the taking up of lead by certain hard waters, although it may be associated with an alkaline reaction, was to be accounted for by the nature of the saline constituents and the nature of the gases dissolved in the water.

As to the necessity of stringent conditions, Prof. Delépine entirely agreed with Mr. Dixon, but he thought that a limited number of essential conditions capable of fulfilment and securing a water of good quality answered the purpose in view better than a great number of conditions, several of which had to be waived because they could not be fulfilled and were not essential.

With regard to Mr. W. T. Burgess's remarks about the condition that the water should never take up more than 0.05 parts of lead per 100,000, Professor Delépine said he agreed with him in considering this a low standard, but this was allowed only as an occasional occurrence and was determined by standards generally adopted. As a matter of fact, he was of opinion that it would be quite possible, when mechanical filtration was used, to insist on a much more stringent standard, but at the present time it was difficult to insist upon such a standard because it could not be uniformly enforced.

With regard to methods for testing the action of waters on lead, he (Professor Delépine) proposed to write before long a full account of experiments made with pipes or plates of commercial lead and also with pure lead foil, and he felt convinced that, after seeing the results, Mr. Burgess would feel less confident in the pipe method.

With regard to the hardness, he entirely agreed with Mr. Burgess. From the wording of the suggested clause it would be easy for him to see that by an oversight this clause had been placed in the wrong group of conditions. The condition about hardness was one which should, within limits, be left to the judgment of experts. The question of a limit did not apply to soft waters, but to hard waters. He (Professor Delépine) thought that everybody would agree that when the hardness of a water exceeded 20 degrees, it was desirable to reduce it to something less ; 20 was a quite arbitrary figure. The answer to Mr. F. W. Hodson's questions will be found in Table III. This was not printed in the copy distributed at the meeting, but was thrown upon the screen after the paper had been read. With regard to Mr. Paterson's remarks, the question of the title of the paper was discussed with the editor who was in favour of the shorter title. As a matter of fact the results brought forward were used only as a basis for a discussion of principles which held good for any kind of water. He (Professor Delépine) had pointed out, however, that special treatment was needed for hard waters, and he was glad to hear that in principle his suggestions as to the nature of the clauses was approved of.

With regard to the hardness figure, the condition did not refer to soft waters but to hard waters that required softening. The wording of the clauses indicated that his object was to indicate absolute standards which might be applicable to any kind of water and would safeguard the interests of the consumer without unfairness to the contractor.

As to the cost of chemicals, he had considered this matter a purely engineering and administrative question, and had limited his paper to so-called scientific (*i.e.*, chemical and bacteriological)conditions.

With reference to Mr. R. A. Blakeborough's letter, the measuring of colour by a colorimetric method might be interesting for the purpose of keeping records of the state of the raw water, and if necessary to estimate the amount of work done by the filter, but his (Professor Delépine's) contention was that, as far as the conditions of contract were concerned, what had to be insisted upon, and was entirely sufficient, was that the treated water would be clear and of a satisfactory colour.

As to the amount of oxygen absorbed, he had clearly indicated that this was one of the conditions regarding which the expert must use his discretion.

The quartz used at one of the installations was examined in his (Professor Delépine's) laboratory and found to be of the best quality, but rapid friction of quartz against quartz was bound to bring about some erosion, however pure the material might be.