[No. 68.]

G.W.R. Mechanics' Institution, Swindon.

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Chairman—Mr. G. H. Burrows, A.M.I.Mech.E.

" SELECTION AND IMPROVEMENT OF WATER FOR BOILER PURPOSES, "

BY

W. R. BIRD, F.C.S. (Member.)

With Discussion.

The variable nature of the geological strata is responsible for important differences in natural waters. They may be classified in order of suitability for boiler purposes as follows:—

1. Soft waters containing very small quantities of dissolved salts and free from corrosive acids.

2. Soft waters practically free from dissolved salts, but containing slightly corrosive acids.

   Such waters cause pitting of boiler plates if used alone. The acidity, if due to natural causes, can be neutralized by the addition of half a pound of slaked lime per 1,000 gallons. With this addition the water is of good quality for boiler use.

3. Hard waters practically free from non-incrustating salts.

   These waters form a thick scale in boilers, but can be rendered suitable by chemical treatment in water softening plants. They may be sub-divided into two classes:—

   (*a*) Chalk waters.

   (*b*) Sulphate waters.

4. Soft waters containing appreciable quantities of permanently soluble salts in solution.

These waters do not form scale, but concentration of the soluble salts in the boiler causes "foaming" or "priming," especially in boilers of high evaporative power such as locomotive boilers. This fault cannot be remedied. Such waters are therefore unsuitable for locomotive boiler use.

5. Hard waters containing also appreciable quantities of non-incrustating salts in solution.

This is the worst kind of water from a steam users point of view, as even if the incrustating salts were removed by the softening process, the water would foam and give trouble in the cylinders.

Up-land surface waters are generally soft and more or less corrosive.

The Manchester, Liverpool and Birmingham supplies, obtained from Westmoreland and Wales, are of this character.

River and Canal waters are very variable in character. Except where influenced by tides, they are, as a class, softer than average spring and well waters. The Thames water supplied by the London Water Companies is a slightly diluted chalk water.

The character of spring and well water depends entirely on the nature of the strata permeated.

Soft waters, practically free from soluble salts are yielded as a rule by, Igneous, Metamorphic and Cambrian Rocks, Silurian and Devonian Sandstones and Millstone Grit. Soft waters containing appreciable proportions of soluble salts are characteristic of non-calcareous coal measures, Lower Green Sand, London and Oxford Clays, Bagshot Beds and non-calcareous gravel.

More or less hard waters are yielded by Silurian and Devonian Limestones and Chalk Marl, Carboniferous or Mountain Limestone, calcareous coal measures, new Red Sandstone and Magnesium Limestone, Lias and Colitic Limestones and gravel, the Upper Green Sand and the chalk.

Water issuing from the Middle and Lower Lias is very rarely usable on account of the non-incrustating salts almost invariably present with the incrustating salts. Deep borings through Oxford, Kimmeridge or London Clay into the Forest Marble, Coral Rag or Chalk generally has similar characteristics, but after softening, is sometimes usable in stationary water tube boilers. A careful examination of the geological peculiarities of the neighbourhood is therefore of first importance in the choice of a site for a well or borehole, if risk of useless expenditure is to be avoided. Whatever opinion we may have of the powers of a water diviner, he does not claim to be able to determine by divination the quality of the water he may find.

Naturally perfect waters are comparatively rare.

The most common defect is the hardness which causes scale to be deposited on the heating surfaces of the boilers. This scale is a bad conductor of heat, and offers from 20 to 40 times as much resistance to its passage as an equal thickness of steel boiler plate or, say, 50 to 100 times the resistance of commercial copper. The evaporative efficiency of the boiler is only slightly reduced, but the difference in temperature between the firebox plates and the water is greatly increased, reducing the strength of the metal and increasing the strains due to variations in temperature, in many instances as much as tenfold.

These defects can be removed by softening the water, with the following advantages:—

(1) Decrease in consumption of coal, due to increased conductivity of firebox plates. (The saving on this account alone, although it may be small, should considerably exceed the total cost of softening).

(2) Reduction in cost of repairs, due to the increased durability of the boilers.

(3) Greater safety, owing to increase of the factor of safety of the metal.

Water is hard or soft according to the presence or absence of soap-destroying compounds of lime and magnesia. Carbonate of lime and carbonate of magnesia cause what is called "temporary hardness."

Sulphate of lime and sulphate of magnesia, and occasionally other salts of lime and magnesia, produce so-called "permanent hardness." The carbonates are soluble in water containing carbonic acid, but are insoluble in pure water, or water from which the gases have been expelled by boiling. The sulphates are soluble in the water itself, independent of the presence of carbonic acid.

The common hardening salts are deposited as scale in steam boilers. The deposition of the carbonates is due to the expulsion of the carbonic acid gas with the steam. When deposited alone they form a soft bulky scale. Contrary to the general rule, the solubility of sulphate of lime in water decreases as the temperature increases. At the high temperature existing in high pressure boilers it is practically insoluble and forms a hard crystalline deposit not easily removed.

Water softening processes effect the removal of the scale-forming salts by the addition of chemicals which render them insoluble, when they can be removed by sedimentation or filtration.

Carbonic acid is always present in natural waters, being dissolved in the passage of rain water through the atmosphere and through soil; therefore waters which are collected on chalky strata always acquire "temporary hardness." This can be removed by the addition of slaked lime, which combines chemically with the carbonic acid to form practically insoluble carbonate of lime, and is precipitated together with the then insoluble carbonate of lime and carbonate or hydrate of magnesia originally in solution in the natural water. If just the proper proportion of lime is used such hardening salts are removed from solution by this process without the substitution of anything in their place. The following equation represents the change:—

$CaH_2(CO_3)_2$	+	CaO	=	$2\ CaCO_3$	+	H_2O.
Bicarbonate of Lime. Soluble.		Quick-lime. Soluble.		Carbonate of Lime. Insoluble.		Water. —

Permanent hardness is not removed by the lime treatment, but the sulphates and other similar salts of lime and magnesia can be most economically decomposed by the addition of carbonate of soda, which converts them into the practically insoluble carbonates of lime and magnesia, leaving sulphate or other soluble salts of soda in solution, which do not destroy soap or deposit in boilers. This change may be represented thus:—

$CaSO_4$	+	Na_2CO_3	=	$CaCO_3$	+	Na_2SO_4
Sulphate of Lime. (Soluble).		Carbonate of Soda (Soluble).		Carbonate of Lime (Insoluble).		Sulphate of Soda (Soluble).

The presence of a considerable proportion of soluble salts in the water used does not interfere with the steaming efficiency of ordinary stationary or tubular boilers, but in boilers of the locomotive type they have a tendency to cause the water to prime on very moderate concentration. This fact limits the application of the use of soda for the removal of permanent hardness in waters for locomotive boiler use. Sulphates can be removed by the use of carbonate of barium, the sulphate of which is insoluble and therefore precipitated with the carbonates of lime and magnesia, without the introduction of permanently soluble salts. The process is however at present more costly than when soda is used.

Ten degrees of temporary hardness can be removed at a cost of about one-tenth of a penny per 1,000 gallons.

To remove ten degrees of permanent hardness with soda costs about $\frac{3}{4}$d. per 1,000 gallons for chemicals. If carbonate of barium is substituted for soda the cost would be at least 1$\frac{1}{3}$d. per 1,000 gallons.

There are other chemicals capable of softening water, but owing to considerations of cost, etc., lime and soda ash are at present used almost exclusively for the removal of temporary and permanent hardness respectively. There is therefore no difference in the chemical processes, although the method of application varies considerably in the different water softening plants in practical use.

A good softening plant must fulfil the following conditions:—

Provision must be made for alteration of the proportions of the chemicals to meet variations in the quality of the hard water, and for the automatic adjustment of the correct proportions at all rates of pumping.

The chemicals must be intimately and uniformly mixed with the hard water.

The reaction and settling chamber must be sufficiently large to allow time for the completion of the chemical change therein.

The softened water must be completely clarified, and the supply practically continuous.

The use of slaked lime for the purpose of water softening was proposed more than 100 years ago, but the successful application of the process dates from the year 1841, when Dr. Clark patented his method for exact adjustment of the proportions of lime.

The simplest apparatus used for the purpose consists of a large settling tank in which lime water is mixed with the hard water and the precipitate allowed to settle for seven or eight hours. The lime water is first made in a similar tank of smaller size by mixing a portion of the water with slaked lime. This process has been in successful operation in softening water, for domestic purposes, at Canterbury (Town Supply), Kenley Water Works of the East Surrey Company (illustrated), the South Hants Water Works, and other places for many years. It is used on a small scale on the Great Western Railway, at Swindon Works and Gloucester Docks. The disadvantages of the process are, the large ground space required and the large capital outlay on the tanks.

Archbutt & Deeley's quick settling process reduces the tank capacity required for a given output to about one eighth, by stirring up the accumulated precipitate, from previous operations with compressed air. The very thorough mixing of the reagents also assists the rapid precipitation. The proportions of chemicals are adjusted by weight, and can be varied to meet rapid fluctuations in the quality of the water. There is also an arrangement for carbonating the softened water with gases from a coke stove to prevent subsequent precipitation of traces of incrustating salts in the service pipes, etc.

The reduction in space required and of first cost, and the facility of adjustment to variation in the hard water supply, are favourable to the use of this plant for trade effluents and dirty river water subject to variations due to tides, etc. The principal disadvantage is the increased cost of attendance.

A plant of this type is in use on the Great Western Railway at Foxe's Wood Pumping Station, near Bristol (illustrated).

Greater economy of space is obtained by continuous processes using filters and settling towers for the removal of the precipitated lime compounds.

The Porter-Clark, one of the earliest types of softening plant, consists of a mixing chamber, into which the solution of the chemicals and hard water are pumped by suitably proportioned pumps, coupled together. The turbid mixture passes from the top of the mixture chamber to a filter press. This process is now out of date, owing mainly to the cost of attendance and trouble with the filter cloths.

The Atkins process, in use at Southampton Water Works, and formerly at St. Helens, is an improvement on the Porter-Clark, with an ingenious arrangement for cleaning the filter cloths with jets of steam.

There are a number of continuous softening plants now on the market consisting essentially of a tall square or cylindrical tank or tanks divided into shallow layers by iron plates over which the mixture of hard water and chemicals passes slowly from the bottom upwards. The precipitated solids deposit chiefly on the plates and the almost clear water is decanted from the top through wood-wool, or sand filters. The Desrumaux plant, as used at Goring and Paddington, and the Kennicott apparatus, as used at Aldermaston, and the Severn Tunnel Pumping Station are fair examples of this type.

What is known in England as the Stanhope Water Softener is the earliest example of this type the Author has seen in use. It consists of a square tower with V-shaped plates inclined at such angle that the precipitate slides down towards a sludge cock when a sufficient thickness has accumulated. The water and reagent are mixed in a funnel, conveyed to the bottom of the apparatus and passes upwards in a zig-zag path to, and through, the wood-wool filter at the top. There is now an improved Stanhope Softener of cylindrical shape.

In the Desrumaux plant (illustrated), the main settling tower and the lime water saturator are cylindrical and the water takes a spiral course over the settling plates. A wood-wool filter is used at the top. This is a good apparatus for lime water treatment only. It is giving good results with a chalk water at Goring.

The Kennicott plant (illustrated) is very compactly arranged. It is in the form of a cylindrical tower with the smaller lime water saturator and mixing chamber in the centre. The water passes downward in an annular space of uniformly increasing area, then upwards through a series of sloping perforated plates, and finally through a wood-wool filter at the top. The lime water is made with previously softened water, and the arrangement for the automatic supply of soda solution is a satisfactory one. It is giving excellent results at Aldermaston, removing both temporary and permanent hardness.

The "Criton" water softener of the Pulsometer Engineering Co., and the "Reisert" apparatus supplied by Messrs. Royles, Ltd., are continuous plants differing chiefly from the foregoing in the use of sand filters and in the regulating mechanism. The latter firm have a plant designed for the use of barium carbonate instead of soda ash for the removal of permanent hardness.

The success of the softening process depends upon the accurate adjustment of the apparatus, controlled by means of frequent tests of softened water. The neglect of systematic testing results sooner or later in extravagant cost or unsatisfactory results, sometimes both.

Simple tests have been devised by the use of which the pumper can readily determine the hardness of the softened water and detect any excess or deficiency of chemicals without calculation or chemical knowledge. These tests should be regularly and frequently made and the results recorded. Simple rules can be provided for the readjustment of the plant in accordance with the indications of the test.

The cost per 1,000 gallons depends upon the character of the water softened and the scale on which the operation is conducted.

At Goring 480,000 gallons are softened per day at an inclusive cost for chemicals, labour and interest on capital, of about half-penny per 1,000 gallons.

At Aldermaston the plant is not working to its full capacity at present. The cost is therefore higher—about ¾d. per 1,000 gallons.

At Foxe's Wood it is slightly higher still for the same reason. In all cases the cost is small compared with the important advantages obtained by the use of softened water.

The water at all these places is uniformly softened to between three and five degrees of hardness, an amount which produces no scale.

Boilers using the softened water exclusively for twelve months were found to be perfectly clean inside as new. The heating of the plates is therefore at least 300° to 400°F less than when hard water was used, and the repairs required have been almost nil.

The boilers of the long distance express engines which take sufficient hard water at Paddington to carry them to Goring, but are otherwise supplied with soft water, were coated with a very thin layer of scale after six months running. The improvement on previous experience with hard water was very marked. The advantages gained well repay the cost of softening.

DISCUSSION.

Mr. G. H. Burrows said he had read an account of a very careful experiment on the Illinois Central Railway, which was carried out in 1898, to test the effect of scale on the best transmission. A locomotive which had been in service 21 months was tested. The boiler was afterwards retubed and thoroughly cleaned. The average thickness of scale was $\frac{3}{64}''$. Before cleaning, the evaporation per square foot of heating surface per hour from, and at, 212° was 5·99 lbs. After cleaning and retubing it was 6·78 lbs., an increase of 13 per cent.

The scale analysis was as follows:—

Silica ...	...	15 per cent.
Iron and Alumina	...	6 ,,
Calcium Carbonate	...	44 ,,
Magnesium ...	...	3 ,,
Calcium Sulphate	...	14 ,,
Magnesia ...	...	10 ,,
Undetermined	...	8 ,,
		100 per cent.

This shows a great increase in evaporation, independent of the saving in cost of repairs to the boiler.

Mr. J. G. Griffin said Mr. Bird's investigations into water softening and his experience entitled his views to a great deal of respect, and he was very interested in his description of the plants. He should not think of pitting his opinion against the Author's, but from the views of the Kennicott and Desrumaux's Softeners and his description of them, the plants did not appear to be a mechanical job; they depended, as far as he could see, on the head of water working a float. He should like to ask him if with the same arrangement of clarifying and mixing he would not prefer a plant which had a positive method of adding the re-agents. Thus a feed pump pumping water with an extension pump on the end of the rod which must pump a definite amount of re-agent for a definite stroke. It seemed to him that it would give far less trouble and more definite results. With reference to waters with acids in, Mr. Bird said if water was acid $\frac{1}{2}$lb. lime per 1,000 gallons would put it all right. Was that quite irrespective of the quantity of acid? Was there any magnesia in the

Swindon water? They had a plant at the Corporation Electricity Works, and he had found a certain amount of difficulty in getting clarification perfect. He had tried various things, but the best results had been obtained with crushed fire brick as a filter, but even that was not perfect. Mr. Bird mentioned that it was necessary to wash about twice every 12 hours. Was he to understand that it was necessary to empty the tank? (Mr. Bird: "Run it down about a foot.")

Mr. Griffin, continuing, said Swindon water, was a peculiar water altogether for dealing with, and their difficulties were added to in connection with the condensing system and the cooling tower. They found that a part of the scale was brought down at under 120° F., the water was taken direct from the hot wells. There was a jet system of condensation by which the circulating water was mixed with the condensed steam, and they very frequently got more permanent hardness in water than temporary hardness. They seldom had to deal with water exceeding 15° or 16° hardness and in cleaning the cooling tower out last summer, the troughs, which are 4ft. or 5ft. deep, were filled to within an inch of the top. How often do you think a boiler should be blown down? Take a boiler holding 5,000 gallons of water, and that water being changed ten times a day, what proportion of the amount of water in the boiler should be blown down per day?

Mr. Bird replied that with Swindon water the boiler should be emptied completely once a week. That was the kind of thing done with locomotives. It would answer the purpose and be equivalent to blowing down every day, say one-sixth each day.

Mr. Louis Waefelaer: In the States they had a scheme for changing water without reducing the boiler pressure. They did it by running the hot water from the engine as she came in through a heater and they heated up fresh clean water which they forced into the boiler. The boiler being entirely emptied when this hot water was put in it immediately generated pressure and they only banked the fire whilst the water was being changed.

Mr. Nash wished to know the effects of an excess of carbonic acid in the water in the boiler. Also, something about the relative conductivities of hard and soft scales; the evaporating efficiency is reduced only slightly due to the scale. How did Mr. Bird account for this?

Mr. Cuss said he believed a thin scale was looked upon as a valuable protective coating to prevent the pitting by acids in the tubes, and only to a very small extent did it affect the evaporating efficiency. There was some difficulty, he believed, in getting the authorities to take the sludge which came from softeners. With the Criton Softener at Reading, the sludge lime would be driven up from the top of the sand filter at a sufficient level to be taken away by other means instead of going to a river. Would there be any commercial value to the sludge which is removed?

Mr. Bird: The regulation by pumps is more complicated than regulating by a varying head of water. The arrangement at Goring answers perfectly; there was not more than one degree variation in twelve months. The Kennicott people's arrangement for the soda was excellent, but he did not think there was any necessity for the use of a walking pipe for the lime. The acidity of natural waters never exceeded the quantity which could be rendered practically inert by the addition of $\frac{1}{2}$lb. of lime per 1,000 gallons. There was a very small amount of magnesia in the Swindon water. It was not a difficult water to soften, but the water Mr. Griffin has had to deal with possibly presented difficult, as some of it was condensed, and the proportion of permanent hardness due to evaporation was increased. With reference to changing the water in the boiler, some salts caused priming more readily than others, and the design of the boiler must also be taken into consideration. *Carbonic Acid:* The object of testing was to see you did not get a great excess, but only sufficient for the purpose. He found that keeping the water's hardness at least 4° prevented corrosion. However, carbonic acid was a very feeble acid. *Conductivities:* The hard scale was a better conductor of heat than the soft scale; something like 50 per cent. Some figures in that connection would be shewn in an appendix. *Evaporating Efficiency:* This was reduced only slightly by scale. He had seen calculations showing that the percentage loss with $\frac{3}{16}''$ of scale was something like 95 per cent.; of course that was ridiculous. With a scale that was only 1-10th of an inch thick, it increased the resistance to passage of heat 10 times; but to get 10 times the difference between the boiler plate and the temperature of the water they got as much heat through. The only way the heat could get away except through the chimney was through the scale, and if it did not get away freely it accumulated in the boiler plates to a sufficiently high temperature to overcome the resistance of the scale. It was his practice to aim at having a slight scale in the boiler—not more than a film—to act as a protective coating. The sludge was a great difficulty. He did not know how many tons they had; 10-ton truck loads about every five days to take away from Goring. There was more work taking this sludge out of the pit and putting it into trucks than there was with the whole of the remaining operations of softening. He did not know of any profitable way of getting rid of the sludge, but had heard of it being used as the mineral constituent of India rubber cables. Of course it would be a very cheap substance to use. It had been attempted to press it into bricks and to re-burn it into lime again, but this was found to be impracticable. The only case that he knew where it had been disposed of, and then at a nominal figure, and only a very small proportion of that produced, was in the North of England, to a tooth powder manufacturer. He would not recommend it for this purpose. The best solution known was to erect a softener where it could be sluiced out into a tidal estuary, or to get a large piece of waste marsh ground and put a clay bank round it and fill it up. In some cases farmers took it for dressing the ground, as there was a slight amount of free lime in it. If anyone would take it away the offer should be jumped at.

Mr. Cuss said he had heard of engines working in Wales in one division scaling heavily, and then sent away to another division and the scaling had entirely disappeared.

Mr. Bird: The drawback to such a practice was that once a boiler was scaled and overheated the joints were all strained, and then if the scale came off it very soon showed signs of leaking.

Mr. Burrows proposed a vote of thanks to Mr. Bird, which was heartily accorded.

The Committee here record its indebtedness to the G.W.R. (London) Debating Society for the loan of blocks used in illustrating this Paper.

Appendix I.

GREAT WESTERN RAILWAY.

REPORT of Water Softening Plant at...

For Week ending....................................*190* .

M402. 9-05.

Day.	Hours Run.	Gallons Pumped.	Hard Water		Soft Water.				Lime used.	Soda used.	
			Hard-ness.	Alkal-inity.	Time of test.	Hard-ness.	Alkal-inity.	Excess of Lime.			
SUN. ...											
MON. ...											
TUES. ...											
WED. ...											
THURS.											
FRIDAY											
SAT. ...											
Totals and Averages											

Remarks..

....

....

....*Attendant.*

Under "Remarks" make request for new supplies of Lime and Soda at least a fortnight before they will be required.

Send a copy of this report to the Laboratory, Swindon, every Monday morning.

GREAT WESTERN RAILWAY.

REPORT OF WATER SOFTENING PLANTS.

Laboratory, Swindon. *Four Weeks ending*..190 .

M. 403. 11-5.

PLANT.	Gallons pumped.	Lime per 1,000 galls.	Soda per 1,000 galls.	Hard Water.				Softened Water.				Remarks.
				Hardness.		Alkalinity.		Hardness.		Alkalinity.		
				Attend-ant's average.	Labora-tory sample.	Attend-ant's average.	Labora-tory sample.	Attend-ant's average.	Labora-tory sample.	Attend-ant's average.	Labora-tory sample.	

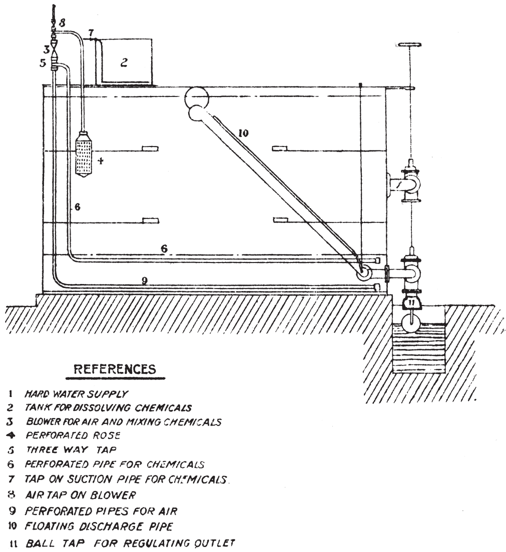
Appendix III.

CONDUCTIVITY OF BOILER SCALE FOR HEAT.

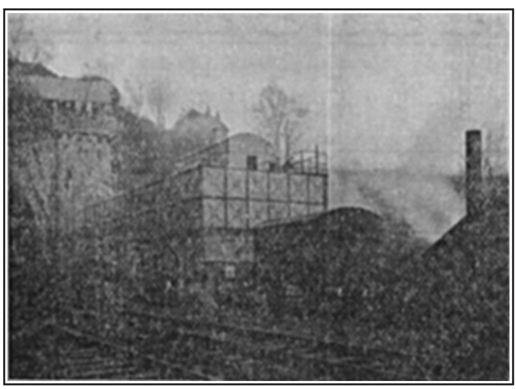
SAMPLES FROM DIFFERENT POSITIONS IN THREE LOCOMOTIVE BOILERS.

Boiler No.	Position in Boiler.	Chemical Composition. Oil.	Carbonaceous matter.	Carbonates.*	Calcium sulphate, etc. (by diff.)	Description of Conductivity Test Pieces.	Thickness in inches.	Relative Conductivity corrected for thickness.	Mean.
		%	%	%	%				
1	Barrel near feed	None	0·72	61·10	38·18	Hard, brownish grey, in contact with boiler plate ... Rather soft, brownish grey, from water side of scale ...	·100 ·050	172 104	138
2	Side of firebox ...	None	1·98	48·60	50·42	Hard, brownish grey, in contact with firebox plate ... Rather hard, light grey, from water side of scale ...	·100 ·049	169 106	137·5
1	Side of firebox ...	None	0·71	43·60	55·69	Very hard and brittle, dark grey ... ... ,, ,, ,, ...	·050 ·050	144 126	135
3	Top of firebox ...	0·13	1·33	48·60	49·94	Hard and dense, greyish black ... ... ,, ,, ,, ...	·034 ·037	135 131	133
1	Top of firebox ...	None	0·76	38·20	61·04	Very hard, dark grey ... ... ,, ,, ...	·050 ·100	135 125	130
2	Top of firebox ...	None	0·77	69·20	30·03	Very hard, grey, in contact with firebox plate ... Soft, very light grey, nearly white, not in contact with firebox plate	·050 ·090	174 80	127
3	Side of firebox ...	0·13	0·89	48·80	50·18	Rather hard, brownish grey, in contact with firebox plate ,, ,, from water side of scale ...	·049 ·044	130 113	121·5
3	Barrel near feed	0·26	1·21	68·70	29·83	Hard and dense, brownish grey, in contact with firebox plate ... ... Rather hard, brownish grey, from middle of scale ... Rather hard, but somewhat porous, brownish grey, from water side of scale	·050 ·100 ·044	112 103 85	100
2	Barrel near feed	None	0·80	71·20	28·00	Rather hard, brownish grey, in contact with boiler plate Rather soft, very light grey, including part in contact with boiler plate ... ... Rather hard on one side, soft and porous on the other, light brownish grey, including water side of scale	·050 ·090 ·150	100 100 83	94

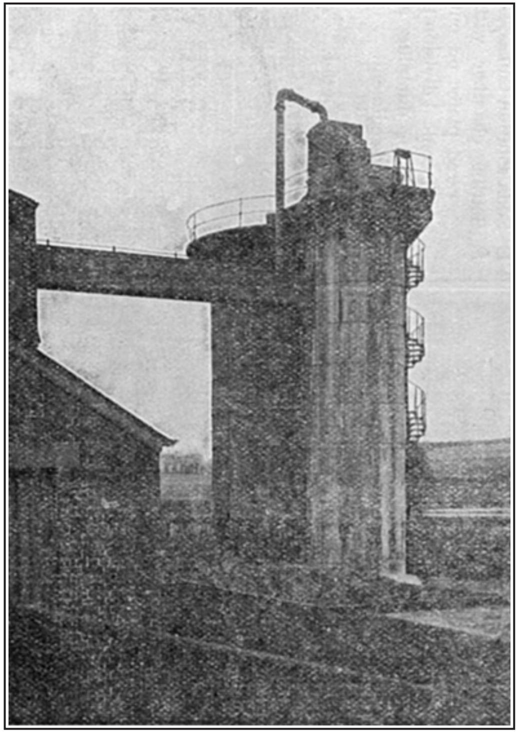
* Carbonate of Lime with a very small quantity of Basic Carbonate of Magnesia.



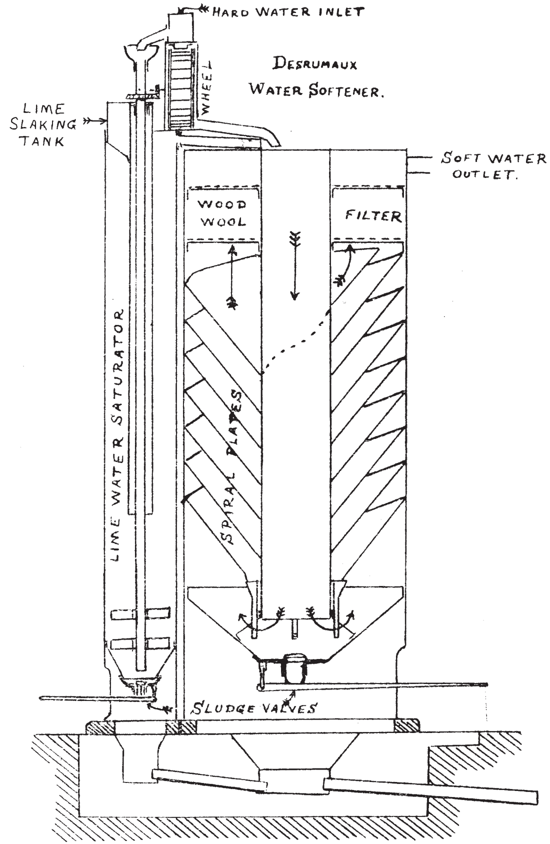
Section of "Archbutt and Deeley" Plant.



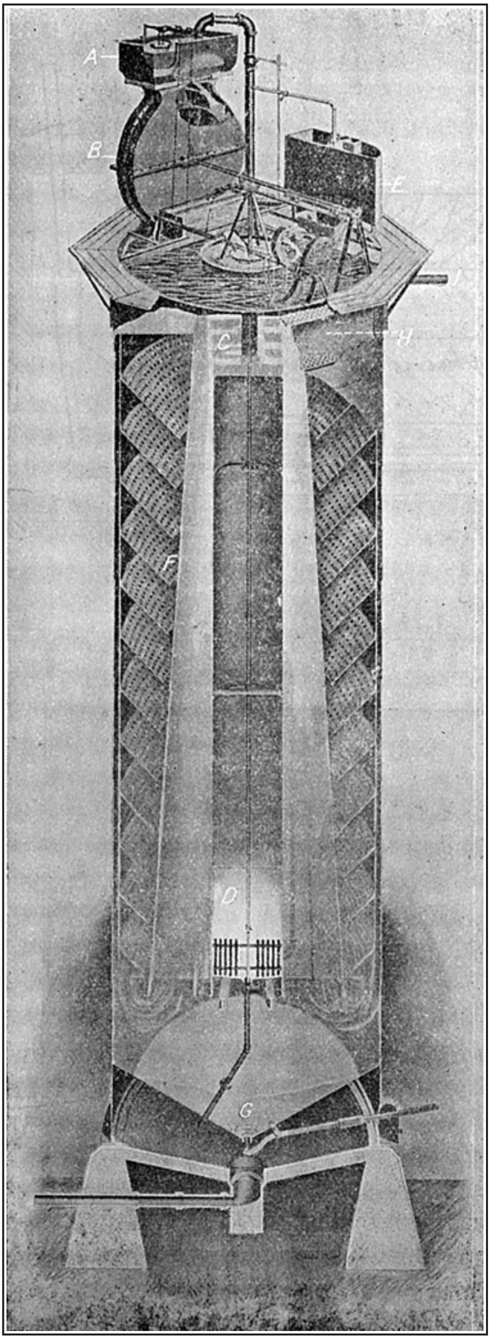
"Archbutt and Deeley" Water Softener, Foxe's Wood Pumping Station, near Bristol, supplying Water Troughs at Keynsham. Capacity, 20,000 gallons per hour.



"Desrumaux" Water Softener, supplying Water Troughs at Goring. Capacity, 20,000 per hour.



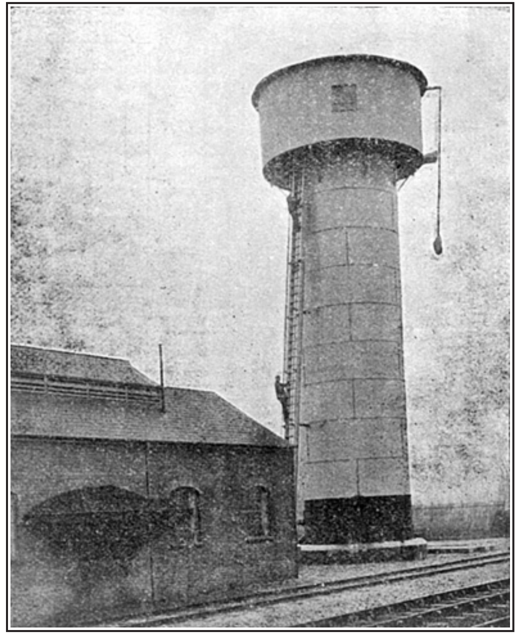
Section of "Desrumaux" Water Softener.



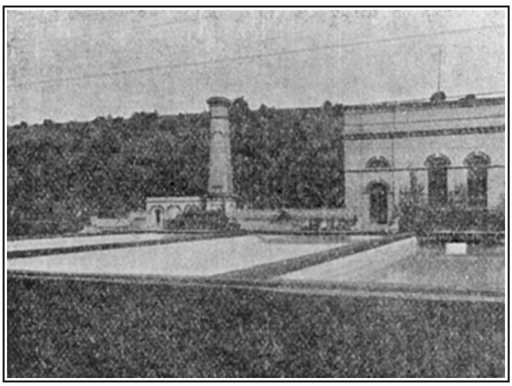
SECTIONAL VIEW OF A TYPICAL "KENNICOTT" WATER SOFTENER, SHOWING CLEARLY ITS INTERNAL CONSTRUCTION.

A Hard Water Tank, with regulating float.
B Water wheel working stirrers, &c.
C Mixing chamber.
D Lime water saturator.
E Soda solution tanks.
F Settling chamber, with perforated plates on outer side of conical division plate.
G Valve for dumping accumulated sediment.
H Filter.
I Soft Water Outlet.

" Kennicott" Water Softener at Severn Tunnel Pumping Station. Capacity, 30,000 gallons per hour.



" Kennicott" Water Softener, supplying Water Troughs at Aldermaston. Capacity, 10,000 gallons per hour.



Kenley Waterworks.