

THE
INSTITUTION OF LOCOMOTIVE
ENGINEERS, LONDON.

The Lassen and Hjort System of
Water Softening for Locomotive Use.

BY
J. P. O'CALLAGHAN,

Member, London.

With an abstract of the discussion upon the Paper.

TWELFTH PAPER
(OF TRANSACTIONS).

SESSION 1912.

*Read on Thursday, 28th November, 1912,
at St. Bride Institute, London,*

*Presided over by Mr. Charles A. Suffield, Chairman
of Council.*

LONDON :
Published by the Institution .
1913.

Price One Shilling net,

The Institution of Locomotive Engineers.

PAPER No. 12.

The Lassen and Hjort System of Water Softening for Locomotive Use.

BY

J. P. O'CALLAGHAN, Member, London.

In the short paper submitted to-night it is proposed to deal solely with the special aspects of the problem of water softening which present themselves in the case of water intended for use in locomotive boilers. In this, as in the treatment of water for dyeing or bleaching or kindred operations, the general chemical principles governing the question are limited in their application by a set of special conditions which are not so prominently evident in other cases. The chemistry of water softening having been the subject of an excellent paper recently read before this Institution, renders it unnecessary to devote more than a passing reference to it, and the present paper will deal rather more particularly with the necessity for limiting the occurrence of an excess of reagents in the softened water while at the same time reducing the hardness to its lowest limits, and the mechanical arrangements which have been found to effect this successfully. A very superficial consideration of the question will make it evident that in the treatment of water for any of the purposes mentioned above a rigid control over the softening process is essential, and it is equally obvious that this can only be obtained by the employment of a mechanical apparatus for measuring and mixing the water and reagents, capable of extreme nicety of adjustment and of a high degree of regularity in working.

The great majority of water supplies in this country must be classed as hard, the hardness being usually due to the salts of calcium and magnesium, particularly to the carbonates and sulphates of these bases. The carbonates are held in solution by carbon di-oxide which the water has derived from the atmosphere and the soil, and when such a

water is deprived of its carbon di-oxide, either by boiling or more completely and thoroughly by the addition of lime, the carbonates, being insoluble in pure water, are precipitated. On this account hardness due to carbonates is termed "temporary hardness."

The sulphates, chlorides and nitrates of lime and magnesia are soluble in water of themselves and do not owe their solubility to carbon di-oxide ; therefore, the hardness caused by these salts is described as "permanent hardness." These two forms of hardness together make up the "total hardness." The expulsion from the water of the salts constituting the permanent hardness can only be brought about by the addition of some chemical reagent which will precipitate them, and the cheapest and most readily available material for this purpose is sodium carbonate. This substance, however, will not act efficiently as long as any free carbon di-oxide is left in the water, as it is converted by carbon di-oxide into bi-carbonate of soda, which has little, if any, action on the salts constituting the permanent hardness. The first essential, therefore, in water softening, is the complete removal of the free carbon di-oxide, and no process can claim to be effective which does not completely accomplish this elimination. As previously mentioned, this can be satisfactorily carried out by the use of milk of lime at a cost in most cases of only a fraction of a penny per 1,000 gallons. Once the carbon di-oxide is removed, the sodium carbonate required for the precipitation of the permanent hardness is free to act and destroy the soluble salts of lime and magnesia by removing their bases and leaving the sulphate, chloride or nitrate of sodium in their place.

The removal of the permanent hardness is thus a conversion of these salts into their sodium equivalents, whereas in destroying the temporary hardness, the carbonates are actually and entirely removed from the water. Many text-books on the subject of water treatment state that carbonate of lime is soluble in pure water free from carbon di-oxide to the extent of three to four grains per gallon, but closer investigation has proved this to be a mistaken view due to the experimental error of not completely getting rid of the free carbon di-oxide in the water with which the experiments were made. If carbonate of lime were soluble in water to the extent mentioned, it would be impossible to soften below this figure, but, as a matter of fact, it is a common occurrence in ordinary practice to obtain the reduction of a water carrying a large proportion of carbonate hardness down to as low a figure as $1\frac{1}{2}$ to 2 deg. Clark

by a very careful adjustment of the lime required to remove the free carbon di-oxide.

It is therefore established that as the nature and quantity of the scale-forming substances in any particular water can be determined with the utmost accuracy, so their elimination from the water can be effected with equal exactness by employing suitable apparatus for measuring and mixing the hard water and the softening reagents. In this connection it will be readily understood that the mechanical device employed for adding the softening reagents in the correct proportion to the water under treatment is the vital part of any water softening process, and on the satisfactory performance of this principal function the successful working of such a plant will entirely depend.

RESULTS WITH LASSEN AND HJORT SOFTENERS.

A striking instance of the satisfactory solution of this problem of water treatment for locomotive use on a practical scale is afforded by the results obtained by the Great Western Railway Company with a water softening plant of modern design, which has now been in use for two years at their Swindon Locomotive Works. The water dealt with in this plant is derived from four different sources, the supplies from which are, however, mixed in constant proportion, giving a water the hardness of which, in the untreated state, averages 17 to 18 deg. Clark. The analysis of this water is as follows :—

					Grains per gall.
Silica	...	...	...	...	.17
Oxide of Iron	...	...	...	...	.13
Sulphate of Lime	...	...	...	...	.68
Carbonate of Lime	...	...	...	...	15.41
Nitrate of Calcium	...	...	...	...	1.79
Sulphate of Magnesia	...	...	...	...	.90
Nitrate of Sodium	...	...	...	...	2.63
Chloride of Sodium	...	...	...	...	1.64
Total Solids	...	...	...	...	23.35
Hardness	...	...	...	...	17.75 deg.
Temporary Hardness	...	...	...	...	13.61 „
Permanent Hardness	...	...	...	...	4.14 „

The chemicals, determined by calculation and experiment, required to soften this water successfully are lime and soda in the following proportions :—

Lime (Best Fresh Burnt) ... 1.7 lbs. per 1,000 galls.
Soda ash (58 % pure alkali) .5 lbs. „ „ „

A laboratory experiment with this water showed that it was possible by careful adjustment of the lime and soda to reduce the hardness to $1\frac{1}{2}$ deg. Clark. How closely the result obtained in the laboratory has been repeated in the softening plant on the large scale may be seen from the diagram Fig. 1. of tests taken by the Great Western Company, which show that the average hardness of the water after treatment is 2 deg. Clark, while the residual alkalinity, (i.e., excess of lime and soda remaining in the water after the conclusion of the softening process) averages only 1.5 grains per gallon, or $1\frac{1}{2}$ parts in 70,000 parts by weight. The diagram is based on tests carried out by the Railway Company. The capacity of the plant is 15,000 gallons per hour. The variation in hardness of the crude water is mainly due to this being obtained from different sources. It should be particularly noted how regularly the plant is working; an increase of hardness in the crude water is immediately followed by a corresponding increase in the soft water.

This result has been, and is being, obtained with a softener having a capacity of 15,000 gallons per hour, and the softened water is being used in a battery of stationary locomotive boilers working at a pressure of 200 lbs. per sq. in.

The advantages to be derived from the application of a process which admits of the attainment of such remarkable accuracy in the treatment of the water required for locomotives on the line, and particularly for long-distance expresses, are sufficiently obvious. Water of such a composition as the treated water referred to will not only not cause any hard scale whatever in the locos., and thus materially lessen the frequency of tube removals due to this cause, but the exceptionally low alkalinity possessed by such water renders it possible to run the locomotives for a longer period without washing out than would otherwise be the case, and the net result is a largely increased engine mileage per loco. per annum and a correspondingly decreased repairs bill.

The North Eastern Railway Company, one of the most progressive railway concerns in this country, has not been slow to perceive the commercial value of a process which

makes possible the attainment of such complete results, and as a result of a preliminary investigation extending over twelve months they have put down four Lassen and Hjort plants to treat the water supplied to expresses on their line. A few particulars of one of these installations may be interesting. The first plant was started to work on October 1, 1908, and was erected at Ballast Crossing, Hartlepool; it has a capacity of 2,500 gallons per hour, uses lime and soda, and reduces a water of 25 deg. of hardness to 5 deg.

This plant was rigorously tested by the North Eastern Railway Company's engineer, Mr. Wilson Worsdell, and the Chief of the Outside Machinery Department, Mr. Pearson, the tests extending over twelve months. On a test carried out with a goods loco. (coal traffic) using the softened water, no priming whatever took place on an evaporation of up to 50,000 gallons, without washing out. The boiler, before the test, was thoroughly cleared of scale and the crown plate of the fire-box scraped; after the test no new scale was found to have been deposited, and the scraped parts were in an even better condition than before. Previously to using the softening water the boilers required cleaning out twice and sometimes three times a week, but they are now cleaned only once a week, and could, if desired, be run longer without cleaning. The majority of the test runs were carried out on a bank under the severest possible conditions, the object of the engineers being to make the boiler prime with the softened water, but no priming whatever occurred up to 50,000 gallons evaporation, and on several occasions this figure was exceeded, nearly 53,000 gallons being evaporated without cleaning out.

The softener supplied for this duty is of the cylindrical type, its overall dimensions being 35ft. high by 6ft. 6in. diameter. The mixing and measuring apparatus (which is the principal feature of the plant) is at the top, and the water and chemicals flow from this to the bottom of the cylinder and then rise up again and pass through a wood-wool filter placed near the top; the water, when delivered, is perfectly clear, and softened to 4 deg., and what is more important still, for railway work, *contains no excess of treating chemicals*. The attention required by this plant is less than half-an-hour daily, all that requires to be done being the pumping of the chemicals from the chemical-mixing tank at ground level to the chemical reservoir attached to the mixing and measuring apparatus, and the opening of the sludge cock for about a minute and a half to two minutes. The level of the water in the storage

tank is made to control the flow of hard water to the plant and by this arrangement the storage tank is kept perpetually full, no attention to this being required either day or night.

MEASURING AND MIXING APPARATUS.

We now come to a description of the measuring apparatus, the accuracy of which alone makes these results possible. The outstanding feature of the mixing and measuring apparatus is the device for the separate and exact measurement, in small, absolutely definite, and predetermined quantities, of both hard water and softening reagents. This device renders it possible to treat water or effluents of any character, with any reagent, or combination of reagents, in rigidly proportionate quantities, which can be varied at will and adjusted to give any quantity desired over a wide range.

The design of the mixing and measuring apparatus is shown in Fig. 2.

The water to be treated alternately fills each of the compartments of a two chambered tipper oscillating on a shaft working in the gun-metal-lined bearings. When one of these compartments is full of water the disturbance of equilibrium causes the tipper to over-balance, and, by so doing, to discharge its contents of water into the tank in which it is suspended; at the same time the other compartment of the tipper is brought under the orifice of the inlet pipe and filled in its turn with hard water, to be discharged in the same manner when full. In other words, the incoming water makes the tipper oscillate backwards and forwards, *measuring off at each oscillation a definite quantity of hard water to be treated*, and thus operating as a gravity water meter by means of which the quantity of water passing through the plant may be ascertained with absolute accuracy at any time by affixing a counter to the tipper shaft.

At each discharge of water from the tipper into the tank in which it works, a corresponding amount of water is displaced from this tank through a standpipe and shoot into the reaction chamber of the softener, and here it receives at the same moment the requisite charge of chemical solution from the semi-circular chemical container. This is effected by means of the valve placed in the bottom of the chemical container, which is opened at each movement of the tipper, and caused to deliver into the reaction chamber

the exact amount of softening reagent (in the majority of cases a mixture of lime and soda ash) required to soften it to the guaranteed figure. The valve can be adjusted to discharge any specified quantity of reagent required by the volume of water in the tipper compartment, *so that the plant can be easily regulated while working without any necessity for changing the solution in the chemical container.*

The *lime-milk* in this apparatus has a strength of 10 per cent. ; the *lime-water* used in other apparatus has only an average strength of 0.13 per cent ; the lime-milk, therefore, has a strength of nearly 100 times that of the lime-water, making it possible to reduce the size of the tanks containing the lime, in the same proportion. A further advantage of using lime-milk is that a known quantity of fresh lime can be mixed with a known quantity of water, a solution being obtained, the strength of which is *definite*.

POSITIVE VALVE FOR REAGENTS.

The part played by the patent positive chemical valve fitted in the chemical container to the plant is of such importance that a detailed description of this valve and its method of adjustment is desirable.

The valve, as will be seen from the illustration (Fig. 3), consists of a fixed cylinder A riveted to the bottom of the chemical reservoir, into which screws an adjustable cylinder B fixed in any desired position by the back-nut C.

Within these cylinders work two valves, D and E, the latter screwing on to a tail-piece F projecting from the valve D.

The pitch of the threads on this tail-piece and the adjustable cylinder being the same, any movement of the cylinder B results in a corresponding movement of the valve E owing to the valve E having a feather G working in a key-way H cut into the cylinder B. It will be seen that the valve D is provided with a flat face and a piston body, which latter prevents any chemical solution being admitted into the adjustable cylinder until the lower valve E has closed the outlet ports J.

The operating gear consists of a double-lever K fixed to the rocking shaft L of the tipper. These levers are fixed to the vertical valve spindle by two loose links M and trunnions N clamped against a screwed sleeve O by the lock-nut P. These levers, when in operation, impart an up-and-

down motion to the valve. The screwed sleeve O works between rollers Q carried on to the bridge R.

The object of the weight S is to keep the valve D tight on its seat.

ADJUSTMENT OF VALVE.

To increase the amount of chemical solution being discharged, loosen back-nut C, unscrew cylinder B by means of the lugs T, then retighten back-nut C.

To decrease the amount of chemical solution being discharged, loosen back-nut C, screw in cylinder B by means of the lugs T, and retighten backnut C. The valve illustrated is shown as fixed to give its minimum discharge.

LOCKING GEAR.

Another important feature of the softener is the recently introduced patent locking gear, by means of which the oscillating receiver is prevented from tipping until it contains a predetermined quantity of water. This is constructed in the following manner: To the end plate of each compartment of the tipping bucket is attached a bracket carrying a ball float and lever, and a vertically sliding rod which is actuated by these; the ball, of course, rises with the water level, and when this level reaches a certain height in the tipper, the sliding rod lifts a lever which is fulcrumed on the angle-iron edge of the tank and is engaged with a notch provided on the bracket before mentioned; on further rising, the lever is disengaged from the notch and the bucket tips.

By this means the tipping of the bucket is regulated to occur at the moment an exact number of gallons is contained in it. A link from the end of the tipper shaft operates a counter which registers the number of tips. By multiplying this reading by the number of gallons in each compartment, it is possible to arrive, with the greatest accuracy, at the amount of water passing through the plant. In practice this device is found greatly to enhance the smoothness with which the apparatus works and the regularity of the results obtained.

DISCUSSION.

The Chairman, **Mr. Suffield**, in opening the discussion, said: We shall be pleased to hear remarks from any visitors present. The paper is, unfortunately, rather a short one, and, I must admit, a somewhat difficult one to discuss.

Apparently, the water softener as explained by Mr. O'Callaghan has no form of agitator—which I should have thought would have been rather essential—in it.

He referred to a plant for the G.W.R. at Swindon. Will he please tell us the capacity in gallons per hour of that particular plant? I understand the G.W.R. have other softeners at work. The other that I particularly have in mind is one at the Severn Tunnel, which, I believe, has a capacity of something like 30,000 gallons per hour, and, I understand, with the process in use, costs something like $\frac{1}{2}$ d. to 1d. per 1,000 gallons. I take it, further, that this $\frac{1}{2}$ d. to 1d. includes the cost of the attention of, say one man. I suppose he would only be required for possibly one hour or two hours through the day. Mr. O'Callaghan states that with his softener, the treatment costs a fraction of a penny per thousand gallons. This seems to be an extraordinarily low estimate as, surely, he has no contrivance that can be run at that rate without the attention of a man during some portion of the day. I would like him to make this point quite clear to us.

I may add that Mr. Lawford H. Fry, unfortunately, is not able to be present to-day, but he has sent us a copy of his questions on the paper, which the secretary will read to you.

The Secretary then read **Mr. Fry's** remarks as follows:

The importance attached to the purification of water is shown by the increasing attention being paid to water softening plants, and the large number of such plants now in use.

Quite frequently, however, boiler troubles are attributed to bad water, when in reality they are due to other causes. It is desirable, therefore, before installing a water softening plant, that the matter should be thoroughly investigated, with a view to ascertaining whether the troubles are really caused by impure water. Mr. M. E. Wells has studied this subject closely and has shown that leaky tubes are frequently attributable to improper feeding, and general careless handling of the boilers, rather than to bad water. As an example of this, he mentions the bad effects due to the

use of the injector while a locomotive is standing. The cold water fed into the boiler while there is no active steam production sinks to the bottom of the water spaces and barrel. A considerable difference in temperature between the water in the top and bottom of the boiler, which may amount to 200 deg., is thus set up, producing an uneven expansion and subsequent leakage of the tubes. It is quite a common practice also for boiler washers to force cold water through a mud-ring blow-off cock into a hot boiler before firing up. This is very bad treatment, as the cold water remains at the bottom, while the hot is pushed higher up the boiler, causing the same inequality of temperature mentioned in the first example.

The scale formation resulting from the use of impure water can be mitigated to a large extent by careful cooling of the boiler when washing out.

If boilers are properly cooled and washed, there is little scale formed by the carbonates of lime and magnesia, and although the sulphates do scale to a certain extent, the formation does not become excessively thick before loosening and washing off. If, however, the boiler is blown out hot, the carbonate deposits, together with the sulphates of lime and magnesia, bake on the hot plates, together forming a scale which is very difficult to remove.

These examples are not intended in any way to belittle the value of water softening, but rather to show how the ill effects arising from the use of bad water may be minimised.

In addition to increasing the life of boiler and tubes, the purification of the water by removing a great part of the incrusting matter reduces the number of wash outs required.

There is one point that has to be carefully watched in connection with softening plants, and that is the question of the alkali addition. As is well known, if alkali is present in the water above a certain value, foaming takes place.

Mr. Wells gives this amount as 175 to 200 grains of alkali to the gallon. It is very important, therefore, that excess alkali should not be added to the water in purification plants. With proper care, owing to the efficiency of present-day plants, this difficulty should not arise. In some parts of the world natural alkali waters are met with, such as on the Arizona deserts in the United States. No chemical method has been developed for removing from the water the salts of potassium and sodium which constitute the alkali. The only alternative, therefore, is to remove the

water from the alkali, which can be accomplished by distillation. The process, however, is too costly for railroad use.

In a report on "Water Softening for Locomotive Use" drawn up in 1905 by a committee of the American Railway Master Mechanics Association, the cost of erection of a purifying plant, 500,000 gallons capacity daily, is given as from £1,200 to £2,000, according to the process used, and the cost of the actual purification as from $\frac{3}{8}$ d. to 2d. per 1,000 gallons, depending on the quality of the water.

The committee further state that by the use of pure water, boiler troubles are reduced to a minimum. One railroad reports that the number of trains abandoned on account of leaky flues was reduced from 27 to two in a stated period. Another reports that passenger trains delayed on account of leaky flues on a division using purified water have been reduced from twelve to fifteen per month to one and two, and an occasional month with no failures. A road handling 60 engines per day has reduced its boiler-maker force from four men to two men—one day and one night—and these men have to be given machinist work to keep them busy.

They do not recommend the use of compounds to be introduced into the boiler where there is a possibility of purifying the water before it reaches the boiler. They believe that the cost of purifying water for locomotive use is more than saved by the reduction in the labour cost of caring for boilers in the round-house, and the benefit gained by freedom from leaky flues and poorly steaming engines on the road is all profit.

Mr. Bennett: I have listened with interest to the paper just read on the softening of water for locomotive use, and I believe it is necessary to remove from the water some of the salts which go to form the permanent hardness; but, at the same time, I certainly think that too much may be done in this matter with the result that the water becomes too soft. My opinion is that a certain percentage of hardness should be allowed to remain with a view to forming on the boiler a slight coating of scale, which would go far to protect the boiler plates and rivets from that most subtle and dangerous disease "corrosion." It is, of course, well known that hard water produces scale and with it comes also the danger of the over-heating of the plates and the liability to fracture from this cause, but, at the same time, it is not so well known that, with soft water, the boiler plates suffer more from corrosion. It is also known that dirty water will conduce to leaky boilers, but they will also

leak badly under working conditions if too clean. Iron and steel will corrode, I know, in spite of anything that can be done if certain substances are in solution in the feed water, particularly dissolved oxygen or carbonic acid, but, if these harmful agencies are removed, then, of course, corrosion will be reduced; although, at the same time, much can be done to get over the evils of steel plates pitting and corroding by care being exercised during the manufacture of these articles. I should like to ask if these harmful agencies are removed by the treatment of the water as explained by the reader of the paper to-night.

Again, the primary cause of leaky stays and tubes is in many instances the unequal expansion and contraction, due, no doubt, to the plates and stays being in a sense insulated from the water by a layer of scale or dirt. A thin layer of scale or grease on the heating surfaces of a boiler greatly reduces the evaporation and also increases coal consumption in proportion. I have heard authorities state that a layer of scale about $\frac{1}{16}$ in. thick causes about 20 per cent. increase in coal consumption, although porous scale that allows the water to penetrate to the plate may not seriously affect the economy of the boiler.

At the same time, I should also like to ask if the reader of to-night's paper can inform us as to what results were obtained by the use of the "Luminator," an invention of a German scientist named Herr Brandes, which gave to ordinary water, after simply flowing over it, remarkable properties. I cannot, personally, explain the Luminator water treatment, but have no doubt that the writer of the paper to-night will be conversant with it, it certainly being in his line of study; but I am informed that the following advantages have been claimed for it, and should very much like to know if these advantages have been substantiated in any way: That it prevents the formation of hard scale on the tubes and plates; that its action is automatic, continuous and uniform; that no chemicals are used, it being under no chemical supervision, even when treating waters of variable composition, the action being physico-chemical; that the boiler material is not affected in any way and that corrosions and pittings are absolutely prevented; that it saves coal bills and repairs to boilers and increases boiler efficiency and life; also that no precipitation, filtration, or subsidence plant of any kind is required; and, what is more, that it is considered to cost much less than any other treatment.

Mr. Wardlaw: I am sorry to say that Mr. Bennett

anticipated one of the questions that I wanted to ask and that was the increased proportion of coal necessary owing to the deposition of scale on boiler tubes: what that ratio is. No doubt Mr. O'Callaghan has made a study of that and can tell us. I have seen it in print. For instance, 1/16in. of scale—what increase in coal consumption does it represent? For $\frac{1}{8}$ in. Mr. Bennett has said 20 per cent., and so on.

I would like to ask Mr. O'Callaghan (referring to the special valve which he has mentioned) whether the valves D and E at the bottom of the cylinder are ever in the chemical mixture or in the purified water. The reason for the question is simply to get at the cost of the operation of the plant.

Mr. Chignell: I should like to make one observation arising out of the question the Chairman asked Mr. O'Callaghan. I do not want to anticipate his reply, but you referred to the question of agitation in the water softener for the cream of lime. Well, of course, every other softener but the one Mr. O'Callaghan refers to has that, so far as I am aware. I will leave him to reply to you.

The reason I raise this question is to let this company know that there is now a machine designed on very different lines altogether to the cream of lime machine, and that is a machine that uses and introduces the required chemical to the softener in a dry form. There is a water wheel in it on which the measured quantity of water falls and every time that goes over it throws out the required amount of dry lime through a canister that is placed parallel to it. You see the main object of this was to avoid making up a chemical solution which frequently is a very troublesome matter when you have to deal with large quantities. In most cases it has to be arranged to be done mechanically, and that, of course, adds to the cost of the whole installation. There are a large number of these machines at work. Of course, as I say, it is quite a new practice; when I say new practice I mean that they have only been in use for a period of six years; but, up to the present, they are being manufactured for quantities as much as 5,000 gallons per hour, and they are treating locomotive boiler feed water—not on a railway—but one instance is a large manufacturing engineering works in Lancashire, where the locomotives used in the works for conveying stuff about the place are using water softened through one of these machines. I thought, perhaps, it

might interest the audience to know of this. I do not speak of it for the sake of advertising it, though, of course, as you no doubt surmise, I am connected with it very closely. The machine is manufactured by Mr. William Bobby, who is well known as a manufacturer of softeners on the cream of lime principle. But this is something quite new and novel as regards treatment of water for manufacturing and general purposes, and I thought perhaps that to you railway men it might be of some interest, as perhaps before very long you will find one or two of them at work on railways. But the main thing that we claim for it is that it avoids—one of the main things it avoids—any question of agitation being required. I am coming again to the point raised. There is absolutely no need for any agitation to be arranged for, because you are not dealing with a solution—you are dealing with a dry powder—and it does not matter if you happen to let your machine stand for six hours and then you make a sudden call on it, it will respond to it at once without any attention whatever on the part of a man. Now, there is no cream of lime machine that I know of that will do that. Lime has a natural tendency to settle at the bottom of the container in which it rests unless continually agitated, and, of course, it ceases to be agitated when the water softener is not running; and that is one of the difficulties connected with water softeners of that type. Of course, it can be overcome, but you have to send a man up whenever you want to start your machine after letting it rest for a certain period. The machine was designed to overcome that, and it also overcomes the question of having to make a chemical solution.

Mr. O'Callaghan, replying to this portion of the discussion, said: With reference to Mr. Suffield's question about the capacity of the plant at Swindon, that is a 15,000 gallon plant—15,000 gallons an hour. It is capable of doing 18,000 to 20,000 gallons, but its nominal capacity is 15,000 gallons.

Respecting the cost of chemicals in this case being quoted as a fraction of a penny, I think the actual figure is $\frac{3}{4}$ d., and that only includes the chemicals—it does not include the labour. The cost of treating water of a very moderate degree of hardness in this country very rarely comes out at under $\frac{1}{2}$ d. per 1,000 gallons. You have got your lime at £1 per ton (that is, if you buy good lime), and the soda ash, as you know, is about £4 per ton at the present time; and when I tell you that a couple of pounds of lime and a pound of soda represent an average addition,

you will see about what the cost comes to. It is no use anyone saying that it can be done for less, because the cost is common to all systems using lime and soda. A water is analysed by the chemist and he finds the proper amounts of lime and soda required to soften it. These amounts are the same for all systems—no system can do it with less ; you have got to add the proper proportions, so when I hear a quotation of $\frac{1}{2}$ d. or less for chemicals, labour, depreciation, interest and everything else in connection with a softener, you must forgive me for being a little incredulous. I know that the lime-water type of softener (employing only lime-water) was once largely in vogue. The G.W.R. have several such softeners of different makes. But lime-water as a reagent has been discredited now for many years. The old idea was to build an erection at the cost of about £1,000 as large as a small church and to put up inside it an immense lime-water container. Your lime-water fluid was added in a large bulk to your water. In a lime-water plant, on an average one-eighth of your water has got to be made into lime-water solution, so you can guess the huge bulk of the tank required for the plant. The plant was exceedingly costly and the lime-water was affected by carbonic acid. The results averaged from eight to ten degrees of hardness in the softened water. Of course, that is not good enough for the people of to-day. We now deal with water of 8-10 deg. which requires to be softened down to two. These lime-water softeners are now practically obsolete. When you get a softener which so accurately measures the chemicals that you can reduce the hardness down to two degrees, you get the full amount of chemical in, and therefore you have got to put your cost up to the proper figure. The cost of the treatment may be a little more than it would be when putting in weak lime-water, but then you are getting an efficient result and you have got to pay for it.

I now come to Mr. Lawford Fry's very interesting remarks. These do not call for very much reply, because they are more or less an endorsement of what has been said. Mr. Fry practically endorses my point about the accuracy of the addition of the chemicals being the essential thing, and more essential in railway work than in any other department.

Mr. Bennett was talking about water being too soft. The expression "too soft," when you come to investigate it, usually means—in connection with softening plants at least—that there is an excess of alkali in the water. A soft water in nature—a very soft water—often proves to be

water containing from 5 to 25 grains of carbonate of soda. Now, in a badly designed softening plant, if you have not an accurate measuring apparatus, adjusted to measure you exactly the dose of chemical required—if you have another apparatus which will not put it in so accurately—you frequently get an excess of treating chemicals in the softened water. The soda accumulates in the boilers and sets up pitting, as you can readily understand, on concentration, so that the evils which have been said to result from having water too soft should not be laid to the door of scientific softening, but rather to unscientific softeners, because you get an excess of soda carbonate, which sets up caustic soda, which causes pitting. When you have succeeded in softening water containing 20 deg. of hardness so well that it only carries two grains of carbonate of lime in it (which makes an egg-shell scale on the boiler), and practically no residual alkalinity, you obtain water that is incapable of corroding or scaling any boiler and is therefore ideal for steam raising purposes.

Mr. Bennett was also asking about the Luminator. We have all heard a good deal about the Luminator, and we heard more about it two years ago than we do now. I daresay if somebody came along and said they had discovered the Philosopher's Stone and talked enough about it, there would be sufficient people to believe them for a while. The fact remains that Luminators have been put in—and taken out. I can tell you of a case where there was a Lassen and Hjort softener softening Kent water down to three degrees and keeping the boilers absolutely clean. The owners, I am told, were offered the rights in the Luminator for a foreign country, and, in order to test the thing, they put it down and stopped the Lassen and Hjort plant and started feeding Kent water, which, as you know, contains about 20 deg. of hardness, over this Luminator sheet. They exposed it to the sun once a week and scraped it down on Sunday morning in accordance with the instructions, and the result was that after three months' run, the boilers were chock full of scale. They said, "Well, this can't go on," so they tried the curious experiment of running the water over the Luminator and through the measuring apparatus of the Lassen and Hjort plant without using any chemicals. Of course, this did not do any good whatever, and so, somewhat reluctantly, they started the Lassen and Hjort plant to work again, and have had it at work ever since. There is no change when you pass water over the Luminator. There is no change in the hardness of that water, and no test that

can be devised by either chemists or physicists shows any change. No chemical or physical action occurs, in fact. The water is just the same as before, and when it is put into a boiler it is no better as regards scaling or corrosion, than before Luminator treatment. I have it on the authority of many men that they have been into boilers fed with Luminator water and failed to detect any diminution of scale, and they think that where you meet, as you sometimes do, a man who honestly thinks he has seen a difference in the condition of the scale of a boiler, the explanation is a psychological one; he has devoted more attention to the water and the boilers than ever he did before. He had a notion that his boilers were full of hard scale previously, and when he goes in after having this plant at work and finds that the scale (which is probably carbonate scale) is soft and in the form of mud, he says "Now, that is due to the Luminator." There is one case—the principal case in England quoted in support of the Luminator—and that is the G.N.R. at Peterborough, and, for some reason or other, when everyone else had found out that the Luminator was a failure, the G.N.R. maintained that it was not, and that it was giving good results. I am informed on excellent authority that the water up there was alkaline and they did not know it. A water containing carbonate of soda was passing over this Luminator, and, therefore, the water could not scale, Luminator or no Luminator. They had a supply, and, owing to the drivers having been told to take their water from this, they ran it out and had to make it up from another source. They tapped another well, which happened to be one of the soda wells one hears so much about—water containing carbonate of soda in solution; no wonder they got no scale, because they had an alkaline water, which would not form scale in any circumstances. That explains the undoubted good faith in the Luminator of the G.N.R. in having recommended Luminators to their friends.

To deal with another gentleman's query: The valves D and E in the drawing of the Lassen and Hjort measuring apparatus are exposed to contact with the chemical only when the positive chamber is filled. You see it is a positive chamber opening ports alternately above and below. When the lime solution is in the positive chamber, these two valves are exposed, but they are made of material absolutely unaffected by the chemical. They last five or six years and cost about 30s. to renew.

Mr. Chignell has referred to the absence of an agitator in the softener. In making this criticism he is signally

misinformed. The plant is equipped with a complete set of agitators for the purpose of keeping the lime emulsion in a state of constant homogeneous mixture.

The agitators in the chemical reservoir consist of two parallel flat bars connected by vertical straps to the rocking shaft and fixed at such an angle that at each oscillation of the bucket the container is swept completely through by these bars. The lower agitator is fixed within half-an-inch of the bottom of the container, and is curved at the point at which it passes the orifice of the chemical valve, so that it is absolutely impossible for the chemicals to accumulate at the mouth of the valve or to settle even for a moment at the bottom of the container.

The angular arrangement of the agitators makes it impossible for them to become fixed, as on the slightest movement of the tipping bucket the motion is conveyed to the agitators and the whole of the chemical solution in the chemical container completely disturbed. (Mr. O'Callaghan here explained on the model which he had with him the position and action of these agitators). I think you will agree that here you have got the fullest system of agitation you can think of.

The powder machine is very interesting, but it is not new by any means. A very estimable company in this country, many years ago, were the pioneers of a small type of water softener of the shaving water sort, and they sold a lot of them in the early days when people had not had time to try them. I daresay some of you remember the machine, which was a powder machine with a slot—the same idea as Mr. Chignell's—a little canister and a nozzle, and a slot in the end. The water goes into a tipper and tips over an agitator, which sends out a little spurt of lime powder through the slot. They would be all right if the powder remained dry, but the old motto "Keep your powder dry" applies more patently to water softening powders than to anything else. A mixture of lime and soda is very difficult to keep dry. If that stuff gets wet, it forms a cement and you will have to have a very big slot in order to push that cement out in chunks. People are not buying many of those plants now. I do not think you will get any improvement on an efficient strong cream of lime solution delivered directly into the water. You can obviously standardise and regulate a liquid much better than you can a powder.

I think that now I have gone over all the points that

were raised. If anybody wants to ask another question I shall be very pleased to answer.

Mr. Wardlaw: I would like to ask one other question, and that is the question of the relation between coal consumption and the deposition of scale. I think we are all interested in knowing that.

Mr. O'Callaghan, in reply, stated: As a matter of fact, that is a very vexed question, and it is an exceedingly hard thing to determine; and I think the only man who ever did anything in that line was Professor Rankine. Professor Rankine was a painstaking man, and he did his best to get at it, but his figures are more or less speculative. I have some figures here with me and will put them forward for what they are worth, but do not guarantee they are absolutely accurate, because it is a thing you cannot determine accurately.

Professor Rankine found that the resistance to heat of carbonate of lime is 17 times that of iron, while sulphate of lime gives 48 times the resistance of iron. He therefore calculates that one-sixth of an inch of average scale necessitates the expenditure of 16 per cent. more fuel, $\frac{1}{4}$ in. 50 per cent., and $\frac{1}{2}$ in. 150 per cent. extra fuel to generate the same amount of steam as compared with a clean boiler; and it has been ascertained that whereas the temperature of the clean boiler plate is only 350 deg. F., the temperature of the same plate covered with $\frac{1}{2}$ in. scale is approaching 750 deg. F., that is, the scale-covered plate has to be heated 400 deg. above the temperature absolutely required to heat the water, owing to the scale.

Mr. Suffield: I was the one who raised the question of agitation. Well, I am not quite satisfied by Mr. O'Callaghan's claim that his plant agitates the water as perfectly as he states. On this model here, he has these two buckets, but how is the water agitated when it gets down to the main tank, because, directly it is there, it immediately begins to precipitate.

Mr. O'Callaghan: The necessity for an agitator in the main tank would be apparent if the results obtained when the water comes to the end of the plant were different from what they are. But if our system of direct measurement of chemicals into the water—measurement in small doses—if that already gives the maximum effect, why should we add to the complications of the plant and have an unnecessary agitator in the main tank? It is unnecessary because this

system differs from other systems in this way, that in other systems you have got a relatively large bulk of water mixed with a relatively large bulk of very weak chemical solution. Of course, in those plants you must agitate, and agitate for hours, in order to get any semblance of reaction. In the Lassen and Hjort plant you have five, ten, fifteen gallons measured out exactly. You have immediately got a measured dose of chemical—very strong chemical—delivered directly into it, and water and chemicals are caught in a mixing tray. There is ample time and ample mixture taking place for the reaction. That the completest possible reaction occurs is proved by the results invariably obtained by Lassen and Hjort softeners—reductions of hardness to 2 deg. and even to 1 deg., which we are able to guarantee under penalty. So if we get the results, why should we lumber up the plant with superfluous agitators or other gear? The insides of some plants are weird and wonderful with slots, valves, and baffles. Why? Because the system is wrong to start with. If we have a certain small amount of water measured here at each stroke and deliver into that a powerful reagent, it requires very little time before that reaction occurs completely.

In conclusion, a vote of thanks was moved to Mr. O'Callaghan by Mr. Suffield and seconded by Mr. Wardlaw, and Mr. O'Callaghan in turn thanked those present for their attention.

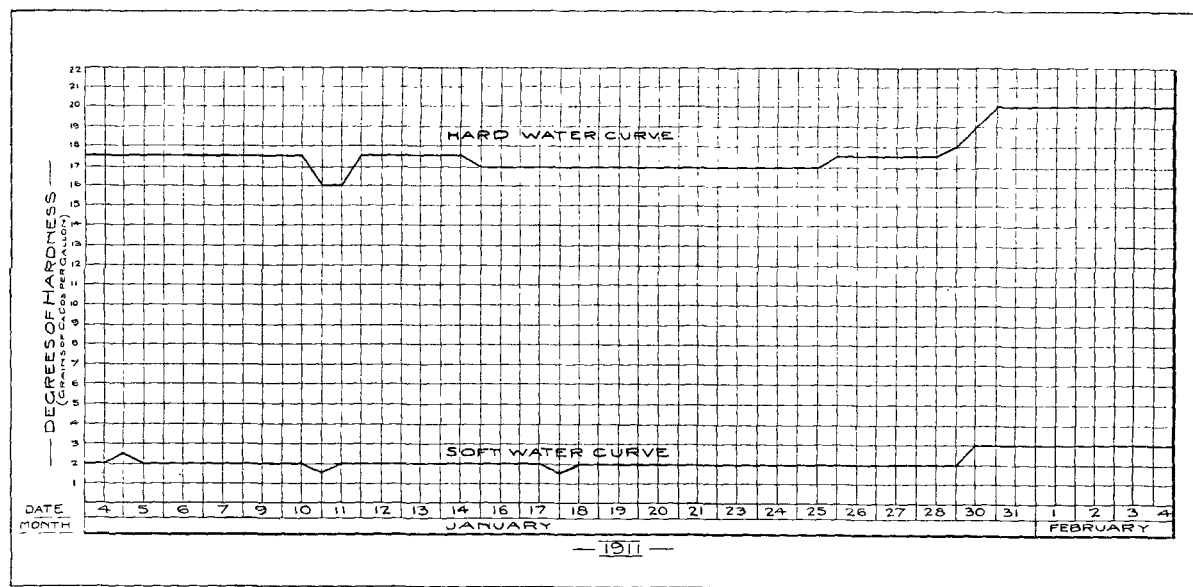


Fig. 1.

Daily working chart of Water Softener at Swindon Works, G.W. Railway.
Capacity 15,000 gallons per hour.

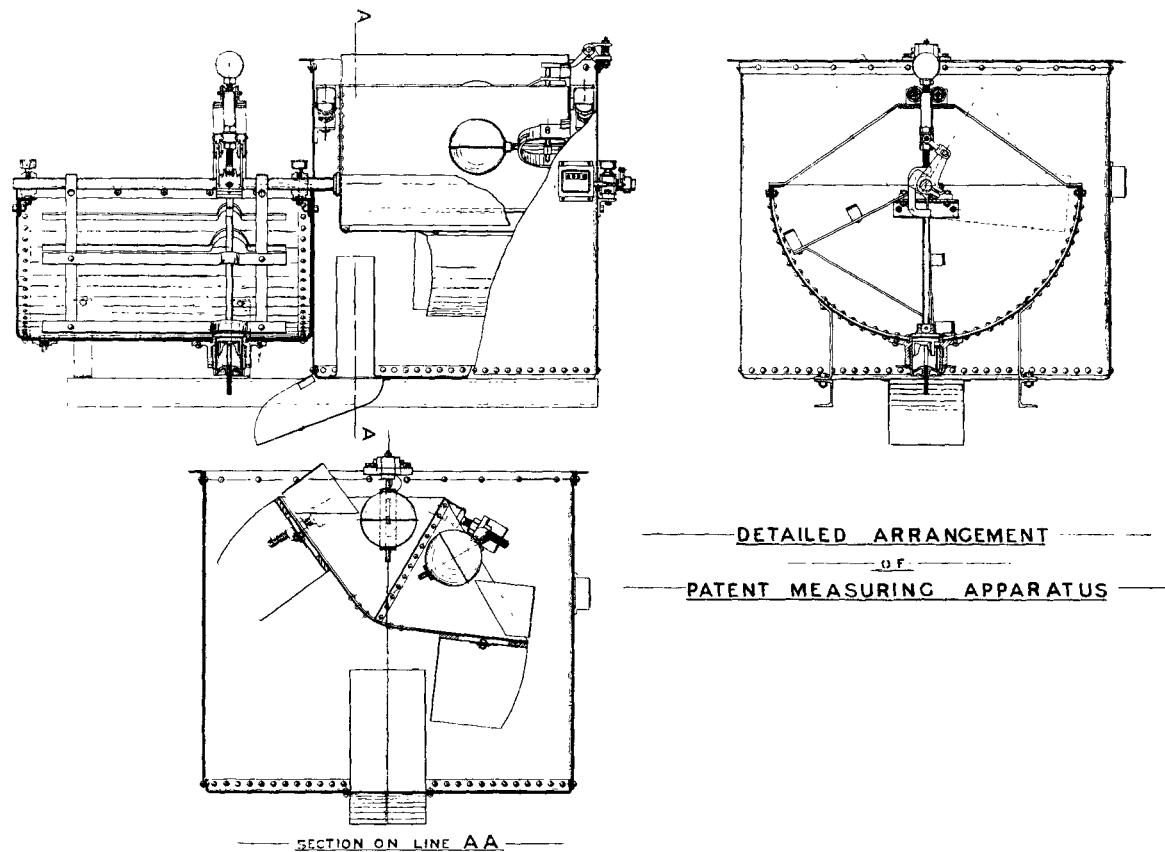
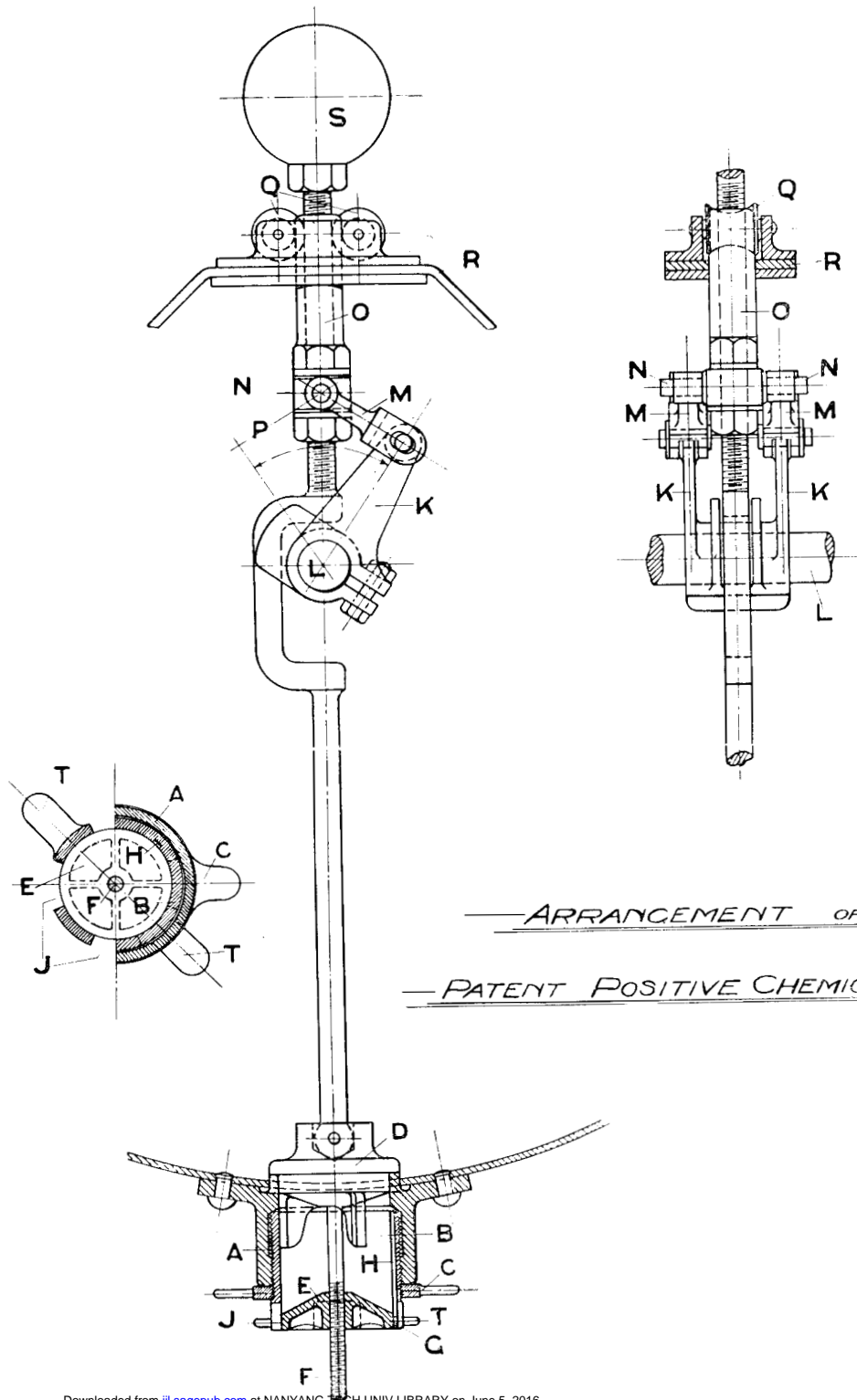


Fig. 2.



— ARRANGEMENT OF —
 — PATENT POSITIVE CHEMICAL VALVE —