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WATER SOFTENING

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Boiler Feed Water and Water Softening on the LMS and the London Midland Region.

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Tony Overton.

Introduction

My interest in water softening came about when undertaking researching prior to building a model of Bath Green Park Station, together with the engine shed and goods yard complex. The motive power depot contained such a plant, and a model was eventually built. The subject is technical, but it has been the objective to make this a readable account without getting bogged down in fine detail. Whilst some information given here is not strictly dealing with water softening, it does go to illustrate the problem of water supply and the continuing fight by the LMS to contain costs that is reflected by the constant references in the LMS minute books.
So, let us begin by considering the water supply position on the LMS.

Chapter 1 - Water for Locomotives.

On the face of it, water supply should not be a problem, but in reality the situation was very difficult from a railway viewpoint. Firstly, there must be a sufficient quantity at the point where it was required and secondly the quality of the supply, in both cases bearing in mind the cost. A railway was not open to take a supply from any stream over which the line passed, as the owners had certain rights to the water that passed along a river, and moreover the quality was frequently unsuitable. In many cases railways paid considerable sums for the privilege of taking water from rivers and streams. A further option was the sinking of wells, the depth of which varied considerably. In some cases when a borehole was sunk, the water rose automatically to a depth from which it could be delivered by a pump at ground level. In other cases the pump had to be fitted deep down in the ground, entailing a greater cost in pumping and increased cost when repairs were required. Water was also 'blown up' by compressed air with further expense.

So why was the public supply not utilized? In the first instance, the public authority may not have had sufficient water to spare, more particularly in times of drought and secondly the cost could be prohibitive, ranging, in 1925, from as much as 2/6d to 3/0d per 1000 gallons bearing in mind a locomotive averaged a little over 5000 gallons per day. A class V on the 8 hour runs to Carlisle from Birmingham would use about 8000 gallons.
On the LMS, a large number of pumping stations were used purely for engine purposes, many of which used steam engines. Interestingly, the fuel used in some cases was the ashes and char taken from the locomotive smoke box before oil or gas engines were substituted, that could be run with much less attention once started.

Supplying the Locomotive.
The simplest method was the standpipe, at the end of which was a leather bag that was placed in the tank of the engine, the control valve being at the base. When this arrangement was not suitable a water crane would be utilized that enabled the bag to be slung over the tender. If the water supply was slow (less that 500 gallons per minute), particularly when an engine would be delayed, a parachute tank was employed. This consisted of a circular tank mounted on top of an iron column containing about 2000 gallons of water, the advantage being that whist it filled slowly, it emptied fast. A further method was the water trough lying between the running rails that allowed the tender to be refilled while running. This was the invention of John Ramsbottom of Crewe and consisted of a 'U' shape trough in the order of 550 yards in length into which the fireman lowered a scoop and raised it again when his indicator showed the tender to be full.
Some standpipes, cranes and parachute tanks were painted red whilst others were yellow. A red painted tank indicated that water should only be taken when absolutely necessary as either the water was unduly expensive or of unsuitable quality, or that it was undesirable for locomotives to stand at that point.

Washing out of Boilers

LMS Traffic Minute 2340 dated 30th April 1930 clearly pointed out that all was not well as far as boilers were concerned as it was explained that the existing water pressure in certain motive power depots resulted in "stay and tube trouble in addition to engines having to be taken out of traffic more frequently for the purpose of washing out than otherwise would be the case".

The Minute called for the provision of booster pumps to give improved facilities for the washing out of engines at the following MPDs that should reduce coal consumption and the amount of boiler washing out that it was impossible to express in monetary terms

Midland Division – Bedford, Canklow, Derby, Gloucester, Hasland, Kettering, Normanton, Peterborough, Sheffield, Staveley, Stourton, Toton, Wellingborough, and Westhouses.

Western Division – Aston, Birkenhead, Bletchley, Bushbury, Camden, Carnforth, Chester, Holyhead, Llandudno Junction, Longsight, Monument Lane, Patricroft, Preston, Rugby, Stafford, Stockport, Walsall and Watford.

The estimated cost was £12,000 and the additional maintenance and renewal charges estimated at £720 per annum. The work was subject to the Governments Development (Loans, Guarantees and Grants) Act 1929.

Water Suitability.

The water should be clean and under normal conditions this was the case, but when it was necessary to take water from a canal or stream that was polluted with matter in suspension, the circumstances would be exceptional, with the water column painted red, as referred to earlier. Filtration could be resorted to, but this was rare. In some districts where water had passed through peat, small particles of peat might be found in the water that were liable to be a source of trouble. A small piece of peat could settle down on the steel plate or tube, when, under certain conditions, it might be converted into humic acid which commenced to erode the metal to form a small but constantly growing "pit hole" that could lead to a serious weakness in the boiler. These were very prevalent in some LMS Districts. A remedy was to pass the water over a bed of broken limestone which rectified the problem, although this was not always possible.

Even if the water was perfectly clear its locomotive suitability was not assured. As an example soda water is as clear as could be desired yet it contains about 24 grains per gallon or 0.03% of its weight of sodium bicarbonate, the salt of which gives it its special flavour, besides any other salts that may be present in the original water. The same thing holds true with many waters that contain a considerable amount of salts, some of which may be seriously detrimental to a locomotive boiler.

In the course of a day, the boiler evaporates several times the amount of water originally contained in it, and steam generated and given off does not carry away any of the salts in the water. This means that latter tend to become concentrated, and rapidly increase in amount if the water was not changed, making it necessary in some districts for the water in the boiler to be periodically and systematically "blown down". This operation was carried out whilst the water was still hot, as some of the salts, although they remained in solution whilst the temperature is high, may be deposited at the bottom of the boiler as the water cools. For example on a trip from Euston to Carlisle, feed water was taken from many sources en-route, all having different properties.

The Cause of "Furring".

Salts are not the only problem, as found to a greater or lesser degree in all waters is calcium bicarbonate or lime. This has a property directly opposed to the salts in the water that might become solid when cold, because although an appreciable quantity may be soluble in cold water, a large proportion will be thrown down upon heating the water. This is a phenomenon

with which we are all probably acquainted, as it is the cause of the "furring" up or depositing of scale in the ordinary domestic kettle.
When water is tested by an analytical chemist, he determines in terms of the "hardness" or property of destroying the soap it possesses by reason of the presence of certain scale forming salts within it. This allowed the engineer to decide on suitable water for boiler purposes. Where scale was thrown down upon boiling, the hardness was spoken of as "temporary" but where the salts remain in solution under these conditions the hardness was known as "permanent". There are many other salts in water besides calcium carbonate, some of which tend to form scale, the presence of which may cause the boiler to corrode, whilst others tend to throw down other salts when present. The full analysis of water is complicated, and the interpretation of the significance of the results requires considerable knowledge.

Table 1 shows the analysis of good, bad and sodium waters. This last phrase, "a sodium water" requires explanation. Many waters, especially in certain districts, contain salts such as sodium carbonate etc. These salts do not cause hardness, in fact the reverse, but are nevertheless a source of trouble from another cause. How soft they are may be shown in the case of a borehole that was sunk near the line, when, having reached a certain depth, water was found that rose to the surface and formed a copious fountain. The water was so soft that one could wash without using soap meaning that the water was "sodium water" and all that was required to turn it into soda water was to aerate it. The problem with sodium waters is the tendency to "prime" or "foam" and cause particles of water to be carried over with the steam and deposited in the cylinders, the presence of which could have very serious consequences, a trouble more likely with locomotive boilers than the stationary type due to the agitation caused by the moving engine causing more free ebullition that carried particles of water along with it.

Unsatisfactory Feed waters
There are three main classes of unsatisfactory boiler feed waters as follows;-

1. Scale forming – These for various reasons cause scale to be formed in the boiler.
2. "Sodium" – These cause "priming" that leads to water being carried over with the steam from the boiler to the cylinders.
3. Corrosive of various types. These had serious damaging effects on the plates, tubes and fittings.

There are various methods of softening that will alleviate the first trouble, but they are sometimes expensive or inconvenient, and in some cases could only be carried out by the introduction of sodium salts that caused the second source of trouble.

The Situation Regarding LMS Boiler Feed-water.
On the LMS it can be said there were no bad waters of types 2 and 3 in Scotland.
In England the waters from colliery districts generally were the worst as all three types of trouble could be experienced. Calcium carbonate (or temporary) hardness was most frequently met in limestone districts such as Derbyshire. Peat trouble occurred mainly in Yorkshire and Derbyshire and other moor land districts with those associated with sodium salts from colliery districts. The mean hardness in England is approximately 15deg. but many important supplies were in the order of 20 to 25 degrees but if significant economies were to be made it required reducing to 4 or 5 degrees. The relative hardness of water is measured by the number of grains of lime contained in 70,000 grains of water (one gallon). A really soft water will not contain more than three grains per gallon - which is expressed as a hardness of 3deg. Hard water will contain 20 to 30 grains or even more. It was calculated that if 10,000 gallons of water having a hardness of 20 degrees were evaporated in a boiler, about 30lbs of scale would be deposited. The effect of a ¼" coating of scale on tubes would increase the amount of fuel to generate steam by 5%, and the effect of a 3/8" coating would

increase coal consumption by 10%. The LT&S section had very hard water with Fenchurch Street having 20 degrees of hardness, Plaistow 22, Tilbury 34, and Shoeburyness 40.

Study of the map, figure 1, shows the location of the first fifty softeners that the LMS installed where it can be seen that no plants were installed on the Central Wales main line, none north of Lancashire and scarcely any in the Pennine region, whilst there is a definite concentration south of Lancashire and between London and the Midlands. The reason being that many different kinds of rock are to be found at the surface of Britain – the thick clay of the London area; the white chalk of the Chilterns; the blue clay in the Bletchley and Bedford area; the red sands and marls of the Midlands; the massive grit stones and lime stones of the Pennines; the slates of Wales and the Lake District etc. All these rocks are made up of different chemical substances, some being porous and others not, meaning that they all yield water in different qualities and quantities. Porous rocks such as sandstone and lime stone usually yield large supplies; impervious rocks such as clay may have a fairly good surface supply but little underground meaning that the water usually had to be pumped from borings that penetrated the underlying porous beds. The rocks that contained lime or allied substances yielded hard water and those that were largely sand or slate yielded soft water, therefore the supplies of soft and hard water depended on the rocks that underlie the surface of the land.

Figure 1 also shows that where slates and grit stones are the dominant rocks, no softeners were necessary as the water was soft. None were needed in Scotland, lines round the Lake District and across Central and South Wales. There were no softeners required on the Lancashire and Yorkshire line crossing the Pennines between Newton Heath and Whitley Bridge down the Vale of the Yorkshire Ouse. The most important series of rocks yielding hard water are known as “Trias” – the red rocks of the Midlands and the lime-stones and chalk that lie between the Midlands and London. Twenty-three softeners were located on the Triassic rocks, mainly between South Lancashire and the Trent Valley. In regions such as Wales and the Pennines that normally produced soft water, rocks did occur that caused the water to be hard with softeners required. The water at Flint and Prestatyn was provided from the limestone of the Clwydian Hills and was hard. At Hellifield, the water came from the Pennine lime stone region of Malham and Settle that was also hard.

Figure 1, showing the location of the fifty- one softeners and the problem areas.

Table 1. Analysis of boiler feed water.

Grains per gallon

	1 Good	2 Bad	3 Bad
Calcium carbonate	0.85	19.58	5.95
Calcium sulphate	0.32	0.51	-
Magnesium carbonate	-	-	4.01
Magnesium sulphate	0.36	14.11	-
Magnesium nitrate	-	0.37	-
Magnesium chloride	-	0.47	-
Sodium carbonate	-	-	14.30
Sodium sulphate	-	-	7.89
Sodium chloride	0.54	2.64	14.77
Iron oxide and alumina	-	-	0.25
Silica	0.10	0.48	0.73
Water not expelled at 130 deg.C and organic matter	0.43	3.24	1.20
Totals	**2.60**	**41.40**	**49.10**
Hardness degrees	1.38	32.42	10.71
Scale forming matter Grains per gallon	1.44	27.86	9.71
Pounds per 1000 gallons	0.21	3.98	1.39

1 – From a public supply to a large city on the LMS with water of exceptionally good quality. (Probably Birmingham with water from the Elan Valley in Wales). .
2 – Water of bad quality from an LMS well in a colliery district.
3 – Water from an LMS borehole, also in a colliery district highly charged with sodium salts.

Whilst soft water was desirable for locomotive boilers, it is also essential for certain other industrial purposes. The Lancashire cotton industry was almost located in its entirety in that part of the County where soft water (under 10 degrees) derived from the grit stones of the Pennine moors was in abundance; there were very few mills on the Triassic lowland of Lancashire. On the other hand the brewing industry needs hard water such as that derived from the Triassic marls of Lancashire and the Midlands, thus explaining why many of the country's brewers are situated in these two regions as at Burton-on-Trent for example.

Referring to 1.above the MR purchased water from Birmingham Corporation at a price of 7d (3p approx.) per 1000 gallons, but in 1931 this had risen to one shilling (5p). The LNWR obtained part of their water from a borehole at Monument Lane and a well at Aston that pumped water as far as Bescot, using Corporation water as an auxiliary supply. The Monument Lane water was of excellent quality, but Aston water was very hard as well as falling below requirements leading to a large amount of water being bought from Birmingham Corporation and the South Staffordshire Water Company. Accordingly it was proposed to sink a borehole at Perry Barr with a pump-house and to abandon the Aston well. A second borehole was to be sunk at Monument Lane with both works expected to bring down the cost to 2½ d (1p) per 1000 gallons, the estimated cost of this work was £11,413 resulting in a saving of some £6000 per annum.

Damage Caused with Untreated Water.

As stated, with few exceptions, all boiler feed-water south of the Scottish Border formed scale during its conversion into steam. This gradually built up a hard stone like layer around the boiler tubes and on the firebox that, in spite of washing out and rodding steadily increased in thickness. Hard scale deposited on the firebox was especially destructive as it prevented heat getting through rapidly enough, with the consequence that the firebox material became overheated and rapidly burned away. The destruction of the stay heads, the bulging of firebox sheets and leaking tubes at the firebox tube joints all resulted from the presence of hard scale within the boiler. A further source of trouble was the gradual blocking up of injector feed water pipes with scale. These pipes, that delivered the water to the smoke box end of the boiler could become so choked that in the course of a few months they had to be periodically removed for cleaning or renewal.

In addition to hard scale, feed water deposited a quantity of soft scale or sludge that settled to the lowest part of the boiler and could be found down the firebox legs and in the water spaces between the lower rows of tubes. Boiler washing had its greatest value in removing this sludge, for, if was allowed to build up in the firebox water space, the burning away and bulging of the plates would ensue and boilers would soon become dangerous. There were many other things effected by the use of hard water such as priming that resulted in additional wear on valves and piston rings due to the abrasive nature of the matter carried over, all of which helps to explain why locomotive performance deteriorated with mileage.

Scale also had an effect on coal consumption and the LMS calculated that at least 70,000 tons of coal was wasted annually on the English Division through the use of hard water.
The LMS used fifteen thousand million gallons of water per annum. To give some reference, this was more than sufficient to meet the annual needs of Birmingham. Most of the scale was comparatively hard and if loaded into wagons would make up some twenty trains. It can be seen that if only some of this problem was solved, considerable expenditure could be justified that prompted an exhaustive investigation that resulted in the decision by the LMS Directors to install water-softening plants where economies could be shown. The usual practice in hard water districts was to withdraw locomotives from service every 25,000 to 50,000 miles for boiler cleaning, requiring the removal of a large number of tubes to enable the sludge to be removed and scale cleaned out. This operation was repeated again when the engine went into the works for an intermediate repair, whilst at a general repair, carried out every 100,000 to 120,000 miles the boiler was removed and a new or repaired boiler substituted.

So what were the Savings?
Initially the problems on the two main lines between Carlisle and London were embraced. This made it necessary to ensure that savings in coal consumption and boiler repairs would justify the purchase and running of the plants. The main evidence in this direction came from comparison between the Scottish and English Divisions. Up to 1930, water softeners on British railways were few and far between meaning that evidence was difficult to obtain. On the other hand water softening in the USA had been in general practice for several years. That country had, in 1933, 1000 plants removing 50,000 tons of scale annually. In America it was believed that the cost in boiler repairs and coal consumption due to the presence of one pound of scale and sludge was sixpence, which, in the case of the LMS, meant that every 1,000 gallons fed into the boiler cost one shilling more than was necessary in boiler repairs and coal. Applying this figure, to the water supplied on the two main lines represented an additional expense of more than £250,000. The softening process removed the potential for scale and sludge leaving a clear soft water capable of forming only a small quantity of deposit, entering the boiler. The earliest plants consisted of rectangular tanks, usually four or five in number, filled with water to which were added the correct quantities of lime and soda ash. Following a period for settling and clarification, the soft clear water was drawn off from the top. Various improvements in design were made, the most important was the introduction of plant in which continually flowing streams of water were uniformly softened
To sum up as far as the LMS was concerned – water was hard owing to the “lime” it contained, and the remarkable thing was that part of the cure demanded the addition of still more lime.

Chapter 2 - LMS Water Softening Plants.

The Midland Railway were certainly aware of the problem as Leonard Archbutt, the MR Chemist, and Richard Mountford Deeley designed a softening plant located in Derby known as the “Archbutt and Deeley Water Softening Plant” that was later manufactured and marketed by Messrs Mather & Platt of Manchester with considerable success **(Plate1)**. They wrote a paper on their process that was presented to the Institution of Mechanical Engineers in July 1898.and had also taken out at least three patents. The plant dealt with 5 million gallons of River Derwent water weekly, using lime and soda ash to remove the hardness and iron sulphate and sludge recirculation for coagulating the precipitate. Briefly water was treated in batteries of separate tanks in which were the appropriate chemicals. compressed air was then blown upwards through the water from perforated pipes at the bottom. When the air was shut off, subsidence of the precipitate was so rapid the clear softened water could be drawn off through floating arms in a remarkably short time. The impression gained from comments made by later engineers was that the work of these two Midland employees deserved wider recognition, as their Derby plant was still working in 1936. The objective of the Derby plant was to simply remove the scale forming properties, later the objectives were extended to deal with reducing corrosion to a minimum. There was also a small water softening plant at Millhouses (Sheffield), installed by the MR in 1921 for experimental purposes, that proved unsuccessful and its use was discontinued in 1925.

Plate 1.

The Archbutt and Deeley water softener at Derby.

Roy Burrows Midland Collection Trust

As far as the LMS was concerned an enquiry was set up in November 1930 consisting of representatives of the Motive Power Department, Chemical Laboratory and Mr A. C. G. Egerton FRS of the Advisory Committee on Scientific Research to investigate the question of water softening for locomotives. Their conclusion was that nothing less that a policy of enhancing the water on the LMS main lines to Carlisle should be considered that required thirty softeners at a cost of £150,000 They stated the operating costs would be about £25,000 per annum with an annual saving of at least £180,000 would ensue. The report pointed out that boilers on engines in Scotland had a 50% longer life than those in England & Wales. The aim was to bring the water to within 10% of that in Scotland. The enquiry also considered an alternative solution of adding boiler compounds that simply made the scale more easily removable whereas in the case of softening plants, the scale forming matter is removed before the water enters the boiler. It was also stated to be less effective, but their use would save on capital expenditure. As a result of this enquiry the Directors authorised 28 water-softening plants of the hydrated lime-soda type, with provision for the use of a coagulant if required, to embrace the lines from Euston and St. Pancras to Carlisle, representing a capital expenditure of £130,000. On the former LNWR line 16 plants were built with 12 on the former Midland line, the locations as shown in the accompanying table and map, figure 2.

Map showing Distribution and Capacities of Water-Softening Plants between London and Carlisle, L.M.S.R.

Figure 2 shows the location of the first twenty-eight plants.

It estimated that in the first year the savings would equal the cost of the installation and that savings would carry on increasing for five years by which time the deleterious effect of the present water would have been removed by repairs or renewals of fireboxes and tubes when the full saving would be realised, summarised thus

Estimated savings.	
Coal Consumption.	£29,000
Boiler repairs in workshops.	£38,000
Boiler repairs in running sheds	£30,000
Boiler renewals.	£47,000
Tubes.	£31,000
Total savings.	£175.000

With the costs deducted of £39,262 a net annual saving of £135,738 would ultimately be made.

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These installations were expected to affect 1,600 locomotives out of the 7,300 on the LMS at that time operating in England and Wales and even if the softeners were added to the other LMS main lines only about 50% of the locomotive stock would benefit.

Many LMS sheds were fitted with either steam or electric washing-out pumps with considerable working costs, the use of which was curtailed once the boilers were thoroughly cleaned. There was also a saving of pumped water as well as staff required on the scaling duties. Locomotive boilers and tubes would have a longer life with the repair and renewal in sheds and workshops being reduced as well as the number of spares. A saving in fuel would also be shown when the scale and dirt in the boilers had finally been removed. The softened water would gradually cause the old scale to break away from the tubes and stay bolts. This required more care in changing water and washing out in order to prevent priming until the boilers had been shopped, when most of the scale and dirt would be quickly removed. Initially the water was not softened right down, but done gradually over a few months. A water test was carried out at each plant in order to prove its compliance with the specified requirements before being brought into use. The scheme was the largest undertaken of this magnitude by a railway company in Europe in one operation and commenced in 1932. In total the plants in aggregate were capable of treating over 4,000,000,000 gallons of water per annum. Five different firms shared the contract with 28 different types and sizes being constructed and was probably the most up-to-date plant used on any railway at that time.

Table 2 Detailing the locations capacities and manufacturers of the sixteen plants on the West Coast Main Line.

Site	**Capacity Galls./hr.**	**Manufacturer**
Bushey troughs	30,000	United Water Softeners Ltd.
Colne Valley (Watford).	50,000	United Water Softeners Ltd.
Tring	4,000	Becco Engineering & Chemical Co. Ltd.
Leighton Buzzard troughs	4,000	Paterson Engineering Co. Ltd.
Bletchley	12,000	Paterson Engineering Co. Ltd.
Castlethorpe troughs	25,000	United Water Softeners Ltd.
Northampton	15,000	Paterson Engineering Co. Ltd.
Rugby	20,000	United Water Softeners Ltd.
Newbold troughs	25,000	Kennicot Water Softener Co. Ltd.
Nuneaton	15,000	Paterson Engineering Co. Ltd.
Hademore troughs	20,000	Paterson Engineering Co. Ltd.
Stafford	16,000	Kennicot Water Softener Co. Ltd.
Whitmore troughs	30,000	Paterson Engineering Co. Ltd.
Moore troughs	30,000	United Water Softeners Ltd.
Kenyon Junc.	30,000	Paterson Engineering Co. Ltd.
Preston	20,000	William Boby & Co. Ltd.

Table 3 Detailing the locations capacities and manufacturers of the twelve plants on the Midland Main Line.

Kentish Town	16,000	Paterson Engineering Co. Ltd.
Cricklewood	16,000	Paterson Engineering Co. Ltd.
St. Albans	2,000	Paterson Engineering Co. Ltd.
Bedford	12,000	Bell Bros. (Manchester 1927) Ltd.
Oakley troughs	14,000	Paterson Engineering Co. Ltd.
Wellingborough	17,000	Paterson Engineering Co. Ltd
Kettering	7,000	Paterson Engineering Co. Ltd.
Market Harborough	8,000	Becco Engineering & Chemical Co.Ltd.
Melton Mowbray troughs	20,000	Paterson Engineering Co. Ltd.
Loughborough troughs	15,000	William Boby & Co. Ltd.
Toton	28,000	Paterson Engineering Co. Ltd.
Hellifield	8,000	Paterson Engineering Co. Ltd.

At the Locomotive and Electrical and Mechanical and Electrical Engineers meeting on 26th April 1933 the CME stated that when the 28 plants were authorized, a plant at Nottingham would have been included had arrangements then under consideration been completed. The new borehole had since been sunk where it was proposed to install the 29th water softening plant at a cost of £6,778. The same committee was advised at their next meeting on 24th May 1933 that 27 plants had been completed with the average hardness of the softened water being 5 deg. and expected to reach the required 4 degrees shortly. The meeting was further advised that whilst they had not been in use for sufficient time to appreciably influence the cost of boiler maintenance there were signs “that the anticipated economies were being gradually but steadily approached and in general the condition of the boilers was rapidly improving”. Trials were also ongoing with various compounds etc referred to earlier, with no advantages forthcoming but would continue for at least nine months. The Capacity of the Market Harborough Softener was increased in 1942 from 8,000 to 10,000 gallons per hour at a cost of £1537.

In view of the negative results achieved with boiler compounds it was recommended that a further twenty two softening plants be provided at the following points with a total capacity of 372,000 gallons per hour:--

Chester. To soften also a supply to be piped to Mold Junction).
Flint.
Prestatyn.
Ditton. To soften also a supply to Speke Junction).
Cheadle. (Supplying Stockport, Longsight and Manchester (London Road).
Kirkby. (Supplying Kirkby Troughs and Aintree Loco Shed).
Rufford. (Supplying Rufford Troughs and HoscarTroughs).
Southport.
Wigan.
Ladybridge.
Bullfield.
Bolton.
Newton Heath.
Thornes. (To soften also a supply to be piped to Wakefield).
Whitley Bridge.
Goole.
Totley. (To soften supplies to Sheffield area and also a supply to be piped to Masborough and Canklow).
Burton.

Bromsgrove.
Gloucester.
Bristol.
Bath.

The Totley scheme was revised as the amount of water from Totley Tunnel was insufficient and the existing trunk main from Millhouses to Sheffield was of insufficient capacity requiring the replacement of 4,500 yards of 8" diameter main by a new 10" main. It also proved necessary to increase the connection from the local authority's supply at Grimesthorpe and install a wayside plant of 10,000 gallons per hour capacity and replace the existing booster pump by one of larger capacity, the additional cost being £6,408.

The manufacturers and capacities of the proposed plants were not stated although William Boby supplied the 10,000 gallons an hour Bath plant. These later plants differed in that wood wool was substituted for sand in the filters and the reaction tanks were of six hours capacity that incorporated a central mixing tube of 15 minutes capacity fitted with agitator panels
The meeting was also advised that it was desirable to improve the water at Tamworth, Walkden, Smithy Bridge and Lostock Hall as the existing waters were incapable of being softened in the first three places and in the case of Lostock Hall it was proposed to extend the use of the already softened water at Preston. It was then considered that with possibly a small number in the Birmingham area and on the LTS section, they had reached the limit of profitable treatment of locomotive waters in external softeners. The estimated outlay, that also provided for the recovery and reuse of water spilled from water troughs at eight locations, and the bringing up to date of the Edge Hill plant, was £135,000 with the first year savings expected to equal the annual cost and that the full and ultimate savings, estimated at £85,250 per annum, would be realised in the fifth year.

The reference to the recovery of spilled water from troughs again goes to show that no possible means of achieving economy was overlooked by the LMS Railway. Minute 331 of the same Committee dated 26th July 1935 requested a block grant of £9,500 be authorised for the recovery of softened water spilled at the troughs where softened water was being drained away. The estimated saving was at least £3,500 due to less water being softened and the purchase and pumping of a smaller quantity. The troughs in question were – Moore, Whitmore, Hademore, Newbold, Bushey, Melton Mowbray, Loughborough and Oakley. A further minute 1254, on 25th July 1937, revealed that only Moore, Hademore, Bushey, Newbold and Loughborough troughs had been modified at a cost of £5,353 and that Whitmore, Walton, Mowbray and Oakley would not be dealt with leaving the scheme under spent by £4.147.

Experience later showed that in hindsight it would have been better to stay with one manufacturer and one size plant if possible, but there were probably three reasons for not doing so. Firstly all businesses at this time used the railways and therefore the railway companies may well have wished to share out their business, subject to satisfactory tender.
Secondly, industry was depressed at this time when the government would also wish to see that contracts were shared if at all possible. And finally, and most likely, that no one company could have undertaken all the work at the same time.

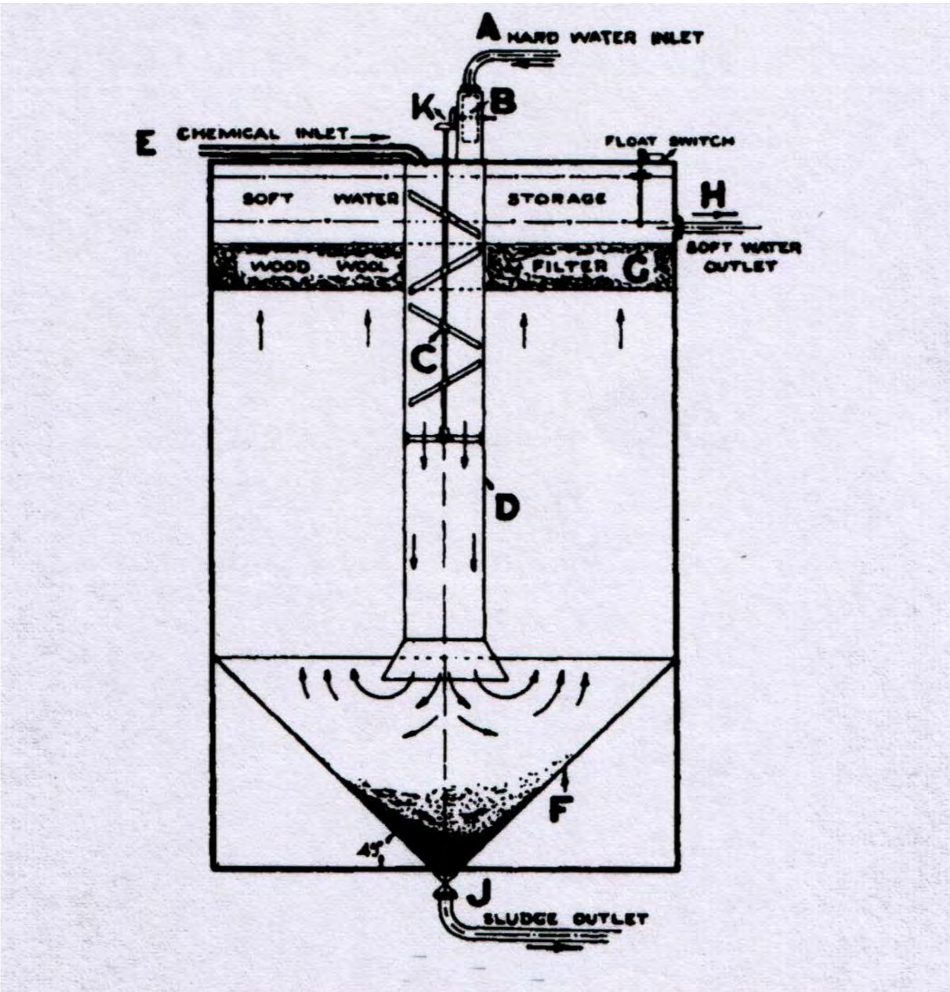
Chapter 3. How did the Softeners Work?

A water softening plant operated continuously – the features being –

1. Apparatus to apportion the lime and soda to the incoming water.
2. A reaction chamber of at least 15 minutes' capacity in which the mixture of chemicals and raw water was thoroughly agitated by means of revolving paddles.

3. A settling tank of such dimensions that the water was retained at least three hours with an upward rate of flow not exceeding five feet per hour.
4. A filter, either of sand or wood wool, to remove the last traces of precipitate.
5. On the bottom of the reaction tank a system of collecting pipes and valves to discharge the accumulated sludge.

The precipitate formed by the chemical reactions between hard water and lime and soda ash was formed of very small particles that were difficult to settle and maybe carried into the filters by the moving water. This was overcome by using a small quantity of sodium aluminate; the particles of precipitate, instead of being small and light, are coagulated into large groups that readily fall to the bottom of the tank. Sodium aluminate had the further advantage of assisting the actual softening, especially of water containing much magnesium salts. Such waters were difficult to soften below 3 degrees of hardness by normal treatment with lime and soda ash and the addition of a small quantity of sodium aluminate invariably reduced the hardness to 1 degree or less. Most of the softeners had a coned bottom from which the sludge was run off from one centrally placed outlet, see Figure 3.



A Reaction Tank with Wood Wool Filter.

Figure 3.
A reaction tank with a coned bottom.
Inst. of Loco. Engr's.

The plants were designed to soften down to 4 degrees of hardness. Figure 4 shows a typical arrangement.

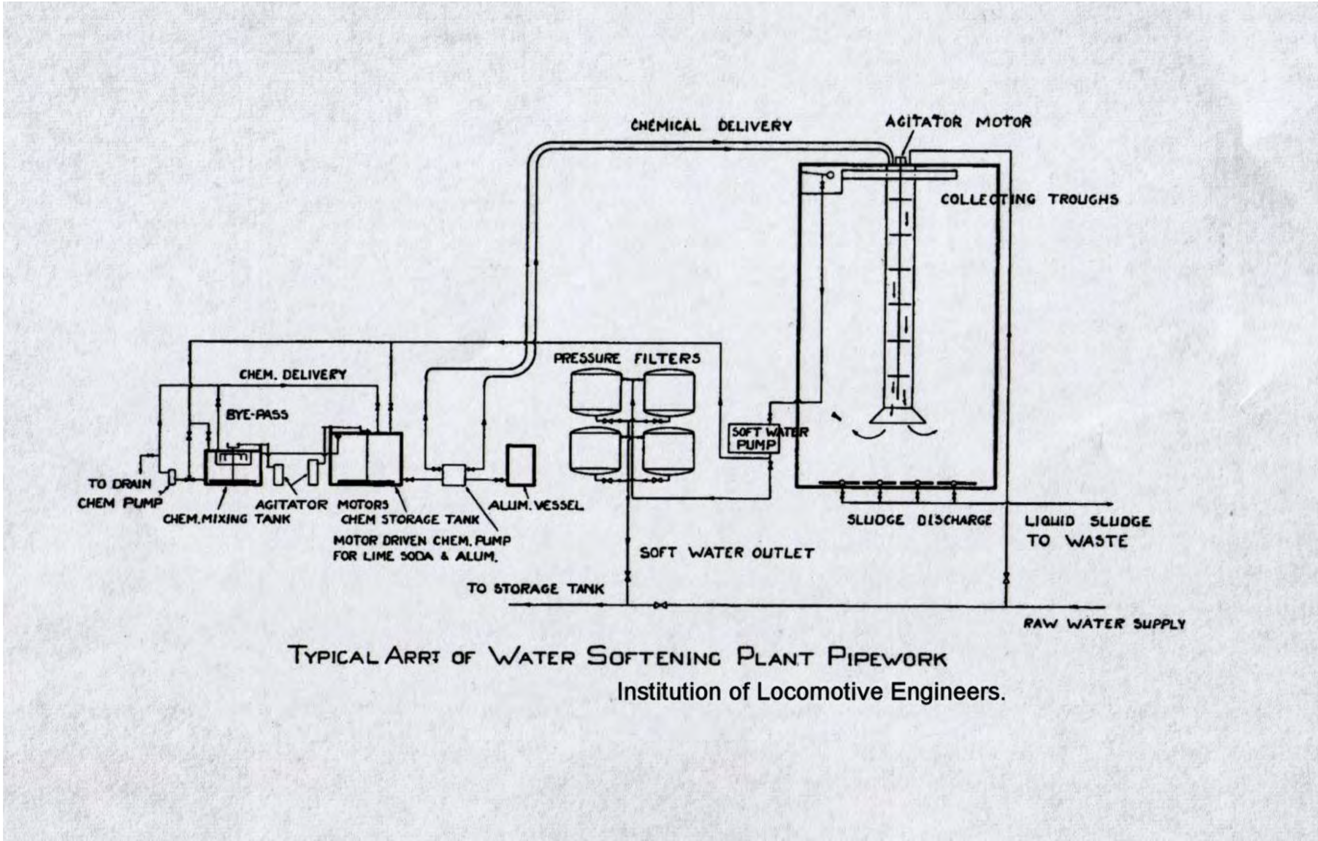
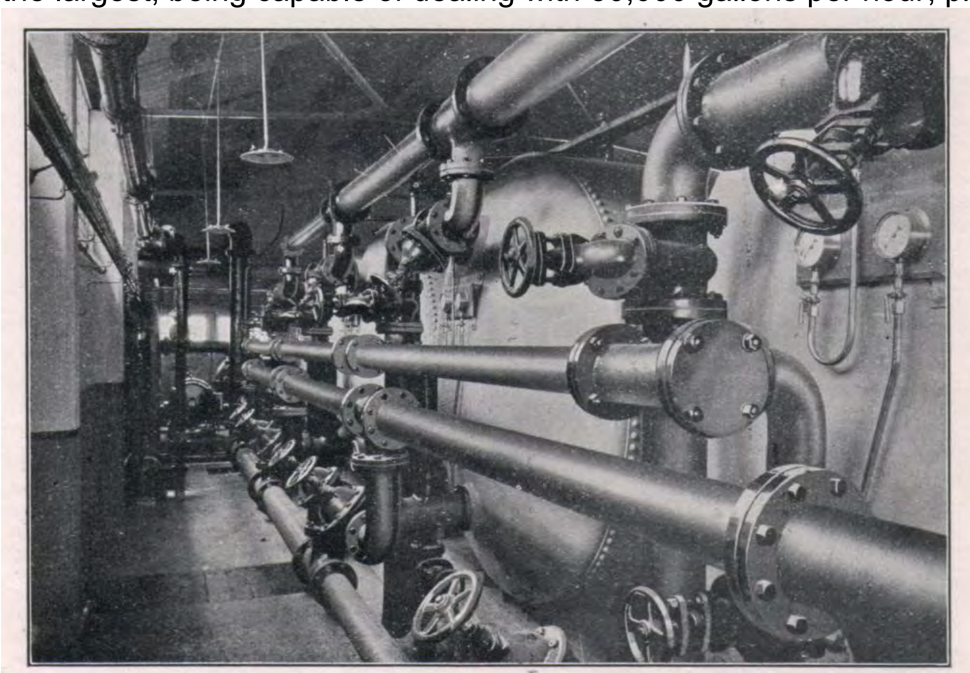


Figure 4. A typical arrangement of water softening plant pipework.

Inst. of Loco. Engr's

The Colne Valley softener, built by United Water Softeners and completed in July 1932, was the largest, being capable of dealing with 50,000 gallons per hour, plate 2.



FILTERS AT COLNE VALLEY

50,000 gallons, constructed by United Water Softeners Ltd. (LMS Mag. March 1933).

Plate 2. Filters at the 50,000 gallon Colne Valley softener constructed by United Water Softeners Ltd.

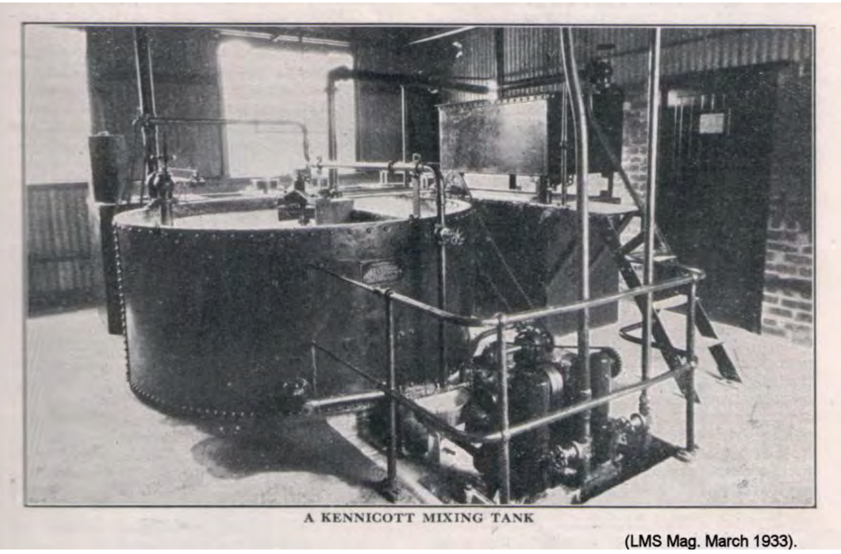
LMS Magazine

It consisted of a small settlement of brick structures dominated by a large iron tower with an external staircase with an overhanging gallery around the topmost storey. Inside was a cylindrical chamber filled with rushing water and moving machinery. A timber gallery ran all the way round the chamber, below which was a whirlpool of what appeared to be dirty milk. Suspended over this was a device consisting of two buckets so arranged that each in turn came under a huge pipe belching out water. As soon as one bucket was full it tipped over emptying fifty gallons into the eddy below, at the same time bringing the other bucket in place for filling. The water to be softened was therefore measured out at fifty gallons at a time with the rocking buckets actuating a mechanism that squirted from an adjoining cistern the correct amount of lime and soda and the little trickle of alum needed for the softening of the fifty gallons just released. The water then rushed downwards to a row of filters in one of the houses below that consisted of steel chambers partly filled with sand, and, as the water passed through, it left the grit that lime had not already deposited at the bottom of the softener.

In a short time the sand became clogged with solids; the pressure rose in the filter and the engineer, warned by a movement of a gauge needle that operated valves that stopped the flow, releasing the imprisoned air that washed the sand clean again. The resultant filtered water was then pumped into the reservoir at Watford to await the next thirsty locomotive. Having found itself in a locomotive boiler it would then become a vapour to be condensed and fall back upon the earth, perchance to enter another water softener further north. The Colne Valley softener was modified in late 1936 or early 1937 with alterations to the reaction tank to increase the effective area and the reaction period, and to the sump into which the sludge was discharged. In addition a steel tower and electric hoist block was provided to facilitate the tipping of sludge to a greater height, the cost being £1,354.

The Bletchley softener, built by the Paterson Engineering Co., had a capacity of 12,000 gallons hourly and was an entirely different installation. This tower was open to the sky and had a bridge crossing the top. There were no swinging buckets, wheels or levers, the tower being a big tank. A fountain was formed by the big delivery pipe from which the un-softened water welled up into what looked like a basin but in reality was a tube dipping deep below the surface and then, by reason of its open lower end, communicating with the “pond”. Smaller pipes delivered lime, soda and aluminate into this basin where the turmoil enabled them to mix thoroughly before passing to the quiet waters beyond. In the peaceful outer pool the solid matter and sludge sank gently to the bottom, and the comparatively clear water on the top trickled though little holes into an octagonal trough through which it passed to the filters.

In the building below, the lime was slaked in a great vat that became hot during the process. In a similar vat the various softening components were being mixed into a milky liquid by large revolving vanes A small piston moved in its cylinder drawing off just the right quantity of this sending it to the fountain up the tower.



A KENNICOTT MIXING TANK

(LMS Mag. March 1933).

Plate 3. A Kennicott Company’s mixing tank.

LMS Magazine.

All softeners were of the continuous type, and being automatically controlled could run unattended through the night and usually required at the largest plants only about eight hours attendance. The mixing of the lime and soda ash with the hard water took place at the top of the cylindrical reaction tank where the chemical proportioning apparatus was usually situated, (plate 3). This mechanism was automatically controlled by the hard water supply so that the amount of chemical added was always proportional to the rate of flow of the hard water, no matter how that may vary. The mixture of hard water and chemicals passed down the middle of the reaction tank through a wide tube to a point near the bottom, whence it passed out into the tank proper and rose slowly to the top. The time taken for this to happen was known as the reaction period and was usually from four to six hours. Sat at the top of the tank the water was collected in troughs and led to the filters. During the reaction time the bulk of the precipitate fell to the bottom of the tank and was periodically run off to waste, whilst the softened water, not yet completely clear, entered the filters, percolating through a bed of specially graded sand to a strainer, and so reached the locomotive storage tank. Nothing was wasted as the sludge deposited in the tanks was squeezed like a sponge in an accordion like machine until all water was driven out and could be used again. The residue became a cake, looking like a huge biscuit owing to its colour and the impression on it of the press, (plate 4).

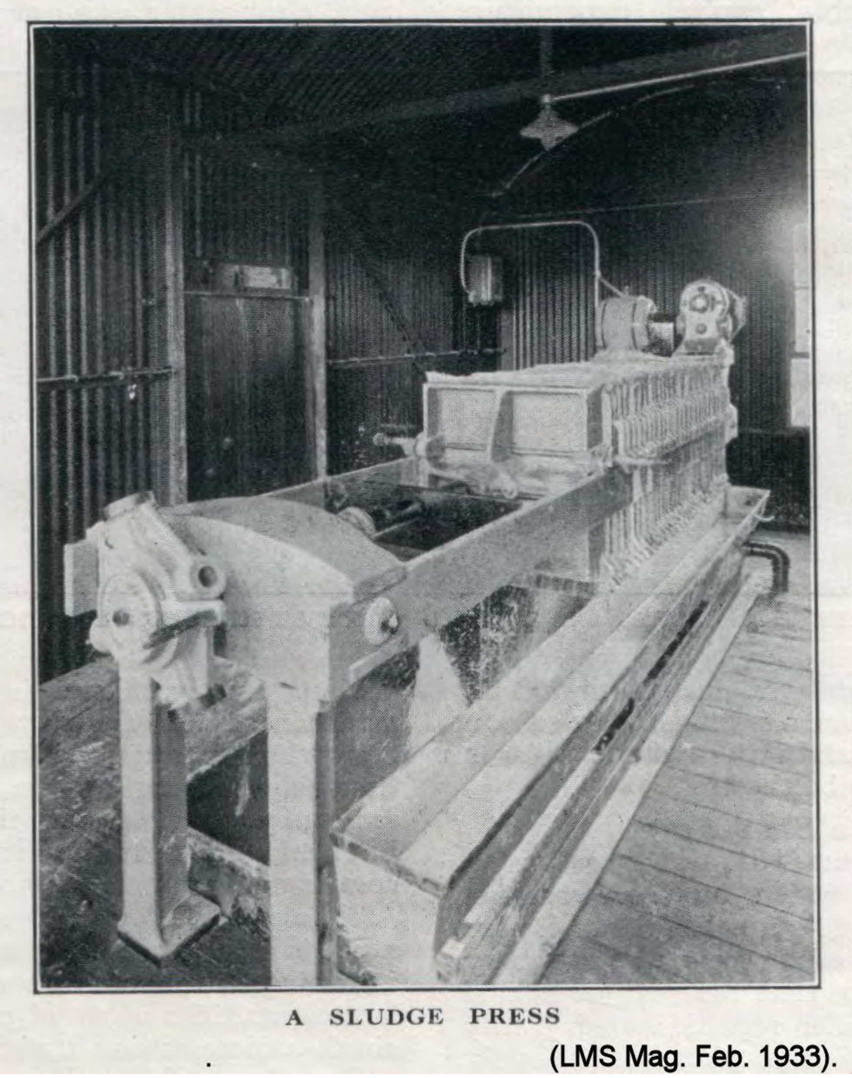
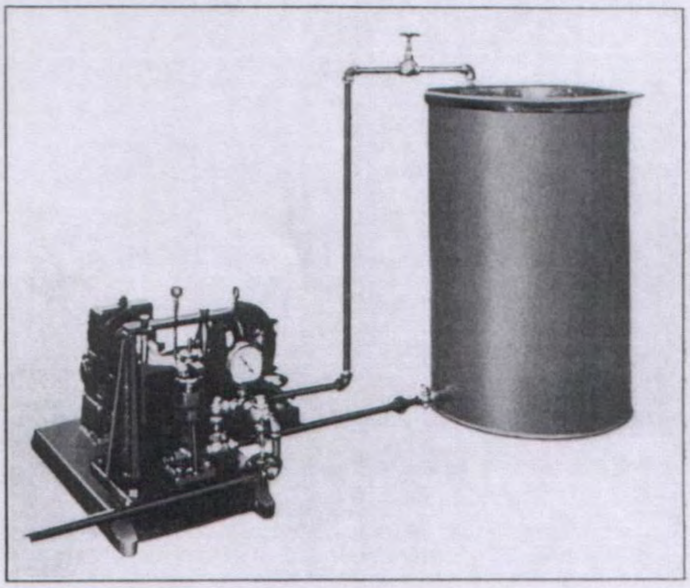


Plate 4. A sludge press.
LMS Magazine Feb. 1933.

The water could be tested in a minute or so using less than a gill of water and a few drops of chemical that told how well the softener was doing, and what correction, if any, was required. Some of the softened water was shaken up with liquid soap inducing a layer of lather, which, by its thickness indicated to the chemist the amount of lime. Further drops of a colourless liquid changed the clear water to a shade of purple and detected any soda lurking in it, a purple that was made to fade away by the addition of yet another colourless liquid.

Wayside Treatment Plants.
Water softening plants were economically justified provided the hardness of the water and the volume of water to be softened did not fall below certain limits, (Plate 5). Small supplies not exceeding 10 degrees of hardness entailed the use of a much simpler plant with lower running costs. The objects of wayside treatment were to precipitate the calcium and magnesium from the feed water as a loose non-adherent sludge easily removed by blowing down and to prevent boiler corrosion by adding rather more than enough soda ash to react with the sulphates and chlorides of calcium and magnesium.



A WAYSIDE TREATING PLANT.
Institution of Locomotive Engineers.

Plate 5 A wayside treatment plant.
Inst. of Loco. Engrs

Chapter 4. Priming and Blow-Down.

On 26th February 1936 the Mechanical & Electrical Engineering Committee met to consider the situation to date and any problems arising. It was stated the first softening plant had come into use in May 1932, with 27 in operation by the end of 1932, and the average hardness of softened water on the Western and Midland Divisions had, by May 1933, been reduced from 20 deg. to 7 deg. with a steady improvement in the condition of boilers and a corresponding reduction in the staff engaged on boiler cleaning. Between May and July 1933 water hardness was further reduced to an average of 5 deg. by increasing the use of soda ash at all plants, but by July 1933 it became evident that further progress was impossible, due to ‘priming’ of boilers and ‘pitting’ of boiler tubes. At this point it was clear that the increase in soda ash had led to a serious epidemic in “priming” in consequence of which the washing out mileages of engines at a number of sheds had been considerably reduced. For example, at Rugby, many engines accustomed to washing out mileages of 1,500 – 2,500 miles were reported to be priming at 400-500 miles. The result of this was that in October 1933 soda ash was reduced to give relief from priming. The mileage that could be run before priming commenced depended on the rate at which the sodium salts accumulated in the boiler i.e. on the amount of sodium salts in the feed water and the rate of evaporation. The success of water softening therefore depended on the elimination of priming as increased washing out reduced the engines availability, also most softened waters tended to be corrosive to steel boilers unless they contained a small excess of soda alkalinity.

There are four methods of preventing priming ;-

***1. Water changing*.**

As far as water changing is concerned using fully softened water, no priming would occur if boilers were washed out every 400-500 miles instead of 1,200-2,500 miles. Such action would not only increase the number of washouts from 30 to 80 per engine per annum, thereby increasing the number of shed staff, it would also reduce the engines availability and increase the engine stock.

2. Use of anti- foam compositions.

Anti-foam compositions containing small quantities of castor oil were on the market for the prevention of priming. Experiments showed that using one of these preparations in conjunction with fully softened water priming commenced at 1000 miles. The disadvantage being that water changing at 1,000 miles was necessary and that very careful dosing at approximately every 150 miles was required.

3. Intermittent blow-down.

Blow down valves were fitted to the boiler for the purpose of emptying the boiler, or blowing down, in the event of excessive priming due to dirty water

Intermittent blowing down was the removal of a portion of boiler water at frequent intervals and replacing it with feed water. This was the standard practice, for example, in America and South Africa, see plates 6 & 7. In the case of the largest engines the volume of water found down at the shed was from 500 to 800 gallons and a blow down on the road lasted from 15-30 seconds discharging 100-200 gallons To be really effective the valve was placed at the lowest point in the boiler and generally fitted on the side of the firebox, at the front corners just above the foundation ring as this was usually the lowest point in the grate and therefore, the foundation ring, sloped downwards towards the front of the firebox.

Plate 6. Blow down chimneys at De Arr shed, South African Railways.

L. G. Warburton.

Plate 7. South African Railways, Class 24 3670, intermittently blowing down at Duiwerivier – 24th October 1980.

L. G. Warburton.

4. Continuous blow-down.

Continuous blow-down means the continuous removal from the boiler of water, at such a rate that the concentration of salts is always kept below that at which priming occurs. This was achieved by means of a valve (Figure 6 & 6A) operated by steam from the steam chest so that blowing down takes place only when the engine is working. The rate of blow-down was controlled by a small orifice in the valve and depended on the class of engine and the amount of soluble salts in the feed water. The rate of blow-down varied from 1 to 2.7 gallons per mile and was the equivalent of about 7% of the total water consumption. In order to minimise heat loss from the boiler, the blow-down water is first passed through a cooling coil in the tender (in the case of tender engines) and made to give up part of its heat to the feed water before running to waste on the track. This arrangement is shown in figure 5.

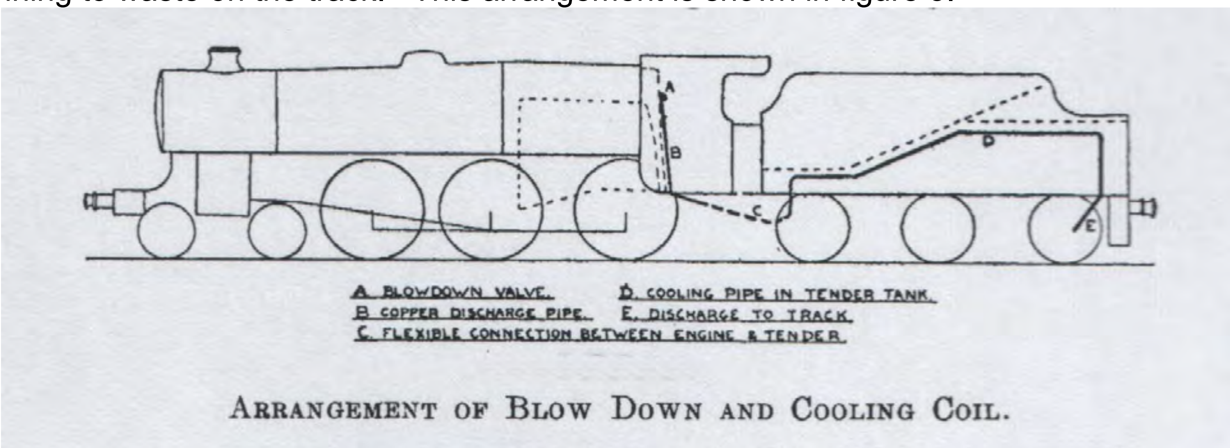
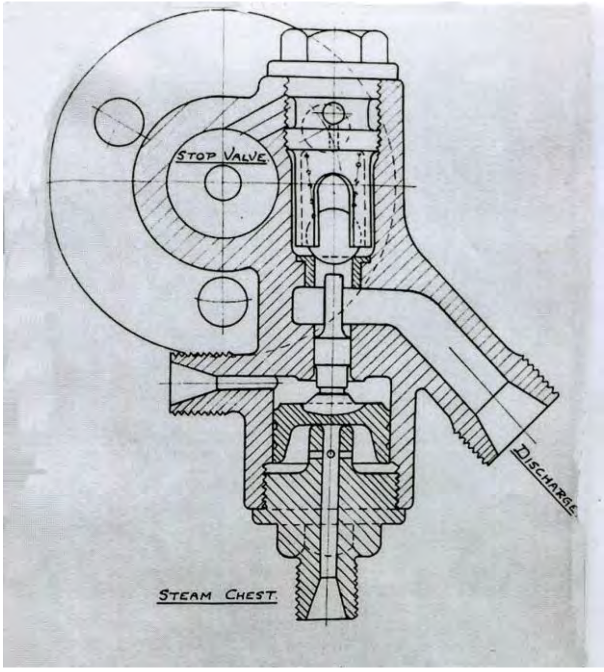
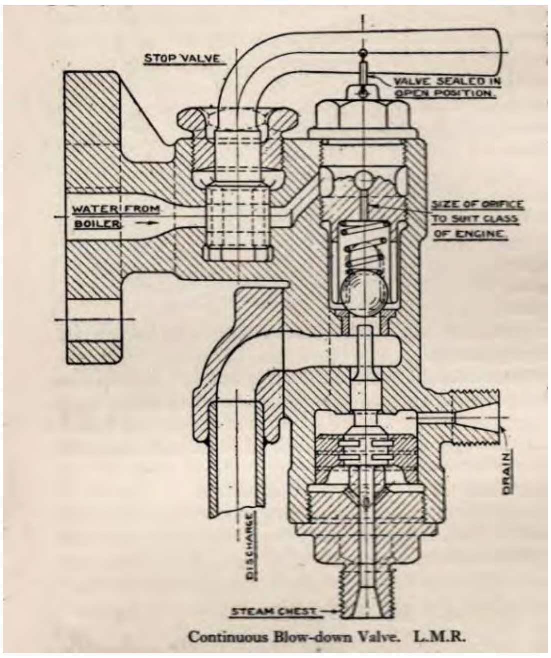


Fig.5 The original arrangement of blow down and tender cooling coil on an LMS locomotive, later the discharge was directed through the ash pan due to damage/corrosion caused to track circuits and electrical equipment etc. Tank engines had no such provision..

Figure 6. *Figure 6A.*





The LMS early and later pattern continuous blow down valves.

The heat in the blow-down water from a Royal Scot engine was found to correspond to about ¾ lb of coal per mile.

The advantage of continuous blow-down over the intermittent type was that it was automatic and removed the minimum quantity of water from the boiler. The concentration of soluble salts was kept safely below the priming point and the amount of water in the steam never exceeded about 1% during the whole of the working period between washouts. It was shown that an engine could run on fully softened water without priming provided it was 'water-changed' every 400 – 500 miles, usually done by bringing the engine into the shed for 12 – 16 hours. Continuous blow-down accomplished the equivalent of a water change without taking the engine out of traffic. In the case of an engine with a boiler capacity of 1,000 gallons, using feed water containing 12 grains per gallon at the rate of 30 gallons per mile, the priming concentration of 180 grains per gallon was reached at 450 miles, at which point it must be 'water changed' with the loss of 1,000 gallons of water. However, the rate of continuous blow-down necessary to prevent priming is 2 gallons per mile – 900 gallons per 450 miles. Not only was the water removed mechanically, but the engine may be kept in service indefinitely. During the early experiments with continuous blow-down mileages of over 14,000 were successfully achieved.

The Application of Continuous Blow-Down.
Experience gained during the first four years showed that the use of partially softened water made no reduction in the cost of boiler maintenance and repairs, in fact on the contrary it was likely to increase expenditure owing to rapid pitting and corrosion that took place. To be effective softening must be complete, in which case pitting was reduced to negligible proportions and substantial economies effected in the costs of boiler washing, cleaning and general repairs. The use of fully softened water, under the conditions then present in locomotive running was impossible due to the priming induced at very low mileages that may be overcome by frequent water changing, intermittent or continuous blow-down.

Ignoring water changing, of the three remaining methods of preventing priming that of continuous blow-down was the most suitable. Commencing in May 1935, eighty main line engines were equipped with continuous blow-down running with fully softened feed water by the addition of soda ash briquettes in the tender. Very little priming took place and the wash-out mileages of Royal Scot and 5X engines were raised from 2,500 to 5,000 miles, thus increasing the engines availability. The trial was a success and gave valuable information with regard to the design of valve together with the arrangement of the cooling coil and connecting pipes. The ball-in-cage, figure 6, showed little sign of wear and became the early standard, later replaced by that in figure 6A. The boiler condition of the eighty engines showed a marked improvement and there was no evidence of boiler tube corrosion. The development of a satisfactory blow-down valve had been completed at the end of 1934, although £2710 had been expended on valves that were unsatisfactory.

Tender engines were originally fitted with a 3-way cock to divert the blowdown water to either the ash pan or to the tender, but as the steaming in express passenger engines was adversely affected by discharging into the ash pan, the 3-way cock was abandoned with the water discharged through the tender cooling coil. The flexible connection between the engine and tender also initially gave trouble until a new type of flexible hose was utilized. Tank engines were not fitted with cooling coils, the water being diverted through the ash pan. Continuous blow down infers that it was in use at all times, but automatic would be a better description.

It was estimated that 4,500 engines from a total of 5,700 in England and Wales were at that time affected by softened water, of which 2,000 were fully affected and 2,500 affected to a varying extent. It was considered necessary to fit blow-down not only to the 2000 fully affected engines but to the whole of the remaining engines in England and Wales in order that inter-changeability of engines would not be reduced and to prevent ‘priming’ on the engines partially affected by softened water. Full economies could only be expected from the 2,000 fully affected engines with substantial economies obtained if fully softened water was provided for all the engines in England and Wales, and for that purpose the provision of 18 additional softening plants (for water supplied that could not be softened without blow-down) and eighty nine wayside treatment plants for soft but not corrosive water. The additional ater treatment plants differed from their predecessors in that the reaction tank was not provided with a cone, the sludge settling on the bottom and being run off through an arrangement of lateral pipes.

Chapter 5. Costs in the first four years.

At the Mechanical and Electrical Engineering Committee meeting held on 26th February 1936 the expenditure and anticipated economies of the complete scheme were listed as follows--

1. Outlay on schemes

Expenditure already authorised on the 51 existing plants	£272,388
Further expenditure on -	
Fitting of blow-down on 5751 engines	£ 95,814
Provision of 18 softening plants.	£ 63,900
Erection of 89 wayside plants.	£ 44,500
Total	£476,602

2. Annual costs

Interest, renewals, repairs & working of plants	£123,000
Interest, renewals, repairs of blow-down	£ 9,000
Additional water consumption.	£ 20,000
Additional coal consumption due to blow-down provision	£110.000
Total annual costs	£262,000

3. Anticipated gross annual savings.

Coal consumption due to clean boilers.	£ 54,000
Boiler repairs (workshops).	£100,000
Boiler repairs (sheds).	£ 85,000
Boiler renewals.	£ 97,000
Boiler tubes.	£ 60,000
Total	£396,000

4. Estimated net annual saving. £134,000

No credit was made in the above for the anticipated savings arising from the greater availability of engines and the decreased washing out then made possible by the use of continuous blow-down and the decrease in the time spent on repairs in sheds and shops.

No indication has been found as to the location and details of the 18 plants and 89 wayside plants referred to above although Mechanical & Electrical Committee Minute 1584 dated 29th March 1939 stated that at Stoke water was taken from three sources, namely the Company's reservoir at Stoke, its canal at Wilton and the canal at Stoke. The water from the canal at Wilton was considerably better than the other two places so the bulk of the water would be taken from there thus rendering a water softener at Stoke unnecessary, replacing it with a wayside treatment plant costing £700. There was also a proposal to erect a water softening plant at Lincoln costing £3,000 that was not proceeded with as it was agreed to obtain softened water from the LNER. In total the LMS erected 66 water-softening plants.

The Pitting of Boiler Tubes.

In 1936 the first serious case of copper corrosion occurred in a shunting tank that had been using fully softened water containing 1 deg. of hardness and four-fifths grains of soda. The copper tubes had lost a great deal of weight, almost all at the firebox end with many copper stays reduced to half their original diameter and the copper tube plate was pitted. A similar situation had been experienced in South America and India. The pitting of boiler tubes was caused by dissolved oxygen in the feed water and the presence of soluble salts. There were two ways of preventing pitting, either by mechanical and chemical methods of removing dissolved oxygen from the feed water or the treatment of the feed water with excess soda ash. Pitting may be almost entirely prevented if the oxygen is removed before the water enters the boiler, but this is both difficult and costly. It can however, be almost completely removed by the system of feed water delivery on taper boiler engines. This was achieved by delivering the feed water at the top of the barrel on to trays over which it runs and finally drops through the steam space to the water surface. The purpose of the trays was primarily to collect some of the scale forming impurities, but at the same time it had a greater value in giving an opportunity for the dissolved oxygen to escape into the steam space before it reached the tubes. If all LMS engines had been fitted with top feeds there would have been no requirement to add an excessive amount of soda ash to prevent pitting.

A similar effect was achieved when the LMS experimented with the A. C. F. I. Type of feed water heater that improved the condition of the tubes and considerably reduced corrosion. The effect of feed water heaters was to remove about 80% of the dissolved oxygen from the feed water thus increasing the life of steel boiler tubes appreciably.

The hardness of the feed water and the condition of the boiler are important factors in pitting. Obviously tubes that are well protected with a covering of scale have the effect of preventing water and oxygen getting close to the metal and therefore cannot attack it. On the other hand with comparatively soft waters, and therefore no scale of sufficient thickness or continuity to prevent contact between water and metal, the pitting can be fairly rapid.

Following some experimental years it was found that this type of attack could be prevented by the addition of about ½ lb of quebracho (tannin) extract to 1000 gallons of alkaline feed water. The LMS then added tannin to all softened and treated waters. Calgon (sodium) was added at the rate of approximately 1lb per 30,000 gallons in order to prevent precipitation i.e. the throw down of solids in the treated water.

Sludge Removal.

By July 1938 the CME reported that 64 water softening plants were installed of which 31 were provided with presses producing a fairly hard type of sludge refuse that could be disposed of at any tip, and that at 11 plants the sludge was run off and deposited on adjoining land. The remaining 22 plants produced sludge of a liquid type that made it necessary to convey to suitable tips in converted tenders, and, as difficulty had been experienced in dealing with such sludge in the Derby North Engineering District, the Lancashire and Birmingham areas and the LTS Section, sludge disposal tips were to be established as follows :-

Derby North, proposed tip at Elmton & Cresswell.	cost £ 712.
Lancashire, proposed tip at Wigan,	cost £ 281.
LTS Section, proposed tip at Rainham.	cost £ 990.
Birmingham, proposed tip at Tipton.	cost £ 759.
Total	£2,742

Progress.

By the end of 1939 the softening programme was almost completed with the Western Division being the first, followed by the Midland and Central Divisions. Washing out mileage was reduced in 1938 to 1,500 miles and then increased to a time basis rather than mileage, with main line engines achieving 2,500 – 3,000 miles per fortnight. The scheme became totally functional in 1940 when about 45% of the total boiler feed water was softened and 35% conditioned. From 1940 to 1952 the majority of locomotive boilers on the LMS and LMR operated on alkaline feed waters ranging in hardness from 2 to 15 degrees to which a little tannin extract (about 2 grains per gallon) was added to inhibit the corrosion of copper firebox plates and stays by alkaline water. The actual savings due to reductions in boiler repairs and coal consumption and to increased engine availability, brought about by the use of all this softened and conditioned water was impossible to determine due to other changes affecting boiler repairs etc., that took place during the same period, when changes in boiler design and boiler repairing methods. Nevertheless comparing 1930 with 1945 a great improvement had taken place as corrosion of steel had been stopped, the use of second hand tubes increased and new tubes reduced by 60,000 per annum. The periodic tube changing at many MPDs had increased from six to eighteen months and the average mileage between major boiler repairs in the works increased from 60,000 to 110,000 miles. Engine availability `increasing the boiler-washing period from a few days to fifteen days for main line passenger and freight engines and to thirty days for smaller freight and tank engines.

During this period the LMS blow down valve gave good service as the result of it being given a complete overhaul every scheduled 7-9 week engine examination. As stated earlier the original design, having passed the blow down water through the tender coil, it was discharged as a mixture of steam and water. This led to the deterioration of track ballast particularly in un-drained tunnels and therefore necessitated some improvement on the method of discharge. From 1946 the opportunity was then taken to re-design the cooling system and to operate the blow down valve off the injector steam supply and bring the boiler water through a small cooling coil placed immediately in front of the injector. The blow down water was then delivered as a comparatively cool stream to the outside of the track with at least 75% of its heat being transferred to the feed water. No difficulty was experienced with injectors failing to pick up warmer water.

Plant Failures.
It was found necessary to pay great attention to the mechanical running of water softening and treatment plants if the maximum efficiency was to be maintained. The usual figure for plants out of service was 3-4% with the majority of stoppages being due to over accumulation of sludge, shortage of chemicals or the failure of mechanical working parts. Sludge was disposed of by either pressing it into a cake and then dumping it by the side of the plant or taking it away in wagons to the nearest tip. Alternatively the liquid sludge was run straight from the reaction tank into a rail tank wagon, generally a converted tender and taken to a tip. In a few cases it was run into lagoons, allowed to dry and then dug out and removed. Any failure to remove sludge as rapidly as it formed led to an accumulation in the reaction tank that could reach a depth of up to 15 feet and had to be dug out by hand. A further cause of failure was the tendency for sludge to solidify and build up in the cone-bottomed type of tank that led the LMS to go over to the flat-bottomed type from which the sludge was removed more easily.

Wartime conditions in 1940 and 1941 were responsible for many plant failures due to the short supply of lime and soda ash. All LMS plants had been designed to hold one month's supply of chemicals, but in many cases this only lasted for 2-3 weeks due to increased traffic and therefore throughput. This difficulty was overcome by maintaining a small chemical ordering staff at the CMEs Headquarters whos responsibility was not only to order chemicals, but also to prevent plant failures by arranging for transfers from plant to plant or from reserves as required. Out of a total of 66 water softening plants the apportioning of the chemicals was done in 41 plants by means of a variable displacement ram pump driven through reduction gear either by electric motor or of the tail shaft of the softened water pump. This type of pump worked satisfactorily provided the strength of the chemical mixture was below 10% and the pump was in perfect mechanical condition. Any slight wear in the valves was liable to cause failure and thus required plenty of spares and spare pumps to be available. The remaining plants used oscillating gear placed on top of the reaction tank or in a few cases at ground level. This type of gear was very accurate and sensitive to the varying rate of flow of the untreated water.

It was LMS practice to treat water of 10degreesand under with a solution containing soda ash, tannin (an acid derived from the bark of certain trees) and calgon (a trade name for sodium phosphate) and in certain cases water considerably harder than this was treated. This was not considered altogether satisfactory as precipitation took place in treated water mains especially if the water contained suspended impurities. This was overcome by using bicarbonate of soda instead of soda ash. In general the softening plants gave very little trouble although freezing of the 10% soda ash solution sometimes took place. With any new plant the strength of solution would have been limited to 7%. The treated waters gave little trouble to injectors and threw down the hardness in the boiler mainly as soft scale that was not corrosive to steel or copper.

Chapter 6. Lessons gained from 1932 to 1945.

1. Boilers should not be fed with a mixture of softened and non-softened waters, which means that if water softening is undertaken it must extend to all water supplies.
2. Raw waters of 10degrees of hardness and under may be treated with soda ash, calgon and tannin but waters over 10 degrees should be softened,
3. All water whether softened or treated should contain 3-5 grains more soda ash that is required to precipitate the permanent hardness. This was to prevent corrosion of steel. They must also contain tannin to prevent the corrosion of copper. All water softening plants for a particular section, or ideally the whole railway, should be of the same make, and if possible of the same sized units. The site should also have

satisfactory sludge disposal facilities and the reaction tank to be vertical and flat-bottomed, fitted with pipes to run off the sludge.

4. There should be no filters except where crude waters were to be treated. Ample storage for chemicals should be provided with chemical proportioning to be the simple oscillating type with spare parts provided at the time of erection. The strength of chemical mixture to not exceed 7%.
5. Ideally the supervision, maintenance and operation should be in one department with an inspector allocated to a group of 8 -10 plants and trained to carry out the usual chemical testing and change chemical charges if required.

Prior to 1932 the condition of the boiler was responsible in most cases for bringing the engine into the works for a general repair that involved both boiler and engine components, but by 1945 the majority of engines were shopped due to the mechanical condition. However, with mechanical improvements such as the fitting of manganese steel liners in axle boxes and roller bearings, the boiler was likely to again become the deciding factor when to shop an engine. As far as the scheme being a success, Traffic Minute 7628 dated 27th March 1946 reviewed a report made by the Chief Operating Manager, the Chief Mechanical Engineer and the Chief Accountant. In 1936 works costing £471,893 had been authorised by the Mechanical and Electrical Engineering Committee. This expenditure included the fitting of 5,751 engines with continuous blow down valves that was expected to make an annual saving of £134,000 by decreasing coal consumption, boiler repairs and renewals and tube replacements. Whilst additional annual charges were planned at £304,000, the improvements and savings had not been clearly revealed. It was estimated that 92% of the locomotive feed water in England and Wales would be treated giving about 87% of softened water as actually supplied to boilers, but owing to wartime conditions these figures in 1945 had only averaged 87 and 82% respectively. A later meeting of the same committee on the 24th July 1946 received particulars of the major variations involved with explanations of the revised expenditure totalling £41,443 and the proposed further outlay of £5,363. The following particulars were submitted with explanations.

(i) Revised estimates for schemes authorized by the Directors; and variations to the scheme.

	Directors' Authorisations (Various) £	Revised Estimate £
Water softening plants.	63,900	73,312
Wayside treatment plants.	44,500	50,504
Blowdown apparatus on engines.	96,686	103,897
Preston area supplies.	1,594	2,114
Stoke area supplies.	3,268	3,921
Elmton & Cresswell, etc. sludge tips.	2,742	3,060
Toton & Brent sectional tests.	5,720	5,720
Totals	218,430	242,928
(ii) Schemes approved by Vice President Subject to Directors' authorisation	-	16,945
(iii) Further works that required to be carried out.	-	5,363
Total	218,430	263,236
Additional expenditure		46,806

The Total amount spent on the scheme as a whole amounted to £518,699.

Consultation with outside authorities suggested that savings did not accrue until at least 95% of the water treated was delivered to the boilers. A further report by the Chief Technical Assistant to the Chief Mechanical Engineer, following a visit to America at the end of 1945, confirmed the requirement to maintain 95% as a minimum of fully treated water and showed the need for imposing very much stricter control on the whole process of water treatment if satisfactory results were to be obtained. The officers therefore recommended a sectional test on the Toton - Brent section as follows.

1. The fitting out of 55 Standard Class 8 locomotives with manual blow down or de-sludging valves, the engines to be called in especially to the works for this purpose, and to be given a boiler clean out at the same time at an estimated cost of £1,100.
2. The provision of apparatus to enable daily boiler water tests to be taken on the above engines at Toton and Wellingborough at an estimated cost of £120.
3. That special attention be given to thirteen softening plants and six treatment plants to ensure that the highest possible percentage of fully treated softened water, of correct alkalinity, was available throughout the test at an estimated cost of £4500.

The total estimated cost of the trial was £5,720 and one full shopping period to the next repair would be necessary before the results could be judged, that was about twenty months after the engines had been fitted. A further report was to be submitted later on additional work for the scheme, also covering the overspending of approximately £33,000 and variations in connection with the water-softening scheme. The final recommendations were to await the outcome of the proposed tests. In the event only fifty engines were fitted, a full listing of which can be found in the "Locomotive Profile" series covering the 8Fs by Hunt, Jennison, James and Essery. All the engines involved in the scheme had a large white '**X**' painted on the cab side and were allocated to either Wellingborough or Toton motive power depots, see plate 8.

Plate 8 - One of the fifty 8Fs taking part in the experimental fitting of manual blow down or de-sludging valves seen here on Aston shed c.1950-2.

R. J. Essery.

The experiment required each gallon of feed water to contain an average of six grains of hardness, two grains of tannin and four grains of free alkalinity, with which it was expected to be sufficient to stop corrosion, precipitate all hardness as sludge and so maintain a perfectly clean boiler. The result was disappointing as whilst there was no corrosion of steel or copper, the amount of sludge formed was negligible, with the boilers continuing to build up scale at much the same rate as before. There was nothing wrong with the plant, but entirely due to the fact that the kind of water supplied i.e. of low hardness, alkaline and treated with tannin, readily precipitated its hardness in these boilers as scale and not as sludge. Knowledge increased and by 1950 more satisfying results would have been achieved with greater knowledge of precipitation from scale and sludge forming waters.

Chapter 7 - The London Midland Region of British Railways period.

By 1950 two new types of anti-priming compound became available, and their use was expected to appreciably reduce the amount of blow down needed to prevent priming, that, as referred to earlier was detrimental to the track. The new antifoams, one being a polyoxide, the other a polyamide, were found to be very efficient and by using these very high boiler water concentrations, even to 2,500 grains per gallon could be reached without priming. The polyoxide was found to be effective with soft alkaline waters but not with hard non-alkaline waters, while the polyamide type was effective with almost all kinds of feed water.

In 1952 the Region began to use a mixture of the two compounds at the rate of 1 lb. to 300,000 gallons of water, and at the same time the rate of discharge from the continuous blow down was reduced by 75% to about ½ gallon per minute that was sufficient to maintain boiler water concentrations of soluble salts at 300-600 grains per gallon. When these anti-foam compounds were introduced the opportunity was taken to increase the volume of water under treatment to near 100%, achieved largely by an extension of the use of chemical briquettes which were compressed mixtures of sodium carbonate, tannin, calgon (sodium) and antifoam. This method was the simplest method of conditioning water for railway locomotive purposes and was carried out by a daily addition of briquettes to the lineside water supply, the number dependent on the hardness and daily consumption. This method was normally used with low and moderately hard waters and on the LMR a few very hard waters, but as the use of sodium carbonate with these waters resulted in precipitation of calcium carbonate in water mains and injectors the basis of the briquette was satisfactorily changed to sodium bicarbonate.

During the period from 1952 to 1956 the internal condition of locomotive boilers improved insofar that less scale was being formed the more especially in the high pressure main line engines reflected in a reduction in the number of boiler tubes changed for boiler cleaning at certain MPDs. Against this there was an increase in leakage from boiler seams, regulator glands, superheater flue tubes and wash out plugs, all considered to be due to the increased facility of highly concentrated alkaline boiler water containing antifoam to penetrate into and through minute gaps. This tendency to leakage was countered by reducing feed water alkalinity to a maximum of three grains, by increasing the dosage of tannin to 2½ grains per gallon and by reducing the dosage of antifoam.

The hard waters on the LTS section were successfully treated using the briquette method, but from 20th. February 1949.this section became the responsibility of the Eastern Region. The first reference to water softening in LMS minutes was dated 26th July 1929 and referred to the provision of a water softening plant at Shoeburyness at an estimated cost of £2,010, the final cost being £2036, when it was estimated the saving in boiler repairs would be £475 in addition to "considerably reducing the time engines were out of traffic". In LTS times water had been purchased from the Military at a cost of 8d (3.5p approx) per 1000 gallons. On taking over the MR sunk a well that was not wholly satisfactory and so the supply from the Military continued. In 1924 the price had risen to 1/4d (6.5p) and a further well sunk. (Can any reader explain the reason why the railway depended on the Military for its water supply?). In 1957 the London Midland Region employed approximately 170 staff on water treatment for 6000 locomotives taking water from 350 main points at a cost of about 1/6d (7.5p) per 1000 gallons.

Summary.

The use of an alkaline reagent such as sodium carbonate or bicarbonate was the basis of successful feed water treatment, and, under certain conditions the most satisfactory results were obtained by using, without further conditioning, a feed water naturally alkaline or made alkaline by the addition of a little soda. Generally on the LMS & LMR small quantities of other chemical reagents such as calgon, tannin, antifoam, and in certain cases sodium nitrate were also be added in order to reach the final objective of scale free, corrosion free boilers without running into caustic cracking, leakage of seams and tubes, and priming. The addition to a feed water of a little more than sufficient soda ash (or sodium bicarbonate) to neutralise the non-alkaline (or permanent hardness) was required, not only to ensure that all the hardness would be precipitated as calcium carbonate, but to also maintain sufficient alkalinity in the boiler water to prevent steel corrosion. This was to universally limit the free alkalinity in the feed water to about 3 grains per gallon to prevent, in certain conditions, caustic cracking in riveted boiler seams. In the low hardness waters of the Lancashire and Yorkshire area, not more than one grain was permissible and the additional protection against caustic cracking was provided by adding to all feed waters a tannin dosage of about 2½ grains per gallon.

Many softened and conditioned waters were inclined to precipitate a little of their hardness in supply mains and in injectors and internal injector pipes. This was reduced very considerably with the addition of 0.15 grains per gallon of calgon (sodium), with very hard conditioned waters sodium bicarbonate replaced sodium carbonate as the basis of treatment.

From 1936 to 1956 the feed water treatment used during this period did not produce clean boilers and that the results did not compare favourably with those on the French National Railways that used a different method of water treatment. The reason being that investigations in 1950 indicated that feed waters that produce scale possess different chemical characteristics from those that produce sludge. Low and medium hard waters (under 13 degrees) are generally scale forming, particularly if they contained tannin or too little free alkalinity, but can be made into sludge forming water by adding to them sufficient Calgon (sodium). Above about 13 degrees almost all feed waters are sludge forming. The French method was subsequently adopted by Bullied on the Southern Railway where very hard water was experienced.

Boiler design.

Locomotive boiler feed water treatment can be said to be 80% chemical and 20% mechanical engineering. Sludge formation and its removal from the boiler are all influenced by its design. The method of injecting water into the boiler on the LMS and LMR differed in that some boilers were fitted with top feed trays in the steam space, others with splash plates and the majority with long internal feed pipes, (figures 7 & 8). All were unsuitable for conditioned waters that required to be fed directly from the outside of the boiler under boiler water level as was done on the Southern Railway's steel fire-boxed boilers. This meant that the minimum of precipitation took place in the injector feed line and advantage taken of the sudden introduction of the cold feed water into the hot alkaline boiler water to accelerate precipitation.

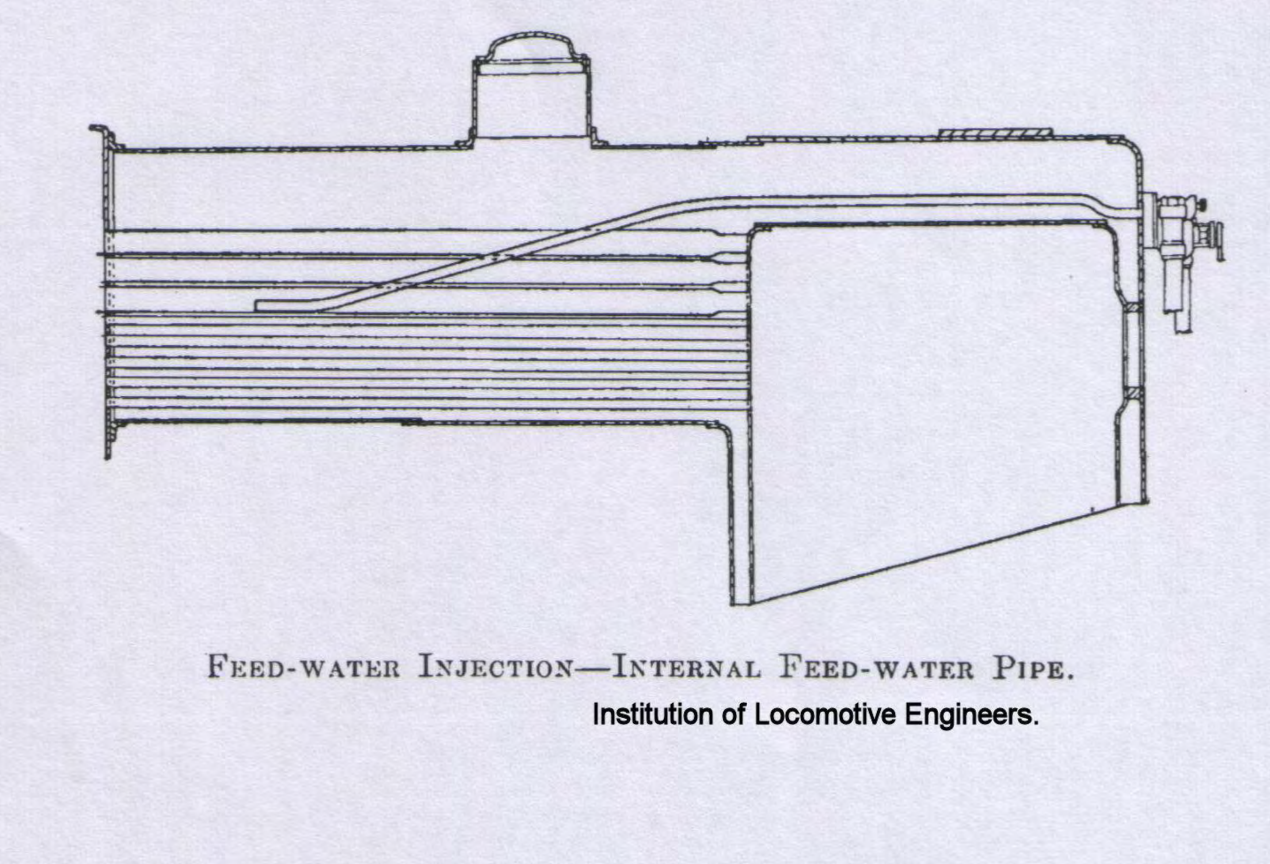


Fig.7 Boiler feed water injection – internal feed water pipe method.

Inst. of Loco Engr's

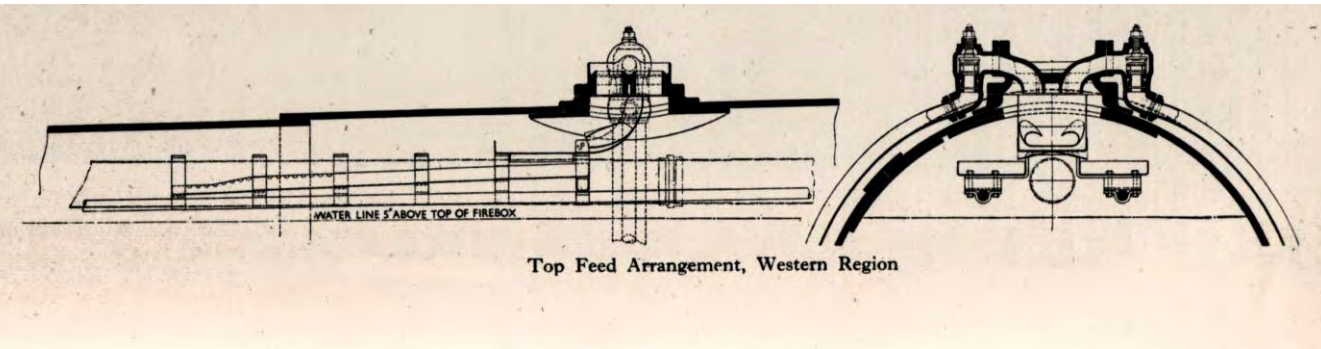


Fig. 8 The top feed arrangement as on Great Western locomotives.

Comment.
From the foregoing it appears, that, as with many things connected with the steam locomotive, water treatment was not an exact science. Put one thing right and something else was affected. What with the costs required to install sixty six water softeners and treatment plants, their maintenance, staffing and the removal of the many tons of sludge and the supplying of chemicals, this coupled to supplying millions of tons of coal to locomotive sheds and the returning of the empty wagons to the collieries, the washing out of boilers, the removal of smoke box char and ashes from the ash pan and then removing it, not to mention the provision of thousands of water columns and water troughs and their maintenance makes it hardly surprising that the steam engine was a very expensive and inefficient means of hauling a train.

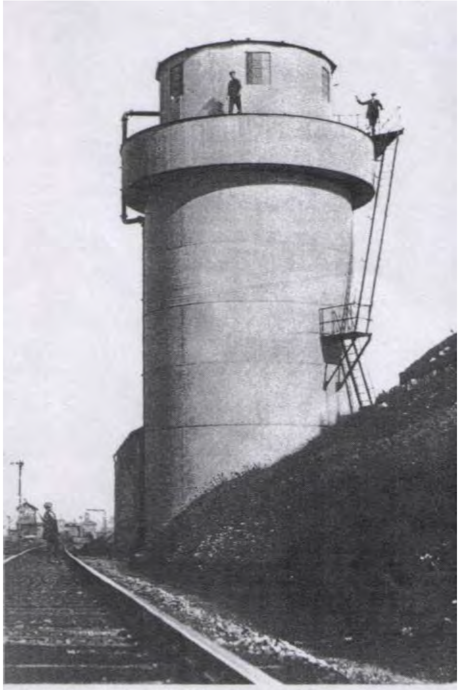
In 1957 there was still no British Railways Code of Practice for the treatment of locomotive boiler water and there never was a single executive who could speak as the expert on the subject. Contrast this with the SNCF that could boast outstanding success in this field, but then, that's another tale.

Clearly the shortly to be announced modernisation plan that spelt the end of the steam locomotive would also bring an end to the need to invest any further in seriously attempting to reduce steam engine maintenance.

And Finally.

The assistance of Hendrick Coombs B.Sc., M.W.M.Soc, MD of Carewater Ltd., is acknowledged in the checking of this article, and, should any of the Heritage Railways are having boiler problems requiring a full professional analysis of the boiler water on their railway and any treatment this may require, then please contact the author via the editor. .

Photographs of various LMS installations now follw;-



The Bushey troughs 30,000 gallon softener constructed by United Water Softeners Ltd. (Rly. Gaz).

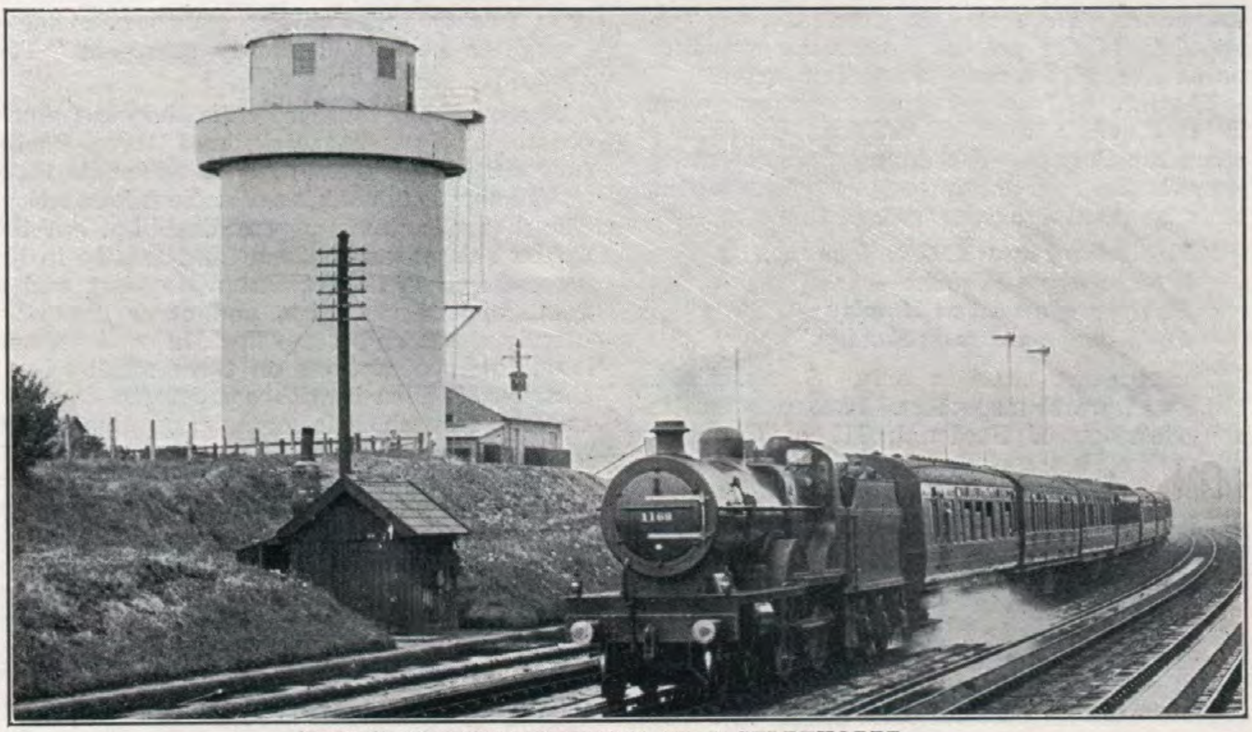
The 30,000 gallon water softener at Bushey troughs constructed by United Water Softeners Ltd.

Railway Gazette.

Castlethorpe (United Water Softeners Ltd.).

The Castlethorpe 25,000 gallon water softener also constructed by United Water Softeners Ltd.

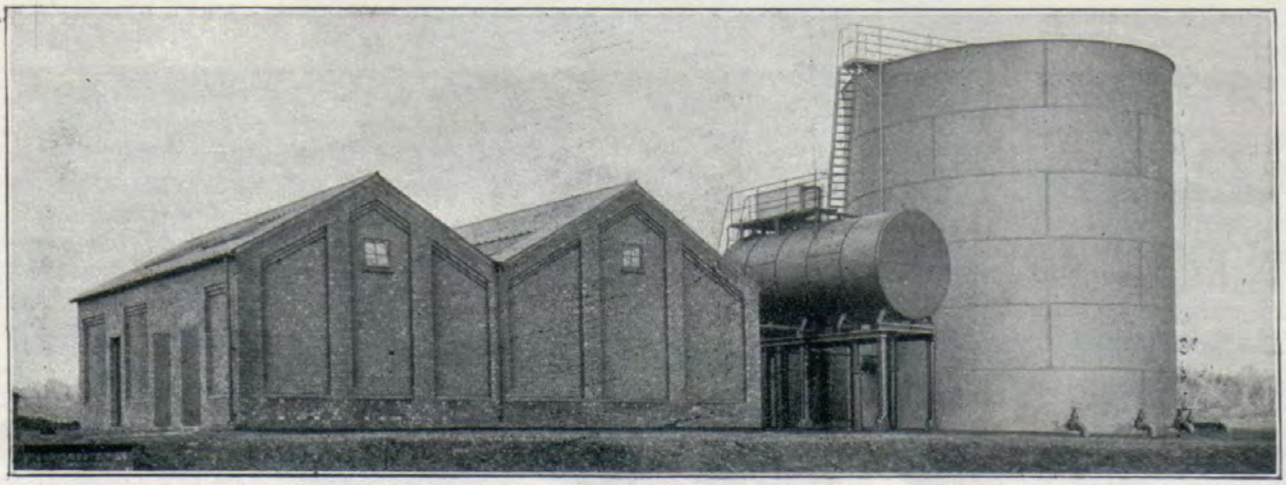
Railway Gazette – May 6th 1932



WATER SOFTENING PLANT AT CASTLETHORPE
20,000 gallons constructed by United Water Softeners Ltd. (LMS Mag. Feb. 1933).

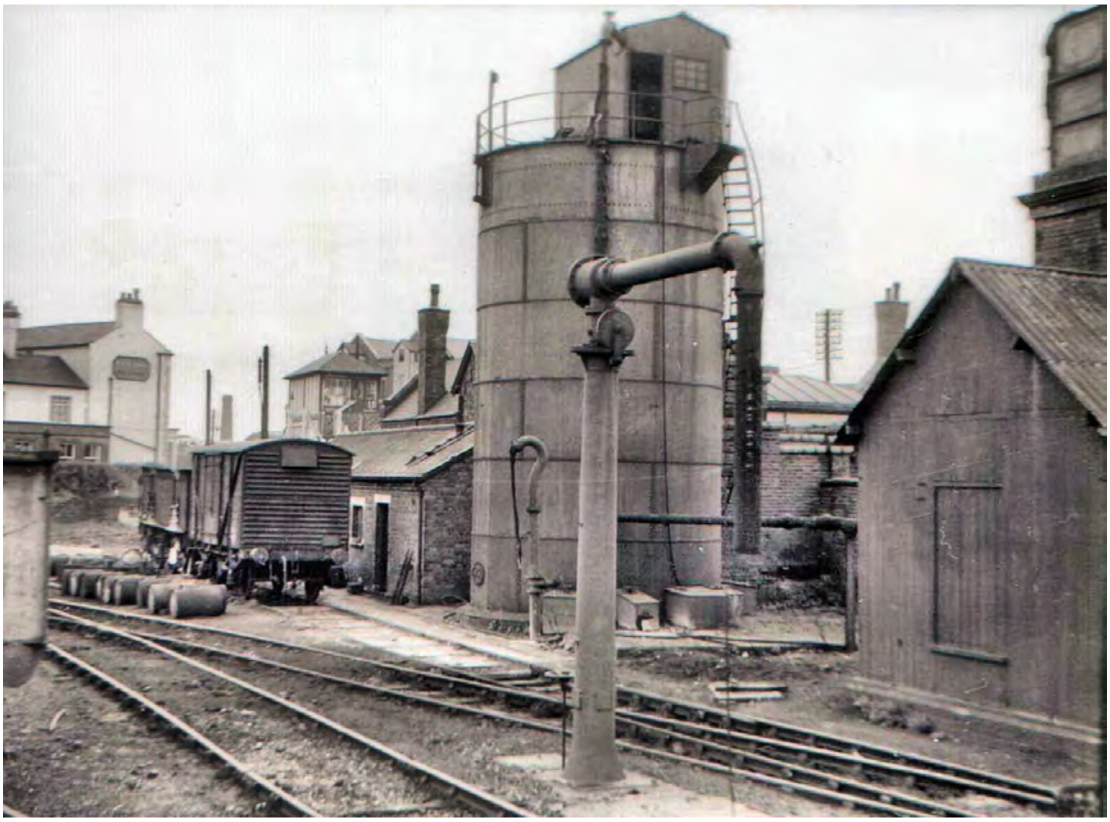
The water softener at Castlethorpe troughs with Compound 4-4-0 1168 replenishing her tender.

LMS Magazine, Feb.1933.



PATERSON WATER SOFTENING PLANT AT KENYON JUNCTION
30,000 gallons . (LMS Mag. Feb. 1933).

The 30,000 gallon water softener at Kenyon Junction provided by the Paterson Company.
LMS Magazine, Feb 1933.



The water softener at Coalville, a site that was not mentioned in the Board minutes, meaning that there may also be others. Coalville Midland Railway water tank is on the right of the picture and on the left can be seen a 12ton van delivering/collecting chemical drums. Behind that is an ex MR 3500 gallon Johnson tender converted to take the sludge away for disposal.

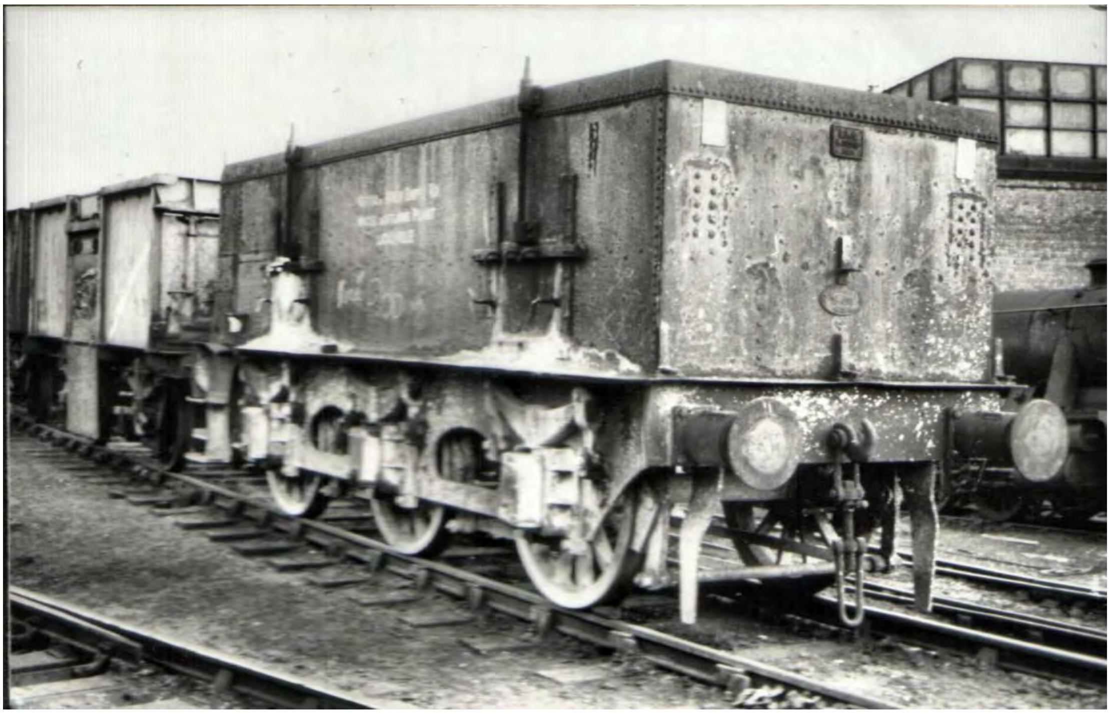
R. J. Essery - 1964

A close up of the base of the Coalville softener with a portable pump used to pump sludge into the adjacent ex MR tender.

J. Essery – 1964.

The far side of the Coalville softener showing the access ladder and the wooden building on the top of the tower.

R. J. Essery - 1964.



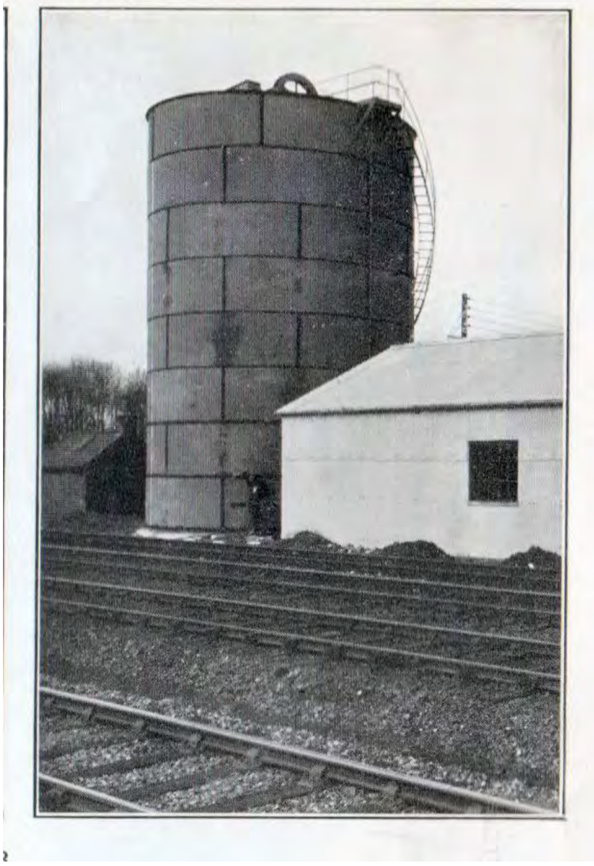
An ex Midland Railway Johnson tender, No.3047 built in 1924 and converted to a sludge tender at Coalville on 15th September 1964.

R. J. Essery

An ex Lancashire & Yorkshire 8 wheel tender serving as a sludge tank at Shoeburyness seen here at Camden MPD in the 1950s.

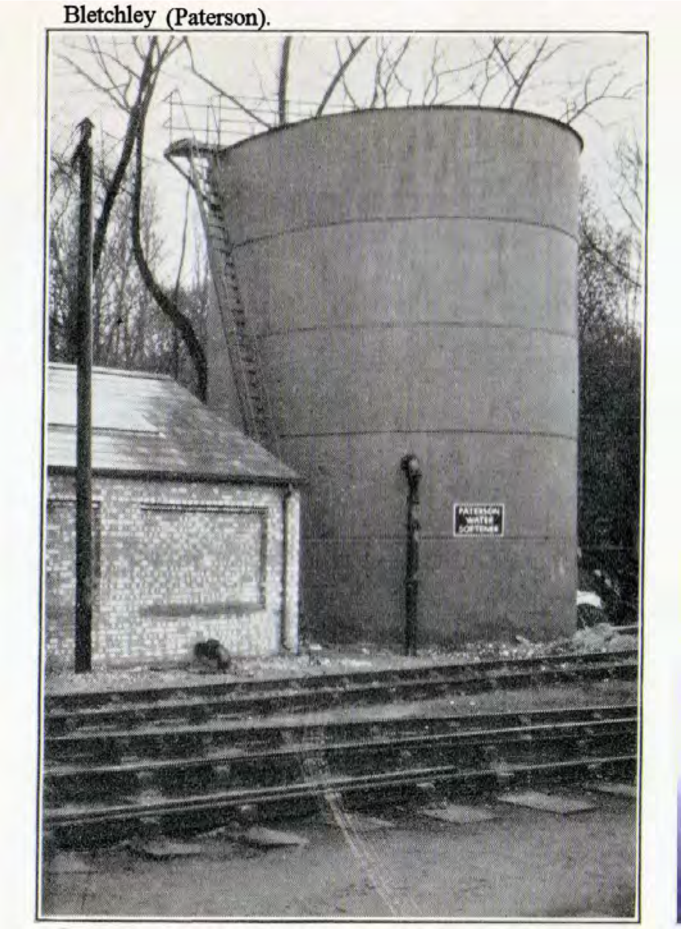
R. S. Carpenter.

Newbold (Rugby).



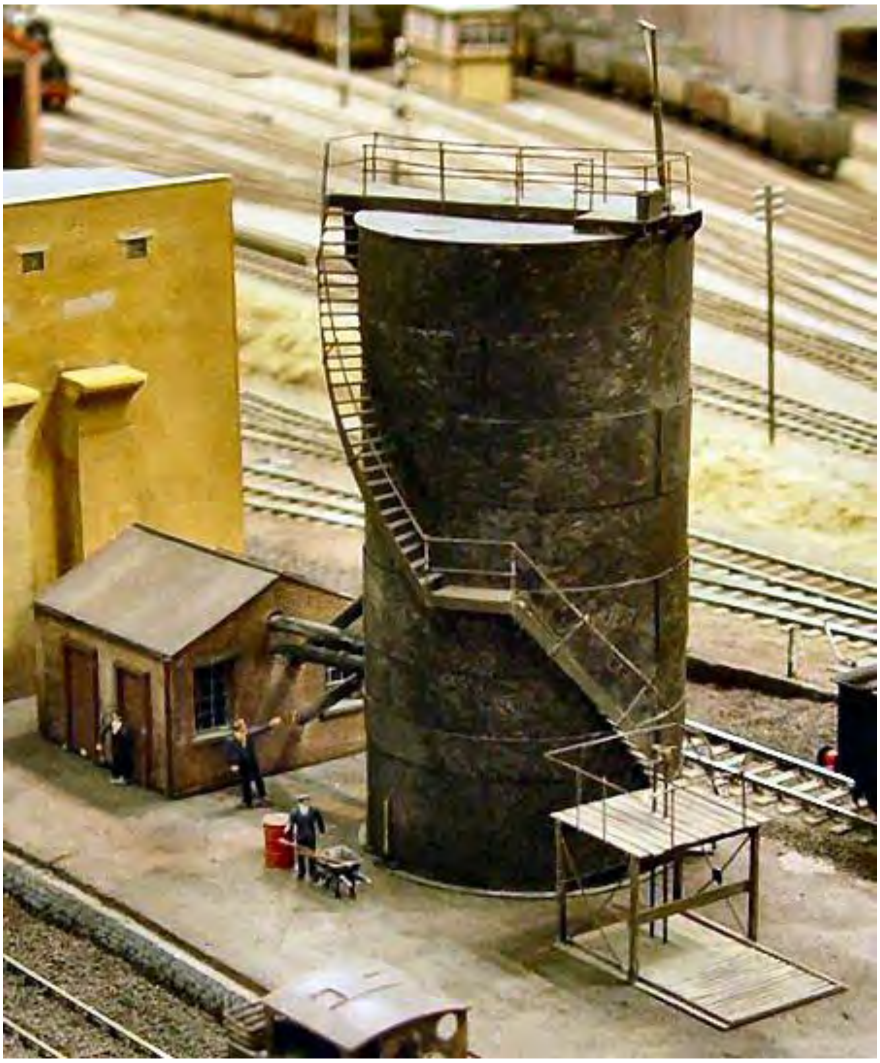
The 25,000 gallon water softener at Newbold, near Rugby constructed by the Kennicot water Softening Company Ltd.

Railway Gazette – May 6th 1932.



The Paterson constructed 12,000 gallon water softener at Bletchley.
Railway Gazette – May 6th 1932.

Bristol Barrow Road shed with the water softener in the background.
L. G. Warburton Collection



Back to the beginning, my model that triggered interest in this subject on the Taunton Model Railway Group's layout, the 10,000 gallon per hour water softener at Bath, Green Park Motive Power Depot, supplied by William Boby.

L. G. Warburton.

FOUNDED 1963

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This monologue belongs to a series produced by members of the LMS Society to provide a background to the activities and achievements of the LMS Railway during its existence from 1st January 1923 to 31st December 1947

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