Porta Treatment Internal Boiler Water Treatment for the 21st Century

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Summary

'Porta Treatment' offers the operator of steam boilers hitherto impossibly low maintenance levels, improved life expectancy and up to 92% reduction in the total cost of ownership. It also has additional benefits which underline the highly integrated nature of the steam locomotive.

The treatment was developed to be both simple and safe to use. As it was developed for under-developed countries it had to be as foolproof as anything ever can be. The fact it survived in fleet service, unlike many other regimes previously tried, underlines that Porta achieved his aim. Thus it can be inferred that in developed countries making it work will be nothing but a formality.

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Index

Figure 1A & 1B Fouling…………………………………………………………………………....-5-
Figure 2A & 2B Corrosion……………………………………………………………………...-6-
Figure 3 Steam Contamination……………………………………………………………….-7-
Figure 4 Porta Treatment Development Locomotive……………………………………..…..-8-
Figure 5 Boiler Water…………………………………………………………………………-9-
Figure 6 Controlled Foaming…………………………………………………………………..-10-
Figure 7 An Example of the Results…………………………………………………………..-11-
Figure 8 Used in Fleet service by FCGB……………………………………………………..-12-
Figure 9 Used in South Africa…………………………………………………………………-13-
Figure 10 Used in Cuba………………………………………………………………………...-14-
Figure 11 Used in the UK………………………………………………………………………-15-
1. Introduction……………………………………………………………………………………-16-
2. The Problems of Boiling Water……………………………………………………………..-18-
    2.1. Fouling…………………………………………………………………………………..-18-
    2.2. Corrosion………………………………………………………………………………..-18-
    2.3. Caustic Embrittlement…………………………………………………………………-18-
    2.4. Steam Contamination…………………………………………………………………..-18-
    2.5 The Problems Combined………………………………………………………………-19-
3. Treatment Development…………………………………………………………………...-20-
4. Porta Treatment………………………………………………………………………………-21-
    4.1 Key Features of Porta Treatment………………………………………………...-21-
    4.2 Inside a Boiler on Porta Treatment…………………………………………………-21-
5. History of Usage……………………………………………………………………………-22-
6. Some Objections Raised……………………………………………………………………..-23-
    6.1 Antifoams Issues…………………………………………………………………….…..-23-
        6.1.1 Antifoams are dangerous…………………………………………………...-23-
        6.1.2 The Products of Degraded Antifoams are harmful to metal…………-23-
    6.2 High pH is dangerous…………………………………………………………………...-23-
    6.3 Porta Treatment and Copper Boiler Components……………………………...-23-
    6.4 High TDS and TSS is problematic……………………………………………………-23-
    6.5 Porta Treatment only works with ‘Hard Water’…………………………………-24-
    6.6 Waste Water Issues……………………………………………………………………-24-
    6.7 It’s Old…………………………………………………………………………………-24-
7. Concluding Remarks…………………………………………………………………………-25-
References………………………………………………………………………………………-26-

Figure 1 - Fouling

A) A boiler where scaling was so bad as to totally impede water circulation for the bottom 6” of the firebox. Not surprisingly the inner firebox was deformed.(23)

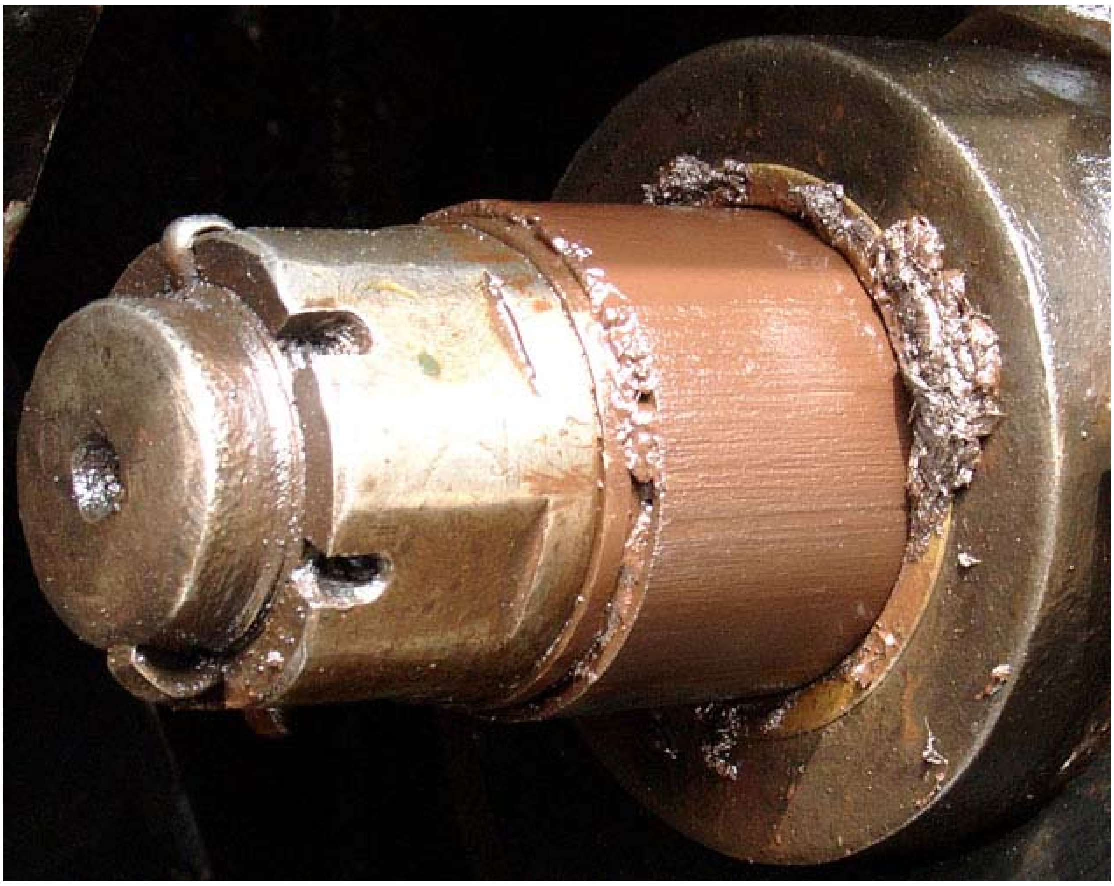
B) Less severe scaling than in 1A but none the less there is scale. These tubes had been in the locomotive in question for just 4 years and that locomotive had been on a water treatment regime, but clearly an inadequate one with scale at least a millimetre thick in places. (13)

Figure 2 - Corrosion

A) Localised corrosion in the form of severe pitting. This boiler barrel plate was reduced to less than ¼ of its original thickness by corrosion.(15)

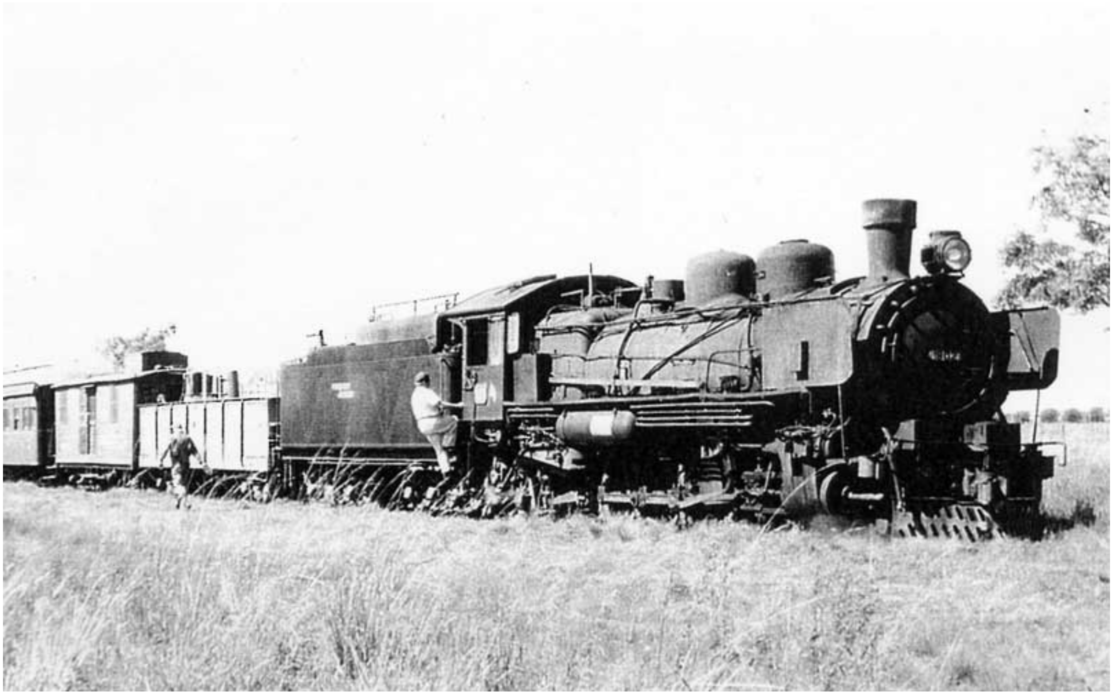
B) Scale allows corrosion to develop unnoticed on these tubes causing localised pitting but also general corrosion over the entire tube. (13)

Figure 3 – Steam Contamination



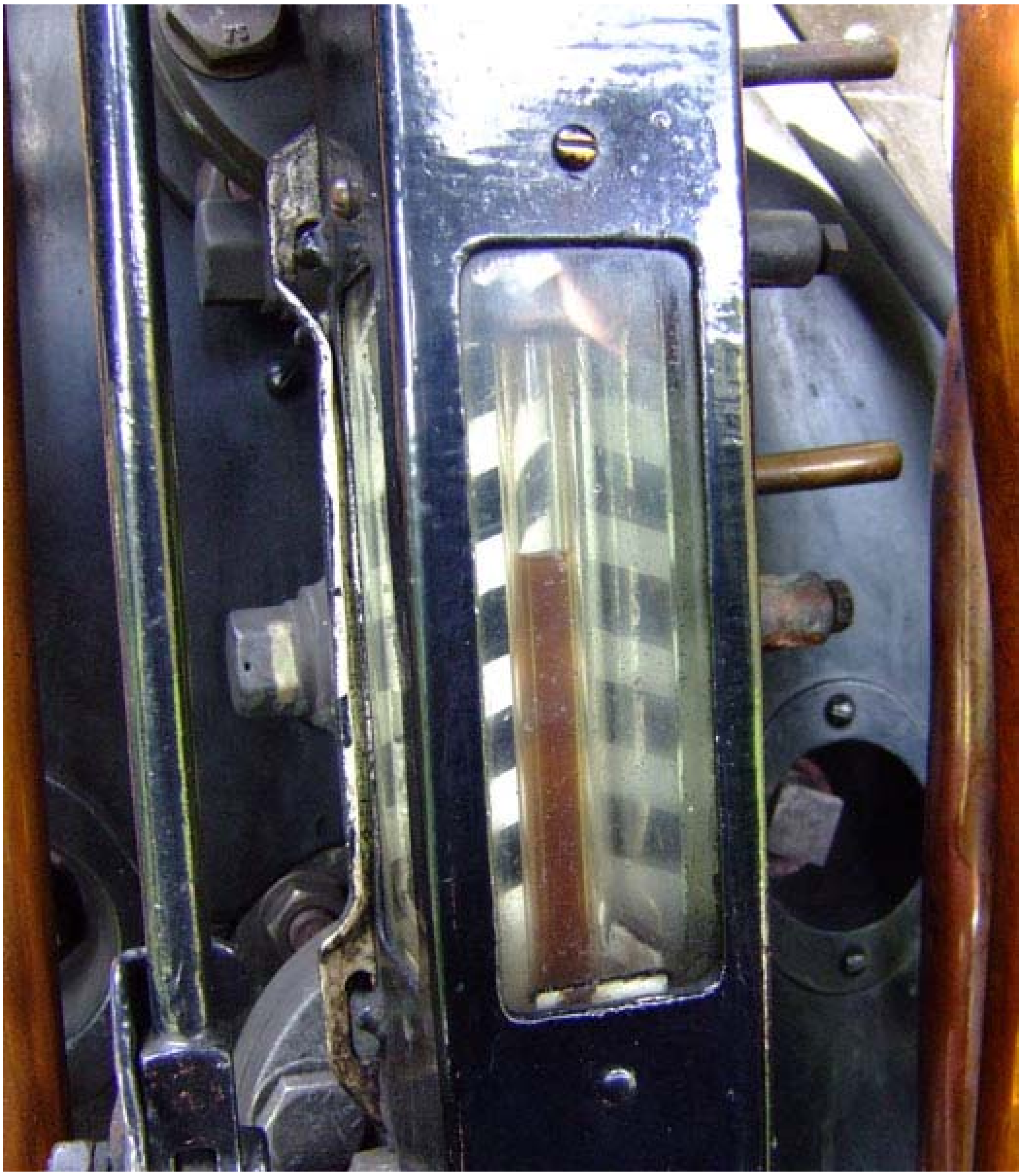
Steam contaminated with tannin has mixed with lubricating oil contaminating and thus compromising the lubrication. This image shows very heavy oil contamination indeed which was doing none of the components shown any good. However it should be noted the contamination was only noticed due to the colouring effect of the tannin. Carried over salts and other solids are generally far less obvious and thus normally overlooked. (4)

Figure 4 – Porta Treatment Development Locomotive



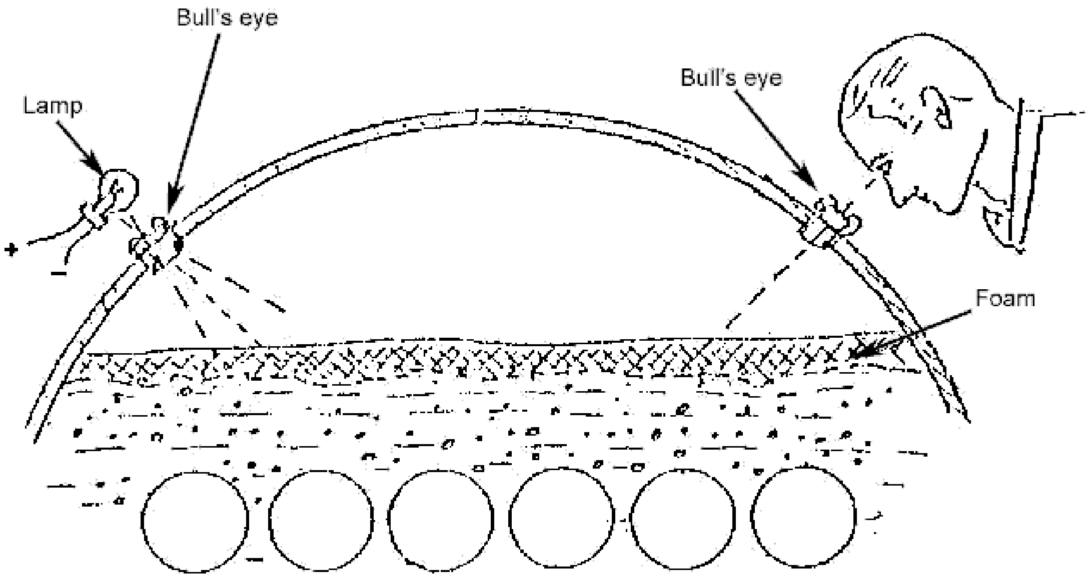
Ferrocarril Nacional General Belgrano Class C16 4-8-2 No.1802 – Porta Treatment development loco from 1969-1974. In parallel this machine was also improved in other ways including the finalisation of the Lempor exhaust ejector design. © Richard Campbell (1)(19)

Figure 5 – Boiler Water



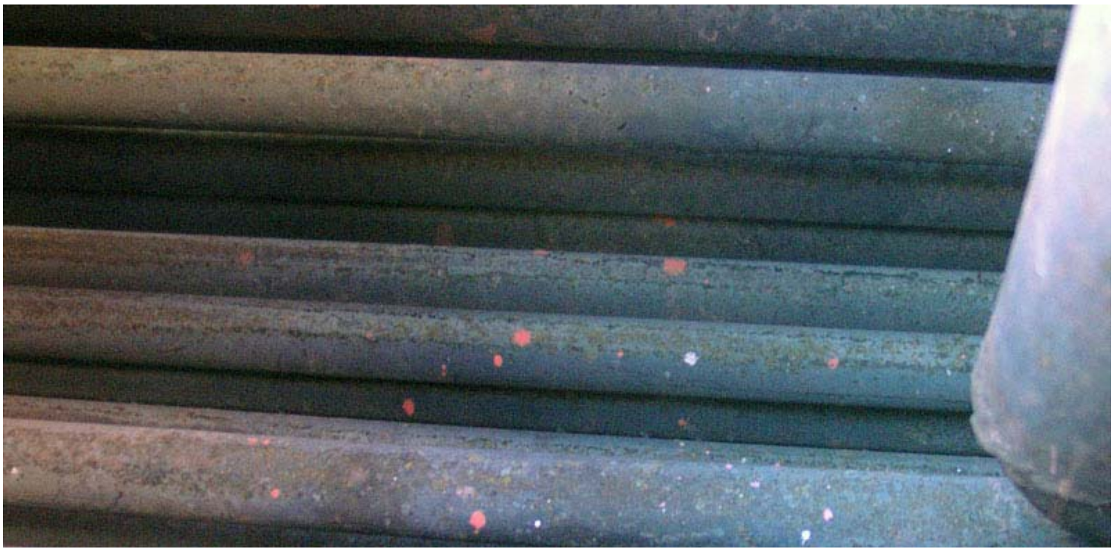
Water showing in the gauge glass of a locomotive on 'Porta Treatment' varies between brown and almost black depending on circulation rates. (4)

Figure 6 – Controlled Foaming



A dense layer of controlled foam effectively sieves steam bubbles escaping from the boiler water ensuring pure steam. (1)

Figure 7 - An Example of the Results



This boiler, fitted to FCAF No.2, had been in use for three years on ‘Porta Treatment’ when photographed. All water surfaces show a covering layer of magnetite ensuring protection from corrosion. No scale or corrosion was present. (14)

Figure 8 – Used in Fleet service by FCGB

The sizeable FCGB depot at Tucumán, one depot of many to have employed 'Porta Treatment' to its entire allocation of locomotives. © John West

Figure 9 – Used in South Africa

A) South African Railways Class 26 4-8-4 'L.D.Porta'. 'Porta Treatment' was an essential part of the modernisation scheme undertaken on this locomotive. It was also used elsewhere on the SAR 3'6" gauge network. © Roger Griffiths

B) Alfred County Railway NGG16A No.141. As with 3450 above 'Porta Treatment' was an essential part of this locomotive's maintenance regime. Others on the line were also recipients of 'Porta Treatment'. © N.A.H. Day

Figure 10 – Used in Cuba

ALCO 2-8-0 No.1816 of the Minaz fleet, another user of 'Porta Treatment'. © Shaun McMahon

Figure 11 – Used in the UK

A) 15" gauge 2-6-2t 'Fox' of the Kirklees Light Railway was the first locomotive in Europe to use 'Porta Treatment. (15)

B) 6024 King Edward I, the first standard gauge locomotive outside of the Americas to use 'Porta Treatment'. (4)

1. Introduction

In recent years the name 'Porta Treatment' has started to gain a degree of recognition but very few really know what this water treatment regime is. Many have had heard something about it but normally that "something" is very much wide of the mark.

It would be wise to start with a statement that is very simple, on the surface, but is also very profound. It is ***THE*** most important thing that can be said about 'Porta Treatment' as it underpins the entire approach to treating steam boiler water, both chemically and philosophically (1):

'What counts is what one has in the boiler, not what one feeds into it'.

It is essential to bear this in mind when reading what follows. It is almost totally the reverse of the classical approach to water treatment, which sadly still prevails.

It is also important to state that 'Porta Treatment' is no experiment, evidence dating back more than 30 years supports the details which follow. (1)

Water treatment worth the name and expense should, as a minimum, be able to deal with (1):

- Fouling in the form of scale and mud
- ALL forms of corrosion
- Caustic embrittlement – also known by other names
- Steam contamination – the overlooked phenomenon

Sadly most treatments, even today, do not manage to deal with these issues especially well but 'Porta Treatment' does. A fairly complete list of the advantages offered by 'Porta Treatment' include (3):

- ***Independent of water source***, waters of radically differing characteristics can be used without altering the treatment regime.
- ***Zero internal scaling*** of boilers in all but the hardest of hard water areas:
    - Old scale removed.
- ***Zero internal corrosion*** of boilers:
    - High carbonate levels in the water prevent corrosion.
    - Boiler surfaces are protected by a layer of magnetite.
- ***Zero caustic embrittlement*** despite very high boiler water alkalinity.
- ***No adherent muds or clays*** internal to boilers. All suspended solid matter is fully mobile at all times.
- ***Significantly fewer washouts***. Reduced to one or two a year even in the hardest of hard water areas.
- ***Effectively eliminates blowdowns***, a big fuel saving. A handful remain necessary in the hardest of hard water areas.
- ***Antifoams*** control foaming and boiler water carryover.
- ***Significantly less wear and tear*** in service due to technically pure steam being supplied through a controlled foam layer.
    - Stops build up of material in superheater elements, eradicating overheating and ensuring maximum superheater performance.
    - Stops build up of materials in passages, ports, valves, auxiliaries around valve and pistons rings, valve and piston heads etc.
- ***Minimal scaling inside pipes***, ***injectors etc.,*** effectively eliminated in all but the hardest of hard water areas.
- **Zero scaling in water tanks**
    - Old scale removed.
- ***Prevents corrosion*** on the water side of tanks and associated items.
- ***Treatment continues to work*** even when the boiler is not in steam and also whilst treated water stands in the tender, even for prolonged periods.
- ***Wide tolerances*** for success. Close chemical control of boiler conditions are not required:

    - Suitable boiler water conditions lie between very wide extremes making regulation of the system easy. There are but two conditions to monitor
- ***Rough handling*** for chemical dosing. No need to be accurate to the gram for success. Treatment chemicals are of low risk.
- ***Boilers are effectively kept "as new"*** on the water side regardless of time in service
- ***Fireside degradation and external corrosion etc***. determines boiler component life.
- ***No "dry" storage is required***. Storage full of water without the fear of corrosion etc is now a reality.
- ***No ongoing consultancy required***. Once setup shed staff can manage the regime effectively.

Are there any other treatment regimes able to offer ALL of these features?

2. The Problems of Boiling Water

2.1. Fouling

This heading includes any substance which forms on the water side of the boiler impeding water circulation and heat transfer. So, in the broadest of terms, this means scale and mud. Scale, which takes many forms, is a fantastic insulator. Certain scales, such as silica based scale, can increase the amount of heat required to boil water on the other side of the scale by 50% even when just a millimetre thick. That has real implications for fuel bills! At the same time it will cause localised overheating of the boiler material, ultimately leading to premature failure. The worse case being total scaling of the water space, as shown in figure 1A.

What is referred to as mud is a very adherent and viscous build up, normally at foundation ring level and in the bottom of a boiler barrel, which acts much in the way scale does. It is not uncommon to find mud 6 inches or more in height from the foundation ring totally preventing water circulation. The long term effect on the boiler is hardly good and neither is the loss of effective heating surface. (1)(3)(7)(20)

See figure 1.

2.2. Corrosion

Corrosion takes many forms. In general terms most readers will be familiar with at least one manifestation of corrosion. One can be certain this is happening in an untreated boiler. Often overlooked by many is that much corrosion actually occurs under adherent scale and mud, thus hidden from direct view. Another good reason to inhibit scale formation! (1)(3)(7)

See figure 2.

2.3. Caustic Embrittlement

This phenomenon, also known by other names, may be uncommon but should not be overlooked. One of the other names used for it is ‘stress corrosion cracking’. This underlines one of the factors required for it to occur; boiler plates must be under stress above the yield point. However other factors related to the chemistry of the boiler water are important. In short cracks occurring in boiler material due to stress failure can be made worse by high, localised, concentrations of hydroxide ions. This action occurs at the inter-crystalline level but leads to very visual boiler plate cracking. (1)(3)

2.4. Steam Contamination

It is described here as the overlooked phenomenon as there is little recognition of it in the steam railway industry, in stark contrast to users of steam turbines in the power generation industry. (20)

Priming is something every loco driver tries to guard against, but what about steam contamination? In many cases priming is a misnomer. In strict terms this is actually the manifestation of boiler water carryover at an extreme level. Priming should, instead, be seen as a function of crew error, running with the water level too high etc., or simply design error. Carryover is a phenomenon caused by the conditions in the boiler water. Dissolved solids in boiler water cause it to foam. This foam has been shown capable of growing in such a way as to fill the entire steam space. Attached to the bubbles of foam are impurities. As steam leaves the boiler a steam wind develops, measured at up to several hundred miles an hour when working hard, which can detach these impurities from the foam bubbles carrying them into the steam circuit of the loco. In extreme conditions slugs of water are also carried over giving the impression of priming. (1)(3)(5)

And the effects? It is well known how undesirable priming is but what about ‘low-level’ carryover? Is it actually low level? Not necessarily. Carryover, starting with a dissolved solids level in the boiler of no more than 1000 parts per million (ppm) (that is 1 gram of material per litre of water) can lead to up to 100ppm of steam contamination. That is a measured figure for locomotives using a well known water treatment regime. In plain English this is 0.1 grams of solid material entering the steam circuit with every 1 litre of condensed steam. It doesn't sound like much? But a quick calculation shows that steam contamination of 100ppm will actually carryover over 1.8kg of material into the steam circuit for every 4000 gallons of condensed steam. Not such a small figure now and this material has to go somewhere. (3)(18)

It becomes deposited in the steam circuit helping to shorten the life of superheater elements, wears regulator and other valves etc., but worse still, it becomes deposited in the cylinders. The ports and passages clog with this material, which also builds up on valve and piston heads and around valve and piston rings. This material acts as a grinding paste shortening the life of components. (1)(3)

On one UK locomotive a sample of carbon from a piston ring was taken for analysis. Naturally it was expected to be substantially oil based. But no! 90% of the material was found to be calcium carbonate. There is but one place that this material came from: the boiler. (24)

As if all of these problems were not enough, some of the carryover will also make it into the exhaust steam circuit clogging these passages and impeding draughting, the very heart of the steam locomotive. In other words ignore carryover at one's peril. If one does one will pay dear for it. Porta calculated that the cumulative effects of carryover was to decrease component life by 10-15%. (1)(18)(19)

See figure 3.

2.5 The Problems Combined

The issue of steam contamination underlines how integrated a machine the steam locomotive is. Solving problems within the boiler are all well and good but not if they are to the detriment of another aspect of the locomotive's performance.

Combined fouling, corrosion, caustic embrittlement and steam contamination presented Porta with a considerable array of problems to solve. However, through detailed scientific development, he proved they could all be controlled. (1)

3. Treatment Development

The development of the treatment came about, perhaps perversely, due to severe carryover problems being experienced on the Ferrocarril Nacional General Belgrano (the FCGB) in the north west of Argentina. Why perversely? Because fouling and corrosion were very major problems as well, but it seems these were accepted as normal, just something to be tolerated when operating steam locomotives. Washouts were weekly affairs and heavy boiler repairs were scheduled for every 2 years. This was despite various external water softening systems being in use. However the carryover problems were making it impossible to maintain timetables. It was just not possible to work locomotives at high outputs without picking up the water. So Porta, then working for the state technology institute INTI and with his considerable reputation for solving problems on the Argentine railway network, was called in. (1)(2)(3)(11)

Over a 5-year period, Porta and his team of both chemists and engineers developed what has since become known as ‘Porta Treatment’. They found it possible to dispel many myths surrounding water treatment, which even today in supposedly more advanced countries are still stated as the truth.

See figure 4

Building on the work of SNCF, who had developed the world renowned treatment TIA, Porta was able to show the following:

- Feedwater type was of no relevance whatsoever once the boiler water chemistry achieved certain conditions.
- Scaling was effectively stopped dead whilst old scale was actively removed.
- Corrosion was totally inhibited.
- Caustic embrittlement was prevented.
- Technically pure steam was produced. That is, carryover of solids from the boiler water was prevented. This also had the effect of allowing a higher water level to be tolerated.
- Blowing down was virtually eliminated.
- Washout frequency was significantly reduced.

Due to these it was possible, even in the bad water districts of north west Argentina, to reduce washouts to just 2 per year, whilst heavy boiler maintenance was eradicated. The effect on locomotive availability and the overall costs of running the services of the FCGB can be imagined. (1)(2)(3)(11)

All external treatment systems were shut down as ineffective and unnecessary. It should be noted that this work was prior to the advent of the current vogue for reverse osmosis systems. These may produce very pure water but nevertheless such systems are outperformed by the correct internal treatment. What is often overlooked is that whatever external approach is used it is still necessary to employ an internal regime to deal with the remaining problems, which begs the question: Why bother with external systems at all?

Porta calculated that the effect of the treatment was to reduce the total cost of boiler ownership by 92% - in other words the boiler, long acknowledged as the most expensive single component on a locomotive, became almost insignificant. (1)(3)(18)

4. Porta Treatment

4.1 Key Features of Porta Treatment

As stated Porta's work built, principally, on the French system TIA. Without going into great depth the key features of the treatment are:

- It is based on sodium carbonate and tannin to control fouling, corrosion and caustic embrittlement, phosphate to control fouling on hot items such as injectors and antifoam to ensure the production of pure steam.
- At the time of the treatment's development, literacy and skill levels in north west Argentina were very low. The treatment had to be able to survive in such conditions and it did.
- Porta was well aware that for a system to be adopted it had to be both technically correct and the easiest option for those using it. This is precisely what he developed and very much with an eye to the future.
- The boiler water condition monitoring had to be very simple if it was to work. Just two factors need to be monitored – total dissolved solids (TDS) and pH, nothing more. Both are easy to measure. No chemistry skills are required. Also, the testing does not rely on the use of hazardous chemicals.
- Coupled to the above, the chemicals had to be safe to handle. Health and safety at work was more or less non-existent. At worst the chemicals were classed as irritants.(1)(3)(19)

4.2 Inside a Boiler on Porta Treatment

What is actually going on inside a boiler to make all of this possible?

Put simply, once the carbonate concentration is above a certain level all other factors fall into place. This concentration, which shows as a high pH, typically above pH11, also means a high TDS, the combination of which deal with variations in feedwater. These conditions, aided by the tannin acting as an oxygen scavenger, lead to the creation of protective layers of impermeable material on the water surfaces of the boiler. These layers, which are microscopically thin, provide total protection against corrosion. (1)(3)(8)

The chemistry of the boiler water keeps any scale or mud-forming material in solution or suspension and mobile at all times. In doing so fouling is prevented, with all the benefits which flow from this. The fact that the boiler water contains a lot of suspended solids can be seen at the gauge glass when the boiler is steaming at high rates. Through very rapid circulation of the boiler water, this suspended material reaches the gauge glass turning the water almost black. In traditional terms this would indicate that heavy boiler water carryover was likely but through the use of antifoams this is not the case. (1)(4)(8)

See figure 5

Many antifoams are described as de-foamers but, in this instance, total de-foaming is not the required phenomenon. Rather, controlled foaming is required. The foam layer is put to good use. Instead of being made up of large uncontrolled bubbles, the condition aimed at is akin to the head on a pint of Guinness. That is, a very dense layer of small bubbles. The effect of this thick layer of foam is to sieve the steam bubbles escaping from the water. In other words, solids attached to these steam bubbles are removed, thus leading to pure steam. Figure 6, showing experimental work undertaken, illustrates the ideal conditions. (1)(2)(3)

See figure 7.

5. History of Usage

After the development period, Porta Treatment was introduced to fleet service on FCGB allowing steam to continue in service until the mid 1980s, something which economically and practically would not have been possible without it.(8)(11)

Since the end of mainline steam in Argentina, the treatment has continued in use within that country, notably on Ferrocarril Austral Fueguino under the direction of Shaun McMahon. During this time, working directly in conjunction with Porta, several improvements were made further simplifying and enhancing the treatment. These were also trialled and applied in parallel in Cuba. (3)(8)

In addition the treatment has since been used or is currently in use in:

- South Africa
  - On 3’6” and 2’ gauge locomotives
- Brazil
- UK
  - Kirklees Light Railway. The very first users in Europe.
  - 6024 King Edward I. The first mainline loco in Europe on Porta Treatment.
- A country of the former USSR
- Australia.

To date the treatment is believed to have been used on locomotives of the following gauges: 4’8½”, 3’6”, Metre, 750mm, 2’, 50mm, 15” and 7¼”. Further applications on different gauges are pending.

See figures 8-11.(3)(4)(5)(8)(10)

6. Some Objections Raised

Over the years many objections have been raised to the treatment. Some of the regularly raised issues are discussed below.

6.1 Antifoams Issues

6.1.1 Antifoams are dangerous

It is amazing how firmly held a few this is. However, as stated earlier, all the chemicals used in this treatment are nothing worse than irritants. This was part of the development criteria. It is certainly true that some antifoams on the market are hazardous or even highly poisonous however, as can be deduced, in the case of 'Porta Treatment' this is simply not the case.

6.1.2 The Products of Degraded Antifoams are harmful to metal

It is said that the products resulting from the breaking down of the antifoams in the boilers - amines, in the case of polyamides - will attack boiler metal. In isolation this is not disputed but when in boiler water treated under 'Porta Treatment' this is not the case. To suggest otherwise is an indication that those making the statement have failed to grasp the fundamentals of the treatment. If this were a real rather than imaginary problem it would have shown up during fleet service on FCGB, would it not? (13)

6.2 High pH is dangerous

Perhaps understandably, people are worried by the fact that 'Porta Treatment' aims for a high pH. However, as any chemist will tell you, it is not the pH of a solution which is the hazard, rather, it is the concentration of ions within a solution. In this case the bulk of ions present in the boiler water are carbonate ions, which are low risk even in large concentrations. If the pH were based on caustic soda, and thus hydroxide ions, it would be a different matter. The author is unaware of boiler water treated with 'Porta Treatment' having ever caused any form of chemical burn - and with good reason. (1)(8)

6.3 Porta Treatment and Copper Boiler Components

The nub of this objection is that 'Porta Treatment' is not suitable for boilers with copper components. This is not the case. A careful reading of Porta's 1975 paper on water treatment reveals he explicitly stated how to alter the chemical dose to suit boilers with copper components. The 4 chemicals used remain the same, just the ratios alter. Evidence to support this also comes from the fact that TIA and related treatments were used with great success on boilers with copper components. As stated, 'Porta Treatment' grew from these treatments. The only other alteration comes in the upper end pH recommended. This is, currently, precautionary. The author is of the belief that maximum pH 'Porta Treatment' can be used on such boilers but wishes to trial this before actually recommending it. Why this confidence? Simply because non-ferrous boiler fittings, when the exception of valve stems and seats which are, of course, subject to friction, do not chemically erode under this treatment regime. The protective layers which rapidly form on them prevent erosion. However, make no mistake, just because the pH is currently limited this does not mean a full application of 'Porta Treatment' is not being made to 6024 King Edward I in the UK, a loco with a copper inner firebox. (1)

6.4 High Total Dissolved and Total Suspended Solids is problematic

Yet another objection heard, is that the relatively high level of dissolved solids achieved coupled with the relatively high level of suspended solids is a problem. Well, as the evidence shows, it is not. Can anyone provide scientific evidence to prove otherwise?

It may sound counter-intuitive to say there is no problem but it is a fact A quick reference to the specific heat capacity for water compared to solids normally found in boiler water might go someway in helping to understand why this is so

6.5 Porta Treatment only works with 'Hard Water'

During the development period, the test locomotive was operated over virtually every district of FCGB. The water types varied widely but the treatment continued to perform. The 'hardness' of the water is of little consequence, as what counts is what is in the boiler not what is fed into it. The only point to make is that 'hard water' has a higher TDS than 'soft water' so locomotives operating in 'hard water' districts will see the water chemistry develop more quickly than those in 'soft water' areas. However in the overall scheme of things this is of virtually no consequence. (1)

6.6 Waste Water Issues

Following on from the pH issue is that of waste boiler water disposal. Gone are the days of draining a boiler and not caring what happens to the waste water, and rightly so. A simple procedure has been devised, requiring a pit, a removable seal on the pit drain and a neutralising agent such as citric acid. By draining a boiler into such a pit ,the boiler water pH can be brought down to acceptable levels to enter the mains sewerage systems. In doing so the vast bulk of the suspended material in the boiler water, plus a significant amount of the dissolved material, settles to the bottom of the pit. It comes out of suspension and solution, conditions only maintained by the boiler water chemistry. Thus, when the water is drained out of the pit, the bulk of the material from inside the boiler remains, instead of entering the mains sewers. Once the washout is complete, it is a simple case of shovelling the solid matter, which has the consistency of wet cement, into a suitable skip for disposal, remembering this material is not especially hazardous. It is, of course, material that would otherwise have formed scale or non-mobile mud. It should also be pointed out that, even at maximum TDS levels, the waste boiler water will contain only 20grams of material per litre. This is not a high concentration of material. It is actually not that different in concentration to the waste water from the average domestic washing machine. (3)

6.7 It's Old

The "it's old" criticism would seem to imply that it must be outdated. The wheel is old but remains the best system yet devised. Age of the chemistry is irrelevant; want counts is performance of the treatment and the author is unaware of any other treatment which comes close when viewed in the round. Of course, nothing is ever the end point for development and there are still improvements to this treatment which can be made and are currently under discussion and active development. Porta was still making enhancements in the final years of his life, which was typical of the man. He never liked to sit on his laurels. However no-one has yet come up with anything better, despite the expensive technology and proprietary chemicals thrown at the problem.

7. Concluding Remarks

‘Porta Treatment’ offers as close to ‘perfect’ water treatment as it is currently possible to get. The extensive use of the regime in Argentina, followed by use elsewhere, has shown conclusively that the claims made for the treatment are genuine, not exaggerated or falsified.

There is no longer any excuse for boilers with fouled or corroded water surfaces, embrittled plates or for the production of anything other than technically pure steam. This has been the case for a little over 30 years; it is greatly to be regretted that in the early part of the 21st century this is still not the case for many locomotive boilers. Sadly, debates are still being had as to whether or not to treat boiler water.

In addition to the performance of the treatment, it is also important to appreciate that the 4 chemicals used are all low risk, even in large concentrations. Thus, it is suitable for low tech environments, whilst in higher tech environments its application should be little more than a formality. Boiler water monitoring is simple, just TDS and pH are measured, further underlining the ease of application.

The above points are all, of course, of great importance but the single most important fact is that:

‘What counts is what one has in the boiler, not what one feeds into it’.

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