THE PRACTICAL APPLICATION OF 'PORTA TREATMENT' - AN ADVANCED INTERNAL BOILER WATER TREATMENT SYSTEM - ON STEAM LOCOMOTIVES OF THE FERROCARRIL AUSTRAL FUEGUINO, REP. ARGENTINA.

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1. BRIEF DESCRIPTION OF STEAM LOCOMOTIVE BOILER WATER TREATMENT.

A continuing problem since the development of the first steam locomotive has been treatment of the boiler water. Water contains impurities (minerals, metals etc.) which can lead to problems in steam boilers. Since the vast majority of locomotives built are non-condensing (i.e. water is used once and exhausted out of the chimney, we will not discuss the cases for and against condensing locomotives in this paper) water treatment is more difficult to control than on ships and stationary power plants which condense their water and reuse it. In a steam locomotive, the impurities become concentrated inside the boiler over a period of time and eventually precipitate out of the solution onto the internal surfaces of the boiler. This process is called fouling. These materials can slow down the transfer of heat from the fuel to the water and decrease the locomotives efficiency and power. Such fouling can also accelerate corrosion of the boilers internal surfaces, thus increasing maintenance requirements and decreasing the life of boiler components. Some water conditions cause boilers to 'foam', which in turn can lead to many other problems. Operators in the past attempted to minimize foaming by periodically 'blowing down' the boiler or removing small amounts of water from the low points of the boiler while the boiler was in steam (for example the scum cocks as used on South African locomotives). If this had to be done very often a great deal of fuel and water could be wasted. Certain geographical areas have much worse water than others do, therefore whilst this phenomena was a nuisance for all railways, it became a tremendous problem for some.

Normal practice on steam locomotives was to 'wash out' the boiler at least monthly. The locomotive would be taken out of service, have its fire extinguished and the boiler left to cool down (cooling down of the boiler was not North American practice, more of that later). Boiler plugs were then removed and washing out of the boiler internals could begin. This consisted of directing a high-pressure jet of water through the spaces provided by the absence of the boiler plugs and followed a systematic course. Undesirable matter is flushed out during this operation. Once flushing out was complete the plugs could be refitted. This process could take several hours, not to mention the time taken to gently re warm the boiler from cold (again not US practice) before proper steam raising could begin followed by a visual check prior to the locomotive re entering service. All of this represented a significant amount of labour accompanied by lack of availability of the locomotive. A more serious problem was that some fouling materials hardened onto boiler surfaces and could not be removed by using normal washout methods. If fouling becomes sufficiently severe, it can actually cause the temperature of parts of the boiler such as firebox surfaces and tubes to become so great that they can be permanently damaged (a practical example of this is given later).

The whole water issue was another 'nail in the coffin' of the steam locomotive at a time when the diesel locomotive was being introduced. However the application of sound engineering principals has shown that problems associated with boiler water can be virtually eliminated from steam locomotive operation.

By the 1930's railway suppliers had begun to develop chemical treatment which somewhat reduced these problems. By adding appropriate chemicals to the water prior to its introduction to the boiler, fouling could be significantly reduced. Some railways were more advanced than others in their methods of water treatment. In France an advanced treatment was developed known as TRAITEMENT INTEGRAL ARMAND (TIA) which SIGNIFICANTLY reduced problems concerning locomotive boilers. The Argentinean engineer L.D. Porta went on to develop a simplified, heavy duty version of the TIA system and applied it to a number of locomotives in Argentina. Advances in the system allowed locomotives to operate for 6 months or more, even in what were known as 'bad water' districts, between boiler washouts. In addition, hard fouling of internal boiler surfaces was completely eliminated. This state of affairs significantly extended boiler life. Some locomotives using Porta’s treatment system operated for some 30 years without replacement of tubes or firebox plates.

2. APPLICATION OF A MODERN BOILER WATER TREATMENT AT FERROCARRIL AUSTRAL FUEGUINO.

The concept of internal boiler water treatment has for a long time been as misunderstood a subject as locomotive exhaust systems with many myths and old drivers' tales being allowed to take over from proper investigation and rigid implementation of corrective systems. Such systems are derived from proper scientific testing with railway engineers working in conjunction with both high academics, running shed staff and locomotive crews. It may be said that over the years too many locomotive engineers did not place their faith in the high academics and by the same token neither did they go out on the engines often enough to gain practical experience as firemen and drivers (the exception to this being in France as I am sure that you aware of). As a result too much 'progress' was achieved in trial and error' fashion, stabbing punches in the dark and without being aware of the practical implementations of instructions.

The Ferrocarril Austral Fueguino (FCAF), translated to English - Southern Fuegian Railway, was a classic case of a former 'working' railway' (this is far from saying that the FCAF does not work for its living nowadays!) being re opened as a commercial tourist line in a country where the railway tradition had almost been lost[1]. Following a traffic boom that took place during 1996 and 1997 a technical review of FCAF was undertaken during 1998[2]. As a result of this review, it was decided by senior management to go ahead with a locomotive modernization scheme. One very important aspect of any such scheme is that of corrective INTERNAL boiler water treatment. Indeed, it is unimaginable to visualize advancing steam without the correct internal boiler water conditions. One could say that FCAF provides one of the hardest testing grounds for railway engineering systems - a line that operates all the year round with an intensive high season service with minimum resources, minimum number of relatively low tech staff, geographically unfriendly location[3], operates a winter service in temperatures as low as minus 25 degrees centigrade in severe snow drift conditions in a country that saw the breakdown of most national systems during the financial crash of 2001. Sounds grim I suppose? However that is the reality of this narrow gauge railway, it is a 'no frills' operation allowing a minimum margin for error.

A corrective boiler water treatment regime was implemented on the railway during 1998 as a result of the L.D. Porta's first critical review of the locomotive situation that existed at the time[4]. Unfortunately the application of the system failed completely as supervision of such did not exist thus each driver was allowed to opinionate over whether the treatment was a good thing or a bad thing or indeed whether it was to much effort to remember to dose the locomotives water tanks on a daily basis! The present writer arrived at FCAF in the capacity of full time Technical Manager during early March 1999 and the water treatment regime was re introduced, though this time under rigid supervision[5]. The short and long term benefits of such a system were explained in detail to FCAF maintenance and operating staff along with senior management and by the end of the year we were beginning to see the benefits of the work. The treatment that was in stock at the time, STOKER 130, dated back to 1998 and it was decided to continue using the same product rather than changing over to a different chemical. The composition of the treatment in powder form had been specified to the supplier by Porta some years earlier.

In the opening part of this paper I briefly mentioned the TIA system as adopted in France[6] and its simplification as a 'heavy duty' treatment for countries such as Argentina where locomotive drivers were not fully qualified engineers but rose from the ranks of cleaners and firemen. FCAF drivers (locomotives are single manned on this line) are (with the odd exception) 'men off the street' or recruited from other branches of industry. Therefore the application of any new system must be as simple and straightforward as possible. Water tank and tender dispensers are normally used to distribute chemical water treatment into the feedwater. In the case of the FCAF locomotive fleet it proved practical to dose each locomotive by hand on a 'per trip' basis. As well as being relatively easy to dose the feedwater to accurate weighed out measurements it gave the operating staff (in this case the drivers) a good 'hands on' feel to what was being done and we managed to eliminate any imagined magic that may have influenced a premature failure of the system[7]. The chemicals used in this system are supplied in powder form. One very important ingredient of the treatment is polyamide antifoam[8]. More of this later as we take a step by step look at how the system was applied to our locomotive fleet. The initial dosages were calculated as best we could in proportion to the amount of feedwater consumed per round trip. It should be remembered that prior to 1999 no record keeping as far as the engineering department was concerned had taken place and therefore we were beginning afresh with daily consumptions of any kind. Initially a good guesstimate was taken as to how much water both 'Nora' and 'Camila' were using on a round trip and treatment dosages were applied on that basis. Looking back through the records relating to that period of time the instruction issued to footplate staff states a figure of '50 g Stoker 130 per water tank filling'. During the winter of 1999 we undertook the heavy overhaul and first stage modification of 'Camila' at the 'End of the World Workshops' and at the same time water and fuel tank gauges were fitted to the locomotive which made life a lot easier as far as accurate record keeping was concerned when this locomotive re entered service later that year[9].

By early on in the year 2000 the corrective water treatment system was well under way at the railway with the writer generally supervising dosages and analysing what we had in the boilers as best he could at that point in time. However, the results of not using any boiler water treatment for the previous 4 years came to light when the increased steaming rate of modified locomotive No.3 'Camila' revealed that the foundation ring and parts of the water space between the firebox inner and outer sheets were packed solid with hard scale[10]. This state of affairs led to severe deformation (evident in the form of a white bulge) of the right hand side inner firebox sidesheet which resulted in the locomotive being withdrawn from service on 12th February 2000, not really a good state of affairs as we were still in high summer season and therefore left with 'Nora' and the diesel 'Tierra del Fuego' to deal with the rest of the seasons traffic. Camila was fully stripped down to a rolling chassis with the boiler removed for a thorough visual examination. This involved having to drill several holes in the outer firebox so as to ascertain the extent of the packed up scale. Likewise inspection holes were drilled in the inner firebox so as to determine scaling levels at the point of the deformation itself. What was there had to be broken up before being removed by the bucket full. Once the inspection was complete and repair method determined and verified by our inspecting body[11] the boiler was sent to a boiler shop in Buenos Aires[12]. The other FCAF steamer 'Nora' was also withdrawn from service for a couple of days in order to check the boiler for signs of a similar build up of scale. It was found to be not quite as extensive as 'Camila's had been, but all the same it was well on the way to a failure of a similar nature. The accumulated scale was rapidly broken down into a substance that could be removed by steel rods and high pressure water jets. The original design of 'Nora's' and 'Camila's' boilers did not lend itself to easy inspection, maintenance and cleaning, therefore apart from the lack of a corrective water treatment system this factor had to be taken into account when assessing the particular failure that we were faced with of failure[13]. At the same time as carrying out repair work to 'Camila's' inner firebox, 3 foam height indicator accommodation bosses were fitted between the dome and the safety valves on the top of the boiler barrel. This failure meant that 'Camila' was out of traffic for a period of over 7 months which, in view of the fact that we had spent the best part of 1999 overhauling it, was not really the best state of affairs. Likewise the company was faced with a substantial repair and transportation bill. During that period of time 'Nora' ran in service and application of water treatment continued. A thick brown soup was beginning to form inside the boiler and as the treatment continued to do its work we noticed that this was becoming increasingly mobile as the steaming cycle proceeded. Boiler washouts were initially set at 30 days in steam and as such were carried out we saw with our own eyes what had once been hardened scale beginning to break up into soft flakes some 50 mm by 20 mm[14]. A muddy deposit was also noticeable as we drained the boiler water, flushed out the barrel followed by the foundation ring.

Camila was back in daily service by early October, the boiler was as internally clean as possible following repair and hydraulic testing. Dosing with the requisite amount of Stoker 130 continued. By now the addition of the water tank gauge was showing its benefit and we were at last able to calculate the amount of treatment required per trip[15], a good practical indicator being that the feedwater overflow from the injector should run with a tinge of red to it, something similar to a watered down red wine[16] ! One may think at this point in time "this is all well and good, but what about carryover of the boiler water due to a high level of suspended and totally dissolved solids being in violent circulation?" The writer had a fairly harsh experience of this phenomena whilst driving 'Camila' on a busy day not long after the engine had returned to traffic. What the theory book says is one thing but when you are at the front of a heavily loaded passenger train trying to control a locomotive that has an out of control boiler giving a false water indication, passing such through the steam circuit to atmosphere and not being able to put the injectors on represents a different case altogether. The system is designed to work by maintaining a high level of alkalinity within the boiler. The mobile sludge had accumulated very quickly at this stage of development and the scheme was more advanced than I had thought it to be, I had been caught out because the level of alkalinity as a proportion of totally dissolved solids was to low - far to low in fact! At the time we recorded a pH number of 9,5, this was raised relatively quickly by adding caustic soda to the normal treatment dosages in order to give a pH number of 11 and the problem ceased. On the day in question much blowing down of the boiler had to be carried out in order for 'Camila' to continue working its trains and application was suspended for a couple of days whilst the problem was thoroughly investigated. In this particular case (which was relatively early on in the timescale of the project) blowing down was carried out in order to apply a temporary re balance to the internal boiler water conditions, if re application of the treatment causes a further imbalance of these conditions then a full washout must be carried out before a new steaming cycle is started This problem was only to reappear twice in the future when we were supplied with a poorly made up batch of the treatment, in these isolated cases foaming[17] occurred after only 14 days into the steaming cycle. As concentration levels in the boiler rose additional (and very powerful) polyamide antifoam was added to the treatment applications. Though this antifoam is supplied with the Stoker 130 'as mixed', high concentrations of TDS require an extra amount to be added depending on the internal conditions of the boiler during the steaming cycle, as this is the case these extra amounts are made as an addition to the normal dosages with the 'treatment dosing instructions' altering accordingly during the early stages of the scheme. If for any reason antifoam is unavailable for a certain period of time, cylinder oil can be added to the boiler water make up which acts as an antifoam[18]. This application has the beneficial effect of 'lubricating' the steam which in turn extends the maintenance period of live steam control valves (especially if superheated auxiliary steam is used) and allied with the use of stainless steel seated valves represents a considerable saving in this area[19].

By the end of the 2000/2001 high summer season, we had achieved what can only be described as a concentrated, fully mobile, brown sludge in the boiler of locomotive No.3. Locomotive No.2 had seen limited service following No.3's return to traffic (even though this was the case it had worked as 'second engine' up until it suffered severe mechanical failure in late February 2001 which meant its withdrawal from service and commencement of rebuild and stage 1 modification), though it was possible to gather in service data during this period of time, including detailed statistics relating to fuel and water consumption and internal boiler water conditions. Up until now we had used 'conventional' (for want of a better description) style washouts. It was decided to convert to the American method of washing out boilers, indeed no other method of washing out is suitable in order to deal with such a sludge in mobile form, and prior to its winter maintenance period (June/early July of that year and in fact the locomotives last 'C' examination at the time of writing) that year the first of such involving this technique was very successfully carried out at Ushuaia. Why is the USA method of washing out so essential to the success of such a treatment regime? If one is dealing with the removal of sludge (and this is real sludge, imagine a very wet clay or even mud on a football pitch - not broken up pieces of scale) that is mobile then the correct conditions must be created that will allow such to be cleared quickly and in its entirety. If the boiler was sufficiently cooled[20] and drained there would be a high risk of the sludge 'baking' itself to the internal water surfaces and in its cold state such would be very difficult, almost impossible in fact, to remove using a cold washing method (even at reasonable washing pressures). The result of that would be the internal water surfaces being left coated with a layer of insulating material thus heat transfer is theoretically reduced resulting in higher operating costs as is suffered with scale build up on these surfaces. Bear in mind that a scale build up of only 1/16" forms a SIGNIFICANT heat insulator[21]. Practically speaking the residual sludge would very quickly go back into solution upon the start up of the new steaming cycle, but on the other hand if that were the case then why wash out at pre determined interval an any case[22]? In brief, the American boiler washout method relies on such being carried out in a hot state rather than cold state. At the start of the washout of the washout the boiler should be in 'just off the boil' condition (obviously NOT in steam!). If there is any risk of the internal surfaces temperatures being lower than optimum then the locomotive is lit up for a brief period of time immediately prior to the commencement of washout plug removal[23.] Hot, pressurised water is used in order to remove sludge and any cases of broken down (softened) scale. During these initial days of the USA hot washout method, heavy duty braided wire (such as is used for telegraph poles due to its combined strength and flexibility) was used so as scrape the fouled water space between the tubes[24]. Water for washing out is obtained in this form is provided by our mobile pressure washer, however I hasten to add that this is not an ideal technique as such washers are designed to operate for relatively short periods of time, hence a purpose built steam washing plant is the correct installation so as to ensure continuous success[25] (and not causing frequent failure of the workshop pressure washer). Washing out is performed in the normal manner, positioning of the lance so as to end up with an accumulation of sludge that can be flushed out of the foundation ring. The internal water surface is left in a 'no scale' and 'no sludge' state. The boiler is re filled with hot water and immediately steamed[26] as the boiler has altered its temperature dramatically with respect to the fireside and waterside. Other benefits of washing out hot are that the locomotive is out of service for a matter of a few hours rather than days and return to 'in steam' condition is very short. Availability of the steam locomotive fleet is thus higher and nowadays at FCAF we tend to do wash outs in the evening after the engine has worked its final turn of the day, steam being dropped upon return to the works[27] allowing washout to commence not long afterwards. The concerned locomotive is normally back in full steam before midnight, ready and checked over for the next day's service. If you consider that our operation at FCAF requires maximum steam locomotive availability allied with a small number of maintenance staff, then the importance of such modern practices become apparent.

By July 2001 we had adopted the term 'PT' (Porta Treatment)[28] for what we were using in recognition of the fact that this was an advancement on the TIA (the latter previously mentioned above). 'Camila's' foam height indicator (the term monitor or meter is also used to describe this apparatus) accommodation bosses and electrodes (common automotive spark plugs) were in place and it had been the intention to fit this system in its entirety during this 6 week shopping period[29]. Alas, I had made a miscalculation as to the positioning of such! Theoretically the foam height indicator should be positioned between the firebox outer wrapper and the steam collecting dome in order to take readings of foam height in an area where the water circulation is more violent, however the throttle operating linkage for this particular locomotive passes through the water space in order to mate the throttle handle with the valve inside the dome itself. Therefore whilst theoretically correct it was not practical to fit the requisite sensors to the electrodes as the throttle linkage was foul of these! The foam height indicator was not connected and trials continued without such. Meanwhile No.2's replacement boiler[30] was being modified in order to fit to this locomotive during its rebuild (which was taking place at this point in time) and part of the modifications included the fitting of a foam height indicator, though this time positioned between the dome and he smokebox due to the fact that the throttle valve of this engine is fitted on top of the boiler barrel between the firebox and the dome. We were to see at a much later date the importance of being able to fit such an indicator on the firebox side of the dome[31].

High levels of alkalinity keep silica in solution, if this were not the case such would lead to a hard egg shape type of scale. Scale in this form is a silicate (such as glass); therefore gaugeframe glasses can be dissolved. Such is not 'erosion' of the glasses as many have believed it to be in the past as such an action is mechanical; in this particular case it is chemical. Alkali resistant glass should be used for gaugeframes in conjunction with the PT otherwise the ends of the tubes become dangerously thin[32] and cause a safety hazard for footplate crews. It is interesting to note that fusible plugs have been developed which avoid alkalinity attack and therefore frequent changing, hence premature decomposition of the boiler concentration during a long steaming cycle. The element fusible element composition in these plugs is: Pb 88%, Sn 12% allowing a melting point 258^0C. Thin copper plating has also been developed as a means to countering this effect.

We have mentioned antifoams earlier in this text. It should be remembered that antifoams are substances that have a limited life in the boiler, exponentially diminishing with temperature. As this is the case a long station stop or layover could result in depriving the boiler water of their presence. As a result of experiencing this first hand with the 15.00 departure from Estacion fin del Mundo[33] whilst on the footplate of 'Camila', a means of rapid injection of antifoam into the feed line was investigated and means of fitting such to this locomotive and No.2 are in progress. Whilst on the subject of rapid injection and mixing of feed elements it is worth drawing attention to the fact that locomotive No.2 is fitted with side boiler feeds whilst 'Camila' is fitted with a top feed arrangement. Tannin as incorporated as part of the treatment for various purposes one of these being to serve as an oxygen scavenger together with sodium sulphite. The physiochemistry of the process of precipitation imposes a submerged feed therefore no opportunity exists to use the steam space in order to de-gasify the incoming water as is the case with a top feed system.

With all going to plan as far as the application of the PT to 'Camila' was concerned it was decided to go for a longer steaming cycle and this was achieved during the spring of that year when the locomotive achieved over 90 days in steam on normal passenger train duties[34], the engine only being 'shopped' for a couple of hours during evenings in order to replace its fusible plug at 25 day intervals along with a gaugeglass check. The best that we had achieved before this cycle was 45 days in steam earlier on during the same year, severe attacks of foaming during the 43rd, 44th and 45th day signifying that a full washout was required. Working on the principle that boilers should be treated when not in service as well as when in service, dosing of No.2's replacement boiler had begun once fitted to the main cradle frame of the engine in September 2001. A heavy quantity of Stoker 130 was applied along with caustic soda. This was subsequently mixed inside the boiler using a compressed air hose attachment. Once in traffic we monitored the effect of treatment application to a new corrosion free boiler[35]. The modified Garratt locomotive No.2 'Ing. L.D. Porta'[36] suffered a premature mechanical failure in traffic on 4/2/02 and PT trials recommenced during November of the same year upon completion of a second phase of component repair and renewal. At the time of preparing this paper it is in its second steaming cycle since November 2002, its last boiler washout having taken place on 2/1/03 having completed 43 days in steam[37]. The completion of the foam height indicator as fitted to 'Ing. L.D. Porta' has proved to be popular amongst drivers as their 'third eye' so as to keep a close check on internal boiler water events.

Long steaming cycles of locomotives are now normal practice at the railway, if at least 90 days in steam are not achieved then something is suspected to be out of place. The aim is now to double this time period so as to be able to wash out locomotive boilers on a twice a year basis. Repair and maintenance work in this area has been significantly reduced and locomotive drivers are fully partaking in this interesting project and are now able to 'control' the behaviour of the boiler water by the use of simple instrumentation and chemicals that are applied by hand to the feedwater in the locomotive tanks. More importantly, operating and maintenance staff, having witnessed the effectiveness of the treatment, understand its importance and trust in it - unfortunately in many cases (especially steam locomotive engineering) what is not understood is all too often thought of as 'wrong'!

3. COMMENTS AND CONCLUSIONS.

The writer was first made aware of the PT during 1992 and made several attempts to implement such in its entirety as a preventative measure against a predicted 'boiler epidemic' in the UK. It was realised by Porta, and others, that it was impossible to advance steam traction beyond first generation levels without the perfection of internal boiler water conditions. The RFIRT in southern Argentina proved to be a good testing ground for this system and resulted in the boilers the railways Santa Fe class locomotives working for extended periods of time without having to remove such for heavy repair work. During 1969 the Argentine State Railways called upon Instituto Tecnologia Industrial[38] to solve the widespread epidemic of water carryover and severe corrosion problems that its locomotives were suffering in the north of the country. C 16 class 4-8-2 locomotive No. 1802 was set up as a test engine and worked between Salta and Socompa[39] (a northern section of the FC Belgrano system). A regular crew was allocated to 1802[40] accompanied by Porta for most of the in service testing. Boilers in that region were fed with very hard water and these areas had become known as 'boiler cemeteries'. Locomotive boilers had to be washed out every couple of weeks and tubes replaced every 2 years due to severe scaling of the internal surfaces. We should remember that the results of a corrective system are not gained overnight, however by 1974 locomotive 1802, and others of the railways fleet in the same area that had been put on to the corrective system, required washing out only twice a year. This state of affairs represented incredible savings in terms of labour and infrastructure costs, not to mention ease of operation for the crews themselves.

At FCAF, water quality is of low hardness as it is derived from melting ice and snow, however during what is locally known as the 'flood season' the river water contains a large amount of suspended solids (clay and various other impurities). Given the use of tannin in a highly alkaline medium the lack of corrosion relating to boiler tubes, firebox sheets, general piping and water tanks has been observed.

The most important point regarding the PT system is the following: IT IS NOT WHAT IS PUT INTO THE BOILER THAT COUNTS, BUT WHAT ONE ALREADY HAS IN THE BOILER. It is an internal treatment system[41] and therefore relies on what is built up inside the boiler not what is fed into such. This was stressed to the writer in the past and having now gained experience of the system he also stresses this point to the rest of the railway world! The TIA system was the result of the necessity to provide an answer to heavy boiler maintenance resulting from a number of treatments, which included, as in Britain, wayside feed water-treating plants. There is always some good luck involved with development schemes and the writer is of no exception to this rule (as has been proved at FCAF!).

A whole new book could be written on the subject of the PT, this paper merely touches the tip of the iceberg as far as the subject is concerned, concentrating on the recent experience gained during its application at FCAF in Argentina. The writer, as well as being a steam locomotive development engineer, is a practical engineman and therefore much of what is stated here relates to the overall view of making it work in adverse conditions whilst at the same time ensuring that the system is as user friendly as possible.

I would like to re cap on some fundamental points relating to such an advanced internal boiler water treatment system:

1. The necessity of an advanced water treatment system for low tech countries led to research and development work that produced a system that was somewhat more advanced than the TIA and British Railways systems. In such an advanced system the boiler is considered as a crystalliser.
2. Highly advanced and very powerful antifoams (such as the Foster Wheeler polyamide type) allow the boiler water chemistry to be 'played' with at will.
3. High concentrations of totally dissolved solids allied with high quantities of sludge formation are aimed for.
4. This type of water treatment is an integral part of advanced steam locomotive technology and it is unthinkable to be able to advance in this field without such.
5. Operation at running shed level has been simplified to the extent that chemists are not required on site[42].
6. Washouts are supressed and blowing down is eliminated.
7. Boiler water specifications lie within very wide limits.
8. Very high alkalinity levels are aimed at in the boiler water.
9. The treatment chemicals are designed for rough handling by running shed and footplate staff. One member of staff can control the boiler water of up to 30 locomotives in one running shed.
10. The whole system is based on a revised physiochemistry relating to scale formation phenomena.
11. Chemists carry out their work at central laboratory level, remote to the railway.
12. Foam height control apparatus permit a very high loading of the available steam space.
13. Advanced concepts of points 1 to 12 allow us to envisage the application of corrective treatment or 3rd generation steam locomotives working at 60 bar/550^0C.

Once major areas of improvement and modification work have been tackled, in this particular case the steam locomotive fleet of the FCAF, reliability in service is much dependant upon component performance. This is achieved by patient observation and detail correction, each railway administration indeed builds up its own 'tradition' dependant on location, local culture[43] and general working environment. Such exercises cost money (yes, hard cash!), however the result is being able to offer a trouble free service to the travelling public. The experience at FCAF proved the failure of the concept that narrow gauge, commercial tourist railways can be managed by the much loved 'good enough steam locomotive engineering' principles. Fortunately, nowadays this is not practiced here at Ushuaia but unfortunately continues to be adopted elsewhere in the World by other railway administrations - the failure to provide the, to date, best developed internal boiler water treatment being an example of the 'good enough' principle!

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REFERNCE NOTES MADE IN MAIN READING TEXT (APPLICATION OF P.T. INTERNAL W.T. SCHEME AT FCAF, USHUAIA, ARGENTINA).

[1]FCAF was 'restored' during 1993/1994 on part of the old state prison railway. It was re opened as a commercial tourist passenger line on 11th October 1994. The driving force behind the project to re open the railway was the eminent Argentine entrepreneur, Enrique Diaz. He had already set up a successful international shipping agency during 1987, based in Ushuaia, Tranex S.R.L. In his much younger days, Diaz had served as a merchant navy officer and during his spare time in British ports he had the opportunity to travel inland and see the Welsh narrow gauge. This experience inspired him to concentrate efforts on such schemes in his native Argentina. Tranex Turismo S.A. was formed during 1993 and are the owners and operators of FCAF. It is interesting to note that Diaz was already planning on moving tourists by ship from Ushuaia to Isla del Estados as early on as 1991 and he went as far as Finland during 1992 in order to investigate how this might be done efficiently and economically, the reader may like to ponder over whether had this scheme been successful would Tranex be running a fleet of steam ships rather than steam locomotives nowadays? The present length of FCAF is 5,25 km with severe adverse gradients, the most severe of these being 1 in 22 on the outward journey at the approach to the intermediate station of 'La Macarena'. The mainline passenger service is operated by 2 steam locomotives - No.2 'Ing. L.D. Porta' (formerly named 'Nora'), 0-4-0 + 0-4-0 KM Garratt, built at Carupa workshops, Buenos Aires, Argentina in 1994 and No.3 'Camila', 2-6-2T, built by Winson Engineering of the UK in 1995. Both steamers have undergone stage one modification and rebuild as part of the ongoing FCAF locomotive modernization scheme, this work being carried out at FCAF's 'End of the World Workshops' at Estacion fin del Mundo, Ushuaia. Stage 2 modification of both locomotives is to be undertaken during the next couple of years as money and resources become available. The diesel fleet, used for standby, shunting and engineering train duties consists of locomotives No.1 'Rodrigo', No. 4 'Tierra del Fuego' and No.5. A new steam locomotive, designated LVM 803, is in the design stage at the time of writing. The specification for this engine, FCAF fleet number 6, represents a state of the art 2nd generation machine employing compound expansion rather than simple expansion as used in locomotives 2 and 3. The extension of the line to the city centre of Ushuaia is planned to take place within the next 3 years, with planning almost complete. For most of its 10 km route the extension of FCAF will form a new permanent way, the former having been heavily built upon during recent years as part of the continuing development and expansion of the city of Ushuaia. Apart from the LVM 803, new passenger and engineering rolling stock are in the pipeline.

[2]The writer first visited FCAF during July 1998. Initial in service testing of locomotives 2 and 3 took place and a general technical review of the railway was carried out at the same time. A report on such was written and submitted to Tranex senior management. This review of the state of affairs found at the time formed the basis for a multi stage upgrading of the railway in order to meet predicted traffic demands. The latest high summer traffic figures (2002/2003 Southern Hemisphere summer) have proved how accurate these predictions were.

[3]FCAF is the most southerly railway in the World being some 360 km (601 km by road) nearer to the South Pole than the neighbouring Red Ferroviario Industrial Rio Turbio. Ushuaia is just over 2,300 km south of the capital Buenos Aires (very little in terms of populated areas separate the two locations). As a result of the geographical location of

FCAF the reader can imagine the difficulties experienced in conjunction with maintaining the infrastructure of such a line!

[4]L.D. Porta officially served as Engineering Consultant to FCAF between 1997 and 1999 and it was as a result of this that the writer was made aware of its existence (personal correspondence between Porta and the writer dated 4/1/97 and 19/4/97). Porta made an initial critical review of the railway upon his first visit and described it as "the presentation card" for future projects to be undertaken by Tranex Turismo S.A. One such project that the company was working on at the time being the development of a broad gauge, steam hauled luxury train service between the capital city of Buenos Aires and the coastal resort of Mar del Plata. It was this particular project that had attracted the writer to work for Tranex and the original intention had been for him to spend some 2 years upgrading FCAF before moving north to continue with the Bue/MdP scheme. To date this development project has not materialized due to provincial difficulties however there is still hope as the project file is still on the table in Buenos Aires. In order to operate this daily service it was the original intention of Porta to modify 2 existing ex state railways 4-8-0's that happened to be in stock in Buenos Aires at the time. This modification scheme would have involved raising the indicated horsepower of the locomotives in question to a diesel equivalent of 3000, this being necessary in order to keep up with existing timings on the 400 km route allowing high acceleration rates and a normal running speed of 130 km/h. An improved oil burning system was to be used along with feedwater heating, advanced internal feedwater treatment and a high degree of superheating allied with mechanical improvements. Other locomotive projects that Tranex's Technical Development Department have been involved with during recent years were the LVM 801 for 'Tren a las Nubes' in northern Argentina (a new 2 - 8 -2T 2nd generation steam locomotive with a water car added for use on the outward 'mountain climbing' part of the journey that allows the full use of the 'supply ballasting principle' quick release couplings enabling this to be rapidly detached from the engine unit for the return downhill journey, such a scheme would have enabled this railway to run a full steam tourist service from its base in Salta to its terminus high up in the Andes at Socompa and was first proposed by Tranex Chairman E. Diaz during the inaugural meeting of the Association of Argentine Tourist Railways held at Ushuaia during June 1999), a design to convert an ex Chilean Railways Class 57 from conventional coal firing to a modern oil burning system (this scheme also included other modifications such as improved exhaust system, motion and valve gear) and the inspection and overseeing of transportation of 2 Indian Railways YP class steamers from India to a new temporary home in Togo, Africa on behalf of the north American company Rail Development Corporation (a modification scheme which included options for converting from conventional coal firing to oil burning or wood firing using the gas producer combustion system, regauging and conversion to air braking was also drawn up at the time). From early 2000 onwards Porta continued to assist the writer on a personal basis with matters concerning steam locomotive development.

[5]Whilst the writer is an advocate of 'free creative thinking'; the application of quantified improvements in the field of steam locomotive engineering must be carried out under controlled conditions. A common vice within railway administrations worldwide is to wrongly blame any failure on the 'idea' and not the 'application of the idea'.

[6]Following the Second World War improvements to, or rebuilding of, the older French locomotives (the type of treatment required and the engines to which it should be applied) were decided subject to any alterations in the depreciation programme. In brief the plans included improvement of steam circuits, improvements to exhaust systems, feed water

heating and the fitting of water purification devices. This last matter was met by the TIA system (a much asked question is 'what does TIA stand for?' the answer being that TIA stands for Traitement Integral Armand, the highly effective method of water treatment invented by M. Armand). By this system a 'disencrustor', consisting of carbonate of soda, phosphate of soda, caustic soda and tannin was introduced into the feed water by a distributor. Armand had started working on this system in 1940/41, basing his investigations on the physico - chemical action of tannin on a soda environment and, at the temperatures of boilers, on the calcium encrusting salts. The particular importance of this equipment was that boiler repair constitutes the most expensive part of steam locomotive maintenance and that the introduction of water purification on American railways had reduced this cost by some 50 to 60 per cent.

[7]Some years prior to being employed by Tranex the writer had begun research work into internal boiler water treatment systems in the UK. The British private chemical treatment company, M & S Water Services Ltd. had looked closely at the work of Porta in this field and essentially followed the same train of thought as far as this was concerned. This state of affairs eventually led to the writer being offered a permanent position within that particular company in order to set up a section devoted to steam locomotive internal boiler water treatment in the UK and possibly further afield. This fairly lucrative offer was humbly declined as the writer's plans to move to the Alfred County Railway in South Africa were well advanced by the end of 1993. However relatively successful internal water treatment systems based on the adoption of Porta's thinking and practices by M & S (and others) were implemented at the Ffestiniog, Welshpool & Llanfair, Snowdon and Isle of Man Railways, some years later the Vale of Rheidol Railway also decided to adopt an internal treatment system. Upon applying an internal chemical treatment system at the Alfred County Railway, the writer was soon accused of applying 'witchcraft' to the steam locomotive fleet when he was to be seen directly dosing the boiler barrel of NGG 16 Class Garratts on shed at Port Shepstone depot following boiler washouts. It was thereafter explained to Mandla Cele (the boilermakers assistant) that what we were putting into the locomotives water tanks and boilers was actually for the benefit of the engine and not to harm it - some time had to pass before Mandla was fully convinced of this fact. Though the operating department of ACR was issued with a strict instruction to the effect of not blowing down the locomotive boilers, this long established South African Railways practice (it could probably be more accurately described as a ritual on the SAR!) was very difficult to control. As a result of this (minor, continuous boiler leakage was also a contributory factor due to the, by then, slack boilermakers attitude), the high level of totally dissolved solids required in order to achieve the predicted results was never attained, nevertheless clean boilers on this privatised section of the SAR system were achieved.

[8]Internal water treatment can be divided into 2 generations according to Porta's research and development work on the subject, these being: BEFORE the adoption of antifoams and AFTER the adoption of antifoams on the locomotive scene.

[9]For detailed, illustrated and up to date accounts of the work carried out to the FCAF steam locomotive fleet, the reader is invited to visit the various websites listed in the reference and bibliography section of this paper. 'La Locomotive Vapeur' (A. Chapelon. English edition translated by G. Carpenter and published by Camden Miniature Steam Services 2000) also gives an accurate account of the FCAF steam locomotive development programme up to the end of 2000. 'Locomotives International' issue No. 62 carried a brief article describing the rebuilding and first stage modifications to FCAF's Garratt locomotive No.2. The 'End of the World Workshops' refer to the workshop

installation at 'Estacion fin del Mundo' (End of the World Station) and is meant to reflect its geographical location, not its possible effect on the moral of the workshop staff!

[10]The thermodynamic improvements carried out to 'Camila' as referred to in [9] allowed the concerned locomotive work to its full potential (taking into account of course its still unresolved defects). Solving one problem often leads to revealing another associated with the locomotives design and/or subsequent lack of repair and maintenance. This overall view of the steam locomotive should not be lost site of (as indeed for any machine), as a chain is only as strong as its weakest link. Camila and the FCAF at that point in time of its evolution had many such weak links as the writer was to find out almost on a day by day basis!

[11]The official inspecting body for FCAF is Instituto Nacional Tecnologia Industrial. Porta himself worked at INTI as head the thermodynamics department from 1961 up until his retirement in 1982.

[12]No suitable boiler shop was available in Ushuaia in order to carry out such repair work as was required to the right hand side sidesheet of 'Camila's' inner firebox. Likewise the then limited resources at the End of the World Workshops did not stretch to work of this nature. The dismantling of the locomotive after only 3 months in service following overhaul and first stage modification was disheartening for all involved, however it served as a good lesson that the 'good enough' engineering standards worked to in the early years of the FCAF lead to very short term solutions, in this case the neglect of boiler maintenance and corrective treatment. However, it should be remembered that "nobody knows what he or she do not know until they know it!"

[13]Upon arrival at FCAF the writer made a thorough examination of the boiler design and state of locomotives 2 and 3, along with the spare boiler that had been manufactured for the former. Such revealed the following: The boiler manufactured for Garratt locomotive No.2 had been done so with reference to the Hamburg Boiler Code of 1906, upon investigation it was revealed that this particular code of boiler practice excludes locomotive boilers, no fusible plug had been fitted along with only one form of determining the water level inside the boiler, foundation ring washout plugs had been fitted to one side of the outer firebox sheets only thus no cross check along the foundation space was available, no backhead plugs had been provided, mudhole inspection doors in the upper/outer firebox had been blanked off from accessibility by the original boiler cladding, no front tubeplate boiler plugs had been provided, the throttle valve fitted was of a spherical type and the drawings supplied by the manufacturer did not match the manufactured boiler. At the time of building No.2 a set of spare parts had also been made, including a whole new boiler which carried the same faults as described above. It had been the intention of the company to build a second Garratt locomotive in order to strengthen the existing fleet of steamers. As a result of this decision these spares were sent away to the workshops of Girdlestone & Associates in South Africa during early 1999 (at that point in time Girdlestone & Associates were in the process of manufacturing a new diesel locomotive for FCAF - 'Tierra del Fuego', fleet No.4) with a view to commencing the manufacture of 'Nora 2' (as it had become known at the railway by then) early in the year 2000. Due to an economic crisis the manufacture of such was delayed and when No.2 suffered severe mechanical failure in traffic during late February 2001 a vast number of these spares were used in order to replace existing worn out components during the rebuild and stage 1 modification. The spare boiler was modified to the extent that it was now 'legal' to use having had a fusible plug fitted along with a second water gauge glass and the opportunity

was taken to install a foam height indicator. This boiler replaced No.2's original during the rebuild, as upon inspection the crownsheet of the former showed signs of extreme bulging between the crownstays. Locomotive No.3's boiler revealed that no fusible plug had been fitted during its manufacture, however a modification had been made a couple of years later which provided such in the firebox crownsheet. The manufacturers had however provided a low water indicator attached to the upper left backhead washout plug but this had failed not long after the locomotive had entered traffic during 1995, likewise by the time that the writer arrived at FCAF the fusible plug that had been fitted to No.3 had been blanked off by an old bolt as it proved to be 'a nuisance to crews when it leaked water into the firebox and began to put out the fire' (readers are invited to draw their own conclusions as to early operating and maintenance practices at FCAF). The foundation ring had been provided with 'diagonally' fitted washout plugs, whilst this allowed access to wash out nearly all of the foundation ring as long as one used a specially adapted head for the pressure washer along with flexible steel rodding, it made visual inspection of the water space in this crucial area very difficult indeed. The washout plug accommodation bosses as fitted to the foundation ring were very long and therefore made life extremely difficult when it came to washouts. No dry pipe had been fitted for the auxiliary manifold and this allied with a round top firebox as opposed to a Belpaire type box made life interesting to say the least. The throttle valve had been positioned very low down in the dome; in fact the dome itself was very low with the brass cover giving an optical illusion as to the reality of what lay beneath. Both boilers suffered in having being manufactured using rigid stays as opposed to flexible stays coupled with the fact that that the inner and outer firebox had been joined by welding the corners at right angles, this included the foundation ring. Neither of the boilers had been fitted with gaugeglass frame extension tubes so as to give 'true' readings of boiler water levels rather than the optical illusion created by the circulation hump that appears at the backhead. As part of the stagework of the FCAF locomotive modernization scheme, it was decided to partially modify locomotives 2 and 3 concurrent with heavy overhaul in order to provide 'demonstrators' of what could be achieved with minimal investment in a very limited timescale. In this state the FCAF locomotive boilers are still in saturated rather than superheated state therefore the full benefits of modification have yet to be reaped at Ushuaia. Stage 2 modifications, again at minimal financial outlay, are planned for both steamers and design work for such is well in hand. The focal point of this work is the heavy rebuild of No.2's original boiler and No.3's existing boiler. In the case of No.2 it is convenient to prepare the original boiler (removed 2001) before stage 2 work commences on the locomotive itself thus not having to withdraw such from traffic at a premature point in time (i.e. revenue earning capacity will not diminish relative to time in service). Boiler work will consist of designing and manufacturing a new Belpaire type firebox with rounded corners and replacement of the rigid stays by the flexible Tross type. The foundation ring of such will be of the 'U' Tross design and the auxiliary manifold will be moved outside the cab in order to improve crew comfort and satisfy safety requirements. The design of the longitudinal stays will be improved as well as mounting on the carrying cradle. The boiler will be superheated, some 75% of the tubeplate will be occupied by superheater flues whilst the remaining smoke tubes will be fitted with a 'superheater booster'. The fitting of a superheater header and feedwater heater will require the existing smokebox to be lengthened so as position the exhaust system directly in between the 2 components parts (the exhaust system may need some alterations to be carried out as a result of the boiler gas flow cross section area being altered during superheating). The boiler of locomotive No.3 will receive similar treatment as to that of No.2 however in addition will receive a new oil firing combustion system and therefore the volume of the firebox will alter accordingly. Both boilers will receive combustion primary air pre heating and feed water pumps. The position of No.3's rebuilt boiler will be slightly higher than as fitted at the moment yet it is not planned to dramatically alter the overall shape of this very aesthetically pleasing and popular locomotive. This particular area of design has often been overlooked by many and it should be remembered that it is not necessary to alter the overall 'form' of something in order to improve it when a little reshaping of component parts can achieve the same result.

[14]Up until 1993 the writer had been accustomed to determining boiler washout frequency at mileage intervals. This practice, whilst reflecting the steaming rate of the boiler as long as the locomotive concerned is being 'worked' rather than coasted, does not take into account the true 'in steam' conditions of a modern, highly insulated boiler that retains its pressure overnight. For this reason (whilst as yet FCAF steamers do not fully hold boiler pressure overnight) the writer decided to adopt the South African Railways practice of counting days in steam between washouts rather than kilometres run. The latter's requirement to adopt such a system was due to the fusible plugs being changed at 21 day intervals whether the locomotive in question was steamed or not, all fusible plugs being date stamped so as to reflect the frequency of re leading and replacing. Research and development work in this field had taken place at the Alfred County Railway, South Africa during the late 1980's under the direction of its Mechanical Engineer P. Girdlestone and such allowed fusible plug replacement to be extended to a safe 25 day steaming period.

[15]We had begun this practice once 'Camila' was outshopped during late November 1999, however as our attention was focussed on the in service testing and general performance of the locomotive following major overhaul and initial modification (and dealing with odd daily crisis that came our way!) attention to the exact amount of treatment added to the feedwater was surprisingly low on the agenda. At the time of entering service in 1999 'Camila' was still suffering from leaking tubes, though seal welding had been carried out during August of that year. The problem was temporarily solved by adding fine sawdust shavings and horse droppings to the boiler water - the smell of the steam emitted in the station area was not always appreciated by the traffic department staff.

[16]This was the best physical description that the writer could give to the local locomotive crews. Red wine is very popular (and very nice!) in Argentina with water occasionally being used by some to dilute it slightly at the dinner table.

[17]There are many reasons for locomotive boiler water being carried over into the steam circuit. The terms 'priming' and 'foaming' are commonly used to describe this action, though the reasons for both cases are different. A good summary of boiler carry over/steam contamination is given in Porta's introduction to the boiler foam height monitor and reads as follows (the present writer has made a few minor alterations to the wording in this text, though on the whole it is as Porta wrote it in 1984): Technically, pure steam is a must in locomotive technology. Impurities result from boiler water solids being entrained by four mechanisms - 1. Aquaglobejection, in which tiny water drops resulting from the bursting of bubbles in the water/steam interface are projected into the steam space as in the case of a soda glass. 2. Light foaming, in which the whole of the steam space is partially or completely filled up with large foam bubbles. 3. Heavy foaming in which the liquid concentration of the foam filling the steam space greater up to the point of showing as wet steam on the exhaust. 4. Heavy contamination consisting of slugs of water entrained as a result of a violent increase in the steam demand leading to a rapid pressure drop, the latter causing a steam flash over the whole mass of boiler water. The resulting swelling is the cause of the slugs. Provided that there is a foam layer on the water surface, mechanism 1 does not occur. This condition is met when the level of TDS is greater than

6000 ppm and a powerful (not all antifoams are powerful!) is used. Reaching this concentration of TDS in the boiler as quickly as possible after washing out was found to be convenient in research work carried out in Germany. Mechanism 2 was the most frequent condition found when no antifoams were used, this leading to some 2% moisture in the steam. Mechanism 3 occurs as a result of an increased tendency of the water to foam whilst mechanism 4 occurs when the said sudden steam demands are not instantaneously counteracted by the production of steam by an instantaneous increase of heat liberation in the furnace. This can occur, in coal burning locomotives, if the fire is too thin and in oil burning locomotives if the fireman does not react almost instantaneously with the oil valve. ALL DESCRIBED PHENOMENA HAPPEN WITH GREATER INTENSITY WHEN THE STEAM SPACE IS SMALL, hence the sensitivity of the old men to work with "no more than three fingers in the glass!" When a powerful antifoam is added and boiler water conditions are appropriate for its action, (the presence of tannin and high alkalinity when diestearilethytendiamide is used), bubble bursting over a 2 to 3 inch foam layer occurs in such a way that mechanism 1 does not happen, no foam fills the steam space (which then shows transparent) and technically pure steam results even if the volume of the steam chamber is perhaps as small as one third of the normal. This occurs no matter what the TDS (tests having been made up to a level of 50,000 ppm) or the suspended matter concentrations are. Thus it is possible to work with the boiler at maximum load even with the water "on the top of the glass". A powerful antifoam can only palliate the effects of mechanism 4, the only cure to this being careful driving. Residual contamination (about 1 to 2 ppm) occurs mainly because the flow of steam in the steam chamber entrains liquid much like the wind entrains liquid droplets over the surface of the sea.

[18]Years of experience have proved that the presence of superheated cylinder oil in the boiler water is harmless, this is contrary to the widely held opinion on the matter. Cylinder oil in this form has been used as an antifoam at FCAF and many other locations in Argentina in years gone by. To date experimentation has not taken place so as to verify that such satisfies steam purity requirements. It is also known that in Spain fuel oil was used as an antifoam during the curtailment of imported American antifoams and local development of such. No damage was produced in the boilers of the concerned locomotives, though throttle valves were found to suffer from carbonisation. Cylinder oil can be applied in this manner by the use of a simple reservoir and valve arrangement, on the Welsh narrow gauge system the throttle valve lubricators as fitted to the Great Western Railway locomotives of the Welshpool & Llanfair and Vale of Rheidol Railways act in the same way. FCAF steamers have yet to be fitted with application valves, however cylinder oil is added directly to the water make up via the auxiliary manifold or spray (slacker) pipe operating valve.

[19]The conversion of FCAF locomotive control valves to the stainless steel type began during 2001 and it is planned that such will be complete by mid 2004 if not before.

[20]FCAF locomotives have highly insulated boilers, steam circuits and cylinder blocks (including 'between the frame' insulation). Though full boiler pressure (in the case of No.2 reasonable boiler pressure is maintained overnight) is not maintained overnight as yet, the natural cooling down of the boilers takes several days to achieve.

[21]Refer to notes [10] and [12] above.

[22]This question as posed to the reader has a deeper meaning relating to the extended frequency of boiler washouts under a modern internal boiler water treatment regime and is

intended to stimulate the intuitive mind. A good example was a question posed to the writer by Porta asking how it was possible for a Rio Turbio 'Santa Fe' Class locomotive able to work forwards in 20% reverse gear? He insisted that there was a sensible answer to this question!

[23]All FCAF steamers are oil burners (gas oil supplied by YPF being burnt instead of bunker oil or waste oil) rather than coal, wood or biomass burners. Zero spark emission must be guaranteed within the densely forested Tierra del Fuego National Park. Likewise minimum smoke and noxious gases are avoided as the company makes stage by stage improvements to its oil firing combustion systems allied with the fitting of state of the art Lempor exhaust systems. 'Camila' is fitted with its original American style flat trough burner which employs external atomisation. In contrast 'Nora's' flat burner was replaced by an internally atomised, rotary burner during its rebuild and modification of 2001. At the time of writing comparative testing of the old and new systems as fitted to each locomotive using a modern industrial gas analyser is under way, it is expected that full test reports on the performance of each locomotive following stage 1 modification will be available during March 2004. Superheated steam for burner atomisation has been applied to both engines, at the time of writing such has been removed so as to carry out quantative testing in this area (i.e. before and after results), the use of superheated steam for oil burning applications has proved to be successful. Closely controlled solid fuel trials have been carried out at FCAF (outside of National Park boundaries) and the successful burning of unseasoned wood logs was noted using a 'reactive' exhaust system (in this case the reactive exhaust ejector is the most advanced system developed to date, further development of exhaust systems continues apace).

[24]The tube bundle of a smoke tube boiler represents a vulnerable area as far as scale build up is concerned and as far as we were concerned at FCAF was the last and most difficult place from where we had to extract broken down scale. Once back in traffic during August 2001 the improved steaming of this engine was noticed by drivers (the writer being one of them!) and was reflected in reduced fuel and water consumptions.

[25]In the United States full washout houses supplied with continuous boiling water supplies from adjacent plants were built into steam locomotive depots.

[26]It is common to perform a 'slow warm up' when re lighting oil fired boilers from cold state. This in effect simulates the slower heating up action of a conventional coal fire. At FCAF this method of re lighting following washout has been done away with following adoption of USA washing out methods. At the time of writing 'Camila's' boiler has not cooled down since outshopping from exam 'C' during late July 2001.

[27]FCAF locomotives 2 and 3 are fitted with steam sampling valves (this fitting consisting of a valve and condensing pipe) which can also be used as 'pressure relief valves' (blow - off valves) when lowering of the boiler pressure is required.

[28]The official language of Argentina is Spanish (in fact it is the official language of Latin America apart from Brazil, which adopted Portuguese due the Catholic Churches' division of south American land between Spain and Portugal), however many English phrases are employed in the particular dialect of this language as spoken in the country. For example 'OK', 'Stop' and 'Yes' can be often heard spoken by Argentines who are not the least bit fluent in the English language - PT should really have been christened TP if the Spanish lead were to be followed! Another American English language carryover into the Spanish

language seems to have been the adoption of FC to represent Ferrocarril as RR stands for Railroad in the United States - can you see a second capital C or capital R in the respective translations of Railway? The narrow gauge railway was originally referred to as FAF and at a later date FcAF, though both are grammatically correct as far as the Spanish language is concerned, FCAF is the correct railway representation!

[29]The boiler foam height monitor is based on the signal foam meter developed around 1940 by the Dearborn Chemical Company of the USA and was modified slightly by Porta for application during water treatment trials in Argentina. In essence it allows the driver to 'see' inside the boiler and is a great practical aid for monitoring internal conditions of the boiler water. It is an essential tool when working with antifoams and has been known to allow superheater elements last up to 30 years without repair or replacement. The system consists of an electrical circuit which is closed when the top of the foam layer touches the tip of the electrode sensor extensions mounted in the steam space. As this is the case a series of indicating lamps are lit, such forming part of the locomotives 'flight deck'. The electrode extensions are positioned at varying heights over the minimum water level, the longest one corresponding to 'half a glass' indication, the intermediate one to 'full glass' indication and the shortest one to 'over the top nut' indication. The circuit is fitted with test switches corresponding to the respective indicating lamps, thus the driver is able to carry out a functional check prior to departure. The system is permanently connected though an 'on/off' control switch is provided on the locomotives electrical control panel. In NO CASE is the system to be connected to other apparatus or its indications to be related to safety.

[30]Refer to note [13] above.

[31]The sketch drawing in Porta's detailed paper on the foam height indicator shows the electrodes as positioned between the firebox and steam collecting dome, however this relates to locomotive designs that have throttle linkages that do not pass through the water space down the centre line of the boiler - for example throttle valves located in the smokebox with external drive linkage. The electrodes must be fitted on the centre line of the boiler barrel so as to give true foam height readings.

[32]Whilst using non-alkali resistant gaugeglass tubes it was common to replace these at the same time as the fusible plugs, both at ACR and FCAF. A few isolated cases of gaugeglass failures has been known to occur due to insufficient care being taken to monitor the conditional behaviour of such fittings.

[33]The threshold of antifoam concentration in the boiler is hard to define, but it can be said that the smaller the water content per unit of water evaporated per unit time then the better. This is the case for modern high draughted boilers, such as the ones fitted to FCAF locomotives 2 and 3. However, even though No.3 is a moderately modified locomotive with an efficient exhaust ejector it would carry over its water due to foaming on the heavily graded approach to La Macarena station some 7 minutes into the journey.

[34]For a large part of this steaming cycle, Chris Parrott, Technical Assistant UK Division, Tranex Turismo S.A. was the regular driver of 'Camila' and the opportunity was taken for him to record as much detailed in service technical data as was possible at the time.

[35]By the time that the modified locomotive was ready for steam testing during December 2001, the internal water surfaces of the boiler were seen to be clean, and by the time the boiler was first washed out on 4/1/02 following a very short steam cycle of only 14 days it

was apparent that the internal surfaces were a brilliant grey colour. The writer had witnessed this effect before during observation of Welshpool and Llanfair Railway locomotive boilers following treatment using M & S Water Treatment Services chemicals but never to such a rapid extent as that experienced with FCAF's modified Garratt.

[36]Locomotive No.2 was renamed 'Ing. L.D. Porta' at a ceremony attended by over 80 invited guests at Estacion fin del Mundo on 11th December 2001. The locomotive had been previously named 'Nora'. The rebuilding and first stage modification of No.2 constituted a replacement of about 70% replacement component parts and a brief review of the work carried out is attached to this paper as an appendix. Porta himself attended the ceremony whilst the locomotive was christened by Mrs. H.M. McMahon. Porta celebrated his 80th birthday during March 2002 and the re naming of the locomotive combined with the painting of such in bright red livery according to his principle that all locomotives incorporating his technology should be painted this way, were carried out in recognition of this milestone.

[37]This particular washout coincided with replacement of the fusible plug and the attendance of D.T. Morgan, Chairman of FEDECRAIL at FCAF. It would have been possible to run the locomotive longer before washing out took place however it was convenient to inspect the internal surfaces at a relatively short interval due to the boiler being 'new'.

[38]Refer to note [11] above.

[39]Nowadays used by the commercial tourist operators of 'Tren a las Nubes'.

[40]Porta took the opportunity to modify 1802 prior to the water treatment trials.

[41]During earlier trials of the PT system in Argentina and more recently at FCAF, the testing of the feed water was deliberately ignored so as not to distract attention from internal boiler conditions.

[42]Not a single visit has been made by a chemist to FCAF during the 4 years of application of the PT system to its locomotives. An analysis of the boiler water is made when water samples are occasionally sent to the chemist's laboratory in Buenos Aires. So far the advice of a chemist has not been required in order to solve any problem that occurred during in these trials.

[43]Upon observation (and participation) of different working practices carried out in various locomotive depots and workshops situated over 4 continents, the writer realised that such varied greatly as did the local culture. What is applicable in one part of the World is not necessarily applicable in another, for example the imaginative, creative and inquisitive mind of the Argentine would not respond effectively to the rigid rules and regulations laid down by the SAR, in this case it was more effective to slightly modify British and USA practices in order to suit the requirements of FCAF.

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