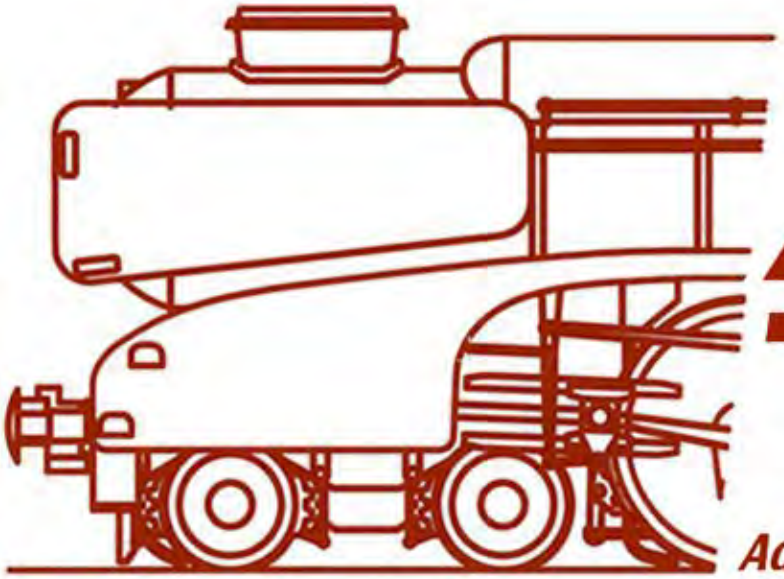


Newsletter No. 8 January 2019

Editor: David A Nicholson

Contents

Editorial…… 2
Chairman's Notes…… 3
Membership…… 4
Book Sales …… 5
Website Updates…… 5
2018 Autumn Conference…… 5
Information…… 6
Testing…… 9
LNWR George the Fifth New Build…… 10
A New Look at Springs & Axle Location…… 11
The Thrill of Steam…… 23
Details of a Modern 4 cylinder 2-8-0…… 24
"Hi Tech" at the GDSF…… 29
Building a Large Scale Fowler Steam Lorry…… 30
Mechanical Cylinder Lubrication Part 1…… 43
David Wardale, on the "modernization" of steam locomotives…… 56

EDITORIAL

I hope that you have all enjoyed the Christmas festivities and are looking forward to the New Year when the ASTT will again be having the AGM in March and Conference in October but with a change of venue to Crewe. A lot of work goes into organising these events and it would be great if we all showed our support by attending.

Many thanks to the members who have contributed to making this a very interesting and varied issue and as always I hope that more of you will do so in the future. I would also like more photographs of any steam related subject. Please send your articles to :-

editor@advanced-steam.org

ASTT Articles Cedric Lodge

By the AGM last year, it was apparent that our Articles needed a review, and if necessary-amended. The consequence of this was me being instructed by the Committee to review the Articles and recommend amendments if necessary. This I have done, and my Draft is with the Committee for final approval. If approved, the amended Articles will be put before the Members at the AGM in March, for approval as a Special Resolution.
The main amendment concerns the way in which Officers are elected. At present, Officers are elected by the Members in General Meeting. I recommend that the Members elect the Committee (as now), but the Committee then elects its Officers. This procedure tends towards continuity, and enables the Committee to respond instantly to the loss of an Officer without reference to the Members. Although not specified in the Articles, the Members would still have the opportunity to express their opinions at the next AGM on the appointment of an Officer of whom they disapproved.
Tinkering with Constitutions and Articles is often a sensitive issue, but sometimes necessary as with a machine, to keep it running satisfactorily.

Chairman's Notes:

Following the feedback we received from Chris Newman's post conference survey, we have been looking for a new venue for our 2019 meetings and have settled on Crewe for our AGM and the October Conference. At the Conference our works visit will be to Locomotive Storage Ltd, which is the former Crewe Diesel Depot, which is where Jeremy Hosking's fleet of steam and diesel locomotives is restored and maintained. One of the conference talks will be on the history of the development of the Jeremy Hosking organisation at Crewe.

The AGM will be held on Saturday the 2nd of March and the conference on Saturday the 5th and Sunday the 6th of October.

This follows our established pattern of holding the AGM on the first weekend in March and the AGM in the first week in October.

The AGM will have the formal part and after that talks on steam locomotive topics; Joe Cliffe has already volunteered to give one on lubrication.

We are planning to hold the AGM at Crewe Heritage Centre.

For the conference we are looking at an alternative venue in Crewe, as the Heritage Centre cannot host the numbers we anticipate.

Formal notification for these events will come out next year.

Later on in the newsletter Mike Horne gives an update on the testing work, that we are doing at the Churnet Valley Railway, courtesy of Rob Alcock, who has joined us a member. Our rate of progress is limited by access to locomotives and thanks to Rob for facilitating it.

If anyone would like to get involved, whether that is on the practical side preparing for the tests and being part of the test team or help with analysing the data, please contact me directly at john.hind@advanced-steam.org . Being involved gives a chance to ride on the test trains, which will be some of the most unique trains to run on Heritage Railways in 2019.

Finally a happy, healthy and prosperous 2019 to everyone.

John Hind Chairman ASTT

1. Membership

Chris Newman

Members are reminded that their annual subscriptions fall due on 1st January 2019. Your Membership Secretary will be very grateful is you could pay your subscription promptly if you have not already taken the trouble of setting up a Standing Order with your bank. As you may imagine, chasing up late fees is both a time-consuming and thankless task that he would like to avoid if at all possible!

ASTT membership numbers continue to grow, five new members having joined since the August newsletter was distributed, bringing total membership to 64. We welcome the following:

1. **Pep Alemany** from the Balearic Islands (Spain), retired Chief Engineer in the Merchant Marine, currently working as a team leader in a large energy-from-waste plant. He is also a founder member of Fundacio Ferrocaib dedicated to the recovery of the railway and industrial heritage of Mallorca, and currently restoring a 2-4-6 Mallet. We were delighted that he was able to attend our conference in Bury and hope that we can look forward to seeing him at future meetings.
2. **James Conway** a Student Member from Pickering, North Yorkshire and currently our youngest member, but already a director of "Conway Rail Solutions Limited", offering consulting services on air brake and AWS/TPWS system design and fitment, CAD design and compliance with group standards for locomotive registration and certification for running on Network Rail infrastructure. His current projects include: design of the air brake system for 4079 Pendennis Castle; ditto for 3672 Dame Vera Lynn; and CAD design for the Standard Steam Locomotive Company building 72010 Hengist. In addition, he volunteers for the Essex Locomotive Company and the NYMR.
3. **Dave Reynolds** from Lancashire: recently retired CME of the East Lancs Railway, Dave gave a most interesting presentation at our 2018 conference. He previously spent 38 years working on/for the Severn Valley Railway after completing his apprenticeship at Crewe Works.
4. **Mats Mattsson** from Sweden: a civil engineer by training, Mats has been i/c of an oil-burning electric power plant, a technical investigator and a rail enthusiast. He is interested in pursuing the use of torrefied wood as a locomotive fuel.
5. **Chris Hodrien** from the West Midlands: a university lecturer with widespread interests and contacts in the rail industry. Chris was late to hear about AST's conference so travelled up at short notice on the Sunday morning to attend the second day's session. We look forward to meeting him at future events, and perhaps being involved in planning some of them.

The current membership base is distributed as follows:

Full Members: 13	UK: 51 members.
Associate Members: 44	EU: 8 (Spain, Germany, and the Netherlands).
Student Members: 7	USA: 3 members.
	Australia: 1 member.
Total Membership: 64	China: 1 member.

2. 2018 Autumn Conference

Chris Newman

AST's 2018 Conference was a great success thanks to our excellent speakers and to the support of the Bury Museum and East Lancs Railway staff. 35 attended the Saturday session and 28 on the Sunday, with 30 at the conference dinner.

An "opinion poll" of attendees and non-attendees produced responses from 15 members all of whom responded positively to the question of holding similar conferences in future. The large majority was in favour of continuing with an annual 2-day event, but most suggested that more time be set aside for Q&S sessions and/or for free discussions. A variety of alternative venues were suggested which will be considered for future conferences.

3. Book Sales

Chris Newman

With the publication of Ian Gaylor's book in September, sales have been more buoyant over the last quarter, as follows:

- **Steam Locomotive Design Specifications and Calculations for New Build Baldwyn 2-4-2T 'Lyn'** (pub. ASTT): 23 sold (total sales 23);
- **5AT FDCs** (pub. ASTT): 6 sold (total sales 190);
- **5AT Feasibility Study** (pub. ASTT): 3 sold (total sales 45);
- **Here be Dragons** by Phil Girdlestone (pub. Camden): 1 sales (total sales 23);

New Titles: After endless hours of proof-reading including valuable and much appreciated assistance from Chris Corney, it is hoped that **Volume 1 of Porta's Papers** will be on sale by the time this newsletter is distributed.

4. Website Updates

Chris Newman

Your webmaster has been pre-occupied with other duties since the last newsletter to the extent that very little work has been done on the website. Only two new pages have been created:

- A new book-sale page was created to promote the sale of Ian Gaylor's new book "*Steam Locomotive Design Specifications and Calculations for New Build Baldwyn 2-4-2T 'Lyn'*" which has been added to ASTT's list of publications – see above.
- A new page reporting on ASTT's 2018 conference containing links to the presentations in PDF format and video recordings.

In addition three new "News" posts were added:

- An announcement of the publication (by Camden Miniature Steam) of Robin Barnes' new book "*Locomotives that Were & Locomotives that Weren't*".
- An update on the fascinating story about the conversion of steam locomotives to CO2 power in China.
- Advanced notice of Free RSSB Seminars in York and London to be held in early December 2018.

Information:

Cedric C Lodge.

Members of a certain age may remember the 'Prisoner' series on TV in the late '60s. One of the iconic shots features the prisoner-No. 6 (Patrick McGoughan), seated in the chair of inquisition. He asks: "What do you want?" The voice of No. 2 replies: "Information!"
When I joined the 5 AT group, I thought I knew a bit about steam locos Since then, and a few Conferences later, I realise I did not know much at all, but from our Conferences and the conversations I have had with other Members, I may have learned a bit.
In the mid '80s as the steam loco renaissance movement struggled to establish itself, it struck me that it might be prudent to start collecting technical books about steam locos. Should the opportunity arise at some time in the future when a steam loco could be built, it would be worth having a library of relevant books to assist with the design. In this case, the information. A naïve motive I admit, but it sustained my determination to collect as many technical books on steam locos as came my way.
Thankfully, technical books did not command as high a price as those populated with photos. of steam locos, so the cost initially remained within bounds. I was particularly fortunate in discovering a cache of books in a second hand bookshop in Canterbury. They had recently received a hoard of books on the subject from the collection of W O Skeat of the I Mech E. Books are heavy, and I was limited by what I could carry rather than the cost, during my first visit. Fortunately, I visited Canterbury on a regular basis for several months, each time going round to the book shop after completing my official duties. In the end, I think I cleaned them out. It was a good start to my acquisition of information. To assist portage, I used two plastic bags one inside the other, with a slit piece of plastic hose under the handles to take the weight. It worked fine. If they failed en route, I could cadge replacements from shops along the way.
Before the days of the Internet, second hand bookshops were numerous, and I claimed at one time to be able to sniff one out two streets away. Whenever possible, I would slink away and spend an hour in the search for information. Mostly, my patience was rewarded by locating yet another gem. By the late '90s, second hand bookshops had thinned out noticeably, and their prices increased alarmingly. When challenged, booksellers would reply: "Well, that's what I can get for it on the Internet!" Thankfully by then, my library of information was well established.
And then there was Camden. I started receiving Adam's wonderful catalogue about fifteen years ago, and regularly succumbed to temptation. But the piece de resistance had to be the 'Steam Locomotive Study Course'. This was a three volume set in A5 format of American origin, reprinted from the '30s. At £100 it was a 'bit heavy', but I realised this was not going to come again, so bit the bullet. I have not been disappointed; it really is a magnificent piece of work despite lacking an index. Another acquisition was George Carpenter's translation of Chapelon's autobiography. I think it was £65 at the time, but as it is now listed on Internet sites for £250, I feel quite smug. I saw an original in French which Camden was offering in the early '80s, and for the first time in my life, regretted not having paid more attention to French at school.
Over the years, I have acquired a number of books which were Vol. I or II etc. of a set. Ever the optimist, I hoped I might some day drop on the complementary volume- a long on shot I know.
I do not remember how, but in more recent years, I encountered Abebooks. This is an Internet business based in British Columbia, probably working out of a shed. You type in the title- and author if possible, of your desired book, 'click', and hey presto: there is your book, listed in ascending order of price. You pay, and in a few days your book arrives-from the next town or the farthest corner of the earth. All Abebooks do is complete the connections and collect their percentage; and all from the comfort of your own kitchen. Abebooks has enabled me to make good on a number of sets which were missing a volume or two, and obtain specific titles for my library. But I miss the thrill of the chase amongst dusty book shelves of the old second hand book shops. That apart, Abebooks remains a wonderful resource.

Through the good offices of a friend of mine-Nigel Day, I secured one of the first copies (and signed) of David Wardale's 'Red Devil'. I read it avidly, albeit with difficulty. (The type is small, and the text goes across the page). But it was one of the most instructive books on steam locos. written so far (1998). It is inspirational.

David Wardale was the last of a small number of individuals who have been instrumental in moving the steam loco forward. But in the Preface, he duly acknowledges the help he received from Dante Porta, calling himself the 'Wizard's Apprentice'. So what of Porta?
Porta made a monumental contribution to the development of the steam loco, but until recently, very little of the documentation of his work was available. Now, through the good offices of his descendants, Shaun McMahon and our own Chris Newman, some of Porta's work is being made available to a wider audience. Elsewhere in this Newsletter, you will see advertised for sale the first tranche of Porta's papers. This truly is a treasure trove of information.

As we entered the new century, one could be forgiven for thinking it was all over. But then along came the 5 AT Group, and the FDCs. (Fundamental Design Calculations). It was some years before I joined the 5 AT Group, but when I did, I immediately purchased the FDCs which were just then being offered for sale. Since then, the 5 AT Group has restructured into the Advanced Steam Traction Trust and Advanced Steam Traction Services Ltd. Under the tutelage of Chris Newman, we are able to offer a number of new ground breaking publications which elevate the study of the steam loco. to an unprecedented level. I will cite one example: Adrian Tester's: 'A Defence of the Midland/LMS Class 4 0-6-0'.It is a mine of information backed up with copious references.
When I was in India, trying to commission DHR loco. No. 1001 which had been converted to burn oil, it came to my knowledge that the Indians were quoting from an otherwise unknown text book. Non of the IR engineers had had personal experience of steam, so they were very dependent on what they could glean from text books. I found out that the book to which they repeatedly referred was: 'Steam Loco Guide', by H C Ratta, and published in India. From my brief perusal, it was a book worth getting. I tried investigating second hand bookshops in Delhi via a website advertised on the side of a van, but to no avail. A few years later at the AGM of the Darjeeling Himalayan Railway Society, there was a seller of second hand books. Lo and behold, there on the top shelf, was a copy of Ratta's 'Steam Loco Guide'. It is a good book, and provides an interesting approach in comparison with British and American authorities. Within are listed two other books by Ratta: 'Illustrated locomotive valve setting' and 'Steam locomotive trouble shooter', for which the search is on.
Beyond books there lay other concentrations of information germane to our cause. They also indicate where we have come from, which is a good guide for where we are going. Of these, the learned societies-professional institutions, are our first port of call. The 'mechanicals' is the most prominent, but there could be gems of information tucked away in the journals of the Institution of Civil Engineers. The Institution of Locomotive Engineers was absorbed into the IMechE over fifty years ago, and their combined journals contain numerous articles on the development of the steam loco. Although many developments failed to be incorporated into the locos. of their day, that is no reason to discard them. Many are relevant to what we seek to achieve with ASTT, and I sometimes wonder how we justify prefixing our title with 'Advanced'.
Most of the Proceedings are in A5 format soft cover books. Those produced over even a small number of years would require several feet of bookshelf. A search requires an alacrity in the manipulation of IT. Copies of articles may be obtained direct from the web sites of the Institutions-as Members, or on payment of a fee. And you have to know what you are looking for before you start. I have not yet found a comprehensive index on the Institution sites, but that may be because I have not looked hard enough.
However, help could be at hand: One of our Members-Robin Pennie, is a member of the Lancashire and Yorkshire Railway Society. He told me that the L&YRS had made available on their web site, papers produced by the Institutions of Mechanical and Locomotive Engineers. Work is in progress

to add papers produced by the Institutions of Civil and Electrical Engineers. The link is: http://lyrs.org.uk/Papers-to-Institutions
The list covers 1847-1946.
In addition, the L&YRS has a list of patents, albeit with particular reference to the L&YR. The link is: http://lyrs.org.uk/Patent-Documents
Immediately after leaving college, I was posted to the offices of the CME, NE Region of BR. One of my jobs was to record and file issues of the Railway Carriage and Wagon Review. Steam was on its last legs, so there were no articles on the subject by then, but the memory lingered, and in recent years I have started searching for old copies.
About five years ago, I spotted three bound volumes in a second hand shop in Abergele, These were from the '30s, and were well populated with articles about steam locos. In due course, I came across an advert. in 'Old Glory' for a job lot of about twenty-fortunately, not too far away. I was successful in their purchase, and now have a burgeoning collection of RC&W Review. A bit ambitious maybe, but my target is to get the complete set from the end of the 19th. C ent. to about 1950. They also appear occasionally in Abebooks as individual magazines.
Other publications worth looking at are the 'Engineer' and 'Engineering', and the web site of the Institute of Engineering.
I commented earlier about the absence of an index in the 'Steam Locomotive Study Course'. What would be a great help would be an index of what is known to be available, with sub indexes of the content of each publication. Any takers?



(Photo: Clive Brewer)

Testing

Mike Horn

The testing has started on the Churnet Valley Railway S160 5197 with a full day on the footplate during two complete line runs (including up the bank) during a Members and VIP dining train. Some two hours of good data at a sample rate of 1000 samples per channel per second was collected and now requires analysis.

Train consisted of 5197, 2 dinning cars, 4 stock and a Class 33 on the rear (to avoid having to run around at the top of the bank).

Data was recorded on both the uphill runs from Froghall to Cheddleton and then Leekbrook to the top of the bank and provided excellent insight into the loco performance.

This data is the property of the railway and cannot be discussed at the moment.

Early in the New Year, after duplicate tests have been carried out on S160 6046, we should be able to provide a direct comparison between the two locomotives to see where performance is good and to identify areas for possible improvement, if any.

Any modifications or repairs will then be subject to further testing to prove that they are working as expected.

Further detailed testing as requested by the railway will then be carried once the requirement has been identified from the above results.



Photo of 5197 at Cheddleton after the runs. (Photo: Mike Horn)

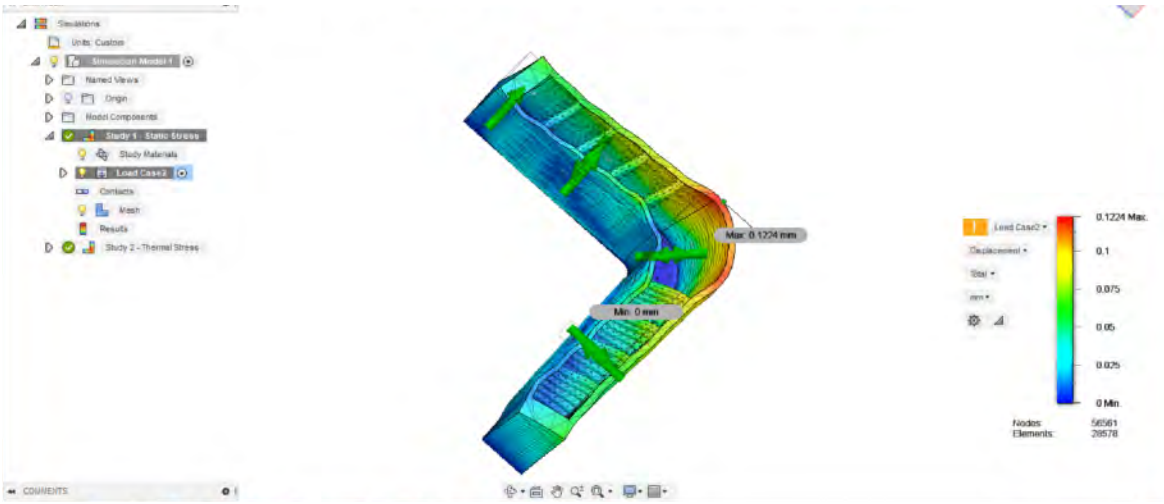
LNWR GEORGE THE FIFTH NEW BUILD Terry McMenamin

Work for LNWR George No. 2013 *Prince George* is focussed on the boiler. It will be very much like the original, with its deep firebox, parallel barrel and with at least the same area of superheater elements. As we are building a replica locomotive, rather than an exercising the craftsmanship of yesteryear, our boiler will be welded. The many lap joints and butt straps of a riveted boiler demand great care in fitting, and welding to modern standards gives a better result. As a valuable bonus, the cost of a British-built welded boiler is about the same as a riveted one made in Poland.

One of the difficulties of designing a boiler is that the standards are very outdated; browse BS931: 1951, BS 2790: 1969 or 1992, then find a way through and comply with their empirical standards while using modern modelling techniques to refine the design. Perhaps the most challenging area will be the firebox stays. The George has a small grate for its power output (22.4 sq. ft. as against 28.4 sq.ft. of the Derby compounds) and we can expect that the inner firebox will suffer high temperatures when working hard. We will model this to determine the stay layout and the possible use of flexible stays. A very basic model of a section suggests that there may be some advantage in locating stays nearer flanged ends than the Standard allows, And the attached gives an exaggerated model of distortion under pressure.

It is planned to increase the depth of the ashpan by taking advantage of either a relatively thin foundation ring (about 30mm as against 4" of the original) or a U shaped one. Again, modelling should help us make the choice.

It is intended to order the barrel very shortly, it is being drawn up right now. During the summer we plan to exhibit the barrel with our smoke box, front covering plates, and splasher/lower cab side, which begins to show something of our finished locomotive.



'Quick and Dirty' Model of stays: Distortion at flanged firebox corner under 210 psi pressure

Revolution – A New Look at Springs and Axle Location

J Keyte 04/12/18

Introduction

At the AST Conference in September 2018 I proposed a novel method of mounting a steam locomotive's axles using elastomeric (rubber) springs. The proposal is to provide an alternative to traditional spring arrangements - and associated problems - which have remained virtually unchanged since the dawn of steam. A summary of these problems are discussed in Part 2. The development of this new suspension and axle location system is discussed in more detail in Part 3, but before moving on to this, it is appropriate to present an historical summary of the use of rubber in rail applications, in particular in relation to axle location, suspension and running gear (Part 1).

Part 1.

In The Beginning…..

The story goes back to the formative years of railway development where a great number of engineers and companies were building locomotives of many different types. Without prior experience to work from, they all had different ideas and each thought that his was the best! As a result (and as might be expected) the period from 1825 to 1875 proved to be remarkably fertile for new ideas – not all of them based on scientific principle!

Locomotive Springing

In 1849 McConnell of the L&NWR[1] [Fig 1] built a 2-2-2 where the axle springing throughout consisted of stacks of square India rubber pads separated by metal plates. 34 locomotives were thus fitted and the spring failure rate was a mere fraction of that of conventionally sprung locomotives where quality of the metal lead to frequent breakages.

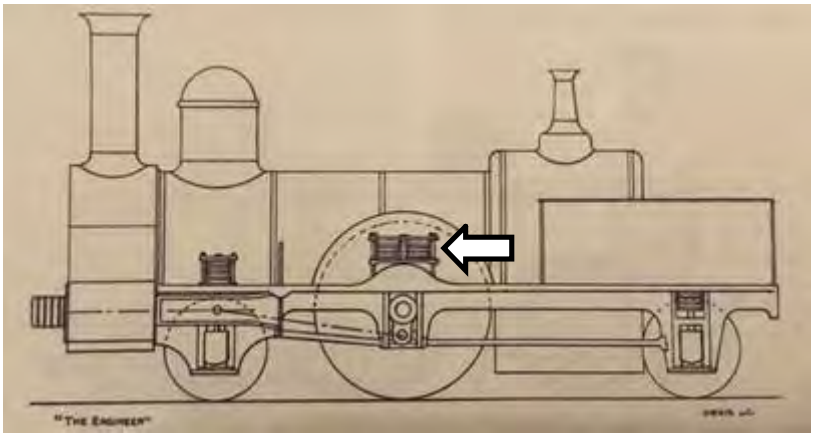


Fig.1. McConnell's rubber suspension stacks (arrowed).

Figures quoted for the six months to November 1854[2]:

- Steel Springs: 199 locomotives, 292 failures
- Rubber Springs: 34 locomotives, 1 failure

[1] Ahrons p.79

[2] Jack Harry, Locomotives of the LNWR Southern Division: L&B Rly, L&NWR and Wolverton Locomotive Works. 2001.

Despite this promising start it appears that McConnell had problems with the consistency of the rubber properties leading to the rejection of batches from his supplier. It seems that the consistent quality of rubber products could be just as poor as metal products.

In the period 1953-54, the Bristol & Exeter Railway took delivery of eight 4-2-4 express tank locomotives from Rothwell of Bolton[3] [Figs 2 & 3], designed by J Pearson, the railway's CME. These locomotives were carried on rubber suspension.

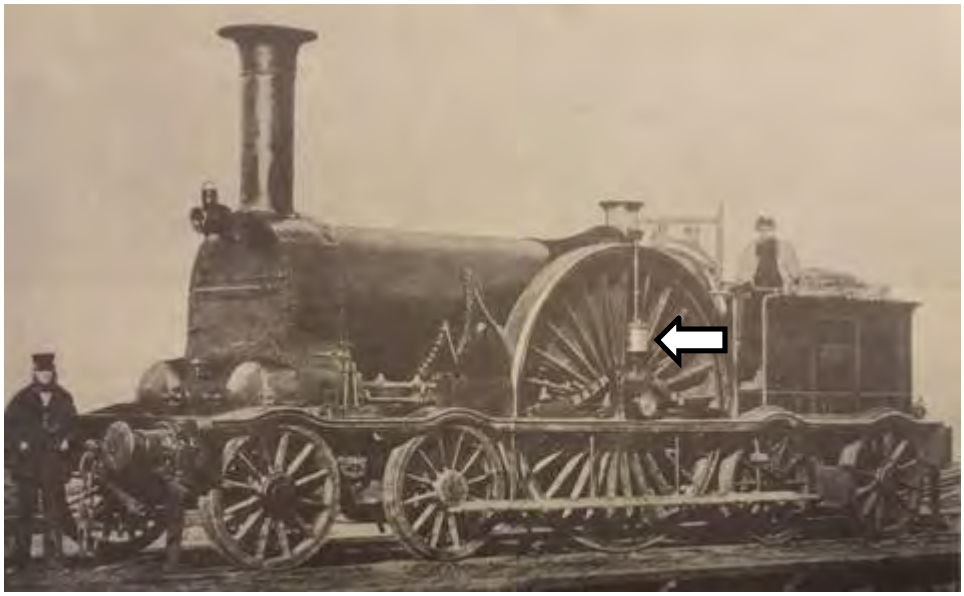


Fig 2. B&E Rly 4-2-4Tank with rubber spring arrowed..

Most notably the 9ft flangeless driving wheels had a novel suspension arrangement: each wheel had inside and outside axleboxes connected over the top of the wheel by a compensating lever which ensured the bearing pressure was in proportion the bearing area.

Between the compensating lever and each of the axleboxes was a stack of India Rubber rings separated by iron plates and encased in a cylindrical housing. The compensating lever at the top end of this rather delicate looking assembly was pivoted off a bracket which in turn was mounted on the boiler. In those days the boilers were much stronger than the frames so it was deemed a natural place to "hang stuff from". The bogies also featured rubber suspension.

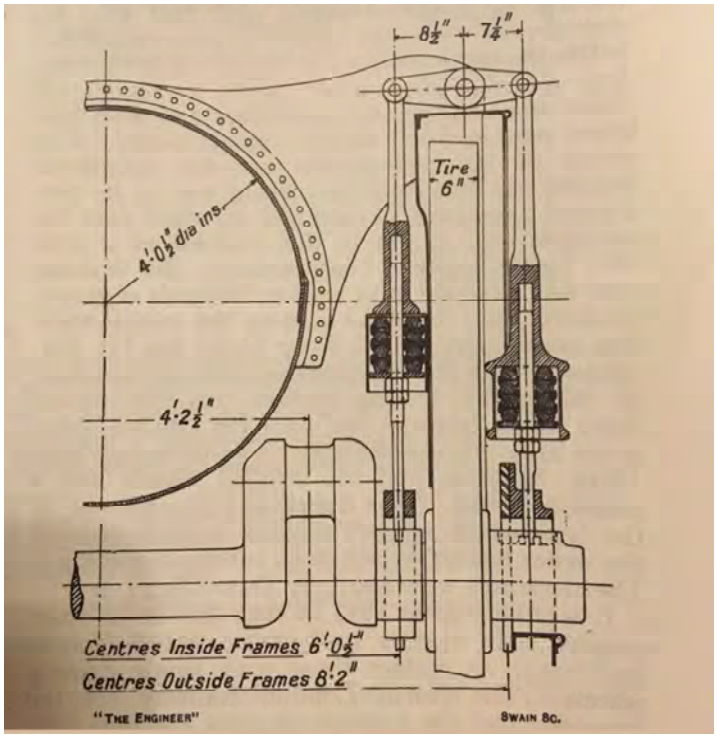


Fig 3. Spring gear of B&E Rly Locomotive

[3] Ahrons p. 106

The original eight B&E locomotives lasted about sixteen years to be replaced by a further series of engines with the same wheel arrangement, but conventional springing. It is not recorded how well their suspension system performed.

Also around this time, an (unspecified) railway in South Wales experimented with a rubber hydro-pneumatic suspension[4]. This would have been well ahead of its time and was, presumably, the forerunner of a range of hydraulic and pneumatic springs in common use today. The spring consisted of a thick walled rubber cylinder enclosed in a casing with plates top and bottom. The cylinder was filled with water. As the rubber cylinder was compressed the sides would bulge in forcing some water out through a hole in the top plate. Above the top plate was a sealed hollow chamber filled with air. Water forced into the chamber would compress the air (much like a modern hydraulic accumulator), adding to the spring force. The hole in the top plate would also add a measure of damping. It is a pity more details of this remarkable system do not exist since it combines elements of controlled damping and variable spring rates.

Accommodating Length

In 1855 W. Fairbairn & Sons built a number of tank engines which featured a novel form of coupling rod[5] [Fig 4]. In this design the split bearing brasses were sandwiched between a pair of rubber blocks which transmitted longitudinal forces into an elongated eye in the coupling rod end. The rubber "cushions" were to "*allow for careless adjustment of the (rod) length by fitters and drivers*". It is assumed that this was an early attempt to deal with the problem of ensuring coupling rod and axle centres were exactly the same.

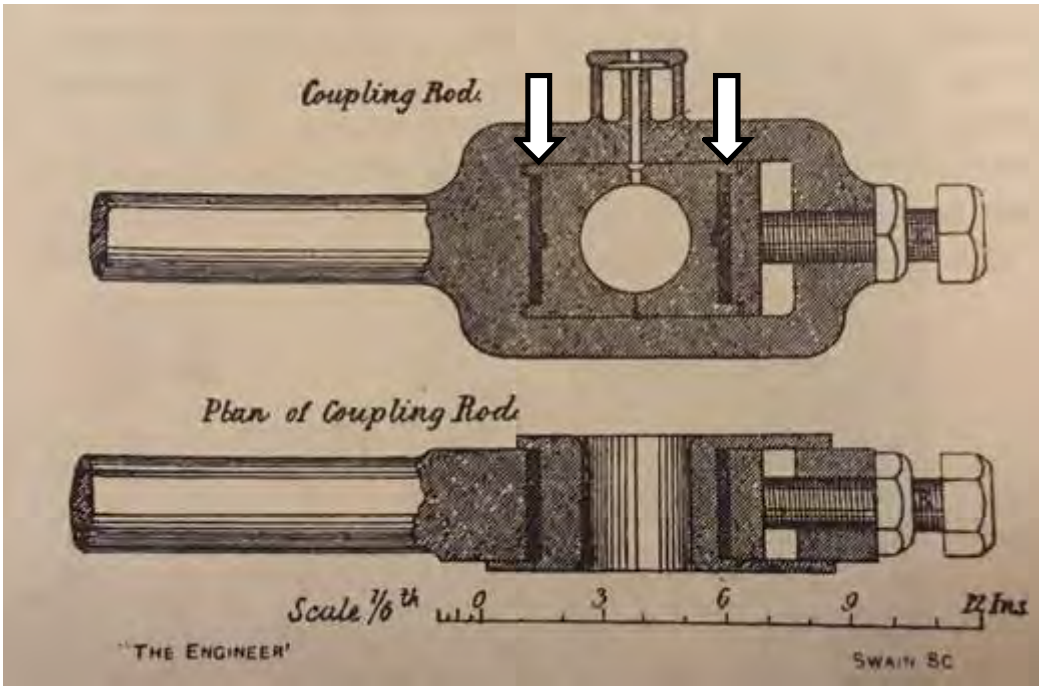


Fig 4. Fairbairn's Coupling Rod with rubber elements arrowed.

[4] Ahrons p. 110
[5] Ahrons p. 126

Around the same time Messrs. Fairbairn introduced a type of axlebox which was designed to give controlled axle side-play, with the ability to restore itself to a central position[6] [Fig 5]. The axlebox was able to slide vertically between a pair of "V" shaped guides. The guides were restrained within the horn blocks but able to move apart longitudinally against spring pressure. Between the back of the V guides and the horn blocks were a number of rubber springs which were able to compress a small amount. When the axle moved laterally the V guides would be forced apart by the axlebox, compressing the springs, which in turn provided a correcting force to return the axle to its normal position.

This was one the first recorded instances of controlled axle side play. It is assumed that it wasn't particularly successful (or was too expensive!) since it only appears to have been used in a few experimental applications, however, such an arrangement would also tolerate small longitudinal discrepancies between rod and axles centres in a similar manner to the coupling rods described above. This is a subject dealt with in more detail in Part 2.

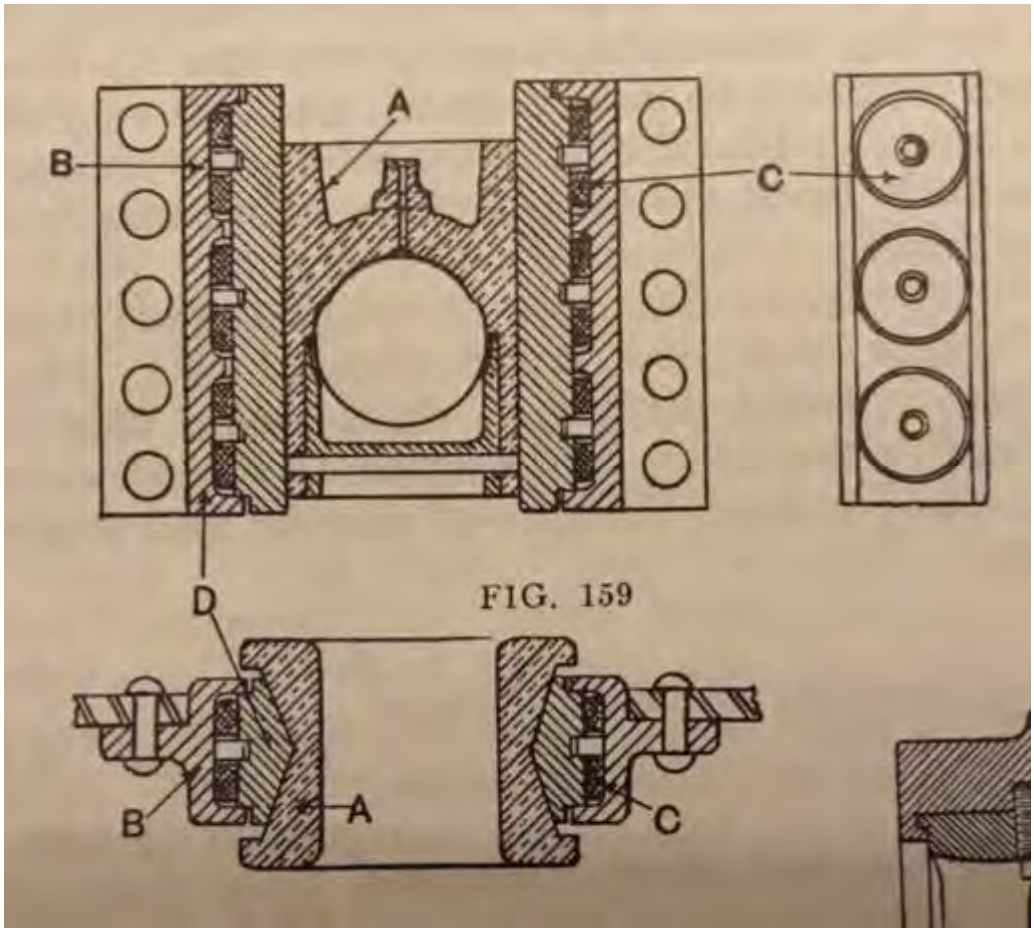


Fig 5. Fairbairn's axlebox (A) sliding within tapered blocks (D) which are held out from the horn blocks (B) by a series of circular rubber springs (C).

[6] Ahrons p. 127

Lateral Control

Rubber was also being used as a spring material to control side play. William Adams employed it to control the lateral movement of the bogie on his North London Railway tanks.[7] [Fig 6]



Fig 6. Adam's North London Railway tank with rubber bogie lateral control springs.

A similar arrangement was employed for a time by F. Webb on the LNWR for the lateral control of his radial axlebox.[8] [Fig 7]

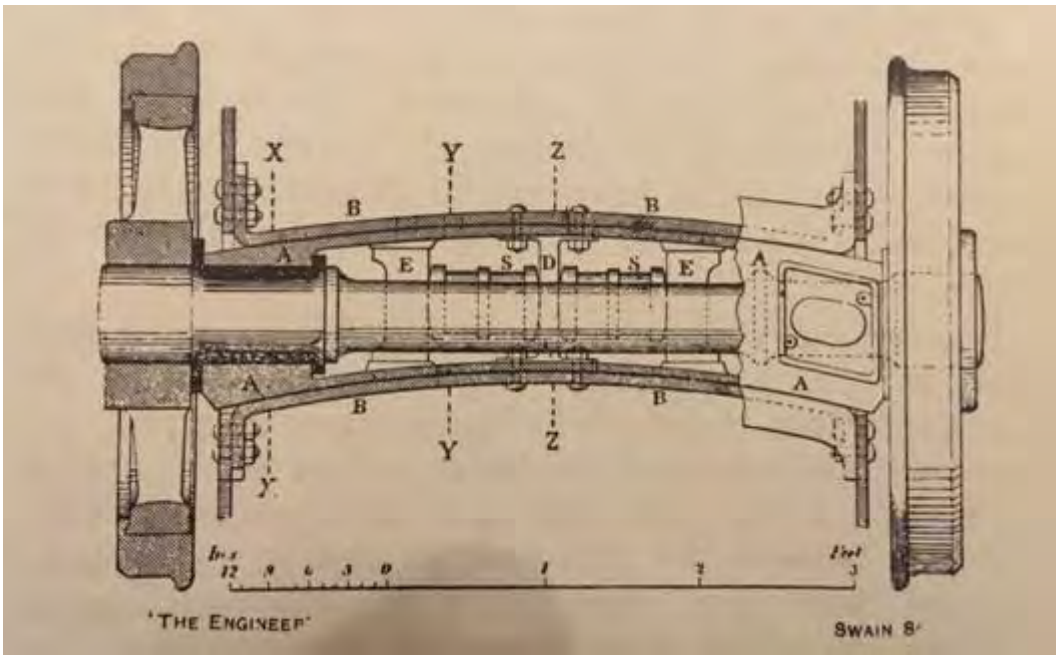


Fig 7. F. Webb's radial axlebox with rubber side control springs identified 'S'. The Bracket 'D' is fixed to the locomotive frame. As the axlebox slides laterally the two brackets 'E' – which are part of the axlebox casting – either move away or towards 'D', so compressing the rubber spring.

[7] Ahrons p. 156
[8] Ahrons p. 225

On the SER James Stirling employed compressible rubber springs as a means of lateral control on the bogie of his locomotives[9] [Fig 8]. This arrangement used an unusual linkage between the centre pivot and the bogie frame. A longitudinal link ensured the bogie maintained the correct position fore and aft, whilst lateral movement caused one or the other of the diagonal links to compress a rubber ring, thus creating a centring force.

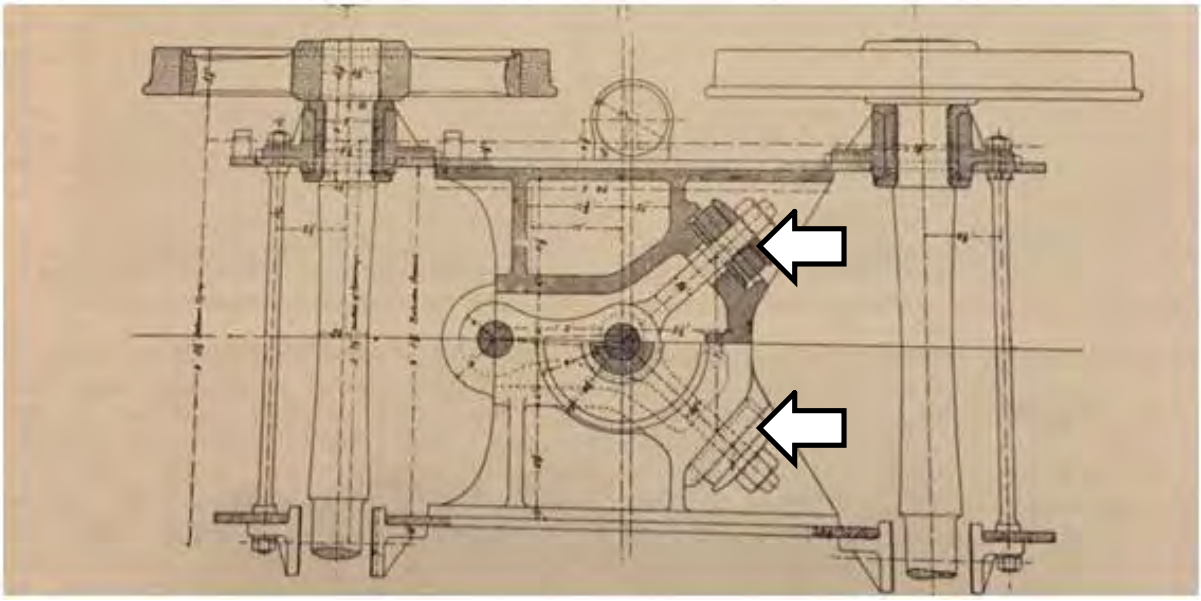


Fig 8. J. Stirling's bogie side control arrangement on the SER.
Rubber control springs indicated by arrows.

Helper Springs

It should be noted that most of the applications discussed above used rubber in direct compression. This poses a limitation on its use since the amount of spring travel is fairly limited and the spring rate is very stiff. This meant that to get a stiffness and travel suitable for locomotive main springs the thickness of rubber needed was considerable.

As the quality of spring steel improved rubber appears to have fallen from favour as the material for primary springing. However it was very quickly recognised that rubber had excellent noise attenuating properties. It was often used as "helper" springs in conjunction with a conventional steel leaf spring in order to get the required travel and spring rate. The helper springs took the form of annular rubber discs held within a cup through which the spring link would pass; tension on the link held the rubber in compression [Fig 9]. This arrangement was favoured by several railways, in particular the GNR and successors. It was noted that by the railways that drivers of engines so sprung were much less likely to suffer fatigue whilst on duty on the footplate. Several thousands of helper springs of this nature were applied to locomotives, tenders and rolling stock. Even when coil springs became commonplace it was (and still is) usual to place a rubber pad between the spring and the supported structure.

[9] Ahrons p.271

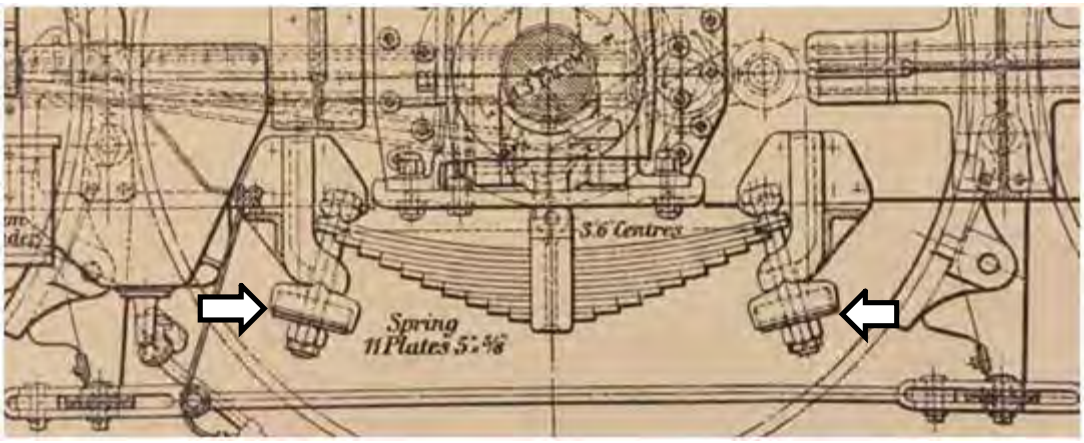


Fig 9. Rubber helper springs (arrowed) on the crank axle of LNER 10000.

Rubber also found widespread use as a spring element in buffers and drawgear and remains so to this day.

New Ways to Use Rubber

"*To eradicate the wear usual in hornblocks OVS Bulleid fitted his experimental "Leader" design, introduced 1948, with axle guides in which the relative movement was accommodated by the shear deformation of rubber units housed in cylindrical pedestals. This should also have prevented the transmission of shock loading from the connecting rods and coupling chains*"[10]

Perhaps it isn't surprising that OVS Bulleid was one of the first to introduce a novel form of axle location to his "Leader" design [Fig 10]. Unfortunately exact details of this system have yet to be found, but it is possible that it was of the "rolling rubber ring" type.

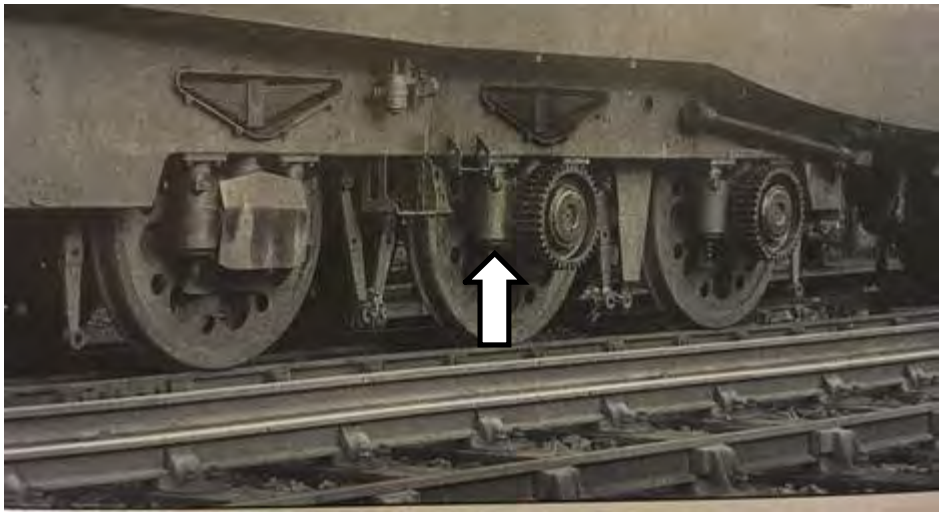


Fig 10. Bulleid's "Leader" with the bogie transmission chain casing removed to reveal the cylindrical axle guide pedestals (one of which is arrowed) which located the axle boxes and transmitted all of the thrust from the engine and brakes.

[10] Rubber Developments vol 20 no 1 1967 17.
http://www.steamindex.com/locodesn/rubber.htm

The “rolling rubber ring” is a spring element sandwiched between a cylindrical housing fixed to the base of the bogie frame and vertical pedestal anchored to the axle box. They are usually arranged in pairs either side of the bearing. The compressed rubber ring rolls between the surfaces as the axle box moves up and down. No weight is borne, but the ring locates the axle box and transmits traction and braking forces with a degree of compliance.

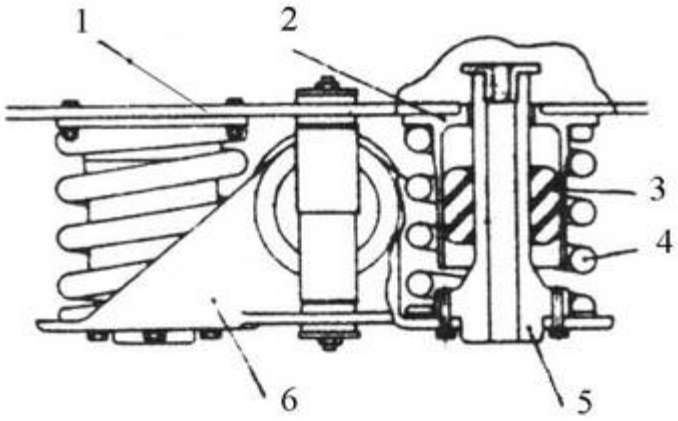


Fig 11. Rolling rubber ring pedestal guide. The rubber ring (3) is compressed between the outer guide (2) fastened to the bogie frame and the inner guide (5) on the axle box.

A variation of the rolling rubber ring (the Clouth Spring) made by Norbert Ackmann GmbH uses pedestal guides which incorporate a tapered profile on the inner faces. This compresses the rubber as it rolls providing a spring force. There are many of these units in use, especially on the continent in primary and secondary spring applications. Chief advantages are simplicity, reliability and variable spring rate by contouring the inner pedestal [Fig 12].

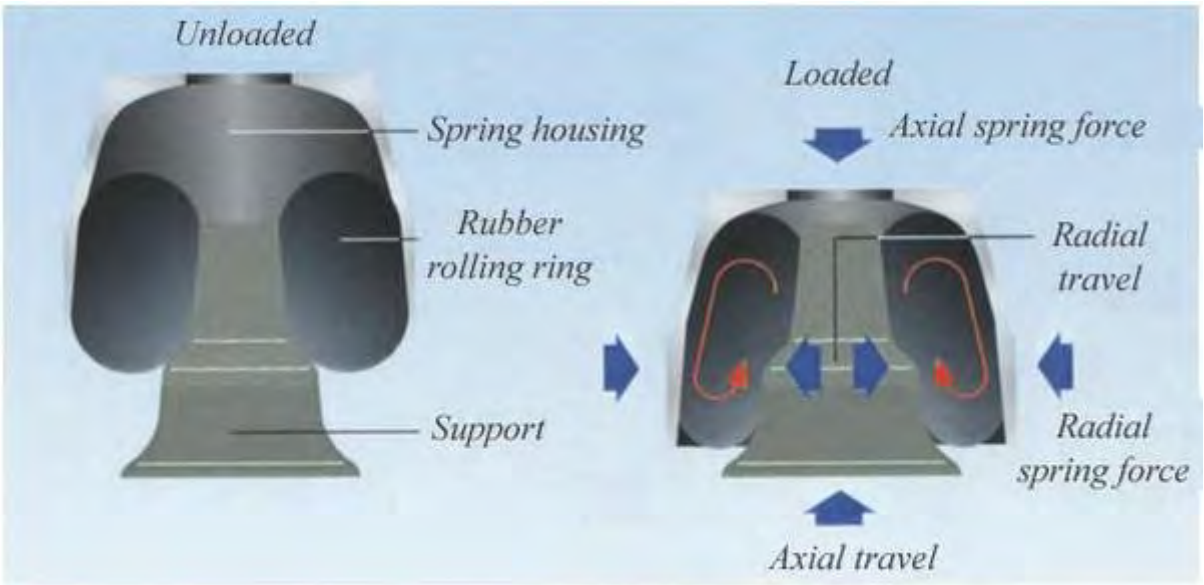


Fig 12. Norbert Ackmann rubber Clouth spring.

Enter the Chevron…

After the Second World War engineers got to grips with the various properties of rubber by creating springs for rolling stock with compression *and* shear. In 1952 London Underground trialled rubber

chevron suspensions on a vehicle. Results were sufficiently promising that by the 1960s all new underground vehicles were fitted with rubber primary and secondary suspension. This is still the case, though air bags are used in many secondary suspension (bogie to underframe) applications [Fig 13] to improve the ride quality.



Fig 13. London Underground bogie with rubber chevron primary springs and air bag secondary springs.

The key to this system is the “Chevron” which comprises a number of rubber elements divided by steel plates. The rubber and steel are arranged in a ‘V’ formation [Fig 14]. A pair of chevron springs arranged either side of the axle box provides all of the functionality which would otherwise be required from the horn guides, liners and springs.



Fig 14. Rubber chevron suspension block.

The chevrons are installed at a slight angle so the main suspension movement (vertical) is primarily in shear, which is relatively soft, with a small amount of compression. Longitudinal stiffness (for locating the axle) is very high since the rubber is acting principally in compression. Lateral stiffness is also high for the same reasons. By tuning the angle of the chevron and the angle of its installation a

wide variety of spring properties in different directions can be incorporated into a single unit. But the real benefit is that there are no wearing parts and so the maintenance costs are relatively low.

The use of rubber suspension was not restricted to London Underground. BR experimented with a variety of rubber suspension types before settling on a rubber chevron primary suspension on the Series 3 bogie [Fig 15]. A key point to note here is that the axles were located longitudinally on radius arms – attached to the bogie frame at the inner ends via rubber bushes – and the rubber chevrons only provide a vertical spring force and lateral location. The chevrons are in pairs, rotated through 90 degrees to the London Underground system, and rest on an inverted V shaped projection on the top of the axlebox. The top end of the chevron spring is bolted to a casting on the underside of the bogie frame. Due to the higher operating speeds telescopic dampers are also fitted to maintain ride quality.



Fig 15. BR/BREL/ABB/Adtranz/Bombardier Series 3 bogie
with the longitudinally arranged rubber chevron springs arrowed.

The design wasn't entirely trouble free at first since it was found that if the pairs of rubber units were not matched, turning moments could be imposed on the axle bearings which were otherwise constrained by the axle itself.

Other Modern Uses of Rubber on Rolling Stock

Rubber elements are used in a myriad of applications on modern stock. These include:

- Rubber bushes for transmitting traction forces through links into bogie centre pivots, traction links and torque reaction arms for traction motors.
- Suspension bushes for radius arms (see above), damper mounts.
- Spherical rubber bushes for anti-roll bar linkages.
- Spring elements for gangway face plates.
- Couplers and drawbar mounting.
- Over travel / Bump stops.

The items above are examples of applications where the rubber provides the main load bearing / reaction force. In each case the combination of flexibility, different properties in different directions, absence of wearing surfaces and very low maintenance, make it a good choice. Rubber components are also extensively used for gangways, air bags suspension units.

A Few Notes on Rubber

The Golden Rule is: Never use Rubber in Tension.

If rubber is stretched it can crystalise at high rates of strain, which makes the material brittle and prone to rupture.

Rubber is excellent in compression but, like most materials, when it is squashed it tends to bulge out at the sides. This can put the outer surface of the rubber into localised tension (which is to be avoided). To prevent this happening the free edges of a compression spring are usually concave so even when the material is compressed the outer surface remains in compression.

Compressive stiffness can be tuned by inserting "interleaves" into the rubber spring. The interleaves are generally bonded to the rubber and serve to limit how far it can bulge out, which increases its stiffness of a given thickness of rubber.

Rubber is excellent as a spring material in shear where it is generally much less stiff than in compression. As noted above, care should be taken to prevent the edges being put into tension, which is why rubber spring units often combine shear with a small amount of compression. Spherical rubber bushes, which are designed to work principally in shear, are often pre-compressed into the housing.

Springs should ALWAYS be designed to retain their integrity should the rubber element fail. This is usually done by surrounding the spring with interlocking steelwork designed to prevent complete detachment.

Hysteresis. Rubber has an interesting property in that the force required when compressing a rubber spring is greater than the force imposed on the load as it is released. This means for every compression-release cycle some energy is absorbed by the material i.e. the rubber is self-damping. This is a useful property which can eliminate the need for additional dampers. London Underground do not need to fit secondary dampers as the relatively low operating speed means the self-damping action of the rubber is sufficient (though the ride can be a bit bouncy at times!). On higher speed applications the amount of energy which needs to be absorbed to maintain ride quality is more than the rubber can absorb, so secondary dampers are required.

Rubber's Achilles Heel is a phenomenon known as "Creep". When subject to a load for a long period of time rubber tends to take on a permanent deformation. It is this which is one of the key governing factors on spring life. Usually an allowance for creep is incorporated at the design stage.

Natural rubber can be subject to attack from various chemicals (in particular mineral oils), ozone and excessive temperatures. This can now be overcome by additives or synthetic materials although careful material selection is still required. Degradation of the rubber may have been one of the reasons for lack of development in the early years of steam locomotives.

Conclusions

Despite early recognition of the potential of rubber as a spring material, it appears that its development was thwarted by issues with quality and the improvement in steel for springs. It was relegated to a secondary role until after the Second World War.

After the war better understanding of materials science paved the way for widespread use in rail applications. In particular:

- the ability to create consistent rubber properties;
- the ability to include additives to modify those properties;
- the ability to synthesise new types of elastomer;
- the ability to increase the resistance of rubber to temperature, creep and chemical attack;
- the understanding of how rubber behaves when subject to loads other than direct compression.

This lead to use on underground and main line rail applications, both as primary springing and in secondary roles, but it was too late for use on steam in its final years.

Post Script

To bring the story up to date, the LNWR George the Fifth project is exploring the possibility of using Polyurethane spring elements between the axle boxes and the equalising beams on the leading bogie. These would eliminate the awkwardly placed leaf springs - which are almost impossible to inspect for broken leaves - and reduce the unsprung mass.

References:

All references to “Ahrons” refer to his work “The British Steam Railway Locomotive 1825 – 1925” Second reprint 1963. The number refers to the relevant page.

The Thrill of Steam!

I cannot explain
The thrill I feel,
When I gaze upon
Those wheels of steel,
With pistons pounding,
Whistle sounding,
The puffing from
The chimney stack,
As a steam train roars
Along the track!

For I am at heart
A railwayman,
The railway is my soul,
My breath
It is of steam,
And my bones
Are made of coal.

Atlantic, Pacific,
Tender and tank,
I watched them all
From a tree on the bank,
I waved at them
And they waved at me,
Trains from the city
And trains to the sea,
No more in love
Could a little boy be!

For I am at heart
A railwayman,
The railway is my soul,
My breath
It is of steam,
And my bones
Are made of coal.

Like so many boys
I did desire,
To drive a train
Or feed the fire,
But sadly when
I reached the age,
There appeared
A Whitehall "sage",
Who to save a little tax,
Allowed to fall
The Beeching Axe!

For I am at heart
A railwayman,
The railway is my soul,
My breath
It is of steam,
And my bones
Are made of coal.

I got to drive
But not for long,
It was criminal,
So very wrong,
Not only did
Go miles of track,
But also the smoking
Chimney stack,
I drive soulless diesels now,
To which poor steam
Has had to bow.

For I am at heart
A railwayman,
The railway is my soul,
My breath
It is of steam,
And my bones
Are made of coal.

The rails now
I'm told they pay,
But I'd give my life
For just one day,
In which to see
My love, dear steam,
At a time when she
Reigned all supreme!

For I am at heart
A railwayman,
The railway is my soul,
My breath
It is of steam,
And my bones
Are made of coal.

There will come a time,
I know not when,
When my dear steam
Will rise again,
When an engine will
Be built once more,
For the joy of it
Will she be for,
Through mountains,
Past river and fen,
Dear steam I know
Will rise again!

For I am at heart
A railwayman,
The railway is my soul,
My breath
It is of steam,
And my bones
Are made of coal.

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Basic Design Details for a modern 4 cylinder 2-8-0 ©Stephen Whitehead September 2018.

My idea for a 'Lightening' Class Express Steam Locomotive; 37001 'Greased Lightening' with the cranks set at 135o and all four pistons driving the second driving axle, British Caprotti Valve Gear and Water-tube Firebox Running on Bio-Gas Oil.

I have always been a big fan of the Bulleid Pacific's ever since I was a loco-spotter as a kid. Influenced by the experience of living in Croydon and having seen as a child, around 4 years old, a Maunsell tender engine, from the road leading down the side of the track from the bridge in front of West Croydon Station, and then later Mr Bulleid's Pacific's, also a once only sighting at Euston Station, when loco-spotting around 1962, of the Duke of Gloucester in a siding, adjacent to the platform on the extreme right of the station – and being awestruck; and this would have been just before its withdrawal as that was in the same year.

Being influenced by this youthful experience on the Southern Region, what is suggested here might have been the next logical bio-gas oil fired design for this region, given that a 4-8-0 was proposed by Maunsell; also Bulleid would have preferred a 2-8-2 wheel arrangement to the 4-6-2 that he used. Bulleid was also in favour of oil firing locomotives, for which the long narrow firebox's of the 4-6-0 and 2-8-0 types are much more suitable, and it would seem potentially more stable at higher speeds with a lower profile boiler giving lower centre of gravity.

The idea of this engine is to run a 10 coach train at 90 miles an hour on the flat and up most inclines with minimal loss of speed and with as much economy of fuel and water as possible. Maximum operational speed to be 100MPH. The insulation should be such that the engine left during the afternoon, will have sufficient pressure left in the boiler the next morning to be conveniently fired up for continued usage, and an absolutely minimal day to day maintenance. The eight beats per revolution will minimise torque variations and uneven tire wear and will therefore have much reduced wheel slip, a more even exhaust draft, also reducing the stresses in the chassis and running gear.

The locomotive should look like a Maunsell engine with the same type of smoke deflector, with almost completely enclosed longer cab and long sliding side windows, wedge shaped front windows to improve drivers view which will be helped by the round topped tapered boiler; the cab sheets to be folded in behind the drivers seat to reduce draft. The numbers and names to be;- 37001 'Greased Lightening', 37002 'Nay-Sayers Lament', 37003 'Flying Dinosaur', 37004 'Pterodactyl', 37005 'Pigs Fly'.

Wheel arrangement to be 2-8-0 with 6ft 2inch drivers with lateral motion devices on the first and last pair of drivers and bissel bogie with 3ft diameter wheels and lateral control geared rollers, wheel base 29ft 6in; Distance between bogie wheel and first driver 9ft 8ins, then 6ft 6in

to the second, third and fourth drivers. *(The same as the Lord Nelson class 4-6-0's).* The axle box's to have 'Franklin' spring loaded wedges to take up wear and play, the driving axles and crank axle to have spherical (self aligning) roller bearings.

The axle box's to have 'Franklin' spring loaded wedges to take up wear and play, the welded on horn guides to have pedestal braces. The wheels of 6ft 2ins diameter of the Bulleid- Firth-Brown type, the driving wheels to have clasp brakes. The connecting rods of lightweight alloy and profile from the rear (4^{th}) pair of wheels to have tapered roller

bearings to control the uprightness of the connecting rod to the third pair which should be spherical roller bearings, spherical from the third pair of wheels to tapered roller bearings for the driven (2^{nd}) pair of wheels, spherical roller bearings from the driven to first pair of wheels which also spherical roller bearings. The axle loadings to be 20 ton's each, with equalised springing, giving an adhesive weight of 80 tons and a total weight of 90 tons.

The four pistons to drive the second wheel axle and the fully balanced crank shaft with the cranks set at 135° and placed so that opposing crank positions are adjacent (if possible the wheels to be balanced without the driving rods from the pistons to give zero hammer blow as per Holcroft), with eight beats to the revolution there is always going to be pulling and pushing of the crankshaft at every degree of rotation of the driving wheels and therefore unlikely to have a position where the crank position (blind spot) will prevent the locomotive from starting. British Caprotti Valve Gear to be used with the two centre valve gears driven by Cardan shaft from the adjacent outside valve gear, the steam supply for lifting the poppet valves should be controlled by a valve operated by the driver before opening the regulator.

The pistons with tail rod to be 24 inch stroke 15 inch bore, to have multiple narrow piston rings and multi ring glands for the piston rod for steam tightness. The driving rods of machined lightweight alloy and profile to have taper roller bearings at the outside cross- head and spherical roller bearings at the second pair of driving wheels. The inside driving rods to have needle roller bearings with nitrided steel for the journals and the big end housing in two halves with the joint vertical, spherical roller bearings at the cross head – the crank shaft will need to be well beefed up! (Needle Roller bearings for slide bars?)

Tractive Effort 152×24×300×85×2÷(72×100)= 38,250TE

Indicated Horsepower (38250×90)÷375= 9180 divide by 2 = 4,590IHP at 90MPH or (38250×60)÷375= 6120 2/3 of = 4,080IHP at 60MPH; Dividing the greater by 2 and the lesser by 2/3 allows for the greater losses at 90MPH; therefore some 3 to 4 thousand (DBH) continuous horsepower should be possible at the drawbar. At these levels it would be sensible to restrict the maximum cut off to 75%.

Direct pumped lubrication with steam oil containing 0.2% colloidal graphite (for friction and wear reduction) to the pistons in the centre of the cylinder timed to feed into the piston rings at the centre of the stroke every 40 strokes or so. The pistons should drive in the – Right outside – right inside – left Outside – left inside order with the outside pistons feeding the front-blast pipe and the inside pistons feeding the rear blast-pipe; the eight beats will then alternate between the front and rear blast-pipes. The outside and inside pistons to have a common steam chest between them equal to 1.5 times the combined swept volume of the two cylinders each side, also there should be a balance pipe between the left and right steam chests of at least 4 inches diameter. The fabricated stainless steel (for its low thermal conductivity) cylinders and end caps to be insulated and the liners to be pearlitic chromium cast iron and have multi ring glands to the piston rods for the least amount of steam leakage possible and minimal clearance volume. The pistons to be light weight of steel with 7 narrow rings, five of cast iron one grade harder than the piston liners, the second and sixth rings to be of bronze (will bronze the cast iron and further reduce friction and wear). The outlets from the cylinder drain cocks should be routed to the front centre to avoid depositing oil on the rails.

The boiler to be All welded steel round topped boiler to be used tapering up at the top from 5ft 4in at the smoke-box to 6ft at the fire-box, the barrel to be 12ft long, an economiser plate one third of barrel length away from the smoke-box tube plate to isolate the feed water; three safety valves to be mounted radially in front of the fire-box and the

dome for steam collection in front of the valves. The boiler pressure to be 310lb per sq in to run at 300lb per sq in to avoid the safety valves blowing off. There are to be 88, 92 or 96 large tubes (flue's) for the super heater (no small tubes). The boiler smoke-box and fire- box to be surrounded with 4 inches of the best type of insulation. Use automatic pumped water feed with Porta feed water treatment.

The all welded steel fire-box to be of the water tube type, as this completely eliminates the problems of stays, which in the case of the Nelsons (LN class) were prone to braking, as was re-discovered in 2004 when such braking precipitated the collapse of the brick arch while running on the main line. The length of the combustion (grate) area to be 12 feet. The top of the fire-box to be an oval shaped drum tapering down from the barrel to the cab, and the sides tapering in by 6 to 8 inches to the cab, this will give better forward view, the gas tight welded together pipes leading down to a smaller drum each side of the fire brick grate area, with a shaped combustion area in the firebrick grate with tangential air tubes to swirl the combustion of the vaporised oil from the primary jet and the pilot jet (Laidlaw Drew Swirly-Flow). The arch could be either concrete or high temperature steel.

For the oil burner, the fire-box to have an aperture at the front centre under the boiler barrel, for the atomised gas-oil from the burner, powered with superheated steam controlled by the

regulator, into a combustion area under the fire arch, pointing slightly upward[1] with tangential air flow to swirl the combustion; there being no impingement with the firebrick or steel boiler walls which will reduce maintenance. A smaller burner below for a pilot powered with superheated steam. (An alternative may be to have two burners with the pilot between)

Feed-water heated by two closed circuit surface type feed water heaters, one for the the outside and one for the inside exhaust outlets and placed each side of the barrel just behind the chimney, being inside the hot smoke-box the pipes will not need to be insulated, as they will feed up directly into the feed water heaters above, which will be placed directly onto the barrel and the insulation placed over the top of the feed water heaters and the barrel of the boiler. The feed water pump to be on the right hand side above the running plate and also the two clack valves below the boiler waterline feeding into the economiser, the second clack valve for a standard live steam injector.

Type E super-heater to be used, each bifurcated element occupying two flue's (or four?). Two 12 inch diameter pipes from each end of the super-heater chest feeding each steam chest between the pistons one on the left and one on the right. The steam should be heated to 450°C. The three regulator valves, small – larger – big, to the same design as the Caprotti poppet valves, to be after the super-heater, these valves can be steam operated (held open, held shut by reversing the steam pressure from bottom plunger to top plunger) from the three position regulator, their resting (no steam) position being closed.

The smoke-box to be sufficiently long, around 6 ft, to allow the blast pipes to be positioned low down in front of the inside pistons. Use double Lempor blast pipe, one fed from the outside cylinders and the other fed from the inside cylinders each with coaxial Kordina under to isolate the exhausts from their respective cylinders, with a take off between the Kordina and the Lempor blast pipe of each for the two surface feed water heaters and the two element heat exchanger to heat the combustion air. The blast pipes should be Between the tail rods of the centre pistons and at the lowest possible point – sunken into the lowest point of the round topped straight sided smoke-box.

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1 It may be that there is enough tendency for the flame to rise that the burner should be horizontal.

The tender to have the rear part of the cab built into it and be of the double bogie water cart type holding 10,000 gallons of water 2,500 gallons of Bio-Gas oil fuel, to look outwardly like a Bulleid tender with corridor to support wagon. The wheels to have clasp brakes.

CAB INDICATORS drivers side (left), Speed indicator showing miles per hour, Indicator to show variation of speed between bogie and driving wheels so that any tendency to wheel slip is

visible to the driver, steam chest pressure gauge, water gauge, in cab signalling, vacuum and pressure brake gauges and any others deemed necessary.

CAB CONTROLS drivers side, three position regulator giving cracked open for coasting, small opening for engine movements, then full open, the steam valve for lifting the poppet valves should be so placed that the regulator cannot be moved until it is open; cylinder cock lever, reverser making one full turn in each direction from mid-gear for easy full regulator driving control, the steam brake levers each conveniently placed for the drivers hands from his seated position and a foot operated brake for the driving wheels only to control wheel slip. Not forgetting a lever for the whistle so that the driver (or fireman) can announce Yeah-Yeah-Here-We-Come.

CAB INDICATORS fireman's side (right), boiler steam pressure gauge, superheat steam temperature gauge, water gauge next to which should be the gauge with floating ball to control the feed water pump, lubricating oil pressure gauges.

CAB CONTROLS fireman's side, water injector controls, oil feed taps for the burners, fire-box air damper controls.

DAY to DAY Maintenance, none other than inspection, ensuring that oil reservoirs are topped up, and polishing the paintwork! Also of course seeing that there is enough fuel and water in the tender.

The entire forgoing basic design details are based on the writings and works of David Wardale, Livio Dante Porta, Alan J. Haigh, Andre Chapelon, O.V.S bulleid, R.E.L. Maunsell, Harry Holcroft, E.S. Cox and others.

This is a work in progress, as yet unfinished.

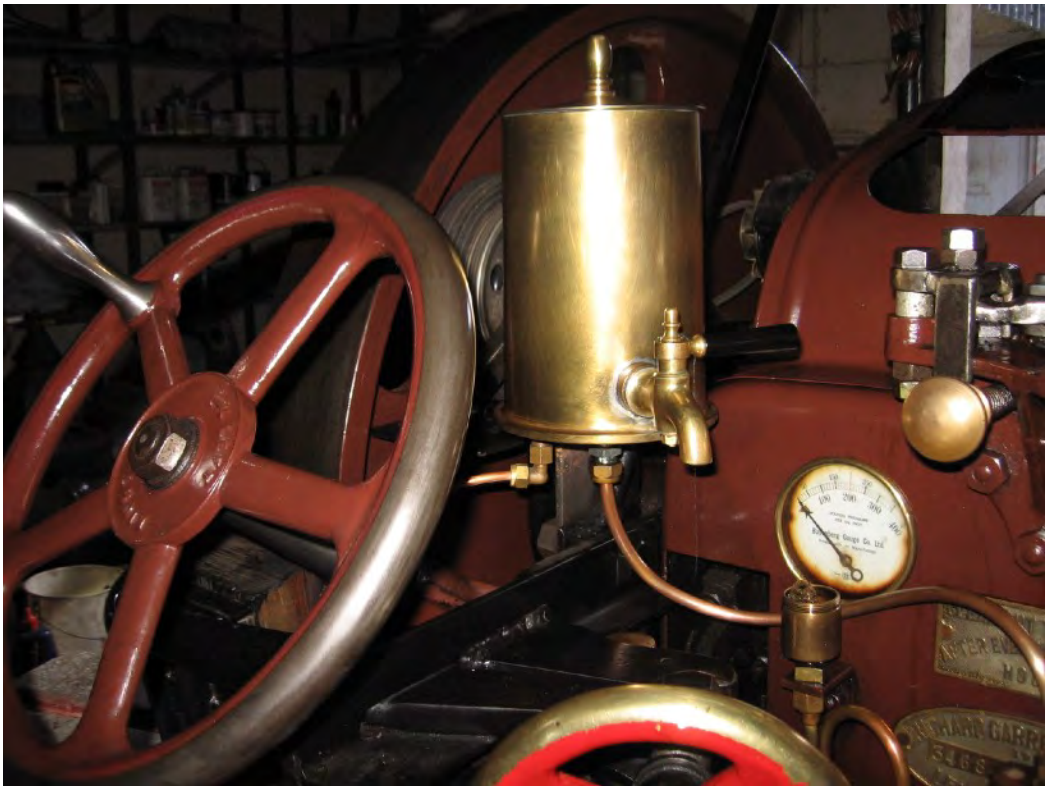
Stephen Whitehead. 13th September 2018.

“Hi tech” Equipment at The Great Dorset Steam Fair

James Evans

ASTT member James Evans’s traction engine at the GDSF with a picture of the steam kettle below. The kettle was made out of a WW1 shell case, every engine should have on for the occasional brew. (Photos: James Evans)





BUILDING A LARGE SCALE FOWLER STEAM LORRY Martin Johnson

1 CONCEPT

Like most model engineers, I have built a variety of models and these days concentrate on road steam since I get bored driving round in small circles. So, for a variety of personal reasons, I decided my next model would be:

1. A model based on the Fowler steam lorry in as large a scale as could be manufactured “in house”.

2. The vehicle to seat two persons (driver and stoker), preferably inside the cab, but at least under cover. (I live in the Scottish Highlands where it rains just occasionally)

3. The vehicle to be capable of a reasonable turn of speed for use on busy roads. The legal limit without having to go through IVA testing is 15 mph and this would be the design cruising speed. It should also be equipped with hazard beacons for high visibility.

4. The boiler would have a Bar-Litre rating just within the 500 limit that could be tested by club inspectors. Anything larger would require testing by a professional inspector, imposing a major increase in running costs.

2. DESIGN PHASE

The design would be my own, based on Fowler’s lorry. Design takes quite a lot of time, but I looked forward to having total control – and not having to blame another designer for the errors in the drawings. I was also keen to explore some of the more theoretical aspects of engine and vehicle design. The full size Fowler lorry had a “reputation” of the wrong sort, and many were part exchanged or scrapped within just a couple of years of new. I would have the opportunity to find and sort out Fowler’s design mistakes along the way. I shall discuss the various aspects of the design work below under separate headings, but in reality they are all connected and were tackled together.

2.1. How Big?

Initially, I tried to work out a design based on the Fowler steam lorry in 9” scale. I even cut some metal, but it soon became clear that 9” scale was not going to work for me. The route out of this problem was found by reducing the engine and gearbox unit to 6” scale, but revving it somewhat faster than 1920 steam practice would suggest, thus getting the proverbial quart from a pint pot. I felt comfortable that 1000 rpm was probably still quite conservative. This had the added bonus of leaving more room in the cab for over scale driver and mate.

The next problem was to see how small the chassis and body could be made and yet still accommodate two people. It is a strange paradox that a 4" and 6" scale lorries usually take just one person "up front". I estimated that something around 5/8 to 2/3 scale would allow 2 people "up front". I then constructed a half cab model in 7” scale, and adjusted it to suit to ensure clearance particularly for heads and feet. I also found that a somewhat higher and longer cab than scale would be needed to sit in, but that these changes could be worked in without unduly compromising the appearance of the vehicle.

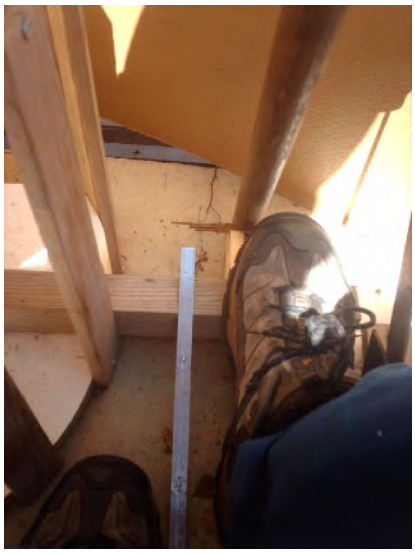


Photo 1 **-** Wooden half cab mock up showing how clearance for feet round the cab, steering column and boiler can be an issue.

Outline Design

There was an outline design phase prior to detailing to ensure that steam demand of the engine and predicted boiler steam production would match. Jim Ewins addressed this type of problem with his Ee factor; however, his correlations are of 5” gauge rail practice which is clearly not directly applicable to larger scale road engines, although the principles certainly are.

It seemed to me that there are two conditions to satisfy:

- Maximum torque - Starting the vehicle from standing against the worst conditions - fully loaded uphill, on soft mud, in a rut for a road vehicle. Equivalent to Tractive effort in a rail based application.

- Maximum power - Running at speed fully laden uphill. Equivalent to maximum Draw Bar Horse Power in a rail based application.

In both cases the resistance will be roughly proportional to vehicle weight (wind resistance being negligible at 15 m.p.h.), so the two ratios Tractive Effort / Vehicle Weight, and Power / Vehicle Weight, need to be similar to other steam vehicles.

Fortunately, I had some published test data for a Sentinel wagon(Steaming Magazine Summer 1987), the full size Fowler wagon (Fowler Steam Road Vehicles, W.J. Hughes) and I had also done some simple tests on my 4" scale Burrell which gave me some benchmark values. To estimate horse power generation, I analysed some results in "A Traction Engine Miscellany" by R.H. Clark to derive an indicated efficiency, which worked out at 50 % based on the available enthalpy drop across an engine. The ability of a boiler to provide sufficient steam must also be considered, so I calculated the grate loading required to produce the steam assuming (rather conservatively) that 1lb of coal produces 6 lb of steam. The results came out as follows:

Table 1: Comparison of key parameters of proposed lorry design

	4" Burrell + Trailer	Fowler Full Size	Sentinel Full Size	Fowler 7" Scale
Estimated Weight lbs	1707	37649	52885	3659
Tractive effort in Low gear lbs.	590	5631	5620	594
TE / Weight	0.346	0.150	0.106	0.162
Estimated HP	1.82	30.61	34.47	6.63
HP / Ton	2.39	1.82	1.46	4.06
Firing Rate lb/sq.ft/hr	21	24	32	31

Estimating weights at design stage is always a tedious and approximate job, so there is uncertainty there and using a 50% indicated engine efficiency without taking account of superheat is also a gross approximation. In addition, a 6:1 ratio of evaporation to coal is usually conservative, but it rather depends on the boiler design. However, the table shows that the proposed miniature should have plenty of starting effort compared to it's weight and the power per ton is generous. The grate loadings are all modest compared to my statistical analysis of model locomotive efficiency competition results which shows typical grate loadings of 40 lb/hour for 5" gauge locomotives. In short, the overall design looks feasible, but there was a lot more detail design and analysis to be done.

As part of the above exercise it became apparent that duplex cylinders in the model would make better use of the available boiler power, which is discussed in more detail below. I notice that most of the model Foden steam wagons have duplex cylinders (the full size ones were compound) but they run very well from a scale size boiler.

2.3. Boiler Matching & Superheaters

The original Fowler boiler was a vertical firetube unit of 3.8 sq. ft. grate, and 85 sq. ft. heating surface supplied via a vertical stoke chute. The smokebox was water / steam jacketed and the tubes were fully submerged. An extra large diameter steam space helped to ensure dry steam. A superheater coil of 12 (or 21, depending on source, I made it 16 by scaling from drawings) sq. ft. was fitted in the smokebox space. Blow off pressure was 225 p.s.i.

The evaporative capacity of the boiler should be similar to the Sentinel product; The grate area of the Sentinel and Fowler boilers are similar. Cylinder sizes for the Sentinel are similar to the HP of the Fowler, but of course there is only 1 high pressure cylinder taking steam on the Fowler compared to the 2 cylinders of the Sentinel. This indicates the Fowler boiler output was under used, by a factor of around 2, thus confirming my decision to make the Fowler miniature a duplex or double high design.

The Sentinel S series had some 24 square feet of superheater, so would have had a much higher superheat than the Fowler, and this seems to be key to a successful design in any scale. Fowlers claimed their engine could develop 55 b.h.p., but the Sentinel developed 130 b.h.p at peak from an identical grate area!

Following on from the above observations I have undertaken over two years of work on the thermal design of miniature boilers. This has resulted in a computer program which will predict performance (quantity and temperature of steam) from the geometry of the boiler; an article describing this work have been published in 5 parts in Model Engineer, starting at issue 4584 running to 4595. I plan to undertake further work to predict engine performance, picking up where Professor Bill Hall left off and have made a start on this, but the work is only just started.

2.4. Engine Valve Gear

I soon found major problems with the Fowler incarnation of Hackworth valve gear. The Fowler engine is of "V" configuration with short connecting rods and each cylinder is a mirror image of the other; this means that one cylinder is going "forward" while the other is in "reverse". Therefore, the valve gear has to give good events in both forward and reverse. Hackworth valve gear can be made to give reasonable results with relatively long connecting rods, but with the short rods in the Fowler engine the problems become acute. Analysis of the design using Dockstader's program gave the rather disappointing results shown in Figure 1. It will be seen that there are large deviations between the forward and rear conditions.

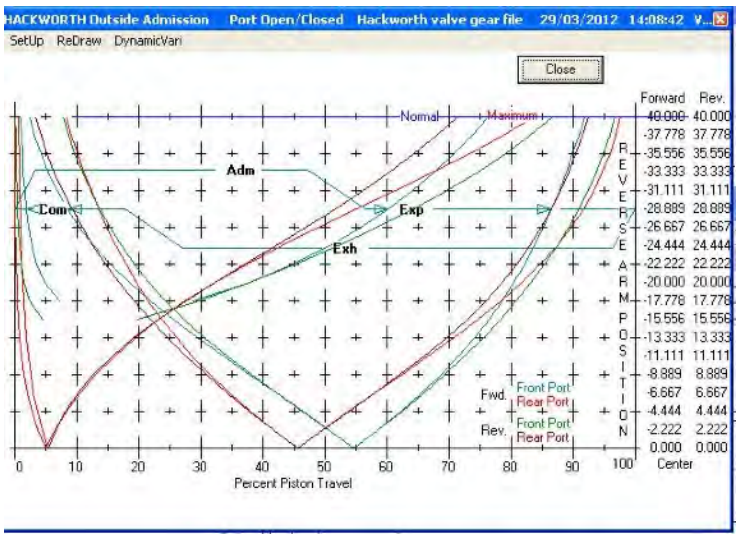
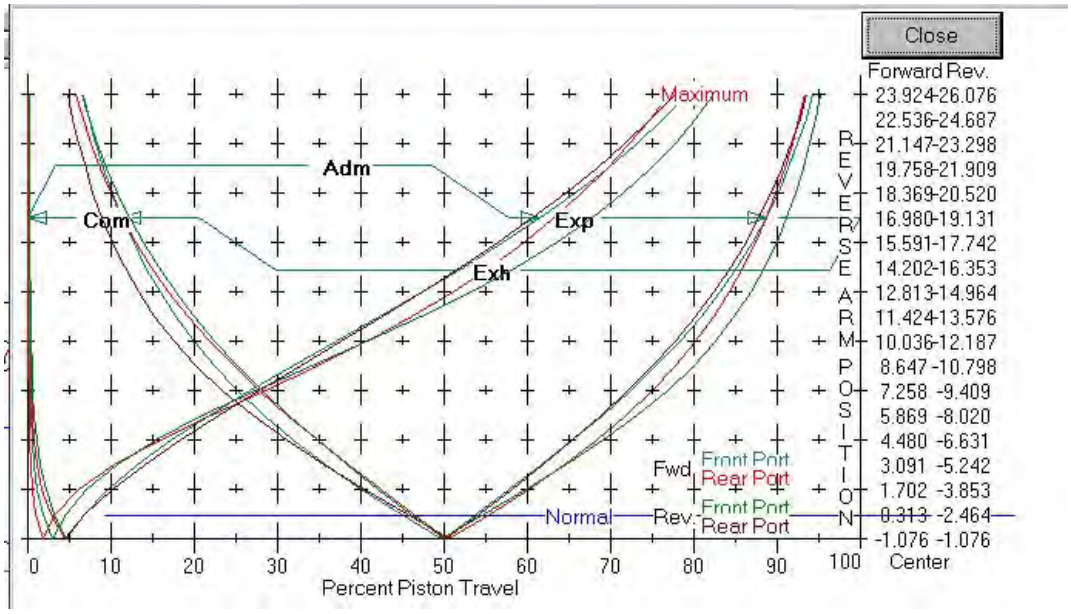


Figure 1: Screen Shot of analysis for Hackworth Valve Gears

I substituted Woolf valve gear for the Hackworth - they are both radial gears, the Woolf having an extra linkage to reverse the travel and hence cancel out some of the inherent errors. I have to acknowledge significant help from Simon Bowditch and Don Ashton in this department, but after some development the results were as shown in Figure 2 which shows much better grouping of the curves, indicating a more consistent performance for both ends of the cylinder in both forward and reverse gears.



Using the Woolf valve gear meant another linkage to design and make, but solved an awkward problem of aligning the cylinder blocks at a strange angle as done on the Fowler. One disadvantage is that the Woolf valve gear applies to outside admission valves, so I have outside admission piston valves on the model - a rather unusual choice.

3. THE ENGINE UNIT

The engine is a double acting duplex unit of 70 mm bore and 100 mm stroke. I have also made patterns for a compound version which would have a high pressure of 60 mm bore and a low pressure of 90 mm bore, both on the common 100 mm stroke. All components for the compound cylinder version are identical except the cylinder block, end covers and piston. This gives me some "insurance" should steam consumption be found to outstrip steam production! The engine is designed for up to 1000 R.P.M. on steam at 160 p.s.i. although the calculations indicate it could be pushed further if required. The total engine& gearbox weight is 125 kg, due mainly to the extensive use of aluminium components (Crankcase, gearbox, connecting rods, eccentric rods, crossheads, cylinder and piston valve covers), and rigorous attention to weight reduction (drilling holes in things, not over-engineering things). Bearings are ball or roller type with the exception of the following:

- Valve gear - case hardened steel on through hardened steel or oilite bushes as appropriate.
- Little ends - phosphor bronze on hardened steel.
- Crossheads - 6086 T6 aluminium on cast iron.

Nitrile rubber lip seals are fitted for oil retention. The Fowler unit was splash lubricated apart from the cylinder oil. However, I found on testing that there is insufficient oil "fling" to get oil to the upper parts of the crossheads & trunk guides, so have modified the design and will be using mechanical lubrication to deliver sump oil to the crossheads and upper areas of the valve gear.

Figures 3 and 4 show cross sections of the engine unit. Both show the piston valves have the events controlled by the piston rings and the valve heads are chamfered off at 45 degrees to aid steam flow.

Cylinder lubrication will be delivered at four points adjacent to the piston valve heads from a 4 gang Manzel style lubricator. I have avoided any atomisation of the oil, since steam temperature is designed to be in excess of the oil flashpoint, but by keeping the oil in contact with metal I hope to avoid lubrication problems.

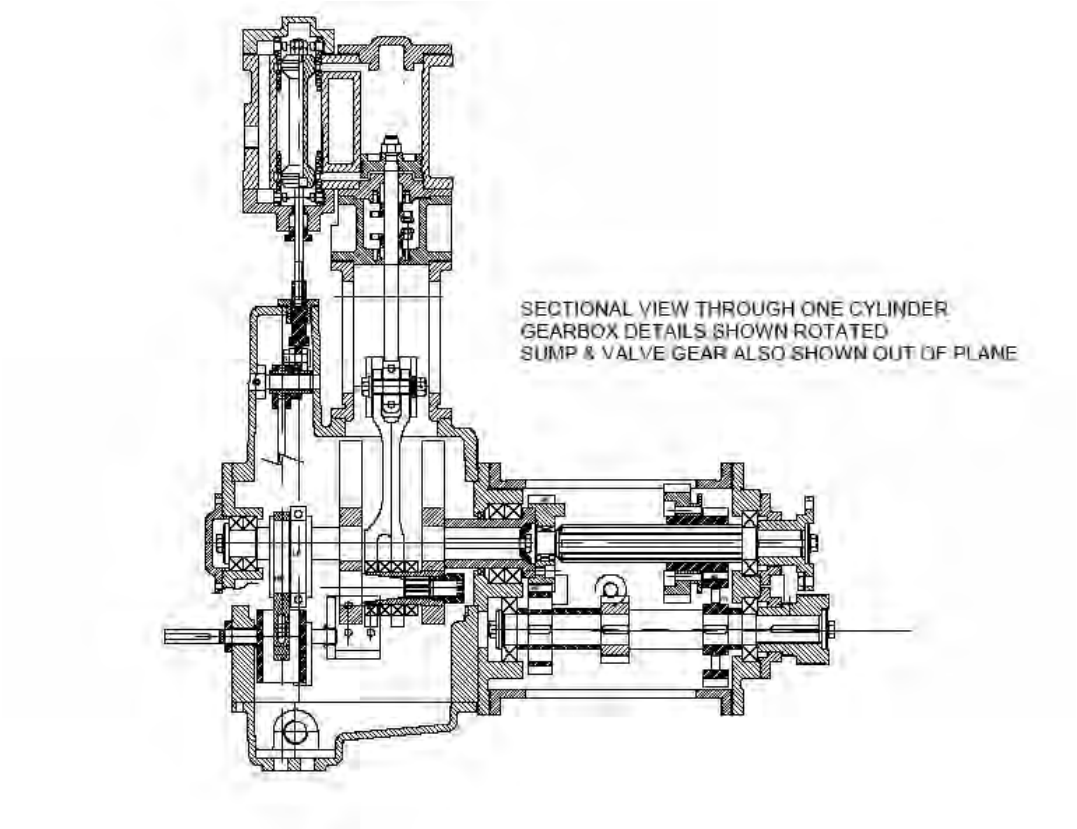


Figure 3 - Sectional arrangement through cylinder bank & gearbox.

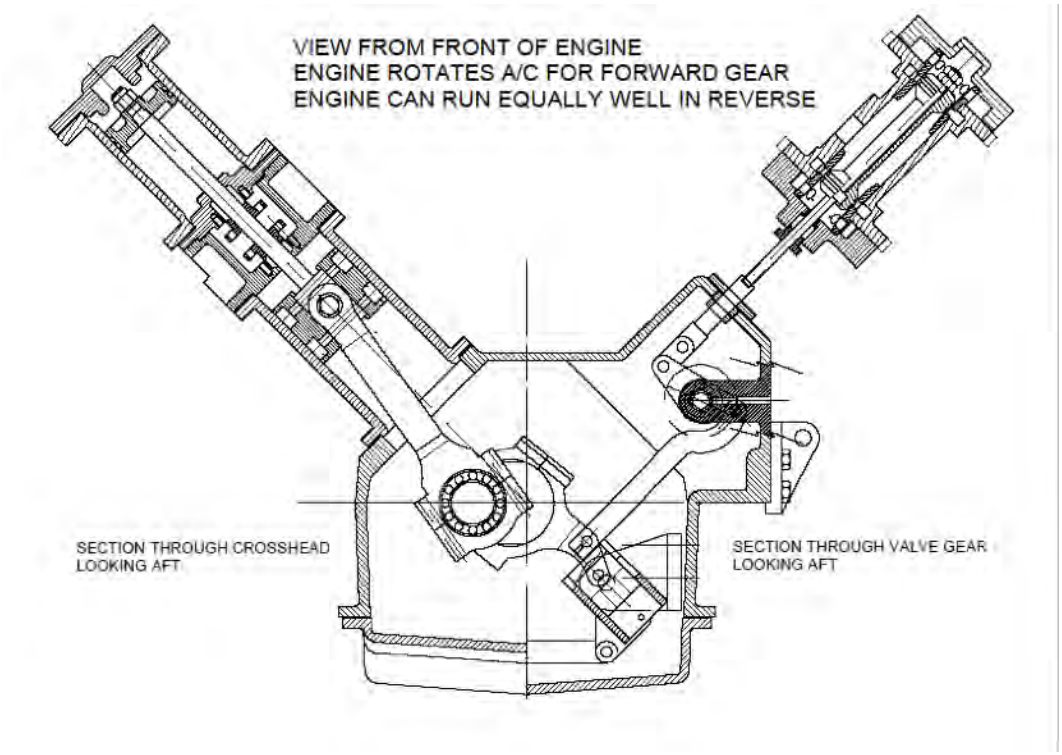


Figure 4 - Sectional arrangement through cylinder and valve gear

The engine and gearbox unit were ready for running on compressed air in Autumn 2015. The complexity of the engine unit can be appreciated from Photo 2, which shows a worm's eye view with the sump removed. The front of the engine and valve gear is at the bottom of the photograph, while the two connecting rods are

toward the top. The size of the project can be appreciated from Photo 5, which shows the engine and gearbox unit on it's building stand in front my 4" scale Burrell traction engine.

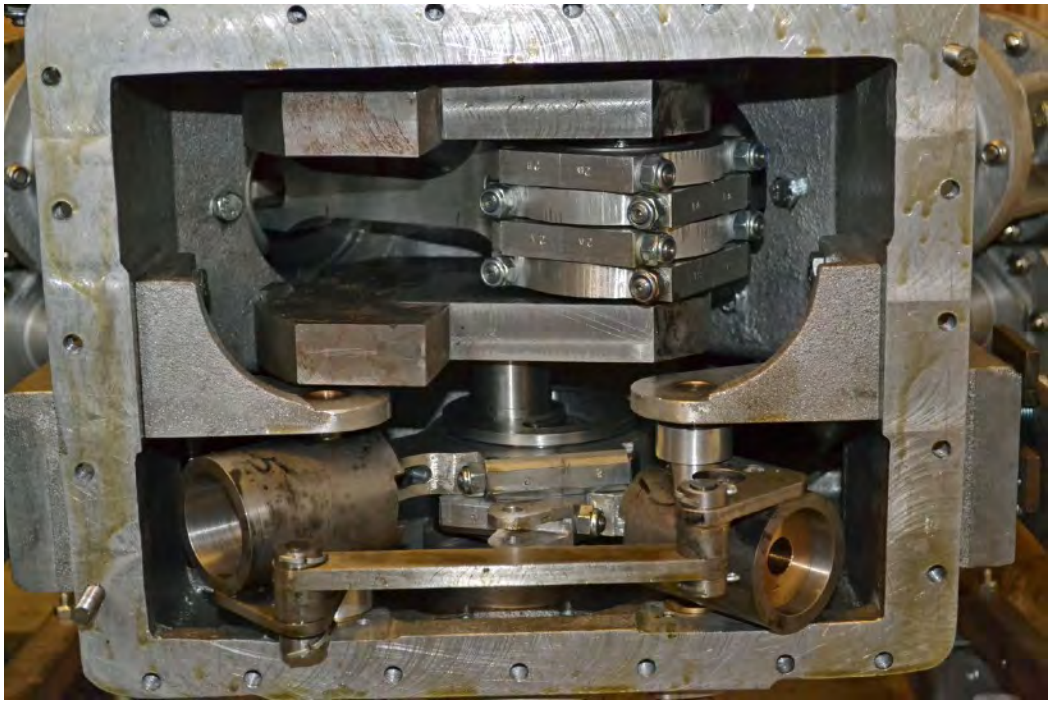


Photo 2 - Worms eye view of engine.

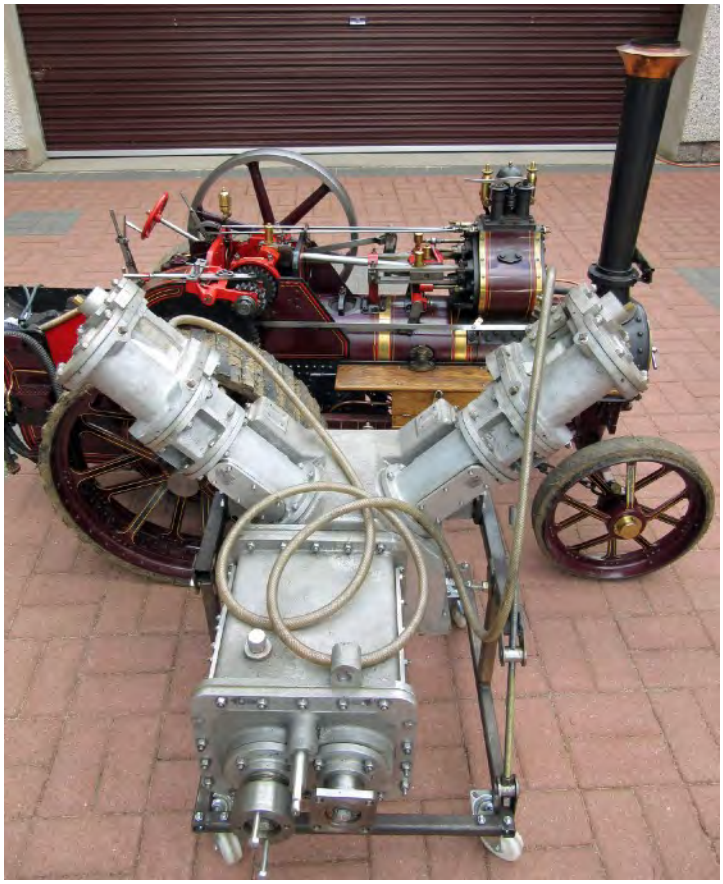
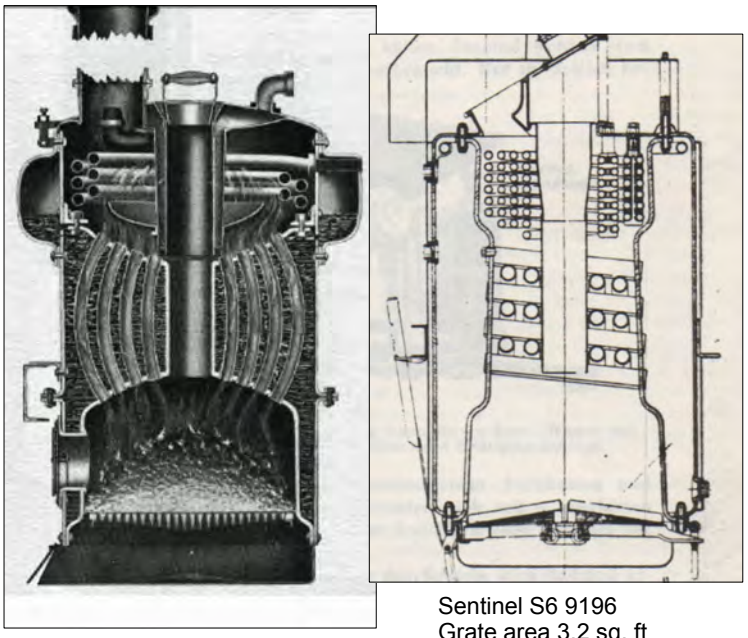


Photo 3 - Completed engine and gearbox unit in front of 4" scale Burrel

4 THE BOILER

The boiler is clearly the heart of a steam lorry, and I set myself a target of keeping the capacity within 500 Bar Litres, which means it can be tested under model engineering club rules. I also decided that the working pressure would be 11 Bar, very similar to the 160 p.s.i. of my Burrell which I feel comfortable being near. It is important to remember that within the confines of a steam lorry cab, there is not much chance of rapid escape if a serious leak develops.



Fowler
Grate area 3.8 sq. ft

Sentinel S6 9196
Grate area 3.2 sq. ft

Comparison of Fowler & Sentinel Boilers

Figure 5: Comparison of Fowler and Sentinel Boilers drawn to same scale.

Figure 4 shows the Fowler unit had a large diameter jacket to provide steam space, which is good for ensuring dry steam and a slowly changing water level. However, a scale version would have been very expensive to construct and would not have left very much room for the driver and fireman, who remain obstinately over-scale. I therefore opted for a parallel outside diameter and selected 18" nominal tube for the main barrel with a 15" tube for the firebox; this latter is not so readily available but is used on some 6" scale traction engine models for the main shell. My initial design was for a unit with steam space around the smokebox. However, a calculation of water volume between top and bottom nuts of the water gauge divided by the peak evaporation rate showed that water level would go from top to bottom in under 2 minutes; if a water feed problem develops, it is unlikely to be solved in under 2 minutes, so, I dispensed with the smokebox steam space, which gives a longer time to sort any water feed problem or drop the fire.

The next thing that is very apparent from Figure 13 is the difference in superheaters. The Fowler has 1.6 square metres, compared with the Sentinel at 2.2 square metres. In addition, the Sentinel uses two smaller steam pipes in parallel, which virtually fills the top part of the flue space, giving efficient heat transfer to the steam; conversely, the Fowler superheater does not fill the space (a baffle being used to direct gas flow) and is a single large diameter tube. Given that hot steam is essential for an undertype wagon to work well, and even more essential for a compound engine to work well, it seems to me that the Fowler was insufficiently superheated. Driving experiences that I have heard reveal that the Fowler only came "on song" during a long run when the whole boiler had time to warm through thoroughly and achieve a sufficient amount of superheat.

Professor Bill Hall did tests on a "Speedy" cylinder to determine the loss due to condensation in a steam engine cylinder. His results can be plotted as a graph of steam ratio (That is the actual steam used divided by the theoretical steam required) against superheat, as shown in Figure 6. This shows the steam

consumption can be up to 2.5 times the theoretical demand if no superheat is employed. For larger engines than Speedy and steam conditions other than around 5 Bar, the values on the graph will change (generally reducing), but the same pattern will be shown. Therefore, effective superheat is critical to getting good performance out of a small boiler and engine, by reducing steam demand caused by condensation loss in the engine.

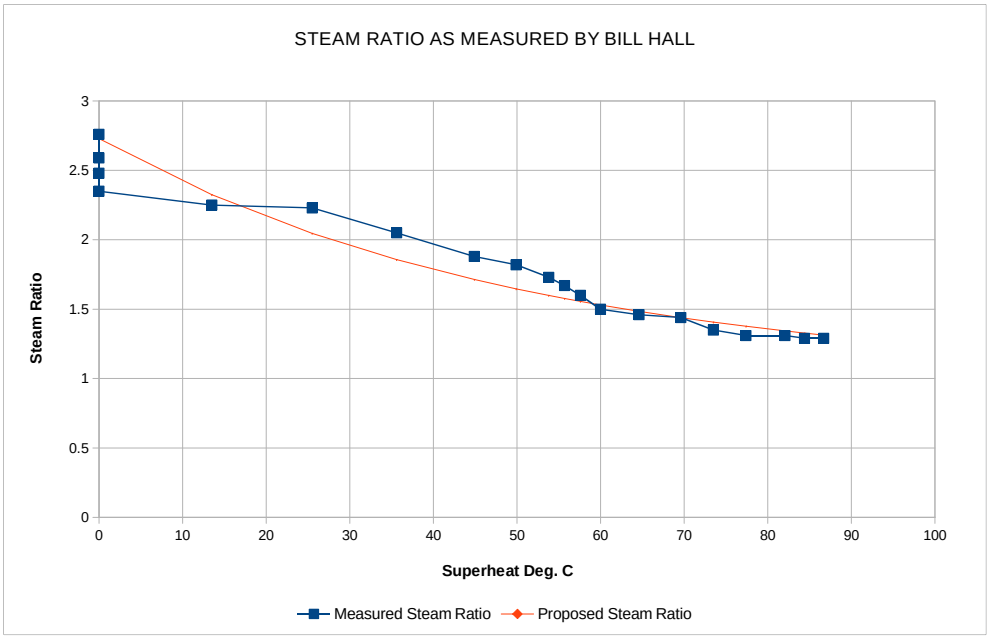


Figure 6: Variation of steam ratio against superheat.

Blue - Measured Steam Ratio Red - Proposed Steam Ratio

I have been studying methods of predicting boiler performance for the last few years and have developed a program for locomotive boiler analysis. This has been reported elsewhere, and a summary along with the program can be found at:

https://www.model-engineer.co.uk/forums/postings.asp?th=136027

I modified some of this work, which was aimed at conventional locomotive boilers, to deal with the vertical fire tube units with smokebox coil superheaters as shown in Figure 5. I am indebted to a member of TractionTalk Forum for passing me a set of tests on a Sentinel S6 steam lorry conducted during WWII in Germany. These included remarkably detailed tests of boiler performance, which allowed me to validate my coil superheater calculations. I summarise in Table 2 some key test results and my predicted results. The table shows test results for the Sentinel in the left column, followed by predicted results for the Sentinel. These show that I was able to get good agreement except for boiler exit temperature. This may be because the German test results were taken at the chimney top and include the effect of exhaust steam, whereas my calculation refers to flue gas at the base of the chimney.

The next two columns show the full size Fowler performance and the model Fowler performance respectively. Note that all three predictions are made using the same calculation procedure that was validated against the Sentinel test results. This table reveals the key difference between a Fowler and a Sentinel boiler:

- The Sentinel boils a relatively small amount of water per pound of coal burnt (7.1 lb/lb), but superheats it to a high temperature (470 Deg. C) giving a superheat (Steam temperature - saturation temperature at that pressure) of 289 Deg. C.

- The Fowler boils more water per pound of coal (8.3 lb/lb), but superheats it to a lower temperature (297 Deg. C) leaving only 117 Deg. C of superheat over saturation temperature.

- The Fowler is slightly more efficient at converting coal energy to steam energy.

- The Sentinel gives the better performance as a vehicle (from various driver reports) since any undertype engine demands high superheat to work effectively.

- As an aside, the high steam temperatures also throw light on the habit of Sentinel engine inlet valves to stick after being worked hard. Note that most steam cylinder oils have a flash point around 290 Deg. C, so will degrade quickly at temperatures above that point.

The final column of the table shows the predicted performance of my boiler design The grate loading is a little lower than full size practice, and the air / coal ratio is a little higher; analysis of full size and model locomotives has demonstrated this trend in practice. I have incorporated twin parallel superheater coils, as in the later Sentinels. This gives a predicted steam temperature of 380 Deg. C, but by injecting the cylinder oil at four points adjacent to the piston valves, I am hoping that the oil will be subject to metal temperature, which is considerably lower than the full steam temperature. If I am wrong, it will be easier to remove superheater surface than to put more in!

Sheet1

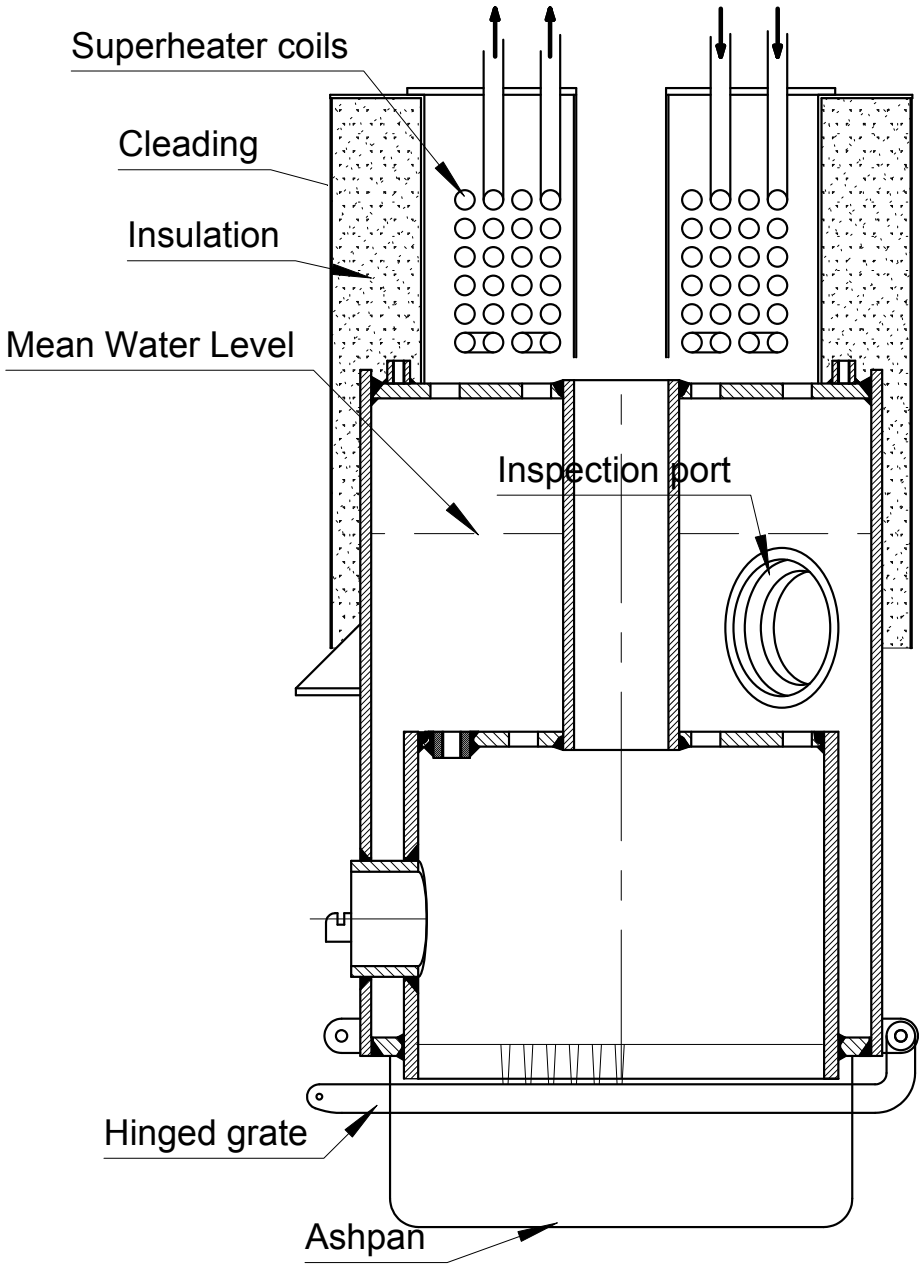
BOILER DESIGN	SENTINEL S6 No. 9196 AS TESTED BY HENSCHEL	SENTINEL S6 PREDICTED RESULTS	FOWLER FULL SIZE DESIGN	FOWLER MODEL DESIGN	
WORKING CONDITIONS SELECTED					
GRATE LOADING	0.0622	0.0622	0.0622	0.0549	kg/m2/s
FUEL FLOW	0.0186	0.0186	0.0221	0.0052	Kg/S
AIR TO COAL RATIO		13.0	13.0	14.0	Air/coal mass
DRYNESS FRACTION OF STEAM		99.0	99.0	99.0	%
BOILER WORKING PRESSURE		17.01	17.01	10.88	Bar
PRESSURE AFTER REGULATOR		9.00	9.00	7.00	Bar
MAX. TEMP IN FIREBOX		1505	1541	1359	Deg. C
INLET TEMP TO FLUES		1180	1186	1175	Deg. C
EXIT TEMP FROM FIRETUBES		910	795	783	Deg. C
EXIT TEMP FROM BOILER	380	587	618	552	Deg. C
CALCULATED EVAPORATION RATE		1.326E-01	1.842E-01	3.768E-02	kg/s
EVAPORATION RATE/ FIRING RATE	7.1	7.13	8.3	7.20	Ratio
ENERGY IN STEAM PRODUCED		423	516	111	kW
BOILER EFFICIENCY		68.08	69.98	63.26	%
SUPERHEATED STEAM TEMPERATUR	470	465	297	380	Deg. C
SUPERHEAT		289	117	217	Deg. C

Table 2 : Summary of test results and predictions for Sentinel, Fowler and model Fowler.

Now Table 2 might suggest that I analysed the Sentinel and Fowler and then came directly to my proposed design - far from it! There were a whole load of variations investigated along the way such as:

- Longer / shorter firebox
- With / without a steam jacketed smokebox
- With spearhead superheaters instead of coil superheaters.
- More / Less superheater coils in various sizes of tube.
- With various sizes & layouts of firetubes
- and in every case, the dimensions were adjusted to make full use of the 500 Bar Litre testing limit.

The net result of my labours is shown in Figure 6, showing a Sentinel style superheater grafted onto a basic vertical firetube boiler.



4.1 Steel Boiler Design

Not many people undertake the design of their own welded steel boiler, but for those that do I hope the following notes may assist.

Once I had an outline design that seemed promising, I had to translate it into a pressure vessel design that would satisfy the Pressure Equipment Directive. As a start I purchased drawings for the Steam Boat Association of Great Britain vertical firetube boiler No. 101. This has an 18" outer shell, but there the similarity ended - different firebox size, different tube size, no vertical stoke tube. In addition, the SBAGB boiler design was from 2005 and things have moved on since then in terms of material specifications, need for detail on drawings and approval process. So while they were of some help, there was not much I could use from the SBAGB drawings.

The Model Engineering Liaison Group (MELG) code for examination and testing has some weasely words on Design Verification (Section 5). The usual starting point is "Chat it over with your club boiler inspector", which revealed that designing from scratch was way out of his comfort zone. So I "Chatted it over with my boiler inspector's boiler inspector", which didn't really get me much further. Boiler inspection and boiler design are very different skills and I would suggest that very few club boiler inspectors could realistically undertake the design verification role for a large steel boiler- unless they happen to be chartered engineers with a professional background in pressure vessel design.

So I downloaded a copy of the Pressure Equipment Directive, and after a LOT of reading it transpired that I wanted to build a Class III vessel, for which "Design Approval" would be needed from a "Notified Body". (The PED Annex II, Table 5 refers - Search for "Pressure Equipment Directive on the internet). A Class III vessel includes most model boilers in excess of 200 Bar Litres, which would include many 4" scale traction engines and 71/4" gauge engines and larger. One assumes that the designers of these models have gone through the design verification procedure applicable at the time.

In practice the P.E.D makes the following requirements:

1. The vessel must be designed to a recognised National or International standard. In my case the relevant standard is B.S. 2790, 1992 for which I suggest you Google "BS 2790 free pdf". BS 2790 is partly superseded by B.S. EN 12953, but for my work was still current. B.S. 2790, 1986 should (in theory) be used for locomotive type boilers, but is now unobtainable, but the 1992 version is used by default for locomotive type boilers.

2. The drawings, design calculations, operating instructions, risk assessments, hazard analysis, Essential Safety Requirements Checklist, nameplate details and material schedules must be reviewed and approved by a Notified Body. I used British Engineering Services (used to be known as Royal Sun Alliance), but others are available; check who your boiler builder deals with.

3. The construction and testing up to hydraulic test (and steam test if you are not using the MELG scheme) stage must be inspected by the Notified Body. The amount of testing is determined partly by the standard to which you are working and partly by the Notified Body. There seems to be some "creative interpretation" of the requirements in BS 2790 for non destructive weld inspection, since several well known suppliers indicated that they do not normally undertake NDT on welds, and yet the standard specifies it.

4. When the Notified Body are happy with the construction, they will sign off the build and allow me to CE mark the boiler.

5. This level of engineering oversight by highly qualified engineers is expensive. A Notified Body will also charge extra if they need to see multiple revisions of your calculations and designs; in other words, carelessness costs!

The above means that the design calculations must be conducted according to BS 2790 and presented in a way which is clear.

After spending considerable time acquainting myself with the intricacies of BS 2790 and translating it into engineering drawings I eventually had 10 sheets of Drawings, 18 pages of Calculations, 2 pages of Essential Safety Requirements, 4 pages of Instructions and 4 pages of Risk Assessment which all went off for approval. Approval was obtained without any great problems, the only point that needed changing were the material specifications and the Notified Body did concede that material selection is presently a rapidly changing topic.

Material standards have changed since BS 2790 was written. In simple terms, suitable materials for a boiler must now have "specified elevated temperature properties", and certification to show it, which excludes just any old mild steel. The following are currently acceptable and are available:

Shell tubes (Including circular fireboxes and anything not a firetube): ASTM A106 Gr B or A333 Gr 6 or EN10216-2 P235GH or P265GH

Firetubes: BS 3059 - 1 Gr. 320

Flate Plate: BS 1501 Type 161 Grade 430B

Bar or plate for bushes, nozzles, brackets etc.: BS EN 10028 - 2 Grade P235 GH

5. OTHER DESIGN ASPECTS

Some other features of the design are:

- A 12 volt system will be included, to run hazard warning lights on the road, plus brake lights & indicators.
- The 12 volt system also to supply an integral low speed vehicle mover and vehicle winch to aid self loading onto a trailer. – to avoid the strenuous manhandling of a large model - I am not getting any younger!
- Hydraulic brakes are provided on all 4 wheels. Steam vehicles can be near silent and pedestrians seem to develop blindness and suicidal tendencies among moving steam vehicles.
- The Fowler engine and gearbox unit are fully enclosed splash lubricated. Every effort has been made to eliminate the oil can from other parts of the vehicle. Most linkages use Glacier DU bearings running on stainless or grease fed bearings.
- Main boiler feed will be from a steam driven pump, giving variable flowrate via a feed water heater. The ability to attenuate feedwater flow will have the effect of making the water level more stable in a high performance, low volume boiler.
- I hope to fit a boiler feed treatment pump running in parallel with the main feed pump, to give a continuous proportional dose of water treatment.
- Auxiliary boiler feed will be from an injector.
- Provision for boiler water level electrodes has been made either to provide warning or to provide an automatic maintenance of water level.

6. AND WHAT NEXT?

I have just issued the order for boiler construction (I am contracting out all construction on this item), which is on a 6 month delivery. In the meantime, I have a huge load of twiddly bits like levers, handles, rods, linkages, brake pipes, plumbing, feed pump, lubrication pumps etc. etc. to manufacture.

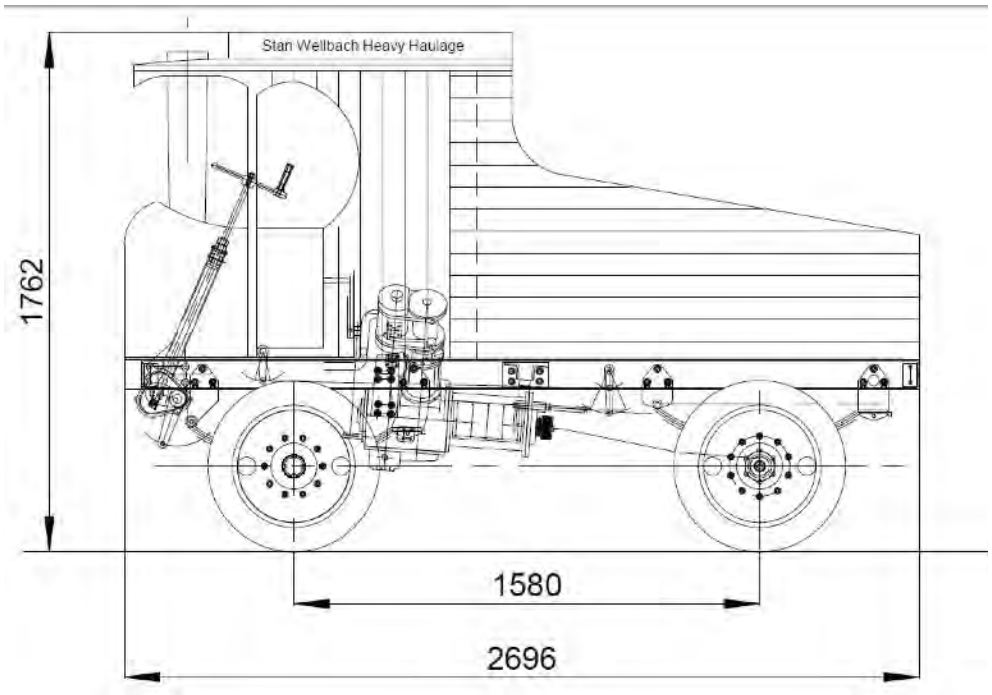
It currently looks basically as in Photo 4, but the engine back end is now held up by the proper chassis cross beam.

The author can also be contacted via the ASTT webpage.



Photo: 4 Rolling chassis as at August 2018

And eventually, it should look like Figure 8.



Follow construction online at:

https://www.flickr.com/photos/140734312@N06/albums/with/72157669955074511

Mechanical Cvlinder Lubrication, Part 1:-

John Duncan

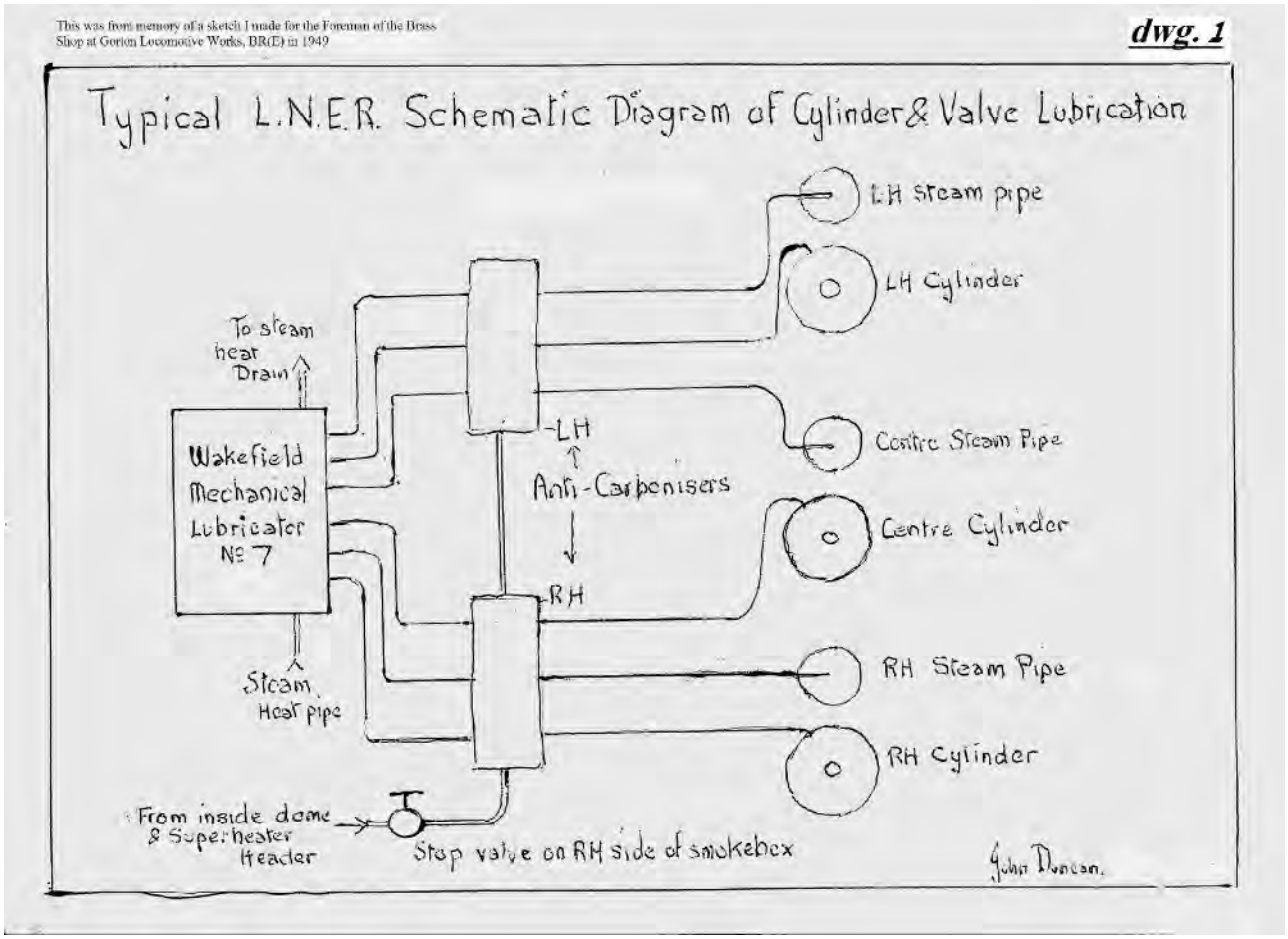
L.N.E.R.Cvlinder & Valve Mechanical Lubrication.

Based on the Wakefield System. At a time of increased superheater temperatures and boiler pressures.

The LNER introduced mechanical lubrication with anti—carbonisers for valve and cylinder lubrication.

Introduced by the GNR and NER from the introduction of superheating with hydrostatic lubricators then developed through C. C. Wakefield & Co.Ltd. Of London with the No.7 mechanical lubricator, anti-carbonisers and 'Spoon ' feed atomiser in the main steam pipe close to the steam chest.

I first came across the Wakefield system during my apprenticeship in the Brass Shop, at Gorton Locomotive Works during 1949. We worked on fiting the parts and copper pipework to 61349,a new locomotive. in No.1 bay in the Erecting Shop. The Brass Shop Foreman asked me to produce a schematic sketch of the cylinder and valve lubrication. (see attached sketch, dwg. I. It is not correct as the the steam supply connects in between the two sets of anti-carbonisers).



Most of the anti-carboniser overhaul was renewing the manganese-bronze valve seats where worn and cut, ball valves and springs. The passages were cleaned and the baffle removed and checked for wear and clean out the fine passages, (see attached sketch dwg. 2).

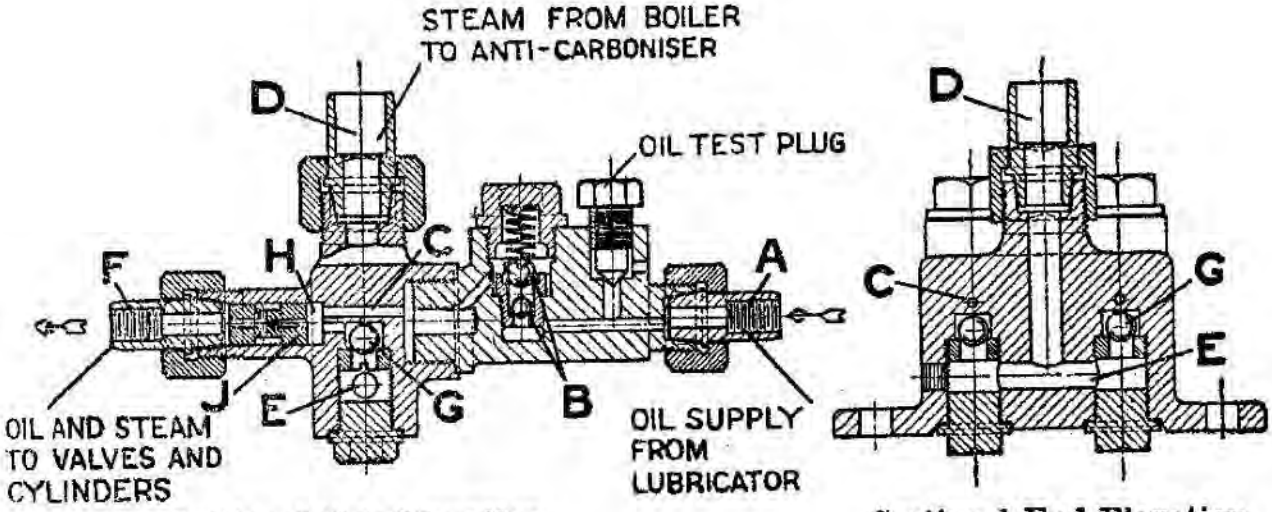
dwg. 2

WAKEFIELD MECHANICAL LUBRICATOR

WAKEFIELD ANTI-CARBONISER—2 WAY

FOR VALVE AND CYLINDER LUBRICATION

Diagram No. 43



Sectional Side Elevation of Anti-Carboniser

Sectional End Elevation of Anti-Carboniser

HOW THE ANTI-CARBONISER FUNCTIONS

Oil from the Wakefield Mechanical Lubricator enters the Anti-Carboniser at A and is forced past the ball check valves B and through the passage C when it comes in contact with the steam jet.

Steam enters the Anti-Carboniser at D and branches along the passage E which communicates with each of the outlets F. A Check Ball Valve is provided at G which prevents the oil and steam from traversing in a reverse direction.

It will be seen that the point of contact of the oil and steam is in the small space or cavity H. The oil and steam together then pass through the baffle J and so to the outlet F.

The object of the baffle is more thoroughly to mix the oil and steam, which would not, of course, mix so well were they merely to pass out through a plain hole.

SPECIAL NOTE—It is absolutely essential that the steam to the Anti-Carboniser *should be kept on all the time the engine is running whether with or without steam.* If this is not done the Anti-Carboniser is inoperative, and fails to perform its function of keeping the valves, cylinders and ports free from carbon deposit.

The No.7 type mechanical lubricator was stripped down, all parts inspected for wear. Ball valve seats examined for cuts and damage, Ball valves and springs renewed. Locking peg springs and driving frame and cam follower and spring. The wire strainer examined for any breaks in the netting.

The 100 tooth ratchet wheel checked for wear. Some ratchet wheels during the War wear built up and re—cut, pawls and

All the regulating plugs were screwed fully down then turned back 3 clicks giving 2/5's feed. 2oz of oil every 100 miles -quote- Bill Harvey.

Ex. Works pin in the hole nearest the ratchet drive for local run in. On return to home depot re-pin in the outer hole in the drive rod. Test that the ratchet takes up 3.5 teeth on the on the ratchet wheel.

The No. 7 lubricator has a 1 gallon capacity. The larger No. 72 lubricator has a 2 gallon capacity. See dwg.3 & 4 for the No. 7 lubricator, these drawings are from :- The LNER Locomans Handbook of 1948.

dwg. 3

WAKEFIELD

MECHANICAL LUBRICATOR

No. 7 Pattern

HOW THE LUBRICATOR WORKS

When the pump plunger D and sleeve valve E are at the outer end of the stroke, oil flows into the pump barrel C through the ports F. As soon as the ports F are covered by the plunger and sleeve valve on the return stroke, the oil in the pump barrel is forced away under pressure to the outlets K. If the oil regulating plug G is screwed right down, the pumps are working at their full capacity. One full turn outwards of the oil regulating plug G decreases the oil pumped by one-fifth as follows—

Plug G	screwed	right down	=full feed.
,, G	,,	one turn out	=four-fifths feed.
,, G	,,	two turns out	=three-fifths feed.
,, G	,,	three turns out	=two-fifths feed.
,, G	,,	four turns out	=one-fifth feed.
,, G	,,	five turns out	=feed cut off.

TO OPERATE

When starting the Lubricator for the first time when newly fitted—

(1) See that each of the oil regulating plugs "G" is screwed right down.

(2) Fill the oil reservoir, taking care to pass the oil through the strainer.

(3) Open the oil-test plug on the combined check valve and oil-test plug.

(4) Work the Lubricator by turning the flushing wheel until the oil is seen at the oil-test plug.

(5) Close the oil-test plug and work the Lubricator a few more times to make sure that the oil-delivery pipes are quite full.

The above operations are essential when the lubrication is first fitted up. The lubrication system is then in working order.

It is advisable before leaving the shed with the engine going into traffic, to examine the test plugs and make sure the oil is there by giving the flushing wheel in few turns.

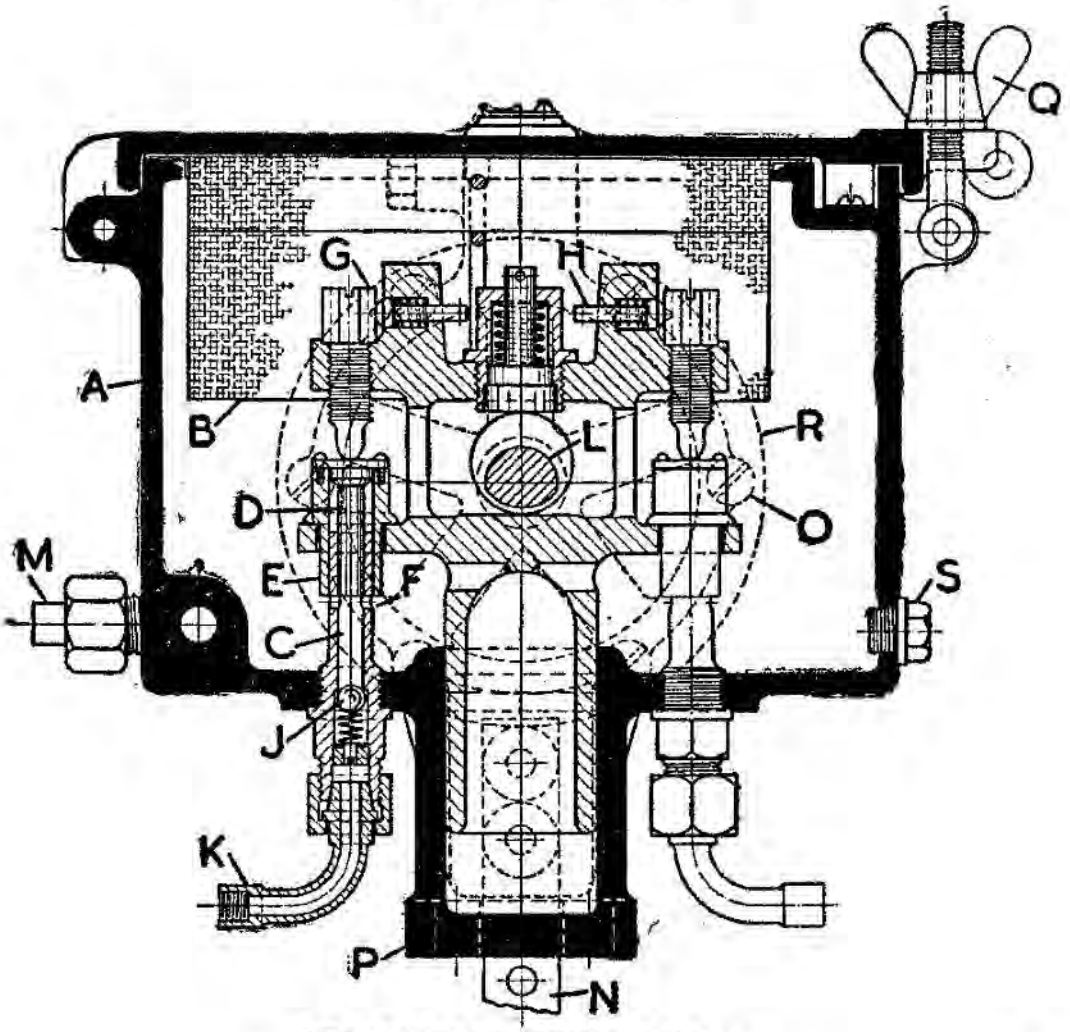
The level of the oil in the reservoir must never be allowed to fall below the ports F in the pump barrels or no oil will be delivered.

The oil MUST pass through the sieve. It is advantageous to WARM the cylinder oil before filling the lubricator.

dwg. 4

WAKEFIELD
MECHANICAL LUBRICAT(
No. 7 Pattern

Diagram No. 42a



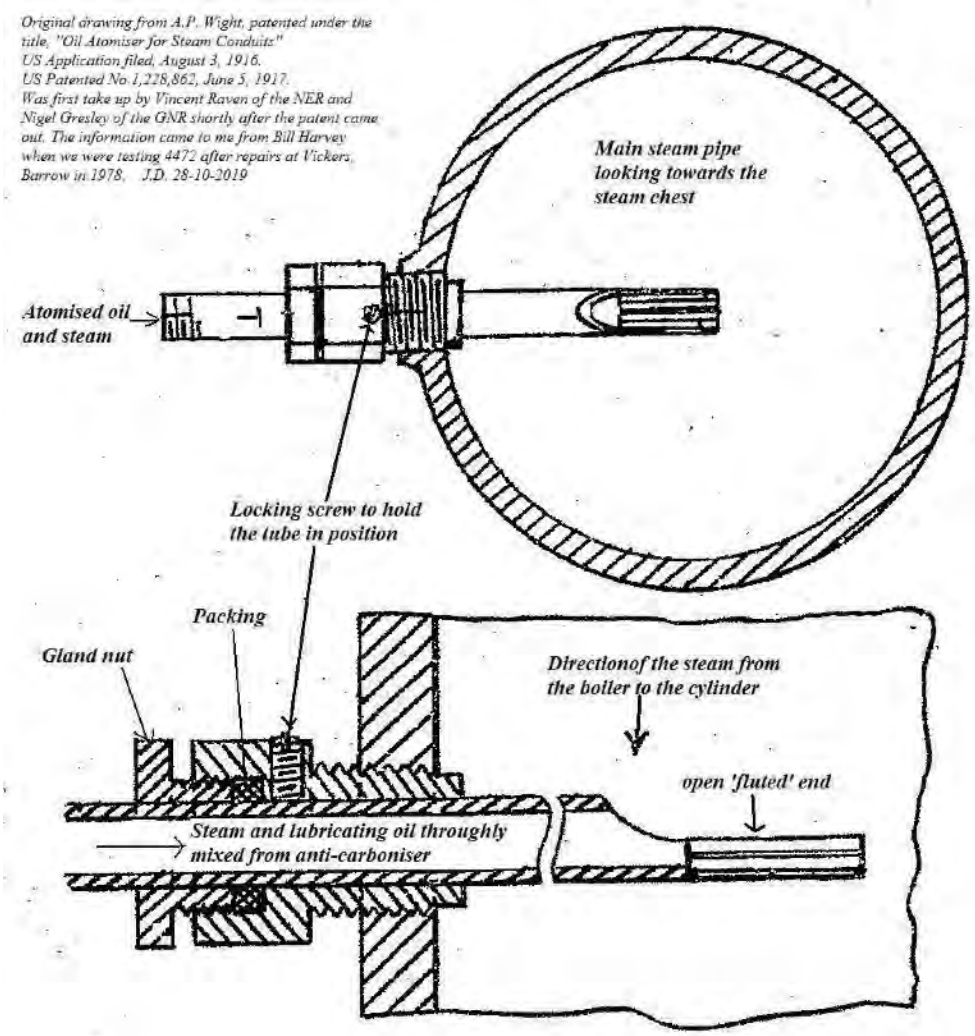
SECTIONAL ELEVATION

DESCRIPTION

A—Oil reservoir.
B—Wire gauze strainer.
C—Pump barrel.
D—Pump plunger.
E—Sleeve valve.
F—Oil ports.
G—Oil regulating plug.
H—Oil regulating locking peg.
J—Non-return valve.
K—Oil outlets.
L—Driving eccentric shaft.
M—Oil warming pipe.
N—Driving arm.
O—Ratchet drive and gear case.
P—Fixing lugs.
Q—Fly bolt to secure lid.
R—Flushing wheel.
S—Drain plug.

NOTE—No. 7 (a) pattern operates in a similar manner to the above, but the oil outlets "K" lead out from the sides of the oil reservoir, level with the centre of the driving eccentric shaft L.

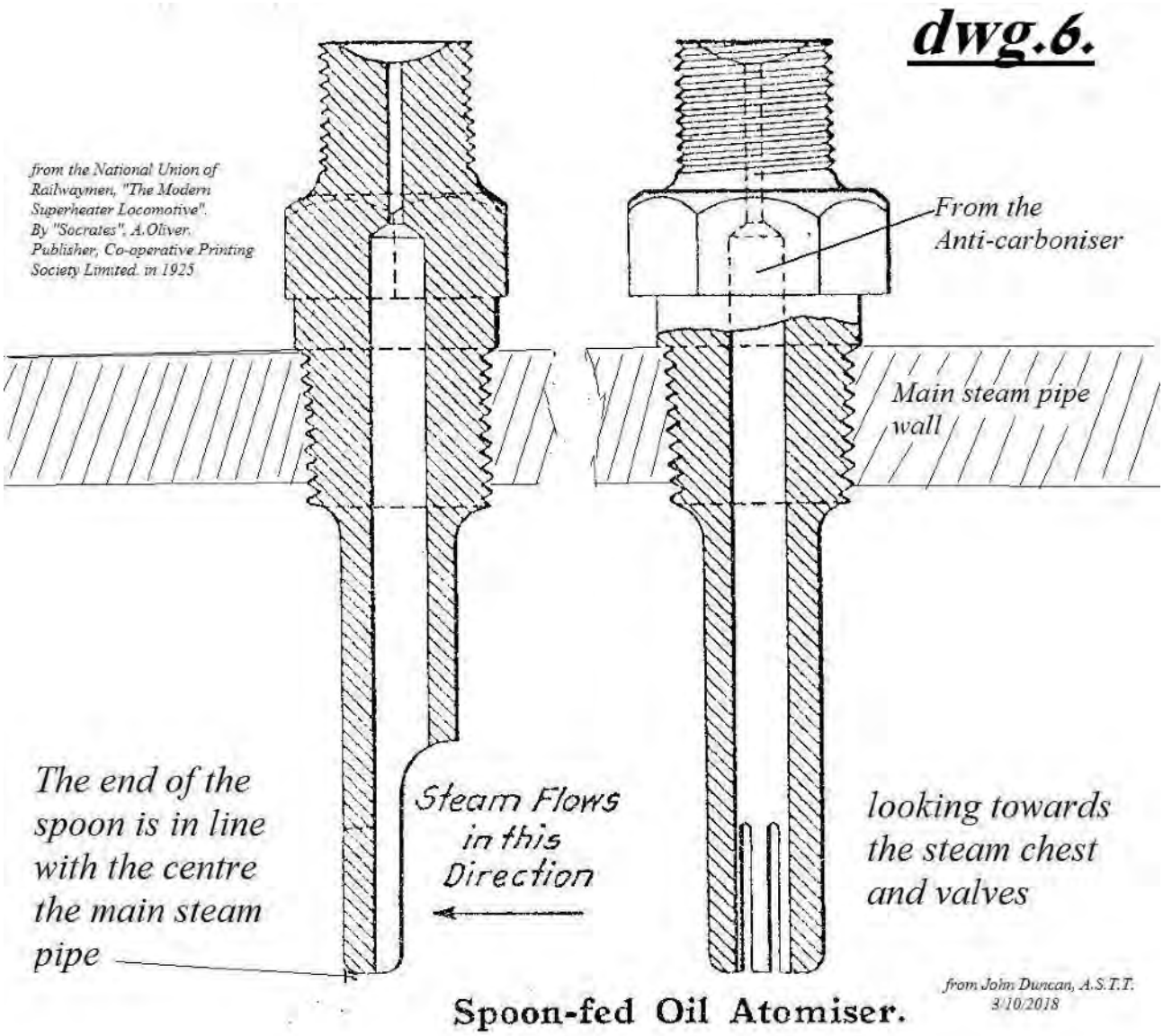
The final atomisation took place in the main steam pipes as near to the steam chest in the cylinders. We called them ‘Spoons ‘. The end of the pipe extended in to the main steam pipe halfway and the pipe cut in half length way half the distance that the pipe projects into the main steam pipe. The open end facing towards the superheater and boiler. Slots were cut in to the open end of the pipe. This produced the final atomisation to the steam chest and the valves. (See:- dwg, 5 & 6).



This method of Atomisation was used and is used by ex. L.N.E.R. locomotives as a means of valve and cylinder lubrication with mechanical lubricators and anti-carbonisers.

dwg. 5.

John Duncan for ASTI
I was introduced to this system of valve and cylinder lubrication in Gorton Works, Brass Shop in 1949. J.D. 28/-10-/2018



The three dimensional drawing, (dwg. 7) is from the LNER locomotive man is pocket book, 1948, with a description about the drawing. The anti-carbonisers are forward of the outside cylinder steam pipes under the casing. None streamlined LNER locomotives they are behind each side of the smoke box.

When you consider the high mileages the A4 is did on none stop trains between Kings Cross and Edinburgh with very few lubrication problems, all with this simple system of cylinder lubrication.

Today the new A], 60163 has the same system of cylinder lubrication. (photos I, 2, &3.



Photo I, A view of the left hand side of 601 63 showing the mechanical lubricator on the far right hand side. The lubricator is driven off the top of the expansion link. The square brass box to the right of the main steam pipe is a trimming lubricator for the valve rod, front of slide bar and piston rod.

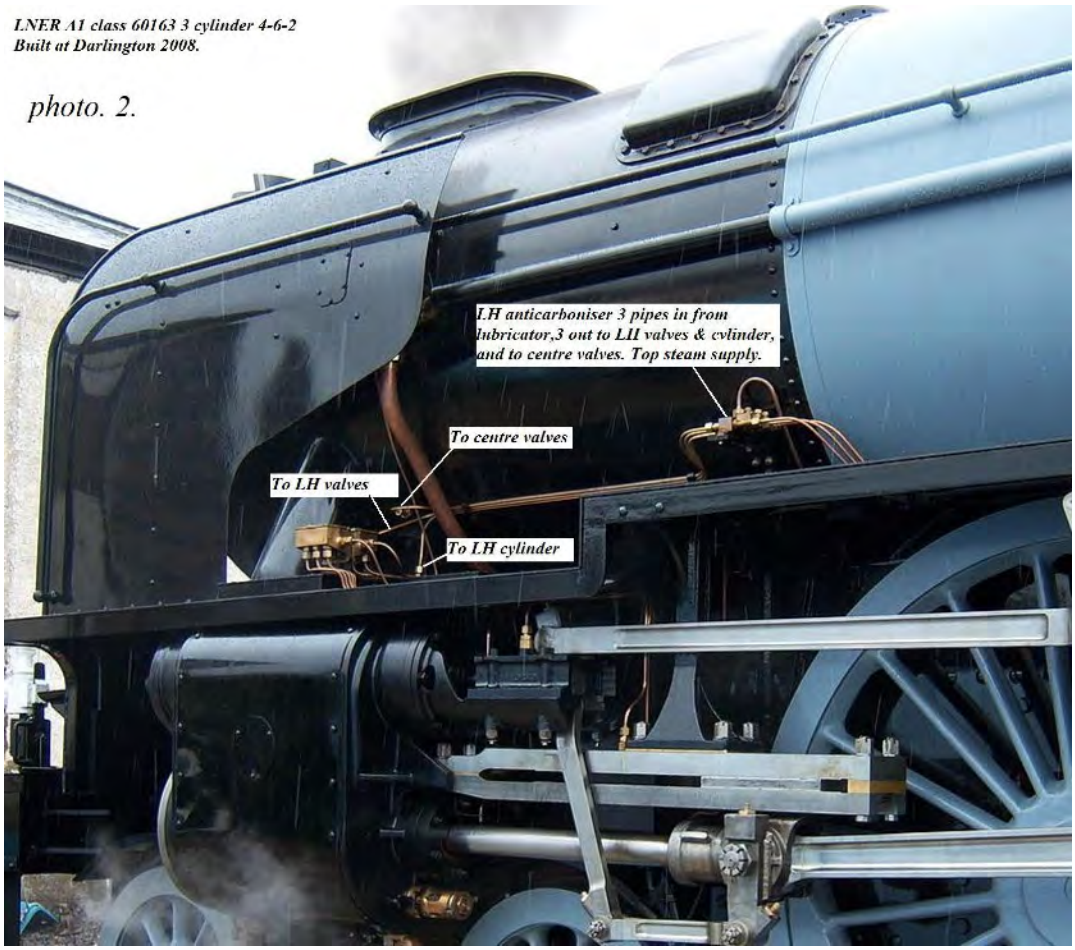


Photo 2, A more detailed view of the left hand side of the smokebox. The anti-carboniser has three pipes on the right hand side from the mechanical lubricator. The testing screws next, then the steam pipe coming in at the top. The left hand pipes to the Left hand steam chest and one to the left hand cylinder and the third to the centre cylinder steam chest. The LNER had a 3—block anti— carbonising one each side of the smoke box for three cylinder locomotives. A 2~block anti—carboniser each side of the smoke box for two cylinder locomotives.

Photo 3, Right hand side of the smoke box showing the anti—carboniser steam shut of valve. It used to come off the superheater header on the saturated side but it was found the the steam supply was cut ofi‘ when the regulator was closed. It now comes directly off the steam dome. The anti-carboniser is on the left. The brass trimming box is just to the left of the main steam pipe casing feeding the same parts as the left hand side of the locomotive. The brass fiting above is the live steam supply to the exhaust steam injector to operate the change over from live steam to exhaust steam when the regulator opens.

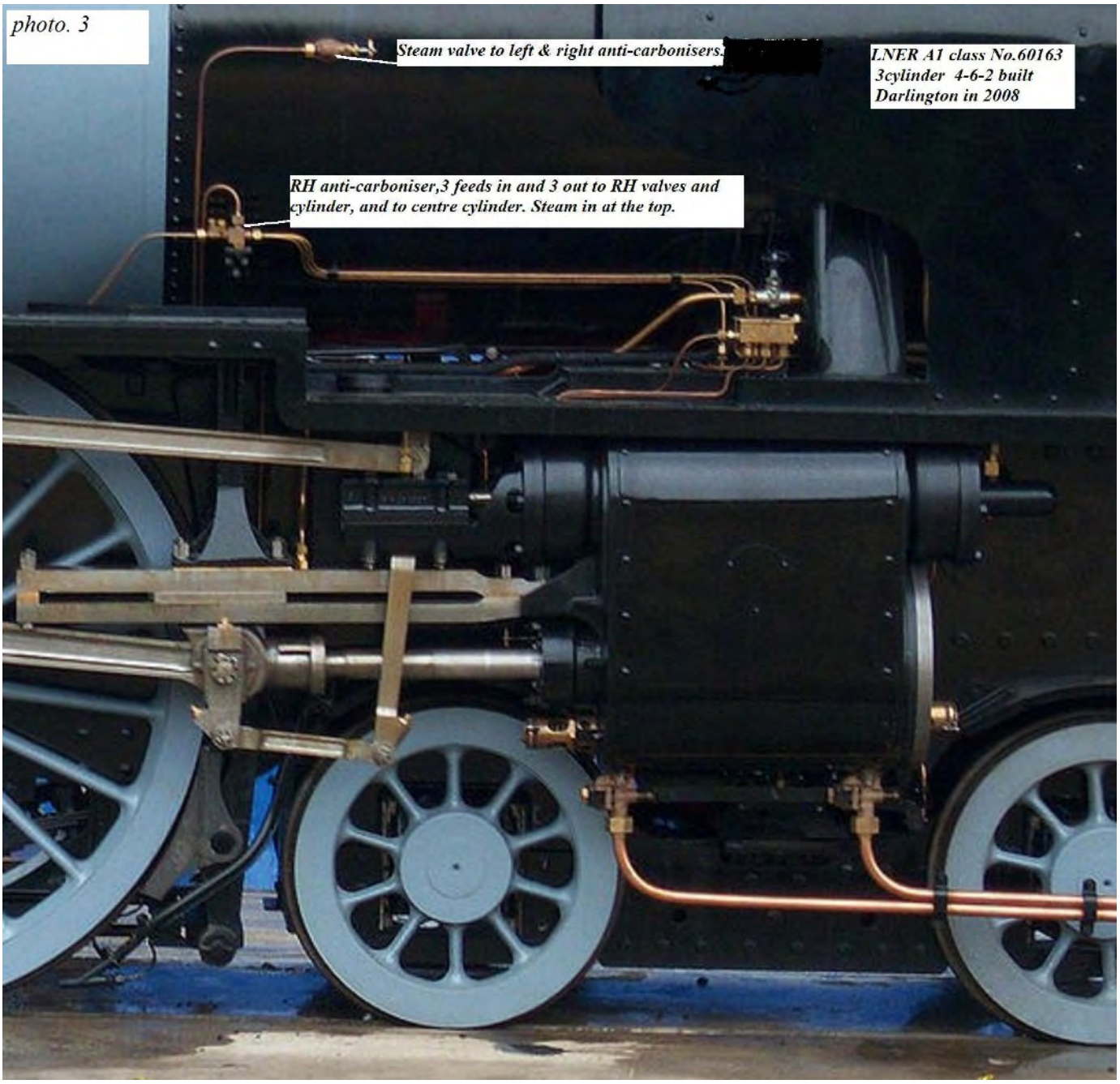
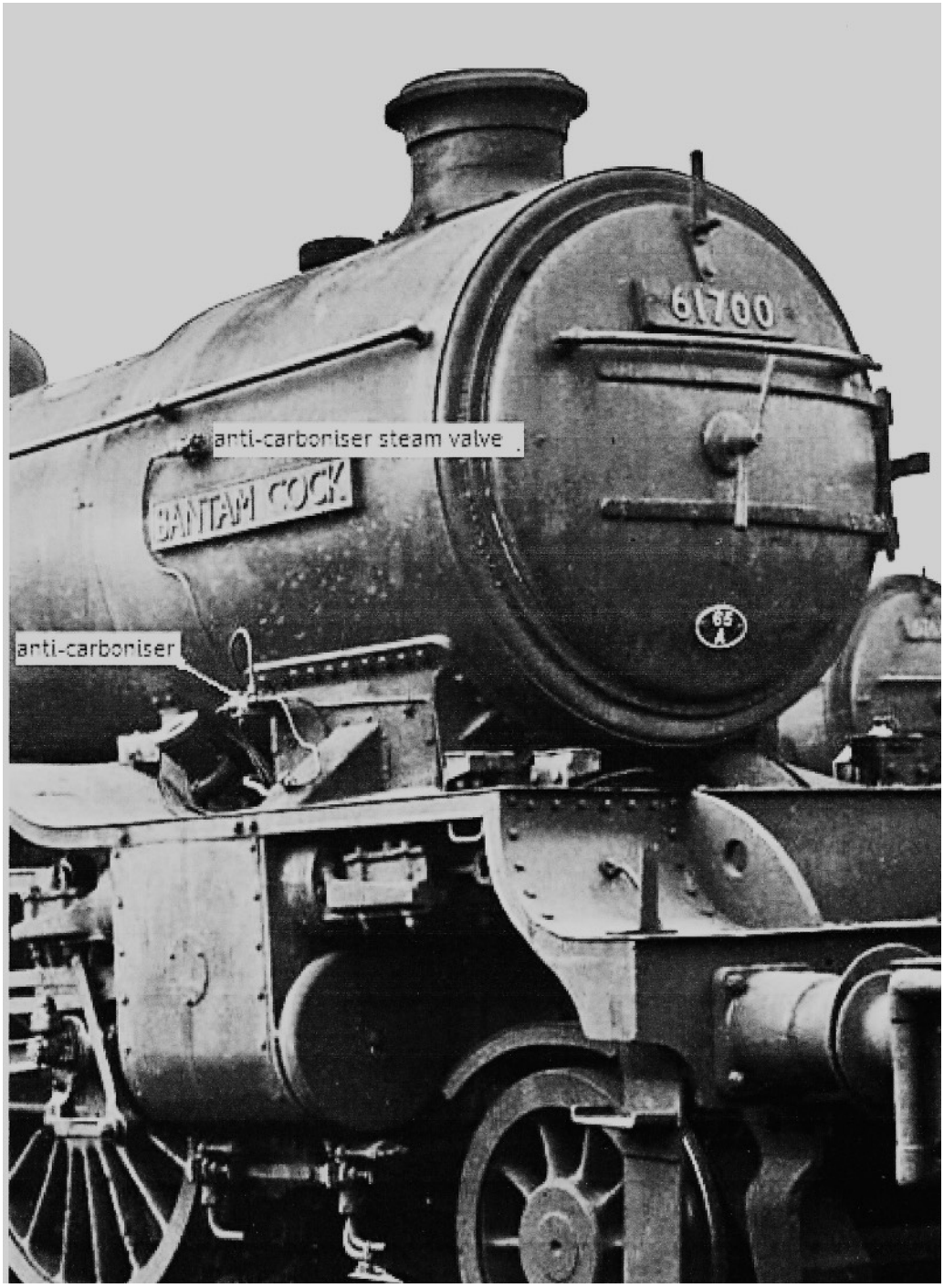


Photo 4 Showing the position of the anti—carboniser steam valve, the right hand anti-carboniser and the pipe on to the right hand cylinder main steam passage in the three cylinder mono-casting.



The connection is on to the ‘spoon ’type atomiser, (see dwgs. 5 & 6).Just above the right hand steam chest, Look at any LNER superheated locomotive with a mechanical lubricator built under Gresley, Thompson or Peppercorn with the same layout.

The locomotives with two cylinders between the flames had standard cylinders under the Thompson time. The lubrication was the same. A separate feed in to each steam chest and to the cylinder on the J39 and JIJ/3. The D11 class had new cylinders when required, a J39 without the saddle, but had the Detroit hydrostatic lubricator. To digress, in 1952 when I was on Section 9, 3 bay in the Erecting Shop at Gorton Works. We had 62665 for general overhaul. I was given the job of of cleaning 0]?" the steam and blast pipe faces and renewing all the studs when my right foot went through one of the pockets on the top of the cylinder block. George Howard the Charge hand Fitter shouted up, "What the 'hell 'are you doing, young Duncan" .1 said, " My foot has gone through in to the steam chest". He went for the Bay Foreman, Mr Mitchell, he had a look then fetched the Erecting Shop Foreman Mr Whitticker, he in turn had the Works Manager, he phoned the Shopping Bureau at Doncaster. All this took about 90 minutes with my foot stuck in the cylinder block. The decision was taken to fit a J39 cylinder block and convert the locomotive to long travel valve gear. This was the last D] 1/] class to be fitted. George Howard & I fitted the new cylinder block, reversing rod and valve rods. George said, "Th 'al learn something here, lad and I did. The locomotive had a Detroit hydrostatic lubricator with one direct connection from the Detroit lubricator to a divider then direct to each piston valve and another to each cylinder, four pipes in all; two down each side of the boiler. The LNER system for lubrication of valves and cylinders has worked well, with few problems with carbonisation or excessive wear over the years from the 1920 is through to today. The A4 locomotives have done long non—stop runs of 393 miles from their introduction to the end of steam, with very few incidents with lubrication, a simple system.

The problems with lubrication of valves and pistons on locomatives with super heaters and larger boilers is water carry over when the regulator is opened too much the water then in the

hot superheaterflashes into steam with huge expansive power that the locomotive overcomes adhesion and results in wheel slip dragging water through the cylinders washing of the lubricant. InNorth America in the late 1920 is with the introduction of the Elesco multiple valve regulator this was fited in the superheater header between the superheater and the cylinders so the superheater elements were always at boiler pressure. This allowed superheated steam to work the air compressors and feed water pumps and other auxiliaries more efficiently. Elements then went from workshop overhaul to the next. It gave the Driver better control of any tendency to wheel slip. This was done on the CPR from 1928, I learnt this on yearly superheater element inspections and tests at Aylth Roundhouse, Calgary, Alberta, at the end of steam in Western Canada.

The second problem is wear, the quality of cast iron used in most liners and rings. At the end of the second World War the cast iron was a poor quality at Gorton, 0n the valve and piston job in the Machine Shop the rings were cut off a machined drum and taken to the locomotive in the Erecting Shop, peened inside the bore and over lapped and scribed in the smallest diameter of the working stroke, cut to give correct expansion gap according to the diameter, fitted to the piston or piston valve heads.

In Canada the larger locomotives had 'Kopper 'segmental rings fited which gave over 60, 000 miles life. (See attached article).

John Duncan, 13/11 2018.

I remember fitting Koppers segmental bronze and cast iron piston rings to CPR 2833 at the beginning of April 195 7, never seen or done it before, they called it the'Chinese Puzzle'. It came as a kit, tied to a plywood board A band was fastened to the piston head with a slot in fit the spring in and the segments.
They were fitted to the larger CPR locomotives and very effective in keeping the pistons steam tight over 60,00 miles.
Koppers are still going as an international company and make these rings for preserved steam locomotives in the US. and Canada. What about 72010 and 71000?

SEE below from Andre Chapelon :- John D.



For several years the Americans have need composite piston rings (Fig. 52) in place of the previous standard cast iron type. Each ring group generally comprises two or more crowns, each made up of several pieces, joined together, which are pressed into contact with the. cylinder "HHS by a spring steel ring. There are two rows of elements placed side by side in each group, with overlapping joints, one being in special cast iron and the other in special bronze and both of great hardness,

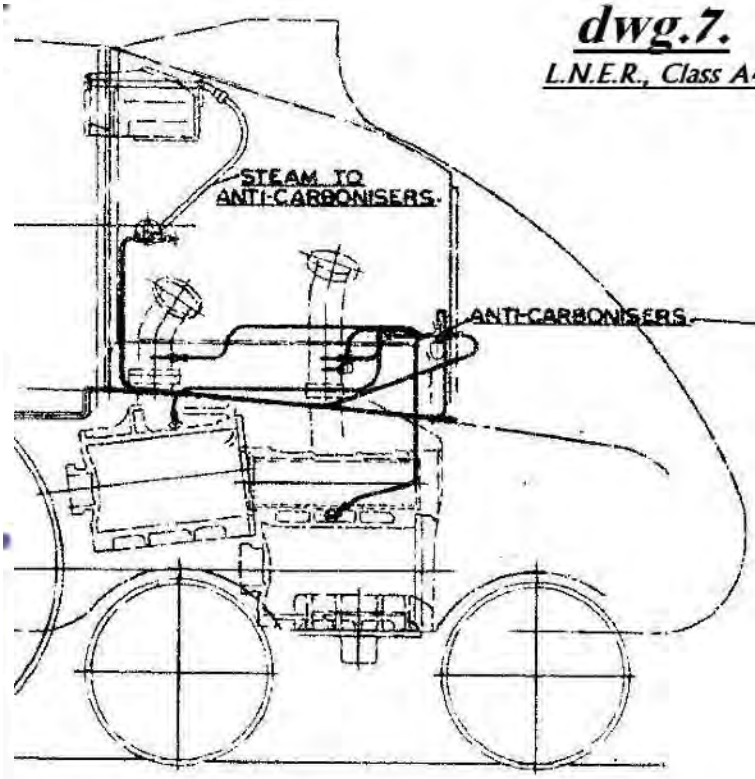
The successive contact of these two different metals against the cylinder walls gives them a beautiful polish with minimal wear. Contrary to What was thought initially, it immaterial whether the bronze or the cast iron segments are located at the inner or outer position. at the piston head.

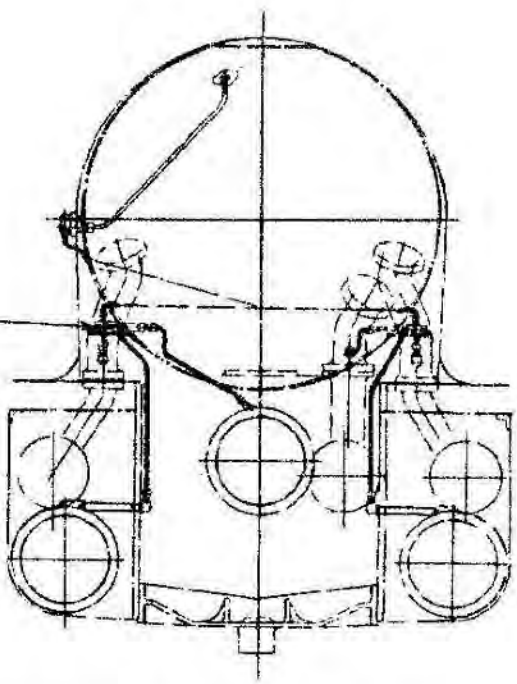
Nevertheless bronze segments housed in the outer position produce less wear in the. cylinder bore near to the end of the stroke Where only the bronze ring head is in frictional contact and for this reason it may be preferred to place the bronze segment in the outer position, but this is not for reasons of steam tightness.

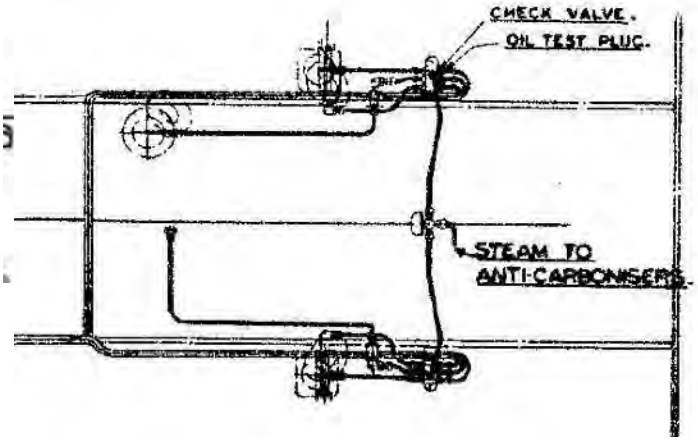
These composite rings run 100,000 km. Without replacement.

dwg.7.

L.N.E.R., Class A4







COPY FROM THE LONDON & NORTH EASTERN RAILWAYS
"LOCOMOTIVEMAN'S POCKET BOOK, Re-printed in 1948

SHOW S THE STEAM SUPPLY TO THE ANTI-CARBONISERS (ATOMISERS) FROM THE SATURATED SIDE OF THE SUPERHEATER HEADER TO THE R.H. SIDE SMOKEBOX SHUT OFF VALVE, THEY DIVIDE TO EACH GROUP OF ANTI-CARBONISERS. R.H. SET SUPPLYING CENTRE AND R.H. CYLIDERS AND R.H. STEAM PIPE, L.H. SET SUPPLYING THE CENTRE AND L.H. CYLINDER STEAM PIPES AND L.H. CYLNDER
THE DISADVANTAGE OF HAVING THE CENTRE CVLINDER OIL PIPES IN THE SMOKEBOX IS OVERHEATING OF THE COPPER PIPES WITH POSSIBLE LOSS OF SUPPLY OF OIL OR CABONISATION OF THE OIL TO THE CENTRE CYLINDER.
THE CYLINDER LUBRICATION ADOPTED BY THE L.N.E.R. FROM HYDROSATIC CYLINDER LUBRICATION TO MECHANICAL LUBRICATION DUE TO HIGHER STEAM TEMPERATURES AND THE NEED ANTI-CARBONISERS. THE ARRANGEMENT OF FEEDS TO THE STEAM PIPE AND CYLINDERS REMAINED THE SAME.

by John Duncan, Member of A.S.T.T 3-10-2018

David Wardale, on the "modernization" of steam locomotives. Chris Newman

David Wardale could never be described as anything less than passionate about steam, yet he is the ultimate pragmatist when it comes to recognizing its shortfalls. He dedicated his working career to the advancement of steam traction as describes in his book "The Red Devil and Other Tales from the Age of Steam". In it, he describes his 10 years working in South Africa and three years in China where his hopes ended in 1988 with the winding down of the "Modified QJ" project. He concluded his book with the same realism (perhaps fatalism in some eyes) that hangs over so many of its pages, by observing that "the classical form of the steam locomotive was essentially right for itself and right for its time" and that "just as an actor must leave the stage when his part has ended, so had the steam locomotive to [do] when its time ran out".

This same realism is evident in a memo that he wrote to his SAR bosses in August 1983 shortly before leaving South Africa, in which he summarized the lessons learned from 2½ years of testing and measuring the performance of The Red Devil. In a recent letter to Chris Newman he wrote: "Like many things I've written, it was mostly meant for myself, to set down clearly and concisely what had been learned. If anyone in the SAR chose to read it, all well and good, but I had no illusions about that."

The memo offers wise advice to any would-be locomotive rebuilders. However readers should be aware that his advice applies specifically to locomotive rebuilds rather than new designs – a point that he stressed in his book: e.g. in section 3.2 under the heading "The Modified 25NC – Design Work" (p. 147):

> An important consideration during this process [of assessing how to incorporate all the planned alterations] concerned the difficult question of fitting the proposals into the locomotive's existing structure whilst keeping major structural alterations to a minimum. Due to structural limitations such rebuilding work could be more difficult from the design aspect than if the entire locomotive was designed from a clean sheet of paper, and it was not easy to incorporate the full scheme within the basic structure of the 25NC class and at the same time design for optimum component performance, compromises inevitably having to be made in order to fit things in. Another important point was that different design solutions to each problem, from which the optimum could be chosen, could not be properly evaluated without working out alternative ideas in some detail, and in the prevailing circumstances, i.e. the limited design resources and the need for quick results in view of the ever-dwindling steam fleet, this was not possible. The best that could be done was to make a brief survey of the possibilities, weighing such factors as thermal and mechanical performance, ease of design, manufacture and fitting, and cost, and to adopt those which whatever engineering intuition I possessed told were most likely to give the best all-round solution. Both the successes achieved and the problems experienced with the rebuilt locomotive should be viewed in the light of these far from ideal conditions in which the design work had to be done and the limitations imposed by the existing structure to which the scheme had to be tailored.

It is with such thoughts in mind that Wardale's 1983 memo (overleaf) should be read.

SOUTH AFRICAN TRANSPORT SERVICES
MECHANICAL ENGINEERING DEPARTMENT

Chief Mechanical Engineer's Office PRETORIA

Ref.: RLS 15/2/22 Tel.: 2810 Date:

1983 -08 - 27

MEMORANDUM

STEAM LOCOMOTIVE DEVELOPMENT : POSSIBILITIES AND LIMITATIONS

The following is a series of statements concerning the development of classical steam locomotives. These statements are the result of experience gained during the rebuilding, testing and operation of modified steam locomotives on the South African Transport Services, a hard won experience that brought the writer face to face with the realities of locomotive design and operation and which taught, as only experience can, what is likely to succeed and what is not. For brevity no elaboration or specific examples are given for the following statements, but it may be accepted that each one can be supported.

(1) Only the coal and water consumptions of locomotives that are normally operated at high power can be significantly improved.

(2) The coal and water consumptions of locomotives that are normally operated at conservative power ratings cannot be significantly improved because the factors which act to lower efficiency and which can be influenced by modifications are mostly proportional to the (steam rate)^2 and are therefore not significant at low evaporations and powers.

(3) The potential for improvements is less where the existing designs are good; however it is generally the older locomotives having the poorest performance, and therefore giving the best potential for improvement, that give the greatest structural limitations preventing full exploitation of the modifications.

(4) The power capacity of all locomotives can be significantly improved, to a greater extent for those of para (2) than for those of para (1).

(5) The increase in power capacity which can be made will generally give only a small improvement in overall journey times, even for locomotives of para (2), and will therefore bring only limited operational benefit.

(6) If use is made of the increased power capacity of modified locomotives their coal and water savings will diminish and may disappear altogether unless (in the case of coal consumption) a better method can be found than is currently available for reducing the rate of increase of unburnt fuel loss as evaporation increases: the user of modified locomotives operating at higher power than before rebuilding can therefore find his fuel and water savings small and his trains only slightly faster.

(7) A significant increase in power capacity in practice means increased evaporation: since locomotives of the type given in para (2) are usually hand-fired, mechanical stoking will have to be employed if their power potential is to be realised. Mechanical stoking has traditionally resulted in reduced combustion efficiency compared to hand firing.

(8) The structure of many locomotives will be unable to withstand increased power without rapid deterioration unless extensively modified.

(9) Many steam locomotive operation and maintenance problems originate from the burning of lump coal at high combustion rates on fire-grates; these problems generally increase with the size of the locomotive and the combustion rate. No method of burning lump coal has yet been used which satisfactorily solves these problems.

(10) Improved performance must be achieved by improving the operation of existing locomotive components whilst maintaining the utmost constructional simplicity. Adding to the complexity of the locomotives must be avoided because, at the current state of the art, steam locomotive mechanical reliability is poor and in practice increased complexity will increase unreliability and maintenance in the conditions under which steam locomotives have to operate. To think otherwise is naive. In other words, keep it simple.

(11) A few important modifications will produce almost all the benefits that can be achieved, after which the law of diminishing returns will apply. Unless a clearly quantifiable reduction in operating costs can be achieved by a modification, it should not be made to an existing locomotive. If you cannot measure the results of what you do, don't do it. Avoid change for change's sake.

(12) The structural limitations of existing locomotives generally result in compromise designs for modifications, which restrict their performance and usefulness.

(13) If, during the design work for a modification, it is found that more and more of the locomotive needs to be redesigned to accommodate the modification, or if it is found that the modification requires extensive additional equipment to make it workable, as a general rule that modification should be discarded.

(14) Not only the potential benefits of modifications should be considered : there is usually a reason why existing things are the way they are, so that by altering them the advantages of the existing equipment may be lost if they are not appreciated and designed in. Modifications can bring benefits but they may bring new problems not previously experienced.

(15) Rebuilding small quantities of different locomotive types, each requiring its own design solution and retaining its inherent limitations, is unattractive. The design effort to rebuild 3 or 4 different classes may be the same as that to design a completely new locomotive. Such locomotives will require small batch production of spares, which is a factor in the very rapid rise in steam locomotive maintenance costs being experienced. A far better proposition is to have a few standard locomotives available to suit the different gauges. Why rebuild obsolete locomotives when new ones can be offered?

(16) The temperament of the railwaymen operating and maintaining locomotives must not be forgotten. 101 improvements can be made to a locomotive which will be taken for granted because the locomotive is supposed to be improved, but if there is one disadvantage compared to the original machines, it will be forever complained about. If the staff directly involved in operating the locomotives are not happy with them, for whatever reason, justified or otherwise, the locomotives will not succeed.

(17) The difference between what can be made to work on paper and what can be made to work in the hostile environment of railway operation must be acknowledged. There is a great distance between the two. Almost every technical and human factor which had not been considered but which is discovered only when the locomotives are put to work will conspire to defeat what is being attempted. Rare indeed is the unforeseen contingency that works in one's favour.

D. Wardale

ASSISTANT MECHANICAL ENGINEER (STEAM LOCOMOTIVES)

Handwritten postscript from DW dated May 2018:

This was written after 2½ years of practical experience with 3450. By the criteria of this memorandum, many (perhaps most) of the alterations made during rebuilding of 3450 should not have been done. They could only be justified if the aim was to demonstrate the maximum potential of locomotive rebuilding, which was my aim but not SAR's!

A brief chronology of Wardale's career.

The above memo was written in August 1983, some 4 months before Wardale left SAR and South Africa.

Wardale himself admits that it is not easy to piece together a chronology of his career from the pages of his book, so readers of the book may find the following brief chronology (provided by Wardale himself) useful:

- 1967 – 71: Engineering degree and practical training through BR "sandwich" course.
- 1971- 73: Employed by British Railways.
- 1974 - Feb: Arrived in South Africa; March: Began working for SAR; August: First contact with Porta.
- 1976 - Jan: First meeting with Porta (in Argentina).
- 1979: Spent modifying and testing 19D No 2644, and designing modifications to 25NC.
- 1980: Designing and implementing modifications to 25NC No 3450.
- 1981 - Feb to Aug 1983: testing Class 26 No 3450.
- 1983 - Dec: Left S.A.R. to start work on ACE Project in USA, but went instead to Germany when project folded.
- 1985 - Jan: Road testing C&O J-3a 4-8-4 No 614 in USA.
- 1985 - Dec: Moved to Datong, China to begin the design of the Modified QJ in Jan 1986.
- 1988 - Dec: End of Datong contract. Moved to Beijing in Jan 1989 to study Chinese.
- 1991 - Sep: Began writing his book.
- 1994 - Jan: Book's text completed, first in handwritten form, then transcribed into typescript.
- 1994 - Oct: Began re-transcribing book into digital format and drawing all diagrams and graphs.
- 1996 - Aug: Completed transcription work; departed Beijing to Germany, thence Inverness Oct '96.
- 1997 - Began converting text and diagrams into printers' format.
- 1998 - Book printed in Inverness and distributed by Wardale.