



## NEWSLETTER No. 23 - DEC 2023



4" blocks of rapemeal cake during the November BVR trials

Gwion Clark

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## CHAIRMAN'S PIECE

### John Hind

Shortly after the last newsletter was published, our Secretary Cedric Lodge resigned his position, to devote more time to looking after his wife. Shortly after, David Nicholson, who was Cedric's planned successor also let me know, that due to ongoing health issues, he could not step into Cedric's shoes and would be resigning from the committee.

On a sad note Cedric's wife, Janet, died on the evening of 5/11/23 and on behalf of ASTT, I'd like to pass on all our condolences.

After discussion within the committee, we asked Henrik Kaptein, whether he would be willing to fill the void and happily he as agreed. In formal terms he has been 'co-opted' to the committee and subject to election by the membership at the next AGM.

Later in the newsletter, Chris gives an update on Revolution. Having past the first milestone of building a rolling chassis and successfully testing it at Stapleford Miniature Railway, work is pressing on with Alex Powell doing the structural design for the boiler. One of the satisfying things about Revolution is that Richard Coleby is passing on his knowledge and experience of designing locomotive boilers to the next generation, who are taking up the baton. Currently the boiler is CAD images, but we will be getting to the stage where we need to turn the CAD into hardware. The boiler is a 'big ticket' item, which prior to Covid we estimated would cost £12,000 – once we get quotes back, we will have a better idea of the cost.

Many thanks to everyone who has donated to the project either as a large lump sum or an ongoing monthly contribution, but if we are to stand a chance of having it ready for 2025, we do need more funds. I make no apology for continuing to ask for donations. Later in the article on Revolution, Chris gives details of how to donate.

2025 is the 200th Anniversary of passenger carrying on the Stockton and Darlington Railway and there can be no better place to have our 2025 conference than in Darlington and be recognised as part of the 200th Anniversary and with a complete Revolution in attendance.

There remains the choice of venue for the 2024 Conference and Chris writes about that in the newsletter.

A happy new Christmas and New Year to everyone.

# MEMBERSHIP MATTERS

## Chris Newman

### Committee Members

As mentioned in John Hind's Chairman's Piece, ASTT's management committee has changed. It is as follows:

John Hind	Chairman & Trustee	Jamie Keyte Trustee
Hendrik Kaptein	Secretary & Trustee	Alex Powell Trustee
Chris Newman	Treasurer & Trustee	Grant Soden Ex-officio
Richard Coleby	Trustee	

In addition to the above, Gwion Clark is the ex-officio Student Representative on the Committee.

### New Members:

We welcome six new members who have joined since our No 22 Newsletter of August 2023:

**Austin Unruh** from California, USA. Austin is an Electrical engineering student and has been volunteering on his local 7½" gauge railway since his teenage years where he is qualified as a steam loco driver. He is also volunteering on a standard gauge heritage railway. He runs his own website at <https://steampunksavant.com/>.

**Stuart Kean** from Berowra Heights in NSW, Australia. Stuart is a retired railway engineer who began work as an apprentice fitter in the Public Transport Commission (NSW). His career subsequently progressed through various engineering positions including the Inspection Engineers section, Mechanical Design Office, Locomotive and Train Testing, Systems Safety and Rail Compliance offices. In the late 1980s he acted as liaison officer for the overhaul of the iconic NSW Pacific No 3801 in readiness for Australia's 1988 bicentenary celebrations and was involved in the planning for Flying Scotsman's visit to Australia the same year. He communicated with Dante Porta for 20 years before the latter's death in 2003.

**Nick Swift from Reading (UK).** Nick is a professional engineer working in the UK rail industry in the area of innovation. He also runs a small-scale hydrogen fuel cell company that is closely associated with [Steamology – Zero Emissions Power Solutions](#) which was represented at ASTT's 2023 conference in Swindon by Matt Candie who gave a talk at it.

**Robert Gwynne from York (UK).** Robert recently retired from the National Railway Museum (NRM) after 26 years there. He describes himself as a "historian, writer and presenter interested in the past, present and future of railways". He is a regular contributor to various railway magazines and has made several video recordings for/with the NRM which can be viewed on YouTube under the pseudonym "[Curator with a Camera](#)". He has recently taken up the position of Environmental and Sustainability Manager with the Llangollen Railway.

**Eelco de Bode** from Amsterdam, Netherlands. Eelco is a practicing lawyer and lecturer. He is also a "fireman in training" on a German Class 5 2-8-0. Eelco was introduced to ASTT by longstanding member Hendrik Kaptein and has travelled over with Hendrik to attend our conferences in both 2022 and 2023.

**Peter Didelius** from Lewiston, Idaho, USA. Peter is currently employed as a welder in the US Navy. He also volunteers on heritage railroad trackwork and vehicle painting and will shortly begin volunteering at the Southern California Railway Museum which he's hoping will include working on steam locomotives. He has a great interest in steam locomotives and industrial archaeology.

### Membership Numbers

The current breakdown of membership is:

Full Members:	38	UK members:	81	Age ranges	
Associate Members:	72	EU:	15	Over 60	Approx. 48%
Student Members:	10	USA:	11	30 to 60	Approx. 38%
		Australasia:	11	Under 30	Approx. 14%
<b>Total Membership:</b>	<b>120</b>	Asia:	2	Av. age	Approx. 56

The figures indicate that we have an encouraging proportion of younger members, but more will always be welcome!

# PUBLICATIONS PAGE

## Chris Newman

### Book Sales

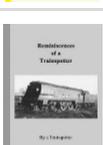
55 books have been sold in the four months since Newsletter No 22 was circulated. The sales numbers are listed as follows:

Publisher	Author	Title	Sales since N/L 22	Total Sales
ASTT	L.D. Porta	Porta's Papers Vol 1	2	139
	L.D. Porta	Porta's Papers Vol 2	1	130
	L.D. Porta	Porta's Papers Vol 3	5	93
	C. Newman (Editor)	Porta's Centenary Compendium Vol 1	9	78
	C. Newman (Editor)	Porta's Centenary Compendium Vol 2	24	24
	Ian Gaylor	Lyn Design Calculations	1	109
	David Wardale	5AT FDCs	2	215
	David Wardale	Reminiscences of a Trainspotter	8	34
	Alan Fozard	5AT Feasibility Study	1	43
Camden	David Wardale	The Red Devil and Other Tales from the Age of Steam	0	260
	Phil Girdlestone	Here be Dragons	0	33
	Jos Koopmans	The Fire Burns Better ...	0	11
	L.D. Porta	Advanced Steam Design	0	5
Crimson Lake	Adrian Tester	A Defence of the MR/LMS 4F 0-6-0	2	42
	Adrian Tester	Introduction to Large Lap Valves	0	19
Total sales			55	1238

Book sales provide a useful income to ASTT which helps to fund our activities, not least our Revolution project. Members are urged to support these endeavours by purchasing books from us.

We'd like to expand our book selection, so we welcome any suggestions for additional titles that we might be able to sell, or new texts that we might publish under ASTT's logo.

## Titles published by the Advanced Steam Traction Trust

	Year	Author	Title	Pages	RRP*
	2015	David Wardale	The 5AT Fundamental Design Calculations	556 (b&w)	£49.00
	2016	Alan Fozard and others	The 5AT Feasibility Study edited	230 (colour)	£35.00
	2018	Ian Gaylor	Steam Locomotive Design Specifications and Calculations for New Build Baldwin 2-4-2T 'LYN'	604 (colour)	£52.00
	2018	L.D. Porta transcribed and edited by Chris Newman	Selection of Papers – Volume 1 - Tribology and Lubrication by	556 (b&w)	£27.00
	2019	L.D. Porta transcribed and edited by Chris Newman	Selection of Papers – Volume 2 - Adhesion, Compounding and the Tornado Proposal	556 (b&w)	£27.00
	2021	L.D. Porta transcribed and edited by Chris Newman	Selection of Papers – Volume 3 - Steam Locomotive Boilers, Fireboxes and Combustion	556 (b&w)	£27.00
	2022	Compiled and edited by Chris Newman	A Compendium of Articles and Papers to celebrate the Centenary of the birth of Livio Dante Porta - Volume 1	226 (colour)	£27.00
	2023	Compiled and edited by Chris Newman	A Compendium of Articles and Papers to celebrate the Centenary of the birth of Livio Dante Porta – Volume 2	331 (colour)	TBA
	2023	David Wardale	Reminiscences of a Trainspotter	67 (b&w)	£16.00

\* the RRP's (recommended retail prices) shown include UK postage. Additional postage costs may apply to some titles. Paid-up members of ASTT are entitled to a 20% discount on these prices.

All these books can be purchased through ASTT's website at <http://advanced-steam.org/books-for-sale/>

# ASTT ANNUAL CONFERENCE

## Chris Newman

ASTT held its annual conference in the Leonardo Hotel in Swindon over the weekend of 7th to 8th October 2023. There were 22 attendees over the two days, 18 from the UK, two from Holland and two from Spain. The conference was also broadcast live on Zoom.

Speakers and their presentations were as follows:

**Andrew Hartland** (ASTT Member): “Why Did BR Give Up on Steam? Part 4 – Shunting locomotives”

**Hendrik Kaptein** (ASTT Member): “Countering Reciprocal Forces in Steam Locomotive Drive Mechanisms – A balanced approach”

**Matt Candie** (CEO of Steamology): “Zero Emission steam heat and power”

**Joe Cliffe** (ASTT Member): “Bulleid’s Turf Burner – is it a pointer to a future Biomass Loco?”

**Owen Jordan** (ASTT Member): “Empiricism and the Steam Locomotive”

**Mike Stockbridge** (ASTT Member): A briefing on what can still be seen in the GWR Railway Village in Swindon

**Graham Shirley** (ASTT Member): “100 Years of Caprotti”

**Jamie Keyte** (ASTT Member): “Progress report on the design and construction of Revolution”

**John Hind** (ASTT Chairman) & **Ian Gaylor** (ASTT Member): “Report on Trials and Research into Coal Substitution”

PDF copies of the nine presentations can be found on ASTT’s website. It is hoped that video recordings of the presentations may soon be available too.

The conference programme also included a visit to the Swindon and Cricklade Railway to see the progress on the restoration and rebuild of Merchant Navy 4-6-2 to its original Bulleid condition by the General Steam Navigation CIC.

The conference also included a conference dinner at the Leonardo Hotel that was attended by 16 members.

Finally, Jamie Keyte revealed the rolling chassis for Revolution which had been successfully tested on the Stapleford Miniature Railway immediately prior to the conference, as reported in the News section of ASTT’s website.



Conference attendees inspecting Revolution’s chassis at the Leonardo Hotel in Swindon – 8<sup>th</sup> Oct 2023

## Conference Plans for 2024 and 2025

It may seem premature to be thinking about conferences one or two years ahead, but the attendance at our Swindon event was down on previous years and we are trying to learn from that. However, we are unsure whether it was due to short notice, choice of topics, the location of the venue, or the economic climate that caused the lower-than-expected numbers. If anyone has any opinions on this, please let us know.

We believe that it is very important that our conferences continue, for several reasons: (1) they provide opportunities for members to learn from one another and from outside speakers; (2) they provide opportunities for trustees and members to get together to renew friendships and to develop new ones; (3) they will provide us with valuable credentials when it comes time to register ASTT with the Charities Commission.

One thing we can easily do is make our plans visible earlier than we've done in the past hoping that we can attract more members to attend. Another is to survey our members for their preferences.

### 2024 Conference

**Location:** In order to increase attendance at our 2024 event, we would like to seek members' preferences as to its date and location. We currently have three options to offer with regards location:

**Dudley** (near Birmingham) with an afternoon visit to [Tyseley depot](#);

**Derby** with an afternoon visit to the [Midland Railway Centre](#) in Butterley;

**Doncaster** with a visit to the [Danum Gallery, Library and Museum](#) (which houses Green Arrow and Ivatt Atlantic No 251) and/or the [Markham Grange Steam Museum](#) which houses a selection of stationary steam engines.

**We are open to other ideas if members would like to suggest them.**

**Date:** The choice of date may depend on the available dates for accessing museums or steam centres, however we will take account of members' preferences where possible. Our usual choice of date is the first weekend in October, but we are flexible within the limitation that it takes place sometime in the autumn months of September and October.

We will shortly circulate an invitation to members to indicate their preferences for location and date, and we will make our plans around the feedback that we receive.

### 2025 Conference

2025 will be a year of celebration that will mark the bicentenary of the opening of the Stockton and Darlington Railway on September 27<sup>th</sup>, 1825. Plans to mark the occasion are still being developed, but they are likely to be held all over the country under the auspices of an SDR200 organisation (see <https://www.sdr200.co.uk/> and <https://railway200.co.uk/>). Listen also to Peter Hendy's talk about "Railway 200 & how the railway made the modern world" in [Green Signals' podcast No 7](#).

ASTT would like to participate in these festivities, both through its 2025 conference and through our *Revolution* project which we hope to complete in time for the bicentenary. Our current idea is to plan for our conference to be held in the Darlington/Shildon area and for *Revolution* to be put on display at some suitable location – the aim being to publicise ourselves and increase membership.

We would very much like to receive suggestions from members about how we might go about promoting ourselves at, and in advance of, the bicentenary. We will be even happier to receive offers of help with organising and promoting our presence at the event, both in terms of the conference and displaying *Revolution*.

**Please let us know if you can offer any suggestions and/or help.**

# REVOLUTION PROGRESS REPORT & FUNDING APPEAL

## Chris Newman

Jamie Keyte's inspiring presentation at our Swindon conference in October resulted in a very generous donation from Andrew Hartland who was in attendance, however the flyer that we distributed to members later in the month has so far proved disappointing as only one additional member has signed up to make a monthly contribution. **We therefore appeal once more to the generosity of our members to provide additional support to help see the project through to completion. As previously stated, if half of our members could donate £20 per month for 2 years, that should be sufficient to see the locomotive finished.**

Meanwhile, progress continues. Jamie Keyte reports as follows:

On the design front:

Alex Powell is progressing the boiler design.

Jamie Keyte has taken Grant Soden's designs for the tender and cab and is looking to get them to the point where parts can be made.

Richard Coleby has taken the completed valve gear drawings and has been seeking quotations for the manufacture of the components.

Richard has also been looking at detailing up the internal cylinder components with view to manufacture.

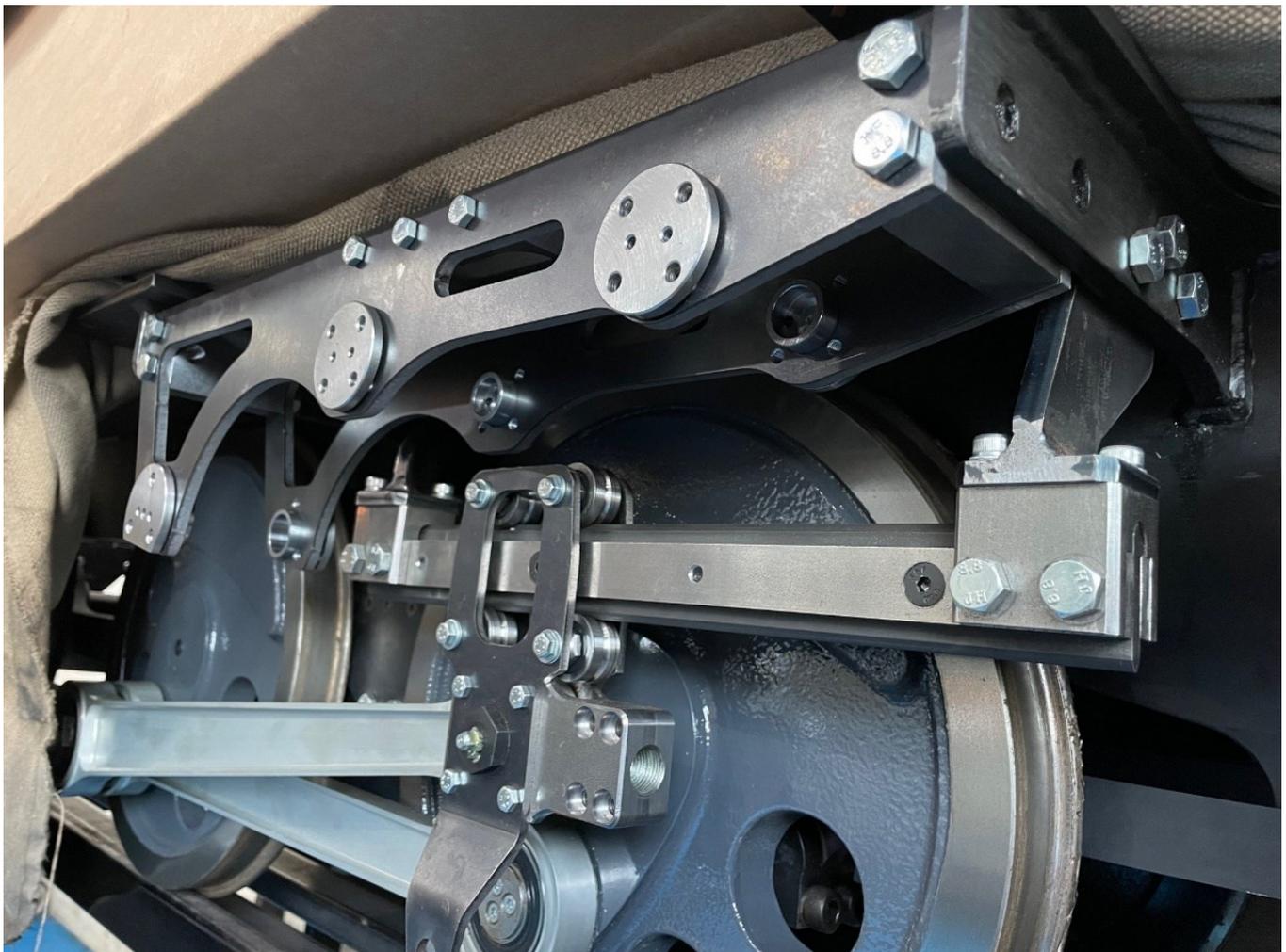
On the manufacturing front, some of the simpler components for the valve gear have been made by Jamie and are shown on the following images:



**Left: bearing housings for the reversing link and combination lever hanger.**  
**Right: bearing housings for the expansion link trunnions.**



**Left: profiled blanks for the side plates and the mid-spacer block with appropriate machining allowances.  
Right: the assembled valve- gear frame**



**Above: Richard Coleby's aesthetically pleasing valve-gear frame, positioned on the locomotive. It may be seen that the valve-gear frame is not bolted into place but held in place by the close fit between components – a credit to the accuracy of John Dunn's main-frame machining!**

**(Note: the apparent scrubbing on the leading wheel flange is the remains of masking tape from painting.)**

### **Cylinder, piston and valve design**

Just arrived from Richard Coleby is the "exploded" drawing of the cylinder, piston and valve components for *Revolution* – see overleaf.

Readers will appreciate the level of detail that the design work has involved and the elegance of Richard's work and the complexity of his design.

Currently available funds should allow the commencement of procurement, manufacture and assembly, but **additional funding will be required to complete these items.**

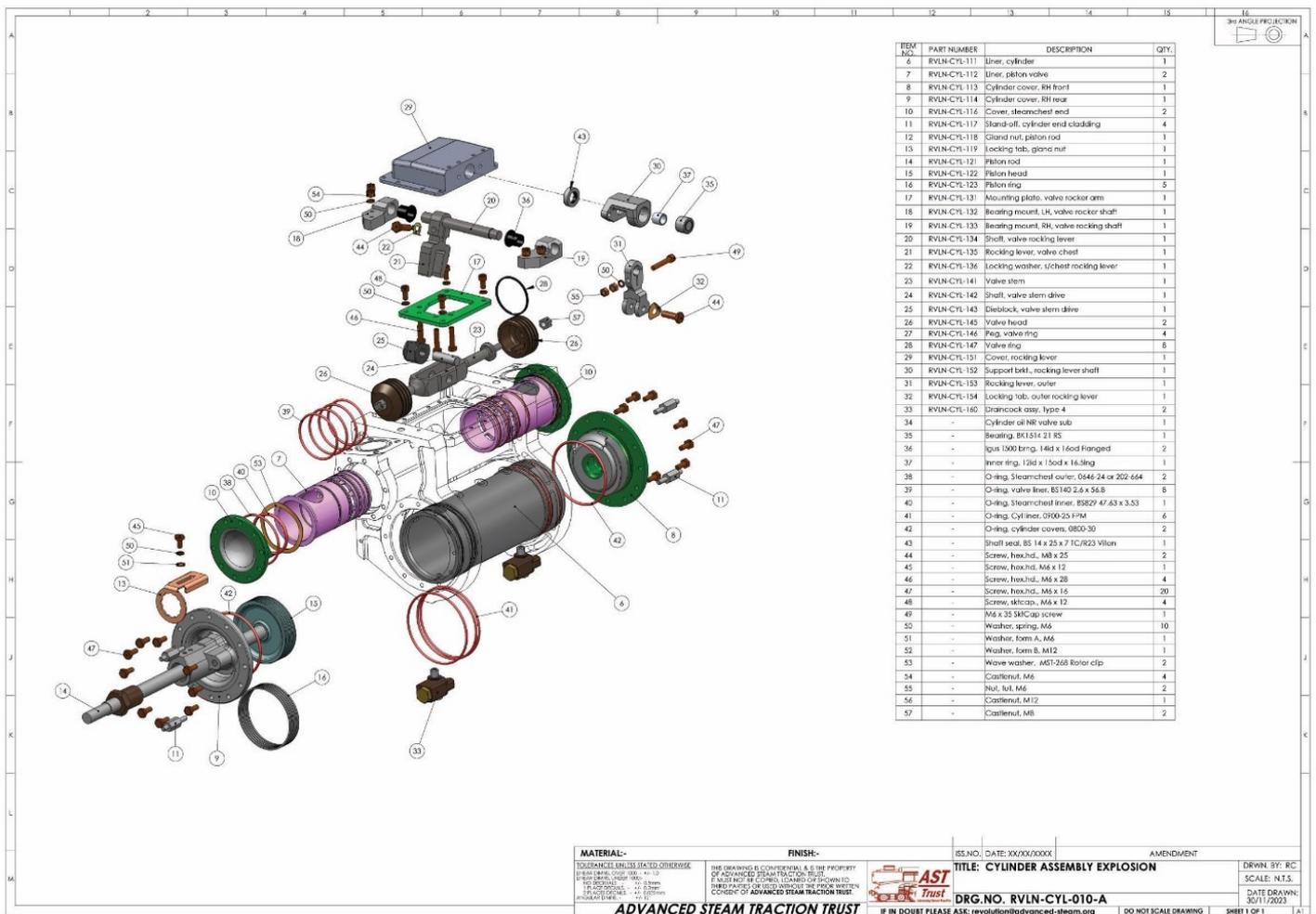
Richard offers the following commentary on the drawing:

“So why go to the trouble of creating an exploded view of an assembly?

Back in the day when this was a job for the graphics department, often involving hours of painstaking and expensive work on complicated assemblies, it was generally avoided by the original designer as his time was better spent on more immediate issues.

However, CAD has changed all that as, with little more than a few clicks with the mouse, hey presto—it’s done!

Of course, as with all things worth doing well there is a bit more to it than that but by and large it now comes within the skill of the designer to accomplish this work, and this also brings in added benefits.”



Richard continues his commentary as follows:

“These benefits may be summarised as follows –

The software automatically generates a Bill of Materials (BOM).

The information in the BOM is added at part level and can contain all the relevant information needed for the individual component. In the shown explosion this is just Part No. and Description, but it can contain supplier details, cost and any other instructions needed to procure the part.

The BOM can be downloaded as a separate spreadsheet file and then added to the main parts listing which itself can be used by the buying department.

The explosion brings to light exclusion of small parts that can easily be forgotten in a complicated assembly (the rocker drive shaft keys are missing in the attached explosion!)

The view angle can be instantly adjusted to simplify the clarity of many individual parts.

The explosion can be used on the shop floor to aid assembly.

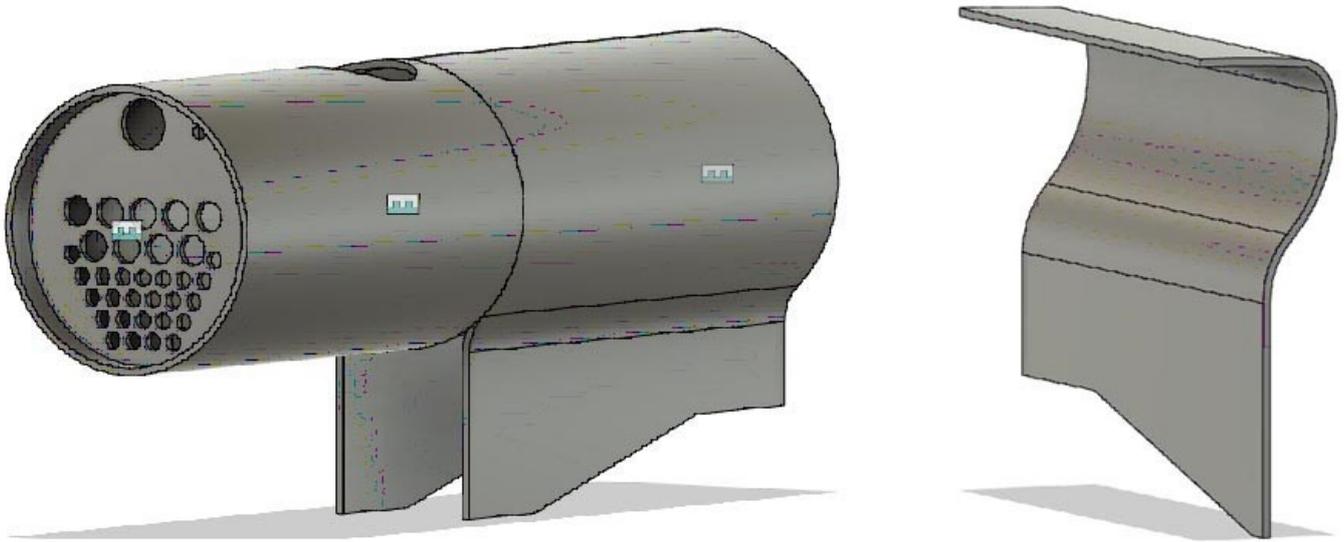
The illustrated cylinder explosion is not quite complete as it is missing the guidelines to show how the individual parts fit together but still represents just one evening’s work.”

### Boiler progress

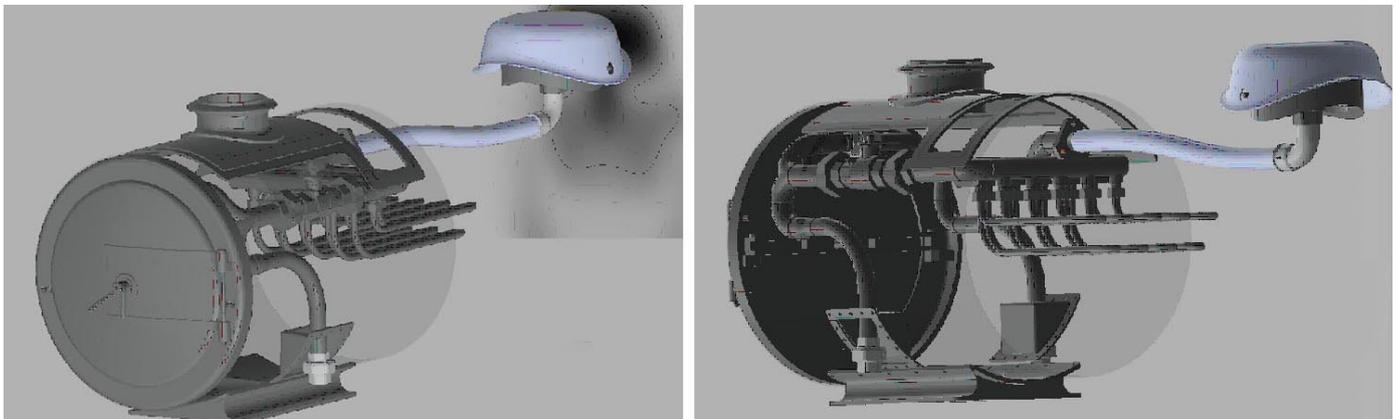
Alex Powell, who is heading up the boiler work reports as follows:

Heat transfer calculations were completed some time ago. A big thanks to Martin Johnson for his help with these.

Stress calculations are around 75% complete which has allowed the boiler plates to be designed. The unfinished calculations are for stay sizing and spacing, and for the back-head plating. Preliminary CAD drawings are shown below.



Designs for the main steam pipes and superheaters, including the shut-off valve in the dome, were completed by Richard Coleby some time ago – see images below.



**Steam pipes and superheater design by Richard Coleby**

It is hoped that the boiler design work may be completed by the end of 2023, but a later finish may be necessary. Anyway, **additional funding will be needed before the boiler’s manufacture can be undertaken!**

## **Revolutionary in more than name**

As explained in the flyer sent out last month, *Revolution* will be revolutionary in a number of ways:

Its revolutionary frame and suspension system will control stress levels by directing piston forces directly between cylinder block and draw gear through the spring beams rather than the frame.

Its revolutionary pony truck and suspension is not only elegantly simple, but it also allows quick and easy adjustment of the horizontal and vertical loads that it carries.

Its revolutionary motion with its own mounting frame and roller bearings on all joints (photos above) and outside admission piston valves driven by rocking levers, minimise maintenance costs.

It will be able to run on a simple stationary testbed driving a hydraulic dynamometer through a chain driven from its axle-mounted sprocket. In this manner, *Revolution* will be used to accurately quantify the effects on its performance resulting from design changes to its boiler, engine components or draughting, or when burning different fuels etc.

It will provide a model that can be replicated at standard gauge, offering heritage railways low-cost, high efficiency, low-maintenance steam traction that will meet the expectations of most of their patrons, leaving classic heritage traction to operate on “enthusiast’s days”, thereby imposing less wear and tear on the ageing fleet of historic locomotives.

# **Appeal**

**If you would like to support this exciting project, please send a donation or, better still, set up a standing order with your bank to make a monthly contribution to **the Advanced Steam Traction Trust’s HSBC bank account: Sort Code 40-28-14, Account No 4176 0947**. Or if you prefer, post a cheque made out to “Advanced Steam Traction Trust” to Chris Newman at:**

**Flat 4, 2 Kimmerghame View, Edinburgh EH4 2GP.**

# BURE VALLEY NOVEMBER TRIALS

## John Hind

Writing this, we have just finished the latest set of fuel trials at the Bure Valley Railway. There were two days of trials and as it was out of season, we could run two trains a day and so tested 4 fuels, though we did have to vary the daily timetable, as there was a charter on each day, which we had to work around, which meant some sharp station working at Aylsham, when we split the train to run round (we double the normal train length for the tests).

Our test team was Ian Gaylor, John Scott and Mike Stockbridge, who was attending for the first time, so we made sure that he got turns in as a footplate observer. Scott Bunting once again drove superbly and consistently for the trials. On the first day of the trials we were joined by Lewis Knights, who took a turn as footplate observer. Lewis is BVR's newest and youngest driver at 21. Phil Thomson from Phoenix Oils joined us for both test days.



### **Mike Stockbridge vacuums smokebox char from Oxbow for weighing**

This time the trials were principally at the request of the fuel suppliers following their reviews of our draft report after the April trials. Ian Gaylor and my presentation at the 2023 conference gave an interim report. (Conference paper available on our website).

The fuels we tested were:-

CPL's Heritage Steam Smokeless Steam Coal (HSSC) – small briquettes

CPL's HSSC – large briquettes

Oxbow – low sulphur

Phoenix Oil – Green Dragon – large briquettes (4 inch square blocks)

CPL had asked for a retest of the HSSC small briquettes as during the April tests, we had only been able to test on the return journey, rather than a full round trip. The chance to test the large briquette variant also adds to our body of knowledge as we can see the effects of fuel size.

Oxbow had responded to our criticism of the high sulphur content of their ‘Newheat’ fuel tested in April, about high sulphur content leading to long term boiler corrosion, by producing a blend with low sulphur, but with an expectation of poorer performance.



**Oxbow Low Sulphur**

Phoenix Oil wanted to test their larger briquette to understand whether the larger briquette would reduce smoke emissions. In addition they wanted to test the exhaust gases in the real world for Hydrogen Cyanide (HCN) gas concentrations, which combustion tests in an enclosed space, in a specialist laboratory had shown were present in the exhaust fumes and may have been the cause of the headaches experienced by footplate crews on two railways after using the fuel.

Ian Gaylor is producing the data for the report on the results of this year’s test programme, so we cannot give any meaningful data at time of writing, though we should be able to give an update in the next newsletter.

Phoenix Oils had purchased a portable gas detector that had been calibrated to detect HCN and calculate on a time-weighted average the level of HCN detected over the Health and Safety Executive’s short-term exposure limit (STEL) of 15 minutes or the long-term exposure limit (LTEL) of 8 hours. The STEL limit is 4.5 parts per million and LTEL limit is .9 parts per million. One of the symptoms of over exposure to HCN is headaches.

Ian modified our test log to include taking an HCN reading at key points on the line to capture results when the engine was working hard or drifting, which in effect meant a reading at two minute intervals. We also logged the levels of HCN for the other fuels to establish a baseline.

We took a step by step approach to testing the rapemeal cake, which started by measuring levels when stationary on shed and then en route to the first passing loop, where we stopped to assess results and take a collective decision, whether to carry on. The HCN results when running were 0, but the engine was not steaming. The fire was thickened to the base of the firehole door by adding more fuel and we carried onto Aylsham, but there was more smoke, though the fuel was the most reactive of all those tested, however the safe limits were now exceeded.

Because of the levels now detected, we terminated the test early and only ran one way to from Aylsham to Wroxham. The levels are very much dependant on proximity to chimney, wind direction, whether the locomotive

**Phil Thomson of Phoenix Oils  
with the HCN Meter**



is working or drifting, or stationary as in station limits or on shed. We did record fuel and water used, so should get some results for fuel usage and compare with the April results.

The high nitrogen levels in the constituents of the fuel are thought to be the source and Phoenix are reviewing whether any other crop wastes can be used as a feedstock.

Every cloud has a silver lining, and in our case, on the return trip it was a chance to do a final test on Ffos-y-fran coal using the last delivery that the Bure Valley had received. We can now compare that, with the results from the first trials we did in June 2021. Ffos-y-fran is used as the baseline for comparison with all our tests.

Although, the tests may seem like they are repeats of tests of what we have already done, they will help our understanding of our test methods as there is sufficient data to demonstrate repeatability or not, of our methods and whether results from a one way trip are comparable with results from a round trip.

The results will confirm our gut feel on the day, that there are any differences in fuel consumption and combustion between large and small sizes of briquettes.

We are at the stage where our knowledge of alternative solid fuels to coal is plateauing and to date we are reactive in that we are testing products produced by others.

Our thoughts are now turning to how we can be pro-active, by testing solid fuels that are a blend of renewables that may give a performance like coal. In previous editions of the Newsletter we have reported on trials at Stapleford using our ideas on blended solid fuels. However, our problem is breaking out of the kitchen/home lab environment where it is just possible to make the 20 kg needed to test at Stapleford, but to test at the Bure Valley Railway is an order of magnitude greater, needing circa 200kg and then on standard gauge where circa 2000kg is needed.

To fund the development programme outlined at the 2022 Darlington conference and produce meaningful quantities of test fuel is going to need more funding than we have available. Grant funding may be available and we will be contacting the Heritage Railway Association to try and make use of their contacts with funding bodies, such as the National Heritage Lottery Fund, who now seem willing to funding projects that mitigate against the effects of climate change.

#### **Scandinavian Contacts – Fuel Testing – John Hind**

Both the Danish National Railway Museum and the Swedish Railway Museum have contacted us via the Heritage Railway Association about the results of the tests at the Bure Valley Railway and we have been able to send them information from the tests.

Henrik Reuter Dahl and Jan Naumburg of the Swedish National Railway Museum came over to the UK in November on a fact finding visit to Beamish, Didcot, North Norfolk Railway, Bure Valley Railway and CPL's Immingham factory. They visited the Bure Valley the day after our tests concluded and the railway ran a train for them and I met them and was able to put faces to e-mail addresses. Their Government has a similar policy as the UK's and they have to be Carbon Neutral for 2030. They operate at their museum and on the mainline and have the same challenges as the UK heritage sector.

# DERIVATION OF THE LOCOMOTIVE ENERGY BALANCE - PART 3

## Martin Johnson

### 1. THANK YOU

Thank you to the following for responding to my plea for firebox data on certain classes in Part 2 of this article:

Steve Rapley, Chris Newman, Nigel Barnes, Graham Shirley

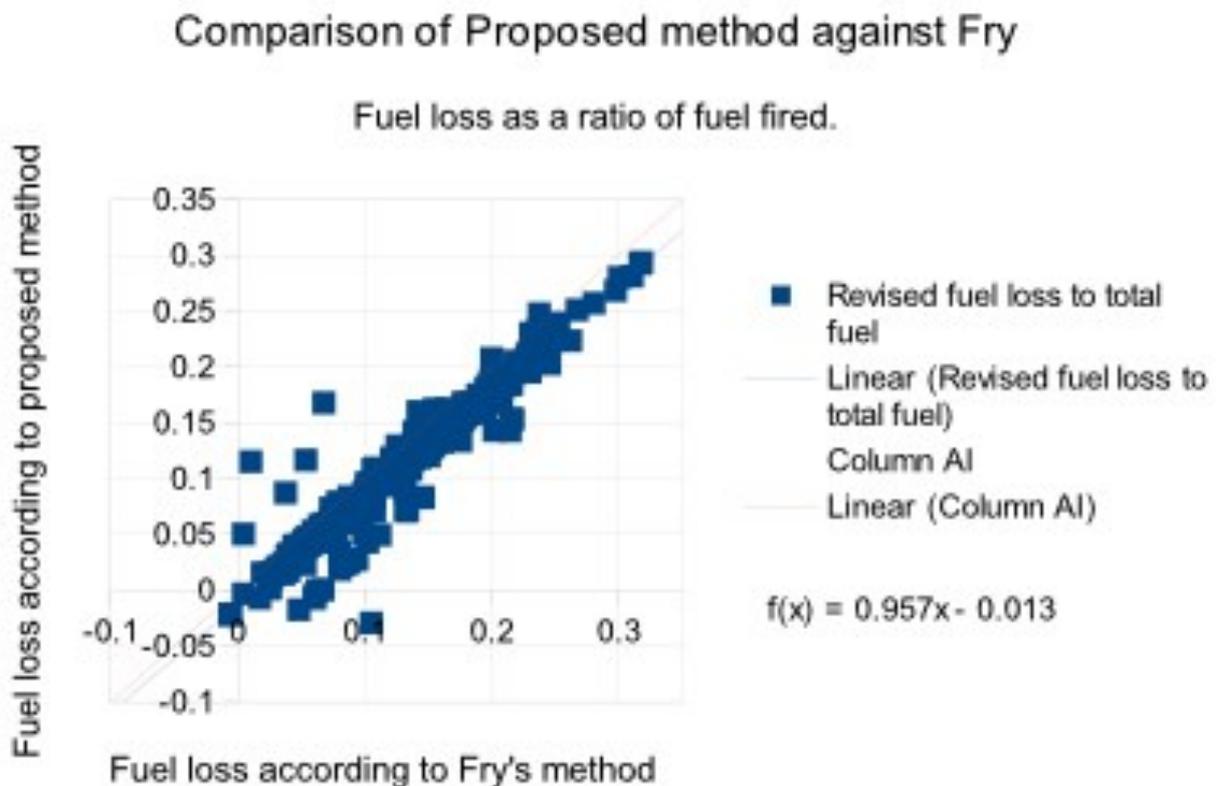
I have done the calculations (using some approximations for the narrow firebox engines) and they are pointing toward a reasonable relationship with retention time in the firebox. I shall discuss the findings next time along with some thoughts on modelling what goes in the firebox.

I have found since my appeal that I do not have the data on the GWR King class that I thought I had and the firebox volume for the Royal Scot also seems to be very elusive. Any offers?

### 2. MATTERS ARISING

#### 2.1. Figure 4 in Part 2 of this article Newsletter 22

The gremlins attacked again. I show below what it should have looked like (gremlins permitting).



Hopefully my commentary in Newsletter 22 makes more sense now.

## 2.2 Why does carbon loss affect gas flow?

I may not have adequately explained why a knowledge of the fuel as burnt is essential for a knowledge of gas flows in a locomotive. I hope the following numerical example might help:

A fuel comprising 0.837 carbon and 0.163 H by weight is burnt. The analysis of the dry gas products is measured as follows: CO<sub>2</sub> = 0.118, O<sub>2</sub> = 0.037, N<sub>2</sub> = 0.845

Calculation	Explanation
1 mol of dry flue gas contains 0.845 mols of N <sub>2</sub>	Assume that the volume fractions can be treated as mols
This is brought in with: 0.845 x 28 x 100/76.7 = 30.85 kg of air	28 is the molecular weight of N <sub>2</sub> . Air comprises 76.7% of N <sub>2</sub> by weight.
1 mol of dry flue gas contains 0.118 mols of carbon which is equal to 0.118 x 12 kg of carbon	12 is the molecular weight of carbon
This amount of carbon would imply the combustion of: 0.118 x 12/0.837 = 1.692 kg of fuel.	0.837 being the ratio of carbon in the fuel.
Hence the air / fuel ratio = 30.85/1.692 = 18.2	1 mol of dry flue gas is produced when 30.85 kg of air is burnt with 1.692 kg of fuel

Summarising all the above in one equation:

$$\text{Air/fuel ratio} = 28 \times \left(\frac{100}{76.7}\right) \times N_2 \frac{C}{(12 \times CO_2)}$$

re-arranging and including for carbon monoxide gives the commonly quoted formula:

$$\text{Air/fuel ratio} = \frac{(3.036 \times N_2 \times C)}{(CO_2 + CO)}$$

It will be seen that because carbon appears in the top line of the above equation, then if the amount of carbon in the fuel changes then the derived value of air/fuel ratio and hence flue gas quantity must change. So if we accept the Fry assumption that the fuel as burnt is the same as the fuel as fired, we get larger gas and air flows than assuming that fuel is lost as pure carbon; that in turn affects the calculation of how much heat is lost up the chimney and hence affects the whole energy balance.

I hope that makes things clearer.

## 3. INTRODUCTION

In Part 2 I showed that the assumption of fuel loss as pure carbon actually fits the Rugby test data far better than Fry's method. However, the results are still widely scattered and I felt it was worthwhile investigating an alternative method of determining the energy balance of a locomotive test. This article is concerned with the results of that investigation.

## 4. THE THEORY

Chris Newman gave a thorough explanation of the combustion triangle in Newsletter 22, so I hope that everybody has read it.

The important point in this context is that any given point on the combustion triangle corresponds to a single combination of fuel and air ratio. Therefore, the combustion gas analysis for a given test shows precisely what

composition of fuel is being burnt and at what air ratio. By comparing the deduced fuel from the gas analysis results to the fuel composition derived by chemical analysis, we can work out how much carbon is being lost from the system. This is subject to the assumption that fuel is actually lost as elemental carbon (which appears to be confirmed in my earlier analyses) and consequently no mass of oxygen or hydrogen is lost. Note that the calculation is also independent of how much fuel is being used or how much steam is generated.

It is possible for some test points to correspond to a "gain" in carbon but these would actually suggest a hydrogen depleted fuel which can occur with a fire that has burnt off all the light fractions and is burning mostly carbon stored on the grate. In a perfect scenario, the points corresponding to carbon loss would be balanced by points indicating carbon gain (or hydrogen loss).

The above is a major simplification of the theory, and I will be happy to provide more details by e-mail correspondence.

## 5. THE METHOD

I wrote a spreadsheet that would take the CO<sub>2</sub> and O<sub>2</sub> gas readings, plus the fuel analysis and then:

1. Correct the CO<sub>2</sub> and O<sub>2</sub> readings on the assumption that CO would combust to produce CO<sub>2</sub> and consume O<sub>2</sub> albeit outside the locomotive. The calculation is based on molar chemistry.
2. Determines how much carbon loss (or gain) would be needed from the fuel to give a CO<sub>2</sub> reading that matches step 1 above. This is achieved by trying an arbitrary carbon loss and calculating the associated CO<sub>2</sub> reading using molar chemistry. A Newton Raphson style iteration is then used to find a numerical solution to find the correct carbon loss to give the corrected CO<sub>2</sub> reading from Step 1.
3. Iteratively determine the air ratio that would give the correct O<sub>2</sub> reading from Step 1 on the fuel as determined in step 2. This step is achieved by taking two arbitrary air ratios and calculating the associated O<sub>2</sub> readings using molar chemistry. A revised value is then determined by interpolation and the process is then repeated until an acceptable solution is found.

The above stages are easily checked by comparing the derived CO<sub>2</sub> and O<sub>2</sub> readings with the target values that were created in Step 1. Figure 1 shows the results of that comparison with O<sub>2</sub> comparison on the left and CO<sub>2</sub> on the right.. The agreement for O<sub>2</sub> drifts slightly at oxygen concentrations below 2%. The CO<sub>2</sub> has a few scattered points that seem to be associated with scatter in the original Rugby data. I think it would be possible to improve the agreement between the lower O<sub>2</sub> values if the iteration process was improved, but I decided not to pursue that.

Comparison of Derived CO<sub>2</sub> reading with actual reading. Comparison of Derived O<sub>2</sub> reading with actual reading

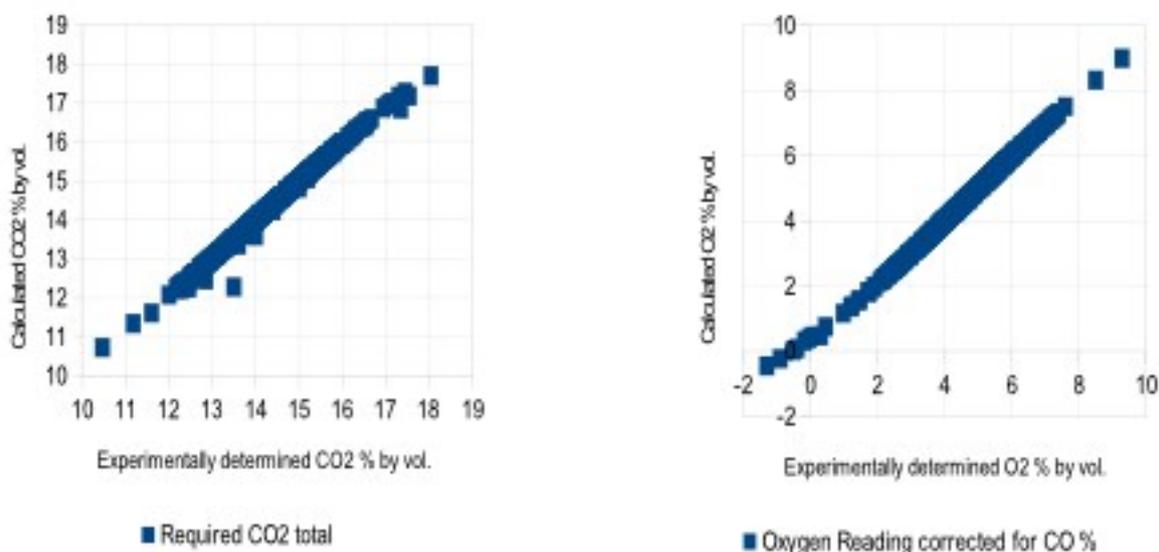
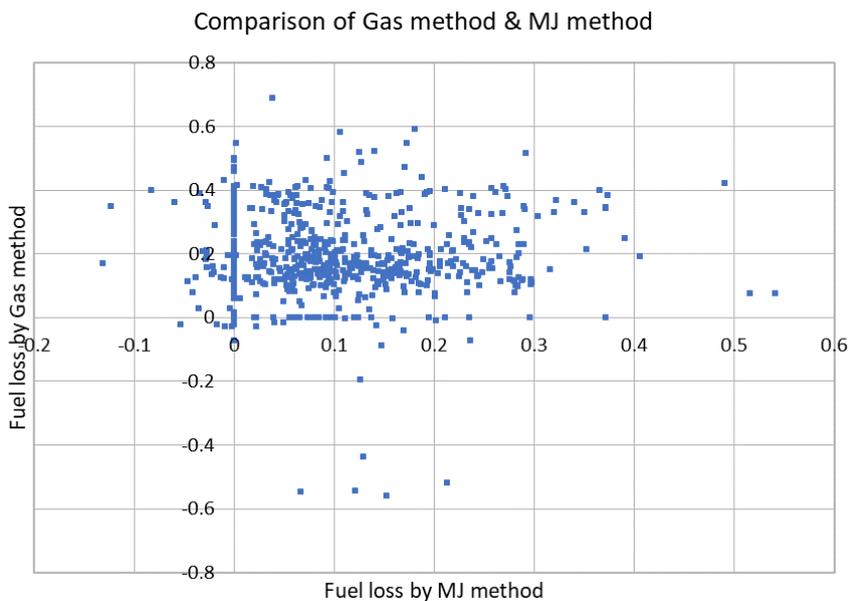


Figure 1: Comparison of derived CO<sub>2</sub> and O<sub>2</sub> readings with target values.

Having derived a set of fuel compositions and air ratios that would produce the observed flue gas analyses, The next stage in the analysis was to calculate the air flows and mass balance using the same methods as described in Parts 1 & 2. An energy balance was also derived using the same methods as described in Part 1. This used the composition of fuel as burnt and air ratio derived as above. I also assumed the standing loss was a constant 100kw for all locomotives tested. (See Part 1 for derivation of this).

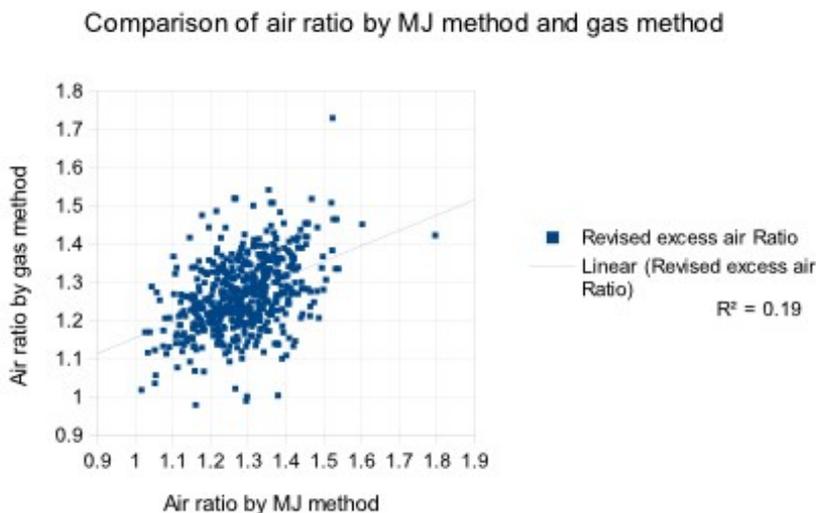
## 6. THE RESULTS

I conducted a comparison of lost carbon derived from my modified Fry method as described in Parts 1 & 2 of this article ("MJ method") and this method which relies only on gas analysis (Gas method). It will be seen from Figure 2 that there is no correlation between the methods.



**Figure 2: Comparison of carbon loss derived by MJ method and Gas method.**

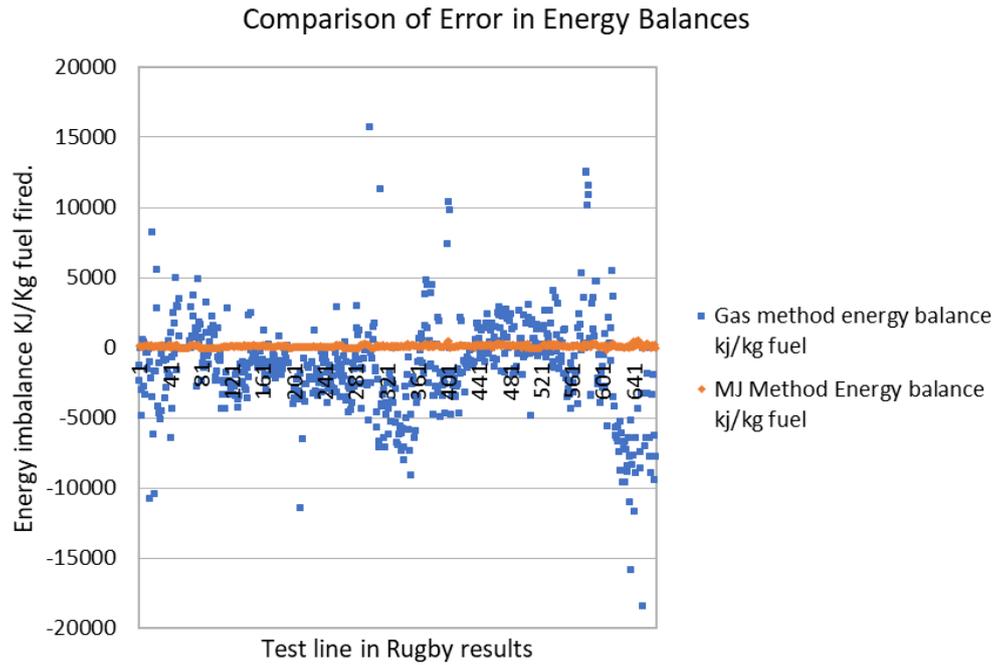
The same exercise for air ratio shown below in Figure 3 gives some correlation, but with a poor correlation coefficient.



**Figure 3: Comparison of derived air ratio by MJ method and Gas method.**

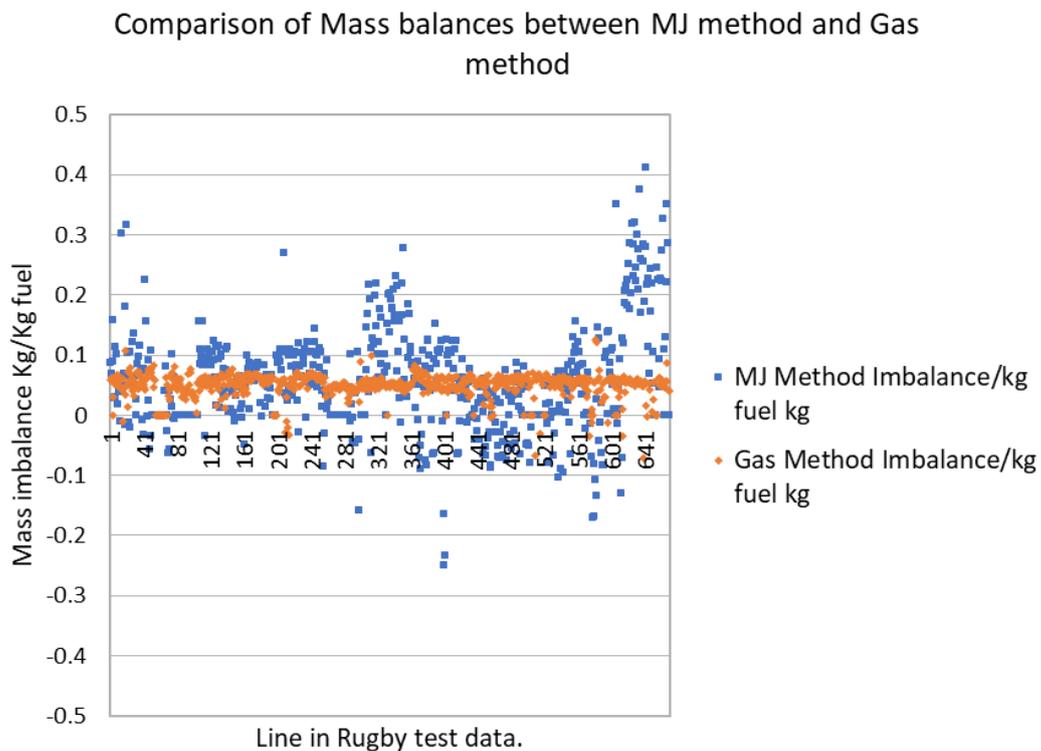
I then looked at whether the energy balance derived by the gas method was possible, which I did by comparison with equivalent results derived by the MJ method. The results of this are shown in Figure 4 which show that the Gas method gives massive errors in comparison to the MJ method. This is not completely surprising as the MJ method achieves an energy balance at the expense of having fuel as burnt composition and air ratio which would not give the observed flue gas test results. Figure 4 also shows that the error in energy balance is predominantly negative - indicating there is more energy being created by the locomotive than provided by the fuel burnt implying perpetual motion which cannot be true! The average and median values are -3000 and -1400 kJ/kg of fuel. For

reference, a kg of fuel as fired contains approximately 24000 kJ/kg net of fuel loss and carbon monoxide loss, so the negative fuel loss error is significant.



**Figure 4: Comparison of residual error in energy balances by MJ method and Gas method**

As a further check the mass balance values for the MJ method and Gas method are shown in Figure 5. In this case, the Gas method gives closer agreement of mass balance, which is not surprising because the chemistry of the system has been given priority in deriving the basis of the fuel burnt. The results from the MJ method are quite scattered and the median error greater than that for the Gas method, but not massively so.



**Figure 5: Comparison of residual error in Mass balances by MJ method and Gas method**

## 7. WHICH METHOD IS CORRECT?

The above has shown there are two different answers for fuel loss, air ratio, gas flow and air flow depending on whether we choose to believe an energy balance, or a mass balance of carbon in the system. So why is there a discrepancy?

To solve that I looked at how sensitive the results were to experimental error, which I did by taking one data point and changing the flue gas carbon dioxide value by 0.1%. A summary of the results is shown in Table 1.

BR5 73031	Gas Readings		Fuel as fired	Revised excess air	Fuel as burned	Gas method energy balance
Run	%CO2	%O2	Carbon %w	Ratio	Carbon %w	kJ/kg fuel
925	14	4.9	73.71	1.29	58.7	-2343
	14.1	4.9	73.71	1.29	62.1	-1367
	13.9	4.9	73.71	1.29	55.6	-3230
	14	5	73.71	1.30	61.6	-1515
	14	4.8	73.71	1.28	56.0	-3096

**Table 1: Sensitivity analysis for CO2 and O2 readings.**

The top line shows the calculation results for Rugby test run 925, while the next two lines show the effect of a variation in the CO2 reading by + and - 0.1% respectively. This shows that a 0.1% variation in CO2 reading (due to instrument error, for example) affects the deduced fuel carbon by 3.25 percentage points. The deduced air ratio is unaffected by errors in carbon dioxide reading but the energy balance shifts by 930 kJ/kg for each 0.1% shift in CO2 reading.

A similar exercise for the Oxygen readings is shown in lines 4 & 5. This shows that deduced air ratio changes by 0.01 per 0.1% change in flue gas oxygen reading. However, the deduced energy balance changes by 790 kJ/kg of fuel and the deduced carbon content changes by 2.8 percentage points for each 0.1% shift in oxygen reading.

In summary, experimental errors in flue gas carbon dioxide measurement affect the calculation to such an extent that carbon loss cannot be reliably determined. However, experimental errors in flue gas oxygen content do not prevent deduction of the air ratio to a reasonable degree of accuracy.

## 8. WHY DOES THE TECHNIQUE NOT WORK?

The reason for the failure of the technique can be found by looking at the Orsat apparatus, which was the method used to determine the flue gas analysis in all the Rugby tests. A good explanation of the basic apparatus and means of use can be found here:

[https://en.wikipedia.org/wiki/Orsat\\_gas\\_analyser](https://en.wikipedia.org/wiki/Orsat_gas_analyser)

A photograph of the Orsat is shown in Figure 6 below.

A simple explanation of the technique is:

- A volume of gas is drawn into the apparatus and measured using a glass burette (right hand side of Figure 6), usually calibrated to 100 ml.
- The gas is then brought into contact with a chemical which will react with and absorb a given gas. For carbon dioxide potassium hydroxide is usually used.
- After allowing a suitable time for the reaction to take place, the volume of gas remaining will have reduced and is measured in the glass burette.
- The difference in the two measured volumes is the volume of gas absorbed.

There are other parts of the apparatus to ensure the gas sample is kept at constant pressure and temperature which are not considered here.



**Figure 6: Orsat apparatus as usually arranged.**

From the above, it is clear that on a 100 ml sample of flue gas, the volume of a given constituent such as carbon dioxide is determined from two readings of the 100 ml burette. The burette is usually calibrated 0 to 100 in 2ml increments over the first 30 ml, each ml corresponding to 5 to 10 mm height. So determination down to 0.1% volume requires interpolation of relatively small divisions into 2 parts. If smaller gas volumes are used, correspondingly finer interpolation is required. For carbon monoxide where volumes are in the order of 0.1 - 0.5% by volume, the error associated with interpolation is large, explaining the wide scatter in any correlation of carbon monoxide production.

The absorption of gas requires that the reactants are "active" and this reduces as the reactants are used. While the operating technique should ensure the gas has been absorbed by making repeated absorptions, any errors in absorption will systematically under - estimate the amount of a given gas. So in the case of carbon dioxide, the tendency will be to over - estimate the amount of carbon lost from the fire.

There are further experimental errors associated with initial calibration of the instrument, maintaining constant pressure and temperature of the gas sample, leaks from the apparatus, and contamination of the sample gas (usually dilution with air).

Thus it will be seen that the Orsat apparatus is only capable of accuracy in the order of 0.1% at best.

## **9. CONCLUSIONS**

While in theory it should be possible to calculate a loss of carbon during combustion using only the flue gas analysis readings, it is not possible in practice due to the limited accuracy of the instrumentation used.

The Orsat apparatus which was used for the Rugby tests has an accuracy no better than 0.1% by volume, with systematic errors which will tend to underestimate the amount of carbon present in the flue gases.

Although in some respects it is disappointing that a new method of determining carbon loss is not feasible, the work has proved useful in better understanding the limitations of Rugby flue gas analyses and putting the energy balance method in context.

It may be possible to use the proposed method of determining carbon loss in the future if methods of flue gas analysis with accuracies in the order of 0.01% by volume can be found.

# CAPROTTI ON PLM IN FRANCE

Graham Shirley, CEng

At the conference I was asked about Caprotti in France. In the unpublished Hugh Phillips manuscript "Caprotti Valve Gear" is the following article:



Figure 1

The story of Milan Caprotti applications outside Italy returned in 1930 to Europe with the rebuilding by the Paris, Lyon and Mediterranean Railway in France of one (Figure 1) of the 4-cylinder compound "Mountain" 4-8-2 locos of the 241A Class with 2CIC valve gear seen here above the cylinder. Originally introduced in 1925 there were 145 members of the class with 1.79m diameter driving wheels and four cylinders, the high pressure being inside the frame driving the centre coupled axle and the low pressure outside the frame driving the leading coupled axle with independent Walschaerts valve gear for each cylinder. There was a history of unreliability in this class stemming from inadequately braced frames which caused axle bearing to overheat and the very short connecting rods generated severe vibration which even resulted in connecting rod fracture. They were designed and built before the fundamental work undertaken by Chapelon became common practice in France and the PLM was not at all satisfied with the class. The experiment with Caprotti Valve Gear was a half-hearted attempt to make improvements but whilst the class was still being produced. In 1931 a single member was built new to a substantially revised design with higher boiler pressure, bigger wheels and rearrangement of the drive in that the low-pressure cylinders drove the second axle and the high pressure inside cylinders drove the third axle. This produced such an improvement - with the incorporation of Chapelon ideas - that rebuilding of the class commenced on these rather than Caprotti lines. No records have apparently survived of which engine had the Caprotti Valve Gear and how long it was so equipped.

If any reader can identify the location of the photo, or even the man on the right of it with the hat would be interesting to hear.

# GREEN SIGNALS PODCAST

## By Chris Newman

Richard Coleby recently recommended this “Green Signals” podcast to me. It has nothing to do with Modern Steam, and indeed steam traction gets only an occasional mention, but anyone who is interested in railways is sure to find it engaging -and enraging when it comes to discussing bonkers government decision-making such as Sunak’s recent cancellation of the Manchester leg of HS2!

I'd only listened to BBC podcasts before, and this isn't a BBC production, so I had to download Spotify onto my phone to enable me to listen to it. I very quickly became a fan - and something of an addict.

I should quickly add that you don't have to listen to it through Spotify. I expect there are other “Apps” that can be used, but you can listen to it directly on the [Green Signals website](#) or you can watch and listen to it on [YouTube](#) if you prefer to see the guys doing the talking. They may not be much to look at, but they are definitely worth listening to.

Anyway, as you'll quickly discover, each podcast is formed around a discussion between the two presenters, **Nigel Harris** and **Richard Bowker**, who are usually joined by an invited guest with special expertise in some aspect of the railways. For instance, in the latest podcast (episode 7) features **Network Rail Chairman Lord Peter Hendy** who talks about the plans for celebrating the 200<sup>th</sup> anniversary of the Stockton & Darlington Railway, and how the railway made the modern world.

For those who don't know of them, Nigel Harris is a “former Managing Editor and Events Director of RAIL magazine which he built up into Britain's market-leading industry magazine and which became a key opinion-former in the sector read by senior Politicians and industry leaders”, while Richard Bowker is a “former Chair and CEO of the Strategic Rail Authority as well as Chair of Virgin Rail Group, Group CEO of National Express and CEO of Etihad Rail in the UAE. A lifelong railwayman with a passion for analysis and debate”. (Both quotes are copied from the Green Signals website.)

The podcasts are released each week and (at the time of writing) seven episodes have so far been made available. All are worth listening to and I'd recommend starting with the first and working through them as there is an ongoing thread to some the topics discussed (mostly HS2!).

Anyway, I thought I'd pass on Richard Coleby's recommendation to our membership because I've found it so thoroughly worthwhile.

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