AST
Trust
Advancing Steam Traction

NEWSLETTER No. 19 - JULY 2022

78022, the loco used in the recent biocoal trials on the Keighley & Worth Valley Railway

CONTENTS

CHAIRMAN'S PIECE
John Hind

Later in the newsletter Chris Newman gives an update on membership; from my own point of view this year is particularly pleasing as we have not lost any members, so we must be doing something right!

In my last Chairman's Piece, I wrote about Paul Hibberd stepping down as Treasurer because of ill health and it is now sad to report that Paul subsequently died peacefully at a Nursing Home on 14/4/22. The funeral was on 3/5/22 and Richard Coleby represented ASTT. Later in the newsletter there is an obituary written by his wife Gill.

The last six months has seen an intense period of work in partnership with the Heritage Railway Association, Bure Valley Railway, Keighley, and Worth Valley Railway to help assess and collect data on fuels that can be used as an alternative to lump coal from Russia or Wales. Later in the newsletter I write about a couple of things that we have done. Thanks to Richard Coleby, Ian Gaylor, Mike Horne, Iain Jack, Alex Powell and John Scott for their support and help. I do not give a complete picture and only give a snapshot and have saved more detail for later newsletters.

Following on from my appeal in the last Newsletter for someone to step take on Paul's role as Treasurer. Hendrik Kaptein has volunteered to work with Chris Newman who administers our accounting spreadsheets.

No one came forward with direct experience of claiming Tax Relief on donations, which relies on being registered with the Charities Commission. Hendrik is now exploring this – fortunately, instructions for this are on-line, but Paul's last advice on this was that it was 'not as simple as it used to be.' The benefit of claiming Tax Relief is that we can claim it from the government from any donations to Revolution, which reduces how much we need to raise our ourselves. In 2021 we had donations of £11199 for Revolution, the Gift Aid on this worth £2799. Total Gift Aid for the project is potentially worth up to £18500, so this is an important task. We can claim back for 7 years from point of application, so we have until 2028 to make a successful application.

By now everyone will know about the 2022 Conference. It's a new venue this year in Darlington and follows the format that has worked in the past – some interesting talks, a chance to see some hardware – in this case the new build P2, a conference dinner and the chance to talk and socialise with like-minded people. As soon as you know that you are coming, please make your booking so that we minimise last minute panics with ourselves or more importantly our caterers – we don't want anyone to go hungry!

MEMBERSHIP MATTERS
Chris Newman

We welcome eight new members who have joined since our Newsletter No 18 was circulated:

Andrew Barnes from Norwich. Managing Director, Bure Valley Railway since 2001 and a director of the Heritage Railway Association.

Zack Dudley from Texas, USA. 18 years old and now our youngest member.   Zack is studying mechanical engineering.

Adam Sugden from London.

Sam Rowbotham from Colchester. Sam is a graduate mechanical engineer with a special interest in engineering innovation and "Structured Ideas Management" (SIM).

James Parkes from Derbyshire.

Gwion Clark from Wales. Gwion is has begun a Master's degree in mechanical engineering at Newcastle University. He is a volunteer trainee fireman on the Welsh Highland and Ffestiniog Railways, and hopes to learn about locomotive efficiency and alternative locomotive fuels through his association with ASTT.

Alan Williams from South Australia. Lifelong steam enthusiast. Career spent in power generation industry (steam turbines).

Mike Stockbridge from Oxfordshire. Retired project (mechanical) engineer from the petrochemical industry. Member of the Darjeeling & Himalayan Rly Soc and of the Chinnor & Princess Risborough Rly Soc.

Membership Numbers

I'm delighted to report that all of our 2021 members have renewed their subscriptions. This is the first year that we've retained 100% of our members. Membership numbers are now:

Full Members:	27	UK members:	76
Associate Members:	67	EU:	13
Student Members:	11	USA	7
		Australasia:	7
Total Membership:	105	Asia:	2

ASTT ANNUAL CONFERENCE
Chris Newman

Members should by now have received two circulars informing them about our annual conference to be held this year at the "Head of Steam" Museum in Darlington. The conference will take place over the weekend of 15th – 16th October.

Draft Programme: We are very grateful to members who have offered to present papers at the conference, and also to David Elliott who has agreed to make a presentation about the A1 Trust's P2 Project and the Trust's plans for the future. We are also grateful to David and his team for allowing us access to view their P2 locomotive No 2007 "Prince of Wales" which has been forging ahead as fast as the money supply permits. Using these offers, we have prepared the draft programme on the next page for the event.

Attendance Fees: We try to plan our conferences in a way that costs are covered by admission fees, thereby minimising what we have to charge members, and at the same time minimising the risks of financial loss to the Trust.   If we have 40 attendees, we calculate that the attendance fee should be no more than £100 for the two days (reduced for those who can only attend on one day). If only 30 attend then we will probably have to charge £115, so please come along to make up the numbers if you can.   The attendance fee has to cover the costs of room hire, refreshments, lunches, conference dinner, a donation to the A1 Trust and any other costs. Anyone who has not yet responded to our invitation is requested give serious thought to coming along, and to let us know asap if you think you can come or not.

Conference Dinner – A conference dinner will be held on the Saturday evening at the Mercure Darlington King's Hotel who have offered us a 3-course dinner for £30 p.p. in our own dining area.

Hotel Reservations – We have suggested two hotels where attendees might like to stay:

   The Mercure Darlington King's Hotel (where the conference dinner will be held) are offering bed & breakfast at £90 (fully flexible) for conference attendees, and

   The Darlington Town Centre Premier Inn which at the time of writing was offering non-refundable advanced bookings for bed only at £45 (non-cancellable) or £71 (fully flexible) plus £9.50 for breakfast.

Other smaller (and probably cheaper) hotels may be found through Booking.com.

The "Head of Steam" Museum is about a 20-minute walk from the Mercure hotel, and about 25 minutes from the Premier Inn. It is hoped that attendees with cars will be willing to ferry those who may be challenged to walk such distances.

Attendees are asked to make their own hotel bookings. [Those who want to book at the Mercure should write to Madeline Klimczak at Events@mercuredarlington.co.uk](mailto:Events@mercuredarlington.co.uk) or call her on +44 (0)1325 380222 (option 2) and tell her that you are an ASTT conference delegate seeking the discounted rate.

Note: there is a limited amount of free parking at the Mercure, however it appears that parking costs £8.50 per day at the Town Centre Premier Inn.

Members and Non-Members Attendance: The conference will be open to members and non-members alike, however we normally charge non-members a surcharge of around £10 in order to encourage them to become members. **Whether a member or not, please let us know if you're interested in attending.**

	Start	End	Topic	Speaker
			2022 Conference Programme – DRAFT only	
Satur-day 15th Oct	09:30	10:00	Registration & Coffee	
	10:00	10:15	Welcome	John Hind
	10:15	11:15	Why Did BR Give Up On Steam? Part 3 - Freight locomotives	Andrew Hartland
	11:15	12:15	Mechanical Efficiency of Reciprocating Steam Locomotives	Hedrick Kaptein
	12:15	13:00	Buffet Lunch	
	13:00	14:00	Update on the A1 Trust and P2 Project	David Elliott
	14:00	14:10	Walk to A1 Trust's workshop	
	14:10	15:40	Viewing of P2 locomotive at the A1 Trust's workshops	
	15:40	15:50	Walk back to meeting room	
	15:50	16:20	Tea/coffee	
	16:20	16:50	Experiences on the Canadian Pacific Railway, 1956 - 59	John Duncan
	16:50	18:20	Free time	
	18:20	21:20	Conference Dinner at the Mercure Darlington King's Hotel	
Sunday 16th Oct	09:00	09:15	Assembly in meeting room; registration of Sunday-only attendees	
	09:15	09:30	Welcome	John Hind
	09:30	10:30	On Locomotive Boilers	Adrian Tester
	10:30	11:30	Development of the Bure Valley ZB locomotives	Ian Gaylor
	11:30	12:00	Tea/coffee	
	12:00	13:00	Challenges of adapting ERTMS for Main-line Steam Operations.	Grant Soden
	13:00	14:00	Buffet Lunch	
	14:00	15:00	Update on ASTT's research activities into coal substitutes	John Hind
	15:00	15:30	Tea/coffee	
	15:30	16:30	Progress update on ASTT's test-bed locomotive "Revolution"	Jamie Keyte
	16:30	16:45	Wrap Up	John Hind
Stand-by Speakers			Developing the K6 engine: the Steam Concept	Owen Jordan
			A long-distance firing turn in South Africa	Andrew Shaw

PUBLICATIONS PAGE
# Chris Newman

Book Sales

75 books have been sold in the five months since Newsletter No 18 was circulated, most being Volume 1 of the Porta Centenary Compendium. The sales numbers are listed as follows:

Publisher	Author	Title	Sales since N/L 18	Total Sales
ASTT	L.D. Porta	Porta's Papers Vol 1	3	125
	L.D. Porta	Porta's Papers Vol 2	3	120
	L.D. Porta	Porta's Papers Vol 3	7	77
	C. Newman (Editor)	Porta's Centenary Compendium Vol 1	51	51
	Ian Gaylor	Lyn Design Calculations	3	100
	David Wardale	5AT FDCs	2	207
	Alan Fozard	5AT Feasibility Study	1	39
Camden	David Wardale	Red Devil and Other Tales ..	0	260
	Phil Girdlestone	Here be Dragons	1	33
	Jos Koopmans	The Fire Burns Better …	1	7
	L.D. Porta	Advanced Steam Design	1	5
Crimson Lake	Adrian Tester	A Defence of the MR/LMS 4F 0-6-0	2	29
	Adrian Tester	Introduction to Large Lap Valves	1	17
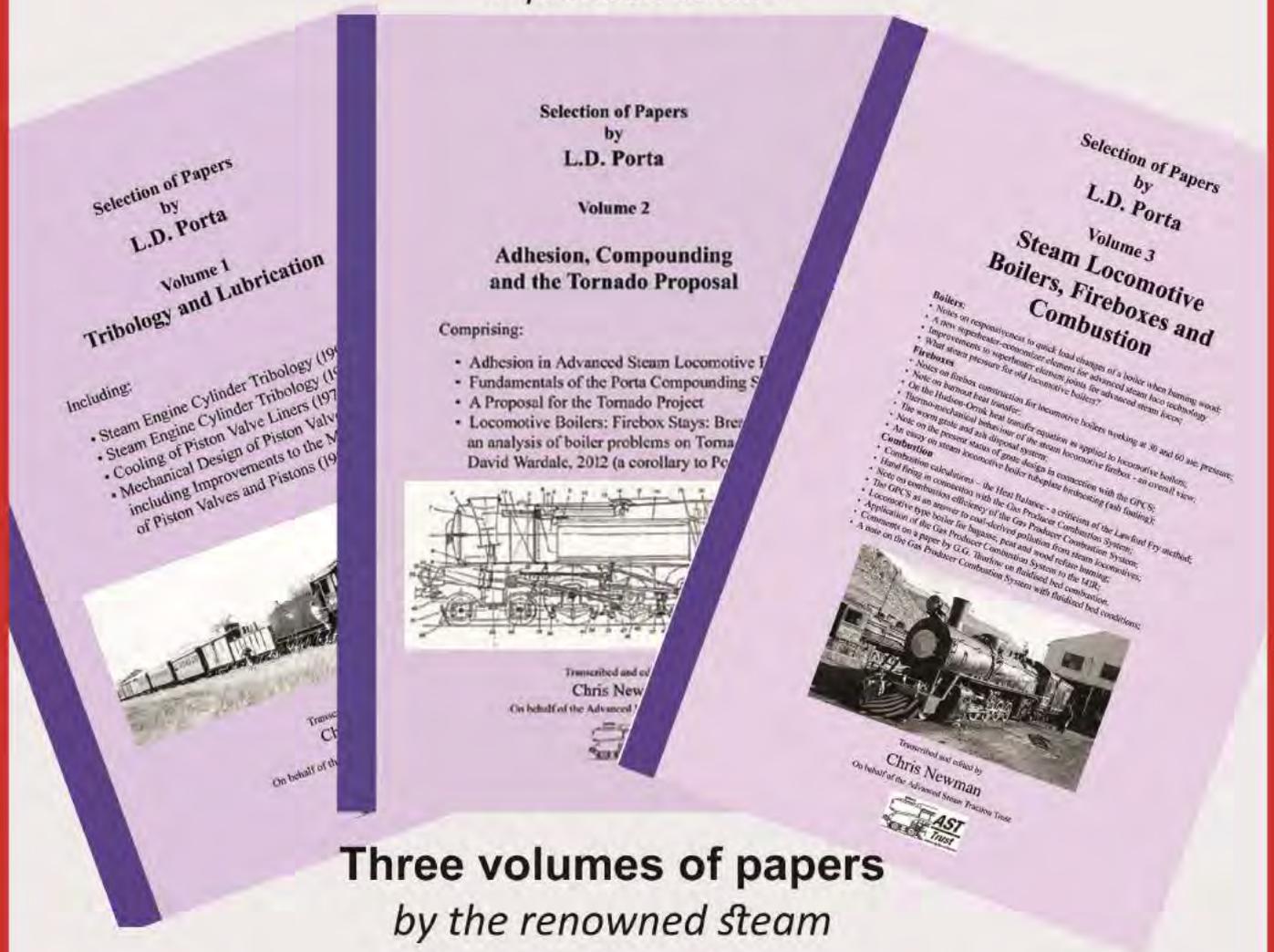
PAUL STUART HIBBERD, 1945-2022
Gill Hibberd

Paul was born on 19th May 1945 in Portsmouth, where he grew up as an only child. At school he was very intelligent and his talents were recognized quite early on when he was used to help tutor other children and get them through their eleven plus! He went on to grammar school and then to Oxford, where he acquired an MA in history. Changing tack somewhat he then went on to obtain an MSc in economics and statistics at Keele University.

Two interests dominated his childhood, one was cricket and the other was steam trains - which he went to see and travelled on at every possible opportunity.

He did briefly play cricket for his college at Oxford and continued to enjoy cricket, particularly test matches, for the rest of his life. However, steam and all its ramifications was his primary focus.

Curiosity was a dominant feature of Paul. So was fearlessness. He travelled extensively. At university he won a scholarship which sent him on a lecture tour in the States. At a time when it was very difficult he travelled in eastern Europe, on one occasion talking himself into Bulgaria when he did not have the required visa. In 1976, immediately after our marriage, we went to live and work in Vanuatu in the south west Pacific (then called New Hebrides). On the way we visited a lot of exotic locations as we did on the way home. When we had finished having our family travels began again both in eastern Europe and more widely. We visited India, South Africa and Cuba. We also had a flat in Spain which he had bought before he married me.

Paul had always thought that his wife would be somebody who he met on his travels. This proved to be true as he met me in France in 1974 though I wasn't the foreigner he expected. We married in 1976. Paul disliked intensely being an only child so one thing he wanted in a wife was a willingness to have "lots of children". We had 6 so I think his ambitions in this direction were met. Paul was a very gentle and kind father, qualities which he also exhibited with others who knew him well and many people have mentioned his gentleness and kindness in the letters which I have received.

Paul's curiosity extended to engineering, particularly in the world of steam. He loved anything which explored the possibilities of steam power in modern times, feeling that there was much more which could be achieved. He was full of ideas but he certainly wasn't going to be the one up to his elbows in grease. His last venture into the practical resulted in his woodwork join falling to pieces in the last second of his carpentry exam.

His first venture in actively supporting preservation activities came in his support for and assistance with pushing forward the building of a replica George V steam locomotive. Neither he nor Bruce, with whom he began this project, will see it through to the end, but I am sure that others will continue the good work that they started.
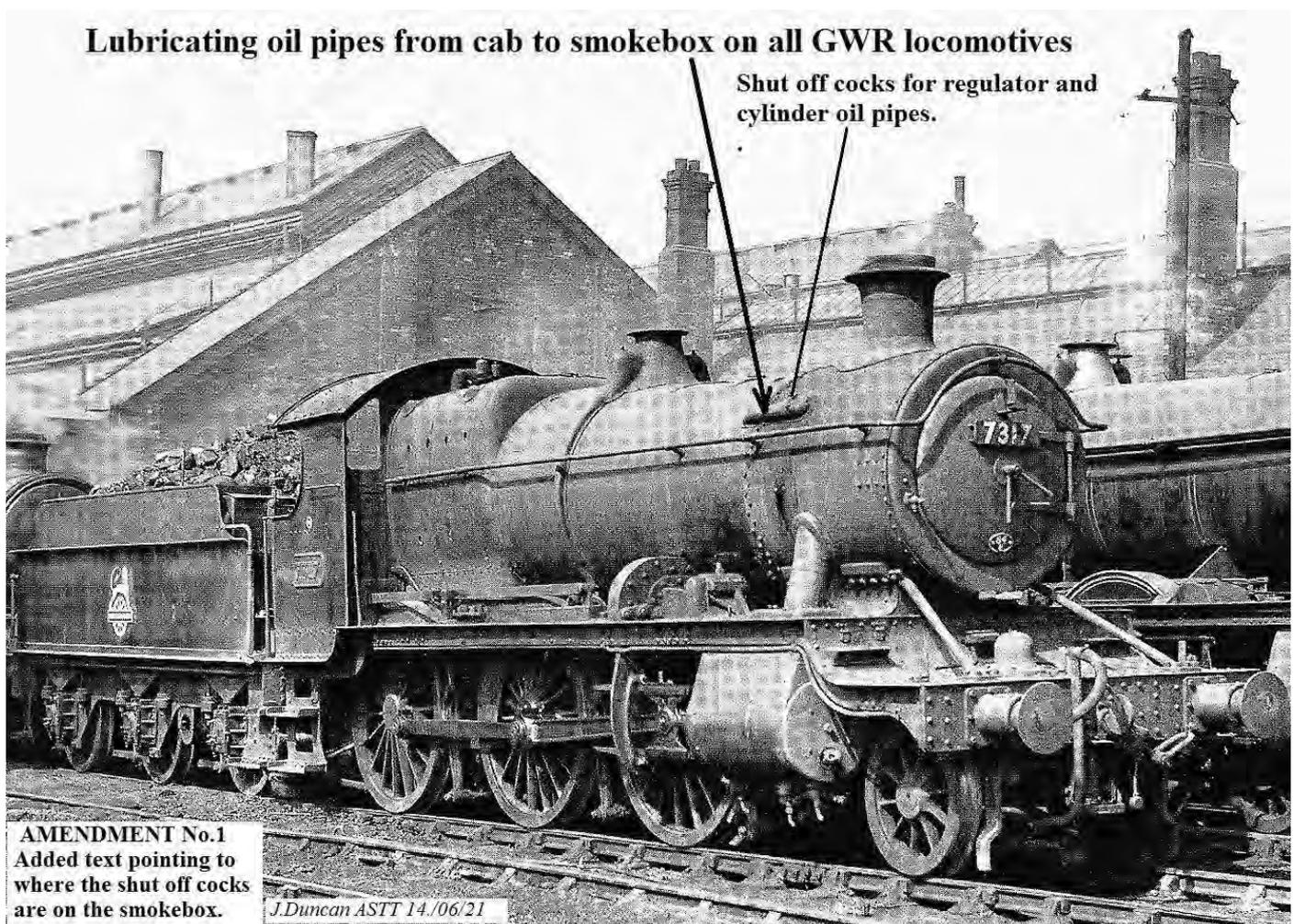
Paul eventually qualified as a Trusts and Estates Lawyer, a job which he continued part time until he was forced to stop. His knowledge of law, especially relating to charities, meant that he was much in demand and one of the biggest tasks which we have had to do is sorting out all the paperwork and making sure it all goes to the appropriate people.

MECHANICAL CYLINDER LUBRICATION, PART V: G.W.R. HYDROSTATIC LUBRICATION TO VALVES & CYLINDERS — ADDENDUM

John Duncan

The author has sent us three updated diagrams to this article, which appeared in Newsletter No. 16.

Lubricating oil pipes from cab to smokebox on all GWR locomotives

Shut off cocks for regulator and cylinder oil pipes.

AMENDMENT No.1
Added text pointing to where the shut off cocks are on the smokebox.

J.Duncan ASTT 14./06/21

AMENDMENT No. 1
Shut off cocks on the
outside of the smokebox
lettering added
J.Duncan ASTT, 14/06/21

Oil pipe to RH inside cylinder
steam pipe from 'O' Oil Divider

Oil pipe to RH outside
cylinder from 'O' oil divider

Shut off cock to divider and
cylinder steam pipes in case
of burst oil pipes

Shut off cock to
regulator oil pipe in
case of burst pipe

Smokebox layout of 'Star' class engine fitted with 'Castle' type cylinders and outside steampipes

From unknown source. Oil reglings by J.Duncan
for ASTT May 9th 2021

G.W.R. SCHEMATIC DIAGRAM of the ORIGINAL HYDROSTATIC LUBRICATING OIL SYSTEM to the ENGINE CYILNDERS

AMENNDMENT No. 1
Added stop cocks on oil
pipes on outside of
smokebox in case burst
oil pipes, 'S' & 'F'.
J.Duncan ASTT 14/06/21.

KEY to symbols :-

✕ ———— COCK type VALVE.

‿ ———— CHOKE in PIPE

MMM FIXED SPRING

▽ VALVE

PERFORATED NOZZLE in MAIN STEAM PIPES and REGULATOR VALVE SPACE

⊠ COCK type VALVE needs a key to operate

KEY :-

C = CONDENSER PIPES
D = OIL from HYDROSTATIC LUBRICATOR to LUBRICATOR COMBINING VALVE
E = STEAM TO LUBRICATOR COMBINING VALVE
F = ATOMISED OIL to MAIM STEAM PIPE and CYLINDER
N = SIGHT GLASS CONTROL COCKS
S = OIL DELIVERY PIPE to REGULATOR VALVE
T = STEAM VALVE to CONDENSER PIPES
U = FILL COCK CONDESERS to LUBRICATOR
W = LUBRICATOR COMBINING VALVE

J.Duncan ASTT, August 23rd 2020

BIOCOAL UPDATE
John Hind

Little did we know how much the world was to change when we conducted the Bure Valley trials in June and November 2021 and how world events would affect coal supplies for Heritage Railways in the UK.

The experience that we gained in running trials with alternatives to coal on the Bure Valley Railway in June and November 2021 served us well, as we developed our testing techniques and learnt about manufactured fuels, so that we were prepared for the challenges to coal supply brought about by the Russian invasion of Ukraine in 2022. Coal supply problems were also compounded by the breakdown of the washery at the Ffos-y-fran mine in South Wales that temporarily stopped the supply of lump coal for steam locomotives, though production has now restarted until November 2022, though at circa £500/tonne to £595/tonne depending on supplier. A two-year extension to the extraction licence is under negotiation with the Welsh Government. But this is only a temporary reprieve.

Following on from the November trials at the Bure Valley Railway (BVR) with the Coal Products Limited (CPL) fuel, the logical next step was to try the fuel on a standard gauge locomotive and ASTT were invited by the Keighley and Worth Valley (KWVR) to attend trials using their Standard 2MT engine 78022, so on Valentine's Day 14/2/22 John Scott, Alex Powell and myself travelled to the KWVR.

We set out to measure coal and water consumption and observer locomotive performance. Alex had prepared a CAD model of the tender tank and from that we could plot a graph of water quantity against water depth. The locomotive has a new tender tank, with the water pick up gear removed so the tender holds 3125 gallons rather than the 3000 gallons as designed.

It was clear at the outset that we could not do as precise an analysis as at the Bure Valley, purely because the quantities are much larger – for instance at the Bure Valley we load circa 120kg of fuel for a 19 mile trip and on the KWVR we use circa 800kg for a 20 mile trip. At the BVR because the quantities are smaller we can accurately weigh the quantity of fuel and load it by hand and at the end of the run easily unload un-used fuel by hand.

On standard gauge you need a bucket loader to load the fuel and unless it has a load cell you cannot measure the weight. So at the KWVR we measure the fuel by weighing a number of shovelfuls and calculating the average weight. For the test we had a footplate observer with a tally counter and the number of shovelfuls multiplied by the average weight gave us the weight fired.

We did not attempt to measure the quantity of smokebox char and firebox ash as the quantities are too large and measured in barrow loads, rather than in just one bucket which is typical of the quantities of ash and char that we see at the BVR.

On the 14th we tested Coal Products Heritage Blend 2 of HB2 for short. HB2 had been produced following our trials in November with HB1 and had been formulated to reduce the smokebox char and carryover. All the CPL products we have tested this year are based on anthracite, which is still available, varying amounts of bituminous coal and petcoke, all held together by a binder. None contain any biomass, though CPL's Ecoal 50 with a 50% biocontent is available. CPL's long term aim is to develop a carbon neutral fuel for Heritage use, but the short term effort over the last few months has been to produce a substitute for lump coal given the supply problems that were foreseen in February.

4 tons of HB2 loaded onto 78022

The KWVR put on a special train without passengers and the first train of the day had a diesel in the consist just in case the fuel did not perform. After the first train, there was sufficient confidence to take the diesel off and to make the train weight the same, two coaches were added for the remaining 3 trains. On the train were representatives from the Heritage Railway Association, the North Yorkshire Moors Railway and Coal Products, and a journalist from Heritage Railway. John Scott was the footplate observer and Alex and I busied ourselves with tender water level measurement at each end of the line. We also noted the boiler level in the gauge glass.

As found at the BVR the fuel was slower to ignite than coal and a thicker firebed (but not thick firebed) was required and the firing technique had to be adjusted to suite the coal i.e., more thinking ahead by the fireman with fire preparation for the run up from Keighley to Oxenhope beginning on the down journey, there being minimal time to prepare the fire at Keighley.

The KWVR is a climb all the way to Oxenhope over just under 5 miles and with HB2 the engine would not steam against the injector. From a qualitative perspective the steaming of the engine deteriorated throughout the day. The cause of this was clear the next day when the grate was cleaned. A layer of fused ash/clinker was seen in the firebox.

Alex Powell measuring tank water level at Keighley

Footplate Observers Sheet from 14/2/22

78022 Fused Ash / Clinker

Also seen was a green patina on the firebox, which was worrying to the KWVR as it was like what they had experienced before when they had used a batch of coal with high chlorine, which had gone on to attack the copper.

Green Patina in Firebox of 78022

Picture courtesy of Ralph Ingham KWVR

The green patina was washed off with water and the engine returned to service.

Over the next two months further trials were carried out at the KWVR with different CPL Blends – Heritage Blend 3 and one of their standard products called Wildfire. As confidence and experience grew these tests were on service trains and all used 78022 and the same load. Both

78022 Firebox post test

HB3 and Wildfire performed better than the HB2, however, all created the same green patina, and all suffered from clinkering to some extent. For these trials Ian Jack, Jamie Keyte and myself acted as footplate observers – a task that demands 100% concentration. As a baseline we also collated data on burning coal - in this case Shotton.

In parallel with the KWVR tests, CPL were making samples available 'free of charge' for other railways to test and the fuels were trialled at the Talyllyn Railway, East Lancashire Railway, North Yorkshire Moors Railway, Severn Valley Railway, Isle of Wight, and Brecon Mountain Railways. As part of an HRA update on the coal situation, ASTT wrote an advisory note about the green patina asking for users to look for it. To date no one else has reported anything so it still is an issue just seen on 78022.

In response to our concerns about the green patina, CPL had an independent laboratory conduct proximate analyses on samples of coal and their own products.

The chlorine contents of coals recently used in the UK are: -

Green patina in firebox of 78022

(Picture courtesy of Ralph Ingham, KWVR)

Coal	Chlorine Content
Ffos-y-fran	.07%
Kazak	.08%
Shotton	.02%

The chlorine contents of the CPL fuels were: -

Fuel	Chlorine Content
Heritage Blend 2	.24%
Heritage Blend 3	.28%
Wildfire	.18%

CPL reviewed the contents of their raw materials and their production process and found two sources of chlorine – the binder that was used to hold the anthracite together and a quenching process that uses brine to prevent the formation of mould, which can occur when the product is bagged.

CPL have now produced a variant of HB3 and Wildfire with low chlorine, which matches the chlorine content of coal. The changes were to the binder and using water rather than brine to quench the product.

Fuel	Chlorine Content
Heritage Blend 3 – low Cl	.03%
Wildfire – low Cl	.02%

The first trials of this took place on the KWVR at the end of May and the picture of the firebox tube plate on 78022 now shows a normal colour, which suggests that the chlorine was source of the green patina, though the mystery remains, why was 78022 the only engine effected?

On the 20th and 21st of June we completed trials at the BVR of the low chlorine Wildfire and low chlorine HB3. The qualitative feel from the trials was that Wildfire is a better product than HB3 and CPL are going to produce this as brand called 'Heritage Wildfire' at £455/tonne.

To collect data on how the fuels were performing on other railways, Ian Gaylor devised a Fuel Trials Record sheet that used a simple scoring system to assess how a fuel performs against several criteria. This was circulated by the HRA and not only collected data on the CPL products, but also on the ovoids produced by Hargreaves and a wood product trialled by the Chatham Dockyard Railway. The BVR set up an e-mail address for collecting the responses.

As of mid-May 29, Trial Records were sent in from 5 standard and 5 narrow gauge railways: - the Brecon Mountain, Bure Valley, Chatham Dockyard, East Lancashire, Forest of Dean, Great Whipsnade, Isle of Wight, Keighley & Worth Valley, Talyllyn, Welshpool and Llanfair.

Normal colour of firebox after burning low chlorine Wildfire

(Picture courtesy of Ralph Ingham, KWVR)

HERITAGE RAILWAY ASSOCIATION

AST Trust

Return to coal@bvrw.co.uk

Fuel Trial Record

Fuel being tested	Trevithick Steam Ovoids
Test Railway	Welshpool and Lanfair Light Railway
Date of Test	04/04/22
Locomotive type, Name and Number	Beyer Peacock 0-6-0, 822/No.1 " The Earl"
Description of train consist	6.5 unit train (average train weight for the line)
Driver	Phillip Ellis
Fireman	Joe Gunby
Test Observer	James Mander (W&LLR Engineering Manager)

Observations and footplate crew comments

Locomotive preparation

| Lighting up including • Ease of ignition • Time to raise steam • Smoke generation	- A large wood fire is required to ignite this fuel; although more difficult to light than traditional steam coal, it produces plenty of heat. - 1hr to start boiling, 3hrs to raise full pressure (typical for this loco) - Some very light white smoke.

Operation

Train haulage including • Under load • Coasting • Run round • Smoke colour and odour • Rapidity of ignition of fresh coal • Freedom of steaming • Evidence of clinker • Evidence of unburnt fuel loss/spark throwing • Fire shape used e.g. saucer, level, wedge, haycock etc • Is locomotive fitted with a brickarch? • Was secondary air used?	- Initially, working the arduous gradients of the W&L, the engine steamed very well indeed - up near the red line of 160psi. More firing was needed (about double that of traditional Welsh steam coal), but the boiler pressure would increase against the boiler feed. - After 8 miles (half a round trip) it was clear that there was a problem with the fire, through no fault of the crew, the engine was not steaming well and pressure was down to 100psi, so had to stop for two x 15min blow ups. It would not keep schedule. - The fuel generates a vast quantity of ash which, accumulates on longer runs, isn't combustible and will not fall through the fire grate. Instead it forms a glowing fluidised fire bed with pea sized ash, which hinders air flow. It is very difficult to remove this from the fire without a lot of raking. - Running a wedge fire - Brick arch is fitted - Smoke was minimal, light blue haze at times - Odour, minimal, similar to anthracite used on miniatures - Some secondary air was used, not beneficial when the struggling for steam.

1   HRA & ASTT Fuel Trial Record - Revision A.docx

Completed Fuel Trial Record Sheet—Page 1

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Disposal

Smokebox • Quantity of char • Evidence of blocked tubes • Unusual deposits on internal surfaces	- Usual quantity of char - No blocked tubes - No unusual deposits
Firebox • Evidence of clinker • Evidence of birds nests • Unusual deposits on internal Surfaces	- Some evidence of clinker setting if the fire is left to cool – minimal however. - No birds nests - No unusual deposits
Ashpan • Quantity of ash • Evidence of unburnt fuel particles	- Quantity of ash completely filled ash pan after 1 round trip. Approximately 5 times the amount of ash compared to conventional steam coal - Much of this ash was still glowing, pea sized particles, assumed unburned fuel.

Qualitative scoring of fuel performance by footplate crew

Freedom of steaming 1=Poor 5= good	4 – initially, 1-after half a trip (8 miles)
Coal ignition time 1=slow 5=fast	3
Smoke colour 1=black 5=clear	4
Smoke odour 1=unacceptable 5= low	5
Unburnt fuel loss/spark throwing 1=high 5=low	4
Clinker and birds nest formation 1=high 5=low	4
Quantity of fuel used 1=high 5=low	1 (excessive)
Quantity of char in smokebox 1=high 5=low	3
Quantity of ash in ashpan 1=high 5=low	1 (excessive)

Other Observations/Comments

- This is an initial report; further testing will be conducted.
- Additional tests will be with firebars removed, to aid ash flow out and air flow in.
- Testing on modified draught arrangements also planned.

Summary

This fuel does show potential to steam well, however modified arrangements are required to handle ash and allow continuous reliable steaming.

Completed Fuel Trial Record Sheet—Page 2

The feedback is a great example of the Heritage Railway sector sharing information. From the record sheets ASTT, generated a report that was circulated to HRA members summarising the results. From the feedback we could compare the performance of the fuels on across several railways, locomotives, and all with different crews. It was interesting to see how most of the scoring was reasonably consistent despite the differences in railways, locomotives, and crews. The biggest inconsistencies were on the formation of clinker and birds nesting with the standard gauge railways scoring worse that narrow gauge railways.

Here are some key charts from the report.
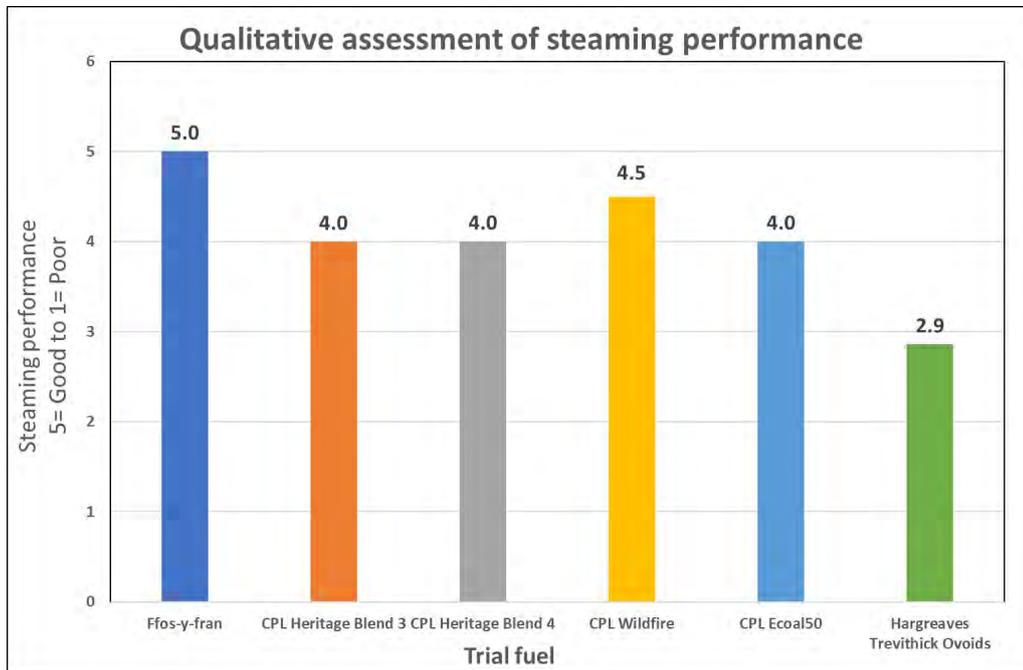
Members can download the full report from the ASTT website. It is available to members only, who will need to logon with their username and password. Copy this link and put it in your browser: -

https://www.advanced-steam.org/qualitativeassessment-of-fuel-performance/

or on the ASTT website look under Projects>Biofuel Testing>Qualitative Assessment of Fuel Performance.

Click on the button at the bottom and the report should download.

So in summary, there are alternative fuels available to lump coal, but you will use more of it, they will be slower to ignite and require more planning by the fireman and there could well be more clinker than you are used to but that generally can be managed by fire cleaning.

Our own steps to develop of a Carbon Neutral Fuel – John Hind

At last years visit to the Stapleford Miniature Railway, we ran trains using a carbon neutral fuel devised by Richard Coleby, Ian Gaylor and Chris Newman. That fuel has now been tested in the Combustion Labpratory of the University of Central Lancashire. It was done in support of an MSc project by one of their students. Results are anxiously waited. Thanks to Alex Twigg for organising this.

From the work that we have done over the last year we have learnt that for a fuel to be suitable there are more criteria than just having a high calorific value, for instance low chlorine and low sulphur are paramount if firebox problems are to be avoided, it has to be durable in outside storage and the raw materials have to be readily and cheaply available.

Currently we only have 'one iron in the fire' and experience from Product Development says that we need 'more irons in the fire'. We are working up proposals to generate more ideas using methods used in Product Development. As the steam engine is a machine to convert chemical energy to mechanical energy, we will be looking to tap into the knowledge and expertise of our members who are Chemical and Combustion Engineers as well as our lateral thinkers – so if you have relevant experience, expect a tap on the shoulder!

To run meaningful tests we need several tons of product and production of this soon exceeds the capacity of home workshops or kitchen laboratories. To do this properly will need external funding so at the HRA's request we have put together a budget proposal that has been used in discussions with Government. Whether the government will fund this, remains to be seen, though one of the 4 briquette manufacturers may also be interesting in participating and funding it.

SOME COMMENTS ON LOCOMOTIVE FRONT END DESIGN PART 5
Martin Johnson

1. INTRODUCTION

In a joint paper (Ref. 7.1 Page 396 et. seq.) Loubser and Cox noted that Mallet and Garratt locomotives needed smaller blast pipes than would be expected for a similar size 4 cylinder locomotive, as did 4 cylinder (8 beats/rev.) locomotives such as the Princess and Coronation classes. W.A. Stanier commented in the discussion on that paper:

"what has always puzzled me is that a 3 cylinder engine always seems to require a smaller blast pipe top than one would expect to put on an engine of that power. One of the possible solutions, of course, is that with a 3 cylinder engine there is not the same volume of steam coming through the blastpipe per pulsation......"

Stanier's technically successful "Turbomotive" took things to extremes with no pulsation at all!

Nevertheless, Stanier was certainly right when he indicated the topic is not well understood.

At the end of the last article, I introduced the thought experiment "*If we could put a very large steam tank in the exhaust line between cylinders and blast pipe, would the engine still go "chuff"?*" as a means of introducing the time dependent domain on front end calculations.

The obvious answer is "No" and anyway, the front of most locomotives is enough of a design challenge without finding space for a large tank. However, it introduces the concept.

I certainly don't consider myself on a level with Stanier, but I hope to draw on progress in the intervening 84 years to throw some light on how the problem might be solved. It would not be easy - I view it as a non linear differential equation with at least 3 degrees of freedom. In engineering terms that is complicated!

Why would we want to understand the time dependent problem of the front end? Possible reasons:

- The subject is certainly of interest in trying to interpret some of the test results that Mike Horne and other ASTT members are producing.

- The "smoother" we can make the exhaust, the more uniform the velocity through the blast pipe and tube bank, and hence less energy will be used to create draught. Putting it another way, can we use Stanier's 3 cylinder engine effect to our own advantage without necessarily using 3 cylinders? This might allow more efficient draughting to be developed.

- It is also of interest in controlling unburnt fuel losses as we trial various coal substitutes. I don't have data to prove it, but I believe that peak flow velocity may be an important determinant in unburnt fuel loss. So if we can control that peak flow, the fire will potentially be more efficient. There may also be a requirement for at least some variation in flow to keep the fire bed "open", although the "Turbomotive" seems to disprove that.

2. A STEAM CIRCUIT DYNAMIC MODEL

For the purposes of simplicity I shall consider the exhaust as two separate systems, the first comprising the exhaust steam circuit up to the blast pipe tip.
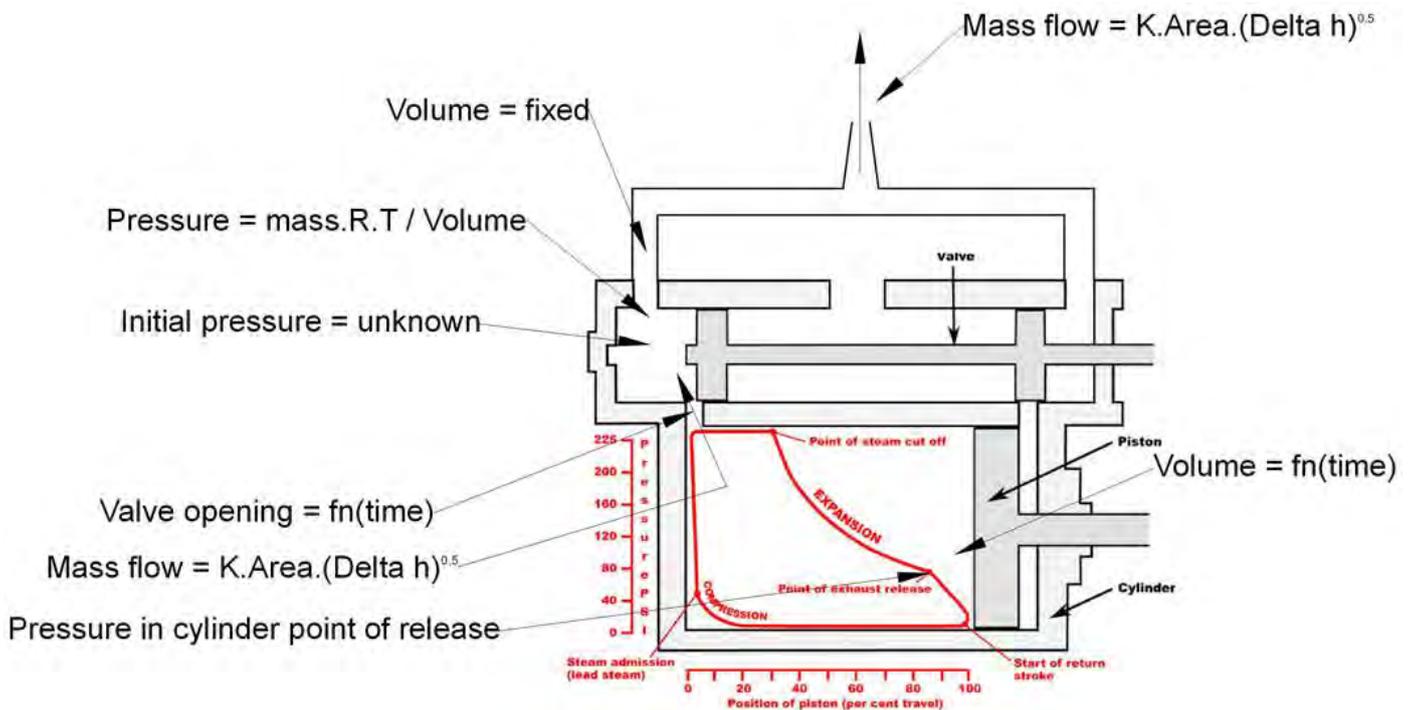

Figure 1: General statement of the mathematics of a cylinder - blast pipe system.

Figure 1 shows a general statement of the typical cylinder to blast pipe system. The valve and piston position change with time while the mass flow across the valve port depends on the upstream and downstream enthalpy or pressure and area of opening. The mass of steam stored and it's pressure in the pipe system up to the blast nozzle is given by the gas laws (approximately), and the mass flow across the blast nozzle depends on area and upstream and downstream enthalpies (or pressures).

The mathematical problem to be overcome is that the mass flow of steam is dependent on the pressures in the system. However, the pressures are also dependent on the mass flow. This type of problem can be overcome with a calculation that steps forward in small time increments. So at an instant:

- The piston position and valve position are calculated.

- The flow across the valve is calculated from previously calculated pressures.

- The mass increase in the pipes to the blast nozzle is given by the above flow.

- The mass lost is given by the previously calculated pressure in the pipe system flow through the blast nozzle.

- The mass and pressure in the pipe system is re-calculated.

- The calculation is repeated at the next time increment.

Bill Hall (Ref. 7.2) gives quite a lot of useful information around solving such problems, although Professor Hall was concerned the mean pressure in the exhaust, not the time dependent nature of the pressure in the exhaust system. Nevertheless, his approach to solving the time dependent flows through inlet and exhaust valves is very relevant. I note that there are typographical errors in some of Prof. Hall's equations. The square root term (which is actually the flow velocity) in equation 6 and similar following equations should take the general form:

$$\sqrt{\left[\frac{2n}{1-n} p_1 v_1 \left(\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1\right)\right]}$$

My own experience in solving pump pulsation problems, suggest that the numerical integration method needs to be quite sophisticated. A simple Euler type approach leads to continuously increasing errors. Hall used the Runge Kutta method, for which quite a good explanation can be found on Wikipedia.

Another obstacle to be overcome in solving the above problem is that the starting mass or pressure of steam in the pipework system is not known. A good initial estimate would be to use Hall's method for estimating the mean

pressure in that area, however the simulation would then need to be run across several wheel revolutions until a settled value was found.

2.1. Further Complications

Figure 1 shows just one cylinder, however locomotives tend to have two or more and the exhaust valve is typically open over 180 degrees of wheel revolution and potentially a little more depending on valve gear design and cut-off setting. If we just consider the period when the exhaust valve is open, we get the diagram shown in Figure 2. The upper part of the Figure shows a twin cylinder locomotive and the sideways "D" shape represents the roughly sinusoidal valve opening. At any given moment at least two cylinders will be open to the blast pipe. The second cylinder opens when the first is about half stroke and so on. Depending on valve timing one cylinder could be about to finish the exhaust stroke, one will be mid stroke and a third will be just starting to exhaust as shown at the red line. Whether all the cylinder ends meet at one blast nozzle or separate nozzles depends on the front end pipe arrangement of the particular class.

The lower part of Figure 2 shows the situation for a three cylinder locomotive where at least 3 and maybe 4 cylinders are open to exhaust at any one moment. I have not drawn the 4 cylinder diagram, but the principle has been established.

Multiple cylinders complicates the computation as there are now at least two cylinder volumes to consider, both with varying valve openings, piston positions and pressures!

In a twin cylinder engine, the cylinder at half stroke will provide a storage volume to soften the exhaust blast of the exhaust stroke from the following cylinder. By extension, more cylinders provide more attenuation to the peak exhaust pressure - which is part of the explanation for Stanier's puzzle. The more complex exhaust pipework associated with multi cylinder engines also provides more storage volume and attenuation. Similarly, Mallets and Garratts with long exhaust pipework provide a larger volume of storage.

A possible disadvantage of multi cylinder engines is that the exhaust peak from one cylinder is raising the back pressure in the previous cylinder and thus reducing the BMEP, which is one advantage of using the Kordina style exhaust. This aspect is not really the core of this discussion, but is noted in passing.
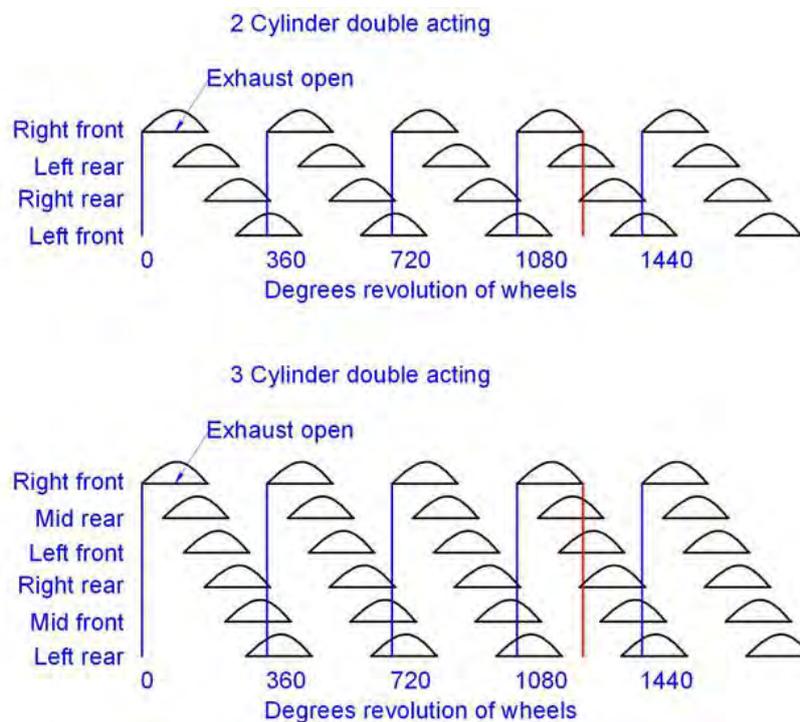

Figure 2: Comparing number of exhausting cylinders for different locomotives.

3. SOME BLAST PRESSURE TEST RESULTS

By courtesy of Jamie Keyte and Mike Horne, I have some of the ASTT experimental data from "Badger" on the Kirklees Light Railway. Sadly, this lacks crank position information, but by comparison with some of the S160 data, I have inferred dead centre positions noting that the sharp increase in vacuum occurs some 10 degrees ahead of dead centre. However, it should be noted that the S160 may not react in the same way to exhaust steam events as Badger.

In addition, I have superimposed typical exhaust valve position data on the ASTT pressure data. I have no data for Badger's valve gear, so have used a typical zero lap exhaust set up and drawn valve position against crank position for a range of cut off settings (78, 71, 59, 42 & 20%). Assuming a reasonably steady speed during the tests, crank position will be proportional to time. I have therefore set the scale on Badger's results to give 4 beats to 360 degrees of crank revolution.

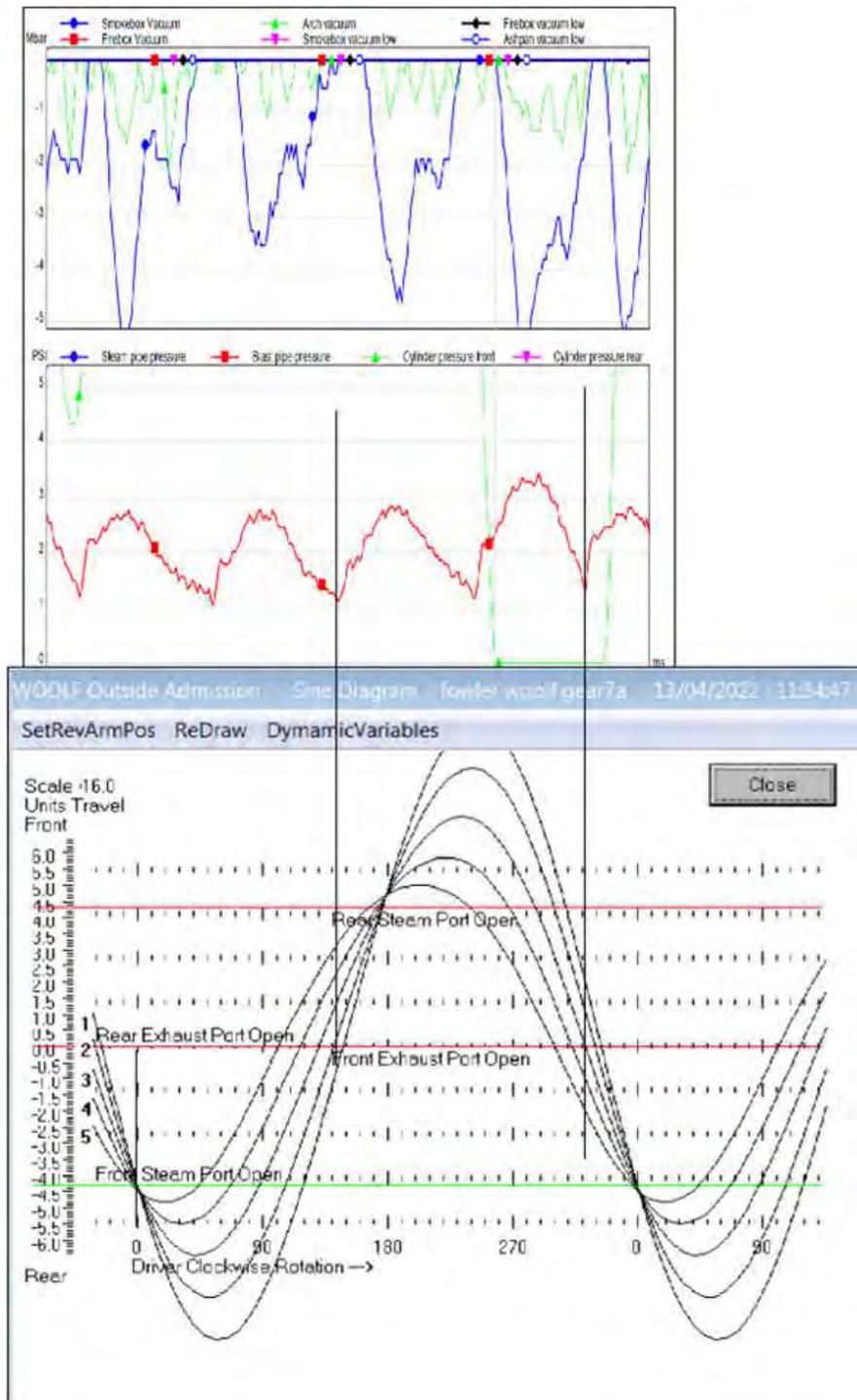The results of this are shown in Figure 3 and discussed below.

Figure 3: Blast pressure, vacuum and valve position overlaid for Badger test results

I have lined up the valve position data to be relevant to exhaust beat 3, starting at about 140 degrees rotation. Blast pressure starts to increase from it's lowest point at exhaust valve opening. (I don't have the cut off setting for this particular set of tests, but infer it was quite late.) Blast pressure then increases in near linear fashion, despite a rapidly changing exhaust valve opening, until levelling off at around 195 degrees. There then follows a decay in blast pressure, despite the piston now forcing steam out of the cylinder and exhaust valve opening continuing to increase. At about 240 degrees the next cylinder begins it's exhaust cycle and the process repeats - note that the exhaust valve for the previous cylinder is fully open and the previous piston at about half travel giving around 50% of a cylinder volume for cushioning the next exhaust beat.

There are some other points to note about this illustration:

- Each beat occurs at approx. 58 ms intervals, which equates to about 250 rpm which is quite fast for a steam engine, particularly in full size.

- The blast pressure and vacuum are relatively low (1 - 3 psi and 0 - 5mBar respectively) indicating the engine is under light load. A greater loading would probably change the form of the blast pressure curve, accentuating some effects such as steepness of pressure rise and diminishing others such as rate of reduction in blast pressure.

- The beats are somewhat uneven, beats 1 & 3 being slightly longer than 2 & 4. I note that Badger has a Hackworth derivative valve gear which is notable for mechanical simplicity, but not for excellent valve events.

4. A GAS CIRCUIT DYNAMIC MODEL

There are two concepts that need introducing before we can consider the wider problem of constructing a mathematical model of the front end. These are "borrowed" from work on pressure surge in water systems.

4.1. Acceleration Pressure

Most of the published formulae for pressure loss across pipework refer to steady state flow (though this is not always stated!). When the flow is accelerating or decelerating another pressure needs to be accounted for. It is simply the inertia of the fluid column, or if you remember school physics:

Force = Mass x Acceleration

In this case force is a pressure exerted across the pipe area. The mass is pipe area x length x fluid density and acceleration is better expressed as dV/dt. Cancelling out the pipe area results in:

$$P_{accn} = L\rho \frac{dV}{dt}$$

Where:

P_{accn} = Pressure required to accelerate the fluid column [Pa]

L =   Length of fluid column [m]

ρ =   Density of fluid [kg/m3]

dV/dt   Instantaneous acceleration [m/s2]

The above equation applies to "slow" changes in velocity. As an example, the free oscillation of water in a U tube would be described well by the above equation, and gas trapped in a tube bank could oscillate in the same way between two volumes, such as a firebox and smokebox. I have derived a formula that gives the frequency for such an oscillation between firebox and smokebox, but need to check it before publishing; anyone confident with algebra, please make contact.

4.2. Wave Effects

If a pressure change is imposed on the fluid column very quickly a pressure wave will propagate through the fluid. The speed of sound in a fluid is given by:

$$c = \sqrt{\gamma R T}$$

Where:

c =   Wave speed [m/s]

γ =   Ratio of specific heats (1.4 for air) [dimensionless]

R =   Gas constant (287 for air) [kJ/kg/K]

T =   Absolute temperature of medium [K]

As an example, I have calculated data for a GWR King class which shows an average temperature in the tubes of around 550 C (at a high steaming rate) and some 5.5 m between tubeplates. So:

$$c = \sqrt{1.4 x 287 x (273 + 550)}$$

Hence c = 575 m/s

Over a 5.5 m length of tube, that gives a transit time of around 0.01 s or 10 ms. Shorter tubes or a cooler fire would give a reduced transit time.

When the wave reaches the end of a pipe and meets a large volume of fluid (the firebox), the wave is reversed in sign and travels back through the pipe until it meets another large volume (the smokebox) and is reversed in sign again. So we could expect wave effects to have a frequency of 2 transit times in a locomotive.

4.3. The Whole Dynamic Model

The mathematical problems in solving the gas flow pulsations are very similar to those already discussed with regard to solving the steam flow pulsation and Figure 4 shows a summary of some of the key equations.
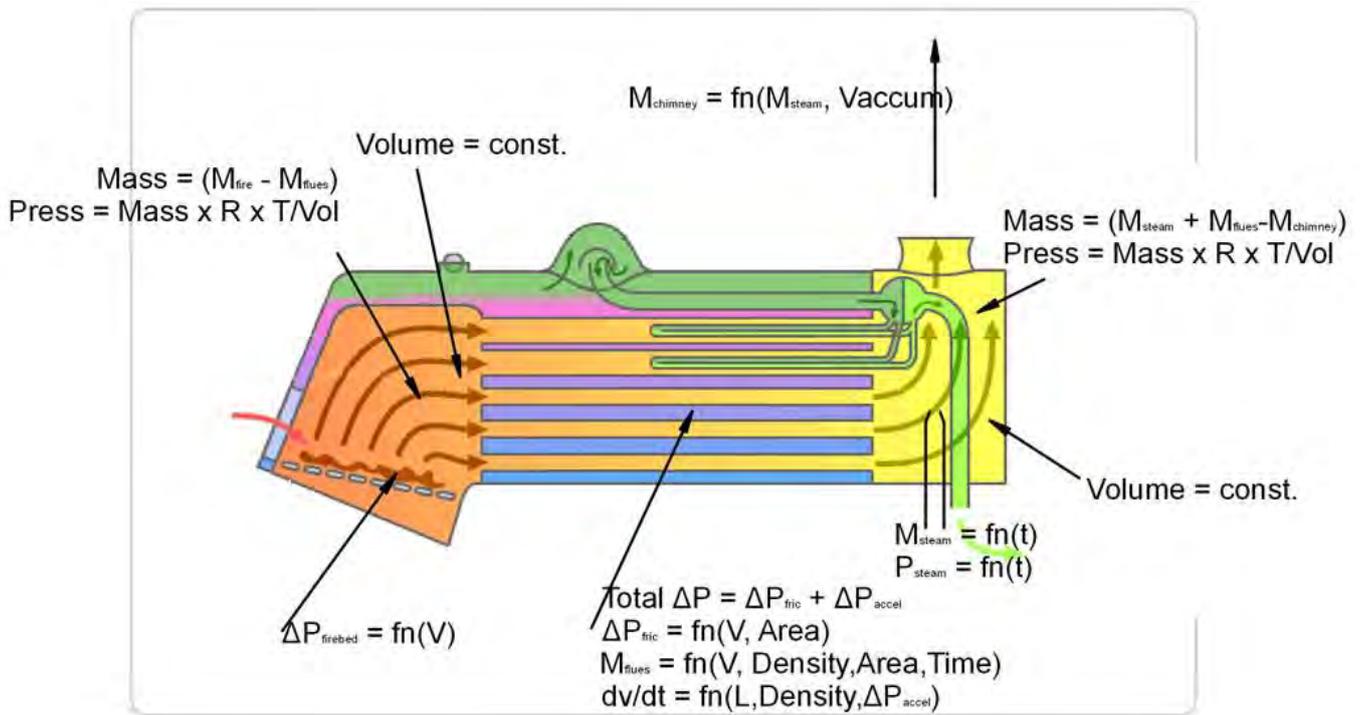

Figure 4: Statement of the key equations governing pulsating gas flow.

The problem would need to be solved over several wheel revolutions using a time stepping calculation, possibly starting from rest (and hence atmospheric pressure throughout the system). For simplicity, I would suggest the system can be split into steam and gas sections as I have discussed here because the smokebox pressure is approximately constant in the context of the steam calculation. By assuming that the steam always discharges to slightly sub-atmospheric pressure, a steam calculation can be used to generate the steam pressure and flow Vs. time data which can then be used as input to the gas calculation. Some may wish to do both calculations together for greater accuracy - I wish them good luck!

For the detail of the calculation method, I would start by assuming that the system is at rest with smokebox and fireboxes at atmospheric pressure and zero velocity at all points. Then, for each time step:

- The blast pipe flow would be determined from a look up table resulting from calculations as given in Section 2 .

- The entrained gas flow is then determined as described in Section 7 of Part 4 of these articles, the entrained

flow being a function of steam flow AND smokebox pressure. There is an implicit assumption here that the equations discussed in Section 7, Part 4 would still apply, but I think it a reasonable starting point. The transit time of steam in a typical full size exhaust is around 3ms, which considerably shorter than other timescales involved in an exhaust beat.

- From the gas exhausted minus the gas flowing from the tube bank, a smokebox pressure could be determined using the gas laws.

- The tube bank gas flow is determined from the pressure difference across it. At the start of a cycle, friction losses would be minimal and all the pressure difference would be used for acceleration pressure creating a rapid increase in velocity. As velocity builds, the friction loss becomes more significant.

- From the gas flow determined through the tube bank, the flow out of the firebox can be determined.

- From the gas laws, a pressure within the firebox can be determined and then a gas flow through the fire can be inferred.

- The calculation is repeated for the next time step, and so on.

The mathematical difficulties in solving the above problem are broadly similar to those discussed in Section 2.

5. EXHAUST GAS TEST RESULTS

Figure 5 shows the test results for Badger as given in Figure 3 but presented in a slightly different format. I have:

- Inverted the vacuum trace to represent how hard the front end pump is working

- Shown one exhaust beat only.

- Scaled the time from my inferred opening of the exhaust valve

- For convenience I have scaled the data from graphs as I have not had time to look at processing the raw Pico data yet.
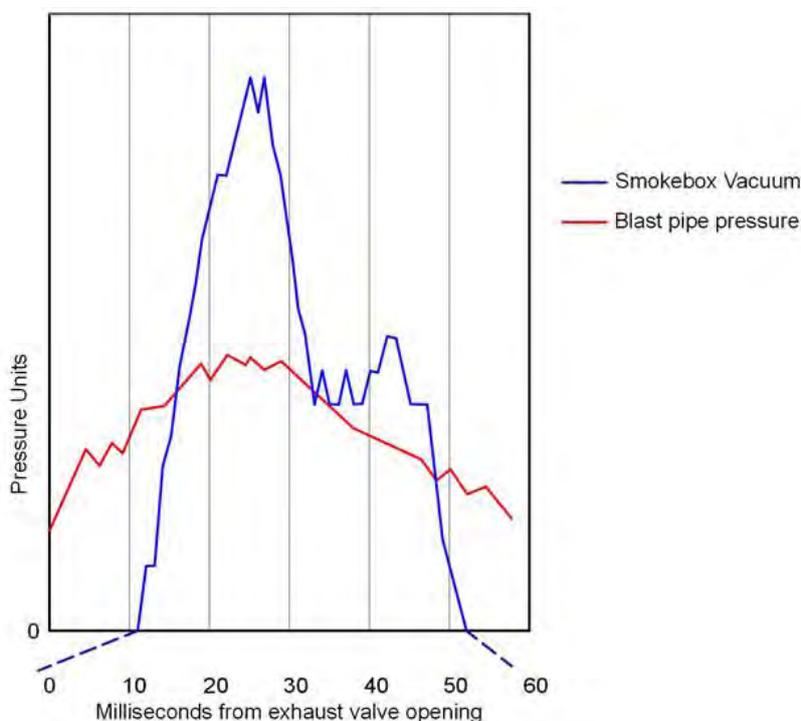
Figure 5: Single exhaust beat for Badger re-drawn from ASTT test results.

The original vacuum trace shows a very flat response at zero mBar, suggesting that the transducer was not a compound instrument - hence it records zero for readings above atmospheric pressure. So it is likely that the smokebox pressure was actually positive at the start of the exhaust beat for reasons I shall cover later. This effect has been seen on a number of test results on various locomotives. A conjecture of the actual trace form is shown dotted in Figure 5.

All the front end theories put forward by Porta, Strahl and me (See Part 4 Section 6.2 onward) etc. would predict that smokebox vacuum would be proportional to blast pressure for a given design but Figure 5 clearly shows that the blast pressure and vacuum do not follow the same cyclic pattern. For example, the blast pressures at 10 ms and 40 ms are near identical but the vacuum readings are dramatically different. So clearly inertia and storage effects are having a major effect.

The vacuum trace only starts to rise after a delay of some 11 ms after valve opening, whereas the steam pressure is rising steadily through that period. The vacuum and steam pressures both peak at around 26ms and then the steam pressure decays steadily until the next stroke commences. However, Figure 5 shows an oscillation in vacuum between 35 and 45 ms. Jamie Keyte has observed that many test results on a variety of locomotives show a similar oscillation and that the timing of the oscillation does not depend on the locomotive speed - suggesting it is dependent on the boiler geometry. The vacuum drops to zero at about 53ms, so 5 ms before the next exhaust beat.

In order to get a better idea of what is actually happening, I have made use of a concept introduced in Section 6 of Part 4 of this series, which for convenience is reproduced in the box.

The performance of a jet pump can be conveniently described in non dimensional terms of:

- A flow ratio, M defined as Secondary (flue gas) flow volume flow / primary (steam) flow volume flow.

- A pressure ratio, N defined as secondary (flue gas) flow pressure rise / primary (steam) flow pressure drop.

- Hence a graph of N against M completely describes the performance of a jet pump.

- The values of the x and y axis intercepts M_0 and N_0 respectively are dependant primarily on the area ratio, R defined as Blast nozzle area / Throat area. Factors such as diffuser efficiency have some effect on the performance curve, better efficiency tending to increase the maximum M value.

So the typical front end performance is generally like Figure 6.which is effectively showing what happens as the entrained flue gas flow is changed. The more the flue gas flow is restricted, the higher the pressure ratio becomes.
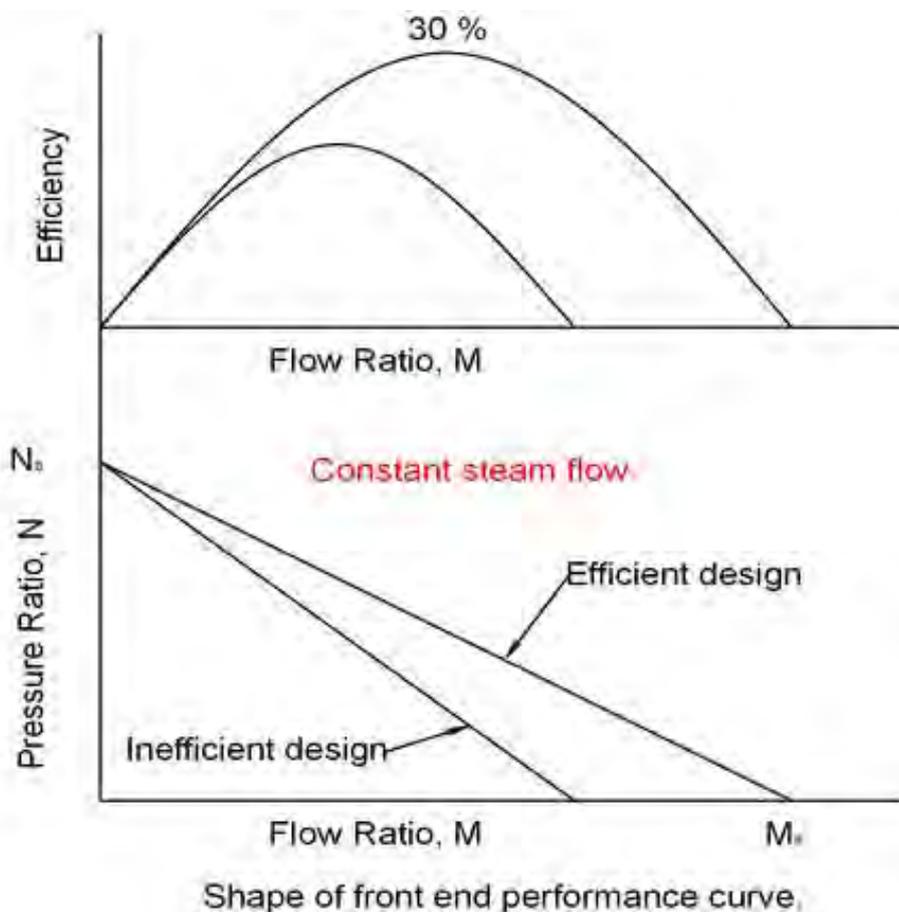

Figure 6: Shape of front end performance curve drawn for a 0.1 area ratio front end.

By dividing the vacuum by the blast pressure at discrete time steps, a trace of pressure ratio against time can be generated, as shown in Figure 7. The oscillations become more pronounced. In producing the graph I have assumed that vacuums recorded as zero during 0 - 10 ms and 54 - 58 ms are zero, even though they are probably positive. If we accept that Figure 6 does represent a jet pump or locomotive front end performance, then at high pressure ratios, the flow ratio must reduce and vice versa.
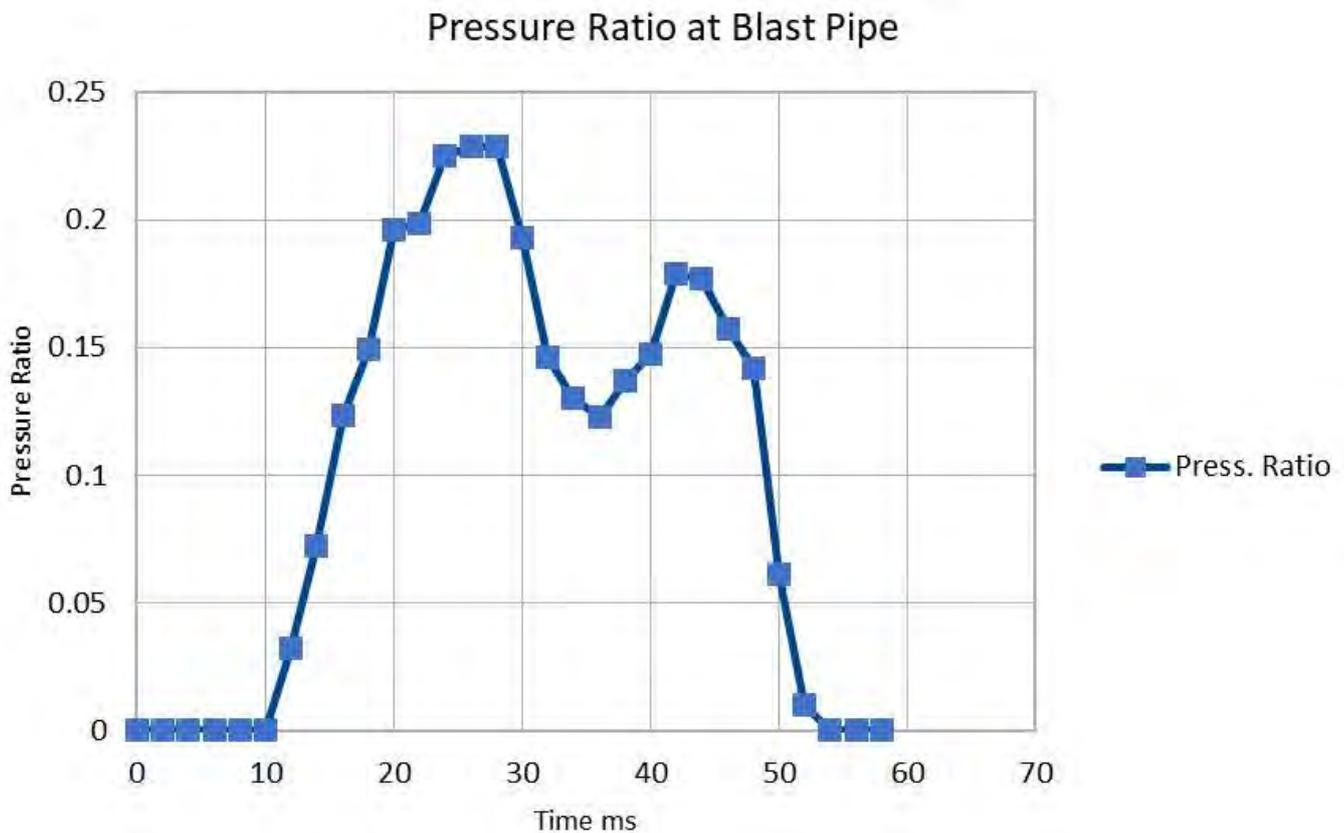

Figure 7: Pressure Ratio Blast Pipe / Vacuum Vs. Time

Although I do not have details of Badger's exhaust geometry, a reasonably good exhaust designed for typical locomotive area ratio around 0.1 will have an N0 and M0 in the region of 0.28 and 2.6 respectively. (Even if the true values are some way from these, the general trends of the following line argument will still stand). It will be seen from Figure 7 that pressure ratios from zero (probably negative) to more than 0.2 are being produced, which implies that the front is working from the far left to far right of it's performance as depicted in Figure 6. Even though Figure 6 shows the N against M curve in one quadrant, the real performance does extend into both the 2 and 4th quadrants for negative flue gas flow and negative pressure rise (negative smokebox vacuum) respectively.

A good approximation to steam flow can be created, being proportional to the square root of the blast pressure. Then, from a knowledge of the instantaneous pressure ratio and a reasonable assumption about the front end performance, it is possible to calculate gas flow against time from the M value derived from the relevant N value in Figure 6 . The rather surprising results of this calculation are in Figure 8 showing normalised flow (instantaneous flow / average flow) of steam and flue gas deduced from the observed pressure ratio, assumed (but realistic) N0 and M0 values and instantaneous steam flow inferred from blast pipe pressure. It must be stressed that Figure 8 shows the flows at the chimney entrance; gas flow elsewhere in the system may well be different at a given instant.
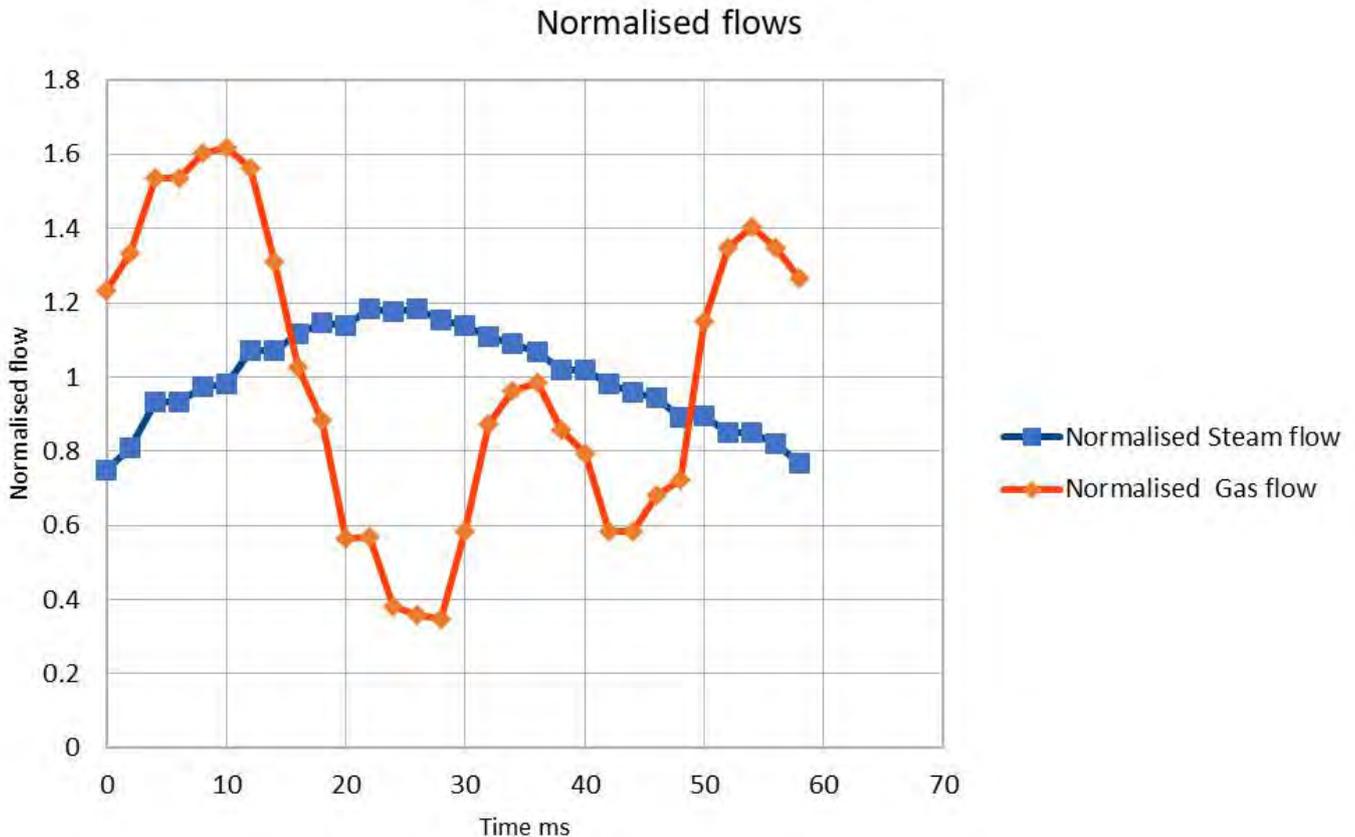
Figure 8: Normalised steam and flue gas flows at smokebox exit.

Considering Figure 8 in detail, the following points emerge:

- The variation in steam flow is remarkably small, varying from 80% to 120% of mean value. This is due to the very low blast pressure recorded on Badger. A less efficient front end would show a larger variation about the mean.

- Maximum gas flow occurs at around 10 ms. The precise timing of this would be different if I had been able to access data for positive pressures.

- Minimum gas flow occurs at maximum steam flow.

- The flow shows 2 full oscillations with a period of around 15 ms from 28 ms onwards.

My interpretation of what is going on is as follows:

If we took account of the negative vacuum, maximum gas flow would take place at around 5 to 10 ms after exhaust valve starts to open. Friction in the gas circuit is relatively high (due to high flow velocities) so flow decays rapidly as there is no smokebox vacuum. As steam flow builds from 0 to 25 ms, the smokebox vacuum is increased rapidly but due to inertia of the gas column within the tube bank little flow takes place. After around 25 ms, the smokebox vacuum has reached a point where gas flow is rapidly accelerated. However, by 35 ms the gas flow inertia has over -run the smokebox to firebox vacuum difference. The gas in the tube bank is a mass with inertia, while the compressibility of gas in the firebox and smokebox act as springs, and at around 43 ms this spring mass system works in opposition to the forward flow of gas causing a dip in flow. By 50 ms, the oscillation has turned to assisting gas flow again, causing a further increase in gas flow despite a falling steam flow and the pattern is maintained until the next exhaust beat commences.

The above explanation only applies to Badger at the 250 rpm and loading that were the subject of the tests. The frequency of oscillations will be a function of tube length plus smokebox and firebox volumes and thus a constant for a given boiler as Jamie Keyte has deduced. The frequency of exhaust beats is obviously a function of locomotive speed. So the precise flow and pressure pattern depends on the interaction of:

- Exhaust beat frequency

- Smoke box and firebox volumes

- Tube length

- Secondary influences might include fire bed resistance and front end efficiency.

5.1. Firebox Arch Vacuum Test Results

The tests on Badger also include some interesting traces of firebox arch vacuum, mostly showing a regular oscillation with a period of around 10 ms or perhaps slightly less. However, the maximum arch vacuum is only 2 mBar and most of the data is around 1 mBar so instrument error is probably significant at these low values. The period of the oscillations noted at the smokebox has been estimated at 15 ms, but there may also be significant errors, so it is not possible to say with certainly whether there are two separate oscillations or if the two are linked.

Once again, a more detailed knowledge of Badger's boiler details would be needed to assess whether the firebox arch oscillation was perhaps a sonic wave effect or a mass oscillation effect. However, for a tube bank length of 2 m, a wave transit time of only 3.5 ms is indicated or wave period of 7 ms which is too low to be credible as an explanation.

6. CONCLUSIONS

There is currently no calculation or computational method that would explain the differences in draughting between 2, 3 and 4 cylinder engines and engines with unusually long exhaust pipework. That in my estimation is a gap in our knowledge that needs filling.

This article has been mainly concerned with how work might proceed in the future to understand the time dependent nature of flows in a locomotive front end, so there cannot be many firm conclusions. I would also like to stress that my provisional analysis of tests on Badger is mainly intended to promote discussion rather than present a series of hard facts.

Development of time dependent front end performance analysis needs measurements of blast pipe pressure, smokebox vacuum and some reference of crank position. I suggest that a greater body of test results including those three variables is needed to validate any numerical studies. This is not a criticism of past ASTT test work; I have undertaken many on site tests in an engineering career and I appreciate just how difficult it can be to develop reliable test equipment and an experimental method.

A considerable amount of constructional detail for a locomotive will be needed for any numerical simulation exercises. For example, this article has indicated the following variables are relevant:

> Firebox dimensions, grate dimensions, tube stack dimensions, smokebox dimensions, cylinder dimensions, exhaust pipework dimensions, blast pipe & chimney dimensions, valve gear dimensions, some estimate of flue gas temperatures (firebox and smokebox), combustion rate or gas flow measurement etc. I am sure that further important variables will be identified.

Finally we can partly answer Stanier's questions as outlined in the introduction:

> A 3 cylinder engine has more steam storage space in the exhaust circuit than a 2 cylinder engine (as do Beyer Garrett and Mallet designs by nature of their long exhaust lines). That smoothes the pressure fluctuations at the blast pipe. The smoother flow pattern requires a smaller blast pipe orifice to convert the steam thermal energy to kinetic energy to entrain exhaust gases. What is less clear is how the reduced steam pulsations affect the flue gas flow, and whether that might reduce the draught requirement. However, there may be a way forward in more testing and constructing a mathematical model to aid our understanding the front end.

7. REFERENCES

7.1.   Loubser, M.M., Cox, E.S. "Locomotive Boiler Design - Theory and Practice" Proc. I. Loco. E. Paper 388 26th Jan 1938 (1938)

7.2.   Hall,   W.   "Predicting   Locomotive   Performance"   https://www.advanced-steam.org/wp-content/uploads/2017/08/Predicting-Locomotive-Performance.pdf

AUTOMATIC CUT-OFF CONTROL
via Chris Newman

The following article was sent to me by Justin Brown in the USA. It describes a piece of equipment that I'd not come across before and which I thought might be of interest. Perhaps it wasn't as successful as implied in the article since it seems to have disappeared by the time the 1941 Locomotives Cyclopedia was published. Nevertheless, it might prompt some thought and discussion within ASTT's membership.

From Railway Age Vol. 76, No. 21 - April 26th 1924

Nickel Plate Light Mikado, equipped with Automatic Cut-off control, hauling a dynamometer car and test train

Automatic Cut-Off Control Tested in Service

Description of Control Device —

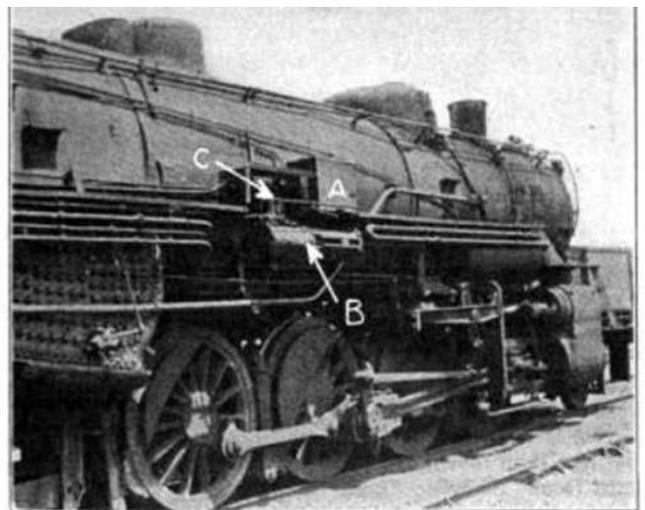### What its Performance on Two Railroads has Demonstrated

THE TOTAL ABSENCE of any means for automatically regulating the point of cut-off in steam locomotives, up to the present time, is contrary to the almost universal use of such regulating devices in the field of the stationary engine.

From the days of the first steam locomotive, the operation of the reverse lever has been by the effort and at the direction of the engineman. The development and practical application of a mechanical device, therefore, to perform this operation instead of the engineman, marks the opening of an entirely new field in locomotive development. It is apparent from data already secured that automatic control of the point of cut-off provides the possibility of a marked improvement in locomotive operation.

Device for Automatically Adjusting Cut-off

The mechanical device, tests of which are described in this article, is known as the Automatic Cut-off Control, made by

Location of the Controller Box (A) and Poppet Type Reverse Gear Valves (C) with Respect to the Reverse Gear (B)

the Transportation Devices Corporation, Indianapolis, Ind. It is actuated by the pressure of the steam in the exhaust passages of the cylinders, and connected to a power reverse gear. The controller, or principal part of the device, is mounted above the power reverse gear and in front of the reverse gear valve. It is contained in a metal box 23 in. by 18 in., by 13 in., located as shown at A in the illustration of the locomotive.

The controller is connected to all four exhaust passages of the cylinders by a one-inch pipe. Exhaust pressure is conveyed by this pipe to the pressure regulator unit of the controller and also back to the cab where it terminates in the back pressure gauge mounted on a small control panel shown in one of the illustrations. A second pipe connects the controller with the main air reservoir from which the controller obtains its source of power to adjust the reverse gear and hence the cut-off.
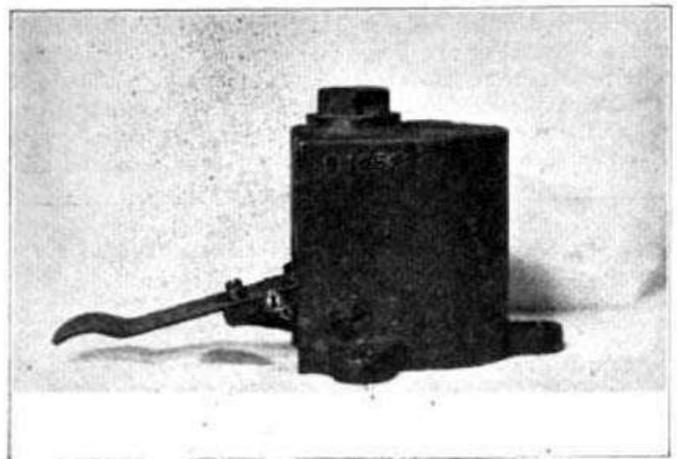
Tests made in road service apparently show that, for any given locomotive, dependent on type, size and boiler pressure, there is a definite constant back pressure which, if maintained constant at all speeds above which it is first reached, will permit maximum rated drawbar pull to be developed. This back pressure is held constant by lengthening the cut-off as the speed decreases and shortening the cut-off as the speed increases. Should the boiler pressure change in addition to a change in speed, the cut-off adjustment will be made accordingly. The proper exhaust pressure to be maintained is shown by the idle hand on the back pressure gauge mounted on the control panel in the cab: the actual pressure existing is shown by the movable gauge hand.

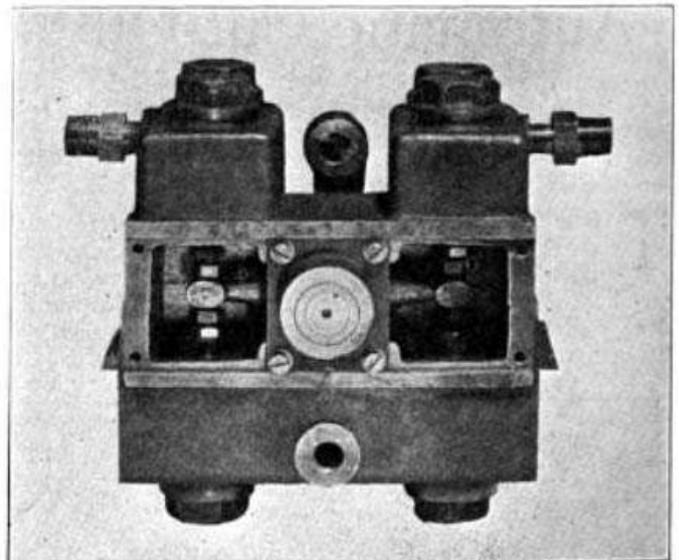The Engineman's Back Pressure Gage and Control Panel

Once the proper pressure for a particular locomotive is determined, the pressure regulator is so set and this setting is known as "High". A second setting, which may be anything less than the "High" setting, is known as "Low", being determined by the minimum operating requirements. The engineman may change from one setting to the other by means of the handle at the right end of the panel, which is pointing either on "High" or "Low."

Whether the cut-off is to be adjusted by the engineman or by the device depends on the throttle opening. A pipe is run from the right steam pipe back to a primary control valve in the cab. This primary control valve is designed to be set so that with the throttle more than 60 per cent open the Automatic Cut-off Control makes adjustments of the cut-off.

Foot Valve for Temporarily Cutting Out the Automatic Cut-off Control

The air supply from the main air reservoir passes through this valve and the action of steam pipe pressure is to supply or cut off the supply of air to the controller. A small slot in the dial of the back pressure gauge displays the word "Hand" when the reverse lever is subject to the operation of the engineman and "Auto" when operated by the device.

The engineman can cut the device in or out by the position of the throttle, or permanently cut the device in or out by turning the valve wheel located in the center of the panel. Again the device can be momentarily cut out, even though the throttle is fully open and the panel valve is also open. To do this the engineman holds his foot on the pedal of the foot valve.

The Reverse Gear Valve Assembly with Poppet Type Valves

In order to hold any predetermined exhaust pressure within the required limits, certain modifications in standard reverse gear design are necessary. The modifications consist of the poppet valve design of the reverse gear valve to eliminate the lap and lead of the slide and rotary valves. Lap and lead must be of independent adjustment and negligible so that fine adjustments and quick response of the reverse gear are positive. The valve of this gear is shown in one of the illustrations. Since the reverse lever must be always available for hand operation and at the same time free to move under automatic operation, the quadrant is circular in form. With hand control the piston of the small locking cylinder at the bottom of the quadrant is against the quadrant, holding it stationary. With the Automatic Cut-off Control in operation the quadrant is free to rotate and allow the lever to follow the gear. The locking cylinder is controlled by the primary control valve, actuated by the throttle opening.

In operation, the locomotive starts the train with the reverse lever in the front corner and the throttle open so that the device cuts in as shown by the word "Auto" on the gage. As the speed increases the back pressure builds up as shown by the gauge. If the engine is to be operated at 9 lb. exhaust pressure, when the pressure builds up to 10 lb. the pressure regulator actuates the reduction valve and the controller causes the gear to be hooked up until the pressure is reduced to 9 lb. This will be kept up until the maximum speed is reached and the cut-off is at its shortest, when the controller is prevented from going into back motion. If at any time a grade or other condition should be encountered that would cause the pressure to drop to eight pounds, the cut-off will be lengthened and nine pounds back pressure restored. This may keep up until the reverse lever is again in the corner. The differential of one pound above and below the constant is as close as practical operation will permit, although the controller is said to be capable of one-quarter pound differentials. The exact value of the back pressure maintained has no bearing on the operation of the device which is designed to adjust itself to any pressure to which it is set, the

The Reverse Lever Assembly Includes a Circular Quadrant Which is Held Stationary with Respect to the Bracket, for Hand Operation, by the Locking Cylinder at the Bottom of the Bracket

characteristics of the locomotive establishing the "High" setting and minimum operating conditions, the "Low" setting.

Should the engineman at any time close the throttle, the reverse lever will remain where it was before the throttle was closed, and not go to the corner. The engineman, when the device is cut in, cannot move the reverse lever to any other position than that fixed by the controller. He may, however, turn from "High" to "Low" setting, which will immediately change the cut-off to the lower exhaust pressure. To control properly the pulsations of the exhausts at low speeds, a uniflow fitting is inserted in the back pressure line between the cylinders and the controller.

The locomotive engineman has no guide other than a varying degree of experience to assist him in determining the proper cut-off to use. Again because of the many other duties, the attention to which is vital to safety, he is deprived of time, particularly continuity of time, to adjust cut-off. It is the function of the Automatic Cut-off Control to provide accurate and constant adjustments of cut-off and to do this without the attention of the engineman.

Nickel Plate Tests Automatic Cut-off Control

The effect on speed and drawbar pull of cut-off regulation as performed by the engineman and by the Automatic Cut-off Control under competitive test conditions is shown graphically in a chart typical of a series taken from dynamometer car tests of a Nickel Plate light Mikado locomotive, stoker fired, on a three-mile section of test track. Each run required about 15 min. The maximum grade was 42.24 ft. per mile *[1 in 125]*, and the maximum track curvature 2 deg. The same train was backed up to the starting point for each test, the engine and crew being the same in each case.

The results of these tests, as borne out by the charts, may be summarized as follows:

There was no appreciable difference in the minimum speeds of the respective trains over the grade where minimum speeds would naturally be expected.

There was a decided difference in the cut-offs used by the enginemen and by the Cut-off Control. In starting the train, the reverse lever remained in the corner longer with the Cut-off Control than when operated by the enginemen, but this was an advantage in getting more quickly to the higher speeds and shorter cut-offs. In slowing down, the Cut-off Control did not hook down the reverse lever as quickly as the enginemen did. In running, shorter cut-offs were used and for greater periods of time when the Cut-off Control was in operation.

The Cut-off Control generally showed equal or better speeds, drawbar pull and drawbar horsepower than those obtained by the enginemen, regardless of the longer cut-offs used by the latter.

The time performance between mile posts was generally in favor of the Cut-off Control.

The enginemen as a rule anticipated the grades by lengthening the cut-off in advance of the train actually being on the grade. The Cut-off Control did not lengthen the cut-off until the grade resistance had actually made itself felt upon the train, this being particularly noticeable between mile posts 38 and 37. It is evident that if shorter cut-offs can be used without lessening the drawbar pull or speed for short runs, the cumulative effect over the entire division will be conducive to lower fuel consumption and better time and tonnage performance.

Because of the shortness of the Nickel Plate tests it should be noted that the enginemen were in a position to devote all the time necessary to adjusting the reverse lever and to take advantage of their knowledge of the roadbed gained through years of experience. They could also look ahead and on approaching a grade take advantage of any peculiarity which might make the lengthening of the cut-off advisable had such a thing been the proper thing to do. The fact is that the enginemen really lengthened the cut-off at the wrong time because of their mental attitude as to the necessity for it.

Fuel Economy Tests on the Big Four

In order to determine the effect of the Automatic Cut-off Control on fuel consumption this equipment was applied to a C. C. C. & St. L. Mikado locomotive, No. 160, and a series of tests run between Springfield, Ohio, and Bellefontaine, Ohio. Tests made on the same class of locomotive over the same territory, in April, 1923, had indicated that 13 lb. back pressure was the proper setting for the automatic cut-off governor, and this setting was used during the fuel tests.

A total of four runs were made in the eastward direction between Springfield and Bellefontaine, two runs with the cut-off controlled by the engineer and two runs with the cut-off controlled automatically. The same train was used during each test, but due to heavy rains during the second, third and fourth tests the train, which consisted entirely of loaded coal cars, gained in weight. An allowance of four per cent of the total weight of lading was added to the original weight to offset this factor.

The coal burned during the tests was loaded from one car, held for this purpose at Springfield, thereby keeping the grade of coal burned constant. Coal was weighed onto the tank previous to each run, and the coal left at the end of each run was weighed off. In addition, the weight of the coal fired before and after each test was taken. The coal figures for the test runs, therefore, include only coal actually burned from the start to the finish of the runs.

In order to make the four runs truly comparable, it was necessary to keep the number and location of stops and starts constant. For this reason, every siding was entered, and the moves in and out of each siding were the same on each run. The speed records, two of which, together with the track profile, are included, show how closely the moves of the test runs compare.

The tank of the locomotive was calibrated and water read-ings taken at each stop. The feedwater heater was credited with a 10 per cent return to the tank during each run. The booster engine was cut in at all starts, but was not used on the ruling grade, Powell's Hill, during runs I. 2 and 4. On run 3, with hand operation of the cut-off, it was necessary to cut in the booster near the top of the hill.

The standing time in sidings was kept as constant as possible. The time standing was greater on runs 2 and 4, with the cut-off controlled automatically. This, without doubt, caused a slight increase in coal consumption but no effort was made to estimate the amount. Runs 1 and 2 were made with different engineers, while runs 3 and 4 were made with the same engineer.
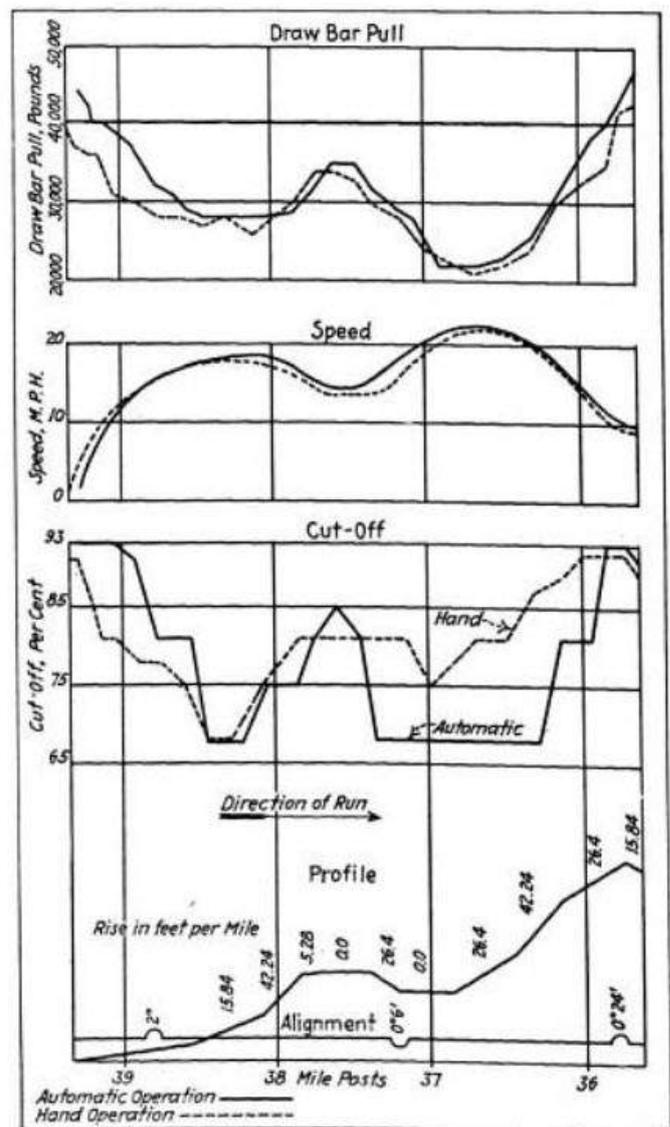
A Comparison of Draw Bar Pulls, Speeds and Cut-offs Developed in the Dynamometer Car Tests on the Nickel Plate

Table 1 – General Data and Results of the Big Four Fuel Test Runs				
	Run 1 – Hand	**Run 2 - Auto**	**Run 3 – Hand**	**Run 4 - Auto**
Actual Train Tonnage	3,597	3,701#	3,714#	3,714#
Adjusted Train Tonnage	4.347	4,451	4,464	4,464
Running Time, min, bridge 295 to Gest Yard	158	176	171	169
Standing Time, min	138	158	186	228
Total Time on Road, min	297	334	357	397
Average Running Speed, m.p.h.	11.2	10.1	10.4	10.5
Average Max Speed between stops, m.p.h.	16.3	14.1	14.1	14.1
Min Speed over ruling grade, m.p.h.	9.5	4.0	3.5	5.0
Average Steam Pressure, p.s.i.	191	195	192	194
Coal Fired, lb.	14,713	13,709	15,631	12,960
Water Evaporated, lb. (10% return by heater)	91,135	92,730	95,480	96,525
Water Evaporated per lb. of coal fired, lb.	6.19	6.76	6.10	7.45
Coal Fired per 1,000 gross ton-miles	138.8	125.4	142.7	118.1 128.9*
# includes 103.8 tons estimated increase in train weight due to rain water penetration (runs 2,3 & 4) * based on mileage to point of stall at mile 104.7				

The stall which occurred between West Liberty and Gest Yard on run 4 was due to a shower which caused bad rail conditions, and inability to get sand to the rail resulted in the engine slipping. A train following pushed the test train about 30 car lengths after which Engine 160 handled the train alone. The coal consumption per ton mile for this reason, was calculated up to the stalling point and also including the stall.

The general averages developed by the test runs are given in Table 1. From the standpoint of fuel economy, the two automatic cut-off runs show an increased water evaporation rate and a decrease in coal consumption per ton mile as compared with the two runs where the cut-
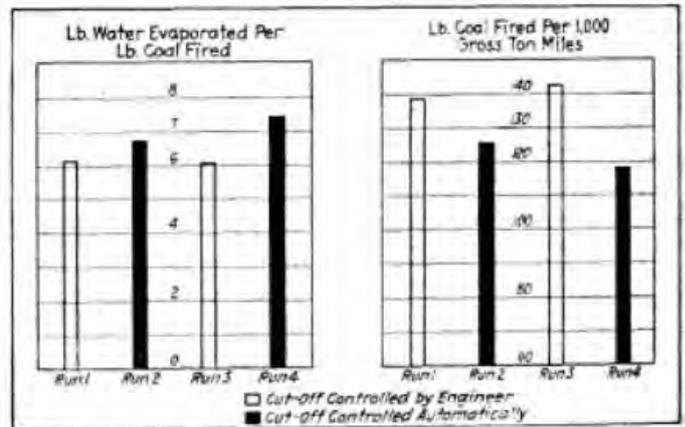
Graphical Comparison of Big Four Fuel Test Results
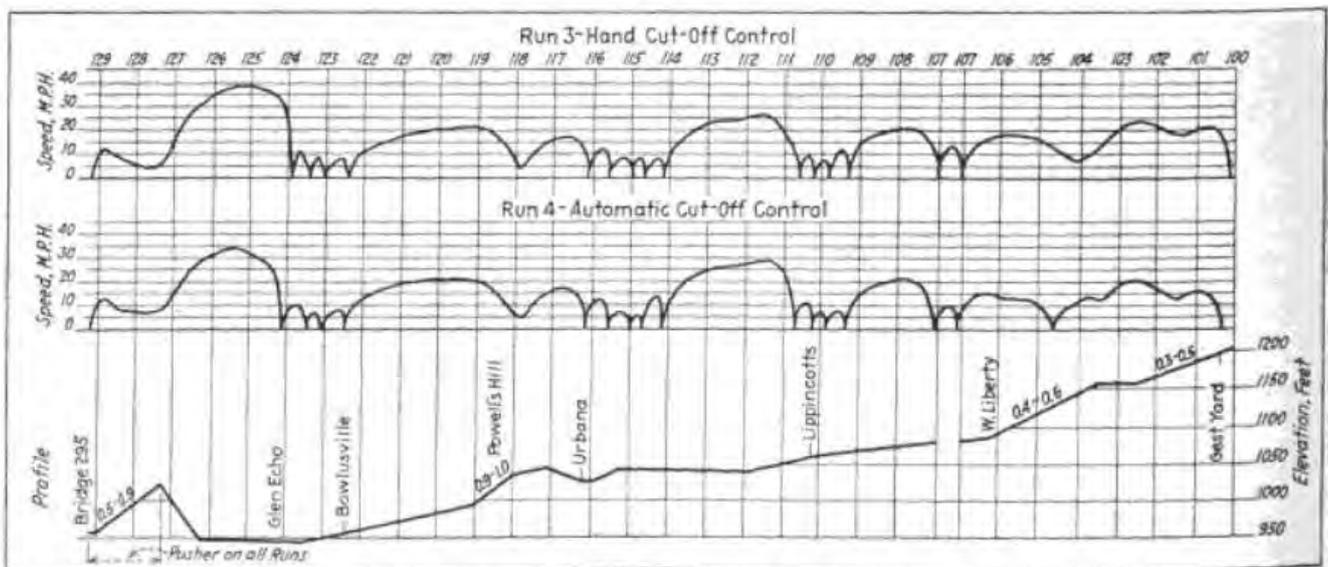
Speed Records and Track Profile of Two of the Big Four Fuel Test Runs

off was controlled by the engineer. The results indicate that with this class of loco motive a gain of approximately 10 per cent in water evaporated per pound of coal fired and an approximate decrease of 10 per cent in coal consumed, may be expected by automatically controlling the cut-off.

It should be noted that the actual running time on all tests, with the exception of the first where the lading was dry and the train lighter, is nearly the same. The more effective firing under the constant draft conditions held by the automatic cut-off combined with more uniform accelerations from stops, account for the increased rate of evaporation and reduced coal consumption, indicated graphically in one of the charts.

Operating Results in Slow Freight Service

The effect of better average drawbar pull and speed on economic operation is shown by the following operating data taken from competitive cut-off control tests in slow freight service on the Cincinnati Northern, a subsidiary of the Big Four:

	All engines of same class	Engine with automatic cut-off	Percent increased produc-tion
Average mites per hour, total time	10.1	11.3	-
Average gross ton miles per hour, 1,000	32.61	39.2	20.2
Average gross tons per train	3,239	3,477	-

This shows the accumulated effect on the rate of produc-tion, in terms of 1,000 gross ton miles per hour, of regulation of cut-off to develop maximum rated drawbar pull at each speed.

It is interesting to note that increased tonnages do not reduce the speed as much as might be expected when the cut-off is adjusted automatically. This is clearly brought out by the following comparison over the same territory and service:

Actual train tonnage	Speed, running time, m.p.h.
3,300 – 3,400	15.2
3,400 – 3,500	14.6
3,500 – 3,600	14.8
3,600 – 3,700	14.4

Certain mechanical and operating advantages, claimed for the automatic control of cut-off and substantiated in varying degree by the tests, are as follows:

1. Standardization of exhaust nozzle sizes. This is possible because the locomotives are uniformly operated as to cut-off.

2. Elimination of water stops. The proper use of cut-off saves water and eliminates certain stops that are now occasionally made, requiring the maintenance of water supply stations that may otherwise be eliminated.

3. Uniform conditions of firing. Constant back pressure provides constant draft and firemen do not have to carry excessive fires in anticipation of a heavy pull on the fire because of the sudden use of long cut-offs.

4. Shock on reciprocating parts is lessened. As the pistons are opposed by a constant exhaust pressure, they are not subject to shocks where this pressure varies widely.

5. Lubrication protection in drifting. The back pressure gauge is calibrated to register a vacuum: if in drifting, the throttle is shut off only to the extent that no vacuum is created in the exhaust passages, no smoke box gases will be drawn into the cylinders to destroy lubrication.

6. Elimination of valve setting errors as they effect cut-off. It is difficult and practically never possible to set the valves so that the same quadrant notch on all engines of the same class will give the same per cent of cut-off. As the Automatic Cut-off Control adjusts the cut-off independent of any mechanical condition as to reach rod length, the proper cut-off is used regardless of errors of this nature.

7. Safety of operation. Many times on critical pulls the engineman is required to watch for signals, the brakes, the sand, the injector and the throttle to keep from slipping. A moment lost in handling the throttle and sand may cause slipping and stalling of the train.

KEEPING THE KETTLE BOILING
Owen Jordan

As recent events have shown, there is a political aspect to buying and burning coal in a world where not everyone respects the basic tenet of civilisation 'thou shalt not covet thy neighbours' nuclear power stations'. Coal has moved, if not up the agenda, then certainly sideways to a point of improved visibility, with various suggestions as to how its use might be invoked to substitute for one's neighbour's gas and oil. The Heritage steam industry – and it is an industry, even though its product is making people happy, rather than supplying them with physical goods – appears to be desperately searching for a position that will secure its energy supplies and not bankrupt it. Within the terms of its existing precarious position in respect of coal it can burn in existing equipment, that means some sort of coal that offers some concessions to the ideal concept of a medium volatile, medium to strongly caking, coal of somewhat higher rank than is currently burnt wholesale round the world in power stations. It also means a sized, rather than run-of-mine product, free of significant pyrites, and with an ash content of 10% or less.

For the most part this kind of coal does not have a significant market; it is a specification for a steam coal that has not really been produced for half a century, and whose reserves in Britain, to quote just one example, were happily dug up after 1950, usually with a face plough and power loading, which reduced all of it to powder, and carted off to be milled and burnt in a power station furnace twenty miles or so from the pit that produced it. Fifty years of that sort of resource depletion – sending a potentially premium product to be used by the lowest common denominator – has meant that there is virtually no readily available steam coal for locomotive use, in the ground and accessible, in Britain. We are therefore reaping what can loosely be described as the harrowing of Britain in the seven decades after 1950, where energy resources - including good steam coal - were literally thrown away, mostly up power station cooling towers.

The question today, then, is are there steam coal resources we could access, and should we access them, and are there alternatives that we could use to substitute, partially or fully, for that coal? This, quite obviously, is a multi-faceted question, and does not just involve the end-user, but everyone with an interest in energy production. We can also appreciate that there might – and that is probably more like a 'will' – be people who are opposed to the use of steam coal – or any other coal – even for heritage purposes; we cannot expect to keep everyone happy. I would suggest however that there are ways and means of securing supplies of steam coal, that the heritage industry is undoubtedly the best place for that coal to be burnt, low overall thermal efficiency and all, and that, which might surprise some, the coal could be used within a long term carbon-negative system of production and use.

That said, I doubt that the heritage industry will gain any brownie points at all by going bald-headed after UK supplies of steam coal; that battle has been lost, for various reasons, not least the politics of the 1980s. To win the war will require a strategic campaign to ensure a future for mining as a profession; where we once led the world we now are looking into the abyss as far as mining expertise is concerned, and another decade will probably see us devoid of the ability to mine almost anything, and obliged to go to the rest of the world for that expertise. Coal mining is probably the most challenging of underground environments, especially in Britain, and keeping those skills alive, prospering, and adapting to the new times it finds itself in, is one way of securing steam coals for locomotives. The actual amounts – perhaps only 50k tons, possibly less – are well below the output of even one face in a 1970s UK mine, which implies that cost will be comparatively high compared to world market prices, and that a business model will have to be built that gets all the necessary components of such a business right, so that it is a long term venture, not a flash in the pan. Before I come to the environmental case for coal mining, we need to look at other options.

The key issue here is to remember that we are looking to boil the kettle. How we do it, at least in the theoretical world of innovation before we get to product or system development, is completely up for grabs. The heritage locomotive, at least at full size, is for the most part a barely stretched beast; it is rarely pushed to even a fraction of its limits, and only those engines with a main line ticket get a good load to haul at decent speeds, but again, only at part load, occasional big bashes apart. The second fact to remember is that the vast majority of the heritage fleet work summers only, and of that, mostly just the weekends outside the school holidays. So intermittent use – which sends boilers to the scrapyard at a rate of knots – is the norm, and any product or system that would permit

engines to sit in light steam at zero cost during the week might have widespread application. The third fact is that a cold locomotive is no use at all, and depreciation charges on turning a cold engine into a hot one, on the boiler alone, run towards four figures in most cases on the full size train set. Conditions are rather less demanding at smaller scale, but still apply to such things as traction engines and steam lorries, though rather reduced; locomotive boiler insurance has developed in a certain way to minimise risk to the insurers, not necessarily to minimise cost to the engine owners and caretakers.

So. What have we got, and what might we have if we did a bit of lateral thinking? The most obvious way to look at this is to list the present fuels and energy sources that might be used, and look at why they are – or are not - at present in use, and the costs associated, both capital and running.

Traditional locomotive coals

     ‘Hard’ coals – Yorkshire, Lancashire, Durham, Scottish, generally medium volatile

     ‘Soft’ coals – South Wales low volatiles, strongly caking

     High rank coals – dry steam coals, semi-anthracites

Traditional locomotive 'waste' fuels

     Bagasse, husk, kernel and shell etc

Other locomotive fuels – actual and potential

     Wood – inc waste from mills, etc

     Peat

     Electricity (various sources inc hydro)

     Plastic waste

     Various gases – inc (bio)methane

     Oil - inc biofuel

Taking these in order.

'Hard' Coals

These are the generally widely used – and originally widely available – general purpose steam coals that also were sold for coking, gas, manufacturing and domestic use. They include the classic Barnsley seam of the Yorkshire coalfield, and the Main Seam of the Durham, but that is to cite just two of many. They generally had some level of caking ability, a rather larger proportion of volatiles – hence the development of the brick arch – and were, at least for railway locomotive consumption, free of large quantities of ash and anything that would clog either a fire or a firetube with clinker, especially iron pyrites. Their availability today from British sources is de facto nil. Most of the accessible leavings of the opencast industry, active since 1941 and only now coming to a finish, concentrated on the shallow stoop and room workings before 1850; these have gone. There are still one or two companies trying their luck with the planning system, but none have tried the heritage coal card, so far as I am aware, and most applications simply get howled down by local opposition, which is entirely understandable. The prospects for even a heritage–based opencast mine getting through the system and producing coal at the rate needed, look slim to non-existent, on technical and not just environmental grounds.

The reasons for that are, like conventional mining, opencast depends on time-related earth movement. That is simply soil mechanics, which applies to rock, too; a 'cut' that will stand for six weeks while the coal is extracted from the bottom, may become dangerous at six months, so the rate of extraction has to be sufficiently brisk to ensure stability. In a local opencast mine, for example (East Pit, Tairgwaith, 2017-19), the void commenced collapsing almost immediately it was opened, and quantities of coal, in that case anthracite, had to be abandoned unworked. Other similar workings over the past three decades have had similar problems; Blindwells, Lothian, caused the collapse of the East Coast Main Line, which had to be diverted round old workings that had been unknown in 1845 when the railway was built. That led directly to the cost of reopening the Waverley Route to Galashiels being off-planet, as every possible mine void was grouted to prevent a repeat. These remainder coals are too dangerous generally to be worked by conventional drift or shaft; most have been mined pre-1850, when mine abandonment plans became a legal requirement, and many so-called 'mine plans' post that date are too poor to rely upon for safety. To date, the Coal Authority, which is responsible for the deposit and conservation of abandoned mine plans, regards these as commercially sensitive information, and does not make them available to the general public. It is not possible therefore for the general public, and certainly not the author (who is persona non grata at the CA) to assess just what resources could be still accessible in the UK.

Imported coals, in the quantities required by the heritage industry are available, but many are from sources that, when examined under the microscope, prove rather less palatable than we might like. Much of western Europe has dealt with coal legacy issues by developing their own opencast, and to get graded steam coal means going further afield, raising costs and, since 50k tons is not enough to fill a bulk carrier, disproportionately expensive. Having gone further afield, there then arises the issues over sustainability, and that is a difficult – but probably not impossible – nut to crack, one far better addressed in the UK.

Soft Coals – Welsh Steam Coal

The current only potential supply of Welsh steam coal is Ffos y Fran opencast site at Merthyr Tydfil, and like all opencast coal, is very much a curate's egg, since output is normally blended on site to disguise the fact that opencast works every seam down to the basal one (which may be at the bottom of the coal measures, but usually is the last thick seam within the working ratio). That means the low ash coals get blended with the rest – some with 40% ash content – to produce a saleable product. What that product is depends very much on how much of the best coals are left, can be worked, are worked at any particular point in time, and what goes into the blend from the unworked seams. Typically there might be ten thin and unworked seams in an opencast 'cut', all under a foot thick, and with wildly varying ash content – anything from under 3% to over 40% - and that might form anything from 20% to 90% of the site output at any particular point in time. That variation is almost impossible to predict on the site, since the major resources – the previously worked thicker seams – are represented only by old pillars in stoop and room workings, around the site of old shafts, in places where washouts, stone partings or coal quality issues meant the coal was originally ignored, and in barriers between former collieries. There is little that can be done on site to adjust for this, beyond varying the site output declared specification to recognise the site constraints. In many cases also there is no methane left in the seam, and some of the volatiles are degraded to some degree. Some of the thin seams have almost no volatiles anyway.

That said, Welsh steam coal is perhaps the coal with the greatest potential to supply the heritage market long term. The steam coal resources of the coalfield were never fully developed, not least because demand for steam coals tailed off as the export trade - which was the major market – failed to recover after WW1. That left the south side of the coalfield with considerable reserves, resources that were used in the 1980s to act as a carrot by British Coal to get opencast consents from the LPAs. Chief among these was the 'Margam Deep Mine', a proposal to mine for metallurgical coal to the east of the Steelworks of the same name. It never happened, but if – and it might be quite a big 'if' – British Coal were telling the truth, then there is room for a mine to operate in this area for as long as the heritage industry wants steam coal. The coalfield here is the edge of a dipping – to the north – syncline, but basically a continuation of the steam and metallurgical coals mined around Swansea and Merthyr c1700-1950. These included seams, four, five and six feet in thickness – ideal for a 'model heritage' operation – and there may be a nine-foot seam as well. The dip is steep, but not impossible, a description that applies likewise to the SSW - NNE fault trends of the coal basin, the combination of which frequently defeated mechanical cutting and loading in the NCB era. The area is also sparsely populated at ground level – much of it is under Mynydd Margam – and risks from surface subsidence damage low. This is also possibly the ideal coal, most of it untouched and thus pristine; low ash, medium to strongly caking, limited volatiles with thus little smoke emission when expertly fired. It is, in fact, the coal the GWR used, mined from slightly further north at Abergwynfi.

High Rank Coals – Dry steam and Semi-Anthracites

As with the Welsh steam coals, the dry steam and the whole rank from semi-anthracite to anthracite proper, were never fully developed in either the nineteenth century or the twentieth; demand never tested supply. The difference today is in how the hard coal industry was addressed by the NCB and British Coal in respect of what was exploited, and what, as a consequence, remains. Demand for these fuels was firm, if modest, from 1914 to 1970, and the NCB planned – and did – supply the demand by opening new pits and closing a whole swathe of older production units so as to transfer their coal resources to the opencast side of the industry after 1950. The opencast industry got by far the better deal. The result is that there is little left on the north crop of the coalfield – one working opencast at Nant Helen, with plans for a rail development centre in hand, perhaps – and one proposed deep mine – a drift, not a shaft – on the same seam (the Big Vein, I believe) at Pentreclwydau in the Neath valley further south, licensed by the Coal Authority in March 2022 as this article was being written. There appear to be significant areas of unworked material to the west of Pontarddulais, but that may be due to high ash content, a feature that led to closure of the last shaft mine there – Brynlliw - in the late 1980s. Further west again there appear to be unworked measures, but British Coal was distinctly unenthusiastic about this area, too, for reasons, I think, associated with strata control and methane; at least one face at Cynheidre was abandoned by a blowout that filled both the heading, and the roadways to the heading, with fine coal.

Whilst potentially a supplier of fuel, the hard coals, which travel reasonably well but give only about 60% of output as graded material – the rest is smalls and dust – look poor against the possible steam coal reserves to the east. They do however, or at least the smalls do, form the basis of a current 'coal', in the form of a pressed anthracite briquette, using an organic binder to make ovoids. At an 80:20 mix, with the anthracite component having an average volatile content of 7%, say, and the organic binder being 50% volatile hydrocarbons, the result should be a form of steam coal. The briquettes are rather smaller than the 'fist sized' graded coals used formerly on the steam locomotive, and there is the issue that the binder is an additive, not an integral part of the original coal and will not therefore have the same binding – caking - qualities when fired on a locomotive grate. Acceptable this might be, but its long term supply is entirely dependent upon both the ability to mine the sized coal for sale, and the demand for that coal; on its own it cannot possibly be a viable commercial product.

When the Phurnacite plant operated at Mountain Ash, it produced 'smokeless' ovoids from the duff washed out of the steam coal collieries, using a pressure and temperature pressing process to fuse the duff into a domestic fuel. Such a plant could be a part of a sustainable UK coal use programme in the future, and would of course rely upon the smalls output from mining the graded product for steam coal. Some hard coal duff could be used as an ash and volatile content modifier, if required.

While hard coals were available on the world market in the 1980s, and may well still be, the European source, from the Netherlands, has closed. There appears little point in trying to source this fuel outside the UK.

Moving then to the organic waste products

Industrial process waste – Bagasse etc

The sugar cane industry utilised the cellulose from the residue of the extraction process in steam locomotives virtually in the form it emerged from the cane presses. As with much organic matter it was – and is – high in water content and would be a rather better fuel if dried. There are various projects around the world in the sugar cane producing areas, and numerous research papers, all trying to encourage utilisation of the energy source bagasse represents. The fact that bagasse can be burnt almost neat in locomotive fireboxes suggests that it would make an acceptable locomotive fuel. The energy content of bagasse is typically related to the bulk density; how far it is compressible so as to make it handleable. This is not an issue being addressed at source, since the electricity generation plant – Hilo on the Big Island of Hawaii, for example – is cheek by jowl with the cane production area, which is localised by the climate, in this case rainfall to the windward of Mauna Loa and Mauna Kea, and thus, even on the Big Island (which isn't that big) distinctly local. Access to this material would imply some significant compression to about 1000g/l to make shipping economic, but the fact that many of the fringe economies of the USA in its sphere of influence in the Caribbean are cane producers, and all close to the sea, suggests some potential. Brazil's ethanol production is also cane-based, with their bagasse going to steam plants producing electricity.

It is much the same with the woody plant matter that arises mostly from sub-tropical agriculture-based industry, where rates of growth of the plants are high. Shells, kernels and husks are all cellulose material, and need some processing to get their bulk density to levels where they could be economically shipped. Sugar beet is very similar to cane, and widely grown in the UK and Europe, but the residue cake is processed into animal feed at present; it is not known if there is a potential for turning more of this 'waste' into fuel; changes in farming practices might well create an opening. As with all these theoretically waste products, because they can constitute a chemical feedstock, there are always studies being carried out to see if their use can be extended commercially.

These last two points – plants with potential feedstock grown 'locally', and the regulatory position of why sugar beet is grown widely in the UK and Europe – perhaps illustrate just how complex matters can get. Sugar beet has been grown mainly within a protected market – tariff barriers – to keep prices high in the subsidy-strewn economies of north west Europe. The action of these tariffs on what it is economic to produce when, as in this case, the primary product is sugar, and downstream effects of the waste are secondary to the subsidy system, is horribly complex. The sugar beet feed nut is equally a standard component of intensive farming, mostly for beef cattle. Trying to sort out what could be available as a fuel, and at what cost, in such a system is difficult, to say the least, and calculations can be upset at a moment's notice simply by one part of the industry deciding to do something else, probably for reasons that have nothing at all to do with the issue we are looking at here. Then there is the effect of government trying to sort out a mess it created in the first place as a consequence of not knowing - or having the technical knowledge to understand the issues – what it was supposed to be in control of.

Getting involved in this complex set of inter-relationships is very difficult unless there is someone who knows exactly what is going on – an insider who can give sound advice.

Wood

The use of wood to fire the steam locomotive is practical at all levels and scales, and there are a range of potential, and actual, sources that require little more than the storage facilities and the ability to either harvest the product or pay for delivery of it. Many of the small scale users are probably familiar with the wood pellets widely marketed, and at about £350/t, 50% more expensive per useful kWh as steam coal. Quite what the industry does to justify that price is not clear, since a ton of wood, for burning, air dried, retails – or did, I have not checked on cost PP (Post Putin) - at £150-180/t depending on location, and that would fit neat – with no processing - in a locomotive firebox, though not one at 10.25in gauge. That simple statement sums up much of the difference between steam coal and wood, whatever format the latter comes as. The issues of substituting wood as a fuel in the full size train set are, given that the majority of locomotives employed are not stretched, except in adhesion, one of supply – and tender capacity - and making alterations to the firebox to adjust for the reduced draught requirements of wood as a fuel. However.

Burning wood on a scale commensurate with the heritage industry demands, that is somewhere of the order of 75k tons additional demand each year, would have a significant impact on cost, unless supply had a lot of elasticity. In the current energy market, elasticity of supply is the one thing absent, so prices would rise if the steam railways started to use wood without sourcing from their own lands. That then begs the question, one long avoided by BR and its successors in title, of how to manage the lineside, so that it both supplies the required fuel, and looks something like what it once was when the steam locomotive was the only motive power. For the steam railways to set up their own harvesting organisation is the obvious way to go; the fuel is never more than a few yards from the line, most have some sort of lifting gear and wagons to take the wood away, and the chief requirement beyond labour for cutting is for storage to reduce the moisture content. An autumn/winter campaign season, combined with a sustainable harvesting regime, added to an internal transport system that saw trucks taken off the roads, and use at the point – almost – of production, should bring the environmental awards raining down on the first successful project. Whether that would be a good thing is another matter. But the energy source itself would be at zero purchase cost. And the lineside in spring would be a tourist draw – flowers galore is one result of rotational coppicing for fuel. My own coppice also produces the most mouth-watering raspberries June – October... Typical yields of coppice grown timber are 6-10t per acre per annum. A typical heritage lineside might run to two acres of ground – possibly more - every quarter route mile, almost none of it out of range of rail mounted harvesting equipment.

Waste wood is also a possible source, but here there are potential issues. Factories making wood products almost always recycle their waste into such things as fibreboard and chipboards, not even disposing of sawdust. What little they do dispose of is probably not worth looking at. Waste wood from end-of-life recycling is rather different. Many wood products today are not just wood; some barely qualify as that. Much, including many building materials, is pressure treated with preservative, and these have potentially toxic volatiles that are driven off in combustion. Not a problem in small quantities, but potentially a significant issue at a heritage site burning by the tens of tons when the site is open for business. Other contaminants are the adhesives in chip and fibre boards, plastic fixings, and paint and laminate finishes. The latter are not normally nitro-cellulose based these days, but may contain substances for which there is no way of determining their level of toxicity at or before the point of use at acceptable cost. This is the reason why much scrap wood goes to landfill; it will decompose there into hydrogen, methane and carbon, with most of the toxic material remaining in the ground.

A third option with wood is to turn it into gas. The vast majority of the small businesses who sell their trade under the label of 'tree surgeon', operate with chainsaws and a wood chipper. The chipped wood is essentially ready for pyrolysing into gas, readily compressible and with a calorific value approaching that of methane, which forms a significant proportion of the gas itself. These businesses, as it stands, are currently emitting that methane as a powerful climate change gas, and burning it first to extract the energy is simply closing the carbon cycle in a much more sustainable way. Compressed biofuel gas as a locomotive fuel might be novel – I can't think of anywhere where it might have been used prior - but the gas producer systems in the last steam locomotives are essentially similar, and it is a smokeless, if not an odourless fuel. The chief requirements here are for the processing plant, and gas storage, and of course the residual carbon can be burnt as well. The return of gas lighting for stations? Now there's yet another option. Perhaps gas lit carriages are a step too far...

Peat

Peat as a locomotive fuel is another source once used, but practically it is difficult to dry, store and handle, unless it is briquetted. Then it becomes a distinctive aromatic fuel, and can be sustainably sourced. The issue of burning it in a locomotive firebox is relatively simple, but the cost as briquettes is quite high. Peat probably sums up many of the

issues with alternative fuels, in that it has been worked large scale in the past, particularly in recent times on the Humberhead Levels, and elsewhere, but that its reputation as a mined feedstock for the bedding plant trade has been under attack for some time. This is basically because the environmental movement has not come to terms with the Carbon Cycle, and that basic ignorance, coupled with a general reluctance on the part of the producers of many items to try and explain just how we all depend upon the carbon cycle, and how management of it is critical for the future. Peat was mined for the nursery trade, and getting understanding across that peat can be a harvest crop, rather than a mined fossil fuel, is the main battle that needs fighting.

There don't appear to be any workable peat resources close to current heritage rail sites, Welsh Highland Railway possibly excepted, and some form of briquetting plant would be needed. That said, two sites in Wales – Cors Fochno, and the Glaslyn levels behind the Cob, could be turned over to some form of environmental management including peat production; both are close to heritage sites and could usefully be developed to integrate production into what are currently nature 'reserves'; another challenge the environmentalist would probably balk at in the first instance. The obvious large site – the Broadlands – where peat is – or was - a traditional product, is another possibility, not least because the open water broads fill themselves in unless managed. Scotland appears to have a number of potential peat production sites south of the Highland Boundary Fault, and if anyone is thinking of turning the never-opened railway from Stornoway to Breasclete, Lewis, into a heritage rail operation, then turf burning there is simple, since most of the proto- lineside is peat, and only very small amounts are cut for fuel on Lewis and Harris these days. Other parts of the Highlands are, of course, very similar in this respect.

Electricity

For heritage steam operators prepared to think out of the box, electricity is one area where much could be done with existing technologies, for modest sums, and without compromise to the fundamentals of heritage operations. The low cost of solar, and its evident suitability for application to fixed and moving structures, especially the roofs of depot buildings and carriages, coupled with relatively minor alterations to locomotives, could cut heritage operation costs dramatically. The major problem with renewable electricity today is the Department for Business' determination to exclude the micro- and mini- producer from the market, with very low – or no – feed in tariff rates, and astronomical grid connection charges for anything they don't have to connect automatically by law. Having a locomotive boiler, especially a large one, as a heat sink, gets around this. Several on one site is even better. Keeping boilers in light steam via either a 'plug-in' electrical boiler, or heater elements substituting for the bottom tubes in the boiler, could transform the steam locomotive and eliminate much of the consequent costs of intermittent operation. That's for starters.

At 200W/m^2, a typical seven coach heritage rail consist with solar roofs on the carriages would generate about 50kW more or less continuously (tunnels excepted) during the typical summer operating hours (1000 to 1700). That's about 350kWh per train per day, and typically 20-25% of the energy required to keep the wheels rolling in service. As there is both a lead-in and tail-off of electrical generation at the ends of the day, which could be utilised for keeping the engine in light steam, that would reduce lighting up times and fuel costs, saving perhaps half of the 5cwt or so needed in the process. Overall a heritage operation with carriage roof solar and boiler electrical elements might cut its coal – or alternative energy – bill by a third. With grate demands reduced, some lining up of the grate to economise on fuel and permit better depth on the firebars (most heritage fire persons run thin fires – as thin as they dare – to economise on coal, and that shows up in leaks on the foundation ring). That in turn feeds back into less boiler maintenance.

The biggest gain though, ought to be in boiler costs. Whilst I have here just considered saturation-side boiler electrical heat, the real gain in running would be from a superheater side electrical installation. Superheaters on heritage railways are a bit of a waste; they don't do much, and runs are never long enough for the initial temperature to be raised a great deal before steam is eased off for the drift along to the next stop. Having 50kW on instant tap at the point of closing the cylinder cocks would be a different matter, saving fuel and water and doing the job even with the blast more or less idle. More complex, yes, but probably worth it, and the heater could be contained in the space of the header, dispensing with the flue tubes. That's a bit of icing; the cake is the elimination of the thermal shocks to the boiler.

Taken objectively, a typical Black 5 on heritage duty, will operate twenty weekends each year, and have perhaps six weeks or so in continuous steam, mostly in July and August. It will have been fired from cold perhaps fifteen times in the year, and from warm overnight between duty days perhaps sixty times. The boiler ticket runs for ten years and covers those 150 cold starts and 600 warm-ish starts. To get another ticket means a boiler rebuild of at least £0.5m, so depreciation charges on each of those 750 starts are the best part of £700 a time. With electrical assistance, that could be reduced to perhaps four cold starts a year and no warm-ish ones. If boiler wear and tear is directly proportional to the thermal shock of those starts, and all other factors remain the same, then there

appears no reason at all to believe that boiler insurance tickets, with reviews, could not be extended progressively to the point that boilers live as long as they did in the BR era – twenty years or more. And need less by way of intermediate repair. Cutting boiler standing charges by 75%? Now that's a carrot worth chasing, and with many heritage operations having substantial capacity to fit their own kit, well within their own ability to determine their future without having to chase people and organisations whose interest in steam is either limited, non-existent or actually negative.

Electricity, by supplementing the energy released in the firebox, also simplifies the issues of burning something else than coal.

On the smaller scale railways the issue of thermal shocks to the boiler diminishes as the boilers shrink with the track gauge, and most carriages are open at gauges below one foot, so having the option to carriage heat and charge batteries – keeping the carriages in better order and again reducing maintenance - while the railway is idle does not apply. Neither is the problem of lighting up so time consuming, and fires and tubes at the small scale need thorough cleaning to keep them perfect anyway. So while a railway at two foot gauge and above should benefit, below that scale the electric steam locomotive is a somewhat reduced attraction.

Finally, it should be noted that the electric steam locomotive was not unusual on Swiss Railways, as a shunter taking its energy from the catenary of the running lines, and if the heritage industry can do it on their own tracks, then there is no reason why support coaches on the main line could not have a pantograph – or pickup shoe - to provide backup steam production for emergency use or when passing through areas where clag is verboten. Mindful of the railway type approval system, and other protocols, that of course is another challenge, but main line steam with the largest engines, would be the biggest gainers from hot starts, reduced boiler costs, and better performing superheaters, not least in much reduced water use. Such kit, only useful on the busy main lines of course, would also do much to reassure other operators that heritage steam reliability on double tracks with no useful refuge loops – Shap for example – was up to scratch, and they would not be faced with delays while red-faced stokers wrestled with poor fuel at 25mph on a 100mph railway, 1:75 gradient or no.

Plastic Waste

This is possibly the number one disposal issue of the throw-away society, and any material that enables this to be concentrated and burnt in a locomotive boiler would almost certainly get the plaudits from society as a whole. Bear in mind that the next generation that will volunteer and keep the heritage steam scene alive through the twenty first century, will approach the issue of where the energy comes from in a different way to the way we do. Having said that, there are all sort of barriers to effective handling of plastic waste by incineration, not least some of the compounds that are to be found in the plastic. My personal view is that these materials are better dealt with by not making and throwing them away in the first place. Plastic bottles for example should be, like the ones I bought in Germany twenty five years ago and still have, permanent durable goods.

Fluid fuels – Gas

We touched briefly upon the generation of gas via the shredded wood that many tree gangs produce in quantity, but there are three gases - all can be renewable, that is made, used, and not have any overall impact on the atmosphere – and these are basically hydrogen, methane (and here I would include the larger molecules in the C_nH_{2n+2} class), and various mixtures containing, like town gas, a certain amount of carbon monoxide.

Hydrogen is the key to the energy content of all these gases, as the chemical reaction with oxygen produces more heat than does the reaction of carbon with oxygen. So hydrogen-rich gases are preferred as fuels, a feature tempered by the difficulty of compressing H to make an energy-dense fuel. Practically, the pure H, and CH_4, are difficult and thus expensive to compress significantly, and the compressed gases available commercially start with propane and butane. After C6 the fuels are liquids.

Making gas from chipped biomass is relatively straightforward, and the yield of the equipment can be improved by solar heating. Whilst unappetising, the gas generator will also take sewage from retention tanks. In round terms, wood chipped for manufacture of biogas yields about 60% of the energy content as gas, much the same as the coke retorts in town gas plants, the process being essentially the same, though carried out at a lower temperature and with a different gas spectrum. Storage is obviously an issue, as is the processing time, and any timeline setting out harvesting and use would need to be carefully planned so that the gas is available when needed. An obvious downside compared to wood storage, particularly insofar as the technology is rather more advanced.

Much the same applies to actually burning the gas in the locomotive. Gas needs to be accurately premixed (with primary air) in order for it to burn with the flame attached to the burner. Not doing this runs the risk of serious blowbacks, but there are a wide range of commercial gas burners made that would do the task perfectly well, and

be up to the robust conditions on a steam locomotive. Again, like electricity, best use of a biogas supply would be made via a separate gas fired superheater; superheat at the flick of a switch on starting. Equally, biogas could be used to keep locomotives in steam, provided of course there is enough being made; automatic firing is part and parcel of gas use today.

Fluid fuels – Oil

Pass any McDonalds truck and it is probable that you will see their boast that their waste cooking oil goes to make biodiesel to run their trucks. Once upon a time I was engaged by this company as a consultant, so I will refrain from further comment. Cooking oil is usually a mixture of sunflower oil, palm oil and other vegetable crop oils, and thus makes a perfectly sound fluid fuel. With or without the burnt food residues. As a waste oil it will burn without any processing in a suitably adapted firebox, and will emit an aroma that is, shall we say, not unique. However, emissions should be similar or better than are discharged to atmosphere via the exhaust ducts of the food chain outlets, so while you might not want to live next to a McDonalds, or KFC, the emissions are accepted globally, I believe, as being satisfactory without any treatment.

Burning waste (bunker) oil in steam boilers has a long history, and while there was fossil oil that was waste, burning it looked a good idea. We do of course still produce a lot of waste oil from vehicle servicing, and there is no reason why that could not be burnt in locomotives. It will be some time yet – at least forty years – before road and rail vehicles cease to use engine oil. However, servicing requirements have fallen dramatically in recent years, and supply is thus rather less than was once the case.

The equipment for handling and burning oil is readily available and, like gas, the commercial and industrial kit is quite robust enough to transfer to the steam locomotive.

The options for direct conversion of biomass to fuel oil however looks much less likely; an energy dense fluid fuel has been the premium product, for land transport particularly, for many decades, and burning that at thermal efficiencies of under 10% looks a non-starter.

Conclusions

It is perhaps slightly surprising that the heritage steam sector has not taken action to avert the position now looming. But there again, you could say that the energy dependency we now can see only too clearly, a dependency on not-very-nice overseas regimes, has been visible for anyone who wanted to see it for over fifty years; if governments lead by example, it is ever so easy to follow. Action in the past would have changed the present; I took the decision over a decade ago to stop complaining about inaction, and do something about it. As a consequence I have no dependency on fossil gas, pay nothing for electricity, have only limited dependency on oil (I could live without it, but life would be rather more interesting than I really want at the minute), and am working – via the K6 engine project – to eliminate that last issue. The heritage rail sector contains both the engineering capacity, and the intellectual resources to use that capacity, to, as the physician is exhorted to do – 'heal thyself'. It is quite likely they also have the land resources to supply the energy needed completely from renewables.

I have briefly run through the options above, and noted that one of the challenges to be faced, is the one of ignorance of the Carbon Cycle. It is not the only one. Energy supply over the past three centuries has been a story of the seizing of resources by the powerful to make themselves rich beyond the dreams of avarice. Coal founded that story, wrote the first twenty chapters without serious competition, and is still a major player in that narrative. It is perhaps only natural that those who recognise the dangers posed by unrestricted plundering of the planet's carbon stores – which make life on earth possible – should adopt a tenor of opposition that is in some aspects equally as blind to the realities of what needs to be done as those living life beyond most people's dreams on that plundering. How do you differentiate between smashing the planet to get coal – which is what we now do – and putting carbon back into the only available long term storage – the carboniferous series cyclotherms – while using the resultant coal that is extracted in the process in an appropriate way? More to the point, how do you persuade people that this is not only possible, but essential; mining has to move from, er, mining a resource, to harvesting it, even if it is going to be millennia before what we put back into store can be used in its turn? Mankind often has difficulty thinking beyond the end of the week, never mind planning for the next million years.

All of that is a long way from people having fun with the products of times past.

And yet it is not.

TRACTION ENGINE STUFF
Jamie Keyte

The engine at Quorn Easter 2022

Some of those who attended the AST conference at Stapleford in were able to have a go at steering our Aveling & Porter traction engine, works No 1995, built in 1884. The more sharp eyed amongst us may have noticed the plate on the side of the boiler: William Townsend Falcon.

William Townsend (actually Edward William – for some reason at least half the family – including his wife – went by their middle names) was the original owner of the engine in 1884. He came from a line of blacksmiths and publicans in the area to the west of Ledbury. He started as an agricultural engineer, then had a portable steam engine and then moved on to owning traction engines. No 1995 was his first and by the time his sons took over the business he had a small fleet. He lived in the hamlet of Falcon all his life and is buried with members of his family at St Michaels, Sollers Hope.

Why am I telling you this? Last year my sister mentioned an ancestor in my family – one William Townsend who was landlord of the Oak Inn, Staplow – just north of Ledbury. The dates didn't quite match but it seemed possible that there may be a distant family connection. After a lot of digging we established a common ancestor; James Townsend who was William (the engine)'s father and William (the Landlord)'s grandfather. This makes William (the engine) my Great (x4) uncle. One of those pleasing coincidences that make life interesting!

During my research one of my contacts said "wouldn't it be nice to have a photo of the engine at Falcon". This was the start of a plan which will culminate this year in us taking the engine back to Herefordshire and touring places known to the Townsend clan. We will start at the Much Marcle Steam Rally (July 23/24), then visit Falcon, Fownhope, Tarrington, Trumpet, Staplow, Ledbury and end up at the Welland Steam Rally on the 30th July. On our tour we hope to engage in the local community and raise funds for the mental health charity Herefordshire Mind.

I have created two pages on Justgiving. The first link is to our Herefordshire Mind page. The second is to a crowdfunding page where we hope to recover some of the costs of getting the engine there and back.
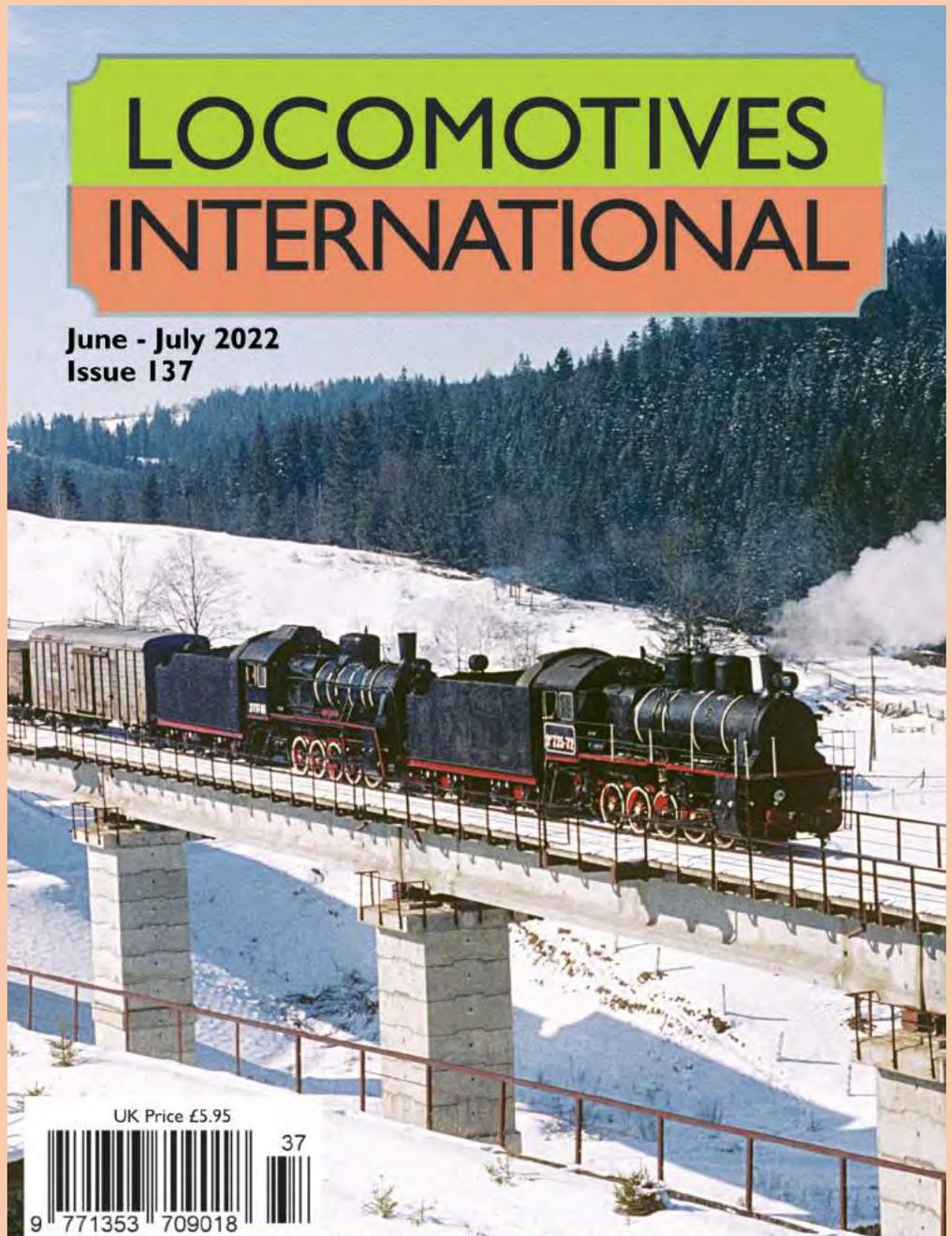
6 HP _S Agricultural_ LOCOMOTIVE.

No. 1995   Name _William Townsend FL for Falcon_

Aug.t 1884

Cylinder. Diam. 12" stroke, gird iron slide valve. Slide valve spindle and socket joint combined, 1¾ × ⅞" bush in column 1½" outside diam., 4½ long between collar and nut, ⅞ bolt in column, C. I. cap on water bracket, with two studs. Two G. M. safety 1½ valves, with steel spiral springs and adjusting lever ferruled off at 110 lbs. per square inch.

Connecting Rod. 2-10½ from centre to centre, large end brasses 5" in. bore, throw 2½ wide, strap ⅞ wide, ⅞ deep, 4 long, ⅞ bolt through. small end brasses 1⅞ in. bore, cross head 2½ wide, strap 1½ wide, 2¼ deep, 2½ long, ⅞ bolt through.

Reversing Gear. Rods 1 11 long from face of collar to centre of pin hole, double lifting links, C I straps, eccentric sheaves Rocking shaft 1½ diam. 1½½ long, stand, link, 1½ wide.

Crank Shaft. Steel, ¾ diam., with throw ⅛ diam. ⅝ from face of collar to centre of throw. Brasses diam. in. bore between collars pieces.

Pinions. Steel fast speed pinion, 11 teeth, 2¾" wide, 1¾ pitch, of boss on face of teeth, and 5¾ through all. Steel slow speed pinion, 14 teeth, 2¾ wide, 1½ pitch, of boss on face of teeth, and 5¾ through all.

Counter Shafts. No. 1. Steel, 4¾ long, 2¾ diam. No. 2. Steel, long, diam.

Gearing. No. 1. ...

No. 2. ...

Driving Axle. Steel, 6 ⅞ long, 4½ diam., C. I. caps on ends, 2¼" through lince pin 6½ long, 1" diam. axle boxes.

Spur Ring. Steel spur ring, 60 teeth, 3⅝ wide. Engine gauge 9¼ long, bolts.

Compensating Gear. Bevel wheel, steel 32 teeth, bolt holes. Bevel pinion, steel 9 teeth, steel pins 1¾" long, 1½" diam. Bevel wheel boss 1½ through diam. ⅝ rivets.

Winding Drum. ...

Original A&P build sheet showing original owner

The engine works plate

William Townsend himself

By Royal Letters Patent.
No 1995
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ENGINEERS.
ROCHESTER.
KENT. 1884.
England.

WILLIAM TOWNSEND
FALCON

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