ASTT Newsletter No12

Editorial - David A Nicholson

In this issue, Jamie Keyte updates us on the progress of the Revolution Project and there are many opportunities for ASTT members to get involved as detailed by Jamie in his article. Martin Johnson is involved with the design of Revolution and we have the first part of his detailed article on the design of model boilers. Many of you will remember Cedric's article on his ways of dealing with clinker and an update appears in this issue. John Hind gives us the history of Biofuels within the ASTT and brings us up to date with recent developments. John and Chris, as always, update us with ASTT management notices.

I would like to thank the members mentioned above for providing the material for this Newsletter and without whom it would not exist. As with many of the jobs in the ASTT, we would like more members to get involved and spread the workload. Please could you all write something for future issues as we have a great deal of knowledge within the ASTT and it would be good to share it within our small group? This year we aim to publish quarterly, so please keep your contributions coming in.

The press date for the next issue is Friday 3rd April 2020.

Chairman's Piece – John Hind

As mentioned in the last newsletter, the ASTT Committee would like to increase the number of Full Members. For more information on the benefits, see the Membership Section later on in the Newsletter.

Unfortunately, but for understandable reasons, James Conway has had to step down as Young Members/Student Representative to focus on his crucial studies in his final year at 6th Form College studying for A Levels. Many thanks to James for stepping forward. This does illustrate that whether you are young or old, retired or in work, there are incredible time pressures on us all. We will be looking to one of our other Student Members to take to take on this role, which as well as benefiting ASTT is a good opportunity to add to a CV!

One of the pleasing things about ASTT is that, though we are only a small organisation, we manage to attract new members and to grow. Chris Newman gives an update on membership later in the newsletter.

We are growing in our activities, as we have started the Revolution Project and are looking to continue biocoal trials in conjunction with the Heritage Railway Association. Updates on these activities and how you can become involved are in the Newsletter.

As ever, I end with a regular plea for help to manage the Trust. Given our small size the tasks are not onerous and tend to come in fits and starts. Most of our interactions are by e-mail and we only get together twice a year, either at the AGM or the Conference. An easy way of getting involved would be to shadow an existing role, by being copied in on e-mails and see what is involved, before taking an active role. There are currently opportunities in helping organise and manage the conference, book-keeping, treasurer, auditing, membership, book publishing and sales. If anyone would like to help with any of these please contact me at john.hind@advanced-steam.org **-you will be welcomed with open arms.**

Save the Dates – AGM 2020

The 2020 AGM will be held on Saturday the 7th of March 2020 at the Crewe Heritage Centre (where we held last years). The format will follow the same pattern as last year with a buffet lunch provided from 12.30 pm (with different caterers this year), followed by the AGM starting at 13.30 pm.

A formal notification will be sent out in early February.

After the AGM, there is opportunity for presentations from members and we already have one lined up from Joe Cliffe on 'Steam Turbine Locomotives and Condensing Modes' and an update on the Revolution Project from Jamie Keyte.

There is time for another presentation so if anyone would like to volunteer please contact John Hind on john.hind@advanced-steam.org

Conference 2020 – John Hind

We are planning to have the conference on the weekend of the 3rd/4th of October and are currently planning holding it in Darlington. We are hoping to have a speaker from the A1 Trust to talk about the new build P2, with a visit to see the locomotive. At time of writing, this is not confirmed as the A1 Trust are holding a roadshow on the Saturday and are concerned that they do not have the capacity to support our conference. As soon as we have news, we will let you know.

We already have a couple of offers of papers, ***but there is room for more, so if anyone would like to present***, please get in touch with myself john.hind@advanced-steam.org or Chris Newman info@advanced-steam.org – sooner rather than later, as we can be oversubscribed with papers.

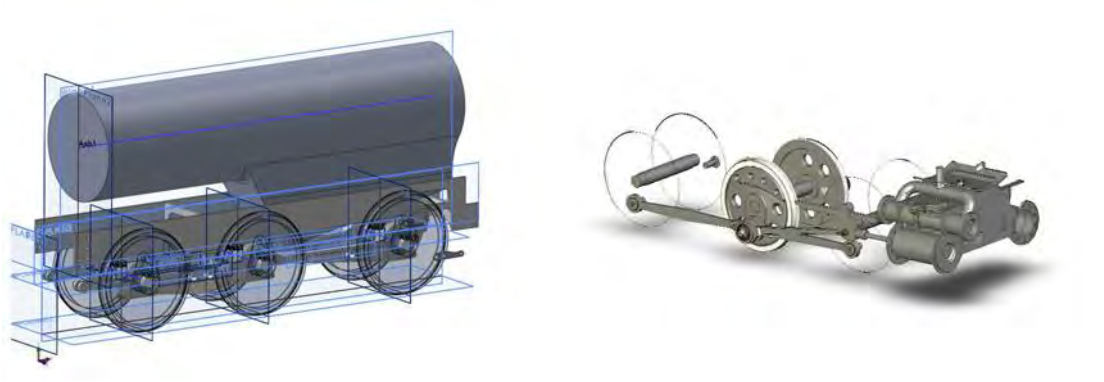
Revolution Progress – Jamie Keyte

Currently myself, Richard Coleby, Martin Johnson and Alex Powell are involved in the design of the frame, suspension, coupling and connecting rods and the boiler.

Since the Kick Off Meeting in March 2019, two subsequent Engineering Meetings and a Boiler Meeting: -

- Draft Locomotive Specification prepared
- Principle dimensions defined
- Main suspension/spring beam design is well advanced
- Axle and main axle bearings schemed out in reasonable detail
- Proposals done for coupling and con rod bearings
- Space envelope for boiler done
- Boiler Design Work Package released
- Preliminary boiler analysis started
- Document Revision Process developed

Most of the above could do with Technical Review, by a small group (3 or 4 people) so that the design can be "tested" from a design, manufacture, operation and maintenance point of view and possible alternatives/changes discussed. If anyone would like to be involved with the Technical Reviews please contact me at jamie-keyte@advanced-steam.org.



Latest CAD Models of Locomotive Assembly and Cylinders and Rods

The CAD models show how much there is left to do. More work packages will be released shortly: -

- Pony truck and suspension
- Air brake system and controls
- Smokebox design (particularly with respect to testing facilities and ease of changing internal arrangements)
- Draughting design (dependent on boiler)
- Tender (a three-axle tender with rubber suspension along similar lines to the loco would be interesting)
- Cab layout and controls

There are also some research type projects: -

- Boiler / cylinder insulation
- Ashpan steam control

On a practical front we are hoping to carry out some leakage tests to confirm assumptions made in the design calculations. The plan is that these will take place at Stapleford in April and will use Porta's method outlined in the 'Red Devil'.

If anyone would like to take on any of these work packages or research projects please contact me at jamie-keyte@advanced-steam.org

Biocoal – John Hind

Since the last newsletter, we have heard back from CSR and we have an 'agreement in principal' with CSR and the University of Minnesota for them to supply a quantity for trials.

It will be a specific batch produced for the UK and there is going to be a cost for production, shipping and also airfares and accommodation for CSR to participate in the tests.

We cannot establish costs and time-scales until fundamentals are answered such as the quantity required. In turn this is dependent on developing a test plan. We have asked the Heritage Railway Association to put us in touch with railways that are interested in taking part in trials.

If these come about, then there are, not only trials themselves, but the management of the logistics of shipping several tons of biocoal from the USA to the UK and the storage and distribution of it round the country – a new skillset we will have to add to our existing ones of conference organising, book publishing and steam locomotive engineering.

If anyone would like to be involved in any aspect of carrying out these trials please contact me by e-mail john.hind@advanced-steam.org

Designing Model Boilers, the Truth about Model Boilers, what Really Happens in Model Boilers – Martin Johnson

This article was originally written for the "Model Engineer" magazine and consequently, it is principally concerned with the thermodynamic design of boilers for small model locomotives. However, the methods that have been developed are just as relevant to full-size design. The excel spreadsheet that was developed is currently being used to assess boiler design for the ASTT "Revolution" project.

1 INTRODUCTION

It is a strange coincidence that when I first started reading Model Engineer back in 1971, such illustrious figures as D. E. Lawrence, Martin Evans, E.C. Martin and other were debating just how to design model boilers. I have to admit that I did not understand what these people were discussing at the time. Here I am, some 46 years later discussing the same topic, but in the intervening years computers have taken over from slide rules and I have had an engineering career concerned mostly with fluid flows, so I now understand terms such as Reynolds number. I think we can do better than 46 years ago.

I am currently designing and building a coal fired boiler for my 7” scale miniature Fowler steam lorry, which is considerably larger than most 7 ¼” gauge locomotive boilers, but not as large as full size. It is a vertical firetube type with a relatively large firebox, a large number of short tubes and the prototype had a smokebox superheater coil. I found that the information available in the model press on proportioning boilers was very short of quantitative design

rules and those that existed seemed dubious to say the least. Even much of the qualitative material seemed to be based on repeated assertion rather than fact. So, the only way forward was working from first principles.

This article deals with the thermal design of coal fired boilers in the 3 1/2” to 7 1/4” gauge range. To avoid confusion with computer **modelling**, I have called them "miniature" boilers throughout this article.

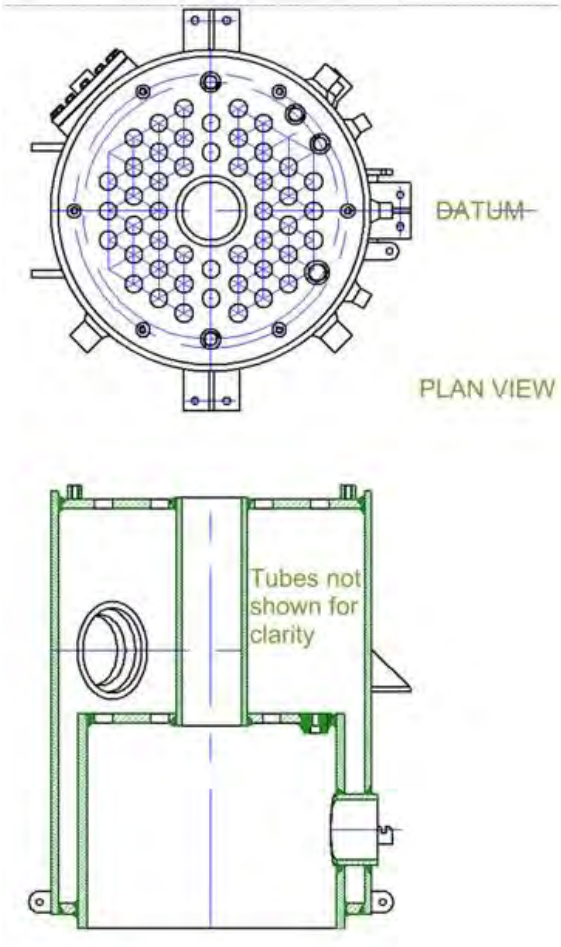


Illustration 1: Cross section and plan of the boiler for my steam lorry. The outer shell is 18" diameter, there are 47 vertical tubes and a coil superheater in the smokebox (not shown).

The ruling equations for heat transfer in fireboxes and tubes are well known and can be readily solved with the massive computing power available to us all nowadays. There have been computational approaches to boiler design before, notably from Bill Hall. However, I decided to develop my own method and this article summarises some of what I have found out along the way. It will hopefully be of use to other designers of “Stephenson” engines with small coal fired, fire tube boilers; and of interest to users of such small engines – whether road, rail, marine or stationary.

I would like to acknowledge generous help in my researches from Duncan Webster who provided copies of previously published material, encouragement and occasional critique; also, Roger Froud, who provided locomotive data and a chance to exercise my computer program for real.

2 CONSTRUCTING A MATHEMATICAL MODEL OF A TYPICAL LOCOMOTIVE BOILER

> *If anyone wishes to flog his brains on heat transfer in ….superheaters, L.H. Fry's paper…….refers. The complex mathematics would probably give 99.9% of model engineers rigor-mortis at first sight! In any case, I think these matters need not apply to our small engines. – D.E. Lawrence ME 3417*

I am not the first to "flog my brains out". Some of the current work follows Bill Hall's methods. However, my program is constructed on the Excel spreadsheet platform (2002 Version) and will run on Open Office, whereas Hall's program was written in C making it a much less open platform for use and public development. Hall did not consider his boiler work "complete". A brief summary of the work was written up in an unpublished report (Ref.8.3).

I have spent over 2 years developing my calculation in which the geometry of a boiler can be entered along with the working conditions. The input data can be grouped as follows:

- Boiler Working Conditions - Working pressure, Pressure after regulator, Firing rate, Air Ratio, Fuel lost rate, Fuel burnt on grate, Combustion Efficiency, Dryness fraction of steam leaving boiler.
- Boiler Geometry - Grate area, Firebox wall area, Length of tube stack, Number of firetubes, Number of Superheater flues, Number of spearheads per superheater flue, Internal diameter of firetubes, Internal diameter of superheater flues, Inside diameter of superheater elements, Outside diameter of superheater elements, Length of radiant superheater section, Roughness of fire side surfaces, Roughness of steam side surfaces, Outside diameter of boiler barrel, Overall length of boiler barrel, Thickness of Insulation, Conductivity of Insulation.
- Coal Analysis - Carbon, Hydrogen, Sulphur, Water, Ash, Oxygen, Nitrogen contents.
- Constants - Firebed emissivity, Specific heat of flue gas, Absorption coefficient of flue gas.

The calculation involves some 14,500 calculation steps, split roughly as follows:

Fire & Heat Release – 46	Firebox heat transfer – 1800
Firetube – 1900	Superheaters - 11000

The calculation produces the evaporative capacity of the boiler and superheat temperature of the steam. It also produces the temperature profiles along the length of the firetubes and superheater tubes. Typical results produced by the program will be discussed in relation to analysis of the boiler for LBSC's "Speedy" design.

I believe my work has advanced the state of the art in model boiler design in the following respects:

- More detailed analysis of the combustion process, in particular account of unburnt fuel, moisture content & coal analysis.
- A firebox radiant heat transfer model that includes the effect of absorbent / emissive flue gases.
- The option of considering wet steam generation.
- A section to calculate isenthalpic property changes across the regulator.
- Firetube performance calculation using well established correlations against Reynolds &

Prandtl numbers.

- Calculation of superheater performance.

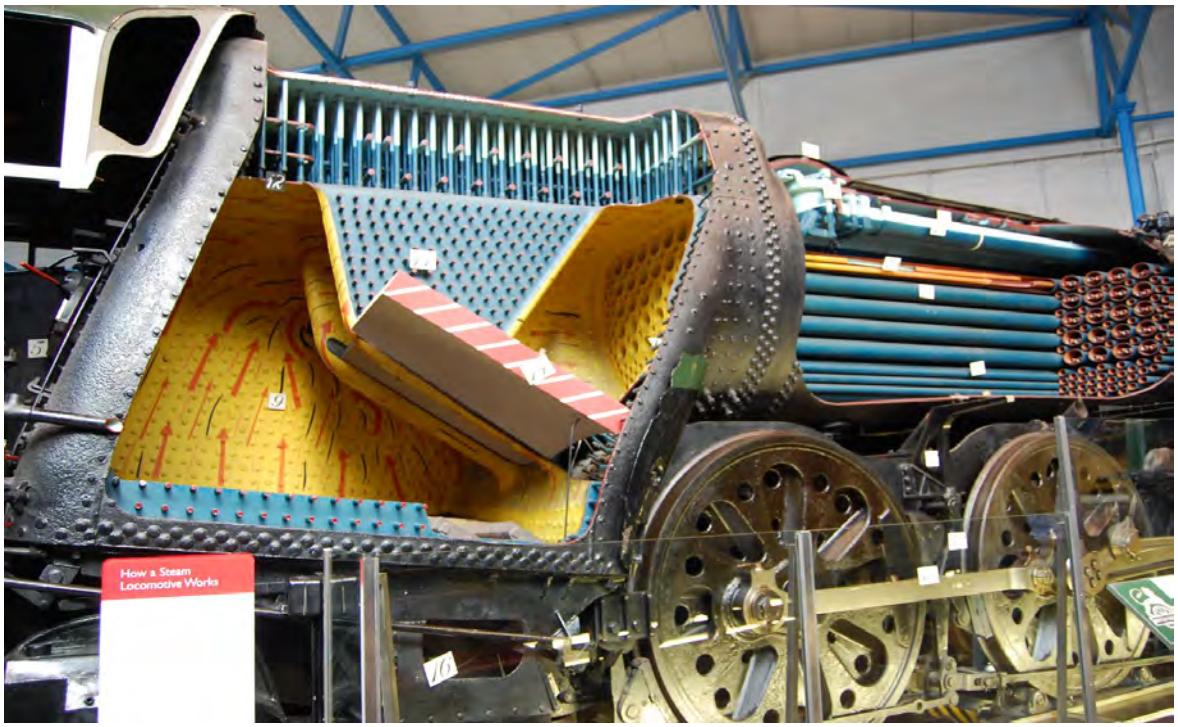


Illustration 2: A complex boiler, but just how do you calculate firebox size, tube size & number & superheater details? - Photo by P. Johnson

The calculation is based on well-founded relationships for convective heat transfer in a tube, pressure drop along a tube, radiative heat transfer from a firebed to firebox walls, combustion process for coals, conservation of energy, etc. Empirical relationships, of which there are plenty, have been avoided because they usually apply to a limited range of full-size practice. Readers (and the Editor) will be pleased that I do not intend to reproduce all the fundamental equations involved, most of which are covered in thermodynamics or heat transfer textbooks or the website http://thermopedia.com/. However, it is worth summarising some of the difficulties encountered in putting the mathematical model together.

The computer has to repeatedly calculate values of densities, viscosities, Prandtl number, enthalpy, entropy etc. over the range of temperatures and pressures likely to be encountered by wet steam, saturated steam, superheated steam and combustion gases. Therefore, a range of equations have been developed which will replicate published values of these data. Combustion gases are assumed to have the properties of dry air, which is the main constituent of combustion gas.

The combustion process is calculated using data contained in Ref. 8.10. This method will account for different quality coals. The calculation further accounts for:

- Some fuel being lost to ashpan, smokebox or chimney before being burned. This ratio is set by the user, and tests have been analysed to determine realistic values for this quantity.
- The quantity of air drawn in to burn the coal tends to vary with grate loading. The ratio of air to coal is set by the user and tests have been analysed to determine realistic

values for this quantity.

- Some carbon burns to produce carbon monoxide, this ratio is user settable.
- Some heat is trapped as latent heat in high temperature water vapour generated from combustion of hydrogen and evaporation of moisture in the coal – this heat is debited from the total generated, since it cannot be recovered in a non-condensing boiler.
- The heat generation can take place mostly in the firebed and partly above the firebed, the ratio depending on what parameters are set in the program. Heat release above the firebed would typically be due to volatiles burning in the firebox volume.

The heat released in the fire is assumed to heat the combustion products to the same temperature as the firebed, and the combined heat increase in the gases plus the radiant heat emitted by the fire are equal to the energy released in the fire. The radiated energy from the firebed to the firebox is calculated using the Stephan Boltzmann equations. Some heat is radiated from the incandescent particles in the flames direct to the firebox surfaces. The ratio of "firebed to firebox" heat transfer to "flame to firebox" heat transfer depends on the emissivity and absorptivity of the firebox gas, plus the dimensions of the firebox. The calculation also accounts for heat transfer by convection within the firebox, which is relatively small but significant. As gas passes through the firebox, the calculation reduces the gas temperature accordingly as heat is transferred into the boiler.

The flow in the firetubes is split into 25 stages along the firetube length. In each stage, the convective heat transfer to the boiler is calculated at the mean flue gas temperature in that stage and then the flue gas temperature leaving that stage is calculated as the input to the subsequent stage. The calculations take account of the formation of a boundary layer starting at the tube entrance and increasing along the tube length, plus the thickness of boundary layer based on correlations against Reynolds number. Thus, a reasonably accurate picture of the temperature profile along the tube is generated. An estimate of the superheater flue evaporation is made by assuming a similar temperature profile to the firetubes, the estimate being refined during the superheater calculation.

The regulator is usually placed before the superheater in a miniature, and the program calculates the change in steam temperature and dryness due to the adiabatic pressure drop across the regulator.

The temperature profile in a superheater flue is calculated in a similar manner to the smoke tube calculation. However, the steam temperature in the superheater at entry to the firebox end of the superheater flue is not known, therefore an iterative calculation is used to determine temperatures along the superheater. In addition, the evaporation from the superheaters is not known until the temperature profile has been calculated, so another iteration process is needed to get over that difficulty.

The computer model does not account for thermal resistance through the metal of the boiler, since it is actually very small compared to the resistance of the gas films. It would be a simple step to add this to the program, but there are more demanding areas of development.

The program has been constructed on a modular basis, so alternative configurations such as water tube boilers or smokebox coil superheaters can be constructed if needed.

For readers interested in learning more about the methods, the author can be contacted via the editor, and will be pleased to furnish the spreadsheet calculation, detailed equations, notes & references on request.

3 VALIDATING THE COMPUTER MODEL

> *…..The gas flow in model boiler tubes, unlike full size, is streamline and the boundary layer characteristics inhibit heat transfer. I personally think it is semi-streamline, or if you like, semi-turbulent because of eddies set up by deposits in the tubes. – D.E. Lawrence ME 3417*

A complex calculation technique such as that described above must be validated against test results. Two sets of miniature tests have been published (Refs. 8.1 & 8.2), those by Busbridge being the better tests, while those of Ewins reported by Evans were obtained using a convenient, but error prone, test method.

3.1 Busbridge's Test on 3.5" Gauge "Britannia" Boiler

Busbridge carried out a well-controlled series of tests on a Britannia boiler to LBSC's design and published the results in Busbridge, J. – Publ. Model Engineer 1st August 1964, pp 565-577 (1964). The tests looked at the boiler only and were conducted at the University of Cape Town.

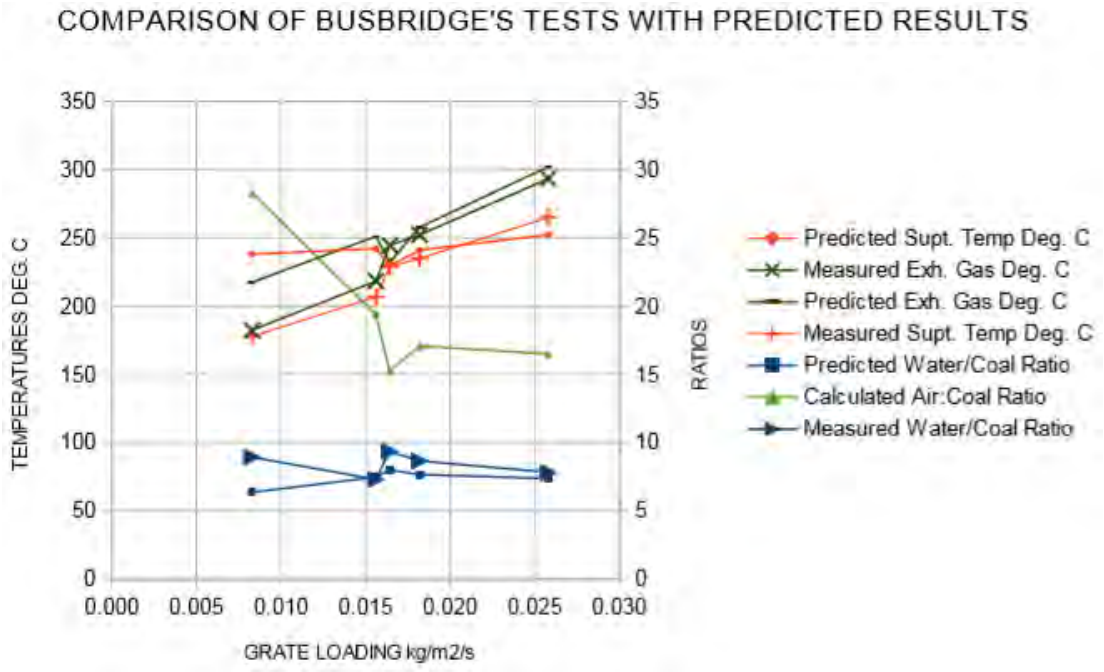


Figure 1 – Comparison of Bushbridge's test results with predictions from program.

Figure 1 shows good agreement has been achieved to Busbridge's tests across a range of grate loadings. The calculated stoichiometric ratio has been derived from Busbridge's measurements of carbon dioxide in the flue gas. It can be seen that the general pattern is for this ratio to asymptotically approach a value of around 15 at high grate loadings. At low grate loadings the ratio climbs to values near 30 or perhaps more.

The quality of prediction becomes worse at lower grate loadings, partly because variables in the program have been chosen to give better agreement at high grate loadings. However, the results suggest that free convection, probably in firebox spaces, become more significant at lower grate loadings. Since the program is intended as a design tool, accurate predictions at maximum grate loading are more important.

The computer confirms that flow in the fire tubes is indeed streamline (also known as laminar flow). Busbridge's tests included careful measurements on the non-radiant superheater

performance, which is fortunate as this gives an accurate indication of heat transfer within the flues. The validation process also confirms D.E. Lawrence's opinion that the flow is not fully settled laminar flow, leading to much better convective heat transfer than well accepted correlations would predict. The results suggest that normal correlations of convective heat transfer need uplifting by about 60%. Possible reasons for this are:

- Gas flow from the firebox to the tubes is turning through 90 degrees, causing major disturbance to the boundary layers in the flues and hence improving heat transfer.
- Gas flow is well into the laminar regime (Reynolds number 500 to 1000 in a miniature firetube) but within the lengths of a miniature boiler, flow is unlikely to be "settled", giving thinner boundary layers and hence improved heat transfer.
- I don't accept Lawrence's opinion that "deposits" would cause such an increase in heat transfer, as Busbridge's tests were on a new boiler.

3.2 Ewins' Tests on 5" Gauge "Mona" Locomotive

Correlations against Ewins' tests are somewhat frustrating. The tests are subject to significant experimental errors and inconsistencies as follows:

- Flue gas volume was measured by catching the gas in a large plastic bag and then measuring the volume by a "water displacement method" – details not given. This seems very prone to large errors.
- The flue gas analyses are not consistent with a predominantly carbon fuel burnt in natural atmosphere. The calculations relating to flue gas analysis can be found at Ref. 8.10. These analyses are used to infer coal consumption and grate loading. This results in experimental error in interpreting how hard the engine was working. If the CO_2 and CO results are assumed correct when burning a good quality coal, the O_2 contents would be as follows:

TEST NUMBER	EXPERIMENTAL O_2 BY VOLUME %	CALCULATED O_2 BY VOLUME %
1	9	10
2	3.5	6.2
3	10	10.9

- The grate loading can be inferred from Ewins' values for "coal consumption per DBHP hour" and "DBHP per sq. ft of grate". If this is done, the predicted flue gas production does not match his measurement of flue gas production. Grate loadings some 12 to 18% higher than those stated would be required to generate the stated gas volumes. Only some 4 % could be accounted for by ash content and the calculation was conducted assuming no fuel is lost before burning, which is an implicit assumption in Ewins' data analysis.
- The smokebox and firebox draught measurements are not consistent with the inferred changes in grate loading. I am indebted to Duncan Webster for pointing this out.
- The gas temperature measurements in the firebox will be significantly in error due to the radiant heating from the fire. BS 2790 Appendix C states this error can be up to 300 Deg. C. Taking accurate temperature measurements in a highly radiant environment needs very specialised (and expensive) equipment.

- Multiple IMLEC results suggest a maximum efficiency of around 2.5 % is feasible on miniatures, while Ewins claims an efficiency of 4.9% in Test 3, which illustrates the probable magnitude of experimental errors in Ewins' work.
- Some sources indicate the engine tested had thermal siphons in the firebox, but Evans in Ref. 8.1, makes no mention of these. I have sought the original SMEE papers of Ewins' tests, but without success. If anyone is able to help with copies of these, I would be very grateful.

Nevertheless, I have attempted to compare some of Ewins' results with the numerical model. Grate loadings are based on assuming Ewins' readings of flue gas volume flow, CO_2 and CO readings are correct, but the grate loadings inferred from stated values of "coal consumption per DBHP hour" and "DBHP per sq. ft of grate" are also included. The following graph summarises the coal / air ratio, superheater and exhaust gas temperature results:

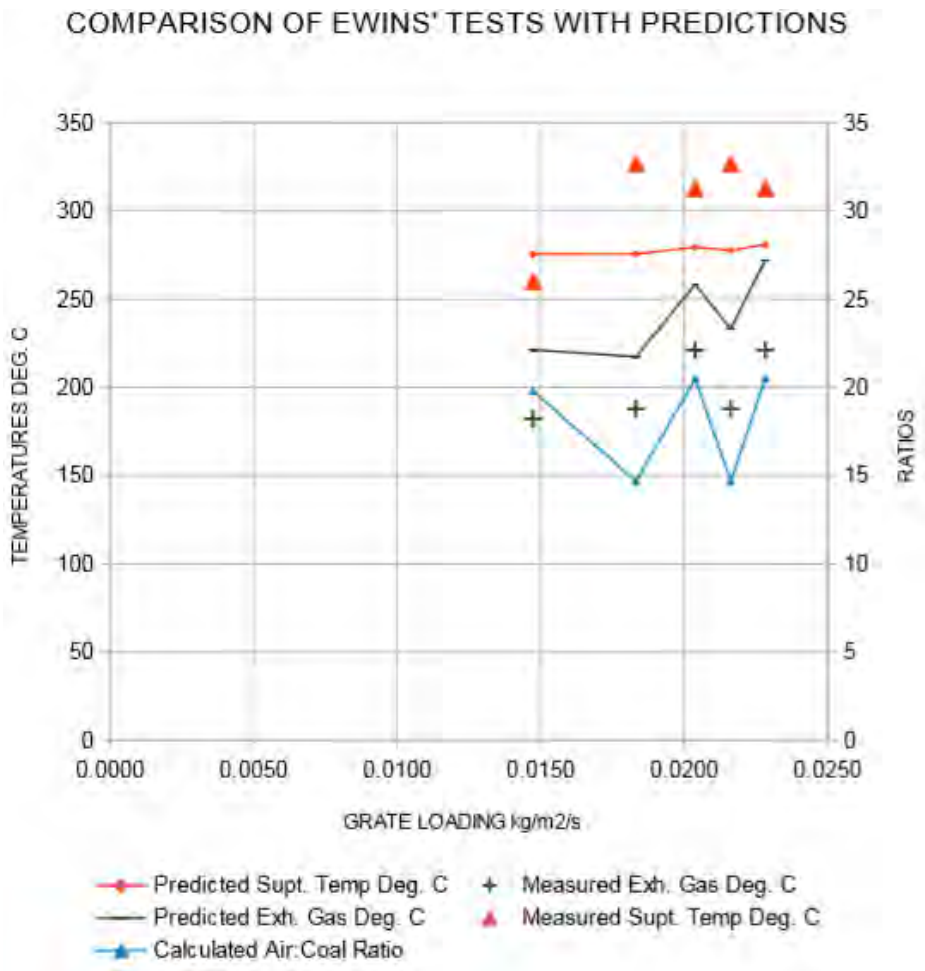


Figure 2 - Comparison Ewins' test results with predictions from program.

Figure 2 shows that Tests 2 & 3 were taken at very similar grate loadings, although the power produced by the engine varied over a 400 % range, confirming that the 5% claimed efficiency of Test 3, is not true and the boiler was not keeping up with steam demand. The air:coal ratio shows a drop from around 20 at low grate loading to 15 at moderate loading, which is consistent with Busbridge's result, but then a sharp increase; This suggest the fire may have had a hole in it, artificially increasing the air ratio.

The superheated steam temperature observed is some 45 to 50 deg. C higher than predicted, while the exhaust gas temperature is some 80 deg. C lower than predicted at the higher grate loading. The actual rate of evaporation cannot be inferred from Ewins' results.

I have also compared the predicted temperature profile in the firetube for Ewins' test No. 2, which appears to be the most reliable set of data. The results are shown in Figure 3, which shows the program predicts temperatures some 175 Deg. C higher than observed at the tube entrance, reducing to 45 Deg. C higher at the tube exit. Firetube exit temperatures observed by Busbridge were also considerably higher than those noted by Ewins.

Ewins' observed fire temperatures are far higher than my predictions (1600 Deg. C against 1150 Deg. C). If the fire were at the temperature Ewins claims the fire would be well beyond white heat. My calculation estimates the fire at yellow to white heat, which seems more logical. The experimental errors associated with measuring temperatures in highly radiant environments have already been noted. Therefore, it seems to me that Ewins' temperature readings must be treated with some suspicion, and consequently so must many of his other conclusions.

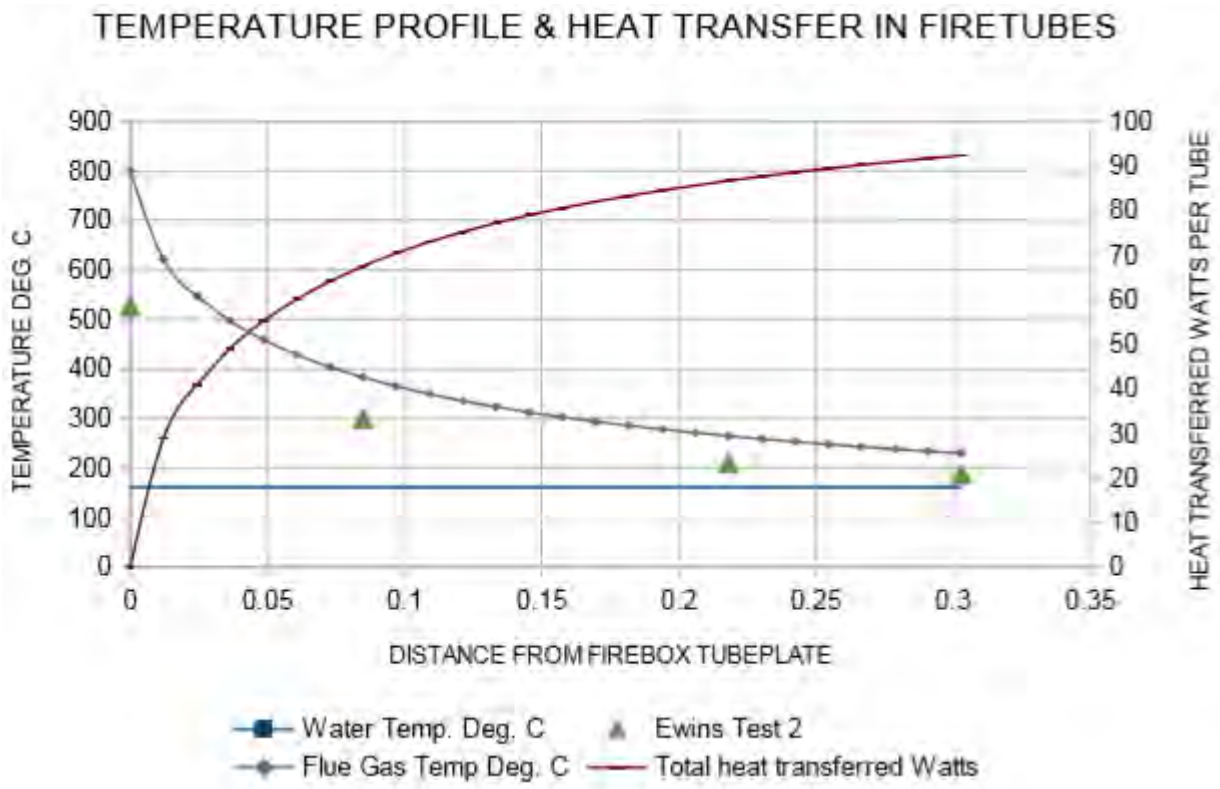


Figure 3 - Comparison of predicted and observed firetube temperature profile from Ewins.

3.3 Full Size Tests

In Ref. 8.4 I found a design chart for the temperature profile in boiler tubes. The chart, originally published in ALCO bulletin 2017, is based on a grate loading of 100 to 115 lbs./sq.ft./hour. Unfortunately, it does not state the relative areas of grate and tube gas flow area. However, I have tried reproducing the chart and have used boiler design details for the GWR Castle class, since I have that data to hand. This is probably not the best choice, since an American test was probably on a wide firebox boiler and certainly not burning best Welsh coal. The results of the comparison are shown in Figure 4, and considering the potential

problems as noted above gives remarkably good agreement. Note particularly that the temperature leaving the firebox is very well predicted.

The flow in boiler tubes for full size loco boilers is turbulent, having a Reynolds numbers in the range 7500 at tube entry to 13000 at tube exit. By comparison, the equivalent numbers in a miniature boiler are typically 500 to 900 which indicate laminar flow. This means there are completely different flow patterns in full size and miniature work, and consequently the heat transfer rates are fundamentally different, which makes any attempt to draw parallels between full size and miniature dangerous; as LBSC said "you can't scale nature"!

To accommodate the difference in flow pattern and heat transfer, the program uses different formulae for heat transfer depending on the Reynolds number, so the comparison in Figure 8 exercises a different part of the program to that used for model comparisons. One of the tasks on my "to do list" is to obtain some of the Rugby and Swindon test plant data now held at York Railway Museum and use this to check and improve that area of the program.

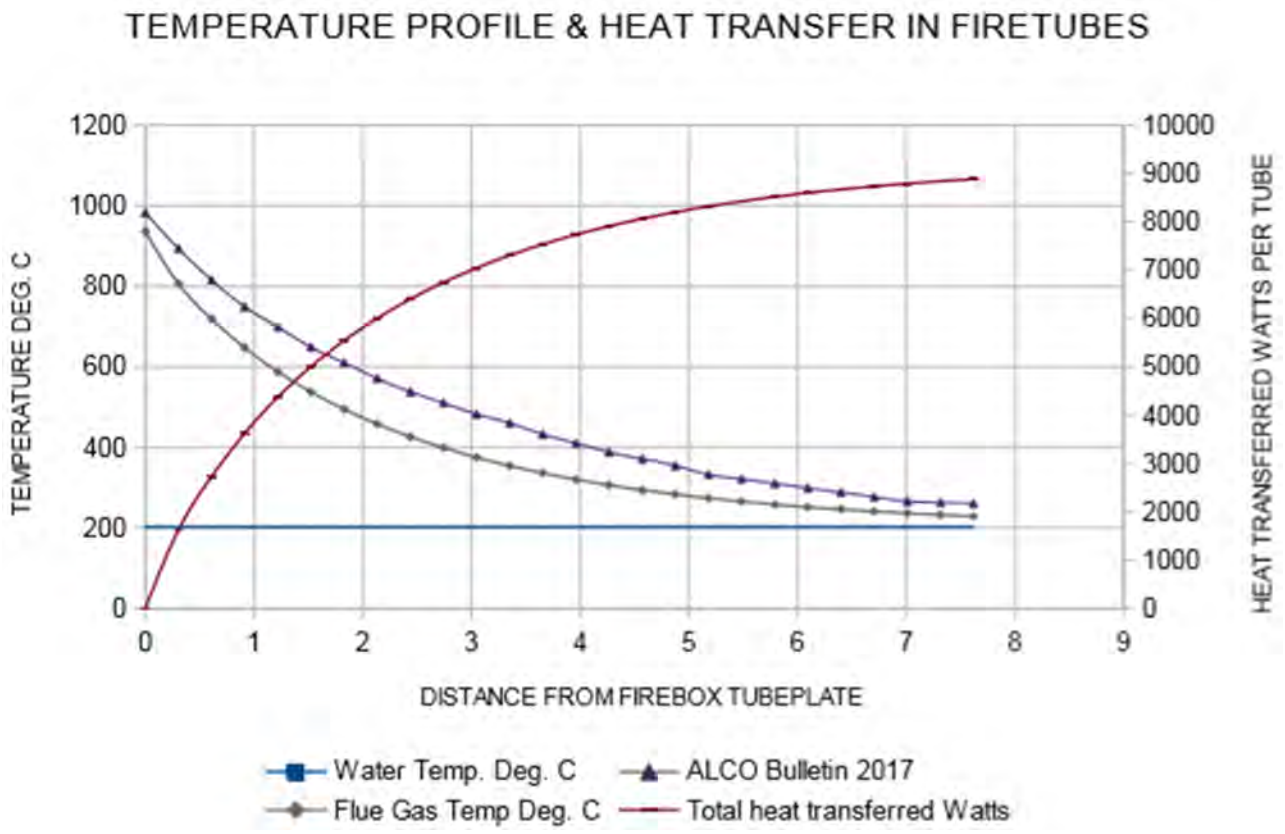


Figure 4 - Comparison of ALCO Bulletin 2017 design values and calculated temperatures

Ref. 8.4 also includes a design figure for evaporation due to firebox walls, which is quoted at 55 lbs evaporation per square foot. The program predicts evaporation of 64 lbs/ sq.ft.; It may be that the design is a conservative value to give some safety margin in design, and there is also the issue of whether my assumptions match the original test boiler.

If anybody can help with a copy of ALCO Bulletin No. 2017, the author would be very pleased to hear from them.

8 REFERENCES

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8.9 http://5at.co.uk/uploads/Bill%20Hall%20software%20and%20papers/Measuring%20Steam%20Engine%20Performance.pdf

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http://5at.co.uk/uploads/Bill%20Hall%20software%20and%20papers/Predicting%20Performance%20-%20the%20Problem%20of%20Condensation.pdf

8.10 Steam, Its Generation and Use by Babcock & Wilcox Company – Chapters "Combustion" and "Analysis of Flue Gases". Can be found at : http://www.gutenberg.org/files/22657/22657-h/22657-h.htm

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8.13 https://www.researchgate.net/publication/43770558_Experimental_methodology_for_characterizing_flame_emissivity_of_small_scale_forest_fires_using_infrared_thermography_techniques

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To be concluded in the next editions…….

Biofuels – ASTT Interests – a Historical Perspective – John Hind

In May 2010, the 5AT Project (out of which ASTT emerged) produced 'The 5AT Project Feasibility Study' which included two appendices written by Brian McCammon (from New Zealand); "Review of Carbon Neutral Fuels with Potential Use in Modern Steam Locomotives" and "Comparison of Greenhouse Gas Emission Footprints for Different Railway Traction Systems".

In the 2009, Brian had guest-edited the New Zealand Solar Action Bulletin No 88 that focused on “New Zealand Rail”, which included articles from Chris Newman and Jamie Keyte, who are now members of the ASTT Committee. At the same time, the 5AT website listed references to Fuels and Emissions (now on AST’s website).

In hindsight, these appendices were ahead of their time given the current concerns about carbon emissions.

The “Review of Carbon Neutral Fuels with Potential Use in Modern Steam Locomotives” came to 22 pages and included commentaries on the solid, liquid and gaseous fuels, that where then available. At that time the only solid fuels commercially available as a carbon neutral alternative to coal were; kiln dried wood chips, wood pellets, and wood briquettes, all of which have lower calorific value and lower densities than coal, which means that a greater volume has to be burnt when compared with coal.

In 2012 torrefied wood became commercially available and the first samples of biocoal started to appear for trials. Both of these have higher calorific values and densities than kiln dried wood chips, wood pellets, and wood briquettes and so were worthy of trials.

In the spring and summer, of 2012 were carried out on compressed wood chips, wood briquettes, torrefied wood and biocoal.

Two trials were carried out at the Stapleford Miniature Railway to understand what was possible with the alternative fuels and then one trial was carried out on the Wells & Walsingham Railway.

The plan was start to start the trials on large miniature locomotives and then provided trials were successful, scale up to narrow gauge, then standard gauge. This strategy also meant that for the early trials we did not need large quantities of the bio-fuels, which in 2012 were in short supply.

Trials were started in April 2012 on the Stapleford Miniature Railway, which is a 10 ¼” gauge with a two-mile track run.

At Stapleford we had sole use of the railway, so we could run as required, without effecting service trains.

The April Stapleford trials experimented with compressed wood chips, wood briquettes and torrefied wood. Biocoal was first tried in June.

Wood chips, wood briquettes and torrified wood were soon discounted because of smoke, spark throwing and inability to maintain steam.





Wood Briquettes





Torrefied Wood

Biocoal showed the most promise, though the product available in 2012, while it came closer to the energy content of coal, was less dense, dusty and could break up on handling.



June 2012 Sample of Biocoal



On the left biocoal, in the middle ovoids, on the right Welsh steam coal



Stapleford test locomotive – Curwen Atlantic



Checking firebed temperature at Stapleford

In July 2012, the trials moved to the Wells and Walsingham Railway, which is a narrow-gauge railway of $10^{1}/_{4}$" gauge with substantially larger engines than the Stapleford engine and an 8-mile round trip on a line with heavy gradients.

The biocoal used for this trial was an improved version of the previous grade with less dust and fines.





Tests on the Wells and Walsingham Railway's Heroine

Three runs on service trains were carried out. The trial provided useful information about the product, some confirmed earlier findings and some were new.

The earlier trials of biocoal at Stapleford gave concerns about fast burning and spark and smoke emissions, but hinted that heat output might be satisfactory. The trial with a larger engine and firebox and a far more rigorous duty cycle confirmed that the heat output was satisfactory.

The major concern was the excessively fast burn rate under high draught conditions, which combined with the lower bulk density of the product made it virtually impossible to build a workable firebed, without constant firing. As a rough estimate the consumption of biocoal was around 4 to 5 times the volume of Welsh Steam coal normally used on this engine.

A steam locomotive can work very effectively with a thin fire provided the fuel is sufficiently dense so that it is not sucked off the firebars. Under light draught biocoal was observed to perform reasonably well and it could be intermittently fired and maintain steam pressure but immediately a higher draught was required then holes appeared immediately in the firebed. Trying the alternative thick bed required constant firing and even then, the bottom of the fire was burning away so quickly that it was not possible to build to a suitable depth.

The view at the time was that if the biocoal could be produced during manufacture with greater compression and hence with greater bulk density and in larger sizes, it would decrease the burn rate and reduce smoke and spark emissions.

Our trials came to end in 2012, as we could not get supplies of an improved product.

In 2017 Richard Coleby carried out a further trial at the Wells and Walsingham Railway using a biocoal produced in the UK and the results were the same as in 2012.

Since our trials, the Coalition for Sustainable Rail (CSR) in the USA have carried out trials during 2016 to 2018 with biocoal in a similar way to ourselves but with still denser product and also starting out on a narrow-gauge railway. Wolf Fengler of the CSR came over to the UK in October 2017 and gave a presentation on the results at the 2017 ASTT Conference.

In October 2019, Wolf came to the 2019 ASTT Conference to give a further update on their 2019 trials at the Everett Railroad in Pennsylvania on a standard gauge locomotive using a denser product, closer to the characteristics of coal.

Our conclusions to date are that biocoal and its use in locomotives is still in the development phase. It may be a viable successor to coal, provided it can come close to the characteristics of coal and can be produced in bulk, to make it a commercially available product, at an economic price.

Dealing with clinker II - Cedric C Lodge.

It's hard to believe it is now three years since my report on dealing with clinker appeared. Since then, my fire irons have proved themselves to be very effective in not only dealing with clinker, but also the sculpting of a fire.

Following some objections to the use of rebar for the shafts of the prototypes, I used smooth bar, and set about making them myself. Perusing the internet, I found Brundles, which makes standard forgings-including rings. So, I got some rings and the other components, and welded them up myself, at considerably reduced cost. I made enough sets for each loco and two spares. Sadly, the initiative did not receive general acceptance: a couple of weeks after I delivered those I made, they all disappeared! Something was amiss. Then one Sunday afternoon, I was contacted by a colleague who told me they were in the long grass behind a storage container. I went and looked, and lo and behold, there they were. I restored them to the usual storage location and said nothing. But a few weeks later, I was on the 'short' turn when we change crews at Dinas around mid- day. It was with a mixture of delight and satisfaction that I saw the relieving fireman coming down the platform with a clinker paddle on his shoulder! Result!

Use of the fire irons has revealed an ignorance on the part of some firemen to the effect of heat on steel. When I was at school, we dabbled with forging, and soon became aware that when steel is heated to red, it is soft and pliable (very). It is a source of mystery and irritation to find clinker paddles contorted into hideous shapes at the business end. They are easily straightened out, but how do they get like that? They must have been left in the fire for a long time. The cutting edge of the paddle can achieve a dull red sometimes, and it is cooled under the injector overflow.

Since then, my fire irons have become an accepted part of a fireman's tools. Victory came last year: I have a penchant for looking in skips containing scrap, and one day I discovered the business end of a 'slice', cut off from its shaft-discarded. So, I retrieved it and now have it as a trophy.



The Trophy - Cedric Lodge

My fire irons were designed for the Garratt locos and I did not regard the small locos. of the Ffestiniog Railway as posing any problems-until the Victorian Weekend last year, when most of them suffered catastrophic amounts of clinker.



Clinker Paddle (small engines) The blade is about the size of a postcard - Cedric Lodge

I made some clinker paddles to the same design as for the Garratts, but smaller, the shafts being 4' 6". But because of the angles at which the paddles must be used on the small engines, they cannot be used to remove clinker from the fire box. I have therefore devised what may be described as a 'clinker spoon', for removing clinker from the fire box. It starts life as a paddle, but the paddle end has tines attached, and the end of the shaft is bent by about 45 deg. I have tried both tools, and am delighted they both performed admirably-so well that I am confident clinker could be dealt with 'on the run' if necessary. The paddle is a great help during disposal, when it is necessary to work the dying embers through the grate.



Clinker spoon - Cedric Lodge

That takes care of the small engines, but what about the double engines?

Access to the fires of the double engines is not good at any time, and lifting clinker from the bars presents a tricky problem; removing it is even more of a problem. Whilst discussing this with a colleague recently, my attention was drawn to a photo of a double engine which had the cab sides on the fireman's side cut down. This would have made firing much easier, and facilitated the use of fire irons to good effect. Although this feature was not widely applied or perpetuated, it does make me wonder if somebody modified the cab side in response to the problems of fire management. It would be worth considering a modification to the cab sides whereby they become removable panels.

Membership – Chris Newman

Membership continues to grow with 3 new members joining since the October newsletter. If all current members renew their membership, this will bring the current total to 84.

Talking of which, **members who have not yet rejoined are reminded that their subscriptions fell due on 1st January**.

Many thanks to all those who set up standing orders which eases my role as Membership Secretary enormously and I would be most grateful if other members would follow suit.

We welcome our three new members as follows:

- **Hielke Hendrikse** from the Netherlands, who is studying for a post-graduate qualification in Mechanical Engineering. He joins us as our 7th Student Member. He has been a volunteer working on loco boiler maintenance with the Rotterdam SSN (Stoom Stichting Nederland) for the last 10 years and is currently training as mainline fireman. He has also been working on an electronic system for generating indicator diagrams on one of SSN's locomotives.
- **Peter Robinson** from the UK.
- **Paul Winstone** from the UK: a Mechanical Engineer in the processing industry; a volunteer on the Talyllyn Railway, and with experience of steam maintenance and operation of 7¼" gauge locomotives.

Summary: The current membership base is distributed as follows:

Full Members:	13 (as before)	UK members:	63
Associate Members:	64	EU:	13
Student Members:	7	USA	3 (as before)
		Australasia:	4
Total Membership:	84	China:	1 (as before)

Upgrading to Full Membership – Chris Newman

The ASTT Committee would like to increase our number of Full Members. We therefore invite (urge) any of our Associate Members who have been regular attendees at our events or who are (or have been) involved in our projects, to apply for full membership.

The main advantage of upgrading is that Full Members are entitled to a vote at general meetings, thereby giving them the opportunity to participate in decision-making and guiding the development of ASTT.

Associate Members who are interested in taking a more active role in the Trust are therefore encouraged to apply for Full Membership by applying to the Membership Secretary at memsec@advanced-steam.org.

Website Updates - Chris Newman

New pages have been added under the “Projects” menu heading covering:

- the **Revolution Project**
- **Loco Performance Monitoring**
- **Biofuel Testing**

A News post has also been added about estimating **Carbon Offsets** for steam operations.

Book Sales – Chris Newman

Book sales since October have seen a significant uptake:

- **5AT Fundamental Design Calculations** (pub. ASTT): 1 sold (total sales 191 since 2015);
- **5AT Feasibility Study** (pub. ASTT): 1 sold (total sales 47 since 2015);
- **Volume 1 of Porta’s Papers – Tribology and Lubrication** (pub. ASTT): 46 sold including 41 to Camden Miniature Steam (total sales 83);
- **Volume 2 of Porta’s Papers – Adhesion, Compounding and the Tornado Proposal** (pub. ASTT): 55 sold including 47 to Camden Miniature Steam (total sales 82);
- **Steam Locomotive Design Specifications and Calculations for New Build Baldwyn 2-4-2T ‘Lyn’** (pub. ASTT): 15 sold including 14 to Camden Miniature Steam (total sales 67);
- **The Red Devil and Other Tales from the Age of Steam** (pub. Camden): 2 sold (total sales 24 + 233 sold previously by 5AT Group);
- **Defence of the MR/LMS Class 4 0-6-0 by Adrian Tester** (pub. Crimson Lake): 1 sold (total sales 17);
- **Introduction to Large-Lap Valves by Adrian Tester** (pub. Crimson Lake): 1 sold (total sales 10)

Members are reminded that they can claim a 20% discount on titles published by ASTT, and 10% on other titles.

