Advanced Steam Traction Trust

ASTT's Autumn 2017 Conference
Abstracts and Introduction of Speakers

Saturday Morning Session – 30th Sept 2017:

10:30 – 11:30 Geoff Turner: "The Clan Project: 21st century manufacturing for a 20th century locomotive"

Geoff Turner I.Eng. M.I.E.D., is the Engineering Director of the Standard Steam Locomotive Company Ltd.

Abstract: not yet available

11:30 – 12:30 Adrian Tester: "The Physiology of the Locomotive Boiler"

Adrian Tester is a retired mechanical engineer whose career included 10 years as an engineer officer in the Merchant Navy and 36 years as a consulting engineer working on, amongst other things, process steam installations. He has enjoyed a lifelong interest in steam locomotives and has worked as a volunteer fireman. He is the author of two technical books (on steam locomotives) that are available through ASTT's website.

Abstract: I am writing a two-volume work on locomotive boilers - the working title being The Physiology of the Locomotive Boiler. It explores the characteristics of the boiler and its response to changes in load in some detail. This is looked at principally but not exclusively from the point of view of heat transfer, since this along with combustion (considered in the second volume) fundamentally define the way it behaves and thereby its characteristics.

While enthusiasts have investigated the engine part of the locomotive in great detail, which has resulted in computer programs such as Perform, I suggest this is not the situation with boilers. In the course of this work a program has been developed which will predict evaporation, steam temperature and barrel resistance from a selected heat input (coal rate x calorific value) based solely on the physical dimensions of the boiler. Tested against Rugby and Swindon results it gives values that are within the accuracy/tolerances of the original data. Furthermore it is simpler and I believe easier to understand in its approach than the one DW used and described in the 5AT calculation book.

For reasons of time and content I suggest it would inappropriate to use the talk to explain how the program works, while in any case it is described in full detail in the book. Conversely, airing some of the effects (large and small) made by changes in boiler design, which the program has revealed, might I think be of interest. For example it confirms quantitatively what I have long believed to have been the case qualitatively, namely aiming for A/S ratios of 400 in the flues and tubes does not result in an optimum design - far from it in some instances.

Saturday Afternoon Session – 30th Sept 2017:

13:15 – 13:45 Tom Kay: "Austerity 90733 Horn Guide and Frame Re-Design"

Tom Kay has been a steam enthusiast since early childhood and at the age of 13 became a founding member of KWVR's Youth Group. He has been a volunteer in the railway's MPD and 3½ years ago took up firing duties on the railway. He recently gained a degree in mechanical engineering from Huddersfield University, for which he spent his third year in industrial placement with Bombardier. His chosen subject for his fourth year dissertation was "Frame distortion and weakness in KVWR's Austerity 2-8-0". Tom is now studying for a Master's degree and in his spare time works with West Coast Rail on its main line and Jacobite services, and with Riley & Sons. He recently experienced a 75 mph run on the footplate of Flying Scotsman.

Abstract: Austerity 2-8-0 locomotive number 90733 was built to aid the war effort. After being sent to the Continent to aid the re-building of the railways it was eventually side-lined and ultimately bought for preservation by the Keighley Worth Valley Railway. After a full overhaul, it ran for a few years until developing rough riding qualities. The wheels were removed for visual inspection and damage was found to have occurred with the axleboxes which act like bearings restraining the axles. Measurements were taken of the horn guide faces which act as vertical guides for the axleboxes, permitting vertical movement.

Due to the KWVR being a volunteer run charity, the expenditure required to repair the damage impacted greatly on the organisations finances, due to it not being part of their planned maintenance schedule.

The purpose of this study is to therefore create a Computer Aided Design (CAD) model of the locomotive frame that will be tested using Finite Element Analysis (FEA) to determine the areas of high stress and deformation within the horn guides and frame of the locomotive.

Modifications will then be designed and tested to determine whether the displacement in the horn guides has reduced and ultimately resulted in a frame design that is structurally enhanced and adequate to cope with operation on the KWVR.

The overall result from this structural modification will mean that the locomotive will be more financially viable to run and cut down on maintenance time ultimately saving unnecessary expenditure.

13:45 – 14:30: William Powell - "Improving small gauge live steam locomotives"

William Powell is a Design & Technology Workshop Technician, he studied Architectural Model-making and completed an apprenticeship in CNC turning. He builds and runs miniature steam locomotives in 2½", 3½" and 5" gauge.

Abstract: A look at the improvements I have applied to my small gauge (2 1/2" - 5" gauge) locomotives. The application of engineering plastics, re drafting to current thinking and rosebud grates for more complete combustion.

One of the biggest, if not the biggest, hurdle to overcome with improving and furthering the steam locomotive (across all sizes and types) is not the cost of the hardware (e.g. Lempor exhausts, engineering plastics for motion bearings, Rosebud grates) or the science/technology. It is the owner/the group of volunteers restoring/maintaining the locomotives that must be convinced to apply the improvements. Small gauge steam can show the possible gains in fuel economy, increase in power output, or reduced maintenance and increased service life. It can also be used as a test bed to reduce the possible uncertainty in applying improvements. With the many circular small gauge tracks (both raised and ground level) across the country, it is far easier

to arrange testing. Yes, there could be scaling issues, or rather 'nature does not scale'; so what works well in the small gauges does not always cross over to the large gauges, and vice versa.

As an example, Rosebud grates were developed in the USA for burning 'brown' coal in the wide fire boxes of standard gauge engines in the 1920s. In its basic form it has been proven to work and miniature steam builders have picked up on this 'old' technology. On a grate 1½" x 2½" you can only use high grade coal; although I have burnt the part-burnt lumps out of a larger engine's dropped fire. The coal used was anthracite. From my use of the rosebud grate in two of my locos, and all that I have read and gleaned from other users of the grates; I now have more questions than answers. If the improvements and technology can be promoted in small gauge and accepted as an integral part of the loco; then resistance from the large-sized locomotive community, due to the Heritage drive of preserved steam (not just railways), can be soften.

Plastic is a new, modern material and has no proven past in the large-size locomotive. The problem with it, is it more for those that like the 'specs' and the designers showing off what the material can do and it will theoretically fit the application. It is a big unknown, and ideas are based on computer modelling. Whilst very good, these can't predict the unpredictable. I have used Peek in my Atlantic for the piston rings and slide valves to good effect, but this couldn't be scaled up to full-sized due to the temperatures and pressures and large sizes used exceeding the materials spec.

14:30 – 15:30: Colin Green – On the latest restoration of Flying Scotsman

Colin Green is employed as workshop manager by Ian Riley & Sons in Bury. He was responsible for much of the recent restoration work on Flying Scotsman and has made presentations about the work to several gatherings, including a recent IMechE meeting.

Abstract: not yet available.

16:00 – 17:00: Joseph Cliffe - "Chapelon and the Advanced Steam Locomotive, or How much superheat is necessary and were steam jackets the missing link?"

Joseph Cliffe a retired consulting engineer. He served an apprenticeship at Doncaster under Edward Thompson before joining Powerjets Ltd. to work on gas turbines where he became acquainted with William Stanier who was then a director of the company.

Abstract: Chapelon found that condensation in the LP cylinders was still occurring despite very high superheat of around 400 C with his transformed pacifics

If one assumes that the benefits of superheating are mainly due to the elimination of condensation by heating the cylinder walls and surfaces, then superheating is an inefficient way of doing this. Rankine theory says that continuing higher temperatures lead to higher efficiencies and this is true on turbine machines, but in practice with reciprocating engines this is very small once condensation is eliminated and any possible gain is due to reduction in leakage because of the higher specific volume and increased viscosity of superheated steam.

The Callender and Nicholson trials in 1896 had shown that leakage formed the larger part the missing quantity, and leakage, was a major problem with early piston valves.

In 1938 Chapelon built a compound 2-12-0 freight engine 160A1 with superheat to the HP and a reheater for the LP cylinders and with steam jackets to all 6 cylinders, with the object of eliminating condensation in low speed freight operation. This it did, but later tests disconnecting first the HP superheater, and then also the reheater, with totally saturated steam, gave some surprising results

In effect without the HP superheater, there was virtually no difference in efficiency and specific heat consumption, and without the reheater, and all saturated steam, the heat consumption penalty was only 6%. This was at a speed of only 60 km/h.

This lead Chapelon to conclude that HP superheat was not necessary on a compound loco, and the complication of reheat to the LP cylinders was also questionable

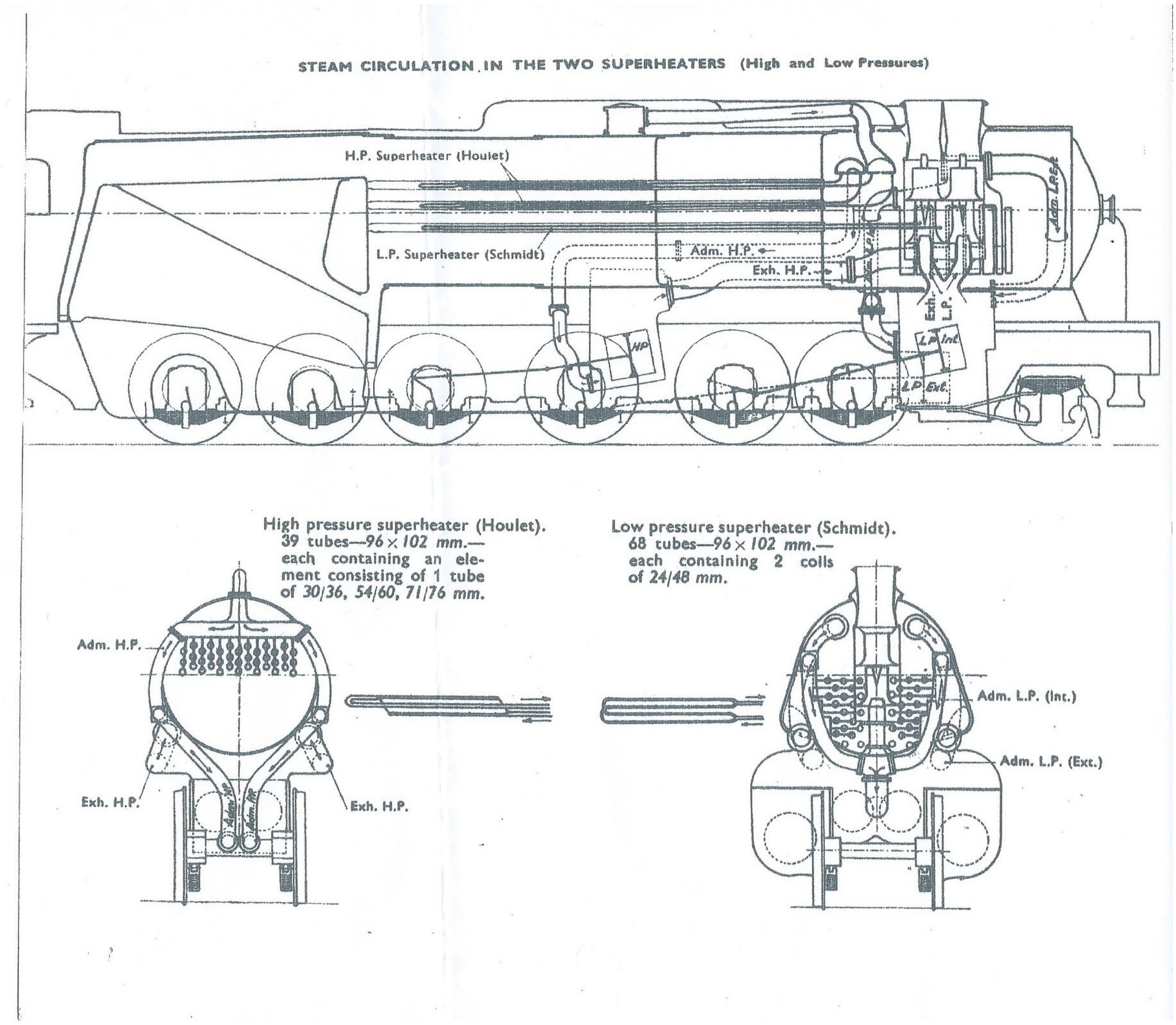
This result was entirely due to the use of straight through steam jackets i.e. the whole steam flow passed through the jackets first, before admission. This latter was the breakthrough compared to earlier steam jacket trials, which had a separate small steam supply to the jackets, and condensation inside the jackets commonly occurred.

Nevertheless the benefits of steam jackets were known by 1905 on stationary and marine engines. However the coming of Schmidt superheating in 1906, with its immediate improvement on locomotives of the time, with an aggressive sales policy by the Schmidt Company, halted any further work on steam jackets

Chapelon showed, too late that an alternative approach to the need for high superheat was possible.

Postscript: I think it is important to publicise Chapelon's final conclusions, coming too late to incorporate in his *Locomotives a Vapeur* in 1952.

Joseph has included the following scanned pages with his abstract:



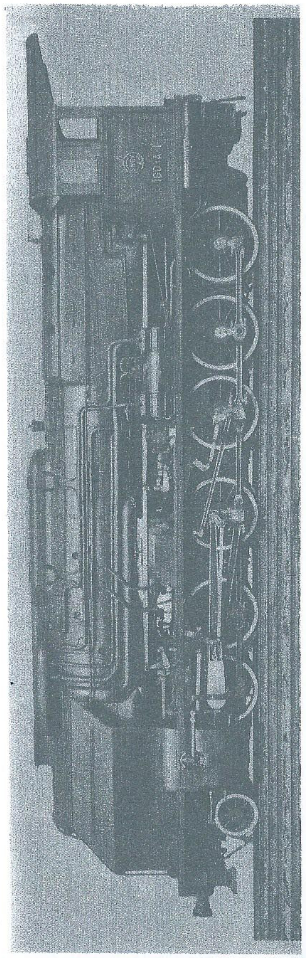


Fig. 198. — 1939-4
160A1, compound
à surchauffe et res

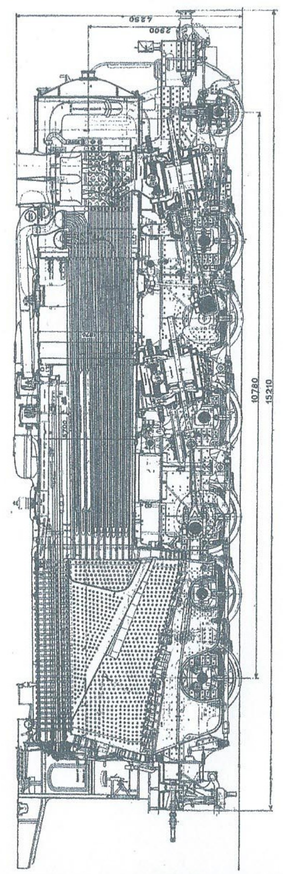


Fig. 199. — Locomotive 16
Coupe longitudinale (A. Ch
lon).

Enseignements fournis par les essais de la locomotive 160 AI. — Les nombreux essais auxquels a été soumise cette machine ont prouvé, d'une part, la parfaite tenue des organes moteurs d'une locomotive polycylindrique contrairement à une opinion couramment admise et malgré qu'il s'agisse de la reconstruction d'une machine ancienne dans laquelle les éléments primitifs ne laissaient pas toute latitude dans l'établissement du nouveau moteur ; d'autre part, des constatations et des enseignements d'ordre thermodynamique très importants ont été enregistrés.

C'est ainsi que pour une locomotive de ce genre, à vitesse faible ou relativement faible et à grands efforts de traction, l'alimentation des cylindres HP, avec de la vapeur saturée, n'a donné lieu, par rapport à l'alimentation des mêmes cylindres avec de la vapeur surchauffée, qu'à une augmentation très faible de la consommmation, ce que l'on peut attribuer à l'efficacité des enveloppes de vapeur sous la forme où elles ont été utilisées ainsi que de l'accroissement du rendement du surchauffeur BP fonctionnant en vapeur saturée.

L'accroissement de consommation en calories par ch/h indiqué n'a varié que de 1,5 % pour 60 km/h à 3 % pour 20 km/h.

Même en marche complète à vapeur saturée, cet accroissement de consommation n'a varié que de 6 % pour 60 km/h à 13 % pour 20 km/h.

Quant à la puissance de la machine, elle ne s'est trouvée réduite en marche complète à vapeur saturée et pour les *mêmes crans de marche* que de 7 % environ, la différence provenant des calories transmises en moins par le surchauffeur.

En conclusion, les essais de la 160 AI ont montré que la machine idéale devrait être une compound admettant de la vapeur saturée dans ses cylindres HP munis d'enveloppes et de la vapeur surchauffée dans ses cylindres BP. On réaliserait ainsi des conditions de marche particulièrement avantageuses au point de vue entretien à cause des faibles températures mises en jeu avec des conditions d'établissement conduisant au minimum de complications tout en sauvegardant le maximum de rendement.

Vitesse	*Cran* HP	BP	*Puissance aux cylindres* Surchauffe HP et BP ou BP seule	Vapeur saturée	S —
km/h	%	%	E	S	E
60	48	32	2600	2375	0,91
40	48	32	2120	1970	0,93
20	48	32	1260	1185	0,94
40	62,5	40	2590	2405	0,93

Les tableaux suivants donnent les dimensions principales de la plupart des machines examinées.

Sunday Morning Session – 1st Oct 2017:

11:45 – 12:30: Jamie Keyte "LNWR "George the Fifth" - Coupling Rod Analysis for the Modern Railway"

Jamie Keyte was a leading member of the 5AT Project and a founder member of ASTT which he now serves as a Committee member. He is professional mechanical engineer and proprietor of the Derbyshire firm of Keyte-Smith Ltd which specialises in compressed air systems. Keyte-Smith also manufactures components for steam locomotives and has built most of the parts so far assembled by the LNWR George V Project.

Abstract: The LNWR George the Fifth Trust is constructing a new locomotive of this class. Designed by Bowen-Cooke, it was first constructed in 1910 and none survived into preservation. The Trust intends to make some modest enhancements to the locomotive performance, and also make changes to the design as dictated by modern safety requirements and construction methods. This will be done sympathetically in order to retain the appearance and - equally importantly - the essence of the original build.

The coupling rod is 10' between centres and is the same as that used on George Whale's less powerful "Precursor" Class of 1904. To understand the loads to which the rod of the new locomotive will be subjected, a full set of load cases have been established. These include not only the transmission of tractive force, but also the effects of rotation at speed and track forces.

The analysis was undertaken using a variety of tools not available to the original designers (e.g. Finite Element Analysis). The analysis highlighted some weaknesses of the original design and, by an iterative process, has allowed a greatly superior design to be established which is compliant with current Group Standards. The analysis has also been used to establish a realistic preventative maintenance / inspection regime. .

Sunday Afternoon Session – 1st Oct 2017:

13:15 – 14:15: Wolfgang Fengler "Preserving Solid Fuel Firing in a Post-Coal World"

Wolf Fengler, MSME is a director and Senior Mechanical Engineer for the Coalition for Sustainable Rail (CSR) Project based in Minnesota in the USA.

Abstract: Economics and environmental concerns are shifting global energy markets away from coal toward natural gas and other technologies. Indeed the last colliery closed in the UK at the end of 2015. Steam operators are already experiencing difficulties in sourcing quality steaming coal at reasonable prices. Preserving the skills associated with solid fuel firing will thus become increasingly difficult for heritage operators. The Coalition for Sustainable Rail, in association with the University of Minnesota - Duluth's Natural Resources Research Institute, is working to stay ahead of this eventuality by developing a direct coal replacement which uses sustainable biomass as its precursor.

Preliminary results and a program are detailed, outlining steps being taken by CSR to perform instrumented testing and refinement of this material. The project is specifically designed to reduce risk associated with development of the fuel by first conducting tests in quarter scale locomotives and then systematically moving toward larger, stoker-fed equipment.

14:15 – 15:00: Mike Horne "An update on steam locomotive instrumentation"

Mike Horne is a retired instrument engineer. He was a leading member of the 5AT Project and a founder member and director of ASTT. He recently stepped down from the position of Secretary in order to devote his time and energies to the development of electronic systems for monitoring steam locomotive performance.

Abstract: In 2013 ASTT was responsible for the design, manufacture and installation of a Lempor exhaust system on KWVR's S160 2-8-0 No 5820. The work was successful and the locomotive owners were happy with the improved steaming that resulted, however the locomotive has been so heavily utilized since the work was done that little quantitative testing has yet been undertaken.

In anticipation of one day being allowed access to fully monitor the performance of the locomotive, ASTT has invested both time and funds in the development of electronic methods for monitoring locomotive performance by measuring (at millisecond time intervals) feed steam temperatures and pressures, cylinder pressures and piston position to enable the production of very accurate indicator diagrams plus exhaust steam temperatures and pressures to enable locomotive power to be calculated. We can also measure smokebox vacuum and firebox vacuums to assess the performance of the locomotive exhaust system and flow through the tubes.

Ian Screeton has kindly allowed ASTT to set up its monitoring equipment on his locomotive "*Badger*" at the Kirklees Light Railway where ASTT's work is ongoing, testing and refining the equipment and methods of measurement. Mike will provide an update on where he has got with the instrumentation and testing work."

15:30 – 16:30: Owen Jordan "Building a Better Boiler"

Owen Jordan gained a degree in architecture before embarking on a career that has included technical and managerial responsibilities covering engineering, financial and supervisory roles. In 1999 he set up his own consultancy focussing on engineering and project management services. In 2010 he became involved with the K3 Project that aims to design a 21st Century steam locomotive. At our Haworth conference in 2016, Owen presented a paper on his the design of a rotary steam engine that he is working on.

The steam locomotive boiler as applied to locomotives in the period 1830 to 1960 followed closely the precepts set out by Robert Stephenson in 1829, the only major change being an increase in output from about 50hp to over 6000hp in the largest locomotives of the 1940's. Locomotive thermal efficiency never rose above about 12% overall, though boiler thermal efficiency rose by degrees to a maximum of about 85%. The key feature of operation was - and remains - the collapse of thermal efficiency as the boiler is forced at speed, leading to considerable design effort to reduce the fire draw by the blastpipe at high outputs, especially at high speed.

In the UK, typical locomotives now in heritage use develop between 500 and 2000hp, though the latter figure is only occasionally reached on the main line; all are coal fired with the exception of some small oil fired units. A typical locomotive boiler thus weighs about 20-30 tons dry and contains perhaps six to ten tons of water at half glass. Firing is by hand, and all operating parameters are manually controlled; water feed, primary and secondary air supplies etc. Only boiler over-pressure control is automatic. Typical useage today is intermittent, a stark contrast to the 1950's regime of six to seven days in continuous steam, followed by a boiler service.

Costs in use are accordingly very high compared to seventy years ago. Standy losses are high, boiler thermal efficiency modest, firing mostly unskilled due to lack of rigour and peak fitness not being made up by determined enthusiasm. Thermal stresses are equally much larger than in times past; thin fires (to save expensive coal) result in foundation ring leaks. Boiler insurance, which is compulsory, means the virtual destruction of a boiler after a relatively short life. In short, life for a 19th century - type boiler in the twenty first century UK rail heritage industry is very hard on the very elderly. A typical boiler might well burn £500 of coal a day and suffer £1000 worth of depreciation at the same time. Boilers out of 'ticket' are the most frequent reason for engines being inoperable.

The concept of a better boiler is not primarily one of a more thermally efficient boiler; halving fuel costs only cuts overall costs by less than 20%. Even the most optimistic designer could not hope for more than a few percentage points in overall thermal efficiency. The collapse of that efficiency at speed is however another matter, one which has a direct bearing on the future of the steam locomotive, which we will consider in due course. A better boiler thus is a cheaper boiler; cheaper to build, cheaper to run in the very different circumstances of the twenty first century, cheaper to maintain, and critically, cheaper to satisfy the inspection regime for insurance by being reduceable to its component parts without damage.

A boiler fit for the twenty first century cannot of course not comply with twenty first century rules and regulations. Steam boilers are still made for stationary plant, and their design is primarily around oil and gas fired vertical multi-tubular units at the small end, and vast complex water tube units in power stations operating at the theoretical temperature limit for steam and the enclosing metals. In between, there is effectively nothing modern in the 1MW class of mobile steam raisers.

With a blank cheque it is possible to do almost anything. Without that magic paper, reality has to bite early and long. There are no industrial plants solely building locomotive boilers, so what is designed has to be doable within the context of plant that is probably doing something else as its prime function. A fully welded - never mind rivetted - pressure vessel twenty five feet long and six feet in diameter made of steel with a couple of thousand components - a unique structure - is not one of them. So fitting the design of the new to the production capacity of the works that will make it is the first essential to keeping cost down. The second is repetition, the third elimination of short run production of individual special components, the fourth the use of standard off-the-shelf components as far as is possible. The end product has to be a compromise of what is needed and what can be built at the right price to do the job.

What you build cannot be designed only to burn coal. It is quite possible that the design process will dictate that it has to burn anything but coal. Like all twenty first century transport it will need to meet emissions regulations for various substances, particularly NOx, particulates and CO2. As one emission will probably be water vapour, using this as an exhaust gas scrubber is an option, and disposal of that will probably not be over the nearest piece of lineside power equipment.

What you build equally must use water, and as this is not readily available, and what is, is of variable quality, you have to use as little as possible and make sure what it leaves behind does as little harm as possible in the most easily maintained space. The use of stage heating - raising the water and steam temperature via a set of compartments whose upper and lower temperature limits are closely defined, and likewise controlling the heat flow between the combustion gases and the working fluid - is an essential. Pumping that water a must. Thermosyphonics is a circulation assistant, not the chief. Combustion control has to be effective, and preheated primary and secondary air supplies look essential. That probably means a combustion chamber separate from the heat exchanger(s), and certainly the end of the blastpipe.

In short, this is a design challenge for the twenty first century, not a tweaking of the products of the 19th. That you might well be able to fit such a unit to a heritage chassis and make it haul trains afterwards, could be a key design requirement, even to the extent that it fits within the cleading of heritage boiler units and is - externally at least - indistinguishable from them.