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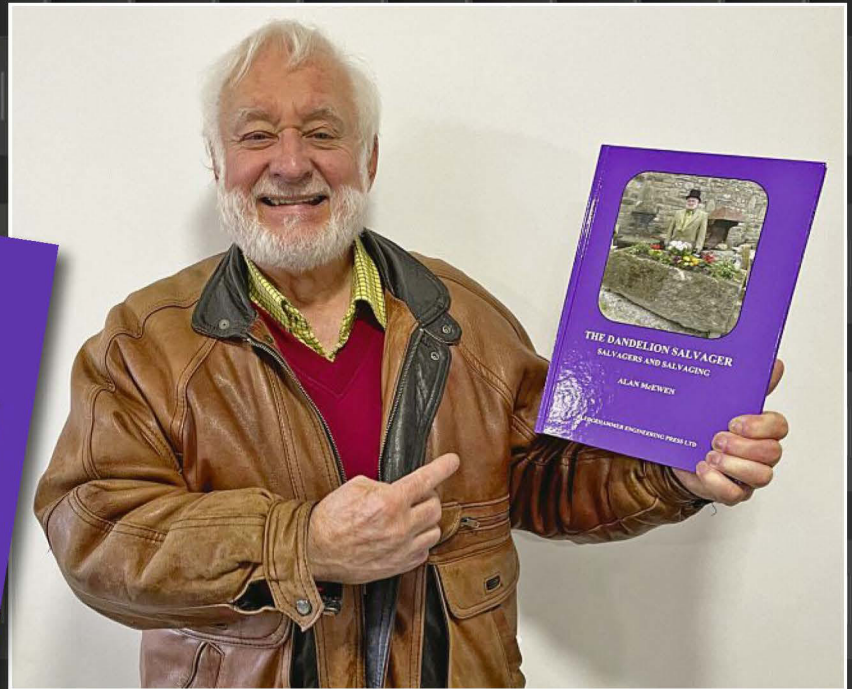
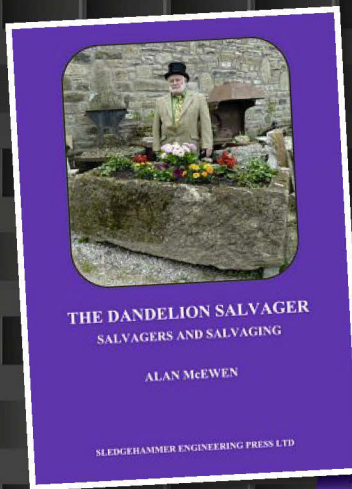


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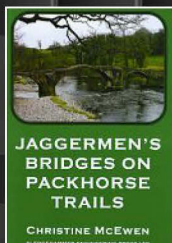
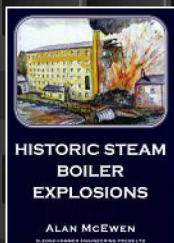
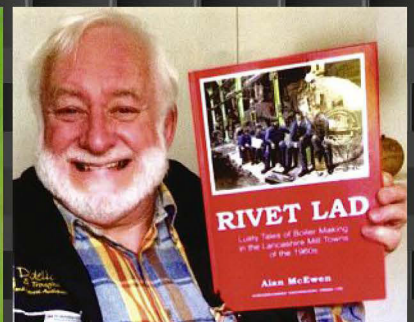
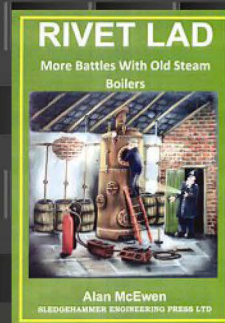
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A Manchester tram circa 1906 seen on the SMEE stand at the Midlands Model Engineering Exhibition (photo John Arrowsmith).

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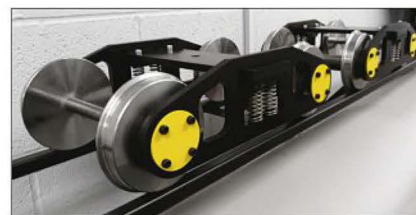
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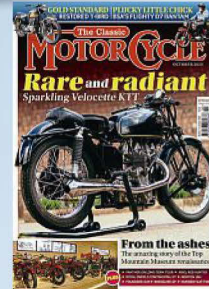
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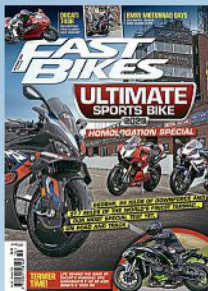
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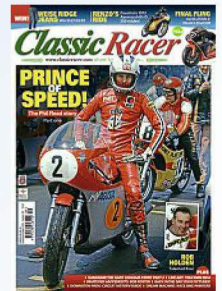
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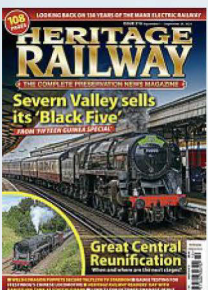
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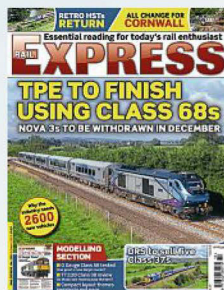
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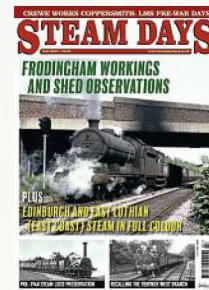
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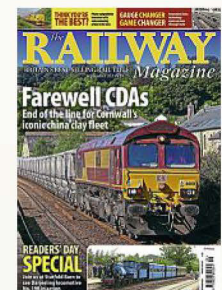
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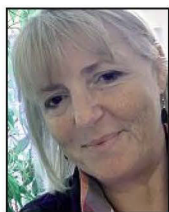
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Traditional Skills

"Well, of course, the old traditional skills are dying out".

How often do we hear that?

Sadly, though, there is much truth in it. There are many reasons for that. Firstly, in our technologically sophisticated world, there is not the same demand for these skills that there once was.

Robotics, computer controlled machinery, 3D printing and other technologies have, in many cases, rendered traditional skills largely redundant. Consequently, companies (with notable exceptions) do not offer apprenticeships to the same extent as they once did, as the profile of their workforce has changed. Secondly, there is undue pressure on young people to go to university, as if this is the only way to 'get on'. This, I believe, has been proved to be false. So many young people end up with pointless degrees and a huge debt that they will probably never pay off. This is not good for them and not good for the country. An apprenticeship, where relevant and valuable skills are learned 'on the job', would in many cases be a far better option.

So – should we let these traditional skills die out? No, I don't think we should. Firstly, for perhaps sentimental reasons, we should cultivate and preserve these old skills simply because they are part of our heritage, just as we do with other products of past ages, and furthermore because, once they're gone, they're gone. Secondly, we never know when these skills may be needed in the future. A need for neglected skills can arise through circumstances beyond our control. For instance, during World War Two, the production of aircraft was augmented by ordinary people exercising their practical skills in 'cottage factories' all over the country, established in sheds, bus depots and garages – even hotels. In this way, for instance, the town of Salisbury alone secretly produced 10% of all the Spitfires ever made.

As model engineers, we play our part in preserving these skills. Although modern methods are (rightly) becoming more widely used, the nature of what we do requires the application of many of these old skills. Moreover, the diverse backgrounds of model engineers ensure that the acquisition of these skills is not the preserve of the 'time served' craftsman. People from all walks of life can learn these skills in order to pursue our very satisfying hobby. In fact, many of our most skilful model engineers have totally unrelated 'day jobs'.

These skills, though, require not only preservation but also promotion. If these skills are worthwhile then, surely, they should be passed on to the younger generation. This should be a priority of model engineering societies. We need to encourage youngsters to join our clubs, make them welcome, and pass on to them the skills we have ourselves acquired. Many clubs are leading the way in this and others should follow, for their own sake because this will ensure the survival not only of our traditional skills but also the survival of the clubs themselves.

Jim Crebbin

If you missed Roger Backhouse's talk about Jim Crebbin at the Midlands Model Engineering Exhibition you will also have missed the film clip of Jim Crebbin driving his Santa Fe Mallet locomotive. In fact, even if you had attended Roger's talk you would have missed it as Roger wasn't able to show the clip at the

time. Roger has now found the clip, which can be found at film.iwmcollections.org.uk/record/4554 and is about 10 minutes long. You will need to be patient, though, as 'Uncle Jim' doesn't appear until after 7 minutes into the film. However, the film is interesting in itself as it shows examples of how peacetime skills were adapted to wartime needs during World War Two – the opposite, perhaps, of the biblical entreaty to 'turn swords into ploughshares'.

Mystery Engine

I have been asked if I can identify the engine shown in the photograph. It is a single cylinder, two-stroke internal combustion engine with a solid flywheel, so probably intended for a boat. It was made by a young lad who died in a motorcycle accident in 1942 at the age of 17. I am told that he made the castings himself – he was clearly a very promising young model engineer. It was made on a Myford ML1 lathe.

So – does this look like a known design of internal combustion engine or is it perhaps an engine of the young man's own design?



Two stroke internal combustion engine made by a young model engineer.



Jim Crebbin

Martin Evans can be contacted on the mobile number or email below and would be delighted to receive your contributions, in the form of items of correspondence, comment or articles.
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The Midlands *Model Engineering Exhibition* *Competition*

**John
Arrowsmith**
reports on
the competition classes.



The main Coventry MES display.

After last year's excellent show, it was perhaps to be expected that participation in the 2023 event may be less simply because many model engineers had not had sufficient time to finish their projects. However, what this year's event lacked in numbers it more than made up by the great quality on show.

There were also two special anniversaries being celebrated which did add quite a lot to the show. **The Society of Model and Experimental Engineers (SMEE)** were celebrating their 125th Anniversary with a great display of current members' work and many items from their archive which have not been seen for many years. The other anniversary was that of **Model Engineer magazine** which was also celebrating 125 years of publication since Percival Marshall started it in 1898. When you consider the vast range of media avenues there how are to disseminate information, it is

some record for a magazine to be still publishing today what it started out doing in 1898. There is a little comment I read, supposedly by Percival Marshall, that he hoped the magazine would help bring young people into engineering as the country needed them. Really - so nothing has changed much in 125 years, because we are still trying to recruit younger people into engineering.

On to this year's exhibition, I think I really ought to start by saying that two of the models

on show were in my opinion worth the entrance money on their own. The LNER P2 locomotive and the Delage 15.S.8 GP motor car engine were outstanding models which caught everyone's attention. There were some excellent club displays with a wide variety of models on show and the mix of traders attending presented a full range of products for consideration.

I mentioned the club stands above and they really are the heart of any exhibition of this type so what better place to start. There is an open competition for the displays which are judged solely by the stand holders themselves. Meridienne have no input to this at all except for giving out the winners' plaques. The competition this year was really good with some excellent presentations on offer. **The Coventry Model Engineering Society** were placed **First** for their comprehensive display (**photo 1**) with the **Hereford Society of Model Engineers** in **Second** place (**photo 2**) and in **Third** place was the **Society of Model and**



The overall display by the Hereford SME.



A smart little Austin 7 chassis under construction at Coventry.



Some of the Young Engineers' work on the Hereford display.



Lovely example of a Manchester tram circa 1906 on the SMEE display.



Terry Mendham using the lathe on the SMEE display.



On the SMEE display was the 100-year old model of a 15 inch howitzer built by Admiral Sir Reginald Bacon.

Experimental Engineers. The range of models on these three displays was really good, providing visitors with such a diverse range of models and equipment. As I said there

was so much to see on these displays that they each could have a report of their own but space precludes that.

On the **Coventry** display was a very nice one third scale

model of an Austin 7 chassis - the radiator is the first attempt (**photo 3**). Like Coventry, **Hereford's** display was also comprehensive, ranging from a 7¼ inch gauge HS 125 locomotive to a diminutive Bell centre punch. The display of work by their Young Engineers was a notable feature, including a 3D printed pattern for a flywheel (**photo 4**). The **SMEE** stand was a veritable feast of excellent model engineering including three of Cherry Hill's prize-winning engines. A couple of other notable models on show were the Manchester Corporation Tram, the original being built in 1903 and modified as shown in the model (**photo 5**) which was built in 1977, totally scratch built and hand painted. The other model was the 100-year old model of a 15 inch howitzer built in

1922 by the then chairman of SMEE Admiral Sir Reginald Bacon. It has been totally refurbished by SMEE member John Clarke (**photo 6**). They also had a Myford lathe set up to show interested visitors the basic knowledge needed to be able to use the lathe. Terry Mendham, as my picture shows, is demonstrating the skills needed (**photo 7**).

The display classes were not as well supported this year so I have mixed them up within the club stand displays to add a bit of variety. However, one display model held centre stage and that was the 10¼ inch gauge model of an LNER P2 locomotive built by John Wilks. This engine was newly completed in 2022 but sadly John passed away in November of that year so this display was a tribute to him. It was the last of five



One of the stars of the show was this 10 1/4 inch gauge model of an LNER P2 class built by John Wilks.



A 10 1/4 inch gauge LNER J11 0-6-0 'Pom Pom' built by Daniel Floyd in three years.



A scratch built 'Jinty' locomotive and driving truck in 7 1/4 inch scale by Tim Coles.

exhibition class models he built in this scale during his lifetime starting in 1963. The locomotive is fitted with Lentz poppet valve gear, a Kylchap exhaust together with an ACF1 feedwater pump and was built entirely from works drawings and original research (**photo 8**). Another 10 1/4 inch gauge locomotive model was that built by Daniel Floyd and this was displayed on the 10 1/4 Gauge Railway Society

stand (**photo 9**). I had a long conversation with Dan and as a young man he is greatly interested in getting younger people into the hobby and that is why he allowed any youngster at the show to climb in his engine and hopefully make that connection. He told me that it took him just three years to build this engine and descriptions of the building techniques, research and details were most impressive.



On the 7 1/4 inch gauge stand was this superb narrow-gauge locomotive FIJI.



The Manning Wardle 2-6-2 tank locomotive, part of the Oxford Society stand.

He even worked out the best relationship for the valve gear positions to always allow the engine to start moving without any 'nudging' or 'slight pushing'.

Continuing with the larger scales, the 7 1/4 Inch Gauge Society had a small but effective display of locomotives. Located on this stand was of course the winner of Class 3 in the competition but the two other engines on display were excellent examples of both standard gauge and narrow-gauge engines. The 0-6-0 Jinty designed and scratch built by Tim Coles, using all his own patterns and castings and finished in the dark blue livery of the Somerset and Dorset Railway, together with a large and impressive driving

truck (**photo 10**), was a great example of excellent model engineer's skill. The other locomotive was FIJI, also on the society display, a fine model which in this scale was an impressive piece of work (**photo 11**).

Moving onto some other club stands, the City of Oxford SME always have an interesting display and this year they had provided a large 7 1/4 inch gauge example of a Manning Wardle Lynton and Barnstable 2-6-2 locomotive LEW with the Southern livery which again was an impressive engine (**photo 12**). In contrast the little 2 inch scale Clayton Steam lorry still under construction looked like it will be a good model when completed. A couple of 7 1/4 inch gauge boiler fittings were showing some fine detail. Past



A fine display by members of the Melton Mowbray MES.



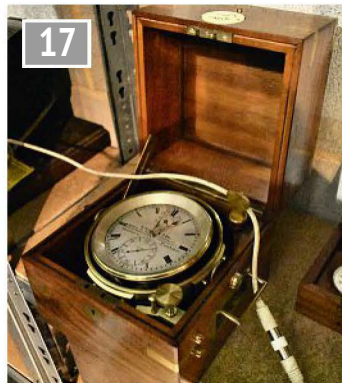
The detailed 'Pug' tender in 7 1/4 inch gauge.



The Melton Mowbray motorised rail bending machine.



In the Clock Shop display by the Milton Keynes Clock Club.



A ship's chronometer displayed in the Clock Shop.



Cutting clock wheels in the Clock Shop.



Part of the Gauge 1 MRA display.

one of their members, which were complemented by an old antique topping tool. In days when measurement was not what it is today this little machine was used to take the top off any gear wheel to ensure a good fit was made to the wheels. A small display of wheel cutting was due to take place on a small dividing set up on a milling machine in the shop (photo 18).

The Gauge 1 Model Railway Association display (photo 19) was a well put together collection of working models (photo 20) and some attractive scale buildings. Many comments were made to me that visitors wished the old large layout could be reinstated, as it was so good to watch. There were some very nice marine craft on club displays and the little Clyde Puffer on the Kingsbury Water Park stand was an excellent example of the

winners of the club shield, the Melton Mowbray MES (photo 13) provided a varied selection of members' models with the little 7 1/4 inch gauge Pug tender an eye catching example (photo 14). The powered rail bending machine was an interesting piece of work (photo 15). Clock making used to be

much more popular than it appears to be today but the Milton Keynes Clock Club had a nice little 'shop' displaying their wares, with some very nice examples on the shelves (photo 16). A ship's chronometer was an excellent example (photo 17) and also a cathedral clock under construction by



The small working shunting yard display by the Gauge 1 MRA.



A delightful Clyde Puffer, part of the Kingsbury Water Park presentation.

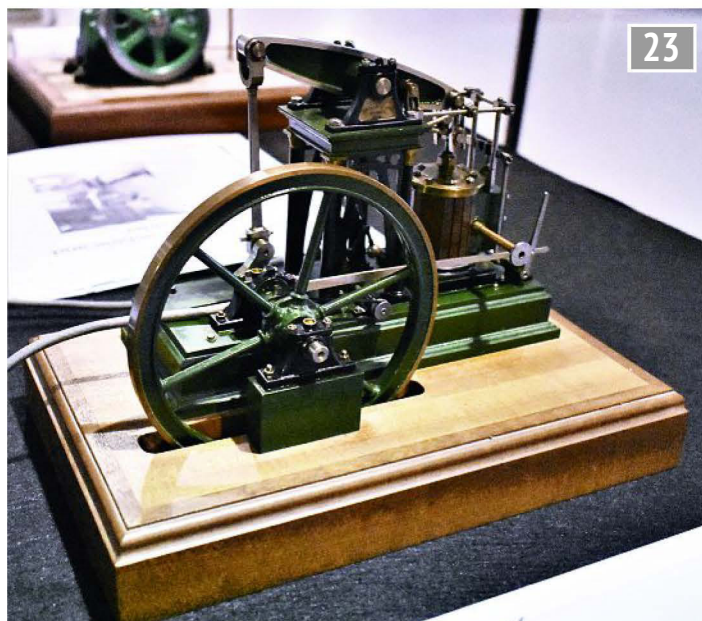


Part of the Knightcote Model Boat Club display.

type (photo 21). The **Knightcote Model Boat club** (photo 22) had a wide range of craft on show which also included a prize winner in Class 10.

The smaller display classes had some excellent work with, for example, a little Stuart No. 4 engine with reversing gear built by John Wing showing how attractive these basic

little engines can be presented. Similarly, the Stothert and Pitt beam engine (photo 23) built by Ian Matthews shows the result of some careful workmanship and finishing. Another fine example of good workmanship and careful finishing was the rare little vertical Sheldon engine shown on the Wolverhampton stand



The Stothert and Pitt beam engine built by Ian Matthews.



A model of a Sheldon tandem compound launch engine built by John Bertinat.

(photo 24). This 'Sheldon' tandem compound launch engine was built by John Bertinat in the mid 1990's to a design by David Piddington. It was taken from an earlier compound launch engine, the Commander, using common castings where possible.

Unfortunately, neither engine is available today but what a splendid piece of work it is.

Well that concludes this part of my report there will be further club displays and activities next time.

●To be continued.

A Five-Inch Gauge 0-4-0 Padarn Railway Tender Locomotive

PART 17

Luker builds a five inch gauge model of a Welsh slate quarry locomotive.



Continued from p.707
M.E.4730 November 17

The cheating!

The right side of the model is as close to scale as can be expected for a working live steam model that needs to pull a ridiculous scale load (me!) at break-neck (scale) speeds. Having just the two crosshead pumps, like the original, was never an option for our track. The old guys like to chat in the station regardless of the queue and who can blame them, I do the same. For my model I substituted the left-hand pump for a live steam injector with a period specific steam valve at the top of the boiler to match. If the locomotive had run into the era when injectors were used, I suspect the configuration might have looked very similar (photo 172). The injector can be any 8-10oz injector with the steam lines to suit. Of course,

anyone that wants to build their own 'perfect' *Fire Queen* only needs to mirror the pump.

The blower valve rod and handle extend past the backhead; this is to make it easier to use with gloves on. The original had the handle behind the back strap which would be difficult to get hold of when in steam.

To the best of my knowledge there was never any pressure gauge fitted to the prototype but one is necessary to run on our public track. It can be easily removed for special display days and is not fitted for any of the model pictures.

The pipework

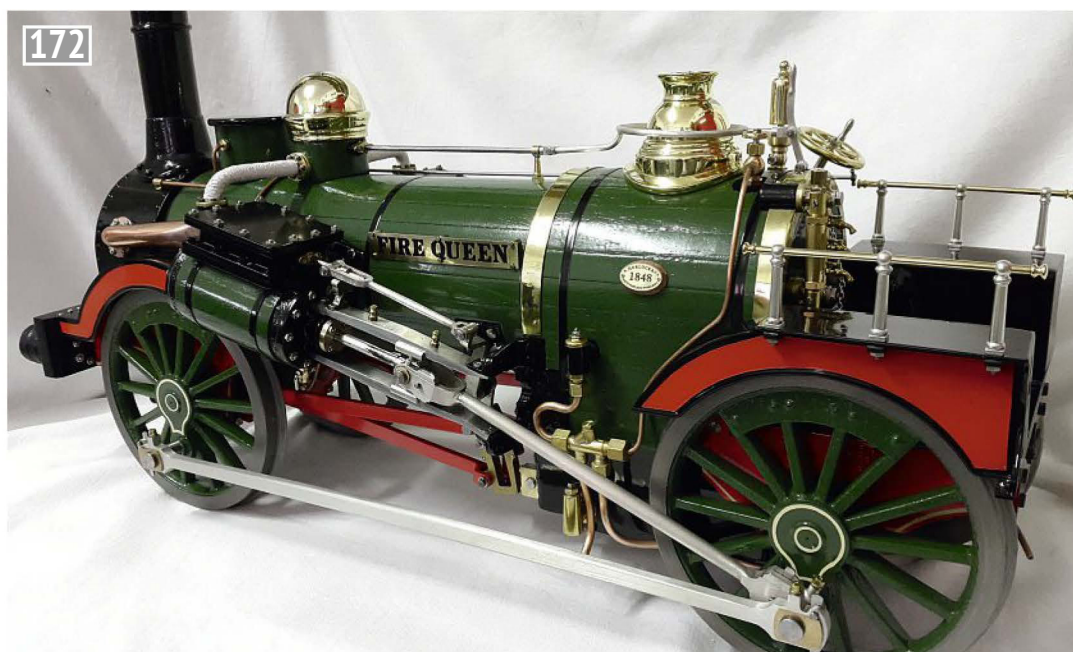
The pipework for the model is principally 2.5mm and 4mm copper lines, for steam and water respectively. I like

to make any lines for the lubricator slightly smaller just to break the monotony of only two sizes but this is not critical.

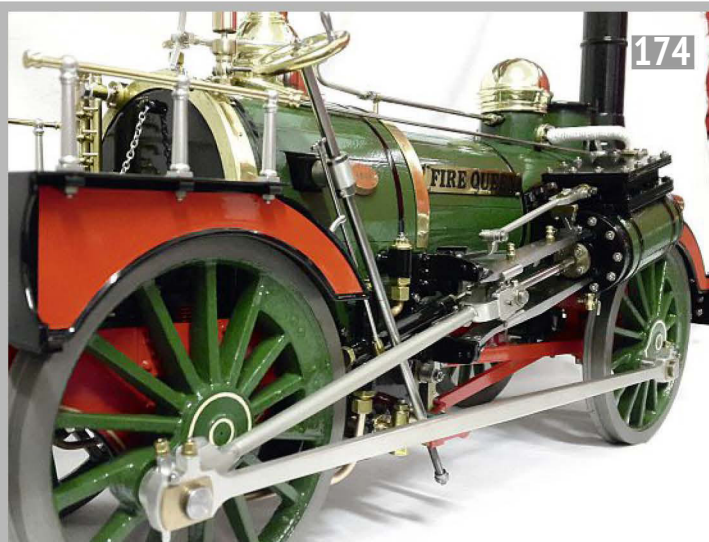
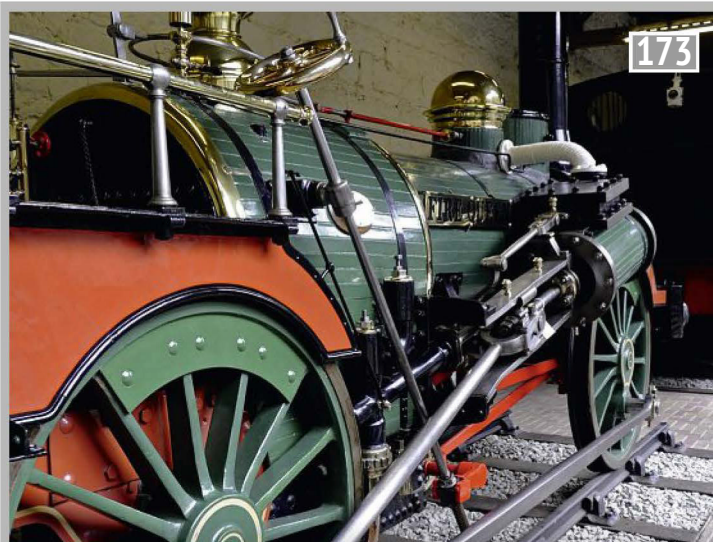
You'll notice that the ferrules and couplings are rather small for the pipework. Commercial nipples, with the shoulder, will not work for the sizes I used. I prefer using nipples with just a point, it makes the pipework closer to scale and you don't end up with oversize nuts. On the down side, you need to make everything but with a turret tool post these little components can be made in the dozens over a weekend.

Notable areas of interest that were challenging

Looking back on the engine build, there were a few assemblies and components that pushed the envelope of my



The cheat side of the Fire Queen. The crosshead pump was replaced with an injector. The corresponding steam valve runs from the top of the boiler, where it can be easily accessed.

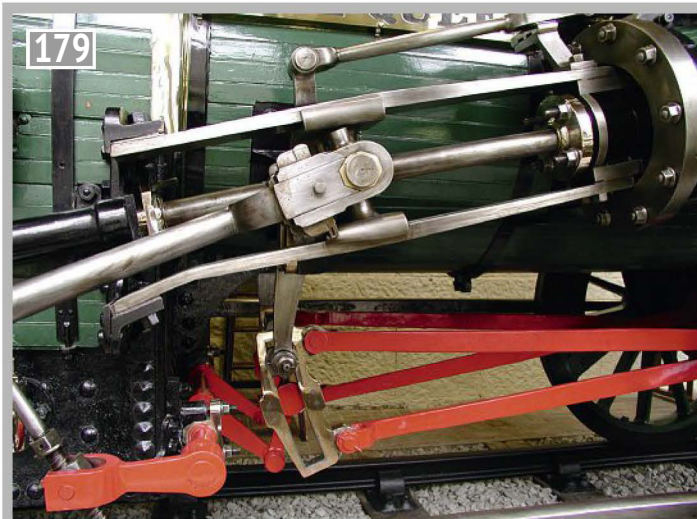


The rear view comparison of the 'Fire Queens'. In the end, the slight thickening of the connecting and coupling rods is barely visible when compared to the real locomotive. I never painted the regulator rod and stand; I felt the model would look better with the red below the boiler only.



The front side view comparison of the locomotives. Here you can see the cylinder end caps were left unpainted. Unfortunately, the model has brass end caps so these were painted black which is less offensive than leaving the golden yellow colour.

One of the trickier items to make, the copper steam exhaust. The real locomotive had the cylinders at slightly different positions which affected the copper exhaust and even the mounting position on the smokebox. The model cylinders were fitted at 14 degrees which is likely what the original builders were aiming for.



The use of gluts and cotters differed between the small end and the big end. This was captured in the model. A noticeable variation of the crosshead is the filed clearance on the large scale at the bottom. In the model I offset the coupling rods slightly so this clearance wasn't necessary and the crosshead was left symmetrical. Other than that, the crosshead is scaled to within one decimal place.



The chain and hook weren't described in the engine series but, essentially, they were made from TIG welding rods by folding them around a purpose built chain making jig. All the links are then soldered closed and the whole assembly blackened using chemical blackening solution.



The copper chimney for the model was cast but the large scale was smithied into shape. The model cap is a light interference fit and can be removed for polishing if required. Unfortunately, I need to keep an eye on it during our open days as copper tends to grow legs.

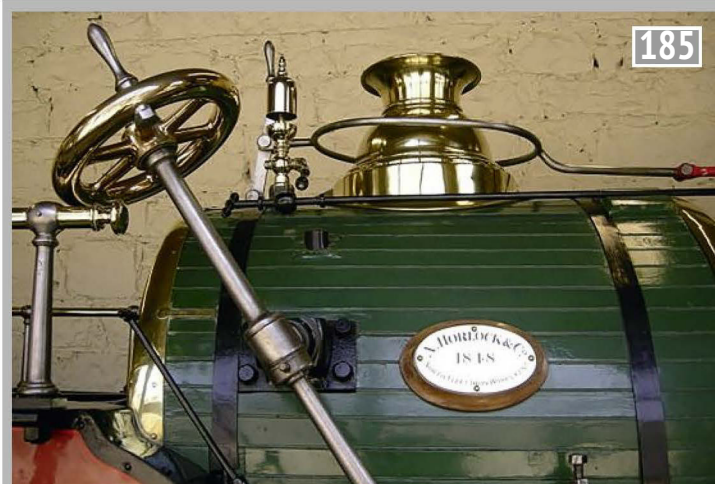
manufacturing capability (in my little workshop). The copper exhausts were rather difficult to make but even more so to fit. In the end, I managed and I think they came out very similar to the prototype. Staying with copper, the copper chimney cap was tricky to cast. Thankfully, a number of castings under the belt helped to solve the inclusion and gas problems I got from the first casting.

One aspect of the build that was recurring was how to take up the manufacturing and assembly tolerances. In the end there were no components, that I can think of, that had

to be radically modified from the given dimensions and drawings. The careful planning when assembling the model played a large part in keeping everything nominal.

Comparing the model to the prototype

So how did the model *Fire Queen* turn out? That is entirely up to the readers and the purveyors of live steam art to decide. Personally, I was very happy with the how my little model turned out. Other than the left-hand side, the model will stand proud as a little working miniature of the majestic



The maker's plate that was laser etched. To give an idea of scale, those two screws are M1.2 glasses or watch screws and the pump handle was made from 2mm TIG welding rod. I made the year slightly larger than the original maker's plate. This was just a personal preference; I felt the original plate was a little sparse between the year and the maker's information. I'm sure the original builders would not take any offense to this! You can also see the difference in the blower handle and pump handle positions.



Then finally, the talking picture of the engine standing proud on its own. In the eternal words of Curly 'nuff said'.

prototype and I hope, if asked, that the original builder would have patted me on the back and said 'well done laddie'!

For this final article in the engine series (tender to follow shortly), I've taken a page from

one of our fine contributors, and filled the space with talking pictures of the prototype and the model. All the large-scale photos are courtesy of Mr. Lander.

Next - the tender - I've

decided to make this a short stand-alone series because the tender was a bought-in item modified to suit the Padarn Railway gauge. It deserves a little more than a brief mention at the end of the engine series...

Reference articles

I try to keep my construction series short, otherwise it does get boring to read and write. Unfortunately, some of the methods and techniques used in the build will be lost, for example, very few of the nuts are standard with most of them opened up and re-tapped in batches, using lantern chucks. The following articles give a little more in-depth information on some of the techniques I used for this build:

- *Making Locomotive Nameplates*, Model Engineer; 225:4650
- *A Humble Tumbler for Polishing*, Model Engineer; 226:4660
- *A Riveting Article*, Model Engineer; 227:4667
- *Zen and the Art of Model Painting and Lining*, Model Engineer; 227:4670, 4672, 4674, 4676
- *Modern Boiler Construction Boiler Construction Methods for the Model Engineer*, Model Engineer; 228:4686 & 4688
- *Backyard foundry techniques*, Model Engineer; 223: 4626, 4627 & 224:4628, 4629 & 226:4662, 4663
- *The Budget Way to go Nuts about Fastener Detail*, Model Engineer; 229:4702

ME

Cutting Fluids

R. Finch shares his researches into this workshop essential.

Introduction

In a recent Monthly Bulletin of Bradford Model Engineering Society ([ref 1](#)), a member had some problems replacing some of his cutting oil when his stocks were running low. He raised quite a few questions about them. He had purchased some 'soluble oil' from a supplier at one of the model engineering shows, only to find that when he mixed it with water, it was not 'soluble' at all! This was despite diluting it correctly by adding the oil to the water and stirring. He was then left with the predicament of just what he should buy - 'soluble oil', a neat cutting oil, a semi-synthetic soluble cutting fluid or a fully synthetic soluble cutting fluid. In the end he opted for the semi-synthetic soluble cutting oil which has proved to be satisfactory.

I have done a little research into the background of cutting fluids, including their history, their purpose and their advantages and disadvantages. The title of this article is 'Cutting Fluids'; this is because some cutting fluids do not contain oils at all, hence industry using the more general term of 'cutting fluids' as a rule. I also carried out an experiment on a 'soluble oil'. About 30 years ago I happened to be working away from home, commissioning a plant for the solvent refining of base oils to make specialist electrical oils and white oils. Whilst on site, I ended up talking with one of the oil technicians about cutting oils in general and he gave me a litre tin of a neat cutting oil and a litre of a 'soluble oil' to try. These were distinctly 'non-branded' types but were prepared as a favour for me. He told me that the neat oil had 'plenty of EP' in it - EP being Extreme Pressure additives to provide adequate lubrication and minimise the

formation of a built-up edge on the tool, which impairs the surface finish. The 'soluble oil' was to be added to water at the rate of something like 5 to 10% by volume to make an emulsified cutting oil. However, after a house move and a change of employment, these two tins of cutting oil remained forgotten under my bench for many years ... until the Society member asked the question about cutting fluids.

Background

In the early days of metalworking, in the nineteenth century, the tool bits were generally made from hardened carbon steel so there needed to be some form of cooling of the tool to prevent its overheating and softening. These early fluids were soda water - a solution of sodium bicarbonate in water. The water cooled the tool bit well, irrespective of whether it acted as a lubricant, and the sodium bicarbonate was used to minimise any acidic corrosion of the lathe bed-ways ([ref 2](#)). Water has an excellent cooling capacity, but has the disadvantages of having a low boiling point and causing rusting of steel items. Later, animal fats were used, particularly 'lard oil', which was separated from rendered pig fat ([ref 3](#)), as this was not corrosive to steel and was a good lubricant. It did, however, have the problem of going rancid, particularly if heated.

Cutting fluids are required to do several tasks:

- * remove heat from the tool and the workpiece
 - * lubricate the tool as it cuts
 - * minimise the formation of a built-up edge
 - * wash away the chips produced
 - * minimise the risk of corrosion of the machine and workpiece
- For amateur machinists in their home workshops, the

generation of heat is fairly low as the components that are being made are generally small, so cuts are relatively small. As the finish required has to be good, some lubrication of the tool is beneficial and preferable to dry cutting. A lubricant can also minimise the formation of a built-up edge on the tool which would mar the surface finish. As the production rate of chips on a lathe is relatively low, the need to wash away the chips is often unnecessary. However, on a milling machine it may be necessary to wash the chips away to prevent their building up and being re-cut by the tool. Finally, as the machine tools are rarely in use on a daily basis, corrosion can be a potential problem with any water-based cutting fluid, so it should not corrode or stain the machine tool.

As mentioned, I had not used the soluble oil for over thirty years. I retrieved it from under my bench and decided to try mixing it with water. Adding 14ml of the oil to 186ml of water would give a concentration of 7% v/v - about half way between the limits that the oil technician had suggested. I added it to some cold tap-water with simple stirring and this dispersed the oil almost immediately, resulting in it looking as in [photo 1](#). I have not yet tried its effectiveness as a cutting fluid on the lathe. After four weeks it still looked the same, so it was obviously stable. From this I concluded that the oil which did not disperse - that had been supplied to our member - was not a soluble oil at all!

Requirements

With regard to the use of cutting fluids, they have to provide the following, according to Hayes ([ref 4](#)):

- * a high specific heat to aid cooling



The 30 year old soluble oil mixed well!

- * good wetting characteristics for maximum contact with the work and tool surfaces
- * an appropriate viscosity for the application
- * high level of oiliness for efficient lubrication
- * high film strength to take the cutting pressure.

Once high speed steel tools became available it became apparent that as the tool would not be softened as easily as a plain carbon steel tool would be, lubricating the tool became the major requirement in the production of a good surface finish. Plain mineral oils have good lubricating properties but have limited heat-removal capacity due to their low specific heat. Consequently, the best of both worlds would be to have an emulsified oil-in-water suspension - with the water providing the cooling and the oil the lubrication. The use of emulsions became widespread and most cutting fluids were of this form.

However, it is clear that all these required properties cannot be met by any one fluid. Oils have a specific heat of around half of that of water, so are less effective at removing heat. Water has very poor lubricity. Therefore a compromise has to be used and this leaves three types of water-based cutting fluids and one neat mineral oil based fluid:

- * soluble oils (commonly known as 'suds' in the UK)
- * semi-synthetic cutting fluids
- * synthetic cutting fluids
- * neat cutting oil.

Soluble oils

The earliest type of soluble oil used a soap solution to emulsify the oil - hence the name 'suds'. When oil is dispersed in water as a soluble oil, the mixture has a high specific heat as it is mostly water and therefore the cooling is very good. However, as the oil is dispersed as fine droplets, it can be difficult for it to adequately lubricate the tip of the tool so additives have to be used to make the oil more able to 'wet' the tool and the workpiece. Suitable additives can reduce the propensity to

form a built-up edge on the tool tip, thus giving a better finish.

The main problem with 'suds' is that because it consists of water, mineral oil and an emulsifying agent, anaerobic bacteria can grow within the coolant and degrade the oil so that it becomes rancid and smells - particularly if left for a few days between use. This anaerobic activity produces what is known in industry as 'Monday morning' smell, usually occurring after a weekend of no activity. However, if used frequently, the coolant is repeatedly aerated and the anaerobic bacterial activity is reduced. Avoidance of a layer of lubricating oil on the surface of the cutting fluid in its reservoir will minimise the exclusion of air and anaerobic activity. Also, there is the potential for rusting and staining of the machine tool and workpiece from the water. To overcome this, there are additives used to minimise the growth of bacteria and to minimise corrosion. Consequently, for an infrequently used machine tool, soluble oils may not be the best choice due to these limitations of corrosion and bacterial growth.

In the average amateur workshop, there can be the need to finish the work within a specified tolerance so very fine finishing cuts may need to be taken. According to Cleeve (ref 5), when taking small (half thou) cuts whilst using a soluble oil cutting fluid, the tool will often fail to cut whereas, if the component is cleaned and a neat cutting oil used, the same tool will take half thou cuts without a problem. He thought it was due to a 'water surface skin' forming between the tool and the work, which was probably due to the cutting fluid not wetting the workpiece fully.

Semi-synthetic fluids

As there were clearly disadvantages to the use of soluble oils, newer products were developed which were designed to reduce or minimise the problems with soluble oils. As the lubricity of mineral oil is not as good when dispersed

in water, certain additives are used to promote the 'wetting' of the workpiece and the tool by the oil, to minimise the potential for corrosion of the workpiece and to minimise the growth of bacteria in the water. These are synthetic additives to the mineral oil and hence the cutting fluid becomes a 'semi-synthetic' cutting fluid as it still contains mineral oil. These have good cooling properties as they are water based, but still have the potential for some staining and corrosion to occur on the machine and the tool. They can also still suffer from the 'Monday morning' problem unless they are used fairly regularly to aerate the emulsion, or mixed in small quantities when required and just applied to the job by a brush.

Synthetic cutting fluids

The disadvantages of the semi-synthetic cutting fluids led to the development of fully synthetic cutting fluids which are water-based but do not contain any mineral oils at all (ref 6). The lubricity is achieved by the use of polyethylene glycols and they also contain corrosion inhibitors. They are completely soluble in water and form a clear solution. In that way, they offer superior performance but are extremely expensive. There is a further problem in that they can become contaminated by lubricating oil which seeps out of the machine tool bearings. This requires some form of separator to skim the oil off the surface and one made for a home workshop was described by John Pace, who also gives more insight into the problem (ref 7).

Neat cutting oils

The final type is the neat cutting oil. This is a mineral-based oil with extreme pressure additives to minimise a built-up edge forming. The advantage of this is that being non-aqueous, it can be used infrequently and will not stain or rust the machine tool or the workpiece. However, there are, as usual, two sides to the coin. If the oil is of low viscosity, it will be able to flow

into the gap between the tool and the workpiece leading to adequate lubrication and a good enough flow-rate to wash the chips away. However if it has too low a viscosity it will tend to have a low boiling point, so may form vapours as it is heated by the cutting action. It can also have the undesirable effect of being flung off the workpiece and therefore may require some form of splash shield to avoid the oil ending up everywhere. In contrast, if it is viscous, it will provide better lubrication and, as it will form a thicker layer on the workpiece, it will remove the heat quite well providing the heat generation is not too great. It can also act as a damper for vibration giving a better finish. Also, it may well be able to provide a higher film strength so the oil film will not break down and will reduce the tendency to form a built-up edge on the tool (ref 4). It may not be able to wash the chips away as well as a low viscosity oil.

Applying cutting fluids

There are three main ways of using a cutting fluid:

- * direct application by brush as needed on a lathe
- * rip feed from a reservoir, on a lathe or milling machine
- * pumped feed to give flood coverage on a lathe or milling machine.

Direct application using a brush is the most economical and least messy way of using a cutting fluid but care is needed if trying to do this on a milling machine as the brush can get caught up in the milling cutter and can make the chips adhere to one another, resulting in a poor finish as the chips are re-cut by the cutter. On a lathe, a brush is less likely to be caught by the work or the tool. However it can have the problem of inadequate, uneven or excessive application.

Using a drip feed is also quite economical and does not require constant attention whilst turning as it can have the drip feed pipe fastened to the lathe carriage to allow it to move along with the tool as the cut is taken. For a milling cutter, the drip fed cutting fluid

may well end up simply making the small chips stick together and obstruct the cutter by re-cutting all the chips previously made. Consequently, drip feed is best used only on a lathe.

A pumped feed is the method typically used in industry, but can be rather messy as the fluid may be splashed about, requiring adequate screens or shields. If there is a large flow, the chips can easily be washed away by the fluid so this is ideal for milling operations. Similarly, a large flow will also provide better heat removal. However, most coolant pumps available to the home workshop user tend to be solely for pumping aqueous-based coolants, so cannot be used for neat cutting oil as it is too viscous and liable to overload the pump motor.

Which is best?

There is a proliferation of cutting fluids available and so the particular choice of any fluid and the method of application can be bewildering. For industrial use where tool-life and production rates are critical, there is very specific guidance offered by some sources, such as *Machinery's Handbook* (ref 8), whereas other sources just give very simple general guidance (refs 9 and 10). A very comprehensive review of the selection of cutting fluids for industry is given by Mamidi & Xavier (ref 11), which includes all manner of fluids and workpiece materials.

In the case of the typical home workshop, production rates and tool life are not really the main considerations. The main criterion is surface finish. In practice, it would seem that for our workshops, there isn't really a 'best' cutting fluid to use. The main governing factors are what equipment you have to deliver the cutting fluid and your own preferences. For turning where the application of the fluid is by brush or drip feed, then either a neat cutting oil or a semi-synthetic cutting fluid is probably a good choice. With the semi-synthetic cutting fluid, it can be prepared in small quantities so that it is not left

for long periods for anaerobic activity to occur.

In the case of having a coolant pump of a standard low-cost design (a centrifugal pump driven by a small 2900 rpm motor), it would reduce the choice, essentially, to water-based cutting fluids as these have a lower, almost water-like viscosity. In this case, as recommended by John Pace (ref 7), the cutting fluid should be mixed regularly to aerate the emulsion and minimise the risk of anaerobic activity and the resultant smell.

Where milling is undertaken, if using a pumped supply, it is most desirable to use a flow of coolant so as to wash the chips away to prevent their being re-cut by adhering to each other. This may require guards or screens to catch the cutting fluid as it may well be flung about by the speed of the cutter. Again, a semi-synthetic fluid is preferable to minimise any anaerobic activity. If the milling machine is used pretty well every day, then 'suds' of soluble oil can be used, but it may be necessary to wipe the milling machine down after use and recirculate 'suds' periodically to minimise the 'Monday morning' smell occurring.

Having discussed my findings with our member, he decided to buy some semi-synthetic cutting fluid (Cutsol Ultra K2 - usual disclaimer) which he applied with a brush and reports that '... so far the results appear good,

it mixes easily, there's no evidence of separation over time, it produces a noticeable improvement in finish when used and there's no evidence of staining or rusting ...'.

Health and safety

There is, of course, the inevitable warning needed about using these cutting fluids. As almost all oils have a damaging effect on the skin, the skin must be protected from direct contact. Although the 'soluble oil' or 'suds' and the semi-synthetic and synthetic cutting fluids are diluted with water, there is still the potential for dermatitis to occur, particularly where there are bacteria present in the fluid. The best advice, therefore, is to keep the fluids off the skin and wash your hands after using them. I use disposable nitrile rubber gloves (usual disclaimer) as a barrier to minimise contact between the cutting fluid and the skin. Further guidance is available in a Health & Safety Executive publication INDG365, *Working safely with metalworking fluids; A guide for employees* (ref 12).

Conclusions

It would seem that the best cutting fluids for amateur use would be either a neat cutting oil or a semi-synthetic soluble cutting fluid.

Soluble cutting fluids should be diluted by adding them to the water with stirring to ensure that they disperse properly.

When turning, application by brush, by drip feed or by flood coverage is practical if care is taken to minimise splashing. If using brush or drip feed with a soluble coolant, then only prepare small quantities to minimise the risk of anaerobic activity.

When milling, brush or drip application is best avoided due to the chips being stuck together by the cutting fluid and being re-cut by the cutter. A flood application should be considered.

Where mineral oil-based soluble oils are used in a pumped system, it may be necessary to recirculate the fluid regularly and avoid lubricating oil accumulating on the surface to minimise the risk of anaerobic activity occurring.

Most low cost coolant pumping systems will not be able to pump a neat cutting fluid as the viscosity is too high.

The use of water-based fluids may induce some staining or rusting of the machine tool or workpiece.

Use suitable protective measures to minimise contact between cutting fluids and the skin.

Acknowledgement

I am grateful to our member of Bradford Model Engineering Society for his helpful comments and suggestions after reviewing this article.

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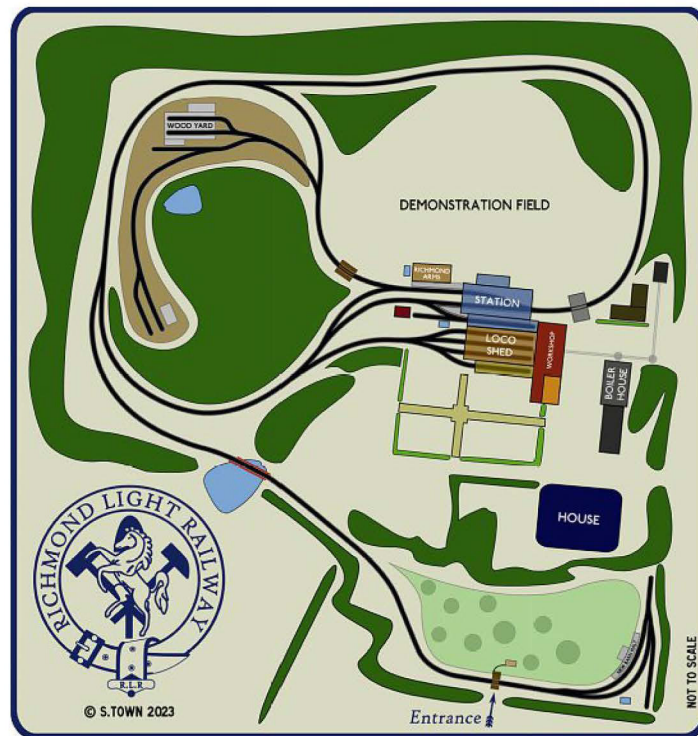
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The Richmond Light Railway – A Kentish Treasure

PART 1

Mark Smithers visits a two foot gauge railway in Kent.



Map of the Richmond Light Railway

Situated in rural Kent, roughly halfway between Staplehurst and Headcorn, is a 2 foot gauge railway 'gem' that is normally only opened to the public once a year. This is for the Annual Charity Gala which normally takes place on the second Saturday in August. The story of the railway goes back to April 2007 when Richmond Farm, which had hitherto been used as a piggery, was acquired by Jeremy and Jenny Martin.

Jeremy had always been interested in railways having

grown up with his father's 7¼ inch gauge railway (Wayside Light Railway) but for him 2 foot gauge was always the real attraction. He likes the history associated with each engine, be it in working on the light railways of WW1 or hauling timber trains in South America. He works in the mining industry and as a result has travelled around the world and has been able to bring back engines from lots of different countries, often finding them in their original working location. A highlight was finding a Couillet 0-4-0T in Lima, Peru.

The other real driver for Jeremy's enthusiasm is the restoration work. At Richmond the aim is to restore the engines to as high a standard as possible and as close to the as built condition. He had already decided that he wanted to lay a 2 foot gauge railway on the site but, before this could be done, extensive renovations and modifications were required to the house and other buildings on the site. Thoughts could only turn to construction of the railway after the end of 2008 once the bulk of this work had been carried out.

A fledgling team was formed, and the initial task was to demolish the old pig sties and level the ground for the construction of a locomotive shed. Erection of the new shed commenced in December 2010 and it was ready to receive its first items of rolling stock in April 2011. By the following month, track had been laid in the yard area in front of the shed and connected to the main line, allowing the first item of motive power, Motor Rail Diesel-mechanical 20HP locomotive W/N 7403, to enter the site. Throughout the remainder of 2011, work continued laying down the main line and the construction of a workshop directly in front of the locomotive shed.

The first steam locomotive arrived in June 2011. Matters were not totally plain sailing, however, as in January 2012,



Having just crossed the bridge on the branch line from New Barn Halt, Couillet 0-4-0T Chuquitanta is seen in this view entering the curve that will take it on to the main loop. The quaint outlines of this tiny but historic locomotive are very evident from this photograph. These are the short wheelbase, outside frames, tanks supported by brackets projecting upwards from the frames, dome with Salter safety valves and external regulator and steam pipes, Walschaerts valve gear and simple canopy. An important survival!



In this view, Chuquitanta is rounding the curve on the approach line to the main circuit. As can be seen from the illustration, the train is a mixed one with the ex-R.N.A.D. wagon visible in its entirety, along with part of an ex-Lydd 'Hudson' conversion.



In this illustration Chuquitanta is on the main circuit with the approach line seen in the background. The crew are well posed for the photograph and the train will soon pull into the station area where the locomotive will 'run round' its train.



Rebuilt ex-Penrhyn 'Small Quarry' class 0-4-0ST Elin is seen here moving empty stock into position at Richmond Station. The stock consists of the restored ex-R.A.F. Fauld ammunition wagon and the Decauville and Penrhyn-pattern carriages. and the non-original pattern boiler and saddle tank on Elin are evident in this view, although the smokebox wingplates and rear frame extension have now been dispensed with.



Elin is seen here on the branch line's main curve heading towards the bridge and New Barn Halt. Part of the 'Prince Philip' bogie carriage can be seen in this view.

following complaints, it was realised that the whole project required planning permission. Work was then paused for eight months for this process to be successfully completed. By the end of 2012, the railway amounted to a circuit of track, the yard and station area and a running line of approximately two thirds of a mile. Further refinements followed with a passing loop being added at Richmond Station in 2013, a pit and a water tower during the following year and a Southernmost branch line extension with a new terminus, New Barn Halt, in 2015. This latter feature incorporates a bridge which is a popular spot for photographers.

Steam Locomotives

Before giving details of the locomotives of the R.L.R. it should be stressed that Jeremy takes great pride in his dedicated team and takes much pleasure in having a bit of fun with a group of people who all share the same passion.

The first steam locomotive arrived on the railway in June 2011. This is Arnold Jung 0-4-0WT W/N 3175 of 1921 which when it arrived bore the name *Howard* but was soon renamed *Jenny*. This locomotive is a representative of the German 'short wheelbase inside framed well-tank' school of design that was built in numerous quantities and variations from the latter part of the nineteenth century and well into the twentieth, having been well represented on the R.L.R. during its period of operation. *Jenny* has proved to be a stalwart at the annual charity Galas and was very much in evidence during the 2023 event. The locomotive also visited the Ffestiniog Railway during its A.G.M. Weekend of 29th April - 1st May 2023 along with Orenstein & Koppel 0-4-0WT *Eigau* (W/N 5668) from the Bredgar & Wormshill Light Railway. This latter locomotive visited the R.L.R. for the 2019 Charity Gala along with Beamish Museum's Lewin-



Elin can be seen here approaching the branch line towards the bridge and New Barn Halt. Once again, part of the 'Prince Philip' bogie carriage is in view.



With Richmond station in the background, Elin is seen on an open mixed working on the main loop - a chance to demonstrate two of the smaller passenger vehicles in action and to show off the fine restoration work on the R.A.F. Fauld munitions wagon. Its handbrake column, 'D' platform, bottom-hinged dropsides (with associated uppermost securing catches) and seven vertical dropside timbers, four of which are rebated to take strengthening irons, are well evident in this view.

pattern 0-4-0WTG Samson constructed between 2012 and 2016.

Three other representatives of this school of design have seen service on the R.L.R. only to depart for pastures new. The first to be considered was Orenstein & Koppel 0-4-0WT W/N 3136 of 1908. Whilst on the R.L.R. it carried the name Susan. This locomotive took part in the August Charity Galas for 2017 and 2018 but departed the line shortly after the latter, in exchange for Bagnall 0-4-0ST Pixie (to be described). Arnold Jung 0-4-0WT W/N 2569 of 1918 Anne-Marie was an early arrival on the line in 2011 and, after a seven-year stint, left for the Czech Republic in 2018. In early 2021, Schwartzkopf W/N 9124 of 1927 Bronhilde (built for the Hamburg Copper Works in Germany) formerly with

Bressingham and the Bredgar & Wormshill Light Railway was acquired by the R.L.R. but its stay was a short one as it

departed, again for the Czech Republic, in the early part of 2023. A fifth representative of this German school of design, Orenstein & Koppel W/N 5745 of 1912, was acquired more recently. This 0-4-0WT was originally supplied by the Berlin-based manufacturer to the Argentine Ministry of Public Works (Irrigation Department) in the Rio Negro province of the country but it was eventually returned to Germany for static preservation in 2005. Identified as available by the R.L.R. in November 2022, negotiations proved successful, and the locomotive arrived during the following month. The locomotive is currently dismantled for overhaul.

The next steam locomotive to be considered is probably the most interesting from the historical point of view, as it is the oldest currently on the railway. This locomotive was supplied in 1885 via agent Enrique Ayulo & Cie to a sugar plantation, Hacienda Chuquitanta, Vale Chilion to the east of Peru's capital, Lima. Jeremy found the locomotive on display in a restaurant in Miraflores (a suburb of Lima) in 2002 and after 2 years of negotiations brought Chuquitanta to England for restoration. Chuquitanta dates from a period when Decauville was reliant on outside suppliers for its locomotives and is a product of the Belgian concern Couillet (W/N 810). Decauville also allocated its own works number, in this case 36. Above frame level this one-time 500 mm gauge locomotive exhibits typical Couillet features of the period with its canopy, distinctive side tanks supported by prominent brackets attached directly to the mainframes and a boiler-mounted sandbox mounted behind the dome. The locomotive is also fitted with a spark arresting chimney (a necessity in a cane field environment) and, as with most of its sister Couillet 'midget' 0-4-0T contemporaries, it is outside framed. Inside framed examples were not unknown,



Arnold Jung 0-4-0WT Jenny rounds the main curve on the branch line with another open mixed working in the direction of New Barn Halt. With its combined inside frames and well-tank, high-pitched boiler, outside valve gear (in this case Walschaerts although Stephenson and Hackworth were not unknown, especially on earlier specimens in the former case) and externally mounted regulator and steampipes, Jenny is a classic example of its school of German design. Note also how the leading carriage is inspired by Penrhyn practice.



A view of Jenny, again on the branch line, but seen from the other side and working in the opposite direction (i.e., towards Richmond Station). Note that the reach rod is visible in this view, and the shape of the mainframes behind the rear axle. The re-purposing of the ex-R.N.A.D. van as a 4-ton capacity permanent way department vehicle is proclaimed on the sides of its bodywork, now painted in Corris Railway brown livery.



This is the vertical boiler locomotive Leary at rest. It spent the August 2023 Gala Day running back and forth along one of the shed roads.



Leary is seen here on one of its 'Driver for a Fiver' workings on which it was employed during the day.

however, and four specimens, built to the non-Decauville standard gauge of 55 cm, survive in Spain, one (W/N 580 of 1882) in Madrid and three (W/Ns 478-9 of 1880 and 545 of 1881) in Zaragoza.

This all feeds into a mystery surrounding an engraving in *La Nature* magazine in 1880 depicting a temporary 50 cm gauge demonstration line set up by Paul Decauville in Paris two years earlier. It is

known that Decauville W/N 1 *Lilliput* was a peculiar inside cylinder 0-4-0T with an almost-Cochrane pattern boiler and a form of cab reversible slip-eccentric valve gear (shades of Crewe Works *Billy*?). This tiny 1.25 tonne locomotive was given W/N 242 by its maker, Corpet of Paris and was initially supplied to the demonstration railway (sadly no drawings of the locomotive appear to be in circulation – can any reader help here?). The difficulty arises when you compare the surviving photographs of *Lilliput* with the engraving, which, although retaining the name appears to show an outside cylinder locomotive with inside frames and definite Couillet features. Unfortunately, examination of the Decauville Works List throws up no clear candidate for such a Couillet locomotive. Works No.s 2 (2.75 tonnes) and 3-5 (3.5 tonnes) were all 50 cm gauge but it is against the balance of probabilities that any of them were completed in time for use on the demonstration line. A surviving illustration of W/N 2 *Passe-Partout* also shows it to have been outside framed.

Against this, we have the fact that the train shown in the engraving would have been a handful for the tiny Corpet locomotive. It is known from Decauville catalogues that a small number of inside framed Couillet 'midgets' passed through its hands but these appear, as with the four non-Decauville survivors, to have had disc wheels as opposed to the spoked ones shown in the engraving. There again, the known evidence on these little Couillets dates from 1880 and afterwards and leaves open the possibility of an earlier locomotive with spoked wheels. We are therefore left with two realistic possibilities: (1) that the engraving was an extreme example of artistic licence and that the train was 'posed' with the locomotive, or (2) (more likely) that, in the absence of external customers in 1878, Paul Decauville somehow procured

a locomotive from Couillet for his demonstration line that did not subsequently pass through his books.

As a footnote to all of this, it should be observed that the 'demonstration' engraving was re-published a decade or so later with the locomotive 'doctored' to have outside frames. Returning to *Chuquitanta*, after import to England, the locomotive was re-gauged to 2 foot, which could (as with many sub-2 ft. gauge outside framed products of Couillet, Decauville and Fowler) be accomplished without replacing the frame stretchers. The motion was overhauled by Crowhurst Engineering Ltd. and the boiler was virtually renewed. The locomotive entered service on the R.L.R. in 2016 and appeared at the 2017 August Charity Gala. In 2018 adjustments were made to the motion and a tender, loosely inspired by Decauville practice, was constructed over a two-year period, making its public debut with the locomotive at the 2021 Charity Gala.

The next current resident locomotive to enter service on the R.L.R. was of a peculiar design. *Leary* was built in Nelson in 2010 by a group of Ffestiniog Railway volunteers and incorporates a vertical water tube boiler originally intended for use in a half-scale Sentinel steam lorry. This never happened and the boiler was eventually fitted to a steam launch. Eventually the F.R. members acquired both boiler and cylinders from the launch and incorporated them into *Leary*. *Leary* appeared at the F.R. 'Quirks and Curiosities' Event in 2010 and was sold to the R.L.R. in 2017, accompanying *Chuquitanta* in the Gala of that year. *Leary*'s transmission involves the use of a clutch and chain drive to one of its rod-coupled axles and both engine and clutch were replaced in 2018. In the 2023 Gala the locomotive was used for the 'Driver for a Fiver' duties as can be seen in the accompanying illustrations.

●To be continued.

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Summary Specification



Length approx 77"

- Coal-fired
- Sprung axle boxes with needle roller bearings
- Two safety valves
- Silver soldered copper boiler
- Etched brass body with rivet detail
- Available in choice of names
- Painted and ready-to run
- Stainless steel motion
- 2 Outside Cylinders
- Walschaerts valve gear
- Piston valves
- Mechanical drain cocks
- Mechanical lubricator
- Reverser in cab
- Boiler feed by axle pump, and hand pump
- Length 77"
- Width 10"
- Height 14"
- Weight approx 120kgs

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Radial Valve Gears Again

PART 14 – TWINING VALVE GEAR

Duncan Webster sheds light on what is often seen as a complex subject.



Continued from p.679
M.E.4730 November 17



Kirklees Light Railway



Bure Valley Railway



General view of Wroxham Broad (photo courtesy of Bure Valley Railway).



Valve gear of Wroxham Broad (photo courtesy of Bure Valley Railway).

This is one of the less used valve gears. It was invented by E.W. Twining (1895-1956) who was initially associated with Bassett Lowke but later set up as a model maker in his own right (ref 25). As far as I can tell this gear was only fitted to three locomotives, *Katie* (1954), *Sian* (1963), both built by Guest Engineering of

Stourbridge, and *Wroxham Broad* (built by Guest 1964 as a diesel, converted to steam 1991 by Winson Engineering).

Photograph 4 shows a general view of *Wroxham Broad* and **photo 5** is a close up of the valve gear, both kindly supplied by the Bure Valley Railway.

Figure 84 is a schematic of the gear and the results

running forward. It is clearly based on Walschaerts, but instead of the expansion link it has a bell crank rqp (q is a fixed point) which turns the outphase component ao to vertical motion of link hp . Point h is a die block which runs up and down a curved slide. Tilting this curved slide drives rod eh backwards and forwards, and e is connected to the top of the combination lever. What we have therefore is a sort of cross between Walschaerts and Joy gears. The curved slide is a box link, and the die at h is actually a pair of rolling element bearings. This no doubt reduces wear but when I had a close look at *Sian* there was some play. The bell crank pivot also runs on ball bearings, as does the pin at the return crank, and *Wroxham Broad* has needle roller bearings elsewhere. Back in part 8 (M.E.4725, September 8) of this interminable series I referred to the use of a linkage to replace a straight slide, particularly as used by Heywood. Were I ever to make a locomotive with this gear I would be severely tempted to use this. It would have all the benefits of Baker (no curved slides, just pin joints) and few of the drawbacks

The drawings of *Sian* show the return crank ao following the main crank ab by 90 degrees, and the angle between the arms of the bell crank also at 90 degrees. I think some small improvement could be achieved by following the backset methodology outlined in the article on Walschaerts (part 12, M.E.4729, November 3). In practice rod or is very long compared with ao , so I

Fig 84

SDL_bgi

Twinnings valve gear

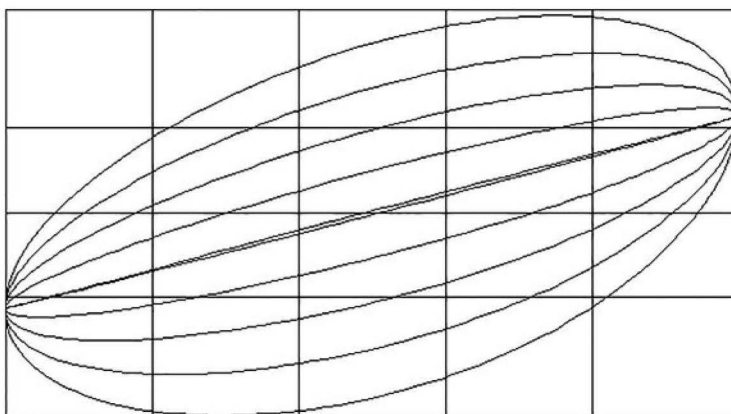
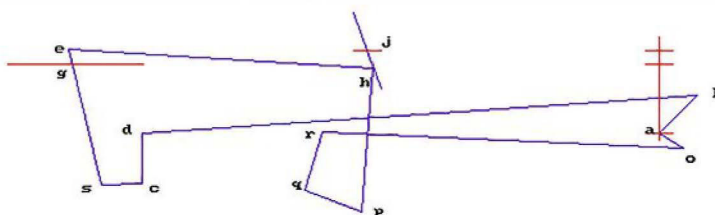
Katie (default)

ab = 4.000
 ao = 1.921
 bd = 41.000
 dc = 3.750
 cs = 3.000
 se = 10.250
 sg = 9.344
 he = 22.500
 ph = 10.625
 pq = 4.500
 qr = 4.500
 ro = 26.071
 retAng = 90.000 following
 rp = 6.364
 lap = 0.312
 port = 0.438
 ajVert = 6.125
 ajHoriz = 21.500
 yUValue = 5.312
 aqUert = 4.500
 aqHoriz = 26.000
 yUValue = 5.312

save results?
 enter Y else any key

+ve forward (acw)
 99 to quit

slide	front lead	front port	front cut	back lead	back port	back cut	die disp
:0	0.041	0.041	6.0	0.041	0.041	5.7	
:5	0.041	0.074	26.0	0.041	0.074	23.9	
:10	0.041	0.161	53.3	0.041	0.158	48.4	
:15	0.041	0.286	71.6	0.041	0.274	65.8	
:20	0.041	0.438	81.6	0.041	0.413	77.0	



Twining valve gear outline and performance.

would expect the improvement to be small. The gear is founded on sound principles and it is easy to make a sound job of construction. As can be seen from fig 84, results are excellent. Despite the heading above the data, the dimensions are for *Sian*.

Yet again there is a computer model. Running it gives you a moving picture, all jolly good fun.

Katie and *Sian* are running on the Kirkstall Light Railway in Yorkshire (www.kirkstalllightrailway.com) and *Wroxham Broad* is running on the Bure Valley Railway (www.bvrw.co.uk), to whom thanks for the photographs.

The next, and possibly final ('hoorah' do I hear?) episode will describe the Ouse gear.

● To be continued.

REFERENCES

Ref 25 en.wikipedia.org/wiki/Ernest_W._Twining

NEXT ISSUE

Driving Truck

Clifford Almond presents a 7¼ inch gauge driving truck.

Valve Gear

Duncan Webster concludes his study of valve gears with a look at another obscure gear – the Ouse gear.

Fire Queen

Luker begins the construction of a tender for his five-inch gauge Welsh slate quarry locomotive *Fire Queen*.

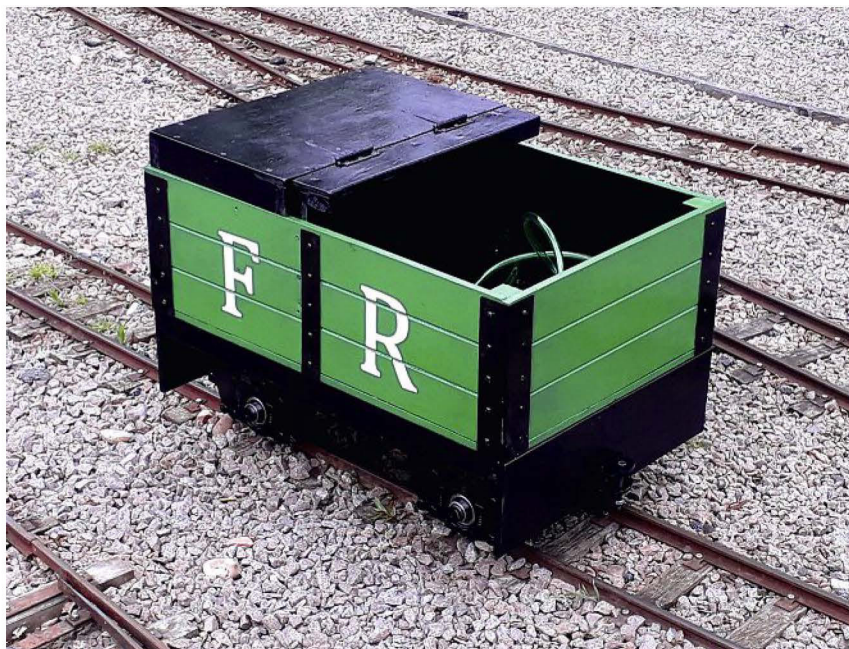
LNER B1

Doug Hewson describes a steam brake valve for his five-inch gauge LNER B1 locomotive.

HERCULES

Chris Walter creates a cylinder block for his twin compound marine engine from a block of cast iron.

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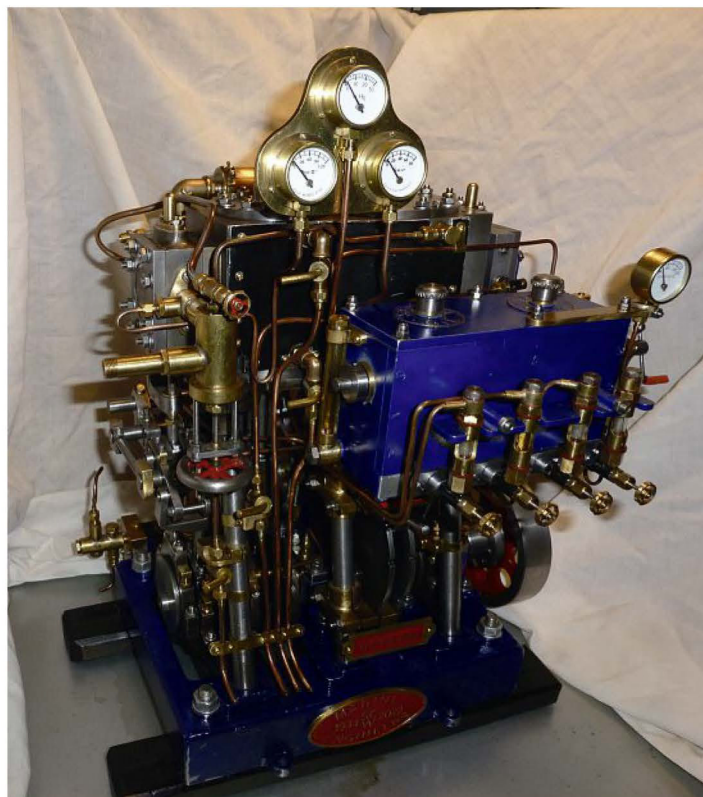
HERCULES

A twin cylinder compound condensing marine steam engine. PART 2

Chris Walter
builds an
engine
described in *Model
Engineer* 100 years ago.



Continued from p.701
M.E.4730 November 17



Main bearing standards

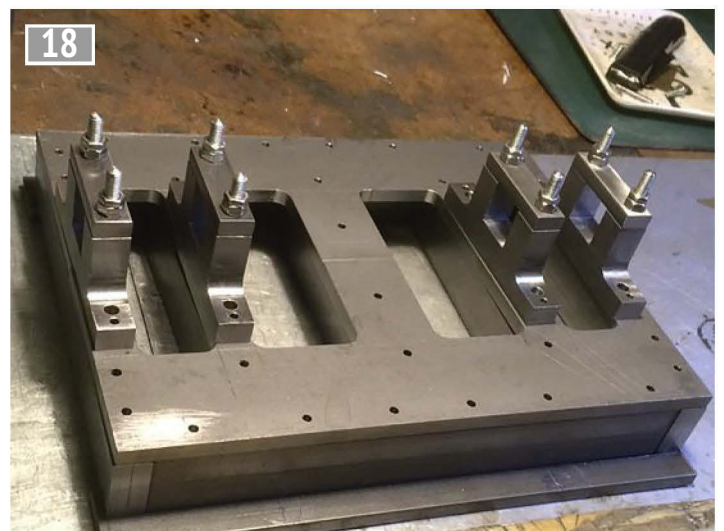
The four main bearings are split bronze shells carried in steel standards which are themselves held in position on the bed plate by M5 studs, nuts and $\frac{1}{8}$ inch steel dowels.

The bronze bearing halves are flanged to slide onto the standards and are retained by a steel cap bar. Shim washers can be used on the cap bar studs to provide adjustment to the bearing shells when necessary. The cap bars are drilled and tapped in the centre for a standard $\frac{3}{16}$ x 40 inch pipe union for the oil feed and the underside of this hole is counterbored for an O-ring seal.

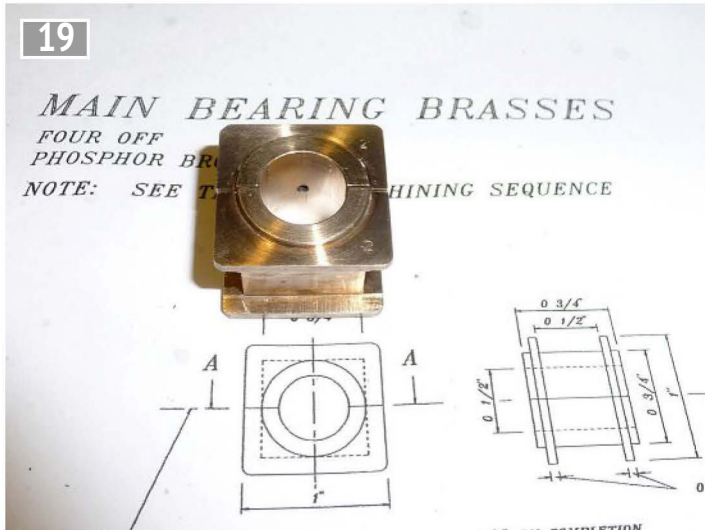
The four standards are made from $\frac{1}{2}$ inch steel stock and were initially machined to their overall dimensions. After marking out they were chain drilled, prior to finishing



Milling the block of four blanks as a unit.



Trial fitting on bed plate.



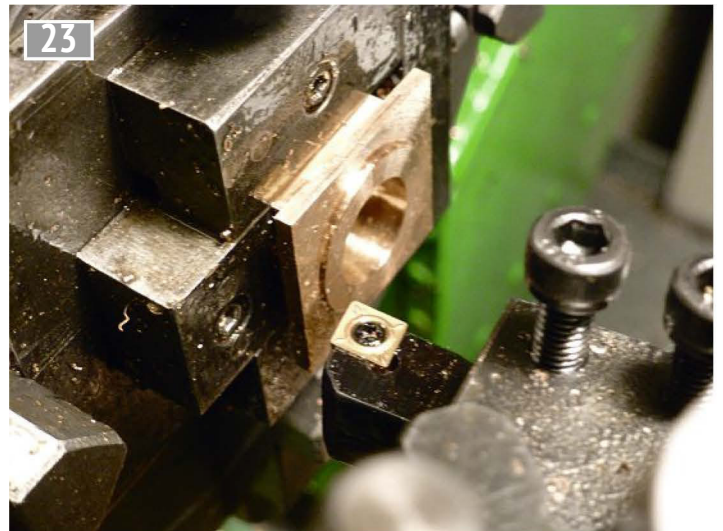
Bearing brasses.



Boring the shaft hole in the bearing.



Machining the slot on all four sides.



Facing the front of the bearing.



Trying the fit in both the jig and the bearing standards.

machining in one block on the milling machine (photo 17).

After drilling for the bed plate studs and dowel pins the tops could be drilled and tapped M4 for the cap studs (photo 18).

Main bearing brasses

As the bearings were to be split bronze shells, held as a sliding fit in the steel bearing standards (photo 19), it made sense to start with bronze square or

flat stock. Initially it proved to be difficult to find anyone who could supply this material. Everybody I tried just stocked rounds. Eventually I found a firm in the midlands from whom I purchased 18 inches of $1 \times \frac{3}{4}$ inch bronze bar ... and after I had recovered from the price I could get on with the job!

After milling the two halves of each pair down to size they were separated into the 8 sections and then sweated together with soft solder. I had pre-tinned each block and the only tricky bit was ensuring that they had the minimum of solder in the joint and the two halves were still in orientation. Every time I squeezed the hot halves together, they had a tendency to move, a bit like bars of soap in the bath!

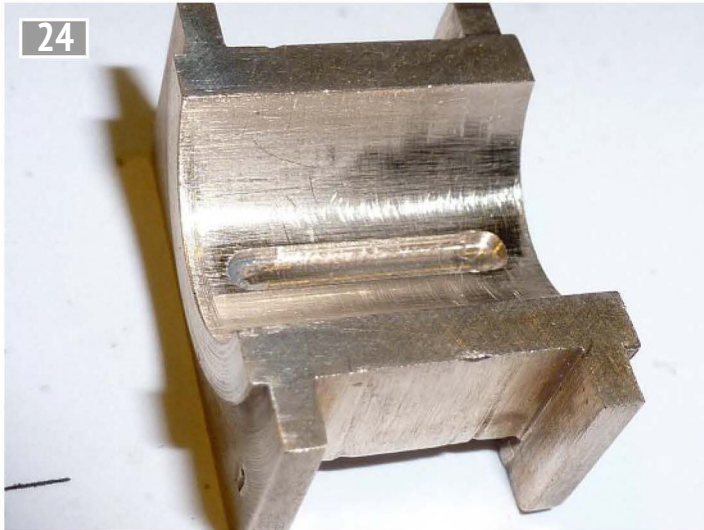
Each soldered pair were then finish machined to size before

the slot for the standards was milled on all four sides (photo 20).

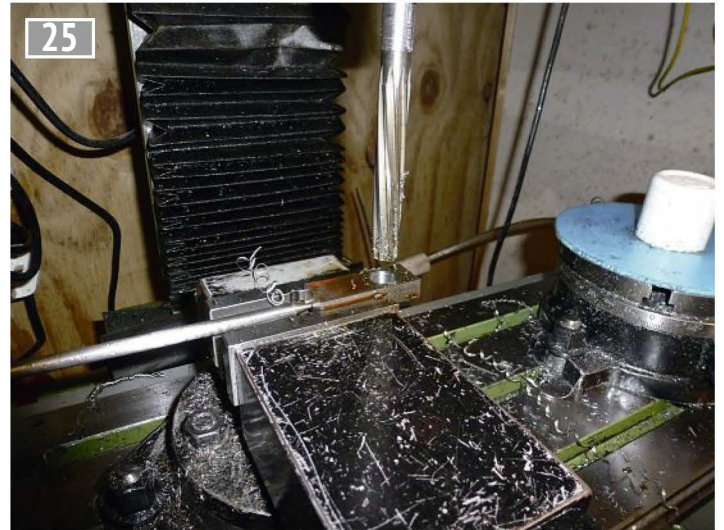
I made up a simple steel jig to fit in the four jaw chuck so that all the bearings could be held and bored at the same settings (photo 21). Once I was happy with the fit of both in the standards and the jig, all four bearings were bored to $\frac{1}{2}$ inch diameter (photo 22).

With this done, each side of the shells was faced off to leave a running flange (photo 23).

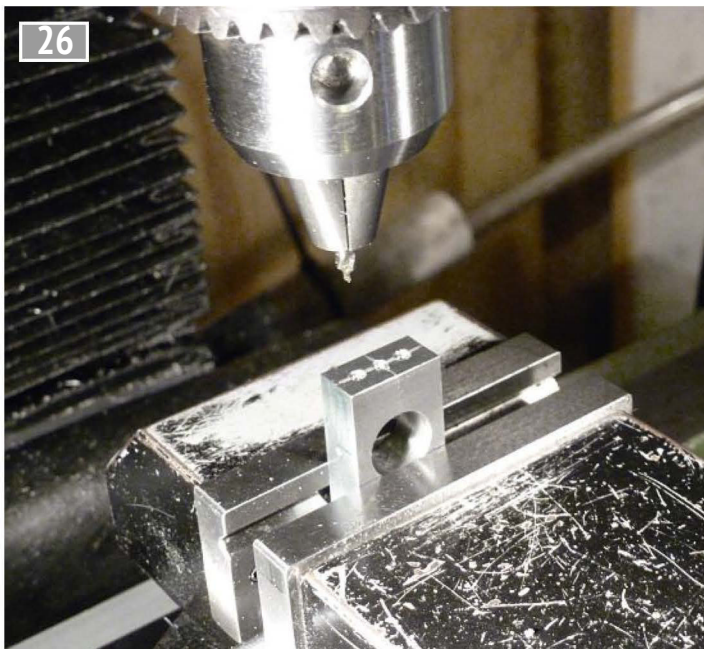
In each bearing the top shells were drilled $\frac{3}{32}$ inch and a short length of copper pipe inserted. This was to connect to the oil pipe union in the steel bearing cap. As previously mentioned, each bearing cap oil hole was counter bored $\frac{1}{32}$ inch deep to accommodate a silicon O-ring to provide a seal between pipe and cap union.



Finished oil keep.



Reaming the crankpin hole.



One end of each of the webs was drilled tapping size for the counterweight screws and the oil passage drilled down the centre.



Machining the curved side with an end mill.

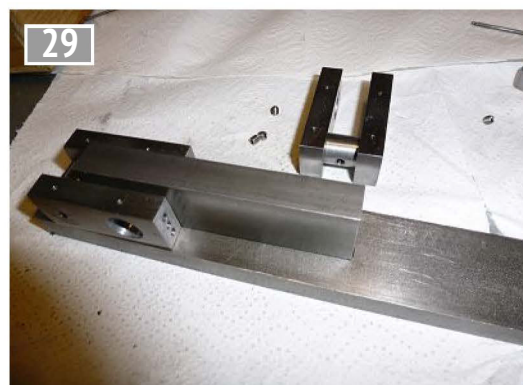


Trial fit of web and weight

To further assist lubrication the bottom shell of each pair had a $\frac{1}{16}$ inch wide by $\frac{1}{16}$ inch deep groove milled across the majority of the bearing surface to provide an oil sump (photo 24).

Crankshaft

Before starting on the crankshaft, it was necessary to consider its lubrication.



Fixing the crankpins in the webs with high strength retainer. A $\frac{1}{2}$ inch steel blank is used as a spacer between the webs.

In previous engines the humble oil cup had sufficed for main bearing lubrication but for an engine of this size I was determined to do a little better.

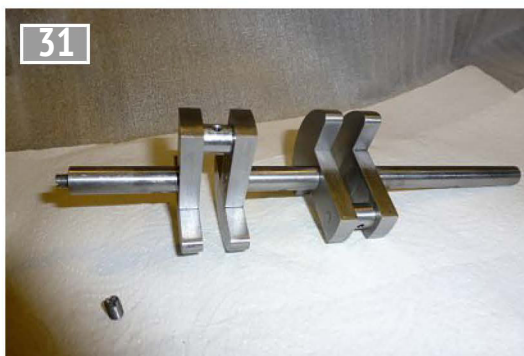


The two crankpins and their webs ready cross drilled with the $\frac{1}{16}$ inch pin.

After some thought I decided on a semi-pressurised feed to each of the four main bearings via adjustable sight feeds.

Oil from the lubricator would

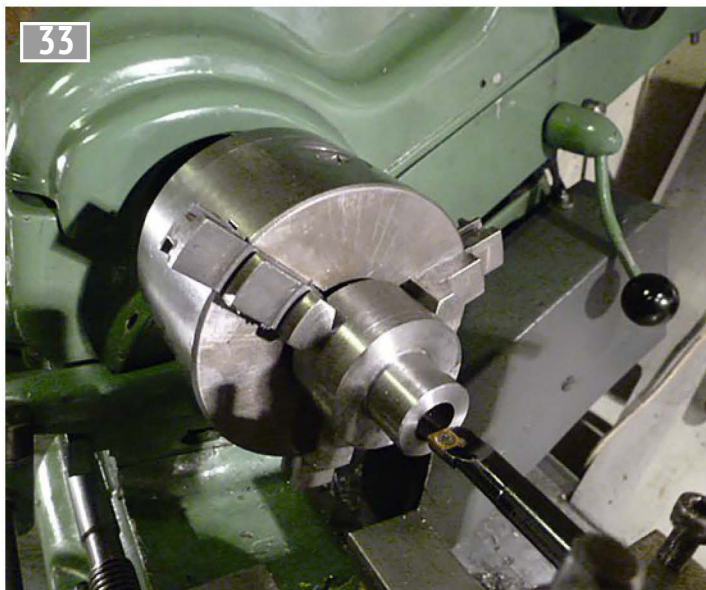
enter the top of the bearing via the pipe union O-ring seal and a short $\frac{3}{32}$ inch copper pipe held in the top half of the bearing brasses. In the bottom brass



Finally finished, just waiting for the oilway blanking plugs.



Finished flanges.



Boring the hole for the crankshaft.



Reaming the two drive pin holes.

of each pair a shallow oil keep would ensure an oil film was maintained over the bearing surfaces.

At each main bearing the crankshaft journal is pierced by an oil hole so that lubricant can enter the crankshaft central oil

way from the bearing. Once oil has collected inside the shaft, centrifugal force should cause it to pass through the passages in the webs and so to the connecting rod bearings.

The main shaft was made from ½ inch diameter silver

steel with a 6mm hole drilled throughout its length to form the main oil way. Each end was drilled and tapped M8 to take a threaded plug, the outer ends having machined centres.

Webs were made from ½ x ¾ inch steel flat and after being drilled and reamed for the shaft and crankpins (photo 25), were drilled lengthways for the oil passages and the fixing holes for the counterweights (photo 26). In addition, they were pre drilled 1/16 inch across the joints ready for pinning after assembly.

Once the curved web ends and the counterweights were finish machined on a rotary table in the mill, they could be assembled onto the shaft (photos 27 and 28).

Spacers were made up to ensure that everything ended up in the correct place. I must admit to having been caught out before when high strength adhesive has cured rather too quickly!

When the adhesive had cured the pre drilled cross pin holes could be further drilled through and the pins inserted right through the shaft with more high strength retainer (photo 30), the ends of the pins being filed flush with the webs. Although the cross pins go through the oilways, I had calculated that there should be sufficient clearance around the pins to allow the oil to flow and testing on the finished shaft proved that this was correct.

I found that the easiest way to remove the unwanted sections of shaft between the crank webs was to secure the whole shaft in the lathe tool post and use a slitting saw on a mandrel between centres. After

this the sawn ends could be finished with a cutter in the mill.

All that remained was to insert blanking plugs into the open ends of the central oilway where this had been compromised (photo 31).

Crankshaft drive flange

The crankshaft is furnished, at the low-pressure end of the engine, with a steel drive flange (photo 32) which can connect to either a flywheel or a propeller shaft thrust bearing if so desired. My choice was for the flywheel, at least for the time being.

Whatever the choice, the connection is made using six M5 cap head set screws and two ¼ inch diameter steel dowel pins to assist with location and power transmission.

The flange has to be removable in order to service the low-pressure eccentrics which can only be removed via the end of the crankshaft. The shaft hole was reamed ½ inch diameter for the crankshaft and for the initial part of the build was secured to the crankshaft by two cross drilled and tapped M4 grub screws.

In an ideal situation the flange would be keyed to the shaft, but as the crankshaft has an oilway along its length there is insufficient wall thickness to accommodate this so another solution had to be found.

Though not ideal, the only way I could think of was by using a 'hollow saddle key', assisted by up-rating the two grub screws to M5, one of which would bear on the back of the saddle key. This has so far proved to be more than adequate.

The flange, from steel stock, is a simple turning job, first turning the outside and then forming the flange (photo 33). Once the shaft hole had been bored the flange was drilled and tapped for the M5 holes and then reamed for the two drive pins using the PCD function of the digital readout (photo 34).

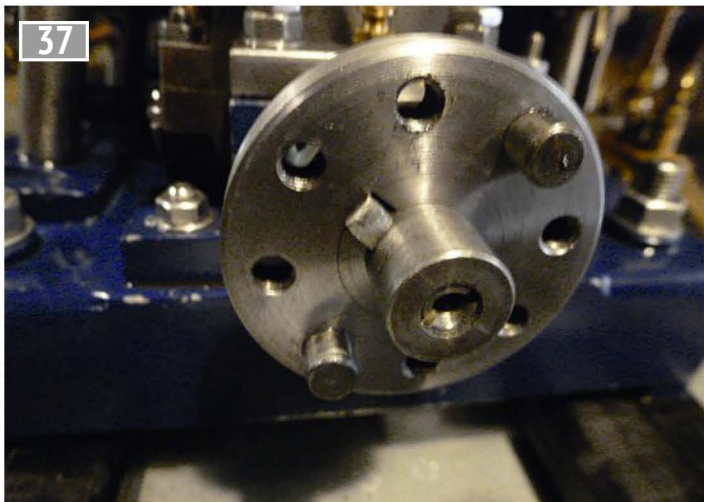
The two drive pins are short lengths of ¼ inch silver steel and were held in the flange by high strength retainer.



35 Making the key. Key partially cut from its tube.



36 Finished key blank. This still requires filing square and fitting.



37 Flange and key fitted to crankshaft.



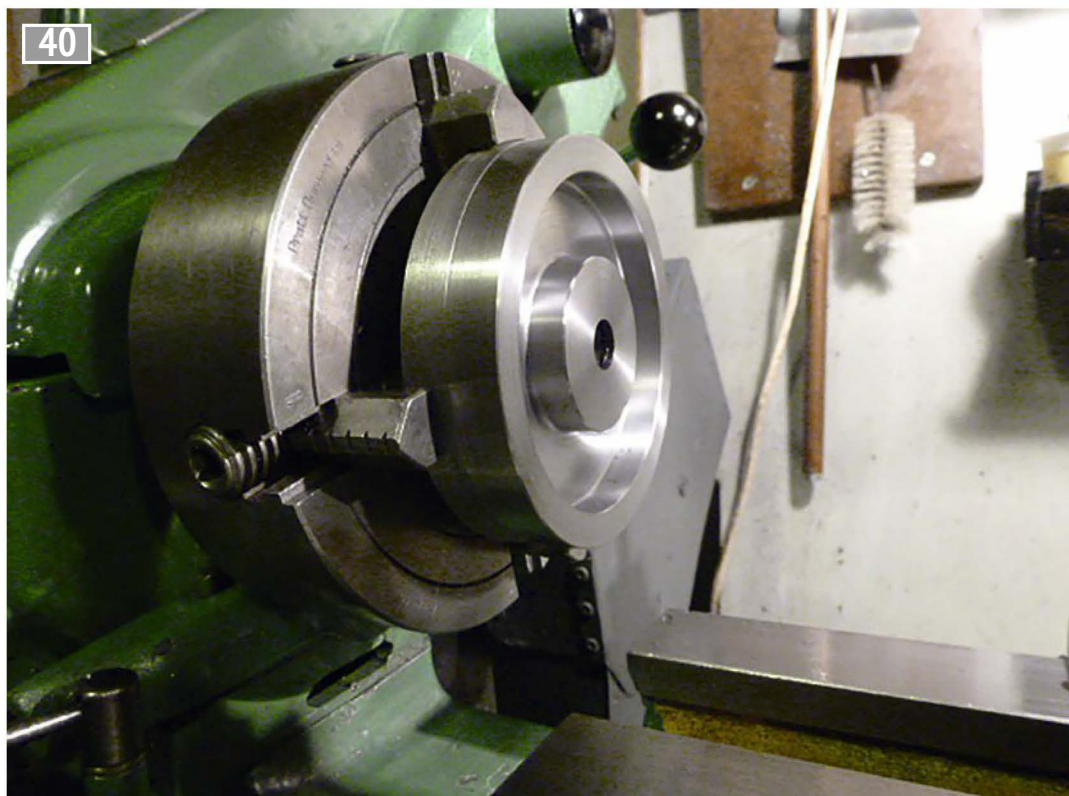
38 Finished flywheel with drive flange.



39 The blank turned down to the finished overall size.

Once the main build of the engine was complete, I returned to the flange to update its fixing. This would necessitate the cutting of a $\frac{3}{16}$ inch wide slot inside the $\frac{1}{2}$ inch bore for the saddle key. This presented me with a slight problem as I do not possess any broaching tools and really did not want to purchase something that would probably never be used again. The other alternatives, of using either the lathe top slide or the mill quill as a shaping machine, did not appeal as the forces generated by even such a small tool bit can be considerable.

In the end I bored out the centre of the flange to $\frac{3}{4}$ inch and then made a steel bush up to this size. Once done, the $\frac{3}{16}$ inch wide slot for the key was milled lengthways right through the bush and it was inserted in the flange using high strength adhesive.



Turning the front flange and boss.



Again, using the PCD function to drill the eight lightening holes.



Finished flywheel. Note the rebate in the boss to provide clearance for the head of the saddle key.

a marine engine model, the engine was not, at least in the foreseeable future, going to be fitted into a vessel.

This being the case I made a flywheel (**photo 38**) to fit to the crankshaft drive flange and which could be easily removed when not required, leaving the engine still completely operable.

As far as material is concerned there was no issue as I already had a steel blank of suitable size, whereas I didn't have a cast iron one. End of story!

The rough blank luckily just fitted in my four jaw chuck and was initially cleaned up (**photo 39**), after which, by machining alternate sides, it was reduced to finished overall size. It was then drilled, bored and reamed $\frac{1}{2}$ inch and the boss formed on one side.

I then mounted it on a $\frac{1}{2}$ inch mandrel and, with tail stock support, finished the rim and inside flange.

It was now reversed and held by the inside flange to machine the remaining boss and flange.

Once removed *in situ* with the chuck, it was held on the rotary table where, once centred, it was drilled for the flange fixing holes, drive pins and then the eight lightening holes, by using the PCD function of the digital readout (**photos 41 and 42**).

● To be continued.

Making the key proved to be an interesting exercise. I turned up a steel tube $\frac{3}{4}$ inch diameter with a bore of $\frac{1}{2}$ inch, twice as long as the intended key so that there would be plenty to grip in the mill vice etc.

Still in the lathe, the tube was tapered turned to the angle of the key (1 in 100) and then moved to the mill. A size allowance must be made as the angled outer surface will need to be filed flat.

Using a slitting saw, two cuts were made along the length of the tube, the width of the key ($\frac{3}{16}$ inch) apart and equidistant from the centre line, after which the key can be sawn from the tube (**photo 35**).

When filing the key to finished size the axiom must be little and often, frequently trying the fit of key, shaft and flange, as it is only too easy to remove too much material, making the key useless. Ask me how I know (**photos 36 and 37**)!

I had never used a saddle key before this but have been agreeably surprised how secure it is.

Flywheel

After thinking about flywheels, I decided that although it was

A Method of Manufacturing Piston Rings of the Clupet Style PART 4

Martin Gearing discovers how to make these rings himself.



Continued from p.688
M.E.4730 November 17

Note: imperial dimensions follow metric dimensions and are in brackets. References are listed in part 1 (M.E.4728, October 20).



Unwanted gap in a Clupet ring.

A set of Clupet rings was made up and then put in the muffle for 30 minutes, before it was turned off and allowed to cool, after which the tube was dismantled and the rings turned right side out.

Whilst the rings 'flipped' back alright it seemed there were still issues/problems that needed resolving.

Problem 4

I'd noticed that the rings after being heat treated and turned 'right side out' had a very slight visible gap between the two separate sections of the ring either side of the 'dog leg connecting bar' (photo 10). This showed up when turning the final diameter, by the lack of even pressure after the mandrel was tightened,

permitting the one end being broken when it was grabbed by the tool.

Action 1

Looking back I don't know why I tried this but I tried

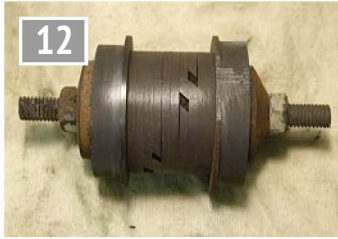
clamping the ring blanks after 'widthing' between two paper washers (photo 11). I thought that the 'give' in the paper would accommodate the variation of thickness. The problem was not resolved by doing this and after destroying three rings, I woke up to the fact that even if it had it worked it would have resulted in rings of varying width.

Action 2

Because the slitting saw I was using was larger than the one seen in the video I modified the arbour on which it was mounted to ensure that there was no chance of the blade being 'deflected' whilst cutting. There didn't appear to be any improvement but I continued to use the adapted arbour as it seemed more substantial and anything that makes a slitting saw less likely to shatter is



An attempt to avoid the gap using paper washers.



A set of rings after the second annealing.

good news in my book (have to confess I'm not a lover of the things!).

Action 3

In desperation I put the rings 'right side out' back onto the heat-treating tube, placing the solid 'dog legs' evenly around the ring pack to locate opposite the middle of the centre cut section, rotating around the tube at 90 degree intervals, against the adjacent rings. I then fitted the end caps a little more than finger tight and annealed them again (**photo 12**). This cured the problem.

Problem 5

Although being able to control the temperature by the use of a muffle furnace meant there was no apparent problem with oxide increasing the blank diameter to the point I didn't apply the chalk based covering, I found the extra 0.05 allowance was still required. I assume the increase was because of the distortion in the form of a slight twisting occurring in the rectangular section when it closed up on the width to fill the gap made by the slitting saw in the annealing process.

Action 1

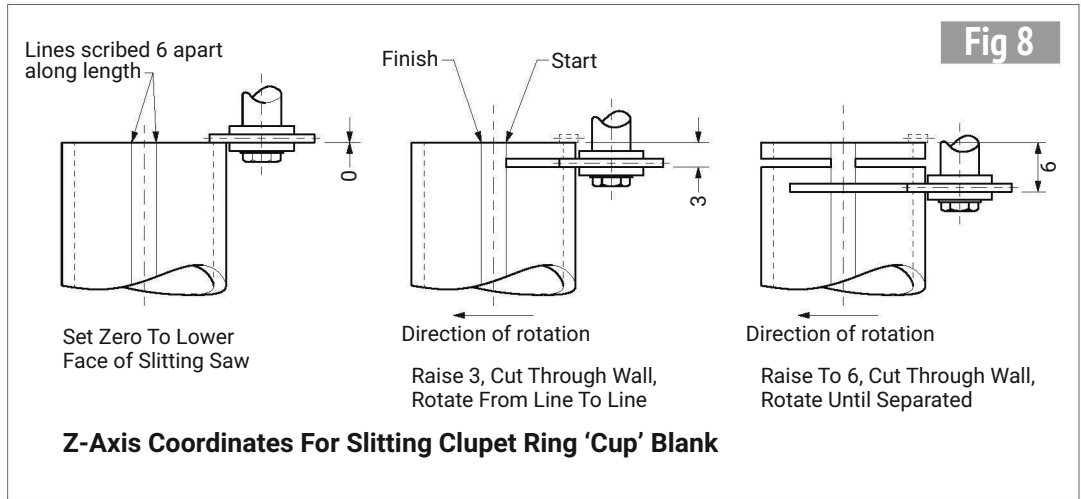
Continue to include an additional 0.05 (0.002 inch) on the blank outside diameter for the 'widthing cup' and 'closure ring' bore diameters. It seemed best to refer to it as an 'annealing allowance'. When this was done, no further problems were encountered.

This resulted in a work plan based on my rings intended for use in a diameter 38.1 (1.500 inch) bore steam cylinder, a copy of which follows.

Work plan

Required design dimensions

Finished Bore (D)	38.1
Finished Width	4.78



Slitting the rings.

Radial Thickness (t)	1.5875
Internal Diameter (ID)	34.93
Heat Treatment Tube	35.94

Tooling and Blank Dimensions

Machining Allowance (MA)
= 0.2

(Note: Applied x1 to D and x2 to blank width)

Gap Cutting Allowance (GCA)

= Saw Width / π

Blank Outside Diameter

= (D + MA + GCA)

Blank Width

= (Finished Width + Saw Thickness + [MA x 2])

Internal Diameter (ID)

= D - (t x 2)

Widthing Cup Depth

= Finished Width - 0.5

Annealing Allowance (AA)

= 0.05

Widthing Cup and Closure

Ring Bore

= Blank Outside diameter +

AA

Tooling and Blank Dimensions for 38.1 diameter ring

Machining Allowance (MA)
= 0.2

Gap Cutting Allowance (GCA)

= 0.4 / π

= 0.13

Blank Outside Diameter

= (38.1 + 0.2 + 0.13)

= 38.43

Blank Width

= (4.8 + 0.4 + 0.4)

= 5.6

Internal Diameter (ID)

= 38.1 - (1.59 x 2)

= 34.93

Widthing Cup Depth

= 4.8 - 0.5

= 4.3

Annealing Allowance (AA)
= 0.05

Widthing Cup and Closure

Ring Bore

= 38.43 + 0.05

= 38.48

NOTE

* Only metric dimensions are shown in this example.

* Both the saw used for the 45 degree end cut to ring section and the slitting saw to be 0.4 (0.016 inch) thick.

Lathe

- 1 Bore the cast iron blank to the designed FINISHED internal diameter 34.93 required by the length sufficient to make between four and six times the designed width plus parting tool width for each ring.
- 2 Turn the outside blank to diameter 38.43.
- 3 Mark two vertical lines on the

outside of the cylinder 6mm apart to give the position for the ends of the slitting saw cut to be made.

Self-centring chuck mounted on rotary table

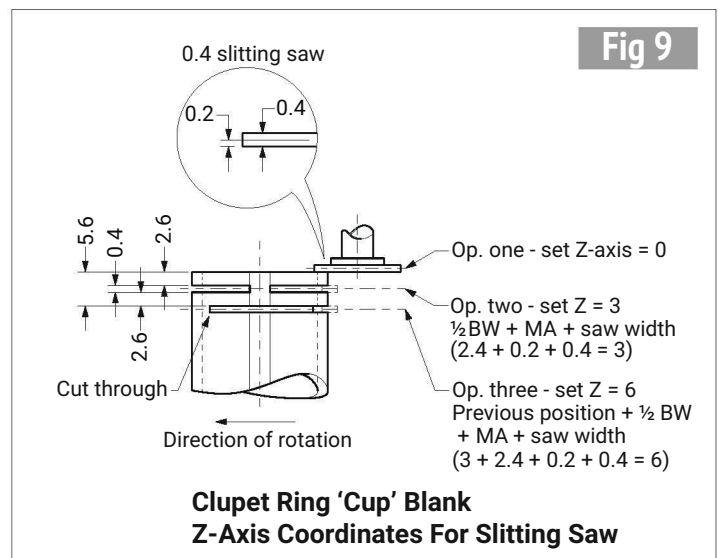
Work rotation is against spindle rotation - mill with a 0.4 (0.016 inch) thick slitting saw on a vertical arbour with supporting 'cheeks'.

4 Secure the blank vertically in the chuck.

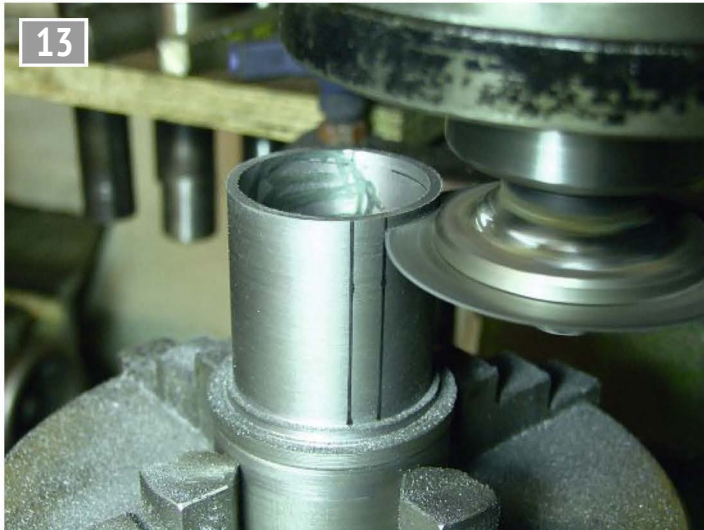
5 (Op One) With the slitting saw held on a suitable arbour raise the blank until the top edge just contacts the lower face of the slitting saw (**fig 8**). Zero Z axis.

6 (Op Two) Move the blank clear and raise $\frac{1}{2}$ BW = 3 (**fig 9**).

(BW = Designed Width + Manufacturing Allowance + Slitting Saw Width)



Slitting saw coordinates.



Initial slitting of the rings.



Squaring the ends of the slits.



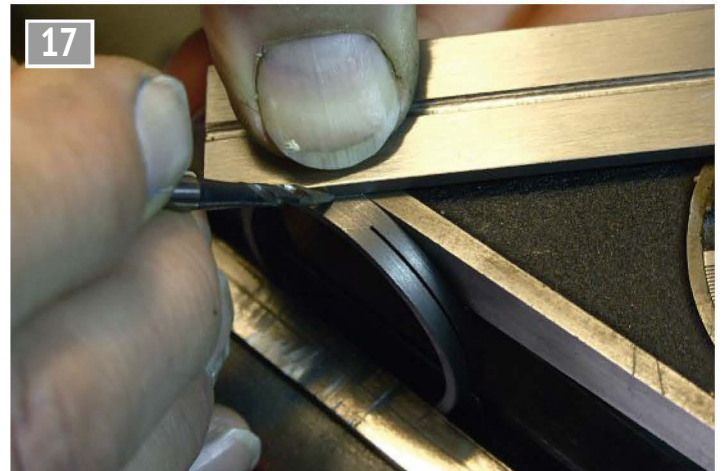
A set of rings, separated.

7 Position the blank to allow the edge of the saw-cut to JUST touch the right hand of the two marked lines (photo 13) before rotating the blank slowly clockwise (against saw rotation) until

the leading edge of the saw-cut JUST reaches the second line.
8 Withdraw the slitting saw.
9 Using a 'jewellers'/'razor' saw or an adapted 'junior' hacksaw (thinned to 0.4



Inserting a support spacer into a ring.



Marking for the diagonal cuts.



Initial diagonal saw cuts.

thickness by removing the 'wavy set' from either side of the blade), remove the radius formed at each end of the slitting saw cut, 'squaring' both ends of the centre slot (photo 14).

10 (Op Three) Raise the blank to the full $W = 6$ value on the Z axis.

11 Re-zero the Z axis, before rotating the blank completely, cutting off a complete ring width from the remaining blank using the slitting saw.

12 Repeat for the remaining rings required (photo 15).

Bench vice

13 Insert a 0.4 shim (packing case steel strapping is ideal) opposite the 'dog leg' to allow the ring to be held without damage between the smooth soft jaws of a vice (photo 16).

Using a protractor mark a 45 degree line from the end of the centre cut to the outer edge towards the plain section (photo 17).



Completing the diagonal cuts.

14 Hold the ring in a smooth soft jawed vice, so the solid 'dog leg' is uppermost with the shim in the gap opposite. Using a 0.4 thick saw, carefully cut from the outside down into the end of the central slot (**photo 18**).

15 If you haven't already done so now would be a good time to make the *Machining Mandrel End Washer*, because the 2mm step turned to match the inside diameter is ideal to use as a support to complete the sawing of the 45 degree end cut. Then bend up a short length of strapping to protect the opposite side of the ring whilst sawing. Fit the ring onto the mandrel and slip on the protective piece of bent strapping. Hold the mandrel washer firmly in a vice, before carefully completing the 45 degree cut guided by the initial cut (**photo 19**).

Because of the saw blade having no set, I found that by very lightly holding the saw and allowing just the weight of the frame to dictate the rate of progress it cut freely at a controllable rate. Repeat on the opposite side. Life will be made a lot easier when carrying out the next operation if you take this opportunity to break the sharp edge on the corners. This is quickly done with the back of a craft knife.

16 Now for the most fascinating part of the

whole process! Turning the ring blanks 'INSIDE OUT'. You can either tuck one end inside or ease an end over the outside, as both achieve the same result. In my case it seemed to depend on how I'm feeling at the time as to which way seems easier but both methods work! The process proceeds by first easing one end over the outside, followed by gradually easing the rest of that section on over the remaining ring and finally flipping the tail out from the inside to the outside ready for cleaning up the sawn area of the 'dog leg' and ends with a fine flat file, removing the minimum amount of material whilst maintaining the 45 degree angle (**photo 20**). Again, further operations will be made easier if the sharp edges now exposed are broken using the same method as before.

Photograph 21 shows the rags left by the sawing and **photo 22** shows the ring section end after their respective rags have been removed. Repeat for the other side of the dog leg and all the remaining rings in the set.

Heat treatment

17 Slip all the rings in the set over a tubular mandrel 1.029 times larger than the designed inside diameter = 35.94 (**photo 23**).



Ring 'flipped' inside out.



Ragged end of the diagonal cut.



Tidying up the diagonal cut.



Rings, still 'flipped', on mandrel.



Rings after second heat treatment.

18 Heat mandrel and rings to blood red heat to between 600 – 615 degrees Centigrade (DO NOT EXCEED 650) and hold for 45 minutes before letting cool naturally.

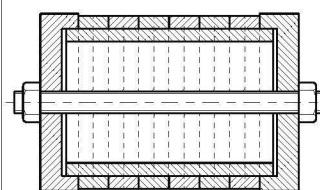
19 Remove all the rings from the mandrel and turn the

rings 'right side out' to the previous orientation, which is where you will appreciate having taken the time to remove the sharp edges.

20 Replace on the mandrel with the 'dog leg' crossovers 180 degrees on from the adjoining ring. Continue in this manner until all rings are on the tube. Fit the end caps and secure with a through bolt tightened just a little over 'finger tight' (**fig 10**).

21 Heat mandrel assembly to blood red heat again to between 600 – 615 degrees Centigrade (DO NOT EXCEED 650) and hold for 30 minutes before letting cool naturally, then wire brush to remove any trace of oxide (**photo 24**).

Fig 10



Clupet Ring Heat Treating Mandrel For 2nd Heat

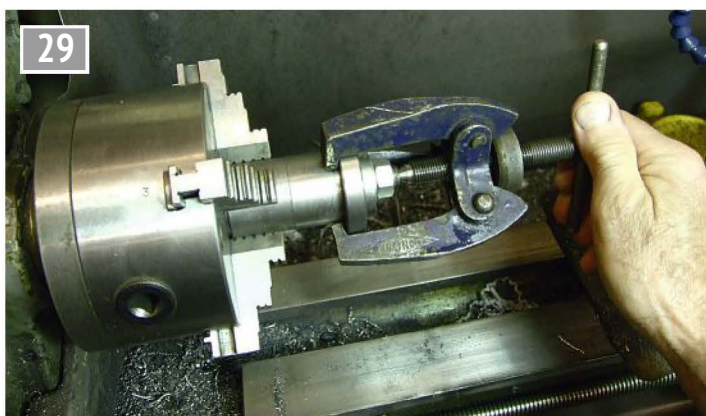
Heat treating mandrel.



Rings removed from mandrel after heat treatment.



A ring in the 'closure cup' for boring to final internal diameter.



Removing the closure cup from the mandrel.



The completed rings.



A ring in the 'widthing cup' for final machining.



Closure cup mounted on machining mandrel.

Lathe

22 Remove rings from mandrel (photo 25).

23 Bore 'widthing cup' fixture to $\varnothing 38.48$ to a depth of 4.3.

Mill

24 Mill three removal slots 6 x 2.5 deep with a diameter 6 end mill for the brass 'extractor lever' in the back face.

Lathe

25 Measure the ring width across the 'dog leg' and calculate the amount requiring to be removed. Fit into the 'widthing cup' fixture. Face each side in turn, taking off **half excess material** to bring to the 4.78 width required, keeping the **split in the centre** of the finished ring (photo 26).

26 Fit in the 'closure ring' bored to diameter 38.48 (photo 27). (Note – The closure ring shown is marked for a different size ring).

27 Mount the 'machining mandrel' in the lathe and check the register diameter runs true.

28 Assemble the blank/closure assembly onto the 'machining mandrel' and fit the holding plate, ensuring the holding plate register locates on the inside diameter of the ring blank before tightening the securing bolt (photo 28).

29 Carefully remove the closure ring using a small three leg puller (photo 29).

30 Machine the outside diameter 38.1.

31 Remove from the machining mandrel.

32 Repeat for the remaining rings.

Following this - **FINALLY** the results were comparable to the commercial Clupet Style ring (photo 30)!

●To be continued.

Buckeye Coupling for 5 Inch Gauge PART 3

Jonathan Buck equips a 5 inch gauge A4 locomotive with prototypical couplings.



When the parts arrived (photos 4 and 5), I found myself somewhat intimidated. The level of detail was as good as I could have hoped for and the fear of ruining some rather expensive parts led to me procrastinating for quite some weeks over exactly how to best minimise the risk. My fear was in part driven by the fact that bringing the holes out to size was a one-shot operation; the

Continued from p.692
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Set-up for finishing pivot hole in coupling hook.



Drilling out coupler pivot pin hole with a 3.5mm extra-long end mill.



Parts as received with convenient universal scale objects.

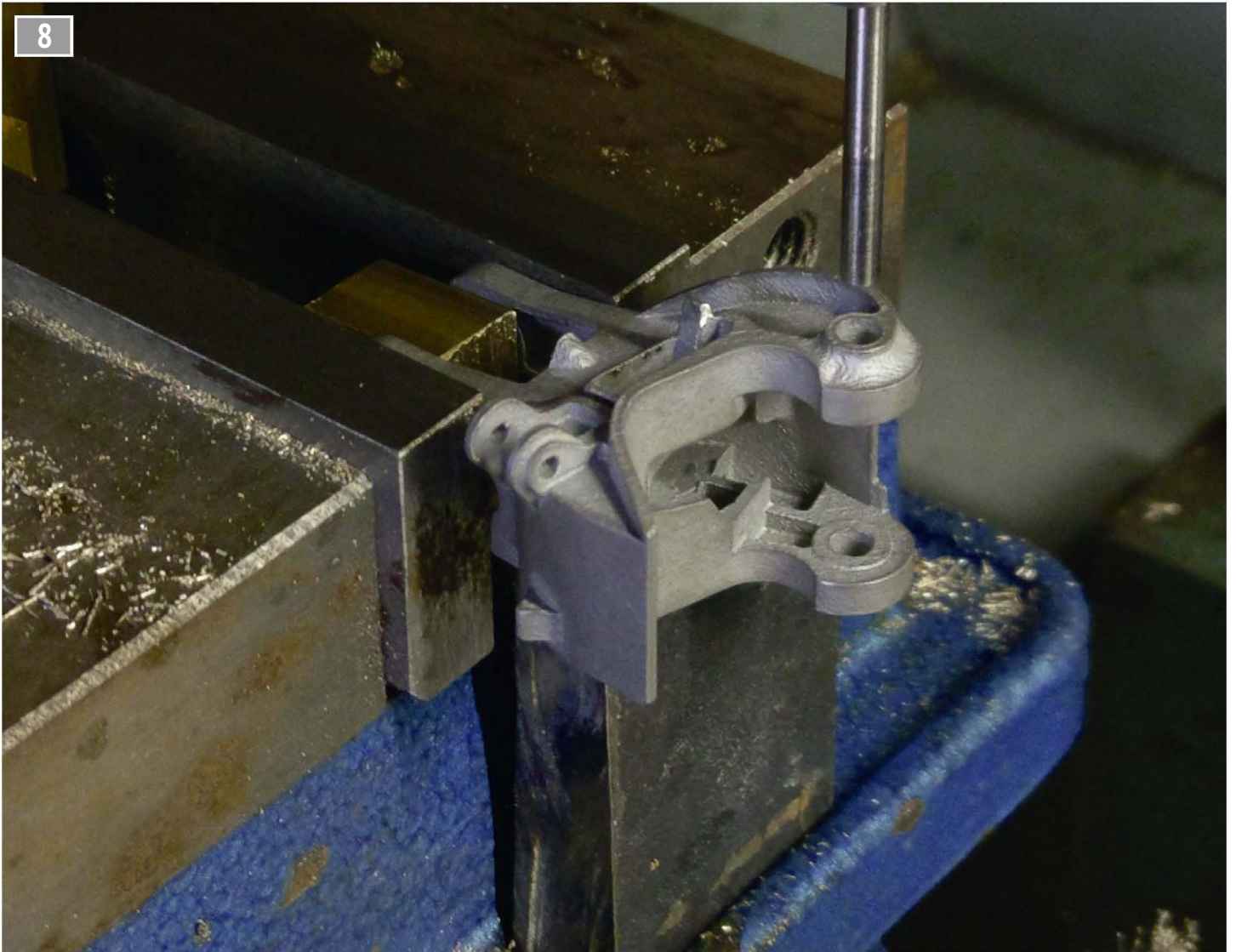
first I would learn about how this material machined was when I was putting the sizing cutter through the first hole.

I chose to start with the pivot pin hole in the hook, on the grounds that it was the shortest hole, in the most rigid and easily held component. I could probably also have bushed it if the first attempt went wrong. I had nothing to worry about, the new, sharp cutter whispered through the machining allowance, leaving some fine needles of swarf and a neat hole.

With the worries over the material and cutters behind

me, I addressed the set-up for the remaining parts. I seem to have neglected to take any photos of the knuckle set-up, but all I did was make some packing from brass scraps to fit in the eye of the hook, allowing it to be clamped in the vice against the small flat surface on the other side of the pivot hole. The entry face was placed coincident with the top face of the vice jaws.

For both the hook and the main coupler body I made up packing for the opposite end of the vice jaws (this can be seen in **figs 6** and **7** - the main body required two spacer set-ups



Lining up to drill knuckle pin holes in coupler body using the shank of the nearest sized drill.

for the different operations). The main coupler body also required packing between the jaws at the trailing end when being set up for the knuckle pin hole to be drilled out, as shown in **fig 8**.

I will admit to a slightly cavalier approach to alignment. Once any flash or local out-of-roundness had been cleaned up with a needle file, I set the parts up as true as I could (the coupler body was the worst for this) and placed a No. 31 drill the wrong way round in the Jacobs chuck on the milling machine. I had already established that this gave a reasonably close but snag free fit in the holes as-printed. Much twiddling of dials would then ensue while I tried to find the perfect position where the drill shank would fit without touching. I found that trying

to get a perfect fit through both of the knuckle pin holes could lead me astray and if the set-up to achieve this didn't have the component set true in the vice, it probably wasn't right, so settled on having the component set true and the drill shank entering the hole cleanly while passing the rigorous 'looks about right' test.

Having established my alignment, I swapped out the drill for a 3.5mm end mill and drilled the hole out without moving the table. The purist will probably object to me using end mills in a Jacobs chuck and indeed I would have been much happier with an ER collet chuck (which I didn't have at the time) but a Clarkson Autolock chuck (which we did) will not take drills and since the operation was purely drilling I decided the Jacobs

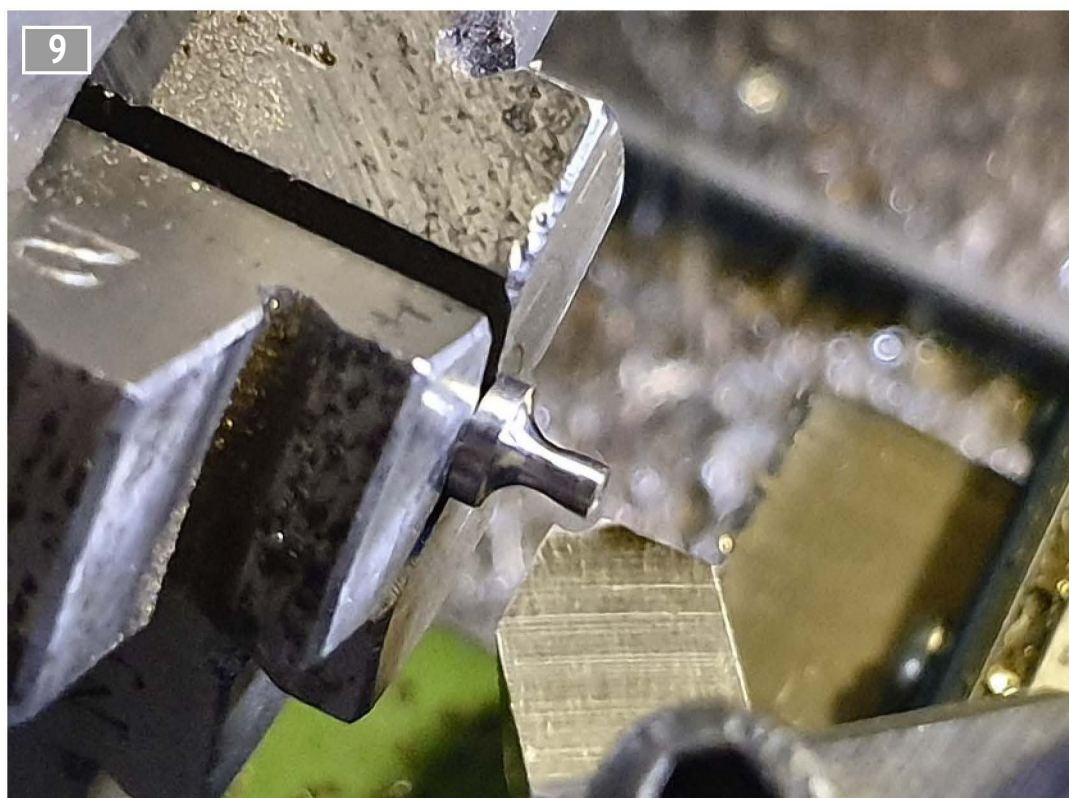
chuck would be adequate. Subsequent measurement has shown that the runout on this particular example of a cheap Jacobs chuck is remarkably good; you may not be so fortunate.

With the major holes drilled out, I turned my attention to the small components. The knuckle pin and pivot pin are simple headed pins, turned with the help of a revolving centre, faced back to remove the over-scale centre hole and cross drilled at the ends for split pins using 1mm carbide PCB drills (an agonisingly slow process using the quill fine feed, because by the time it came to the cross drilling, I really didn't want to break a drill in the tough stainless and scrap the component).

The lock, which had been cast in phosphor bronze, didn't

fit at all as received. It was clearly the correct width, but the 'beak' at the top of the lock was too long to fit through the lower entry pocket. Having frantically double checked my models and the original drawings, I was reassured that nothing was wrong, except for the small matter of the parts not fitting together.

I'm not sure whether some minor vagaries of the parts prevented the lock from rocking into position, as might have been possible with a slightly smaller lock; whether the drawings had later been amended or whether a modification had unofficially been made in production that the drawing office never captured. Checking against the drawing for the coupling fitted to the '60s Metro Cammell Pullmans it was clear that the



Machining the support pin head.

beak was slightly shorter in the later design, so I shortened and rounded off the beak with some small files until the lock could be manoeuvred into position. It was also necessary to clean up the slot ever so slightly to remove a couple of small balls of flash.

The most complicated part to make was the coupler support pin. This sits in the eye of the coupling hook and holds the coupling up in the raised position for use. The end of the pin folds over to prevent it from backing out in use. This

is achieved with a tab-and-slot hinge, pinned with a piece of nickel silver wire bonded in place with Loctite. I ended up using a carbide slitting saw on a homemade mandrel for the slot, after finding that a 1.5mm long series slot drill is a rather delicate beast.

The 'rolling pin' profile of the other end (which is different from that used on later couplers) required a couple of form tools, which I ground from high speed steel. I have generally shied away from this kind of tool grinding in the past,

but the round-nose tool for the concave radius was very straightforward, making sure not to grind away too much at a time and using a drill shank of the correct size as a template to check to, before finishing with a stone.

The tool for the ball end was trickier, having a smaller internal radius than I could achieve on the well-used wheels of the bench grinder. Instead, I drilled a hole of the correct size into the HSS blank using a carbide drill, ground away material to leave a quarter of the hole remaining, then finished with some diamond files and a stone. I left the drilled hole rather shallow for fear of sticking a broken drill in the blank, which left quite a lot of work for the files (the round nose tool took about fifteen minutes from start to finish, while the radius tool shown in **fig 9** took the rest of the morning and two cups of coffee).

As previously noted, both these form tools cut the 431 stainless used for the pins extremely well, leaving an excellent finish despite having less than ideal geometry, which has rather changed my thinking

on when to use HSS and when to use inserts.

The chain shown in **fig 10** came from a forgotten exhibition stand specialising in model ships' stores, who also provided the 1mm split pins used for retaining the various pins. The final link in the chain was made from nickel silver wire, to pass through the 0.8mm hole in the eye of the support pin.

4497 was scheduled to be shown at the 2019 Midlands Model Engineering Exhibition, which at this point in the manufacture of the first coupler was approaching rather rapidly. To make sure the coupler was ready, I decided not to spend time on the complicated torsion spring, although I ended up making two of the related (tiny and fiddly) spring carrier pins, since this component is visible from the outside of the coupler and the first went for a short holiday under the lathe bench without telling anyone where it was going.

The coupler will lock and unlock without the torsion spring, but this leaves nothing positively retaining the lock except gravity and nothing to kick the knuckle open on unlocking. This does leave the coupler with a tendency to come unlocked when hanging down out of use, which isn't strictly a problem but in my opinion isn't its best look.

It was in fitting the coupler to the engine that I finally encountered 3D printed 316 being the mulish and unpleasant metal I was expecting it to be; the tail of the coupling hook had been printed at slightly under $\frac{1}{4}$ inch to allow it to be threaded (not a prototypical mounting) but the shape of the hook didn't obviously lend itself to setting up in the lathe, so I put it in the vice and proceeded by hand with a $\frac{1}{4}$ inch x 32 die. This could have been easier.

Anyway, the A4 made it to the Midlands exhibition with a cosmetically complete coupler on the tender. I breathed a sigh of relief and promptly did nothing on couplers for a while.

●To be continued.



Coupler support pin and unlocking lever.

LNER B1 Locomotive

PART 33 – MORE CAB FITTINGS

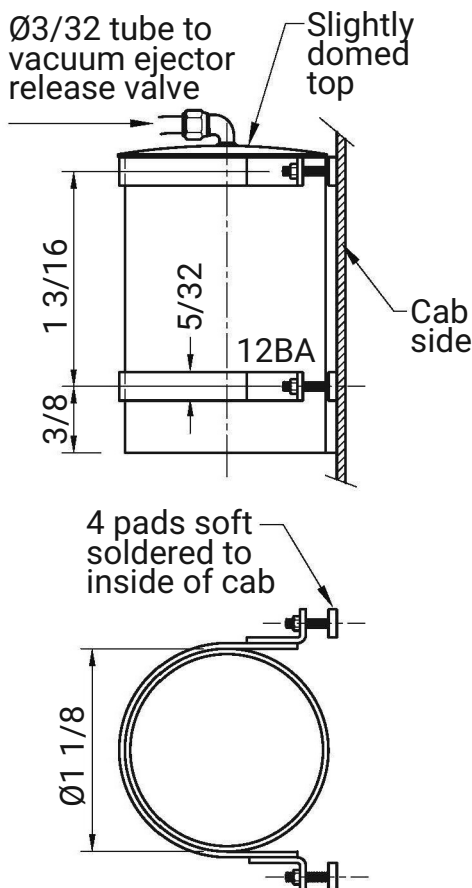
Doug Hewson

presents an authentic 5 inch gauge version of Thompson's B1 locomotive.



Continued from p.676,
M.E.4730, November 17

Fig 123



Vacuum reservoir.

To continue! Before we get stuck in, can I just say that when I have been judging locomotives at exhibitions I love looking in people's cabs. Some of them are quite basic and do not interest me that much. I can appreciate that some are built for ease of operation and I am afraid that those do not interest me too much but good for them as they make the exhibitions well worth the visit. Some engines are absolutely the bee's knees to look at until one gets a little closer and some are quite exquisite from both the outside and the inside. Now these are the engines which really interest

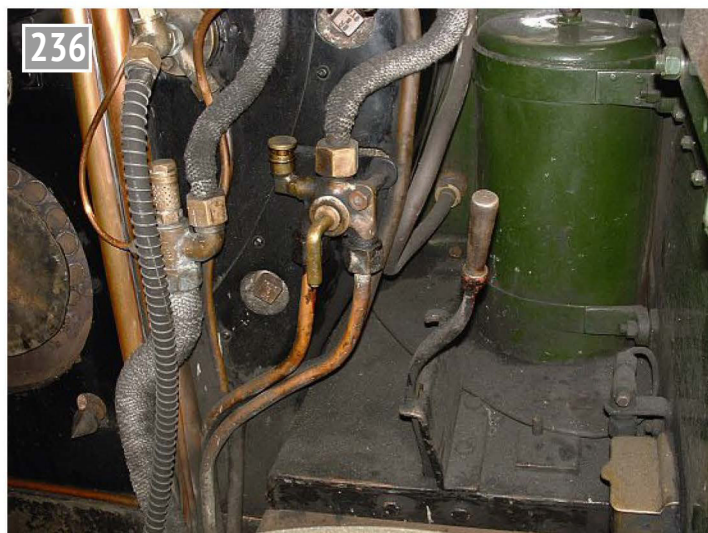
me the most. It only takes a few weeks' extra work to turn a mediocre engine into a very nice one.

There are various societies who cater for the details like the GWR, LMS, Southern, LNER and BR. I recently bought some exquisite drawings from the GER Society and that enabled me to finish my Y4 to a good standard, merely by altering the shape of things to match the photographs which I had obtained from the Transport Treasury. It made such a vast difference to the engine just for the sake of a few hours making alterations to the bits and pieces on the engine.

I have detailed the B1 cab

fittings as near as possible to the works drawings but there are some limits where I have drawn a line in the sand to make the engine drivable. I have used my design for quite a lot of the items, particularly the injector steam valves where I have made them to open quickly, but there is nothing that hasn't been tried either on my own Y4 or my BR 4MT, which I am sure you are sick of hearing about. The one thing that I found to be a great success are my double row of superheater elements, the atomisers, the rocking fire grate and the PTFE valve seats which we will come to very shortly, all of which have been tried out on my 4MT to see if they worked and prior to that some have been tried out on my Y4.

I have made a start on the lower right hand side of the cab with the first job being the vacuum reservoir (**fig 123**). This can just be a piece of $1\frac{1}{8}$ inch tube $1\frac{1}{2}$ inches long. Now, if you are fitting vacuum brakes to your engine then it will need to be silver soldered to store the vacuum, if you can store a vacuum! It doesn't particularly matter too much about the size of the tube as long as it is somewhere near to the size so you could use a piece of 28mm domestic plumbing tube if you know a plumber! The top needs to be dished slightly so that the dome is on top. There are a couple of straps to hold it in position and they are anchored to the right-hand cab side with a couple of pads soft soldered to the inside of the cab. From the top is a $\frac{3}{32}$ inch pipe which runs across the boiler backplate just under the tea can shelf across to the vacuum release valve under the brake ejector and there it should stay. It needs to be $1\frac{1}{16}$ inch forward of the step (**photo 236**).

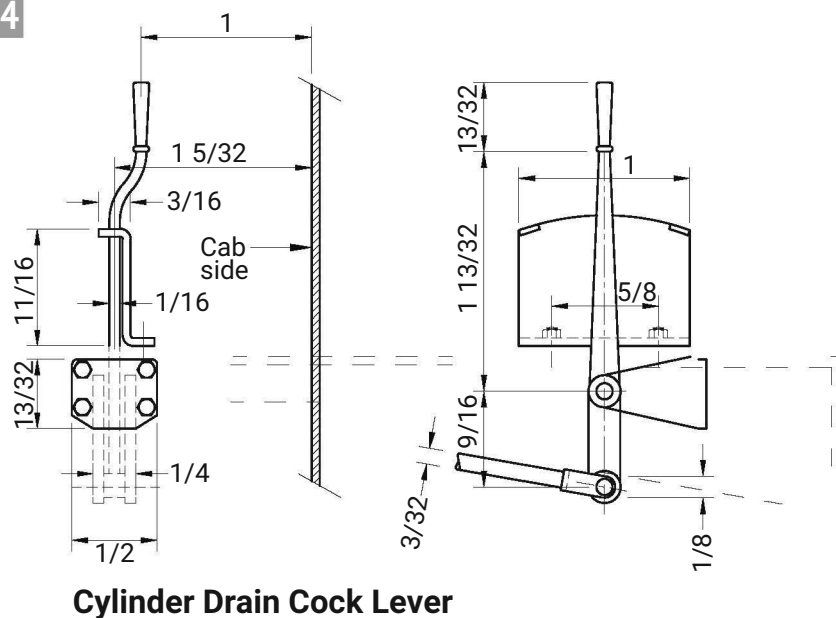


Vacuum reservoir (photo by John Thompson).



Drain cock lever.

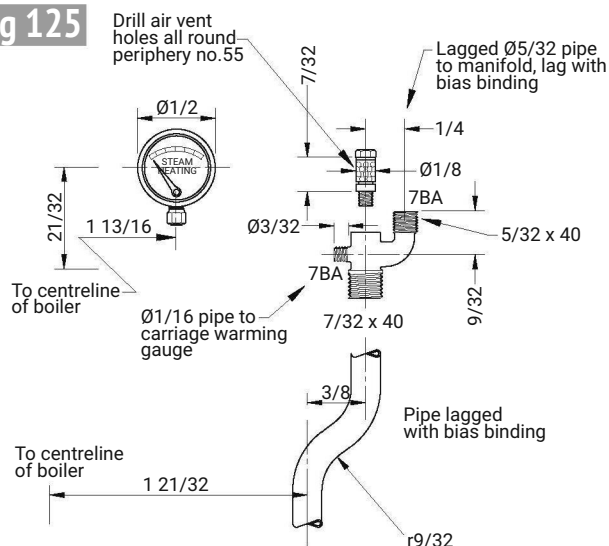
Fig 124



Cylinder Drain Cock Lever

Drain cock lever.

Fig 125



Steam heating 'pepperpot'.

Photograph 237 shows the drain cock lever (**fig 124**) and this can be just a piece of 18swg plate and a length of 16swg steel bar. The trunnion that it pivots on is just a piece of 1 inch wide 18swg plate with the top shaped in a curve using the pivot point as the centre and a notch at either side used as a stop. These two just need bending over and the base just needs bending in the other direction with a couple of 10BA bolt holes to fix it, either with bolts from the underside or a couple of 10BA studs. The handle needs to be a bit stiffer, like 16swg plate, and needs filing to the shape shown. The lever needs fixing 1 5/32

inches inboard of the cab side and be fixed to the back of the step in the footplate and a little bit forward of the step in the footplate – say 3/64 inch.

The actual drain cock rod needs the threading its way through under the cab, through the two rear platform brackets either side of the rear sand box and through the motion bracket and along under the right-hand side platform until it meets the cross shaft to the left-hand side of the engine. If you have got that lot, then top marks to you!

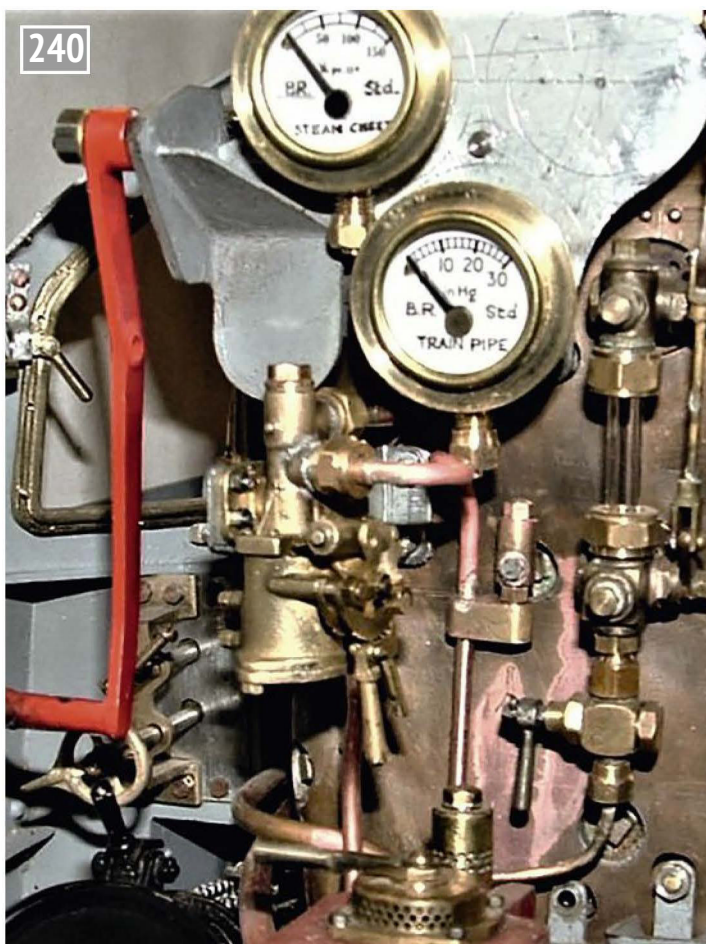
The next fitting to make is the carriage warming valve which can be all dummy, that is unless you really want steam heating on your engine! If you do then you will need some coaches with steam heating so that when you pull into a station you can make sure that there is a leaky pipe between the coaches to add a bit of atmosphere to the scene! I do know someone who has done that, and it does look the part! I think I have given you enough information to make the parts as dummies and I have split it down into its separate parts so that you can actually make it (**fig 125**). The only thing is, be careful with drilling the pepper pot as I may have got the drill size wrong so it might be a question of suck it and see. I drilled my pepper pot on the Class 4 by making a very short drill with the end shaped like a dart, or make one from a broken drill. I am sure you must have one the correct size!



Pressure gauges with flanges.



Substituting a scale nut for the gauge.



Train pipe and steam chest gauges.

Also, on my 4MT I made some very thin brass flanges to go on all of my pressure gauges so that they appeared to be one third the depth of what they really were. **Photograph 238** shows these and I have also shown one of the more to scale nuts on the bottom left-hand gauge. I also made some proper union nuts for them as I thought that the ones supplied were far too large. **Photograph 239** shows the two nuts, one being the nut supplied and the one on the gauge is one of mine for comparison. I was just rather sorry that I didn't think to make some new faces for the gauges on the computer instead of hand painting them. I had to squeeze the word 'CARRIAGE' into a space of 5/16 inch!

The two gauges on my own footplate are on the left-hand side of the cab but are shown with the flanges and union nuts on (**photo 240**). There is also a pepper pot (shown on photo 236) which was drilled with the dart shaped drill with about 1/4 inch protruding from the chuck.

To finish the job off you need to paint the backs of the gauges matt black and then they will be far less noticeable.

The pipe from the manifold down to the carriage warming valve is lagged and to do this I have recommended cotton 'bias binding' from a haberdashers. This is of course far too wide but if it has scale overlaps you can easily disguise that. The pipes are lagged from the manifold down to the valve and then down to disappear under the footplate. The carriage warming valve needs to be 2 1/32 inches from the boiler centre line and 2 21/32 inches above the footplate. The gauge needs to be 21/32 inch above the boiler centre line and 1 13/16 inches to the right of the centre line.

● To be continued.

NEXT TIME

Even more on the cab fittings.

DIY Model Engineering Cylinder Alloys

Luker presents a new cylinder casting alloy.



Some context

When it comes to model live steam cylinders we are all familiar with gunmetal and cast iron. These two alloys not only proved themselves in the hobby but also in large scale with the largest of locomotives successfully running with superheated steam using cast iron cylinders. So why mess with a proven formula? Well, not all cylinders are suitable for cast iron, especially if the locomotive will stand for long periods. My current project has cylinders that are slanted at an angle so any condensate will accumulate on the piston and I suspect oil squirted into the top tallow cock will only displace the problem. Gunmetal is of course the logical alternative but due to rather unfavourable local conditions the availability (and cost) of granulated tin has become prohibitive. I just can't bring myself to use lead free solder as a source of tin; regardless of the quantities, it's just wrong! As the saying goes 'necessity is the mother of innovation' so I set about looking for viable material



Eccentrics and straps in the same mould.

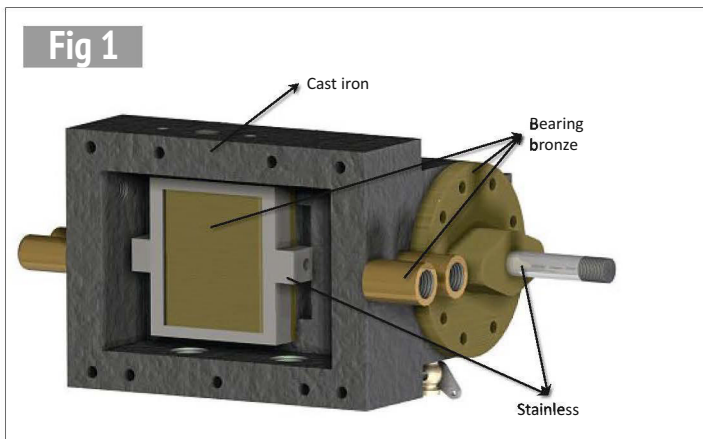
alternatives for cylinder castings. Before I get to what I ended up making those rather interesting cylinders out of, I'll go through some of the alloys I've used and, in so doing, develop a basis for comparison.

Cast iron for steam cylinders

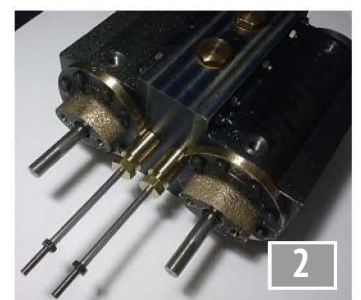
From the onset of my initiation into model engineering I've preferred cast iron for cylinders; it's relatively easy to cast and, provided your mix is correct and you don't let the pot cook, it's easy to machine. The wear and friction characteristics are also incredibly good; in fact, it's better than the bearing bronzes on steel. It's one of the few materials that won't cold weld (commonly called galling) if used for both contact surfaces in a bearing application. In fact, I've even cast eccentrics and eccentric straps in the same mould and they have performed incredibly well so far (photo 1). Incidentally, I read recently that eccentrics and

straps made in this fashion for large scale locomotives were called 'install and forget bearings', provided they were properly oiled.

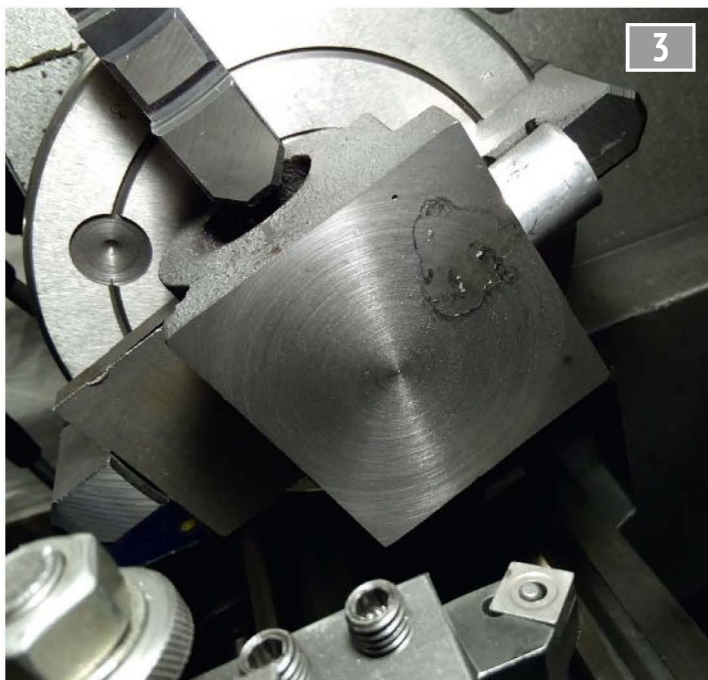
All of the cast iron cylinders I've made have been fitted with cast iron pistons and rings, and the only place where I use a bearing bronze is on the piston side end cap and valve rod bearings (fig 1 and photo 2). I find this a little more forgiving on the stainless-steel rods. I personally haven't had any issues with corrosion but after each run I do squirt some oil into the valve chest and rock the locomotive until the condensate from the drain cocks is replaced



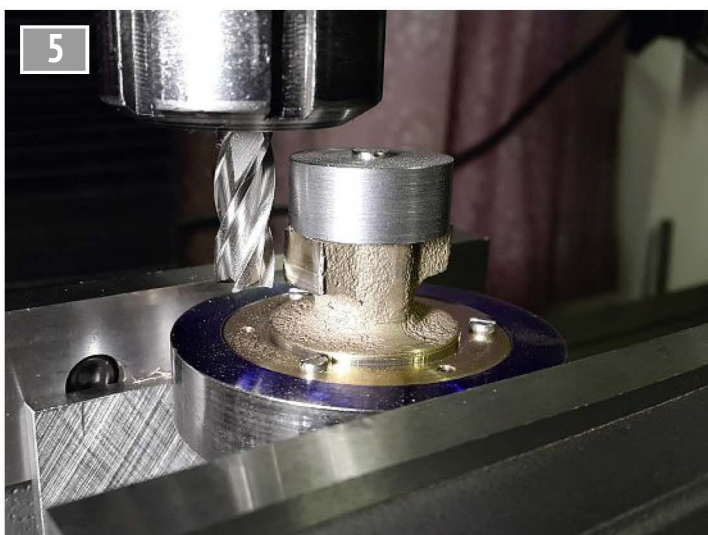
Cast iron cylinder.



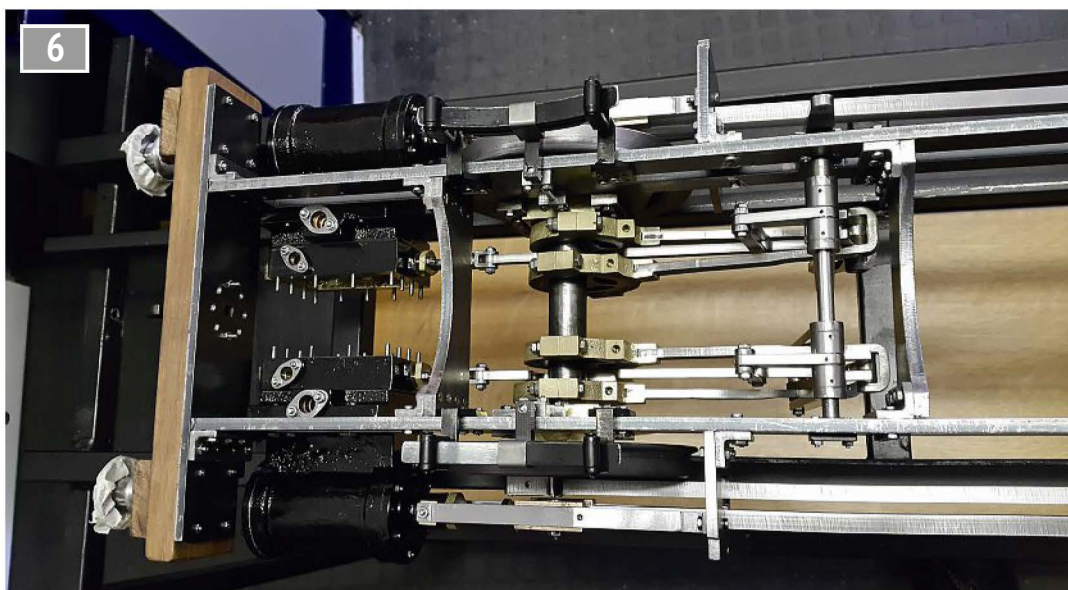
Cast iron cylinders with bearing bronze covers.



Cast iron welding repair.



Typical! Burring when machining gunmetal.



Completed gunmetal cylinders fitted to frame including gunmetal eccentric straps.



Gunmetal cylinders - note the thinning around the steam channels to improve casting.

by the oil. This, sadly, would not work if there is no drain cock at the top end of the cylinder, only a tallow cup that screws into the cylinder cap.

One thing I do make a point of doing with cast iron rings is wiping a little copper slip into the piston ring groove before fitting the rings. I have found this helps to prevent the rings corroding in the grooves due to trapped condensate.

The only negatives I can think of with cast iron is that it takes a little longer to heat up the pot for casting and it is a more difficult to machine if there are any hard spots (which, of course, there shouldn't be). If you've had a bad day on the track **and** for some reason the mechanical lubricator fails **and** you forget to oil the cylinders when packing up, then you might get some corrosion and the cylinders might seize. Then,

of course, if you have a man cave instead of a workshop, you may not like the dust that you can get from cast iron when machining, although if cast properly the dust will be minimal. I most certainly don't have a man-cave because there's a pink vacuum cleaner in the workshop!

Repairing cast iron cylinders is rather difficult; any welding repairs are invariably harder than the base casting and solder (both the high and low temperature variety) doesn't bond easily (**photo 3**).

Gunmetal for steam cylinders

Gunmetal is easy to mix and melts at a low temperature so a small gas fired furnace will do for most small castings (**photo 4**). Getting a sound casting is another matter entirely; any thick sections need to be fed properly with adequate risers and ingates to prevent porosity and draw defects. Gunmetal and brass will also burn-on terribly if the temperature is too high when casting but this can normally be managed by adding flour to the facing sand or by dusting the mould with graphite.

The other issue I've always had with gunmetal is its affinity to auto feed when drilling, especially when using a pedestal type drill or mill-drill combo. You can of course grind a zero rake to the drills; easier said than done on a 1.6mm drill! Gunmetal also tends to burr rather badly when machining and from personal experience its wear

Table 1

Alloy	Composition (%)							
	Fe	Cu	C	Si	Al	Sn	Pb	Zn
Cast Iron (Grade 17)	97		3					
Standard bearing LG		83.5				7	7	2.5
6% AlBr		91.5		2.5	6			

Cylinder alloy compositions

Table 2

Alloy	Castability	Pattern Contraction Allowance (%)	TIG/Soldering	Machinability
Cast Iron (Grade 17)	Good	0	Poor/poor	Good
Standard bearing LG	Fair	1.3	Poor/good	Average
6% AlBr	Very good	1.5	Good/good	Good

Cylinder alloy workability

Table 3

Alloy	Tensile Strength (MPa)	High temperature steam corrosion resistance	Wear resistance	Galling resistance
Cast Iron (Grade 17)	200-280	Good if lubricated	Very good	Exceptional
Standard bearing LG	240	Good	Average	Good
6% AlBr	>250	Good	Good	Good

Tensile strength estimated for 6%AlBr by interpolating between similar alloys.

Corrosion resistance based on personal experience and reported similar alloys.

Wear resistance based on personal experience and reported similar alloys.

Galling resistance based on cold welding on the tool during machining with no machining lubricant.

characteristics aren't as good as some of the other copper bearing alloys (**photos 5 and 6**).

The 'new' alloy for cylinders

A friend of mine who supplies computer aided design tools for the engineer is always interested in my little backyard adventures and on more than one occasion has offered to try out software solutions to solve a **real** engineering problem. He offered to put some design criteria into a new materials selection program his company was marketing to narrow down the search for a viable cylinder alloy alternative. The criteria included all the usual requirements, like castability, machinability, corrosion resistance for high temperature steam, low wear,

low friction and no galling etc. Unfortunately, one of the most critical requirements isn't an option in the selection criteria which I think is an egregious oversight by the programmers. This of course was - all base metals need to be found on the side of the road or in scrap piles. Interestingly enough the program spat out a few alloys I had never heard of like austenitic cast iron and a few rather expensive alloys like the high nickel bronzes. It did remind me of a group of alloys very seldom mentioned in live steam model engineering circles, namely the alumina bronzes. One of the very first alloys I cast was actually an 11% alumina bronze but machining it was like machining stainless; incredibly tough and it did a good job

blunting my HSS tools. The advantage of this alloy group is that the two base metals are very common as scrap. Copper is found in nearly all electrical appliances, as well as plumbing, and aluminium is just about everywhere. Having an alloy group to focus on, I set about formulating a more forgiving AlBr for live steam cylinders.

6%AlBr - the alloy

I don't have access to all the fancy pyro-metallurgical software for calculating alloy compositions and, to be honest if I did I probably wouldn't bother using it. On the other hand, throwing a handful of metals into the pot and expecting a favourable outcome is leaving success to chance which, more often than not, ends up in disaster. Luckily for the backyard guy there are hundreds of listed materials, all including various properties that give an indication of how an alloy will perform. With a basic understanding of what the various alloying elements do, alloys can be left out or substituted depending on the specific characteristics required. Similar alloys in a specific group can be interpolated to get a rough estimate of a new alloy's mechanical properties. This is, of course, a rough guide but much better than shooting in the dark and, for the most part, more than adequate for the backyard foundryman's purposes.

The biggest hurdle with the AlBr alloy range is the machinability. Adding Pb (which is a common alloying element to improve machinability) to the mix will only result in hot tears when casting and ultimately a weak alloy. The lead, kept out of solution by the aluminium, stays liquid during the solidification phase ending up on the grain boundaries which inherently results in a 'soft' (waiting to happen) crack. Silicone (Si) is a viable alternative to improve machinability without the detrimental effects associated

with lead. Lucky for the backyard foundry FeSi is a common inoculant for cast iron and this was used for the current alloy with great success.

When comparing alloys of similar composition, the corrosion resistance (including a steam environment) was found to be very favourable. This will only be verified once the locomotive has done a few laps around our little track.

Casting 6%AlBr

The 3D printed pattern, including the contraction allowance (see table), used for the new cylinders resulted in the end castings spot on, or at least as good as can be expected for sand castings. The risering and ingating is slightly different with larger risers required when compared to both cast iron and gunmetal. One very good casting characteristic of AlBr, due to the short cooling range, is that it tends to solidify compactly similarly to pure metals. This short cooling range does however require larger risers and ingates so that they remain liquid for the full duration of the main part of solidification. The gunmetals and tin bronzes tend to have a larger cooling range which can result in porosity, draw holes, piping etc. (see **tables 1, 2 and 3**).

As mentioned in my casting articles the lower melting point alloy is added to the crucible first and then the copper added as the charge melts. The FeSi is added (with copper) when the crucible is roughly $\frac{3}{4}$ full to improve pickup and prevent fade (which is a fancy word for the Si losing its effectiveness in the melt).

AlBr is particularly forgiving in the sand moulds when it comes to sand penetration or burn-on. I added a little coal dust to the facing sand in the same quantities as used for cast iron for all the AlBr castings.

Machining 6%AlBr

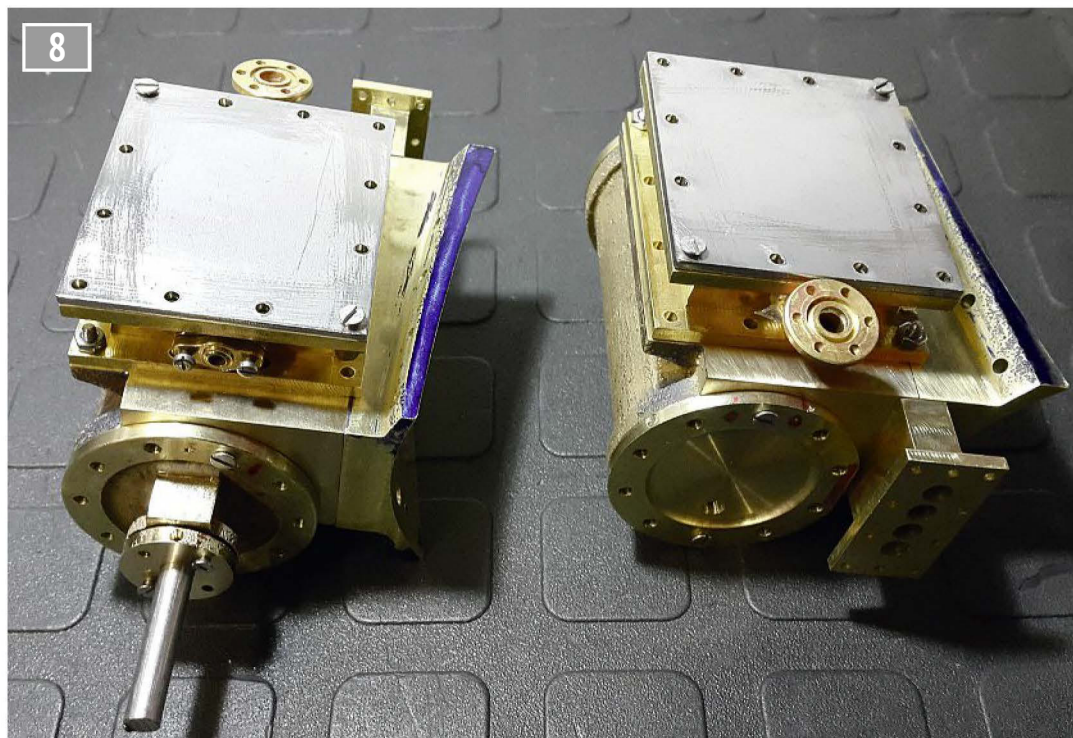
Machining 6%AlBr is similar to machining free machining mild steel. The chips break



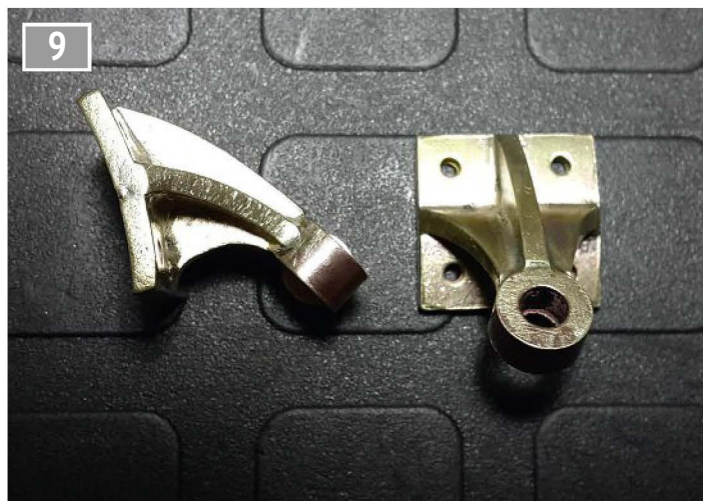
Boring a AlBr cylinder.

off nicely without making long curls that tend to get in the way when machining the bores (**photo 7**). When drilling and tapping small (M2 gland stud) holes no auto feeding issues were encountered and tapping was easier than normal mild steel. All drilling and tapping operations were done using HSS tooling with no special sharpening. The milling operations on the valve ports surface as well as the ports were milled using standard HSS milling cutters. All round, in my opinion, the machining is easier than gunmetal and the end surface quality is better (**photo 8**).

One of the observations I like to make when machining various alloys is how the chip comes off the tool and if any cold welding or galling takes place. Materials like copper or aluminium leave tell-tale signs (build-up just behind the cutting edge) on the tools that they are prone to galling which is a very good indicator that they would make poor bearings. No build-up was observed on any of the tooling used to cut the 6%AlBr with no cutting fluid or lubricant



A set of AlBr cylinder assemblies.



Bearing AlBr soldered to some brass plate.

used (other than tapping fluid for tapping) during machining.

Joining 6%AlBr

The AlBr alloy range can easily be welded using TIG or MIG unlike any alloy containing

Zn which tends to fume (quite violently) during the welding process. AlBr can also be both soft and silver soldered with both soldering processes resulting in a good bond (**photo 9**). I've also silver

soldered AlBr to brass, in this specific case the AlBr was soldered to some brass plate I had lying around to make a neat little bearing stand.

Full steam ahead

Most of the article focused on steam cylinders but I have used AlBr as a replacement alloy for the current builds' eccentric straps, crossheads and axleboxes. Provided you don't need to go and buy the copper (i.e. it's on hand as scrap) this alloy is incredibly cheap and, in many ways, outperforms the more commonly used gunmetals or tin bronzes. For my next build it might be difficult to decide whether or not I go for cast iron or AlBr; that right there says a lot about this 'new' alloy!

ME

A Model Engineer's Clock

PART 6

Jim Clark
makes a
skeleton
clock making good use
of modern manufacturing
methods.



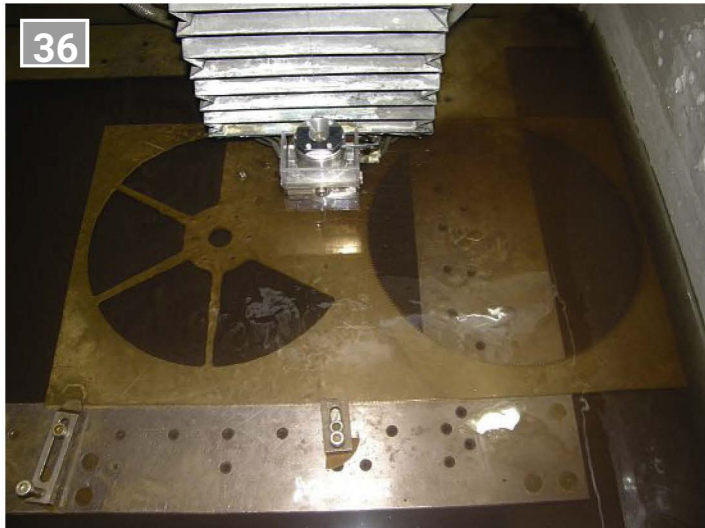
Using modern technology in a traditional craft

One of the objectives of this project was to make the best possible use of available modern technology to achieve the required traditional results.

EDM (wire cutting)

A major contribution was the use of Electrical Discharge Machining (EDM). This is an electro-thermal production process where a thin single

Continued from p.697
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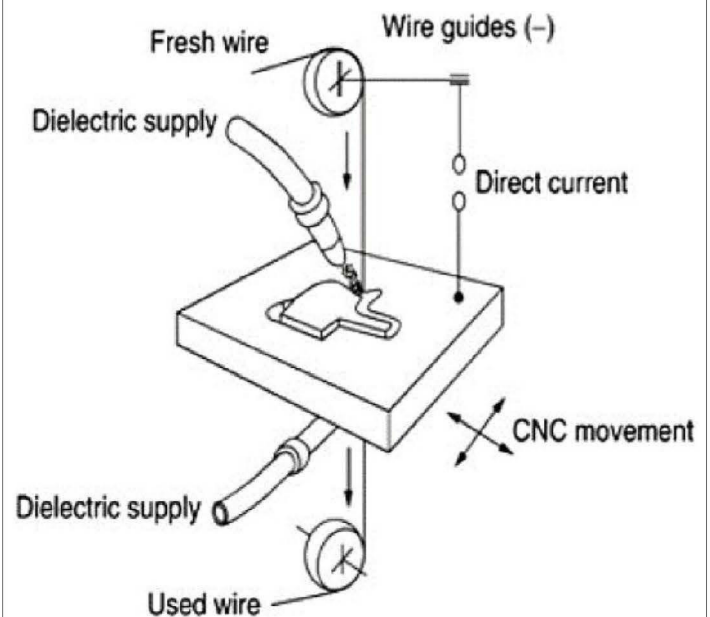


Here is the great wheel being cut out of a sheet of 5mm brass on Ron's EDM. The machine is working on the crossing out of the second wheel, the large empty circle at the right is where the first wheel has already been cut out.



Here is a great wheel completed, with the centre pinions on the left, one mounted on the centre shaft.

Fig 10



Schematic representation of EDM (wire cutting).

strand of metal wire is used to cut through a workpiece (fig 10). A low DC voltage applied to the wire produces sparks where it contacts the metal workpiece and this erodes away the metal. De-ionised water provides a dielectric medium around the spark gap that washes away the oxides and debris from the spark erosion process.

The workpiece is fixed to a table, which is moved past the wire under CNC control to form the required shape - a slow process (mm per minute) but very accurate results can be achieved to very fine tolerances, with an excellent surface finish (photo 36). The whole job and the work table are completely submerged in de-ionised water.

All the pinions were also cut on the EDM machine.

This large wheel with its 300 complex tooth shapes stretched Ron's EDM close to its limits, both in workpiece size and also

the size and complexity of the cutting program (photo 37). Thanks Ron!

CAD/CAM

Another important contributor to this project was the use of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM). Mention has already been made of CAD to design and draw up the clock layout and its parts. The resulting drawing files are passed through a CAM system to produce the cutting files that the EDM uses. The cutting files are CNC commands in G-code that tell the EDM where and how it must move in order to cut out the shapes.

Wheel and pinion tooth design

A further chief design requirement is obtaining the correct shape of the teeth on the wheels and pinions. The earliest gears had a cycloidal tooth form, a design going back to about the 14th or 15th

Century which, presumably, was originally developed empirically to obtain a smooth rolling action between gears. There were many slight variations in tooth form depending on the clockmaker. The full geometric theory came later and the modern tooth profile requirements are contained in British Standard 978 Part 2: Cycloidal Type Gears.

Cycloidal gear teeth are drawn by connecting two curves, an epicycloid and a hypocycloid. An epicycloid curve is the result of rolling a circle around the outside of another circle. Conversely, a hypocycloid curve is the result of rolling a circle around the inside of another circle. In the case of gears, the circle the other circles are rolled along is the pitch circle – the dotted arc in **fig 11**.

The addendum a_h and dedendum d_h of a gear shown here are the distance the tooth projects above and falls below the pitch circle respectively.

The addendum of the cycloid tooth is an epicycloid and the dedendum of the cycloid tooth is a hypocycloid. The addendum radius a_r shown in this sketch is the radius of a circular arc that approximates the epicycloid addendum curve.

For two cycloidal gears to mesh properly, the addendum of one gear must match the dedendum of the other gear and vice versa. This means that the design of a cycloidal wheel is dependent on the pinion it meshes with and that cycloidal gears cannot be interchanged in order to change gear ratios.

The cycloidal gears used in clocks are a special condition of a cycloidal gear. In clock gears the diameter of the rolling circle of the hypocycloid is one half the diameter of the pitch circle. This results in the dedendum flanks of the cycloidal tooth being a radial straight line instead of a semicircle (**fig 12**). On the pinions of a clock the addendum is rounded over so that it is not full length, as shown in the pinion in **fig 12**.

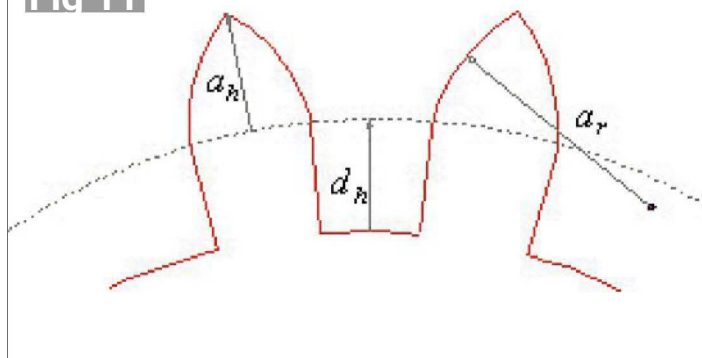
This is done to ensure that the tooth face of the driving wheel only engages with the tooth face of the driven pinion at or after the centre line between the two; not before it.

The tooth faces in contact are therefore always sliding apart, not towards each other, while the wheel turns the pinion. This reduces the effect of sliding friction between the tooth faces and helps to ensure smooth meshing of the gears.

(Side note: Most modern gears are of the involute form, a design which was developed in the early 20th Century and allows for easier production of gears. Involute gears also transmit more power and run more smoothly at higher speeds than equivalent sized cycloidal gears. However, pinions of the cycloidal form can have fewer teeth than involute ones, allowing for higher wheel-to-pinion ratios and cycloidal gears have lower friction, making them better suited to the low power, low speed, high step-up requirements of a clock.)

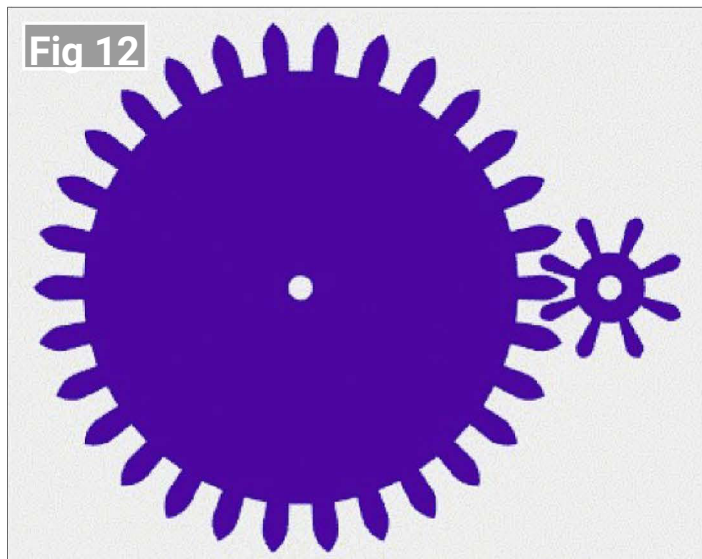
So how do we go about designing the ideal cycloidal tooth profiles for our desired selection of wheels and pinions?

Fig 11

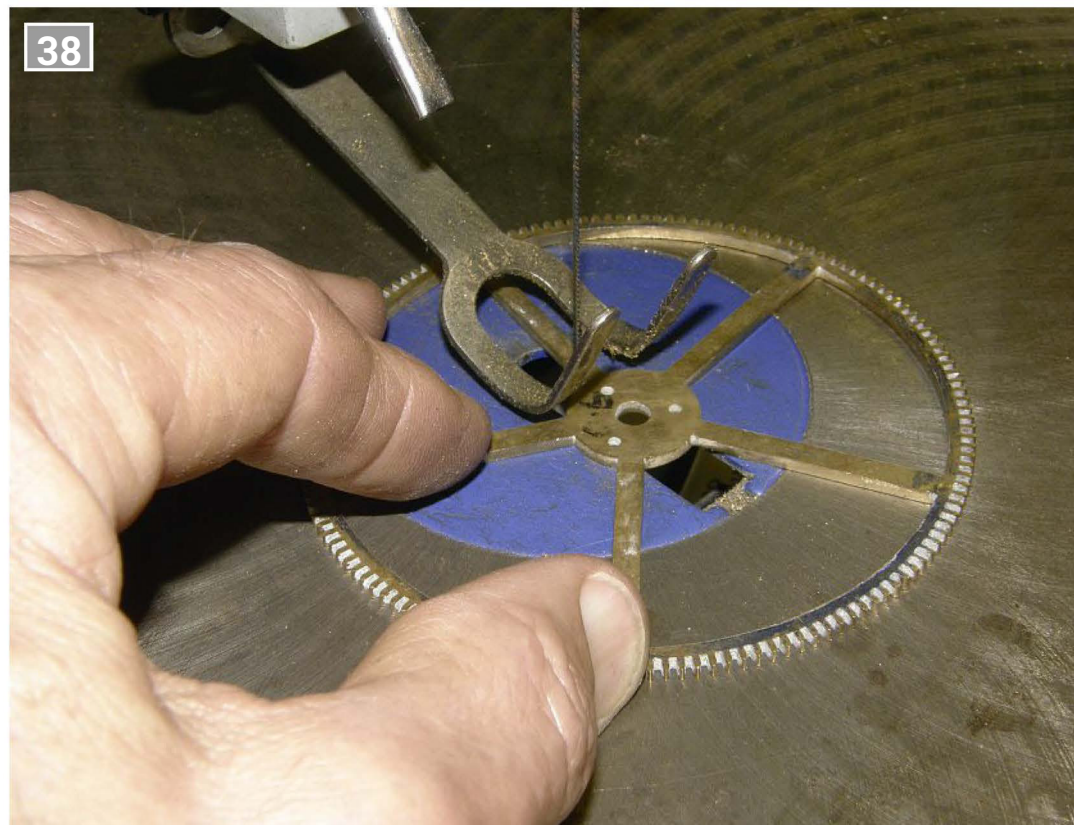


Component parts of a cycloidal gear.

Fig 12



Typical clock wheel and pinion shapes.



Hand cutting wheel spoke profiles.



A commercial tooth cutter for clockmaking.

Fortunately for us, there is a very useful website by Hugh Sparks which contains a great deal of theory on gear tooth design and also a handy calculator, see:

<https://www.csparks.com/watchmaking/CycloidalGears/index.jxl>

There is also a very useful online cycloidal gear builder program developed by Dr. Rainer Hessmer, see:

<http://hessmer.org/gears/CycloidalGearBuilder.html>

This program does the necessary geometric calculations for the tooth shapes and it will generate a drawing interchange file (DXF) for any selected combination of wheel and pinion. The DXF can then be imported into CAD or CAM and used to generate the required cutting profile.

This is what we used to provide the input for the EDM to cut out the wheel and pinion tooth shapes.

How is it done without using new technology?

A good question! Much can be achieved with a fret saw or scroll saw and files in the hands of a craftsman working to carefully marked out profiles (photo 38). This is how the spoked parts of the wheels are traditionally done (called 'crossing out').

The teeth are rather more difficult, however cutters of the appropriate size and shape can be purchased (photo 39). It is also possible to make your own single-point fly

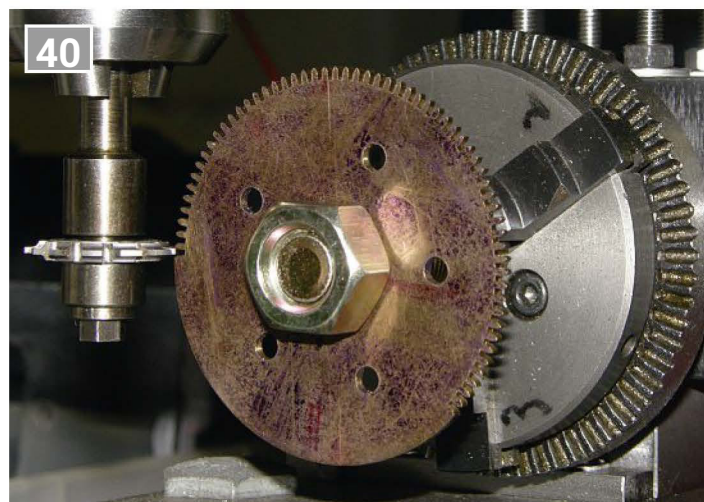
cutters, either by grinding the tooth profile into hardened tool steel, or by machining the shape into a suitable grade of steel and then hardening and tempering it.

The wheel blank is mounted on a dividing head or indexing fixture which allows the blank to be rotated exactly one tooth space at a time. This is set up in a lathe or mill with an arrangement to drive the cutter and each tooth is then cut individually (photo 40).

In actual fact, provided the teeth are evenly spaced and there is sufficient free play between the wheel and pinion to prevent them binding, almost any tooth profile will work – just with more friction and less smoothly. Due to the very high step-up ratio of the gear train and low driving power available, friction is the great enemy of clocks and will cause unreliability, or prevent it working at all so it is worth the effort to get the teeth right.

Historically, gear teeth would have been hand cut and filed out, a very tedious and skilled process and prone to error. This led to the early development of 'wheel engines' in the 18th Century, devices that were specifically designed to cut clock wheels. This improved the quality of clocks and made mass production of them possible.

For an absolutely excellent series of videos describing the building of John Wilding's original skeleton clock using traditional workshop



Example set-up for cutting a clock wheel.



A pair of Model Engineer's clocks together with their builders, Ron Collins (left) and Jim Clark (right).

machinery and techniques, search YouTube for 'clickspring skeleton clock' or see: <https://www.youtube.com/playlist?list=PLZioPDnFPNsETq9h35dgQq80Ryx-beOli>

Conclusion

This has been a fascinating blend of high school physics, old school craftsmanship and modern technology. A project which has provided much historical interest, many

technical challenges and an opportunity for expressing a specific artistic style, all of which I have thoroughly enjoyed.

Thanks also to Ron Collins - without his collaboration, design assistance and patience, not to mention the use of his machinery and materials, this project would not have been completed (photo 41).

Geoff Theasby reports on the latest news from the clubs.



And the tocsin tolls, relentlessly, one Club News after another. Is there no way of stemming the flow of Club News columns, before we go off up the wooden hill to Bedfordshire? There is a green hill far away without a City Hall, where you and I ... (see page 93).

In this issue, RLS, not slot cars, robot wars, a weekend away, shock waves? Souped up family saloon cars, odd number plates and disciplining children.

B&DSME News, from **Bournemouth & District Society of Model Engineers** opens with editor, Brian Merrifield, anticipating the Midlands MEX in Leamington Spa. Debs and I would be going on the Saturday. I see that Barry Linger is disposing of many tools, including a biscuit cutter. I tried one but found that although they last a long time, they don't have any flavour...

W. www.littledownrailway.co.uk

The Bristol Model Engineer from the **Bristol Society of Model and Experimental Engineers**, begins with Jeff Gearing noting the advent of small i/c engines from China. For years in the 1950s and 1960s the market was dominated by Frog, ED and so on, with little Chinese competition. Later, to assist their aerospace industry, they entered the hobby flying scene and nowadays offer 4 stroke and multiple cylinder engines from £150 kits upwards. Some of the designs have features reminiscent of Edgar Westbury... John Allen reviews the club visit to the Underfall Yard at Bristol docks, which has the original steam powered machinery, supplemented by a Colchester lathe. The machinery is still in working order but last turned about 12 years ago. An arsonist struck in May, although the workshop was not harmed, but the yard is running a relief fund for the small businesses who were burned out. Visitors are welcome on the afternoon to the last Sunday every month. Members visited Stephen

Wessel's garden railway which was featured in two separate reports from members. Very impressive!

W. www.bristolmodelengineers.co.uk

According to *Goodwin Park News*, autumn, from **Plymouth Miniature Steam**, the PMS Exhibition was a success. Especially busy was the robot wars display, with several visitors 'having a go'. The A1 Locomotive Trust has a new home, still in Darlington, not far from its previous address, but which is also rail connected and, being a new building, is equipped with a wheelchair lift, washing facilities etc.

W. www.plymouthmodelengineers.co.uk

City of Oxford Society of Model Engineers, sends *CoSME Link*, autumn, in which editor, Steph Delargy, compares HS2 (the plans for which are contracting through government interference) with CoSME's track, which is expanding. (Reminds me of an advert in the business section of my paper years ago, 'expanding contracting company is recruiting...') Anyway, Denis and Sue Mulford crossed the great divide and went to Cambridge visiting Top Field Light Railway. Their satnav took them down a country lane where a sign read 'Road Closed'. Seeing no alternatives, they carried on and emerged unscathed like a rat out of a drainpipe. The standard gauge Whitwell &

Reepham Steam Railway, run by W&RMEC, is ¼ of a mile long but big on ambition! The reason for the Mulford's trip to the area, Top Field Light Railway, was to present some awards. The club track is a 7¼ inch gauge railway with lots of eager youngsters to help and who are seemingly capable of handling any job they are asked to do. The following day Denis and Sue were at Bressingham Steam Museum. There are fewer fairground rides now and the glasshouses, once packed with plants, looked delapidated. There is also a 5 inch and 3½ inch gauge railway, but that also looked a little unused. Nevertheless, Mr & Mrs M enjoyed their visit and said it was good value for money. The Dreaming Spires Rally was well attended and successful. The 16mm railway was a new participant, which also proved very popular, perhaps because of the marquee in which it was located, out of the rain. It attracted 36 miniature locomotives to complement the existing stock. Present also were four traction engines and two miniature fairground organs, run by a matching Burrell Showman's engine, and with a Foster traction engine to boot. Finally, Simon Dawson reports on the Shinkansen 'bullet train', which was built from 1959 to 1964. Its name in Japanese means 'new main line'. In its entire history, there has never been a fatality due to a crash or derailment. The



London horse omnibus.



Viking longship. Surely a misnomer, they were very wide, essentially flat-bottomed.

Marston Court residents visited the railway, as they frequently do, and enjoyed their visit, as they also frequently do. Finally, Rugby narrow gauge rally has become a must for the Mulfords, who visit annually. On this occasion there were nine visiting locomotives, noted Sue and Denis.

W. www.cosme.org.uk

Our sojourn to Royal Leamington Spa was a curate's egg of a visit. The journey down was conducted in heavy rain all the way and a trip estimated at 2 hours became 4½. Driving

through the elegant streets of RLS is no fun when you are tired out and depending on satnav. The MEX was very good when we got there and we were almost alone in the hotel where we downed strong drink and retired at 9pm. The following day was completely different, bright, sunny and dry. The exhibition was well attended, traders and visitors, and with many superb models to admire. I liked the horse-drawn London omnibus (**photo 1**) - such a vehicle was first recorded in 1662 in Paris and in the UK,



Romany Ledge wagon?

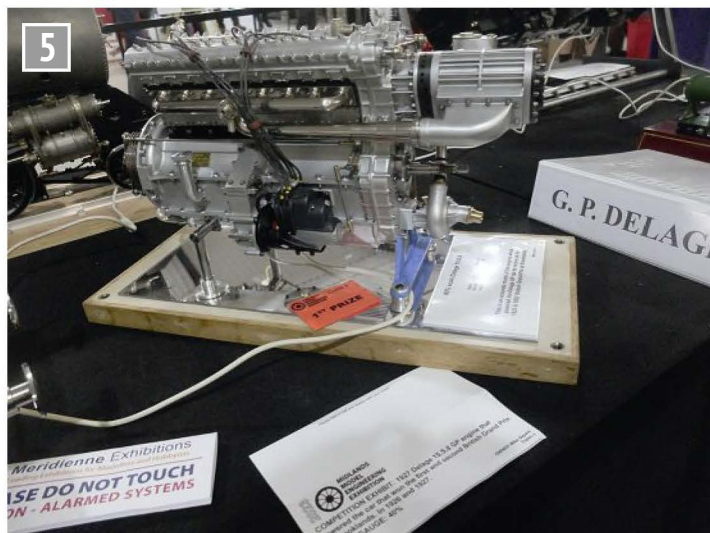
in Manchester, in 1824. I also liked the Viking longship, with active rowers (**photo 2**), and, on the same stand, a Romany



John Wilks's Cock o' the North in 10¼ inch gauge.

'Ledge' wagon. The use of flash illuminates the interior of what is a very comfortable travelling wagon (**photo 3**). John Wilks's Cock o' the North, of course, (**photo 4**) and Mike Sayers's 1927 Delage racing engine (**photo 5**) were the stars of the show. I thought that the most original stand was by Milton Keynes Clock Group, made up to look like a clockmaker's shop. One man scrutinised me across a stall, our eyes met and, for a moment, realisation struck and he turned away. The thought niggled though - where had he seen that face before? *Mad Magazine*? The 1895 gentlemen's lingerie catalogue? A gentleman on the rain who helped me asked where was I from. I said "Sheffield". "Wednesday or United?" I said I don't do football. "Rugby League?" he suggested. "No". "Trainspotting?" (I detected a certain desperation here) so I said amateur radio. He retired, beaten.

I have encountered a couple of items which look like railway points but with slot



Mike Sayers's 1927 Delage racing engine.

car features too. It appeared, after searching t'interweb, that it was part of a once popular track-guided, roadway system by Schuco Varianto, a German company. Each vehicle was guided by a single raised linear guide not unlike slot cars but without the slot. Wikipedia is quite informative on the matter. The track panels are linked laterally but not otherwise, and with no locking system, it would have needed a very smooth substrate on which to lay a running surface. The product was on the market for about 15 years, up to 1960, and was much cheaper than model trains. I'm sure there must be people 'out there' who collect this toy roadway. If that is 'you', these two items are yours for the asking if you email me at the address below.

One of the hazards of electronics is the presence or otherwise of supersonic particles. I bet you hadn't thought of that, had you? So, let me explain. Back in the days of valves and Henley Solon soldering irons, equipment was large and simple and, if it failed in service, then it stopped or it melted. Now, with millions of transistors crammed onto a small slice of silicon, the opportunity for them to go walkabout is correspondingly higher. This can be illustrated by the following voltage regulator Mach 3 saga. I was building a power supply to provide positive and negative voltages from one transformer.

Easy, you may claim. But I failed to notice a fundamental difference between the negative side of the circuit, in that it wasn't a mirror image of its positive sibling. So, overlooking the elephant in the workshop, a KT66 amongst the acorn valves, I plugged it in and switched on. What happened next was too fast (<40 ms, the response time of a circuit breaker) for me to react and a sizeable segment of an LM7924 zinged supersonically like a wayward SR-71, across the workshop into an inaccessible corner, where it tinkled down, like the ball in a pinball machine, bouncing off the shelves of components and equipment to repair, to join its fellows in a small but select group of the BBC (Broken Bits Collection). How glad I was that I had more to hand. Replacing the component, and after checking the circuit, observed by a large, mute, elephant, I repeated the activity, to be met with the sound of an LM7924 zinging supersonically... 'It's not supposed to do that', quoth I, but its aim was good.

Rain (see W. Somerset Maugham). The weekend after Leamington Spa we hied ourselves to Birmingham for a 'memorable' weekend with old friends. The train was cancelled. We departed Sheffield in heavy rain, bound for Birmingham, but going to Manchester and then turn left. The train was late, also slow, then cancelled at Brum. Taxi to

the hotel, still raining. Why did we not stay at the Travelodge opposite the venue? Because it was not an option when booking. Hmmm. Had to be helped from one to 't other after collapsing at midnight. We changed hotels the following day. Still raining. The new hotel is great. The old one had no tea and coffee facilities in the room, everything seemed to be made of plasterboard, and with no room to swing a cat. Debs was very tired pulling our wheeled suitcase up a hill, so I towed it with my disability scooter. Household technical consultant to the rescue - nothing scares me! Sunday, we returned home but, as Derby Station was still closed by floods, Network Rail suggested we retrace Friday's route via Manchester. Huh! Offered a lift by a Friend. Offer gleefully accepted. Now friend for Life! Home now, shattered - what a weekend! At one point, three small children who were having great fun with revolving chairs discovered that screaming at maximum volume was fun. After muttering between ourselves for a while, I stood up and spoke to their 'responsible adult' to the effect that if he didn't stop them screaming, 'someone' might suffer a mischief. Who somebody? he asked. "Somebody", I said and sat down. Debs asked, "You didn't!" I said, "I did". The screaming stopped.

Gauge 1 North, Yorkshire group, October Newsletter, welcomes their new chairman,

Adrian Johnstone. Secretary Malcolm High went to Barrow Hill for the 16mm AGM (Elsecar is being 'improved', I gather it declined after the Covid pandemic) and a claiming date has been set for next year at Bakewell.

W. www.gauge1north.org.uk

On the motorway, interesting vehicles were: a couple of racing vintage cars, a Ford Anglia 105E and Triumph Herald, both being trailered to or from an event, Star Sleeper coach, reg. no. BU55 BED, a SETRA, from Daimler Benz. Other vehicles in this organisation have similar styled registered numbers. A white van claiming to be a 'Tarmac Pirate' (look them up). The numberplate on this vehicle did not conform to the DVLC record if I read it correctly. Also a Nissan Navara and a Chevrolet Camino, both pickups. Lastly, we caught a West Midlands Metro tram back to New Street station, on the newly opened Edgbaston line. It was an 'Urbos 3', by Spanish company CAF (photo 6).

And finally, from B&DSME. The Pleasure Gardens dodgems director has been sacked, he is claiming funfair dismissal.

ME

CONTACT

geofftheasby@gmail.com



West Midlands Metro Tram No. 51.

Club Diary

1 December 2023 – 1 February 2024

December

1 Rochdale SMEE

Talk by Bob Hayter, Castleton Community Centre, 19:00.

See www.facebook.com/RochdaleModelEngineers

2 Tiverton & District MES

Running day at Rackenford track. Contact: Chris Catley, 01884 798370

3 Canterbury MES

Public running. Contact: ginapearson@btopenworld.com

3 Guildford MES

Open day, 11:00-15:00. See www.gmes.org.uk

3 North Wilts MES

Public running at the Coate Water Railway, 11:00-dusk. See www.nwmes.info

3 Warrington & District MES

Running day at the club track. See www.wdmes.org.uk/events

6 Bradford MES

Film night, Saltaire Methodist Church, 19:30. Contact: Russ Coppin, 07815 048999

7 Sutton MEC

Bits and Pieces evening 20:00. Contact: Paul Harding, 0208 254 9749

7 Warrington & District MES

Projects/natter night, St Mary Magdalene Church, WA4 3AG, 20:00. See www.wdmes.org.uk/events

10 Canterbury MES

Public running. Contact: ginapearson@btopenworld.com

10 North Wilts MES

Public running at the Coate Water Railway, 11:00-dusk. See www.nwmes.info

10 Small Model Steam Engine Group

Open meeting. 14:00-17:00. See www.gmes.org.uk

10 Sutton MEC

Track Day from noon – 16:00. Contact: Paul Harding, 0208 254 9749

10 Taunton Model Engineers

Public running – Santa Steaming, Vivary Park, 12:00-15:00. See www.tauntonme.org.uk

10 Warrington & District MES

Running day at the club track. See www.wdmes.org.uk/events

13 Bristol SMEE

Zoom meeting – your questions answered by wise men, 19:30. Contact: secretary@bristolmodelengineers.co.uk

See www.facebook.com/RochdaleModelEngineers

14 Newton Abbot & District MES

Mince pie night at Rydon Community Hall, Kingsteignton. See nadmes.org.uk

15 Rochdale SMEE

General meeting, Castleton Community Centre, 19:00.

See www.facebook.com/RochdaleModelEngineers

17 Canterbury MES

Public running. Contact: ginapearson@btopenworld.com

17 North Wilts MES

Public running at the Coate Water Railway, 11:00-dusk. See www.nwmes.info

17 Taunton Model Engineers

Public running – Santa Steaming, Vivary Park, 12:00-15:00. See www.tauntonme.org.uk

17 Warrington & District MES

Running day at the club track. See www.wdmes.org.uk/events

19 North Wilts MES

Public running at the Coate Water Railway, 11:00-dusk. See www.nwmes.info

19 North Wilts MES

Public running at the Coate Water Railway, 11:00-dusk. See www.nwmes.info

20 Bristol SMEE

Ordinary meeting, Begbrook Social Club BS16 1HY, 19:30. Contact: secretary@bristolmodelengineers.co.uk

21 Warrington & District MES

Talk: Julian Stow on 'Talylyn Railway', St Mary Magdalene Church, WA4 3AG, 20:00. See www.wdmes.org.uk/events

26 North Wilts MES

Public running at the Coate Water Railway, 11:00-dusk. See www.nwmes.info

26 Sutton MEC

Boxing Day run from 12 noon. Contact: Paul Harding, 0208 254 9749

27 Bradford MES

Mince pie steam-up, Northcliffe, 12:30 until frostbite sets in.

Contact: Russ Coppin, 07815 048999

2024

January

3 Bradford MES

Talk – Graham Astbury, 'Twist Drills', Saltaire Methodist Church, 19:30. Contact: Russ Coppin, 07815 048999

4 Sutton MEC

Bits and Pieces evening 20:00. Contact: Paul Harding, 0208 254 9749

4 Warrington & District MES

Projects/natter night, St Mary Magdalene Church, WA4 3AG, 20:00. See www.wdmes.org.uk/events

14 Sutton MEC

Track Day from noon – 16:00.

Contact: Paul Harding, 0208 254 9749

17 Bristol SMEE

Talk: 'Narrow Gauge Railways of India', Begbrook Social Club BS16 1HY, 19:30. Contact: secretary@bristolmodelengineers.co.uk

18 Warrington & District MES

Talk: Ian Lewis on 'Early Jet Aircraft', St Mary Magdalene Church, WA4 3AG, 20:00. See www.wdmes.org.uk/events

February

1 Sutton MEC

Bits and Pieces evening 20:00. Contact: Paul Harding, 0208 254 9749

1 Warrington & District MES

Projects/natter night, St Mary Magdalene Church, WA4 3AG, 20:00. See www.wdmes.org.uk/events



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'Summer Lightning'



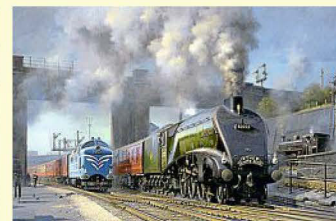
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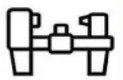
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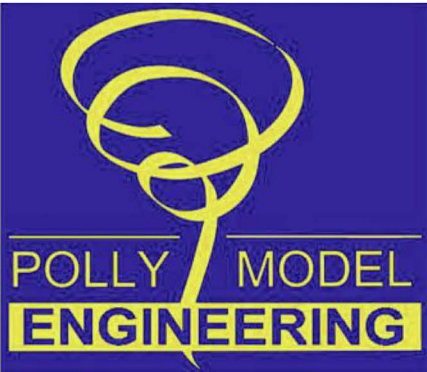


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Devil 7005	400V	5kW	£98.99	£118.79
Devil 6009	400V	4.5-9kW	£124.99	£149.99
Devil 6015	400V	5-10-15kW	£189.99	£227.99
Devil 7015	400V	15kW	£229.99	£275.99

• WAS £83.98 inc.VAT • WAS £117.59 inc.VAT

Clarke CS48 BELT AND DISC SANDER

• Belt sanding can be performed with the belt in the horizontal or vertical position • Includes dust collection bag

PRICE CUT
£199.99
EXC.VAT
WAS £245.00 inc.VAT

Clarke MILLING DRILLING MACHINE

- Bench mountable, tilts 45° left & right from vertical
- Table travel 100x235mm
- Table Effective Size LxW: 92 x 400mm



FROM ONLY
£549.00
EXC.VAT
£668.80 inc.VAT

PRICE CUT
£759.00
EXC.VAT
WAS £848.80 inc.VAT

Clarke TOOL CHESTS / CABINETS

Model	Desc.	exc.VAT	inc.VAT
CTC1800C	6 Dr chest	£389.99	£470.99
CTC1900C	9 Dr chest	£389.99	£470.99
CTC1900C	5 Dr cabinet	£149.99	£179.99
CTC800C	8 Dr chest/cab set	£149.99	£179.99
CTC700C	7 Dr cabinet	£169.99	£203.99
CTC1300C	13 Dr chest/cab	£169.99	£227.99

• WAS £239.98 inc.VAT

Clarke 3-IN-1 SHEET METAL MACHINES

- Bend, Roll & Shear metal up to 1mm thick • Min. Rolling Diameter 38mm • Bending angle 0-90°



Model	Bed Width	exc.VAT	inc.VAT
SBR305	305mm (12")	£299.00	£358.80
SBR610	610mm (24")	£589.00	£717.80
SBR760	760mm (30")	£689.00	£838.80

ROLLING, SHEARING & FOLDING
FROM ONLY **£299.00** EXC.VAT **£358.80** inc.VAT

Clarke INDUSTRIAL ELECTRIC MOTORS

Hp	Speed	exc.VAT	inc.VAT
1/3	4 pole	£79.99	£95.99
1	2 pole	£99.99	£119.99
3/4	4 pole	£104.99	£125.99
2	2 pole	£124.99	£149.99
3	2 pole	£154.99	£185.99
4	2 pole	£189.99	£227.99

• Range of single phase motors suited to many applications

• All totally enclosed & fan ventilated for reliable long-term service



FROM ONLY
£79.99
EXC.VAT
£95.99 inc.VAT

Clarke NO GAS/GAS MIG WELDER

- Professional type torch with on/off control
- Turbo fan cooled • Easy conversion to gas with optional accessories



Model	Min/Max Amps	exc.VAT	inc.VAT
MIG106	40/100	£179.99	£219.99
MIG145	35/135	£239.00	£288.80
MIG196	40/180	£279.00	£334.80

FROM ONLY
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Clarke MICRO MILLING & DRILLING MACHINE

- Bench mountable
- MT2 Spindle Taper
- Face mill capacity 20mm, end mill 10mm
- Table cross travel 90mm, longitudinal travel 180mm



• WAS £294.80 inc.VAT

Clarke DRILL PRESSES

- Range of precision bench & floor presses for enthusiasts, engineering & industrial applications
- B = Bench mounted
- F = Floor standing



Model	Motor (W)	Speeds	exc.VAT	inc.VAT
CDP5EB	350/5	£99.99	£119.94	
CDP102B	350/5	£115.99	£139.14	
CDP152B	450/12	£209.00	£250.80	
CDP352F	550/16	£339.00	£406.80	

• WAS £251.98 inc.VAT

Clarke ENGINEERS HEAVY DUTY STEEL WORKBENCHES

FROM ONLY
£289.99
EXC.VAT
£347.98 inc.VAT

Model	Diags. LxWxH (mm)	exc. VAT	WAS	inc. VAT
CWB1500D	1500x650x965	£239.99	£239.99	£293.98
CWB2001P	2000x650x965	£299.00	£299.00	£368.80
CWB2000D	2000x650x965	£299.00	£299.00	£368.80

• Includes SINGLE LOCKABLE DRAWER

Shown fitted with optional 9 drawer unit ONLY £165.98 inc.VAT

Clarke BENCH GRINDERS

Model	Duty Wheel Dia.	exc.VAT	inc.VAT
CBG6RZ	PRO 150mm	£54.99	£67.99
CBG6250LW	HD 150mm	£59.99	£73.99
CBG6370LW	HD 200mm	£96.99	£116.99

• WAS £80.39 inc.VAT

• WAS £119.98 inc.VAT

Clarke MMA & ARC/TIG INVERTER WELDERS

Model	Min/Max Output Current	Electrode Dia. (mm)	exc.VAT	inc.VAT
MMAT40A	20A-140A	1.6-3.2	£104.99	£125.99
MMAT200A	20A-200A	1.6-3.2	£139.99	£167.99
AT165	10A-160A	2.5/3.2/4.0	£219.99	£263.99

FROM ONLY
£104.99
EXC.VAT
£125.99 inc.VAT

Clarke BOLTLESS SHELVING/BENCHES

- Simple fast assembly in minutes using only a hammer



FROM ONLY
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Clarke ARC ACTIVATED HEADSHIELDS

- Activates instantly when Arc is struck
- Protects to EN379
- Suitable for arc, MIG, TIG & gas welding



FROM ONLY
£36.99
EXC.VAT
£44.39 inc.VAT

Clarke BENCH BUFFERS/POLISHERS

Model	Dia. (mm)	exc. VAT	WAS	inc. VAT
CB8150	150	£79.99	£99.99	£95.99
CB8200	200	£94.99	£119.99	£113.99
CB8250	250	£169.99	£209.99	£203.94

• For a brilliant shine

Clarke ROTARY TOOL KIT

FROM ONLY
£36.99
EXC.VAT
£44.39 inc.VAT

Kit includes:
• Height adjustable stand • 1m flexible drive • 40 accessories

PAY Monthly

- Spread the cost over 12, 24, 36, 48 or 60 months
- Any mix of products over £300
- 17.9% APR

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