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THE LEADING MAGAZINE FOR HOBBY ENGINEERS AND MODEL MAKERS

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Volume: 234, Issue: 4767, August 2025

IMLEC 2025

THE EDITOR REPORTS BACK ON THIS YEAR'S INTERNATIONAL
MODEL LOCOMOTIVE EFFICIENCY COMPETITION



The Stuart Planer

CHRIS GUNN INTRODUCES AN UNUSUAL
MODEL, MADE FROM A SET OF CASTINGS

Riser Design for Successful Castings

LUKER SHARES HIS METHODOLOGY
FOR AVOIDING SPOILT CASTINGS.

INSIDE this packed issue:

Machining Curved Slots with downloadable calculator • A simple Parting Tool Holder •
Machining Locomotive Cylinders • Spark Plug Spanners • A selection of tips – Brian
Wood's final article • Pannier Tank: Making the Boiler • Headstock Modifications for a
920 Lathe • Thermoset Plastics in the Workshop • Making a Corliss Valve Mill Engine.

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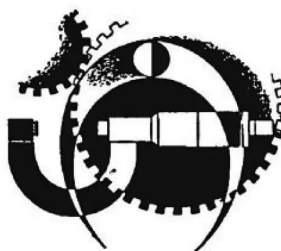
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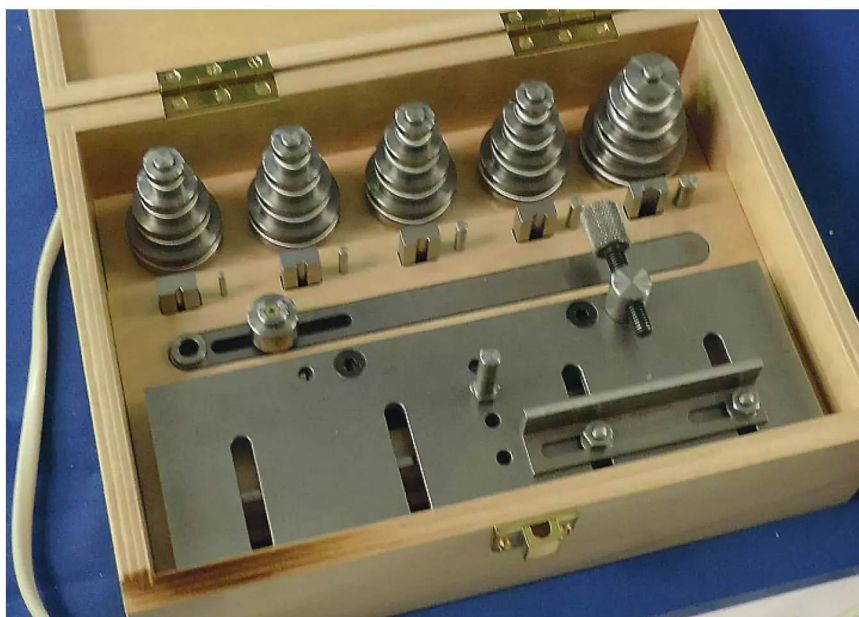


SMOKE RINGS

Short Series Sought

Following the recent reader survey I have
been looking at the articles lined up for the
magazine. There is one type of article that
would seem to fit reader's interests very
well, that I have relatively few of. That is
shorter constructional series, in perhaps
one to half a dozen parts, featuring a

relatively straightforward tool or model.
Mike Chrisp's pipe bending kit, photo-
graphed at Harrogate ten years ago would
be an example of something that could be
covered this way. If anyone would like the
guidelines for contributors, please do get
in touch.



The Bradford Cup and Stevenson Trophy 2025

I would like to remind readers of
these two competitions. Full details and
competition rules were published in issue
4766; I have only received a few nomina-
tions so, if you can help ensure it's a real
competition, please get your entries and
nominations to me as soon as possible.

The Bradford Cup is awarded to the

author of the best article or series in Model
Engineer/Model Engineer & Workshop
during the previous year. To make a nomi-
nation, please send the name of the author
and the article in question to meweditor@mortons.co.uk by **25 July 2025**.

The John Stevenson Trophy is
presented for a well-made and usable
piece of tooling, a modification to a
machine or an accessory for a tool where
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Neil Wyatt
Editor



Diane Carney
Deputy Editor

Neil Wyatt



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Spindle bore: 20mm
Spindle speed: 50-2500mm
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It's time to bag a workshop bargain, or if you have something to sell, email us the details or use the form in this issue.

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Why not follow us on X?

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There's lots of extra content to be found online to support past articles in Model Engineer & Workshop.

Find out more at: www.model-engineer.co.uk/forums

Download Luker's Riser Design Methodology Calculator using

this quick link or QR code:
tinyurl.com/433h4v9n



← Download Johannes Schiff's curved slot calculator using this quick link or QR code:

tinyurl.com/4x662us9

Hot topics on the forum include:

Boiler Design started by Charles Lamont. Online discussion of the Yield Point Method.

All things Beaver Mill started by Robert James 3. Several years of accumulated wisdom for owners of these versatile machines.

Firth Valve Gear started by Andy Stopford. An unusual valve gear arrangement used on Fowler traction engines.

Come and have a Chat!

As well as plenty of engineering and hobby related discussion, we are happy for forum members to use it to share advice and support. Come and join us – it's free to all readers!

On the Cover



Our cover features Andrew Pope's King Arthur Class locomotive *Sir Mador de la Porte* going up the 1:70 incline at Titchfield, during his run at the 56th International Model Locomotive Efficiency Competition. To find out more about the competition, see page 52.

Next Issue



In our next issue, Gerard Dean describes the challenge of bringing a rather large model around the globe.

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CIG81224	7.3 x 3.7 x 2.5m	140613578	£479.00	£586.80	£574.80
CIG1432	9.7 x 4.3 x 3.65m	140613594	£1079.00	£1318.80	£1294.80
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Making the Stuart Models Planer

Chris Gunn builds an unusual model from castings and this month he starts by introducing the Stuart Models machine tool range.

PART 1

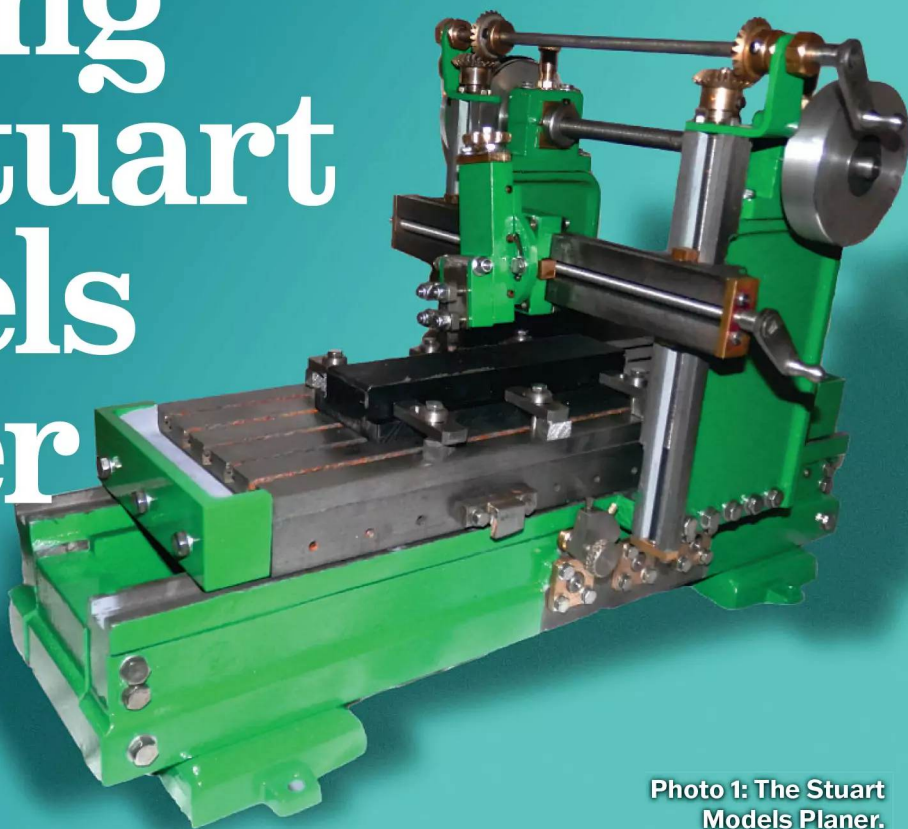


Photo 1: The Stuart Models Planer.

I have always been interested in miniature machine tools, maybe the very best were those built by Barry Jordan exhibited some years ago. I noticed recently that the Bridgeport miller and lathe he built was up for auction, but these will have been sold long before this article gets into print.

When Stuart Models introduced their range of machine tool casting sets I bought them as they came out and have completed them all. I also had an example of the steam hammer from way back which is an old favourite since the castings business was part of Stuart Turner. **Photograph 2** shows the wood turning lathe, and **photo 3** the metal turning lathe, which looks a bit bare without a workpiece in place.

Photograph 4 shows the shaper, also without a vice or workpiece. **Photograph 5** is the drill, this time I did make a small drilling jig to cross drill some pins, and clamps to hold it to the table.

Having built the machine tools I then became interested in putting together a miniature machine

shop, having seen examples of these at various exhibitions and museums.

One of my favourite miniature machine shops was seen at the Edison Ford museum in Fort Myers, Florida. Henry Ford built a winter home in Fort Myers, and was joined by his friend Edison. They set up some workshops and laboratories there and amongst other things used these to look for alternatives to natural rubber. More information can be had at www.edisonfordwinterstates.org.



One is able to visit the workshop and laboratory, which has a mixture of scientific equipment and machine tools driven by line shafts. In the museum section can be found many Edison related items, including

phonographs, and docents lecture and demonstrate the phonographs which I found very interesting.

There is also a model of the lab workshop. **Photograph 6** shows the real workshop, with the lathe front and centre, and a part of the shaper in the bottom right corner. **Photograph 7** shows the model with the lathe in the centre foreground and the shaper to its right.

By the time I saw this in November 2017, I already had this project developing in my head so I took pictures of the line shafting as well, as I intended to install this in my diorama. **Photograph 8** shows some of the line shafting in the real workshop.

I also saw some pictures of a diorama with some machine tools from PMR kits, with the line shafting driving them all, powered by a Stuart Models Victoria engine. I decided to get a Victoria kit from Stuarts and soon had that underway, **photo 9**. I also had a look at the PMR website and they list various machine tools and also line shafting kits; **photo 10** shows the un-machined PMR kit, with the two sizes of white metal pulleys



Photo 2: The Wood Turning Lathe.



Photo 3: The Metal Lathe.



Photo 4: The Shaper.



Photo 5: The Pillar Drill.

available.

They also stock some items to fit out a works office, and doors and windows to suit, which I believe are items used in dolls' houses. This is handy, as the items are to the same scale which means one can add any items that can be found in the dolls' house catalogues, so one could add a kettle, tea pot and mugs, as no engineering office is complete without these essentials!

I decided to order some kits from their range and arranged for them to be shipped to a hotel we were staying at in Fort Myers, Florida, after checking the weights to ensure I could bring them back. This all worked perfectly, thanks to all involved, and I have started on some of these kits. Being mainly white metal-based castings, one needs to adopt different means of holding some of the more delicate items, so I am having to make jigs to hold parts for machining.

To add to the mix I was lucky enough to pick up a part-machined set of castings for the Stuart under-type engine online and, fortunately, these had been started by a good engineer and were beautifully machined. I finished off machining the castings and

assembled the engine which ran very well on air. I decided to make a boiler for it, which was a nice change and kept the workshop warm for a few days in winter. Then I got carried away and made a plinth and a friend turned up some handrail stanchions for me

on his CNC lathe, so I took it apart again and painted it. This too looked good enough to build a miniature machine shop around, in due course. **Photograph 11** shows the under-type ready for work!

I now had the Stuart machine tools all done from way back, plus the Victoria and/or the under-type to drive it all, and the PMR line shafting kits ready to machine, together with some additional items for the diorama.

About this time I also saw the sample miniature planer on the Stuart Models stand at one of the UK exhibitions and this seemed ideal to include in my miniature workshop. When I made enquires, I was told that, at that time, they had no plans to market it. However I didn't give up and at the London exhibition in January 2019 Stuarts agreed to sell me a set of castings and the hand drawn drawings. In due course the castings were ready and I took delivery of them, and drawings, in March 2019.

I was not ready to start on the planer as I was finishing a 6" scale Ruston Proctor for a friend, but I did come across some of the history of the development of the planer in the book by L.T.C. Rolt entitled *Tools for the Job*. My version is the reprint by the Science Museum, an ex-library copy bought from Amazon. This is a good read if you are interested in the history of machine tools in the UK. At the time of writing there were copies still available.

I read that once the lathe had been refined and accurate round work could be undertaken - and Maudslay had produced his leadscrew lathe to enable accurate screw cutting,



Photo 6: Original workshop at the Edison Ford Winter Museum.



Photo 7: The museum's model workshop.

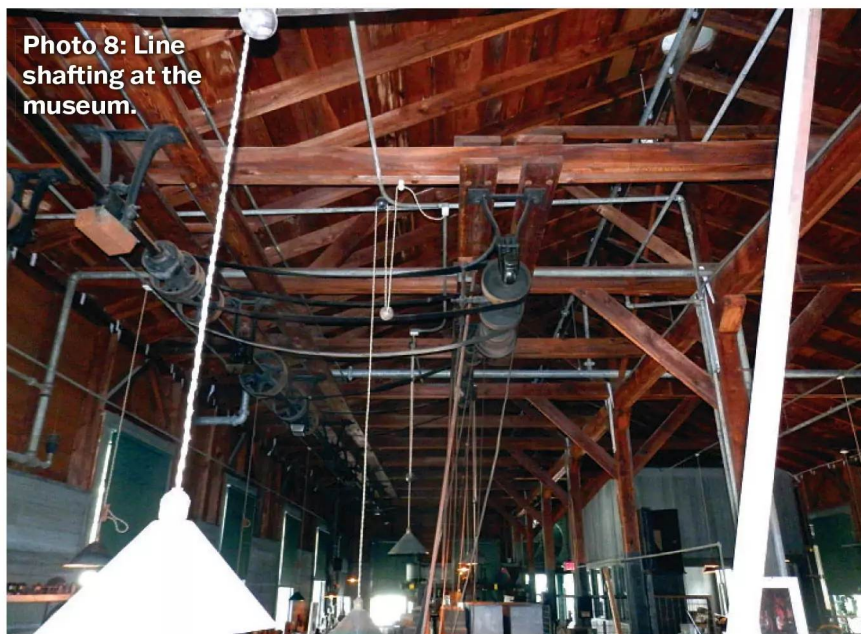


Photo 8: Line shafting at the museum.

measuring and dividing - then attention turned to producing accurate flat surfaces so the planer gradually evolved. The planer and lathes were then able to reproduce themselves.

I have mentioned before that I served my apprenticeship at Timsons in Kettering. At that time they were very big in the manufacture of printing presses, building bespoke machines for anything from postage stamps to postal orders and books and also a range of standard small machines called the Wun-Up. They also had a big planer which was impressive.

I wanted to illustrate the type of work the planer at Timsons used to do in this article, so when I was looking

for a picture of a typical printing machine, I started with a copy of the 100 Year Anniversary souvenir book that employees were given in 1996. I looked at the front cover, and found a picture of the factory way back, with all the machines driven from line shafting and, to my surprise, there in the middle left is a planer, of similar design to the Stuart model and next to it is a large radial drill that was used to drill the frames, **photo 12**.

I did manage to find a couple of pictures of the Wun-Up machines in the book; the original one, **photo 13**, the first Wun-Up, and the Wun-Up Litho S, **photo 14**. (Photographs 12 to 14 are used with the permission of Timsons Engineering Ltd.)

I worked on the Wun-up Litho S prototype when I was in the drawing office there, back in the mid 1960s. I also have a closer picture of part of the Wun-up litho side frame, which I must have obtained at the time, showing the part I was working on, **photo 15**. It can be seen that the base of this machine is a steel fabrication rather than a cast bed in the earlier versions.

All the printing machines Timsons made were built with cast iron side frames, up to 3" thick and up to 12 feet long and 3 or 4 feet wide. The frames were cast in their own foundry and were all machined on the large planer with a bed about 5 feet wide by 20 feet long. As a raw apprentice in 1960 I was fascinated with this machine which was the biggest in the machine shop and a sight to see in action. This was a key machine in the process and manned by a rather serious operator, Ken Pierce. At the end of the day, he was machining expensive castings so needed to be dedicated to his job. I discussed this machine with a couple of my fellow apprentices at a reunion recently, and learned that the planer had a DC drive, rather than the belt drive of the Stuart model. In the winter of discontent the company bought a generator to power the machine shop and someone had to come in early to start the generator then start the planer up early too before the rest of the shop turned up and turned on.

Apart from the drive, the later Timson's machine was similar to the model. The table used to *whoosh* back and forth, the DC drive returning the table quicker than the cutting stroke, and the tool would take a serious cut off the face of the castings. If space allowed, two castings would be machined at the same time. On occasions the planer would machine the steel bed fabrications mentioned above, and then passers-by would need a steel helmet as the chips came off like bullets, blue and smoking. Incidentally, the layout in the 1960s was just the same as in the old picture above, **photo 12**.

In that picture, next to the planer was a large radial drill, used to drill the frames in pairs. When I was there, much later on of course, the layout was the same; quite logical I suppose, as the frames would pass from the planer to the big drill. This was probably the second largest machine in the shop, manned by Bert Mills, one of the smallest men in there. Bert Mills was the brother of one of the Cockleshell heroes of WW2, Marine William Mills who was a Kettering man. William Mills

Photo 9:
Horizontal steam
engine, Victoria.



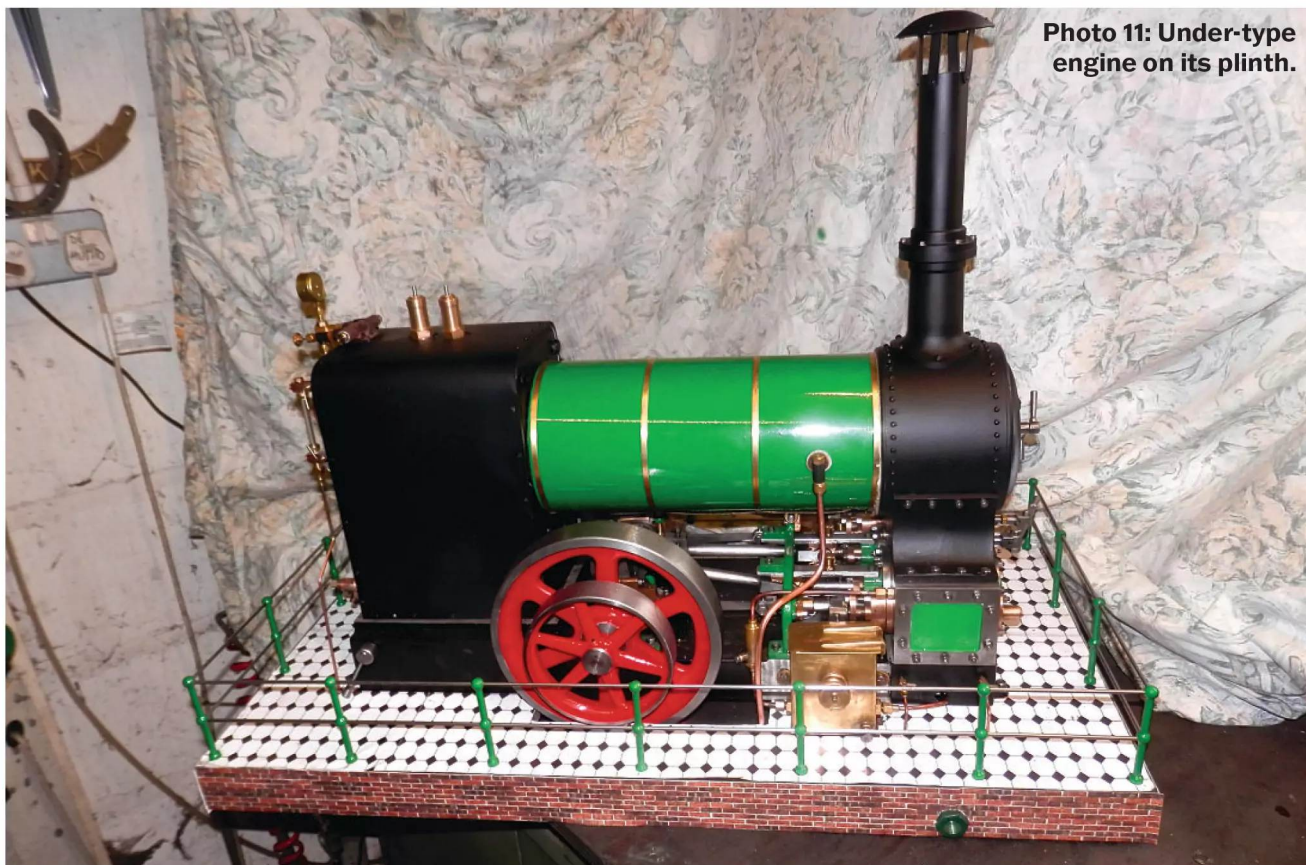
Photo 10: PMR line shaft kit.

was one of the few who completed his mission and placed his mines on the ships, then fled on foot with his shipmate. Both were caught and shot as spies by the Nazis. As I edit this, we have just passed the 80th Anniversary of VE day; a number of my older work-mates at the time went through WW2 and yet made little of it.

Drilling the printer side frames was an exacting job, as the various holes for the gears and shafts had to be very accurately spaced to ensure smooth running of all the gears. A large jig was

used for the standard machines but any bespoke machines had to be set out carefully.

A few years before I left the company, they bought a large jig borer from Germany, which was installed in its own climate-controlled enclosure to maintain accuracy and maybe to cosset whatever control system was employed at the time, as we are talking early sixties - so no CNC as we know it today. When the jig borer was installed, the holes were drilled from coordinates calculated in the drawing office, rather than using a jig on the radial drill. One of my jobs in the drawing office was then to check the hole coordinates from the frame datum. The coordinates were calculated by a lady using a mechanical calculator. I was given her results and expected to check them using another mechanical calculator and square root tables to solve the various triangles. During my stay in the drawing office, an electronic calculator was purchased to speed up the process and was used for the initial calculations. As far as I recall this cost £3,000 in 1965 or so, equivalent to over £50,000 today. I dread to think what the jig borer cost. The calculator was 24" wide by 12" back to front and about 6" tall and fitted with Nixie display modules about an inch



**Photo 11: Under-type
engine on its plinth.**



Photo 12: Planer is visible at the left in the Timson Engineering workshop.

high. I did have a look on the internet and found some information about early calculators and realised this could have been an Anita calculator,

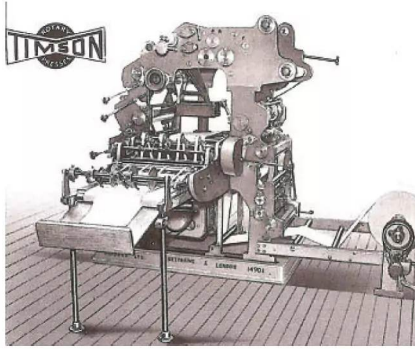


Photo 13: The first model of the Wun-Up printing press.

made in the UK. This had been available in the right time frame. Despite the high cost, the calculator could not do square roots. It did, however, save time on other calculations. Our leader would only spring for one of these calculators so I was left still turning handles on the mechanical calculator. We must have done a good job though, as we never had any complaints.

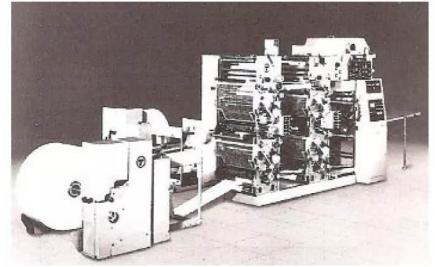


Photo 14: The Wun-up Litho S.

In order to obtain permission to use the Timson's pictures in my article, I did pay a visit to the current machine shop to see if the planer was still there and found it was not. I did learn from one of the old hands working there that it was replaced by a Futurmill Plano miller, **photo 16**. That too was long gone.

I have probably rambled on enough about my reasons for tackling the Stuart planer project so I will move onto its construction in future issues.

To be continued

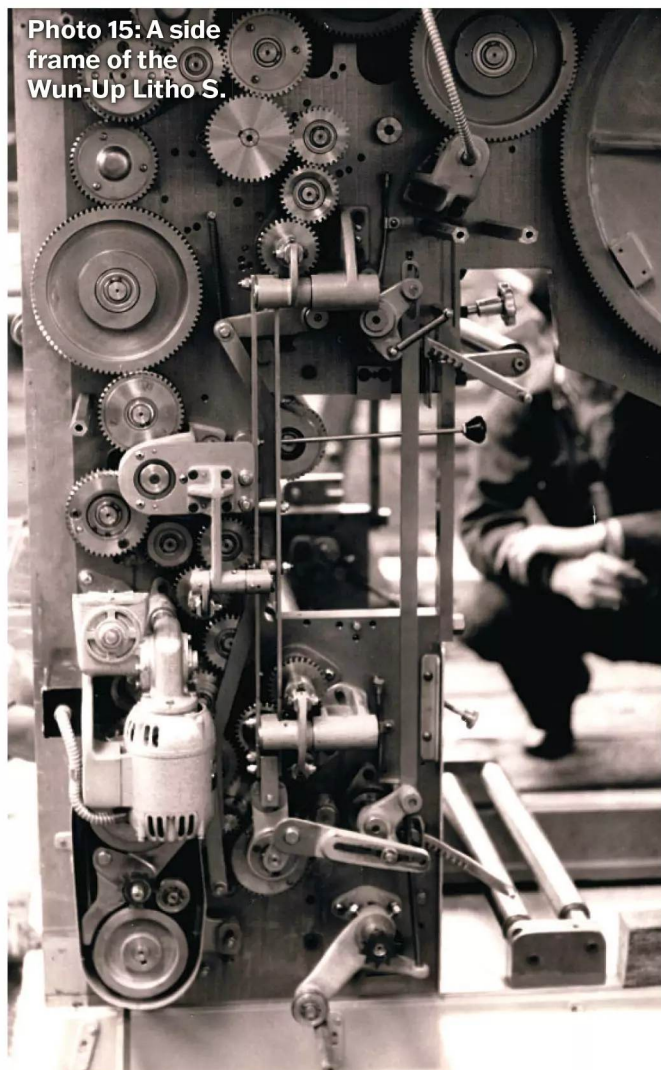


Photo 15: A side frame of the Wun-Up Litho S.



Photo 16: Timson's Futurmill Plano Miller.

POSTBAG

The Editor welcomes letters for these columns, but they must be brief. Photographs are invited which illustrate points of interest raised by the writer

PostBag is one of the most popular sections of the magazine - readers want to hear from you! Drop us a line sharing your advice, questions or opinions. Why not send us a picture of your latest workshop creation, or that strange tool you found in a boot sale? Email your contributions to meweditor@mortons.co.uk.

POLYMERS IN THE WORKSHOP 1

Dear Neil, I was pleased to read the first part of the article entitled 'Cheap Nasty Plastics' by Patrick Hendra. As a child of many polymers in the 50's one of my first forays into engineering in miniature, apart from Meccano, was plastic kits made by the Airfix company. Being able to solvent weld the polystyrene bits together without sticking yourself to the plastic with the high VOC plastic cement was always a bit of luck over judgement, especially when under the influence of the sniffed solvent! Plastics have certainly come a very long way from the thermoset 'Bakelite' urea-formaldehyde and formaldehyde-resorcinol polymers to the modern thermoplastics used so widely for a plethora of applications across all areas of manufacturing. Sadly, most plastics are not capable of being joined chemically, limiting the engineer to mechanical fixings, usually metal as Patrick states. We used solvent welding as well as radio frequency welding and ultrasonic welding in assembling medical single use components. Formerly,

these would have been fabricated from glass, metal, rubber etc. and the wide use of injection moulding to produce plastic alternatives certainly reduced prices making infection control, through the use of single use devices, possible. The use of plastics in additive fabrication using computer-controlled printers has revolutionised our understanding of what engineering is about. The possibility of using plastics in aggressive and high temperature environments as alternatives to metals is possible, however, material science tells us that it is unlikely that apart from toys, plastics will ever dominate in the hobbyist's workshop, until suitable means of joining parts, apart from screws and rivets, is developed.

As a chemist who enjoys model engineering, I look forward to how the two disciplines can work synergistically to bring different exciting plastics into our hobby.

Ron Barson, Chairman Bourne-mouth & District Society of Model Engineers

POLYMERS IN THE WORKSHOP 2

I read with great interest Patrick Hendra's very worthwhile article (ME&W 4766) on plastics. Having worked in the plastics industry in the UK and in the USA for about 30 years, on materials ranging from polypropylene to PET film via continuous carbon fibre composites in Aerospace (both thermoset and thermoplastic resins, PEEK for example) I can more than empathise with many of the points around properties he raises. It's always wise to buy from a reputable supplier who provides a proper Data Sheet, metal or plastic. His comment about the muddle between strength and rigidity echoes J E Gordon's similar observation in 'The New Science of Strong Materials' that in our Western mind we tend to judge that if a structure is rigid, it is also strong - not necessarily so. 'Structures - or Why Things Don't Fall Down'

is also well worth reading. Both books are still in print and available from the usual sources. But one comment I must take issue with. 'Carbon fibre sheet is incredibly strong and it doesn't dent!' Well, perhaps, but what it can do after an impact is crack between composite layers below the surface with no sign of surface damage. Subsequent stress cycles can grow such cracking until the composite is severely delaminated, and the strength and rigidity compromised. This is especially the case with thermoset resins which are not as tough as genuine engineering thermoplastic. That such failure of the structure can be sudden and catastrophic should need no emphasis on my part, given the dreadful loss of the CF composite hulled Titan at depth in the Atlantic in June 2023.

Dr Mike Gray, Louth, Lincs

YIELD POINT METHOD

Good Morning Neil, Thank you for publishing our YPM article, there has been a lively interest shown on the MEW forum and we have been active in responding to comments. One of the comments relates to a mistake in a calculation in our published article and we have responded with a correction on the forum (see marked up excerpt). Please note that this in no way detracts from the philosophy nor the conclusions of the article. We do apologise for the error and will take steps to upgrade our checking procedure should there be any future articles.

Alan Brown, Les Smith, by email

Example 2

From page 31 of *Model Boilers and Boiler Making* by KN Harris, example 2:

Diameter	D	=	6	inches
Working Pressure	WP	=	90	psi
Shell Thickness	T	=	8 2.2	mm
Shell Thickness*	T	=	0.0865	inches

YP Method

$$T = (WP \times 3 \times D) / (YP \times 2) \text{ inches}$$

$$= 90 \times 3 \times 6 / (4,830 \times 2)$$

$$= 0.112" \text{ (Not 0.122")}$$

$$= 0.168 \text{ inches. (About } 11/64" - \text{ just less than } 3/16", \text{ approximately } 7-8 \text{ swg, } 4.267 \text{ mm.)} \rightarrow \text{less than } 1/8", 2.84 \text{ mm}$$

UTS Method

Following the UTS Method:

$$A = (D \times WP \times F) / (S \times T \times 2)$$

Where:

A is the shell thickness in inches

D is the boiler diameter in inches

WP is the Working Pressure in psi

F is a safety Factor

S is the ultimate tensile strength of the material in psi/square inch

T is a Temperature allowance

Using the factors recommended by Martin Evans we have:-

$$A = (6 \times 90 \times 8) / (25,000 \times 1 \times 2)$$

$$A = 4,320 / 50,000$$

$$A = 0.0864 \text{ inches } \checkmark \text{ (12 thou under } 3/32", 13-14 \text{ swg, } 2.2 \text{ mm) } 51\% \text{ of the YP Method thickness. } 77\%$$

WHEEL PROFILES

Dear Neil, I note that Mr. MJP of Louth asks about wheel profiles on P41 of ME+E No 4763. Yes there are a profusion of wheel standards which have been published over the years but for a 5" gauge loco I would stick to the Martin Evans one or the GL5 one. There is very little difference between the two and quite frankly I thought this had been dead and buried long ago. Starting at the very beginning I would not entertain anything with square flanges. It might be all right for a raised track but they should never be used on a ground level track. Dennis Monk used to bring a party piece with him to Gilling and it consisted of a pair of wagon axles with wheels on, one had square flanges and the other set had all the correct profiles. He asked us to gather round where there was quite a long dip in the ground level track and just let the axle with the square flanges run down the hill and then it ran back but on the second trial the No 1 axle came cropper and de-railed but it had been much lazier from the start. This happened almost every time we tried the operation. He then put the other axle on the track and just let the axle run down the hill until it could not roll any further and then it began to roll back again, gathering speed and it arrived almost back to the spot almost level with our gathered friends were standing. Without doubt it is very important to use one of these two published profiles if you want an efficient locomotive. Being one of the founder members of GL5, I of course favour the GL5 version but there is so little difference between the two it will make very little difference, so Mr. MJP the choice is yours! The thing is that if the flanges are all square you will miss out on the differential effect of the taper on the tread of the wheel. It might

work fine on a raised track but it certainly will not work on a ground level railway. The point of the cone is that when entering a curve the wheel flange will push against the outer rail which means that it is running on its maximum diameter. The cone on the wheel means that it will find its own centre on a straight level track thus preventing 'hunting' and is therefore likely to de-rail. Another problem with 'square' flanges is that if there is no 60° chamfer on the inner edge of the wheel it will mean that it is likely to take a shave off the switch blade if it is Aluminium.

The other thing about the track at Gilling

is the track geometry as this is all to do with wheel profiles and is very important. For a start, the main line at Gilling East was all laid with transition curves and calculated superelevation, was designed by John Heslop and friends and was built for running at 7mph. It is very impressive to see the passenger trains with ten Mark 1 coaches (weighing 28 kg each) leaning into the curves and running at a scale ninety MPH and at that speed one cannot feel the superelevation. The whole line at Gilling was built to main line standards even though the 'Six foot' was widened.

Doug Hewson, North Yorkshire



QCAD

Dear Neil, in response to the letter from Mike Collins in the July Postbag re CAD software, I would like to suggest that he has a look at QCAD from RibbonSoft GmbH. I find this relatively easy to use and it can be tried free

with some limitations. If you like it, a full Professional version with a never expiring licence can be purchased at a relatively small cost, and there is a book/manual also available from Lulu.com.

Keith Keen, by email

A7V TANK

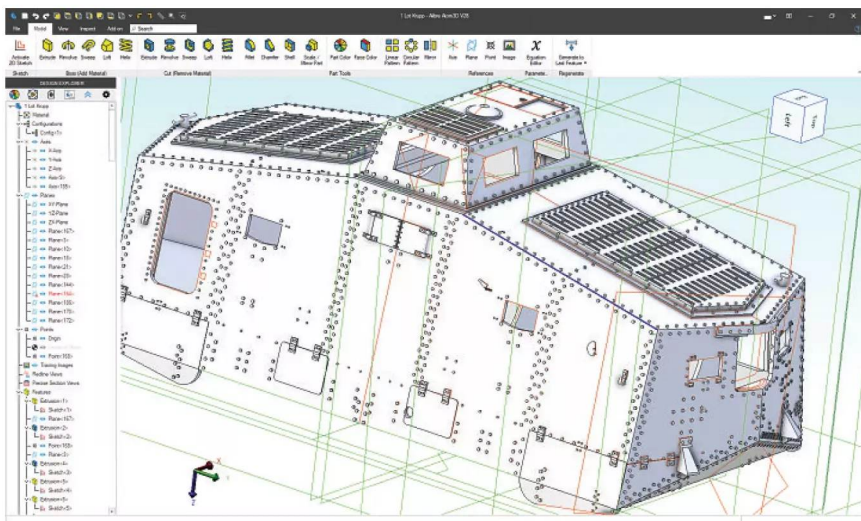
Dear Neil, I opened MEW No. 4763 a couple of weeks ago and there in Smoke Rings was mention of a World War 1 German A7v tank. That set off a lightning flash of 'that seems familiar to me, I know something about that, I think it is here in Australia'. A little bit of Google refreshed my memory. During a push back of German troops by Australian troops at Villers-Bretonneux in April 1918 The German A7v tank named Mephisto - by the Germans - came into Australian possession and was eventually shipped to Brisbane where it is on display. There is a replica A7v named Wotan in Munster, Germany, that was built in 1988 based on Mephisto.

Tony Reeve, Tasmania

I'd like to thank multiple readers who contacted me about the A7v and Mephisto in particular. I now have much new

information and will have to completely revise my own drawings (see the Alibre Atom3D screenshot). Tony also mentioned

some issues with our new design, which I hope we have largely addressed since issue 4763 - Neil.



Readers' Tips



We have £30 in gift vouchers courtesy of engineering suppliers Chester Machine Tools for each month's 'Top Tip'. Email your workshop tips to meweditor@mortons.co.uk marking them 'Readers Tips', and you could be a winner. Try to keep your tip to no more than 400 words and a picture or drawing. Don't forget to include your address! Every month we'll choose a winner for the Tip of the Month and they will win **£30 in gift vouchers from Chester Machine Tools**. Visit www.chesterhobbystore.com to plan how to spend yours!

A Parting Tool Holder

This tip to improve a special parting toolholder is from Mike Worth:



If like me, you have a mini-lathe with a QCTP you may find that parting is painful. Even with a nice, slim parting blade, the tool pressure applied at a point way off the side of the tool-post is often too much: everything tips off to the left, leading to chatter or even binding and breaking the blade.

This problem can be fixed by bringing the load more in line with the supporting saddle arrangement.

I've seen a substantial reduction in parting problems since making up a specific 'parting-blade-holder-holder'. Each time I need to part

off, I unscrew the top handle entirely, lift the whole QCTP assembly off and drop on the holder-holder. This consists of a bottom disc, which sets the tool height, and a top block that holds the parting blade holder. I made it by facing to length, roughing out the slot with an angle grinder, then finishing up with my little Adept No. 2 shaper. Alternatively you could easily make one on a mill, or even with a file if you've got more time than tools!

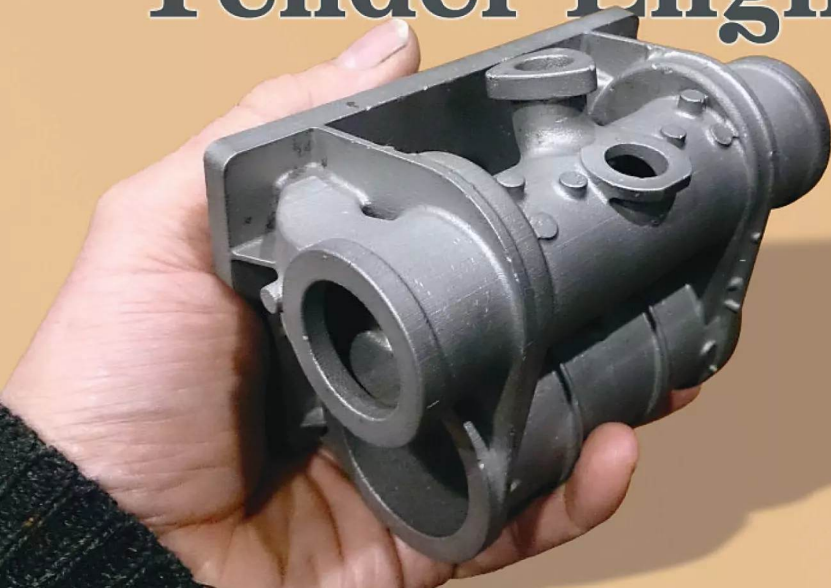
Note that the photos also show my compound slide replaced by another solid block of steel. This is independent of the holder-holder trick and improves rigidity for general turning. When I occasionally need to turn a taper etc. I simply swap the compound back in. The block is the same height as the compound, so tool settings etc. are unaffected.



Please note that the first prize of Chester Vouchers is **only available to UK readers**. You can make multiple entries, but we reserve the right not to award repeat prizes to the same person in order to encourage new entrants. All prizes are at the discretion of the Editor.

Photo 150: Mike Jack's cylinder casting for his Standard Class 3 2-6-2 tank.

The BR Standard 2-6-0 Class 4 Tender Engine



Doug Hewson makes a start on the cylinders of his BR Standard Class 4. 155 of these locomotives, known as Moguls, were built for British Railways.

PART 18

Continued from Model Engineer & Workshop issue 4766

I had a false start because I made an error; I was told by some well-meaning person that the valve gear and cylinders of a BR Standard Class 4 were the same as my 4MT but sadly, I now realise, they are not. They are, in fact, the same as the Standard 3MT, 77000 Class and the 2-6-2 Class 3 tank loco which, fortunately, Mike Jack in New Zealand is well on with building. He has already had the cylinders cast but they are exquisite lost wax casings. I have had to spend a lot of time redrawing the cylinders, **figs 64 and 65**. However, the description will be just the same, fortunately. Mike is going to supply them to The Steam Workshop so many thanks to him for that. Although the photos of machining the cylinders are for my 4MT, the instructions are more or less the same for both types of cylinder.

Now, I was told by numerous people that it would be impossible to cast cylinder blocks with the back plate on so I had a word with the foundry and they sent a chap out to my shop to talk to me. In one word he answered me; his reply was, "Nonsense!" I then asked him to enlighten me and we had a most interesting conversation about cores and core prints, about

which I did not have a clue at that time. I then had another conversation with one of my early 4MT builders and he told me about a recently retired pattern maker who lived in Shrewsbury. He was an Ex-Rolls Royce man

and he made most of the patterns for the Sentinel Steam Waggon, no less! As we were going to North Wales on holiday, we made arrangements to call and see Jack and his wife, Megan and I showed him the



Photo 151: Another view; these cylinders are the same as on our Standard Class 4 Mogul.

Fig: 64

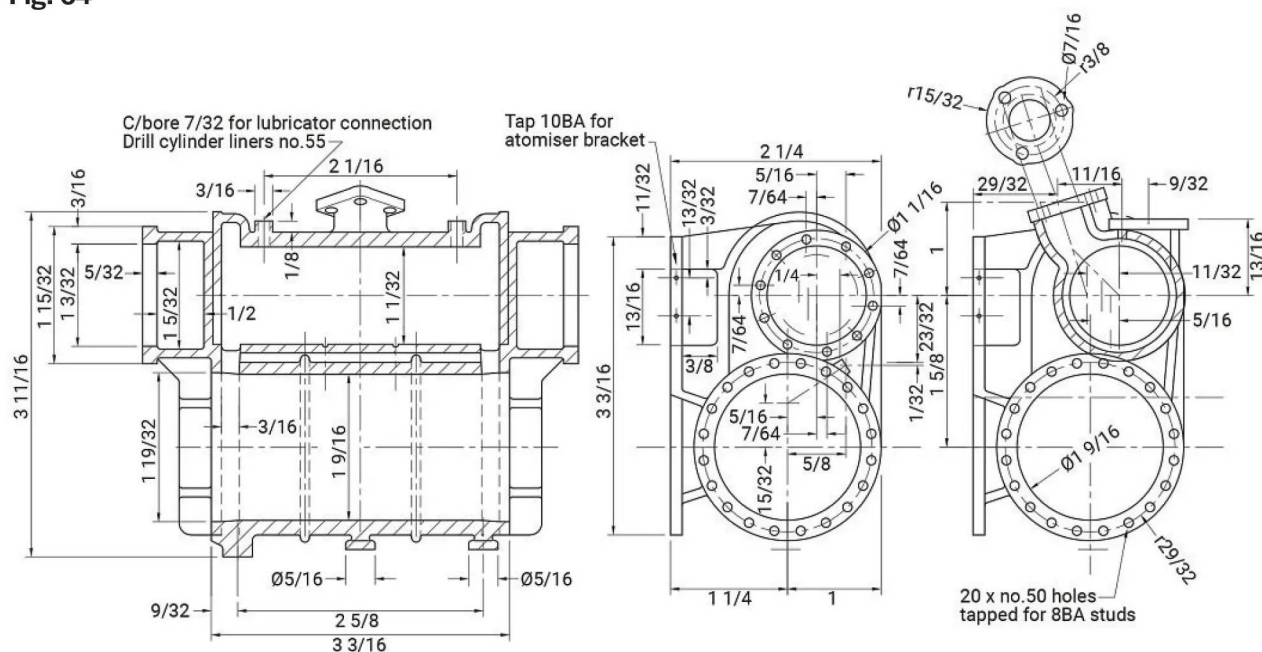


Photo 152:
A view of the back plate, an integral part of the casting.

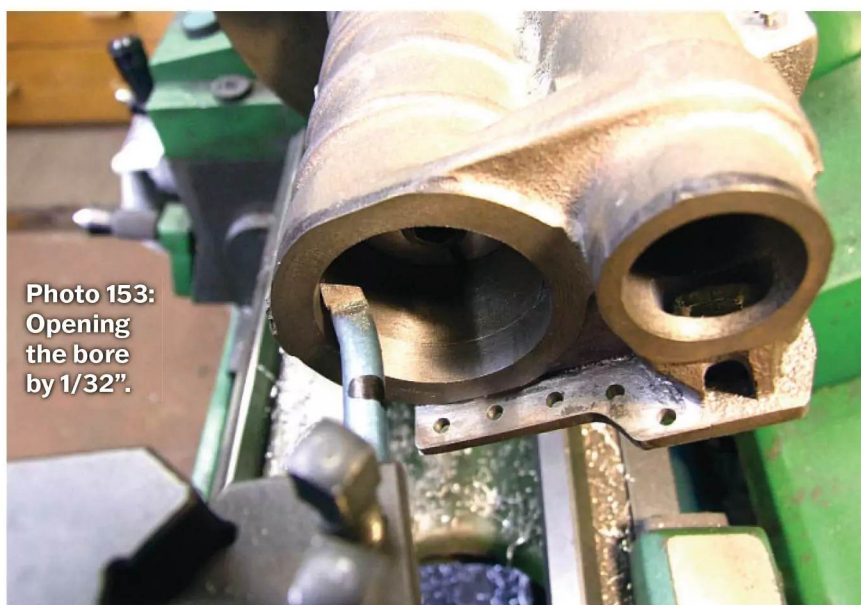


Photo 153:
Opening the bore by 1/32".

drawings which are illustrated here. He said that the patterns would be ready in about three weeks' time, which I thought was quite amazing. Since finding out the error of my ways, however, I have acquired a new photo of Mike's cylinder casting, **photo 150**. There are also two more views; the second one is face on, **photo 151** and the third one shows that back plate of the block, **photo 152**.

The next photos were all supplied by Geoff Whittaker who built 75069 which he has now sold on.

Geoff made a start on boring the cylinders and the first thing he did was to fit a brass bung in the bore with the centrelines marked on it. Thus marked, he could then use them to set up a boring bar and measure everything from those centrelines. In **photo 153** you will see the bore being opened up by 1/32" which is so that the cylinders can be re-bored if necessary - very unusual for a 5" gauge engine but that is how the full size engines were built. This means that the end covers do not need any altering if/when the cylinders are re-bored. (More on this next time.)

In **photo 154** you can see a plate being squared up to locate on an angle plate and **photo 155** shows why the cylinder casting needed to be vertical to allow Geoff to use his boring bar in a facing head on the milling machine to face the outer flanges of the cylinders.

We now come to machining the back plate and Geoff has a photo in his collection, **photo 156**, showing a slab milling cutter in use with the surface set dead square for machining the back plate. **Photograph 157** is similar but taken from different angle. Note how the casting is clamped with bars inside

Fig: 65

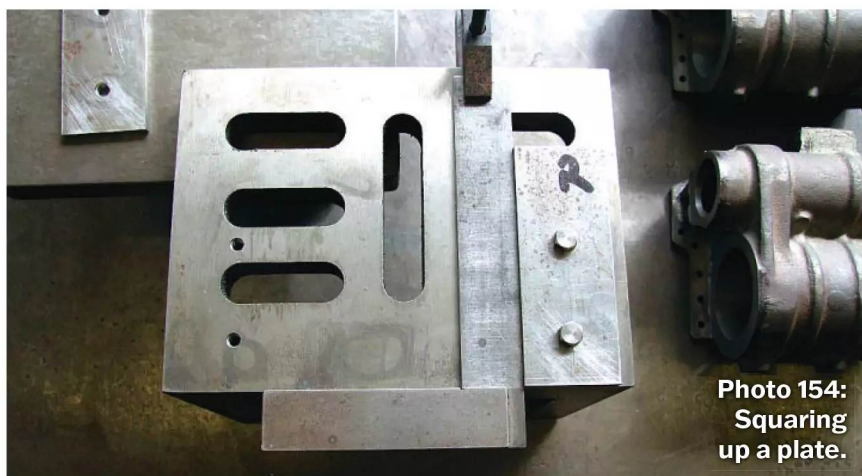
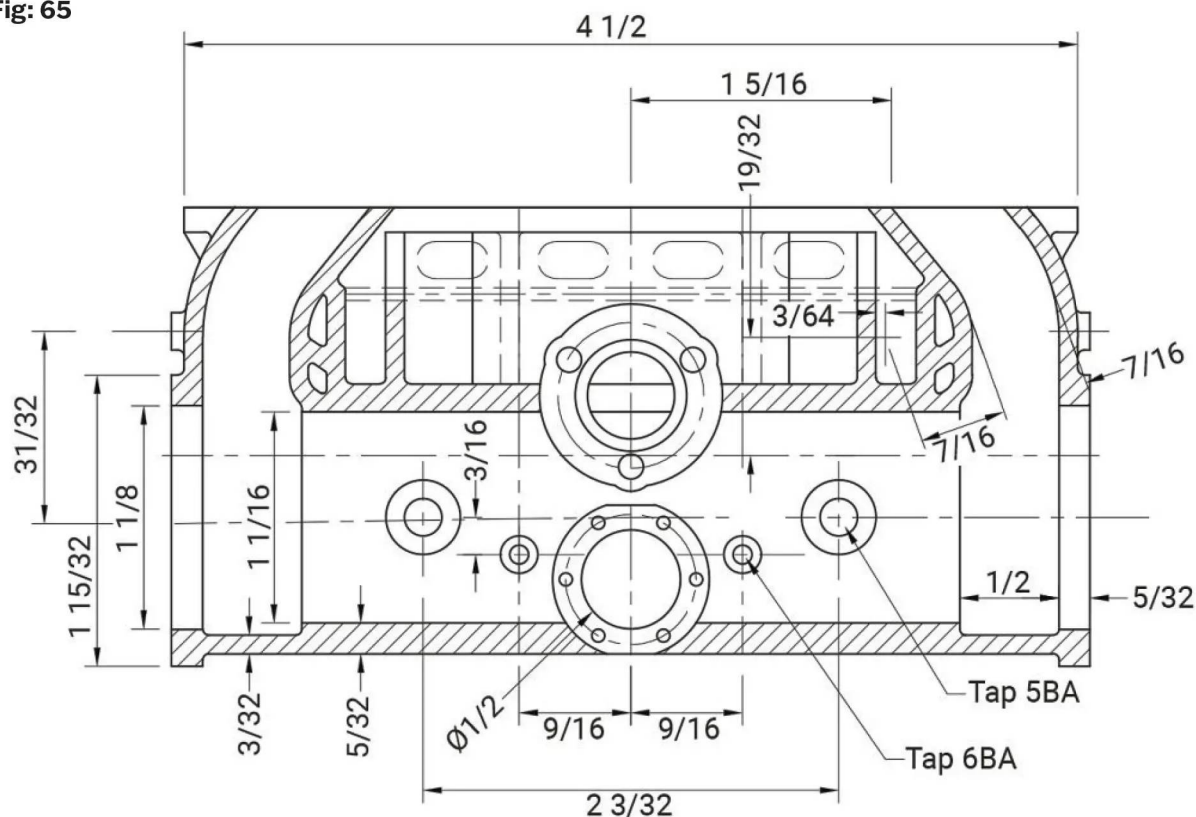


Photo 154:
Squaring
up a plate.



Photo 155: Facing
a cylinder flange
vertically. You can
see an exhaust
port emerging.



Photo 156: A slab milling cutter
faces the back plate.



Photo 157: Another view of the
operation.

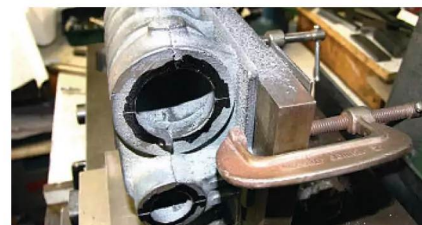


Photo 158: Taking a skim off the
back plate edge.

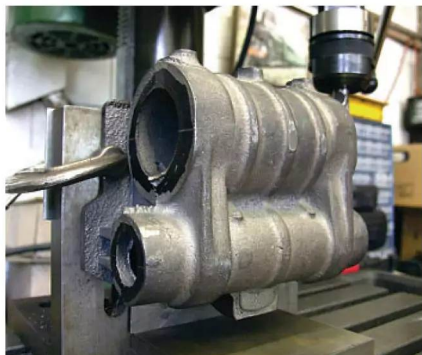


Photo 159: Another view of this operation showing the set-up.



Photo 160: Machining the steam inlet.



Photo 161: Tapping for the cylinder covers.



Photo 162: Tapping the drain cock holes.

the two bores. Now we have got to that stage, and the bores are square to the back plate, the next job was to use an angle plate - again with the back of the cylinder casting clamped to the angle plate with a couple of G-clamps and the bores set square - to take a skim off the bottom of the back plate. This is shown in **photo 158** and, once again, **photo 159** shows a different view of the plate clamped in place.

We now come to machining the steam inlet pipe and the seating for the anti-vacuum valve. A special mounting was made for boring the steam inlet. After Eddy G. commissioned my 4MT, however, he said that the pipes from the superheaters to the cylinder blocks could do with being larger so I have shown them with half inch pipes - so beware! He took my 80080 out for a run one day and noticed that he steam chest pressure gauge was only reading about half what the boiler pressure gauge was showing and the engine was a bit sluggish. Other builders of my 4MT and other locomotives I have designed need to take note of this. Anyway, **photo 160** shows Geoff's set-up for machining this steam inlet. **Photograph 161** shows Geoff tapping the holes for the cylinder covers using the drilling table to get the holes dead square. He also used a similar set-up for tapping the drain cock holes and **photo 162** shows this.

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Another collection of hints and tips for the workshop

In our last issue we shared the sad news that our regular contributor, **Brian Wood** had passed on. Brian was always ready to share his experiences to help other model engineers and, with the blessing of his family, we would like to share his final article with readers.

Photo 2: Simulating smoothing of the keyway.

From time to time, I trawl the YouTube videos out of interest to see how things have been made, repaired, re-purposed or created by those who earn their living doing that kind of work. This is a second gathering of clever ideas and short cuts that save these people unnecessary effort or time in getting things done.

I have also added a few thoughts and observations of my own that I have found helpful and included an unusual workshop experience from my last industrial employment which might make interesting reading.

A SHORT COLLECTION FROM YOUTUBE MATERIAL

The first of these comes from Kurtis Allen, owner and CEO of Cutting Edge Engineering (CEE) in Queensland



Photo 1: Web measurement on my big drill.

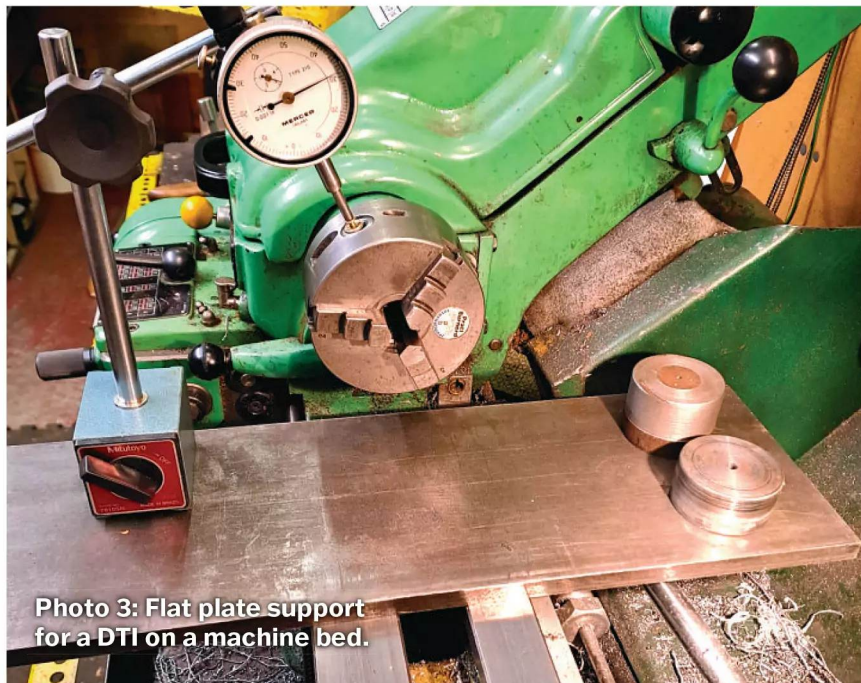


Photo 3: Flat plate support for a DTI on a machine bed.

Australia. They do a lot of repairs and rebuild work for the mining and earth moving industry.

He was asked recently, in a rare question and answer session between jobs, why he was using an 8mm diameter pilot hole to guide a 50mm diameter drill he was going to use to hog out the meat in a new hydraulic piston shaft. This was prior to boring out the hole to size for the welding location spigot of a new eye he had made to replace the broken one that came with the job.

He believes the pilot hole serves one of two purposes. The first is to make a guide hole, in this case 8mm in diameter, no larger than the measured width across the chisel end of the large drill.

It only needs to be of sufficient diameter to remove the metal in the path of the central part of the drill which is least well equipped for cutting into metal.

The hole diameter thus created will then guide the core of the big drill down a straight path, having removed the metal ahead of it, to leave the cutting edges of the drill free to do their job of clearing a path for the body of the drill. It was an interesting concept I have not come across before.

On the job in hand, this theory worked extremely well. Admittedly, the lathe he was using was big and powerful enough to fully exploit the drill to full advantage and swarf streamed out of the hole with no apparent effort. **Photograph 1** shows the concept, measured on one of my larger drills. This was on a 27mm diameter drill. I also measured a 1-inch diameter drill which had a core size of about

4mm and I look forward to trying it out some time on my much more modest equipment, using a 4mm diameter pilot hole.

Adam Booth demonstrated the second on one of the jobs he presents on his Abom'79 website. It is a clever dodge, passed on to him by an old timer when he, Adam, was a young man. It allows a job to be dialled into true running in a four-jaw chuck when the stock material has an external keyway cut into it that will interrupt and damage the dial indicator. For this demonstration, Adam was using an off-cut from a big shaft that had a hefty keyway machined into it.

A workshop ruler is leaned against the job, rather like a ladder, with its foot lodged into the inner side of the Vee guide on the front lathe shear. The DTI is mounted so that its tip is in contact with the outside surface of the ruler.

When the job is rotated about in the usual way to centralise the part in the chuck jaws; the ruler rides over the keyway, smoothing out the step it causes. It is not perfect by any means as there will still be a ripple of motion transferred to the DTI, the magnitude of which depends on the width of the keyway, but it protects the DTI from the risk of damage. The only pre-requisite required in fitting the job in the chuck is to ensure the keyway is positioned midway between two of the four jaws so that they can all be adjusted as necessary.

It comes with a useful bonus, this dodge also works well for centralising an externally threaded workpiece.

As I didn't have a suitable test

specimen to use for demonstration, in **photo 2** I have instead simulated the method with a black marker pen to show the concept in principle; I hope readers will be happy to use their imagination.

The third of these YouTube tips comes from STAN Canada, an organisation located in Edmonton, Alberta. They are an overhaul agency for decent quality, often large, machine tools. In this example I was following the work involved in stripping down a Russian lathe that needed a bed grind, it was to be followed by the associated scraping work to restore its customary precision.

The Norwegian engineer, to whom the job had been assigned, began by removing the triple-Vee drive belts from the lathe spindle using nothing other than a bit of rag to do so! He demonstrated the method on the first belt in one smooth and fluid movement.

He threaded the rag round behind the belt and by simultaneously pulling up on the rag to lift the belt and pulling the belt along by hand between the pulleys, it was urged up onto the pulley rim and then off. I have since tried it out and it works remarkably well.

This struck me as an exceptionally neat trick and I feel sure it is equally applicable in a wider field than just machine tools. Removing vehicle fan belts might be one obvious example.

OTHER IDEAS

I do not own one of the multi-flexible DTI holders used by the professionals. Instead, I make use of a long section of steel plate for my magnetic DTI stand to sit on which can be slid across and along the lathe bed at will to achieve the same result. **Photograph 3** shows it in use on a flat-bed machine. It is just an unfortunate illusion that it looks as if it is 'clocking' the chuck!

It can of course be used on either bed design. A simple weight or two parked on the far side of the plate will provide a counterbalance as necessary for the DTI.

My last industrial employment was with a local firm of agricultural engineers where one of the simple jobs that were needed from time to time in large numbers was for square plates with ½ inch holes through the centre. These were produced from cold rolled boron steel strip which came from the stock holders in long lengths; for this job we used 6mm thick strip, 60mm wide.

The standard method of making these things was to drill a pile of them, gripped in the six-inch Abwood machine vice on the big vertical mill (there is another, rather bizarre story further on concerning the use of this



Photo 5: The damaged drill adjacent to a new one.

mill), using the powered down feed to drill the stack in one pass.

Inevitably, the process of rolling strip induces slight variability in strip width along the length of a strip and when gripped in hard jaws, some of the sections cut from it were not held as firmly as others. When the drill reached these, they tended to wander from correct position within the stack, and many had to be scrapped as a result.

To cure the problem, I found that a strip of double folded printer paper, trapped between one vice jaw and the plate stack, gave enough grip variability to hold the whole stack firmly as the

drilling proceeded. The scrap rate then fell to much more acceptable levels.

On a recent REMAP job I had to braze a threaded piece onto another section. There was a lot of heat involved along with the usual risk of scaling and oxidation up inside the threaded section. The outside surfaces were not a problem, being readily accessible for cleaning up afterwards by the usual methods.

A thorough coating of Coal Paint, **photo 4**, sprayed up inside the threads, prevented the worst of the oxidation damage. This material expands a little with heat into a slightly sticky coating and in this application it responded well, after cooling, to chasing out with a tap. Coal Paint is an aerosol spray, used as a black coating on the loose ceramic 'coal' inserts in gas fires.

Some while ago Gary Wooding published an article in *Model Engineers' Workshop* describing a piece of tooling he had made for setting the guide wheels on his bandsaw correctly to hold the blade vertical between them.

Recently, I had to change the blade on my

saw. I suspected that one or both sets of guide wheels needed resetting. I used a toolmaker's clamp to grip the blade in conjunction with a small set square off the bed of the saw to achieve the same result.

I don't like to undermine another man's work, and I hope Gary will accept my apologies, but this took only minutes to do from things I had readily to hand.

Many years ago, I had to straighten a track rod on our old Land Rover in preparation for the MoT. It was both an unwelcome and badly timed discovery; one we had inherited on purchase, undoubtedly caused by some oaf who had used it as the hitching point for a tow rope, leaving it bent into a pronounced Vee shape. The front wheels were grossly 'pigeon toed' as a result. I only had the simplest of facilities to hand at the time.

The job was done completely satisfactorily using a spare fence post, through which several holes had been drilled for galvanised water pipe, and I used this as a makeshift vice.

With it suitably braced at the base and again high up by hand, I was able to bend the track rod true by simply levering it against one of these holes.

It bent quite easily too which may have been helped by it being made from thick-walled tube rather than solid bar.

I still had to track the steering afterwards of course, but that is another story of improvisation, involving



Photo 4: Coal paint



Photo 6: Close up view of chuck debris.



Photo 7: Heat scaling of the Jacob taper fitting.

Dexion slotted angle and other bits and pieces to make a functional gauge. The story of the milling machine needs a little background information to set the scene. This was a magnificent German machine tool with hydraulic drives to all three table motions, one of which rotated the table a full 360 degrees in either direction. With the business being a small-scale, family owned and operated enterprise, staff numbers were limited and operator time on workshop machines was shared where it made sense to do so.

For this job, the blanks were cut from a stack of strip at the bandsaw on one side of the workshop while they were being drilled in the mill on the other side. I was operating both pieces of equipment at the time. I became aware of a deepening note to the usual motor loading sound from the mill while I was at the bandsaw collecting sawn blanks, and on looking across the workshop I saw smoke pouring out from the drill chuck.

I raced over and hit the emergency stop button to cancel the power and lift the vertical column manually to see what had gone wrong. Rather than withdrawing the drill, it was being left behind in the stack of blanks as the chuck was raised.

Clearly, the drill had grabbed on breakthrough, locking it in place. Meanwhile, the 4 horsepower down feed motor had continued to run and failed to trip. The drill chuck had been patiently 'machining' its way down the drill stem! The remainder of the afternoon was used in finding the cause for

this failure. Eventually, we traced it to a junction box built into a pocket on the side of the table and with the cover off, the cause was all too clear.

The gasket had deteriorated over the years and coolant had leaked inside to flood the wiring. After blowing it out, followed by cleaning and drying, normal operation was restored.

A new gasket was made up from thick card by the time-honoured method of tapping round the shape of the housing lid using a ball pein hammer. Silicone sealant on the lid side of the card completed the job.

I took the drill chuck home with me to see if it could be salvaged. The

investigation was interesting and this is what I think took place.

Photograph 5 shows the damaged drill alongside a brand new one. The one in use was old, having been sharpened many times, and probably had scars on the stem from spinning in chucks in the past. This time, with the drill held immovably, combined with the relentless down feed to the chuck, the chuck jaws, being harder than the drill stem, were crudely but effectively tearing their way down the drill and effectively removing any semblance of grip on it.

Meanwhile, the blunt end of the drill stem was forced into the back of the chuck and burned its way through the thin section. Small flakes of the chuck body were all that were left where it burst through. They are a little more obvious when seen in the close-up in **photo 6**.

With nowhere left to go, the drill stem now attacked the Jacobs taper mounting and with that being hard, rapid heat build-up was inevitable. **Photograph 7** shows the scaling of the surface that had taken place before I was able to stop the job.

Apart from the hole at the back, the chuck itself was surprisingly undamaged, as was the Jacobs mounting. **Photograph 8** shows a new drill through the chuck body to demonstrate the 'clearance' that had been created. I reinstalled the Jacob taper and tested the chuck for true running in my lathe, a test it passed with flying colours.

After this experience, I never again left a machine tool out of reach whilst on auto feed! ●

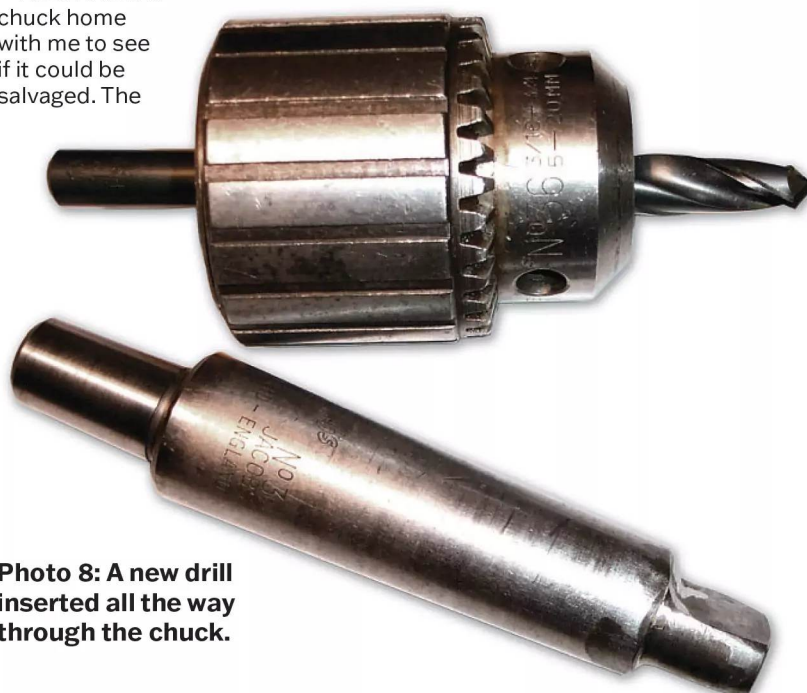


Photo 8: A new drill inserted all the way through the chuck.

Photo 1: Alignment bars fitted to lathe.



Headstock Modifications

Bret Meacle makes some changes to his 920-type lathe.

Photo 2: Spot-face cutters and pilot arbours.



When I first bought my lathe, I was just an enthusiastic amateur who knew I wanted one, but not totally sure what I was going to use it for. It was about that time I found *Model Engineers' Workshop* magazine, along with other classic machining books, and started to learn about all the possible uses you can put them to, not just turning a shaft or making a bush.

As I learnt more, I wanted to modify the lathe, adding things 920 style lathes were not fitted with from the factory. Starting with converting the tailstock to lever operation to make drilling more efficient, by not having to pick up, put down or search for the spanner to loosen or tighten the clamp nut. Then moving to the headstock with a spindle lock and later a tumbler reverse for the leadscrew.

To add the spindle lock, I removed the headstock from the lathe bed. Completed the machining operations, reattached the headstock and adjusted the spindle parallel to the bed with everything turning out well.

As time has gone on, I found this was something others deemed to be fraught with danger and ill winds. I will admit it did take a few attempts and a little trial and error to set up the spindle parallel, with things sometimes moving unexpectedly.

The headstock on this style of lathe is held onto the bed with four bolts and when I first attempted to realign the headstock, I had a suspicion the clamp bolts were moving the setting as they were tightened, changing the alignment.

When I removed the headstock again to add the tumbler reverse mechanism, I decided that as there were no locating surfaces to aid alignment, I would add something.

I'm not sure how other lathes align the headstocks to the bed, or whether they clamp against a machined datum or Vee. This mod' is suitable for the 918/920 square-head style lathes and possibly some of the newer, curved front versions.

Photograph 1 shows the two bars bolted to the underside of the headstock and fitted with grub screws to locate on the inside of the lathe bed. These grub screws move the alignment in a refined way and hold the headstock in the position as the headstock is tightened onto the lathe bed.

At this time, the four factory 8mm bolts were replaced with studs, nuts and thick washers to give a more rigid setup. The screws don't exert much sideways pressure, just enough to

hold the headstock in position as it is tightened to the bed. To adjust the grub screws, an Allen key is used but may need to be shortened to allow it to be inserted as there is not a lot of room between the bars.

ALIGNMENT BARS

The two bars were made from 12mm square steel stock with three M5 Socket cap screws to attach them to the headstock and two 5mm grub screws with smooth, radiused ends to adjust the alignment.

Making and fitting the bars is a simple job, just drilling and tapping a few holes.

They could be marked out and drilled on a drill press and that was how the job was done originally. I would first drill and tap the holes for the grub screws, close to each end, then mark out and drill the three mounting holes but only to tapping drill size. Work out the position of the bars on the bottom of the headstock and spot through one hole on each bar.

Tap that hole in the headstock and open up the hole in the bar to be a close fit on the mounting screw. Using that one hole, secure onto the bottom of the headstock, tighten the bar parallel to the bed and spot through for the second mounting screw. Remove the bar, drill and tap the headstock and open up the bar again. Repeat again if you are using a third screw in the middle. Spotting through one component into the second is a low-tech way to get the holes to line up accurately.

Having upgraded to a milling machine, I would now use the table leadscrews and dials to first drill the bars and then tap the headstock

casting, knowing the holes will be spaced accurately.

While the headstock was bolted to the drill press or mill table to fit the adjuster bars, another job was to clean up the surfaces the mounting bolts seat onto, as these had been left in the 'as cast' condition. This will provide a solid base for the bolts or clamping nuts.

As the surface on the inside of the headstock casting is inaccessible from the top, the spot-facing was accomplished using a cutter with separate pilot shaft, as described by George Thomas in his book, *Workshop Techniques*, while working on his VDH casting. The cutters are relatively simple to make from silver steel, following GHT's instructions in Chapter 23 and, after hardening/tempering and sharpening, cut freely, **photo 2**.

The cutter can be used in the normal way to counterbore or spot-face a surface, but it can also be used to machine a surface inaccessible from the top by first putting the pilot through the hole from the underside then fitting the cutter. If you are using a cutter you have made for normal use, you will have to reverse the direction of the spindle to cut the seat. For machines that won't run in reverse, you can make the cutter with teeth of the opposite hand so it will cut in the normal drilling direction.

Photograph 3 shows the principle of cleaning up the surface of a casting, although not the actual headstock, as it was done many years ago and it is securely bolted to the lathe.

If you don't have the tooling to create a spot-face to clean up the cast surface, you could knock any big lumps off with a file then fit a thin, annealed



Photo 3: Spot-facing a casting surface with no access from the usual side.

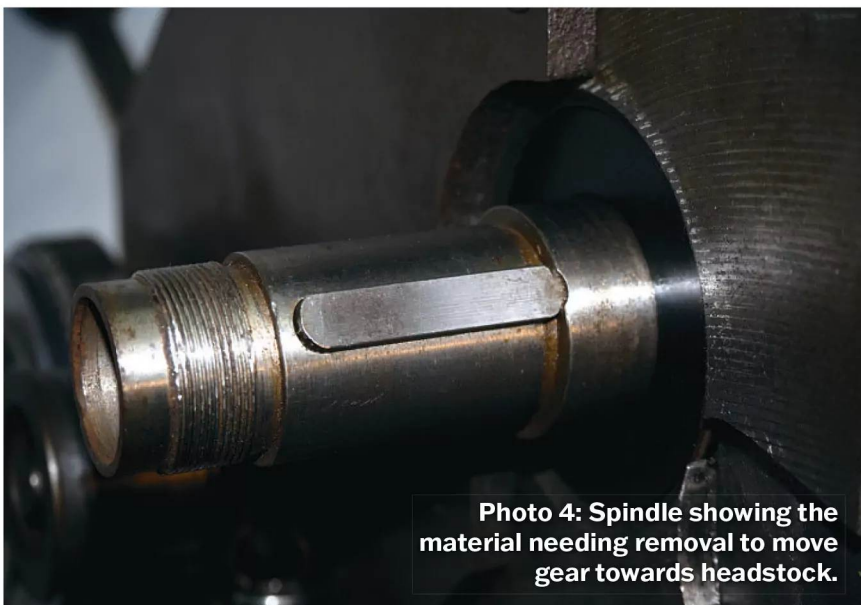


Photo 4: Spindle showing the material needing removal to move gear towards headstock.

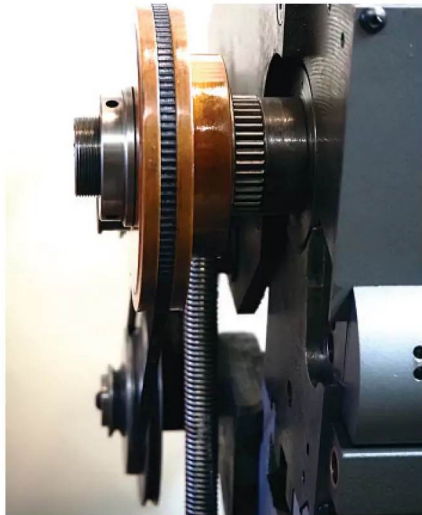


Photo 5: Wooden pulley fitted while reducing the thickness of the aluminium drive pulley.

copper washer between the casting and the thick steel washer; the copper will conform to the irregular surface and form a more solid surface.

I wouldn't suggest you dismantle your lathe just to do this little upgrade, but if and when you do remove the headstock, it's a small addition that may take the stress out of getting back into operation again.

SPINDLE MODIFICATIONS

The modifications that prompted the removal of the headstock included drilling holes to attach the spindle clamp, tapping and counterboring a pivot bolt hole for a tumbler reverse setup along with adding the alignment

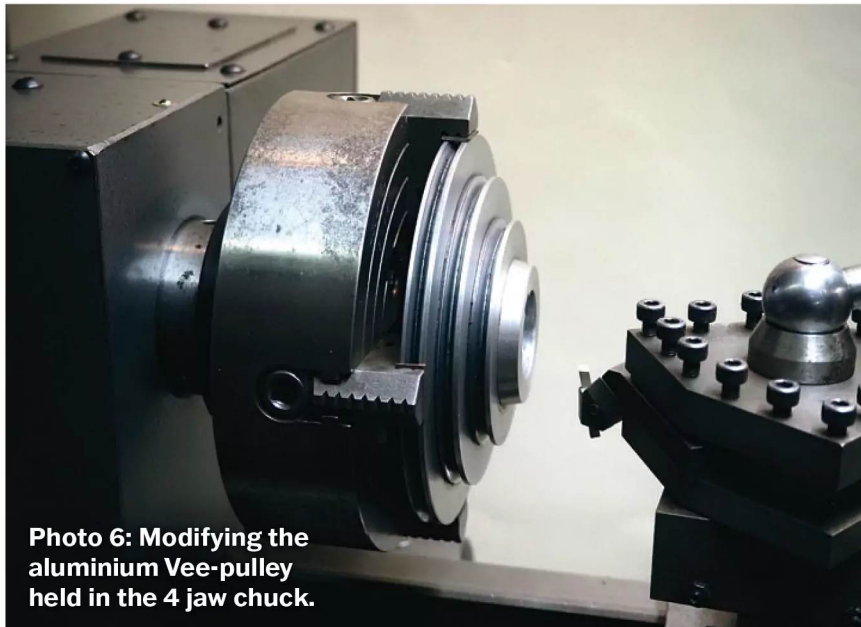


Photo 6: Modifying the aluminium Vee-pulley held in the 4 jaw chuck.

bars. That part of the job went smoothly as a drill press or milling machine was used to do the work.

One of the other operations required to complete the tumbler reverse fitment required modifications to the lathe spindle. This raised a small obstacle as I was not able to access a second lathe to complete the machining. I had to ponder on the problem of how to use my one and only lathe to modify itself, particularly as the end needing work was the bit poking out the rear of the headstock. This prompted some thinking outside the box.

The tumbler reverse setup needed the spindle drive gear to be moved closer to the headstock by replacing the normal spacer ring with a shorter

one. This was to allow the rest of the change gears and banjo to still line up correctly. For this to happen, the spindle shown in **photo 4** needed to be modified by machining away some of the larger 35mm bearing seat diameter, reducing it to the 30mm diameter to match the pulley and gear bores and extending the keyway.

As part of another project, I wanted to fit an additional 60 tooth gear wheel to the spindle to create a headstock dividing attachment. Sharp-eyed readers will notice that this project still has to be completed as, although fitted, I still haven't finished machining the outside diameter or cut the gear teeth.

As time marched on, the tumbler reverse setup was upgraded to a 'screwcutting simplified' style clutch after reading about Graham Meek's designs that he adapted from the Hardinge lathe to fit to Myford and numerous other lathes. Graham's book, *Projects for your Workshop, Vol 1* describes making the threading clutch as well as other useful projects.

The spindle drive gear for the screwcutting clutch was a lot wider, being fitted touching the bearing seal without a spacer ring. With the fitment of additional gears, the aluminium Vee belt pulley now needed to have some of its width reduced to allow the drive belt to align with the other pulleys.

As part of adapting and designing the modifications I wanted to fit, drawing out all the components using a CAD programme was a great tool, but even paper drawings or sketches can help you see how any changes you make might interact with other components. This helps with putting together a plan

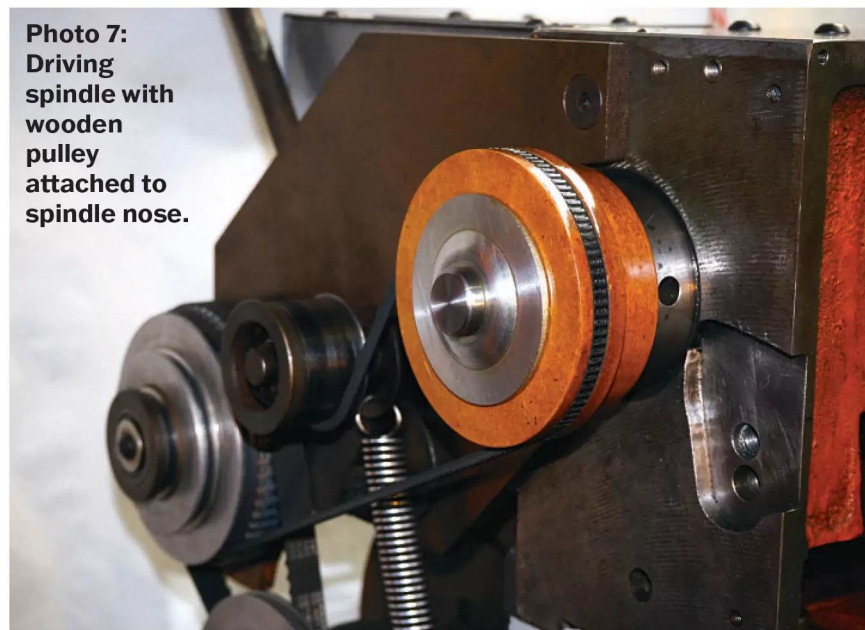


Photo 7: Driving spindle with wooden pulley attached to spindle nose.

of all the things that need making or modifying and in what order they are required.

Planning is a good skill as some time spent before starting work might save hours later on. Things don't always go to plan; you don't always think of everything and sometimes strike an unforeseen problem while you are halfway through the job but the skill to learn is adapting and problem solving. Planning and problem solving skills are good to have; sometimes patience comes to the rescue as not rushing in and, instead, rethinking a problem can bring up a solution totally different from your first thoughts.

With this design of lathe headstock, the taper roller bearings on each end are the same size. I was able to remove the spindle and re insert it into the headstock the opposite way around, adjust the bearing preload and drive the spindle using a temporary wooden pulley. Then I machined away the amount of material required to fit either the standard gear with a shorter spacer ring (allowing the gear to line up with the tumbler reverse) or the wide gear for the screwcutting clutch mechanism.

Refitting the spindle this way around is not possible with some types of

lathes and only worked for me because the taper roller bearing fitment on the spindle was on the tight side, allowing the bearings to be pressed onto the spindle and not move during the light machining operations. Only you will know how tight the bearing fit to the shaft is on your lathe but judging by how much pressure was required to move the bearings on my lathe, I knew nothing was going to move with a few light cuts. If the bearing is a light or sliding fit on the spindle, something else may be needed to hold the bearing in position, if indeed possible.

From your plan, you can prepare all the items you need before you disassemble the spindle. Are you using an existing gear or making new gears? Make a shorter spacer ring to locate the gear. The drive pulleys need to be made; they can use any material you have available. As these were to be only temporary drive pulleys, I decided on using MDF. A fine-grained timber would be more suitable for a longer lasting job. The pulley fitted to the spindle nose was plain bored to match the outside diameters of the thread and register. When making the pulley, create the bore first then attach to the spindle nose to complete the outside diameter and Vee-groove to match the

Vee-belt. It was held in place using a large washer and long threaded rod through the spindle bore. This held firmly enough to drive the spindle.

The timber pulley for the outboard end was bored to match the shaft and the bore grooved to clear the key fitted. It was fitted to a 30mm arbor to finish the outside diameter and belt groove. In use it was clamped on the spindle using the normal adjuster nuts.

Before disturbing the spindle bearings, the aluminium pulley was removed from the outboard end and replaced with the wooden pulley.

Photograph 5 shows the temporary pulley driving the spindle but also shows the 40T spindle gear and spacer in the original position.

The pulley is shown in **photo 6**, held in a 4-jaw independent chuck and centred accurately to allow the material to be removed.

When choosing the sizes for the temporary pulleys, I tried to select speeds to match the different materials, but I have found a sharp HSS tool in a diamond tool holder gives an excellent finish at a large range of speeds. When facing an item with a bore, I normally machine outward from the bore. This does two things; firstly the cutter produces a finer finish and

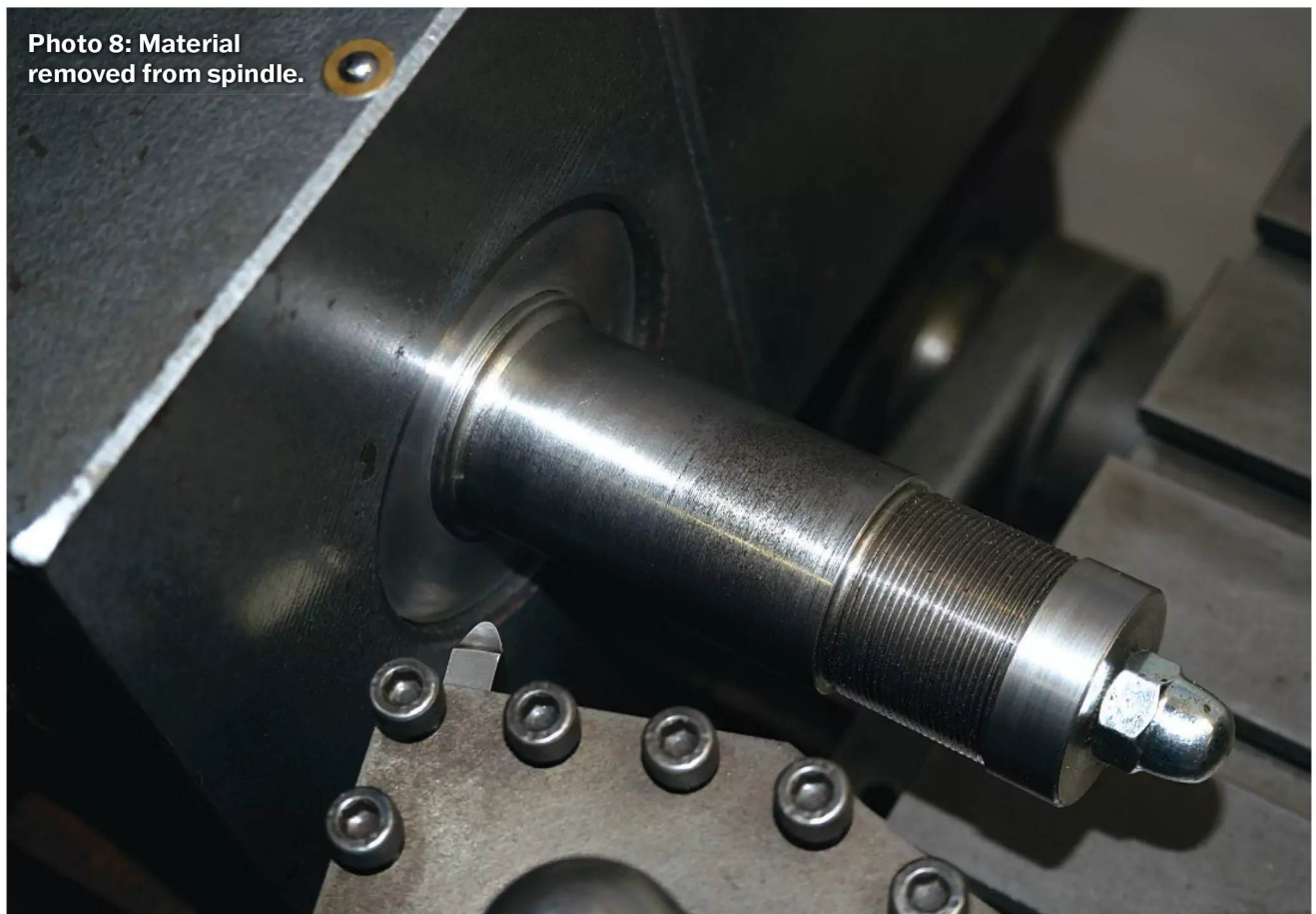


Photo 8: Material removed from spindle.

Photo 9:
Short spacer
ring and gear
position for
the tumbler
reverse.



secondly, if the tool wears slightly as it is cutting, the surface produced will be concave which is more desirable than a convex surface. Another thing you can do with a diamond toolholder is fit round HSS tool steel in place of the normal square bit to give an even better finish.

When the spindle has been removed and refitted into the headstock with the spindle nose on the drive belt side, the temporary pulley is attached to the spindle nose and driven by the Vee-belt as in **photo 7**.

To keep swarf out of the bearing while reducing the shaft, depending on how much material you are removing, you can fit one of the bearing seal plates or, if you need extra clearance, make a thin sheet metal washer.

A thin sheet metal washer held in place by the bearing grease can be seen in **photo 8**, along with the spindle reduced to the 30mm diameter. The amount of material removed in this photo is to fit the wide gear for the screwcutting dog clutch.

If you are using a shorter spacer, **photo 9**, you need to leave an amount of the larger bearing diameter protruding from the face of the seal to locate the spacer ring, as it is just a thin walled bush.

The spindle is now transferred to the mill to lengthen the keyway and fit a new key. When you are ready to reassemble, clean and grease the bearings with a good quality grease. Assemble the spindle into the headstock and adjust the bearings to the correct preload for your machine.

The extended key is shown in **photo 10**, along with the reduced spindle finishing just below the surface of the bearing seal, to ensure the clamping forces are transferred through the gear to the seal, then the bearings to set the preload.

The spindle set up for the screwcutting simplified clutch with wide gear, embryo 60T gear for the dividing attachment with modified pulley, can be seen in **photo 11**, along with a new bearing adjuster nut and rear spindle steady/locknut.

CONCLUSION

Upgrading your machine tools increases their versatility, allowing you to do more and varied tasks with greater ease, at the same time as improving your skill level.

It is good if you can do an upgrade without changing the original machine, but this is unavoidable at times. The option to revert back to original is sometimes desirable but after you have become accustomed to the new features, it may be the last thing on your mind. If you ever sell the machine, the additions may realise a higher value but even if not, knowing the new owners experience is enhanced by your improvements may be reward enough.

I still consider myself an enthusiastic amateur but working through jobs like these helps gain skills and confidence, seeing ideas transform into drawings then workflow planning and problem solving to completed tasks. 🎯

**Photo 10: Machined
spindle end with
new key fitted.**

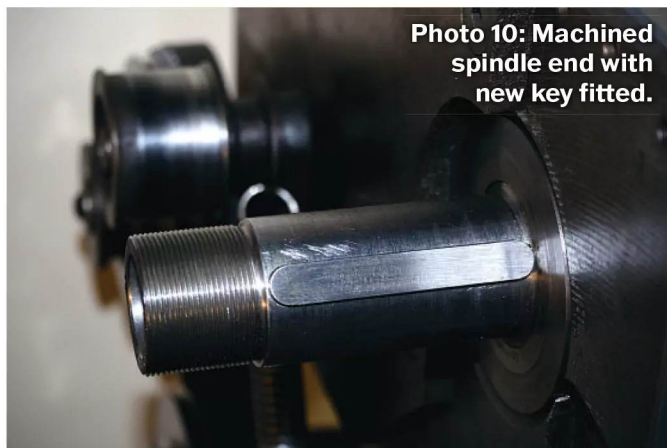
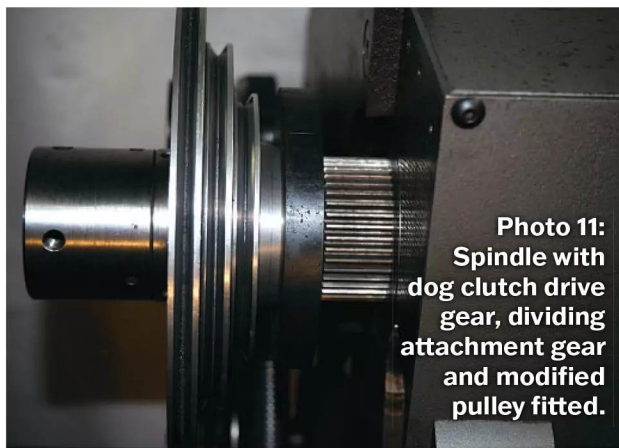
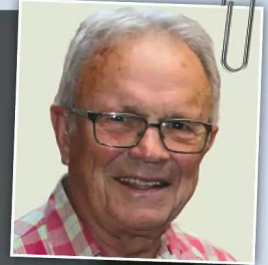


Photo 11:
Spindle with
dog clutch drive
gear, dividing
attachment gear
and modified
pulley fitted.





A Toolpost Drill

As the saying goes – ‘waste not want not’, **Jim Perry** recycles an old battery drill as a lathe accessory.

Photo 1: The adapted drill on the lathe.

Quite a few years ago, I went to get rid of an old battery drill. As usual I first dismantled it to see what it's made of. Despite the cheap exterior it had a very well-made electric motor and chuck assembly. Much too nice to throw away, so, into the 'sometime' bin it went.

On a number of occasions recently I needed to drill holes in a work piece, ideally whilst it was still in

the lathe chuck and typically on a pitch circle diameter. The solution was to mount a drill on the tool post, much as a grinding spindle would be fitted.

It proved to be perfect time to utilise the ex-drill motor and chuck. The photos show the result. **Photograph 1** shows it in work position and **photo 2** has the tool post swivelled to better show the adaptation. **Photograph 3** shows the fixing bar.

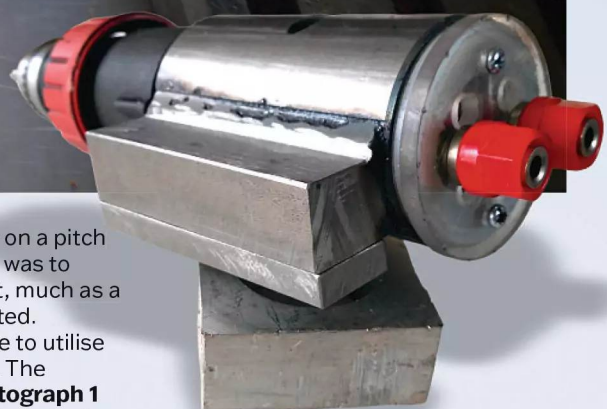


Photo 3: The bar used to mount the drill in the toolpost.



Photo 2: A clearer view of the lathe itself.

It originally ran off 9 volts. It now uses a 12 volt battery. The split sleeve has ventilation slots etc. to match its original requirements. It runs happily and doesn't appear to overheat. It's probable that the split sleeve itself is already an adequate heatsink.

I don't think it needs descriptive sketches. The only particular accuracy required was ensuring the drill chuck height matched the centre of the lathe.

It must have been years in the 'sometime' bin; I always get a kick when the bin proves its worth! ●

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Gerald Martyn builds a locomotive he can lift. Continued from Model Engineer & Workshop issue 4766

A GWR Pannier Tank in 3 ½ Inch Gauge

PART 15

Photo 104: Test pieces made prior to boiler construction commencing.



BOILER SHELL

Time for the big one; the boiler. This is a job that uses heat, hammers and nasty fluxes - and forget about getting parts accurate to a thou' or two (except for machined components). It's good fun. The design is to what I will call the 'enhanced Rob Roy boiler code' with a dash of LBSC and is targeted for readers in the UK. Those of you elsewhere in the world or working to other codes will need to make your own adjustments. The Australian code is often mentioned here but most of the rules are mandatory and it is impossible to manufacture to this code in the UK because it specifies use of materials which are not available here, such as cadmium bearing solders, or to specifications which are not recognised - so, no thanks. Lots of Rob Roy boilers have been built by people with little or no previous experience (including me) so it must be a) possible and b) unless you know otherwise, safe. Calculations say this latter should be the case, too, so using it as my guide makes a lot of sense.

The boiler G/A drawing main views are shown at **fig. 46** and a firebox section and the extension panel details are at **fig. 47**. It is the same diameter (3.25") and uses the same tube as Rob Roy but the firebox end is rather different. This diameter tube should be readily available but is a little over-scale for the engine so the insulation and cladding needs to be kept to a minimum to maintain clearances. Don't worry about this, lots more can be added later to the inner face of the tanks and underneath the top cover plates. The grate is small but the firebox is deep and allows a similar volume of coal and has a similar heating surface to Rob Roy. I often think that some designs have fires which are too shallow and my previous narrow, deep fireboxes have all been a success. Keeping the firebox between the axles means there is space to have a roomy ashpan, too, without the shallow area that hampers Rob Roy. One drawback is that the boiler does not protrude far into the cab (as is also the case in full-size) so there is nowhere for the usual steam turret to screw in. Instead, there will be a manifold above the boiler fed with steam

from the highest point possible under the external cladding top panels. There is no provision for a superheater. The performance of LBSC style superheaters has been questioned in the past and, certainly, it is not possible to keep the flues as clean as one would like so the hot gas flow must be inhibited over time, reducing efficiency. With no superheater, there's one less complicated assembly to build and a greater tube heating surface is possible so is equivalent to Rob Roy tubes and flues within a shorter barrel. I've closed the firebox stay spacing up to 5/8" as it fits in better (and is stronger). The boiler is round-top, as Rob Roy, for ease of manufacture, whereas the original was a Belpaire. The boiler top will be hidden underneath the upper tank covers and the backhead will be hidden behind a Belpaire shaped insulated cover so there will be no external sign that anything is not to scale.

Back when I started model engineering, threaded and soft solder caulked firebox stays were still commonplace, but all-silver-soldered copper (rivet) stays were just becoming popular amongst those

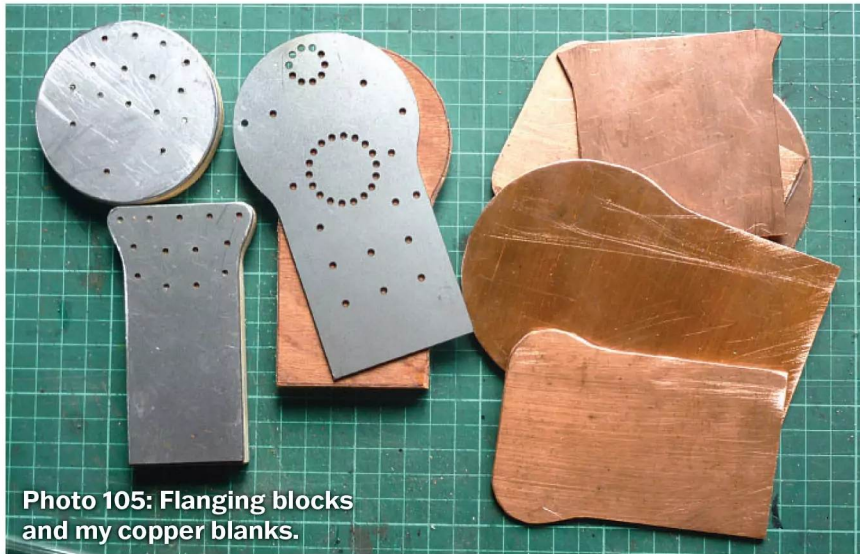


Photo 105: Flanging blocks and my copper blanks.



Photo 106: Flanged plates.



Photo 107: Superwool helps prevent heat loss.

with access to welding torches. There is no reason why threaded and soft solder caulked stays, as per the original Rob Roy design, should not be satisfactory

here and it may be easier to build this way. The threading is rather time consuming and the soldering sequence will not be as I describe but just follow the Rob Roy book. Concerned ...? Think on them as being an array of fusible plugs and perfectly satisfactory with water in the boiler. You may be surprised to hear, also, that drawn bronze threaded stays are stronger than soldered copper ones in spite of the loss of core area due to the thread. Alternatively use silver solder throughout as described by Alec Farmer and others. As I intend to make and test the whole engine before publication, then, I've chosen to use this boiler to trial a hybrid method which I hope will be easier and quicker for those without access to oxy-acetylene or oxy-propane welding gear. This method uses 1/8" copper rivets

as stays. They are fully silver soldered into the fore and aft ends of the firebox but in the sides they are silver soldered into the outer wrapper with the heads taking the inner wrapper loads caulked with a high temperature soft solder. The whole job was done using a single Sievert 5325 cyclone burner with no need for any welding kit. Finally in this section; it's about 20 years since my last boiler build (yes, I succumbed to temptation and bought one) and I've forgotten a lot. So one thing I did this time was to do soldering trials with solders and fluxes 'new' to me. These test pieces are shown in **photo 104**. You may find it helpful to complete a similar exercise. The other thing is that my hands shake more than they used to so the solder rod didn't always hit the right spot first time!

I've prepared models for the laser cutting flanging block facing plates in 2mm steel and these have pilot holes for all the drillings that should be put into the copper plates after forming but before soldering. The flanging plates need to be glued or screwed onto strong plywood or hardwood before use, and a small radius (say, 1/16") put onto the outward facing edges. There are also models for flame cutting the 2.5mm copper for the plates, though cutting them out does not take too long to do by hand as no great accuracy is required. A nominal bend allowance for straight bends would be around 5/16" plus some spare to give a bit of tolerance in positioning the plate and to give a flange with just a bit to trim back, with a bit more on concave curves and less on convex. Note that, apart from the front tubeplate, the copper plates are (should be) over tall so they can be cut back nice and square, and the flanging plates taller again to prevent overhang at the bottom edge. The backhead cover shape is also available as a laser cut flanging plate, for manufacture of the cover in brass. This will be described later but the plate may as well be ordered now. Here is the table with the laser and flame cut parts:

Tube materials, sheet, bar etc. are available from our usual suppliers and hopefully, having specified commonly used sizes, will remain available for years to come. For 16 SWG sheet material I purchased an over-length piece of barrel tube then sliced lengths out of the extra piece and flattened them out. About 11" extra is required and this worked out a bit cheaper (at extra work) than a standard size piece sheet and is just a few thou' thicker than the 1.5mm sheet now available in place of the good old 16 SWG.

Where to start? Before soldering, it's best to prepare a more or less full kit of parts then all the bush holes (for example) can be put in and checked whilst it's easy to do. The firebox inner and outer

Title	M.E. Laser Part No.	Material	No. Required
Front Tubeplate Flanging Plate	30787	2mm Mild Steel	1
Backhead Flanging Plate	30788	2mm Mild Steel	1
Firebox Flanging Plate	30789	2mm Mild Steel	1
Backhead Cover Flanging Plate	30790	2mm Mild Steel	1
Front Tubeplate Blank	36983	2.5mm Copper	1
Backhead Blank	36984	2.5mm Copper	1
Throatplate Blank	36985	2.5mm Copper	1
Firebox Plates Blank	36986	2.5mm Copper	2

wrappers cannot be bent up until the flanged plates are available to shape them to, so perhaps it's best to start with these. The plates drawings are shown in **fig 48**. Two flanging blocks complete and one awaiting gluing with Evo-Stick, and my copper blanks, are shown in **photo 105**. To ensure the pilot holes can be drilled in the right place, do check that the backhead plate is glued on the right way round, with the water gauge holes and low level water feed hole on the left.

There are no pictures of me whacking copper sheet into submission as it's not that interesting. To do the job just anneal the copper in the usual way, clamp it in position on the former in the biggest vice available (with spreaders and packers as required) and work around the flange, hitting it over with a hammer. I will reiterate the advice given in the Rob Roy book which is to stop and re-anneal as soon as the metal work hardens, which will be after only a hit or two in any one place. I didn't work the flanges too hard and tried to keep the bend even so the throatplate took four annealings, the backhead and front tubeplate five and, because of the tight corner radii, the firebox plates eight. The only problem I had was in extracting the front tubeplate

former which was well gripped by the flange. I ended up breaking out the ply layers as can be seen in **photo 106**. No problem, as I only wanted one plate, but thicker ply or a block on the back with screws through the plate would have been a good idea and given something better to grip it with. The plates need trimming and a bit of filing to get them to size, then the holes can be drilled. No marking out is needed! Using the 3/32" pilot holes laser drilled in the flanging plates, firstly drill from the metal side through the wood so the holes can be found from the back face, then pop them into the copper plates, metal side in, and drill through the copper. Opening out to size takes care but I've found that copper does not grab the drill in the same way as will happen with brass so the job is not too difficult. The hole rings for chain drilling are best opened up to 11/64" to give a bit of spare to clean out. I cut between the holes using a piercing saw. This little tool has been mentioned before and is a most useful item for all smaller cutting jobs.

The drawings for the bushes and bits are shown in **fig 49**. There is nothing much I need to say about them as the job is simple machining and the only thing worth a mention is that threads for fittings

should generally be started while the bush is in the lathe, so they will run true, but should not be put right through until after soldering is complete.

After a couple of trial pieces my first soldering job was to put the bushes into the backhead, using a higher temperature silver solder such as (in the old days) C4 or (these days) perhaps Silverflo 24 or L13S depending on supplier; something with a melt temperature starting around 700 degrees C or a bit higher. Use an appropriate flux, one that spans the melt range of the solder and has long life. Most model engineers will have heard of Tenacity No. 5 (600 - 900 degrees C). I used Thessco 'F' (650 - 850 degrees C) which is easier to clean off after soldering, but Thessco went into administration in 2023 so this may not be available. There is CuP Alloys FT5 (550 - 950 degrees C) which I've not tried. For pickling after each soldering session I use citric acid, which is readily available and less toxic than Sulphuric but takes a little longer to do the job. Unless you're running a production line, then the longer time doesn't matter too much. After pickling, check all the joints and drill the tapping holes in the regulator bush to full depth, noting that they go into, but not through, the copper plate.

The tube for the barrel is best cut with a hacksaw and squared-up using files, a square and surface plate. This doesn't take long and is quicker than messing around trying to fit it into a lathe as some do. Mark out and carefully cut the slits to allow the firebox end to be opened out, then anneal the flaps and open out to allow the backhead to fit at both ends (to make them the same). Fit and trim the throatplate to size and drill the stay holes. Trim the flaps back to drawing and hopefully this will give two off-cut pieces just about right to make the doubler straps.

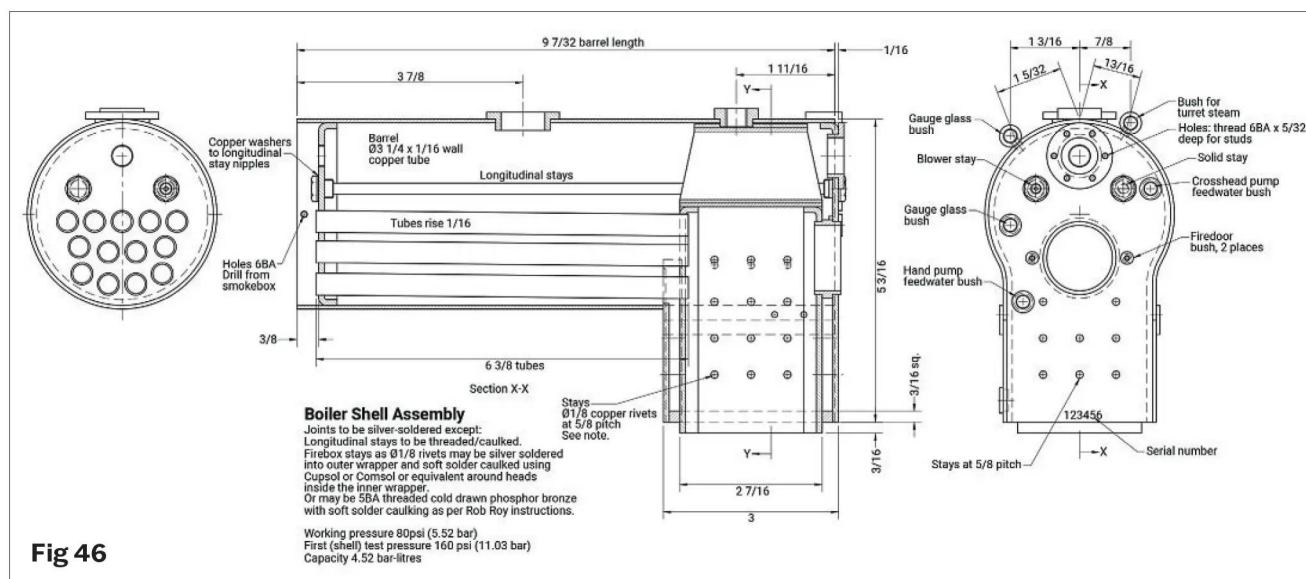


Fig 46



Photo 108: Spotting through by hand due to the confines of the throatplate.

Make up two extra pieces to extend the sides down and hold the throatplate and sides assembly together for soldering using lightly closed 1/16" rivets. Use as few rivets as possible (rivets can be leak points) and try to avoid a clash with the expansion bracket holes yet to be drilled. File some spare slivers of copper to fill any gaps at the top of the throatplate and solder up using the higher temperature silver solder. Ensure, too, that the rivet heads and tails are covered, at least on the outer face, to prevent any leaks. My set-up used some Superwool blanket to minimise heat loss, **photo 107**. The photo shows the joint fluxed ready for soldering. Do the throatplate then put the barrel on its side to do the doublers, otherwise the solder runs off down the hill. More than one heating may be required. After final cleaning-up, mark out and cut the holes in the barrel for the bushes as this is best

done while access is good and there's not a firebox and a mass of tubes inside to get in the way. Superwool is a ceramic fibre, high temperature insulation and there seem to be no safety issues with it, but a dust mask would be a wise precaution.

A note on drilling small diameter holes for rivets. Copper may be soft but it is very capable of breaking small drills if the swarf chips jam. One trick is to hone one side of the drill point to make it cut a little oversize and give more chip clearance. Even with this it's best to lift the drill out frequently to clear the chips and use paraffin or white spirit as a lubricant.

Next, the firebox wrapper can be cut, annealed and bent up to fit the flanged plates, using whatever tools and suitable bits of bar are handy. It's not worth the effort of making a fully shaped former. Unfortunately, the length required is about 10 3/4" so it will not quite make from a simple ring of boiler tube. Drill the wrapper and both flanged plates for a couple of holding rivets each side and loosely fit the plates. Make the crown stays to set the firebox at the correct height in the barrel and adjust them as necessary. Note that the CAD reference dimension on the drawing has no allowance for gaps for solder or the lumps and bumps caused by metal forming so the stay itself will need to be a bit less than this. Some trial and error is needed here.

Now remove the rear plate, rivet the front plate and the crown stays to the wrapper, apply flux and solder them up using that high temperature solder again. I've used the Rob Roy crown stay layout, by the way, rather than the rod stays many now favour, because I feel this way is better for beginners with limited heating equipment and it facilitates my hybrid stays method. For rod stays bear in mind that the maximum rod pitch should be 3/4" unless the wrapper crown is reinforced, so the regulator tube will rather get in the way.

Time for a break from soldering to make up and/or fit the assortment of bits necessary before moving to the next soldering stages. Cut the tubes to length and turn down one end of each to 23/64" for a length of 5/32", to fit the tubeplate holes without dropping through. Make up the front piece of foundation ring, clamp the firebox in place, check everything and mark out and drill the rivet holes for the crown stay to barrel joints. I found some 10BA bolts that would push through these holes and used them to hold things temporarily while a couple of rivet holes for the front foundation ring were drilled through. Next make up and loose fit the rest of the foundation ring, and also loose fit the backhead. Note that the foundation ring, too, suffers from forming wobbles and thickness tolerances so a fair bit of filing may be required. Check everything

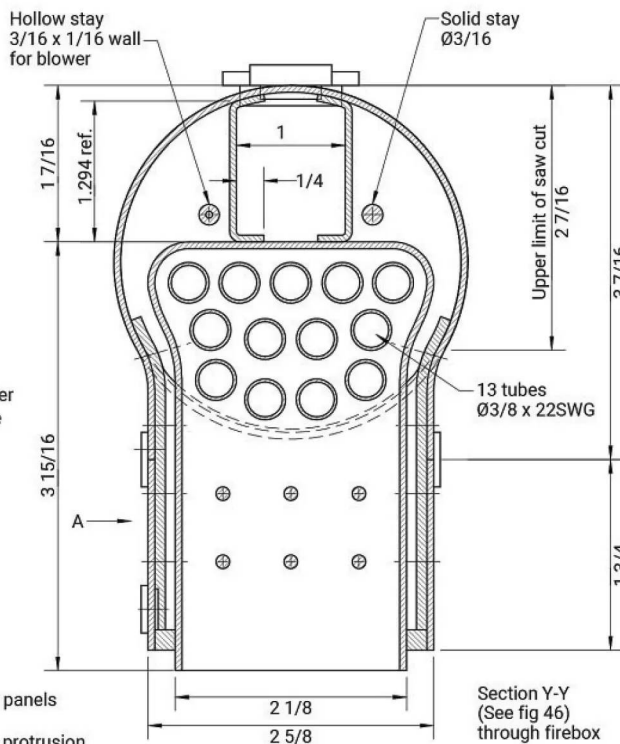
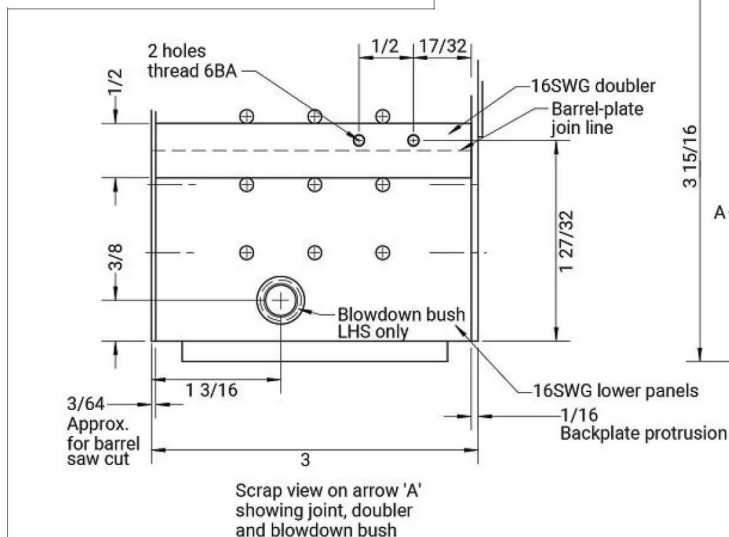


Fig 47

again then put the firehole ring in place in the backhead and mark out the for hole in the firebox backplate. Dismantle and cut the hole, then re-assemble, check everything again and drill the stay holes through the front and rear firebox plates. The throatplate stay holes are too close to the barrel for a normal drilling machine and chuck so I used grandad's hand drill again to spot them through before dismantling and finishing in the pillar drill, **photo 108**. The hand drill is also the best tool for putting the usual shallow dimples in the outer holes to help retain the silver solder. The assembled and clamped firebox and barrel are shown in **photo 109**. Now take things apart and then fix the rivets and solder the joints as follows, pickling and cleaning each joint to be



Photo 109:
Assembled and
clamped 'box
and barrel.

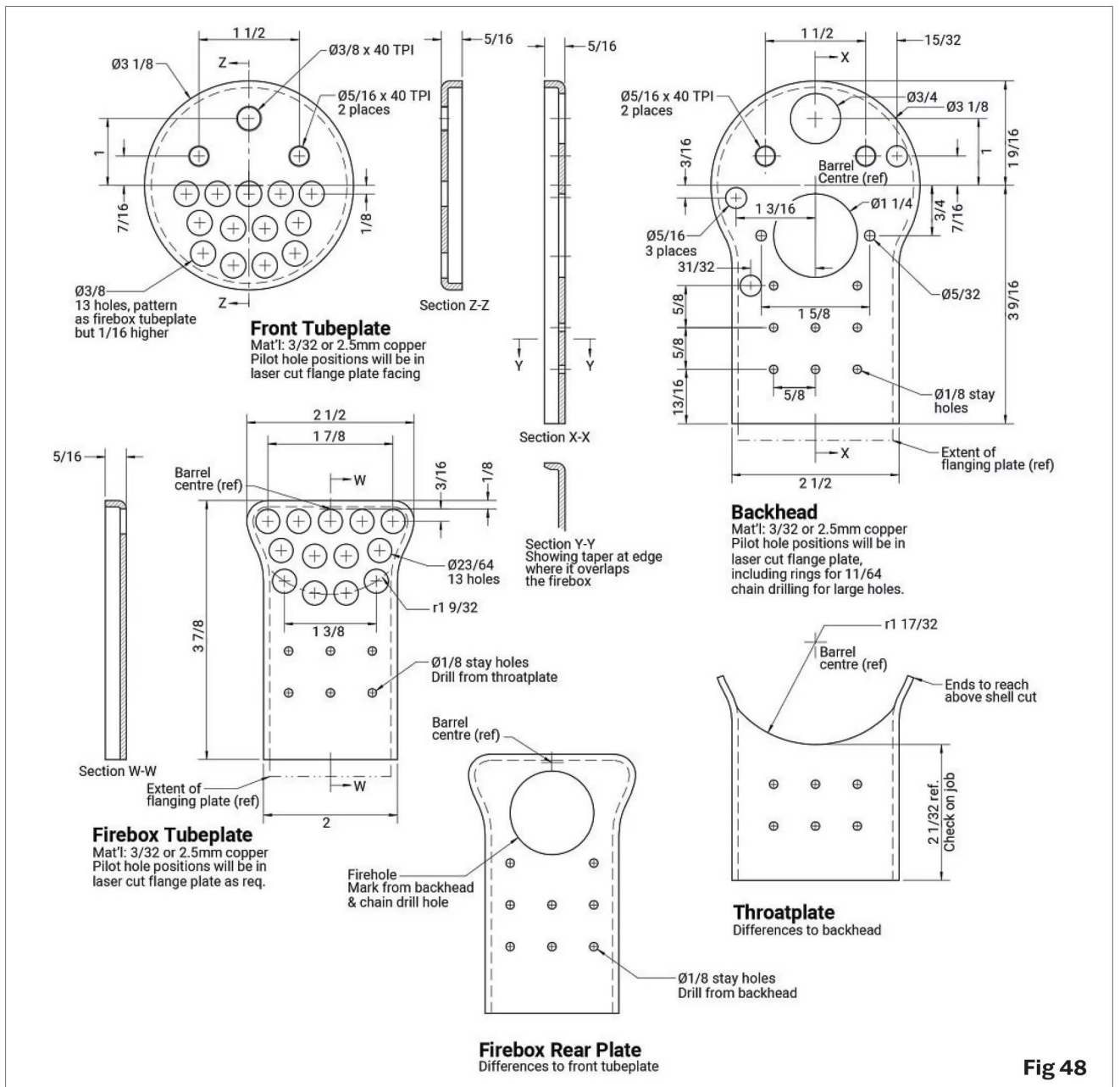


Fig 48



Photo 110: Heat is applied inside the firebox.

soldered between each step.

Use the high temperature silver solder to fix the firehole ring and the stay rivets to the firebox backplate. The rivets will stay in place if centre-punched a couple of times on the diameter where it will fit into the plate (to provide a burr to add a bit of friction). The crown stays and the firebox front plate can be soldered onto/into the wrapper next, again using the high temperature solder. The next job is to fit the tubes in place. Assemble the tubes with a ring of the lower temperature melt silver solder, Silverflo 55 or equivalent, around each and with a good layer of flux, and slide the front tubeplate on at the top end to keep them stable. Fit the stay rivets as above, again with a ring of solder and flux. Carefully position the assembly for soldering using a square and rule to get things right. Apply the torch inside the firebox, **photo 110** and soon the solder will run. Add some more if necessary but

not too much or it will just run down the wrapper and need to be filed off later. This is a worrying but rather easy job as most of the heat goes up into the tubes, which is just the right place. The last job in this sequence is to fix the firebox backplate into the wrapper using the lower temperature silver solder. These steps should give three sub-assemblies and a few bits of foundation ring, looking much as in **photo 111**. Now that the job is needing the lower temperature silver solder, it's useful to have some silver solder paste handy and put blobs on tack-rivet heads and tails. This resolves most of the difficulty getting them properly sealed and can also be used, now, on any higher temperature joints that may be of concern, as opportunity arises.

The next step is to bring together the firebox and tubes sub-assembly and the barrel. Fit the two parts together with just the front piece of foundation ring and put

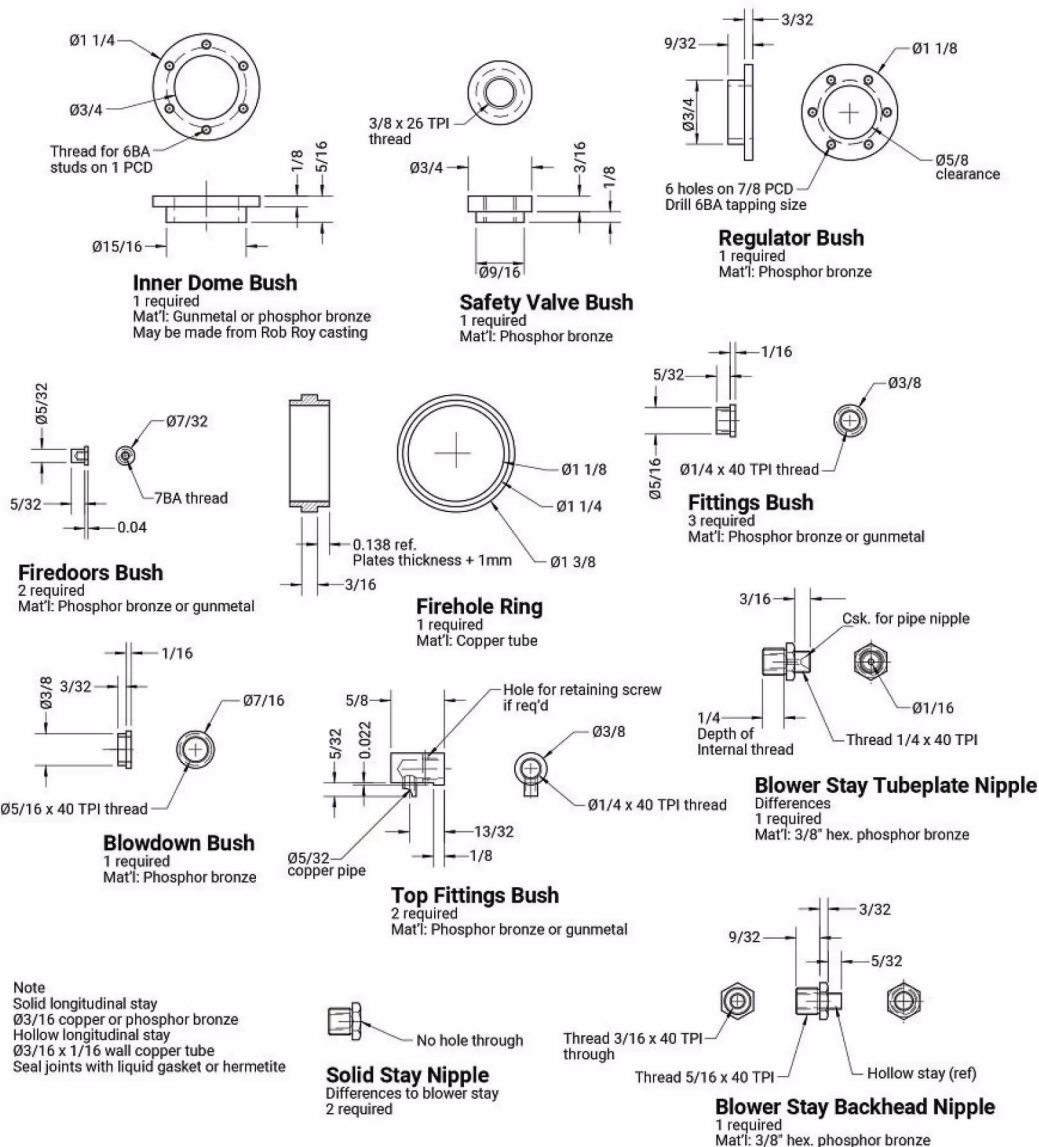


Fig 49



Photo 111: Three sub-assemblies.

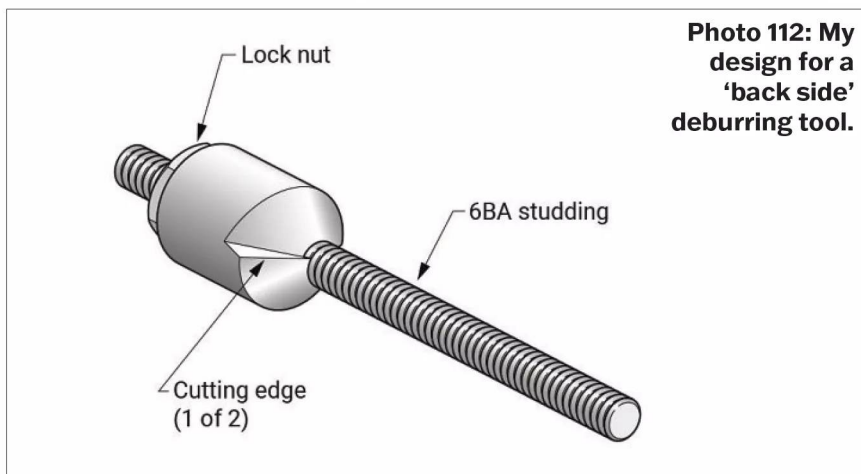


Photo 112: My design for a 'back side' deburring tool.

the tack rivets in here and in the crown stays. Fill any voids around the foundation ring using slivers of copper. Now flux the crown stay to barrel joint for high temperature silver solder and the foundation ring and front stay rivets for the lower temperature. These joints are far enough apart to allow the two solders to be used during the same heating cycle. Put the whole assembly on its back, raised an inch or so off the firebricks and with full access to the crown stay joint, and surround it with bricks and insulation. Heat the crown stay joint and solder with the high temperature solder. Now use tongs to raise the barrel up to about 45 degrees, prop it and solder the foundation ring piece and the throat-plate stays using the lower temperature solder. There's a lot of heat so it's at this stage that I started working outside my wooden workshop to remove the fire risk and also, from this stage, I don't quench until the assembly has well cooled for fear of popping a joint due to differential contractions while the solder is still hot

and weak.

Mark out and drill for the side stays and carefully de-burr the holes. In my hybrid process the stays will be 1/8" copper rivets fixed in the outer wrapper using silver solder and at the inner wrapper the rivet heads will take the load and be sealed with a soft solder. It is important, therefore, that the heads sit firmly on the wrapper but they need not be flat to the surface. To do the important internal de-burr that facilitates this, a special little back-side de-burring tool can be made using silver steel (shaped then hardened/tempered) for the cutter and a piece of 6BA studding for the shank, much as in the sketch in **photo 112**, and grandad's drill can be used to do the work. Fit the foundation ring side pieces and all the stay rivets. It helps, again, to use a centre punch to raise burrs on the rivets to keep them in place, but this time also pack the firebox tightly with Superwool or equivalent but leaving the foundation ring area clear. Both sides can be silver soldered

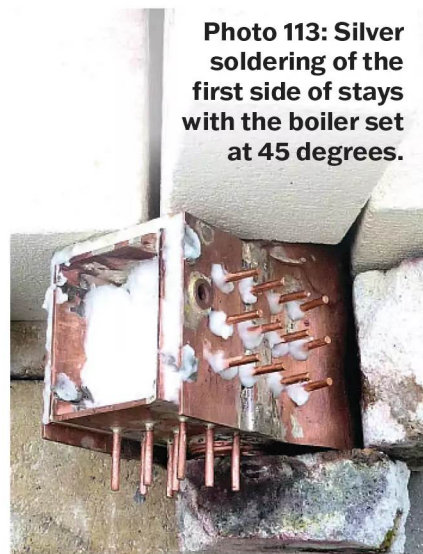
at one session. Apply flux to all the joints and stays and set the boiler at 45 degrees ready for heating, **photo 113**. Do the first side, roll the boiler over and do the other.

The backhead and last bit of foundation ring are fairly straightforward and, if a good fit, then no rivets other than those in the foundation ring are required. Solder all the stays (guess who missed one) and the firehole ring too.

Next are the top bushes. The two raised ones for the backhead fittings can be positioned using dividers set to the chordal dimensions on the drawing. The bush location tubes were intended to just push into the boiler, but my drilled holes came out oversize and I had to make up a couple of screws from 1/16" copper rivets to hold them securely. This option is indicated on the bush drawing. The screw sections through bores can be easily cleaned out when putting the final threads in. Keep an eye on the backhead joint when soldering these and add some solder if necessary.

Lastly comes the front tubeplate. There is a reason to leave it until last. If done too early then repeated heating and the associated differential expansions and contractions can cause buckling or bowing of the tubes. It's quite common and not generally safety critical, but may be considered unsightly when looking through during testing and cleaning. To get the plate in the right position, mark out and drill for three 1/16" rivets equidistant around the circumference to set the plate at the right level. The rivets are popped in and just used as location pegs to sit the plate on. Undoubtedly the tubes will not line up with the holes in the plate but they can be easily pulled into position and the plate set onto the rivets. Add solder rings around all the joints, including the one to the barrel, apply flux and heat up, adding solder as necessary. **Photograph 114** shows the flux just

Photo 113: Silver soldering of the first side of stays with the boiler set at 45 degrees.



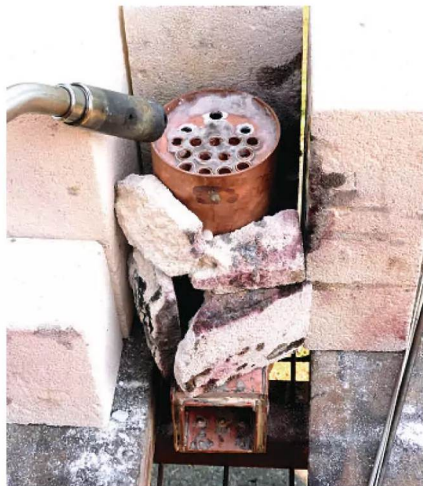


Photo 114: Soldering the front tubeplate.

starting to melt. This, too, is one of the easier jobs. Allow to cool naturally before giving the whole boiler a good pickle and clean-up, paying particular attention to those rivet heads in the firebox, and flush out the inside using a hosepipe. The boiler should now look something like **photo 115**. That completes the silver soldering, and for your information I used 5½ lengths of the 'hot' silver solder and 8½ lengths of the lower temperature type.

I think now is the time to tap all the threads, before moving on to the caulking. If a tap should break, then there's a better chance of carrying out a repair whilst still having the option of lots of heat and/or silver solder. Such things are ruled out after soft soldering. Go gently and carefully, especially with the ones in the copper for the expansion bracket screws. Note these can go right through, which is perfectly safe.

For caulking use a high temperature lead-tin-silver soft solder such as Comsol (Johnson Matthey) or CupSol (Cup Alloys) or an equivalent. These melt at



Photo 115: The silver-soldering is complete.

296 degrees C and an appropriate flux is Baker's Fluid or similar. I used CupSol 1.5mm wire and this was ideal as will be seen.

Set the boiler on it's side and elevated so that the burner can heat the lower outer wrapper and put insulation around areas not being soldered. Put a ring of 1.5mm solder around each rivet head and then just a few drops of flux into each ring using a small paint brush. The solder will follow the flux so it's best not to slobber it everywhere because this takes the solder away from the joint. I've used one of my test pieces as a sort of 'before and after' illustration, **photo 116**. The flux is quite aggressive and will clean the metal as it boils off, then, at a slightly higher temperature, the solder runs onto and through the joint, forming a fillet on the rear, but will not run where there's been no flux. I've checked all this works, too, using a suitably pre-oxidised specimen just in case the final pickle does not get everywhere. Back to the main job; heat the boiler gently from below the outer wrapper until the solder runs at all the rivets. There's no need to apply a flame

inside the firebox. Allow to cool, give a short pickle to the other side and set up and repeat the process there. Carefully inspect and repeat 'touch up' any suspect areas in a further heating if required. Give one last pickle, a wash out and a scrub and the job's done. A few years ago my house had a well hidden leaky pipe and I purchased a cheap borescope to enable its inspection, knowing this may have other uses! Inside the boiler is a bit close-up to focus and interpretation of what is seen needs some experience, but inside the firebox is easier, **photo 117**. The photo shows how mine looked.

Now fit the longitudinal stays using a suitable liquid gasket type sealant. I used Loctite 5660 purchased from a well known car parts and bikes shop. It is temperature resistant up to 250 degrees C, so in theory it would be feasible to soft solder over a minor weep without taking the stays out. Normal 180 degrees C soft solder will be found adequate for sealing any tiny weeps. The boiler is now complete and ready for testing, but please just wait until I introduce the fittings before rushing ahead. TBC



Photo 116: This test piece illustrates the action of the solder.



Photo 117: An inspection of the inner firebox by borescope.

A Response to the Yield Point Method

Mark de Barr offers a critique of the recent article on boiler shell design calculations.

The article by Les Smith and Alan Brown 'The Yield Point Method' (issue 4765) appears to be reinventing a wheel that has already been perfected by others.

A point to note is that only low carbon steels and wrought irons exhibit a clear yield point in their stress-strain curves. For other materials engineers use the 0.5% or 1% proof stress values instead of the yield point.

Industrial boiler design standards require the designer to take into account both the ultimate tensile strength and yield/proof stress values when developing the allowable stress for the design. As an example BS EN 12953 requires the nominal design stress to be taken as the smaller of the yield stress at the design temperature divided by 1.5 and the room temperature ultimate tensile stress divided by 2.4. This is stated in the following equation.

$$f = \min \left\{ \frac{R_{p0.2tc}}{1.5}; \frac{R_m}{2.4} \right\}$$

For copper used in a boiler with a design pressure of around 100psi gauge the yield stress at the design temperature will be the ruling value because the yield stress value will be deteriorating fairly rapidly at these temperatures.

The design temperature is given as the temperature of saturated steam for parts that are not exposed to heat transfer. 25°C is added to this value for smoke tubes and 50°C is added for parts exposed to the fire.

Assuming a design pressure of around 100psi gauge (7bar gauge and 8bar absolute) the saturated steam temperature is 170°C. The parts of the boiler exposed to the fire must therefore be designed for 170°C + 50°C = 220°C.

It is here that we run into problems because I know of no published data from a reliable source for the yield strength of copper at 220°C.

BS EN 1653:1998 Copper and copper alloys — Plate, sheet and circles for boilers, pressure vessels and hot

water storage units reproduces the values given in the German standard AD-Merkblatt W 6/2 but only temperatures up to 150°C are tabulated for annealed copper.

The graph, **fig. 1**, extracted from Copper Data, 14th impression, indicates the reduction in tensile strength of copper bears an approximately linear relationship to temperature up to about 350°C. Linear extension of the 1% proof stress given in table B.1 of BS EN 1653 indicates a conservative estimate of $R_{p1.0} = 40\text{N/mm}^2$ at 220°C. Dividing this by 1.5 gives an allowable design stress of 26.7N/mm^2 (3860psi). This compares well with the value that the article says Martin Evans used (25000psi / safety factor of 8 = 3125psi).

The yield point data quoted in the article seem very low. The European standards quote 60N/mm^2 (8700psi) and the American ASME code quotes 9000psi as the 1% proof stress values for annealed copper.

In the article the authors recalculate an example boiler barrel using their method, but they still use the same factor of safety of 8. The factor of safety of 8 already takes into account the difference between UTS and yield stress so a lower factor of safety should be used if the calculation is based on yield stress. This is why the authors are getting consistently higher values for shell thickness.

With regards to boiler testing at twice working pressure, the design stress of 26.7N/mm^2 at working temperature, as derived above, is less than half the yield stress of 60N/mm^2 at room temperature. Testing at twice working pressure at room temperature is thus a good guide to the proving that the design and construction are satisfactory.

The article only considers the design of a boiler barrel with internal pressure. This is the trivial part of boiler design. Things get much more involved

when you start considering flat plates with stays, tubes with external pressure, and compensation for cut outs in the boiler shell. If you value your mental health the only practical way to design a boiler is to follow a design standard or code. The industrial codes can be quite complex to apply. If anyone wants to design a copper boiler, or verify the scantlings of an existing design, I would recommend using the AMBSC Code Part 1 published by the Australian Miniature Boiler Safety Committee. Parts 2 and 4 of the code, relating to steel and duplex steel boilers respectively, are also very good.

The AMBSC Code does not state an allowable design stress as it is based on using tabulated values. Back calculating the tabulated values however shows that the tables for boilers operating at 7 bar have been based on a maximum allowable stress of 26N/mm^2 . This provides a very reassuring verification of the value derived above.

Creep is a significant factor for copper used at elevated temperatures and this results in lower allowable stresses being quoted in guidance for industrial pressure vessels that will be in continuous use. BS EN 1653 quotes a creep stress of 42N/mm^2 for an allowable metal temperature of 220°C and a boiler life of 10,000 hours. ●

PROPERTIES OF COPPER AT ELEVATED TEMPERATURES

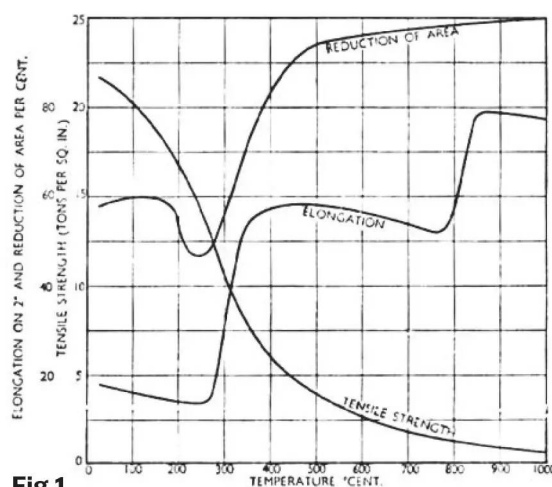


Fig 1

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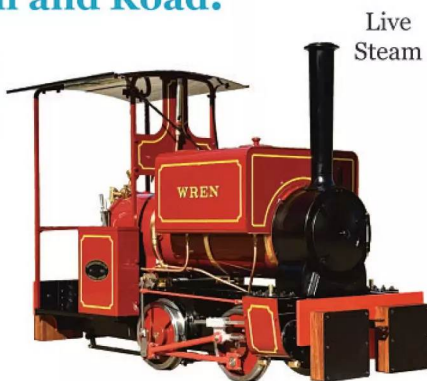
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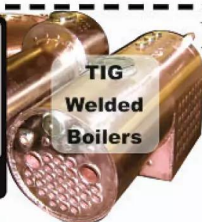
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Methoding refers to the process of planning and optimising the steps involved in creating a cast metal part. **Luker** looks in detail at riser and ingate design to help those with home foundries increase their success rate.

Backyard Foundry

Riser and Ingate Design (Methoding)

Techniques

Using a well designed riser and ingate can help produce quality castings like these gunmetal cylinders.

Reading is a pastime that compliments all hobbies, gives direction and sparks ideas. I don't have an idiot box and yes, we do have power here in Africa; sometimes. So the nights out of the workshop are spent reading arbitrary technical treatises.

Unfortunately, casting is one of the very few subjects where reading up on the topic results in diminishing returns rather quickly. The older books (the ones I prefer, written in the 1900s) give loads of examples and casting recipes but very little information on riser and ingate design.

The newer (hobby and industrial) books tell you to buy stuff from suppliers, items that can be found in the local grocer at exorbitant prices. Literature relating to the subject in academia is useless to say the least; most foundrymen do what academia call novel on a daily basis and this includes the solidification simulations used by industry. R. Wlodawer (one of the pioneers in mathematically describing metal casting) wrote an incredible book in the 1960s describing directional solidification for riser design in steels. Most of today's industrial foundry techniques are based on some of that early work. Unfortunately, all the industrial sources make two assumptions that don't seem to apply to the smaller backyard foundry. Firstly, the formulations for industry assume a much heavier casting where the emphasis is on yield and secondly, and probably the most important factor, the casting temperature is controlled rather accurately. Another issue with modern techniques is they typically assume a rigid mould (i.e. the phenolic binders) which requires different methods, especially with cast irons.

A good jobbing foundry (this is a foundry that does odd castings,

Methoding for casting			
Compiled by Luker for Model Engineers			
Last update 2020/08/13			
Inputs			
Material (alloy)	Cast iron		
Section volume	48512.2	mm3	
Section surface area	9412.71	mm2	
Height of riser	43	mm	Ok
Outputs			
Section mass	354.1g		
Section casting modulus	5.2	mm	
Riser base diameter (D)	28.2	mm	
Max feeding distance max (L)	49.5	mm	
Notch diameter (Dn)	5.9	mm	
Notch depth (Hn)	2.0	mm	
Minimum ingate area	107.2	mm2	
Ingate half circle radius equivalent	11.7	mm	
Use standard riser			
Pattern contraction allowance	0.97%		No contraction allowance needed
Note: Riser taper 12 Deg included			
Broken lines for cast iron (bottle) risers for improved yield			
H>1.5D			

Photo 1: Screen shot of methoding calculator, spoked wheel example.

typically for repairs) aims for a scrap rate of less than 7%. Most foundries don't achieve this. I consulted with one particular investment foundry that had a scrap rate more than double that, but the problem there was a people problem which I don't have the necessary skill set to solve. My scrap rate is typically below 5% with most of the failures on the first pour because the temperature is a little low resulting in a short pour. I'm also a little more pedantic with my castings; I count repaired castings as scrap and only perfect castings are included in my score card, so my methods seem to work.

With the prices of castings for our little hobby being exorbitant I have tried to make backyard casting more accessible to the average Joe who can't afford trade castings. There are a number of stumbling blocks for the beginner, with the riser and ingate design a major one that very few novices will get right. After casting hundreds of components you develop a feel for how big the ingates and runners should be but who wants to spend that amount of effort paying casting 'school fees' with hard earned tears?

THE METHOD CALCULATOR

I've spent the better part of a decade developing methoding to improve the metal feeding for small sand castings. The methods are based on industrial practices but because of the smaller

castings and the wide range of casting alloys and pouring temperatures, the calculations had to be re-derived from first principles and matched with my casting experiments. Don't worry, I'll spare you the maths; I've made a concerted effort to describe the methods in a practical fashion eliminating the calculus (fancy maths). I've also steered away from charts and tables because they can fill up these pages very quickly and honestly who wants to tear pages out of their prized magazine collection? Besides I don't bother with charts or tables, all my data is in a simple spreadsheet, **photo 1** that has evolved over the years. Our editor has been kind enough to load the calculator onto www.model-engineer.co.uk for all who are interested, for free! I only ask that it is used for model engineering and the big evil commercial vultures develop their own methods. The download link is <https://tinyurl.com/433h4v9n> or use the QR code.



THE BASIS FOR CASTING METHODOLOGY

I gave a brief description of my methodology in my Backyard Foundry

Photo 2: Spoked wheel pattern and risers.



Photo 3: Casting inclusion when no riser is used.

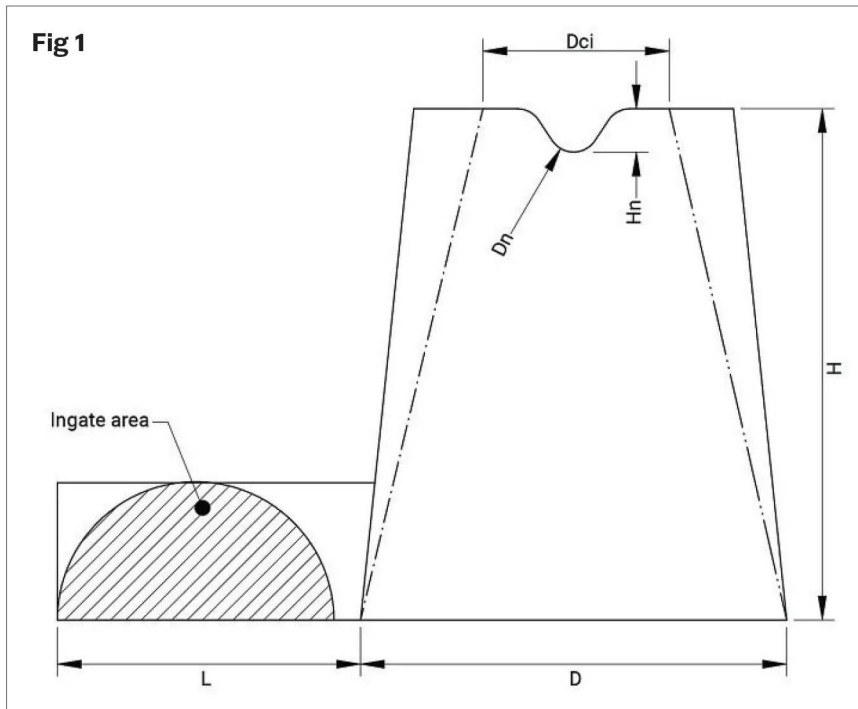
Techniques series but a quick recap won't go amiss. For most of my larger cast iron risers I use the bottle (modified for model engineering castings) type riser, **fig. 1**, are they easy to make and come out of the sand very easy. For all the non-ferrous risers I use the more common riser system typically used in industry (similar to the bottle but with a standard 12° taper from the base). They are both blind risers meaning they are completely covered with sand, with only the breather holes extending to the top of the moulds. The problem with casting is simple; as the molten material cools and shrinks the last bit to solidify will have nowhere to shrink, causing the dreaded blow hole or casting cavity. The idea of a riser is to feed this volume as it shrinks preventing a cavity. With this in mind the design of the riser must be such that the riser stays molten longer than the section of the casting it's feeding (as well as the metal flow path to the section being fed).

The heat loss is from the surface of the casting into the sand so if we take the volume of the casting and divide it by the surface area, we have a number (let's call it a casting modulus) that describes the heat loss area in terms of the casting volume. All we need, then, is to make sure the riser is designed with a larger casting modulus making sure it doesn't freeze prematurely. The metal flow path is a little more complicated but my calculator solves that in the background, so we don't need to worry about it.

$$\text{Casting modulus } (\mu) = \frac{\text{Part (section) volume}}{\text{Part (section) surface area}}$$

When working out the surface areas of cored castings the core will not always remove the same heat as the outside surfaces. If the core has a volume of less than a third of the casting, the core surface can be neglected. Anything between 1/3 and 2/3 assume 50% and greater than 2/3 the entire surface needs to be included.

Fig 1



Calculating the volume and surface area of a component can become complicated but if you break the component down into simple shapes and volumes it's easy. You also don't need to calculate the casting modulus for the whole part, only the areas that would require feeding. For the most part I calculate the volume and surface area using CAD but using the simple formulations in **table 1**, based on information from **ref. 1**, sections of the casting can be calculated. Remember using a conservative casting modulus will do no harm, for example: drawing a box around the hub of a wheel and using Equation d will give a conservative answer which is beneficial.

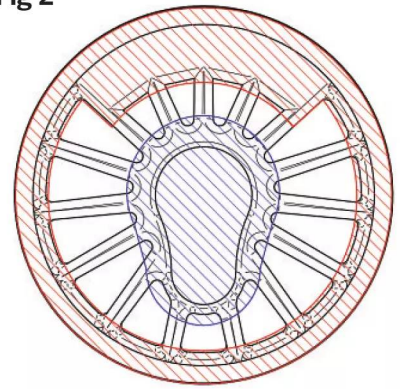
The base of the riser needs to be at least as high as the top of the pattern in the mould. Typically, with a two-part split pattern I place the riser directly on the section I want to feed and just grind it away afterwards. If you want to put the riser on the mould split line you would need to prop the riser up so that the base of the riser aligns with the top of the pattern by extending the base of the cone.

The notch at the top of the riser is important but the size isn't critical. It's there to promote piping through the riser, this just improves the feeding. If the riser is made properly the final shrinkage cavity will be in the riser and the entire cast component will be clear of any defects.

USING THE METHODING CALCULATOR

I've limited the calculator to the main metals used in model engineering and by simply selecting the correct alloy in the dropdown, the rest of the calculator is updated. The section volume and surface area is calculated from CAD or if the casting modulus is calculated using the table, then change these inputs to generate the correct casting modulus in the

Fig 2



output. The height of the riser should be as high as you can manage in the cope but at least one and a half times the base diameter of the cone.

The outputs give the general dimensions of the riser with the phantom line showing the bottle type risers I use for cast iron. The ingate area, equivalent radius and maximum feeding distance are a guide for the size and length of the ingate to feed the section properly. I generally go larger on the ingate and shorter on the feeding distance, but it depends on the method you use to cut the ingates in the sand. If you compare the ingate cut in the sand to the outputs of the calculator, you'll see very quickly if you need to make the ingate larger or shorten the path to the casting. For the most part our castings can be fed from the sprue. The calculator has built in logic that indicates when you can feed from the



Photo 4: Machined spoked wheel castings.

sprue and the base riser diameter then becomes the minimum size of the sprue.

Then finally the pattern contraction allowance is the amount, in percentage, you need to **add** to the pattern for solid state shrinkage.

For interest, the comment column will give guidance and advice on the input values. I do this with all my calculators because I tend to forget how I solved a particular problem. I had to clean up some of the comments, sometimes I code in things like 'Luker you're an idiot' - that pops up if I put in nonsense values, such is my sense of humour. Makes for an interesting conversation if you lend a calculator to a client that you haven't used for a while!

EXAMPLES

Anyone can draw up a fancy calculator taking into account the heat transfer characteristics of sand and the flow dynamics of molten metal, but the proof is in the practical. You ask an academic to pour metal and they will run for the hills! I am by no means an academic or armchair engineer so here are two common model engineering examples showing the methods and end results.

A SPOKED WHEEL

For all my main wheels, **fig. 2**, I work out the casting modulus for the hub (blue cross hatching) and the rim (red cross hatching) and I feed those sections separately; the spokes don't need to be fed as the casting modulus is very low. The ingate feeds under the rim riser catching much of the entrapped slag, with this typically positioned at the counter weight which will stay liquid the longest. You'll notice the standard riser type was used for this casting due to thermal requirements, **photo 2**. The standard riser can of course be used for cast iron, but the bottle riser should not be used for non-ferrous castings. This logic is in the calculator, so you don't need to worry about it. I have a great number of risers, so if I have a riser larger than required, I just use it instead of making a new one.

For this specific casting I actually cast a test piece without any risers for training purposes, **photo 3**. Without feeding the centre hub you likely to get draw at the centre of the volume. If this is compared to the machined (cast with a properly riser) wheel set the advantages of

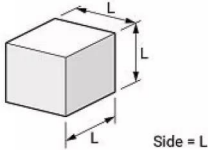
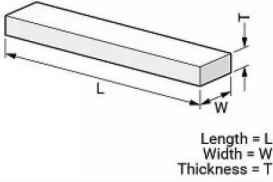
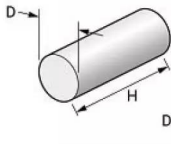
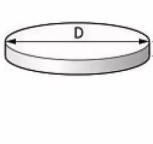
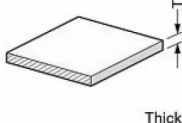
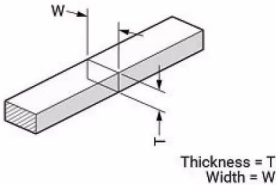
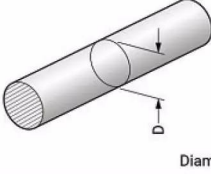
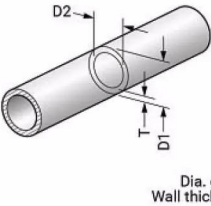
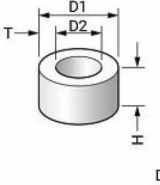
Shape	Dimensions	Modulus
A. Cube	 Side = L	$\frac{L}{6}$
B. Bar or plate	 Length = L Width = W Thickness = T	$\frac{TWL}{2(TW + WL + LT)}$
C. Cylinder	 Diameter = D Height = H	$\frac{DH}{2D + 4H}$ Note: If H = D the modulus is $\frac{D}{6}$
D. Disc	 Diameter = D Thickness = T	$\frac{DT}{2D + 4T}$
E. Endless plate (ends terminated by another part of casting)	 Thickness = T	$\frac{T}{2}$
F. Endless bar (ends terminated by another part of casting)	 Thickness = T Width = W	$\frac{TW}{2(W + T)}$
G. Endless cylinder (ends terminated by another part of casting)	 Diameter = D	$\frac{D}{4}$ Note: Because radial heat flow is faster than that from a flat surface, calculated moduli for endless cylinders may be reduced by multiplying by 0.85
H. Endless hollow cylinder	 O.D. = D1 Dia. core = D2 Wall thickness = T	$\frac{D1 - D2}{4} = \frac{T}{2}$
I. Annulus	 O.D. = D1 Dia. core = D2	$\frac{(D1 - D2)}{2(D1 - D2) + H} = \frac{TH}{2(T + H)}$

Table 1



Photo 5: Gunmetal cylinder and valve chest as removed from the sand.

taking the time to do the correct methoding is clear, **photo 4**. Incidentally the screen grab for the casting calculator is for the centre hub of this wheel.

A GUNMETAL STEAM CYLINDER

Gunmetal and brass can be difficult to feed properly, especially if there is no method of proper temperature control. The following example is a combined casting of a valve chest and cylinder. The cylinder has a rather large volume between the bore and valve surface that required a decent feeder. This was decreased to a certain degree by removing material around the steam channels, but it still resulted in a large casting modulus. After sizing the riser it was placed at the highest position in the mould directly above the area that

required feeding. The valve chest had a favourable casting modulus low enough to feed directly from the sprue, **photo 5**.

The machined cylinder looked pretty good when machined, see the header photo, so the riser did its job!

IN CLOSING

Nobody likes to battle and experience is just another word for tried and failed many times (I would know!) I hope that the methods described and the calculator will help any backyard foundryman battling with draws and inclusions improve their castings. At the very least it will take away some of the guesswork (that later becomes experience) allowing the novice to hit the mark first time!

POSTSCRIPT

The methoding (and calculator) was passed on to fellow foundryman, Gerald Martyn. I was delighted to get the following feedback: *'Just thought you'd like to know that I used your methods to calculate riser size recently and got a couple of perfect castings. First bit of casting I've done in a while so it was not a certainty that all would go well. The latest project is a small one using Rob Roy castings...'* It's really nice to know the methods work for different foundrymen and not just my setup.

Reference

1. Brown, JR.2000. *Foseco Ferrous Foundryman's Handbook*. Butterworth Heinemann: ISBN 0 7506 4284 X.



Selected patterns (that fitted on the dining room table).

Quick Notes from the Workshop

Following last month's article by Gavin Blakeman, here is some more explanation of the use of a tailstock chuck. When a workpiece needs to be supported at the far end it is usual to drill a centre and use a fixed or revolving centre to support it. If the work can't be drilled at the end, then you

might use a fixed or travelling steady or a revolving cup centre.

There are times when it isn't practical to use any of these approaches, due to machining requirements or for other reasons. In the example here a small aluminium bar needed 'waisting' over most of its length, but it only

had tiny threaded ends, **photo 1**. One solution would be to cut the waist first, then hold the work in a collet, but in this case a tailstock chuck was used. Held between the headstock chuck and tailstock chuck by the two shoulders, **photo 2**, the part was successfully completed, **photo 3**. ●



Photo 1



Photo 2



Photo 3

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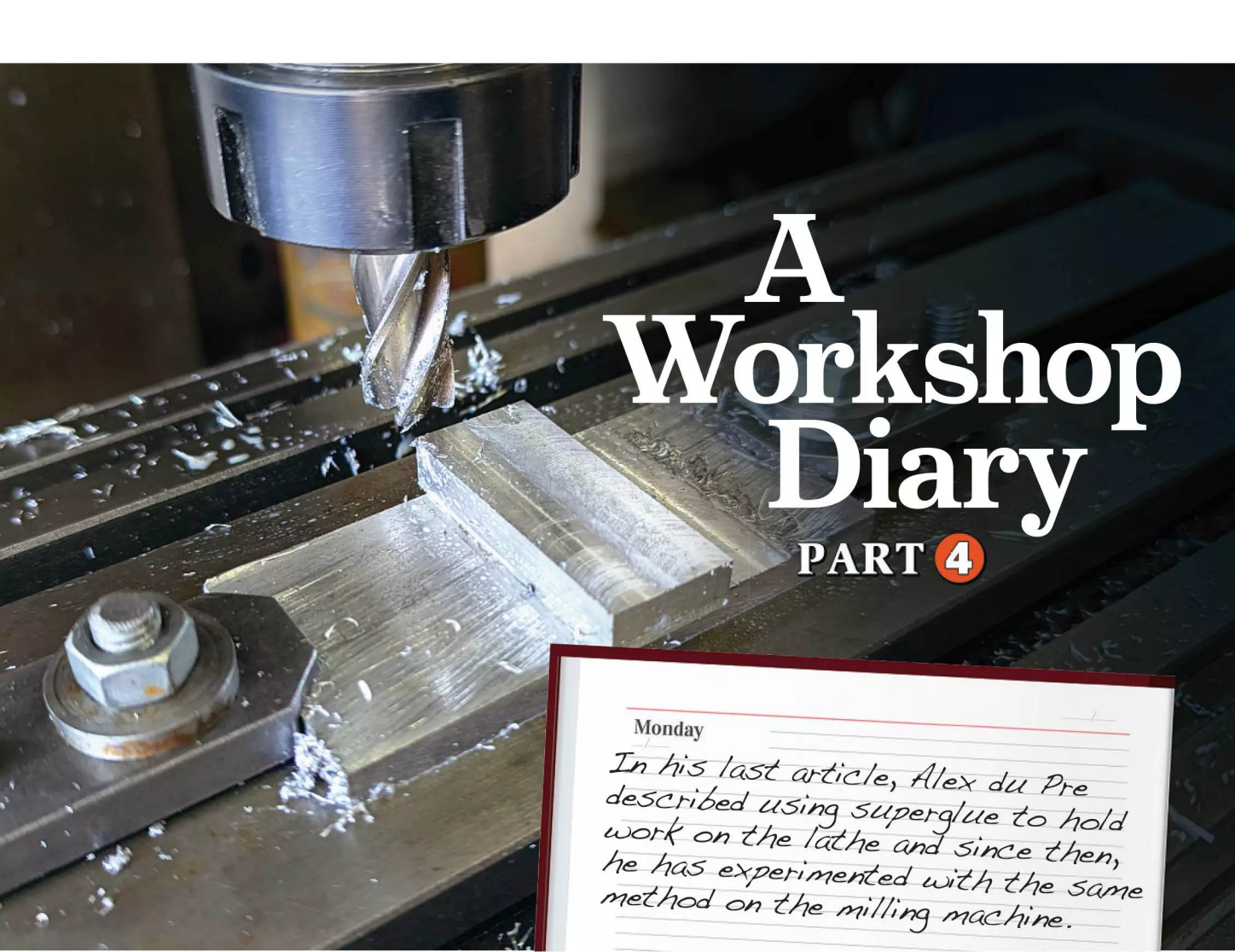
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A Workshop Diary

PART 4

Monday

In his last article, Alex du Pre described using superglue to hold work on the lathe and since then, he has experimented with the same method on the milling machine.

As a quick recap from last time, I explained how thin, small or otherwise fiddly workpieces can be successfully held for light lathe operations by supergluing them to a faced-off piece of aluminium bar held in the lathe chuck.

MILLING MACHINE APPLICATIONS

Most milling jobs are held on the mill table either by a combination of bolts and clamps or by using a machine vice. There are of course many variations on this theme and other methods too.

As with lathe work, there are sometimes milling jobs that present a workholding challenge. For example, thin work or work needing to be machined on all edges. The normal solution to such a job is to use several clamps, removing and replacing them in sequence to allow the cutter to reach all parts of the work. This is never very satisfactory, and the work can easily move.

One option for light work is to glue the work to an aluminium fixture, much

like the method described for the lathe. The fixture may be held in the vice or bolted to the mill table or rotary table and so on. This allows access to all the upper surfaces and edges of the workpiece to be machined at the same setting, with similar advantages to the lathe version.

A few examples will give you the idea, and I would stress that this method is not going to be suitable for heavy duty work.

A FIXTURE IN THE VICE

In this test, the task is to machine a small steel plate square on its edges. It would be fiddly to clamp this to the mill table, so it is glued to a fixture held in the vice. The fixture is made from a suitable aluminium offcut from the scrap bin. In this case, a piece slightly smaller than the finished dimensions of the workpiece was chosen, avoiding the need to machine away any of the fixture. Aluminium is easy to machine

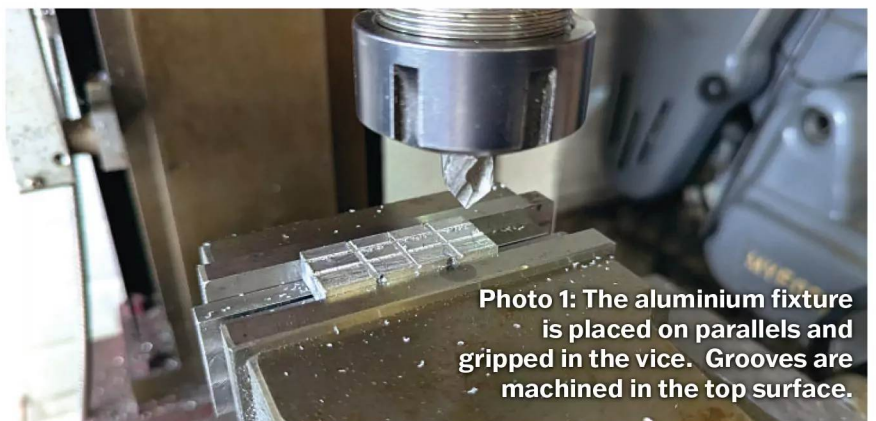


Photo 1: The aluminium fixture is placed on parallels and gripped in the vice. Grooves are machined in the top surface.

and can be quickly prepared but there is no particular reason why other materials could not be used, including wood in some cases as we shall see.

If the workpiece is not flat, this must be rectified first as a close fitting, secure glued joint is essential. Once the fixture is clamped in the vice, some shallow grooves are machined the top surface to allow air to circulate and help the glue to set, **photo 1**. The top surface is then skimmed flat with an end mill, **photo 2**, all burrs removed. Next, the mating surfaces of the fixture and workpiece are thoroughly cleaned with isopropanol or similar and the workpiece is superglued to the fixture and held until the glue has set, **photo 3**. The glue will grab very quickly but may take a few minutes to harden.

With the work secured, machining can be completed, **photo 4**. The glue will give a very secure hold if the job has been prepared properly, although getting too crazy with the feed rate or depth of cut is not recommended as the work will heat up and melt the glue.

When finished, the work can be

separated from the fixture by prying it off with a screwdriver or addressing it sharply with a hammer, protecting it from damage, **photo 5**. It can also be removed by heating gently with a blowtorch to soften the glue. If the fixture is to be reused, a further skim will remove all glue residue and leave it ready to go again.

A FIXTURE ON THE MILL TABLE

The second test shows a different approach where a larger fixture is clamped to the mill table, **photo 6**. The workpiece is a thicker aluminium block that needs to be squared and have two countersunk holes machined into it.

In this case, the fixture is sacrificial as it will be cut into by the mill and drill. As it came from the scrap bin, no great financial loss arises although it may still be used several times. For this test, the fixture previously used now becomes the workpiece, so already has the grooves machined into its bottom

surface. Otherwise, the new fixture would need to be grooved accordingly before gluing the two together.

The squaring operations are completed first, **photo 7**, followed by the drilling, **photo 8**, before the workpiece is freed from the fixture by a hefty hammer blow.

A FIXTURE ON THE ROTARY TABLE

The final test is a notional arc-shaped component from 3mm aluminium sheet, **photo 9**. This was made using the rotary table to ensure accuracy and as with the other examples it is superglued to a fixture that is itself bolted to the rotary table. Given the thinness of the sheet material and its awkward shape, there are few other ways to hold this workpiece which don't involve cutting it from a much larger sheet of material, and none that I can think of that are as convenient and satisfactory as the glue method. For this example, I wanted to prove the use of

Photo 2: The fixture is skimmed flat with an end mill.

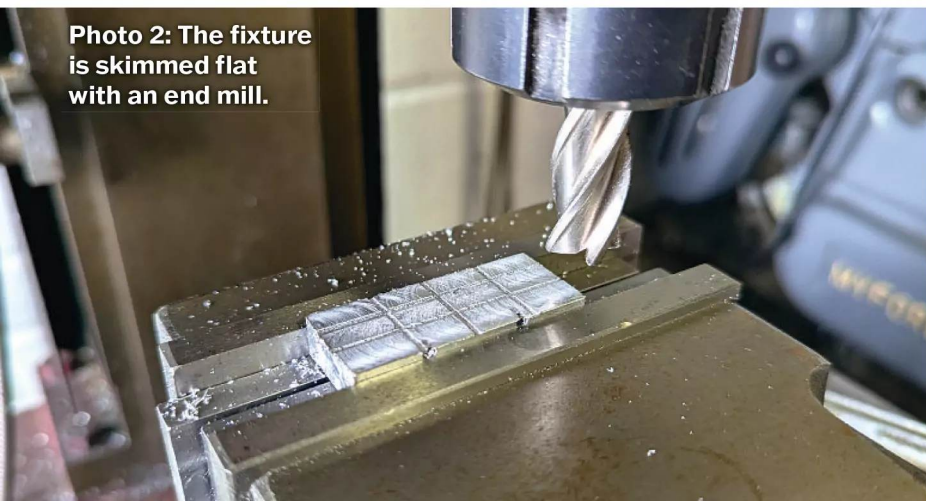


Photo 4: The workpiece is machined square by running an endmill along all four edges.



Photo 3: The workpiece is superglued to the fixture.



Photo 5: The finished workpiece is checked for square.



Photo 6: The fixture is clamped to the mill table and skimmed flat where the workpiece will be attached.



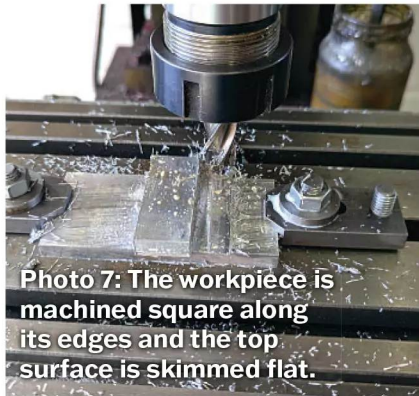


Photo 7: The workpiece is machined square along its edges and the top surface is skimmed flat.

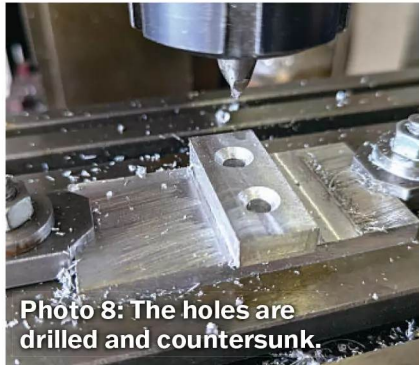


Photo 8: The holes are drilled and countersunk.



Photo 9: The workpiece is superglued to a plywood fixture bolted to the rotary table.

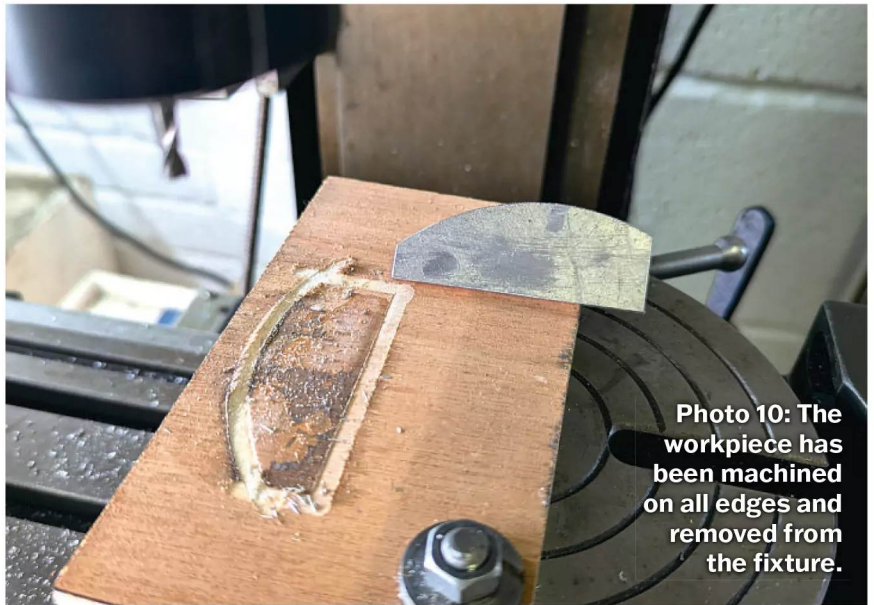


Photo 10: The workpiece has been machined on all edges and removed from the fixture.



Photo 11: The finished workpieces.

a plywood fixture and see whether the glue would hold, but I was surprised by how much force was needed to remove the workpiece after machining all edges. Again, I used the hammer method, and the clamping bolts shifted before the workpiece let go, **photo 10**.

SOME VARIATIONS AND FURTHER CONSIDERATIONS

As demonstrated, using wood for the fixture rather than aluminium is worth considering, especially for larger work. A thicker (more viscous, grade of superglue may be needed to avoid it disappearing into the

grain of the wood. Plywood should be flat enough for most work, especially where the machining is limited to holes or slots or similar.

Double sided tape can be a satisfactory alternative to glue for some jobs, particularly where the surface area of the tape is large relative to the size of cutter being used. I am envisioning a largeish sheet of material being held for drilling operations, for example.

If using the superglue method for a large workpiece it may not be necessary to cover this whole joint area with glue. A few blobs spaced at reasonable intervals should suffice.

If you are worried about the ability of the glue to hold the work a few strategically positioned dogs around

the perimeter of the work will resist cutting forces. These may be repositioned without disturbing the work as machining progresses. Light cuts with sharp tools can only help.

CONCLUSION

I hope this has given you some ideas to boost your repertoire of workshop techniques. As always, it is horses for courses, and the suitability of a particular method depends on the work in hand. As for all work, don't push the machine or the set up beyond its limits, think through the risks and take sensible steps to mitigate them to keep yourself and your equipment safe from harm, **photo 11**.



An Introduction to IMLEC

Photo 1: The IMLEC flag is decorated with the names of past host clubs.

The editor, **Neil Wyatt**, visited this year's International Model Locomotive Efficiency Competition. As a prelude to the full event report, he explains the competition.

This June the 2025 IMLEC was hosted by the Fareham Society of Model Engineers in Hampshire. Regular readers of *Model Engineer* will be familiar with the annual report, but since our combination with *Model Engineers' Workshop*, many readers may be unfamiliar with the event and its significance. I have attended an IMLEC once before, at

Ishaw Heath in 2018, however that was just for an afternoon. IMLEC takes place over three days and I was at the magnificent Titcham site, **photo 2**, on Saturday and Sunday, as ME&W sponsors the event and I was presenting the prizes to the winners. My intention here is to explain the competition rather than present the result, which will be in our next issue.

So, what is the competition about, you may ask? Model engineers compete to drive a train pulled by a model steam locomotive around a dual gauge 5"3 1/2" gauge track for about half an hour, as efficiently as possible, **photo 3**. For various reasons the small scale (and the fact that model engines are primarily designed for disproportionate pulling power rather than efficiency) means that the efficiency is typically very low – often under 1%. With careful preparation and skilled driving, **photo 4**, it's possible to conserve fuel, make the best use of steam and achieve higher figures, sometimes 3% or more. Lionel Flippance has won IMLEC on seven occasions, using several different locomotives (the rules are designed to stop a single locomotive dominating the competition). A number of other drivers have won three IMLECs and last year's winner, Steve Eaton, is one of just two people to win four times. This shows that the driver's skill is hugely important. A great variety of engines participate, **photo 5**, and large, heavy and powerful locos arguably have a significant advantage; for this reason a special prize is reserved for the best performance achieved with a 3 1/2" gauge loco.



Photo 2: Kevan Ayling and his proposed BR 2-8-2 locomotive with the station and clubhouse beyond.

HOW EFFICIENCY IS MEASURED

Behind the locomotive a dynamometer car is fitted, **photo 6**. This records the distance the loco travels and the drawbar pull. Multiplying these values gives the total work done. This number is divided by the calorific value of the coal consumed during the driver's run and gives a percentage efficiency, **photo 7**. In reality, the calculations are much more complex. The dynamometer car takes many readings, **photo 8**, and any periods when the engine is stationary or running in reverse are disregarded, for example if it halts on a slope and has to back up to try again. Only useful work pulling the train forwards counts. There are rules governing how the state of the fire is assessed to ensure an accurate measurement of coal use is made.

A speed limit with a safety margin is set for each track, and exceeding this three times leads to disqualification. Exceeding a higher safety limit results in instant disqualification. In practice, this limits how much momentum can be built up on a downhill section and used to help climbing the next gradient.

THE CHALLENGE

Each driver aims to maximise the work done while minimising the quantity of coal burned. They select for themselves the number of passengers and passenger cars appropriate to their locomotive's capability and the gradients of the track. Sometimes, a train will halt because the loco cannot transmit enough power to the track and the wheels slip; on other occasions the loco simply can't generate enough power. A heavy, powerful loco may commence a climb fairly slowly, maximising the work it does hauling up each gradient, while smaller locos may have to rely more on the train's momentum in order to get a decent load around the track. This is where the canny driver, who understands all this, succeeds.

For those not familiar with driving a model locomotive, there are several controls. The regulator controls the steam supply to the cylinders and the valve cut-off is used to make more economical use of that steam, at the expense of power. The driver also stokes the fire and can use the blower to jet steam up the chimney, thus drawing more air through the fire. This gives control over how hot the fire burns, how much steam is consequently made and the rate coal is used. Over the course of a run, extra water is often required, **photo 9**. (Water used is not measured,

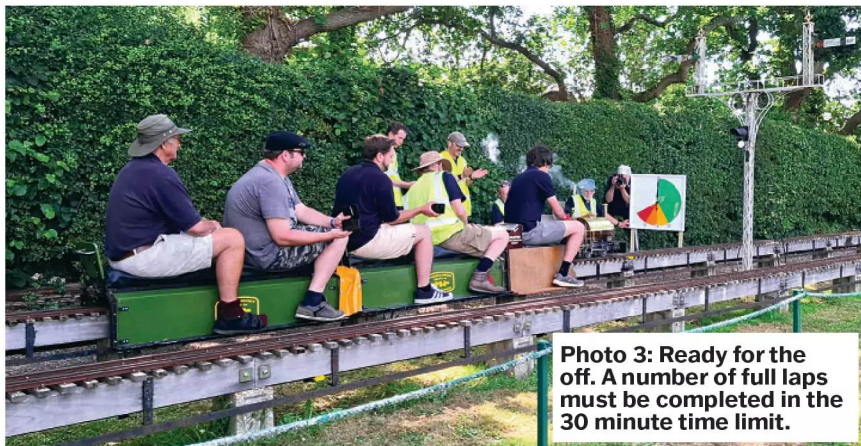


Photo 3: Ready for the off. A number of full laps must be completed in the 30 minute time limit.



Photo 4: Steam is raised using charcoal, the switch to coal is made at the start of the run.



Photo 6: One of the two calibrated dynamometer cars used to measure the work done and distance travelled.



Photo 5: Alasdair Croft's LNER A4 heads up a line of locos waiting their turn.



Photo 7: Each entrant collects a measured amount of coal; at the end of their run what remains is measured, and the amount consumed calculated.



Photo 8: The dynamometers put vast amounts of data onto an SD card. The spreadsheet speeds things up, but some manual calculations are done as a check.



Photo 9: Observers have a secondary task – collecting extra water on the move.



Photo 10: An observer looks apprehensive, as a marshal inspects the train coupling and Steve Eaton checks his War Department Austerity.

Over a long run, ash can build up and clog the grate or ash-pan, starving the fire of oxygen. Of course, there is also the potential for mechanical failures. The line between success and failure is a thin one, and there can sometimes be quite high numbers of retirements.

THE EVENT

There are two sides to the event. First is the running of the competition itself, which requires many skilled volunteers. As well as marshals around the track, observers ride behind the drivers watching the speed and ensuring that there is no 'leaning on the tender' or the use of a foot to



Photo 11: One loco is steamed up while another cools down as another is having its run.



Photo 12: Locos were placed onto the track using this traverser.



Photo 13: Evening entertainment include a fish and chip supper accompanied by live music.



Photo 14: A brace of Austin Sevens added a touch of class.

of course, and is freely available.) There are also 'tricks of the trade': arriving at the start line with a roaring coke fire, for example, so that the 'measured' coal isn't actually burned until needed. (Competitors light up with, and are free to burn, as much coke on the steaming bays as they wish.) This can sometimes result in disaster, though, because a coke fire has a habit of disappearing before the driver's eyes, before the coal fire has properly started burning!

Things can go wrong... if the boiler pressure gets too high, the safety valves 'blow off', i.e. vent steam, shooting hard-earned energy into the sky - which is, of course 'wasting coal'! In contrast, being too skimpy on fuel can result in a thin fire and a loss of much-needed steam pressure, usually manifesting itself on a tough uphill gradient.



Photo 15: A large boating lake sits within the track.



Photo 16: Live steam 32mm narrow-gauge locos were running on the garden gauge track, this one is gas fired.

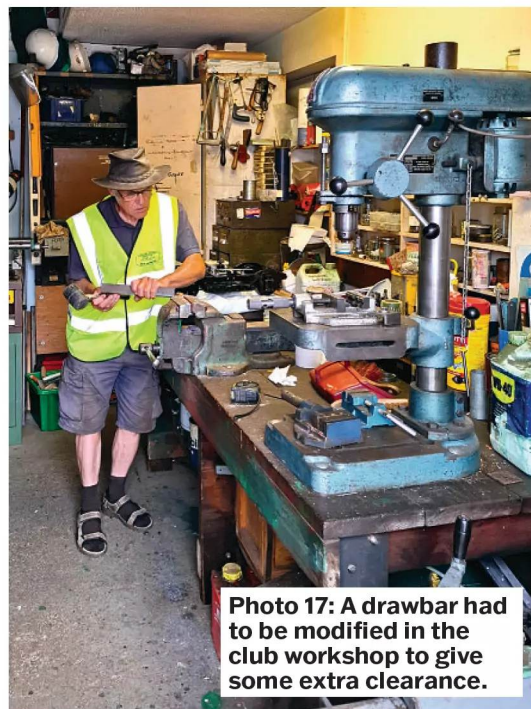


Photo 17: A drawbar had to be modified in the club workshop to give some extra clearance.

help a stuttering loco keep moving, **photo 10**. A whole team manages the constant cycle of preparing locos, **photo 11**, moving them onto and off the track, **photo 12**, ensuring safety and measuring time, weighing coal and processing the

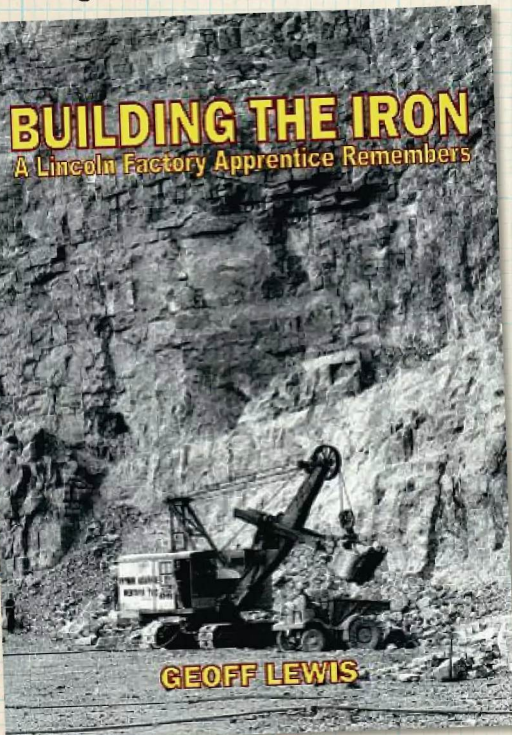
dynamometer data.

Equally important is the wider event management, **photos 13 to 16**, feeding, watering and entertaining a large number of visitors, marshalling the car park, liaising with camera crew, erecting marquees and gazebos, and

keeping everything tidy – as well as dealing with unexpected events, **photo 17**. I have to say I was hugely impressed by the job done by Fareham SMEE's volunteers in handling all this and ensuring a very enjoyable and friendly weekend. ●

Review

Building the Iron, by Geoff Lewis.



As the austere 1950s became the swinging 60s, Geoff Lewis spent five years as an apprentice with Ruston Bucyrus Excavators, working on the production of their huge machines. The book starts with his childhood in post-war Swansea, fascinated by the machines clearing WW2 bombsites and working on construction projects around the city. Despite a few mishaps, his father eventually secured him an interview with Ruston. After completing his school examinations he was off to Lincoln with his fishing rod but without his Meccano.

The book is presented in an engaging style that speaks directly to the readers. As you might expect, there are many factory floor tales, from the water otter to the slipshod worker running to keep pace with a slow drill he'd got caught up in. Geoff also recounts some of his life outside the factory, such as watching people fly control line planes in the park and fishing matches at the gravel pits.

What will fascinate readers of ME&W are his detailed descriptions of the machines, their workings and how they were assembled. As an apprentice, he was moved around every section of the factory. Geoff describes each stage of the process with explanations of how the hearts of these metal monsters functioned. He started filing clutch keys and moved through the different departments until he was working on calibrating safe load indicators, filing cams to shape by hand (coincidentally, I have a friend who works making load cells, the modern equivalent). There was a lot more than filing in between, including hobbing huge gears. Slow and lumbering, the machines were made with on-site repairs in mind – hauling a forty-ton excavator back to base for fixing is not very practical.

With around 190 pages in A4 format, the book has excellent period photos, but these do not dominate the text. Building the Iron is a long and engaging read that will bring back many memories for anyone who served a traditional engineering apprenticeship and give a real flavour of the time to anyone who was not there.

Building the Iron is published by Shedgnome and is priced £19.94, available from www.diggerynook.com ●

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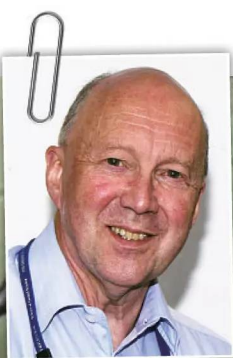
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A Tandem Compound Mill Engine

PART 18

David Thomas builds Arnold Throp's model of a Corliss mill engine. Continued from Model Engineer & Workshop issue 4766.

Photo 287: Setting up the rough (actually, not so rough) cylinder casting on the mill.

The low-pressure cylinder casting, **fig. 46**, was in gun metal and, unlike a lot of the other castings for this engine, had reasonably generous machining allowances. Generous, that is, except for the thickness of the base and the height from that to where the cylinder centreline had to be. What the casting didn't have was any immediately obvious surface to choose as a starting point for machining and getting it to its final size was going to be a process of successive approximations. Fortunately, the cored space for the cylinder bore was very smooth, straight and aligned very close to where the bore had to end up. With only a little filing the cored surface was made smooth enough to allow it to be used as the first reference surface when the casting was mounted on an expanding mandrel. In addition, the as-cast valve port face was close to being at a right angle to the base and so the mandrel was set up between centres on the mill table with the port face against an angle plate and the axis parallel to the long axis of the mill table, **photo 287**. At this stage I didn't know the precise height of the HP cylinder centreline above



Photo 288: Setting the height of the facing cutter so the height of the cylinder centreline above the base will be close to correct.

the cast iron base (that would have to be measured before the bore was finished) but the base had to be milled flat before any other surfaces could be machined. Having measured the distance from the mandrel centreline to the rough base, it was then possible to work out the minimum amount of metal that had to be removed to flatten the base. **Photograph 288** shows the facing cutter being set to the OD of the parallel part of the mandrel (the base has already been machined so I think I'd forgotten to take the picture and had to go back and dummy the process) and **photos 289** and **290** show the milling of the X and Y datum surfaces. Having the cylinder centreline close to the correct location and alignment was paying dividends. The distance from the port face to the centreline isn't critical so the part was then rotated 90 degrees, located by the newly machined base against the angle plate, and the port surface finished, **photo 291**. The mounted cylinder was then put between centres in the lathe to finish the cylinder ends to final OD and the cylinder to length. **Photograph 292** shows the lathe tool picking up the longitudinal datum before the end was machined, **photo 293**, and the process repeated at the other end, **photo 294**. The burrs left from NOT machining into the mandrel disappeared when the bore was finished.

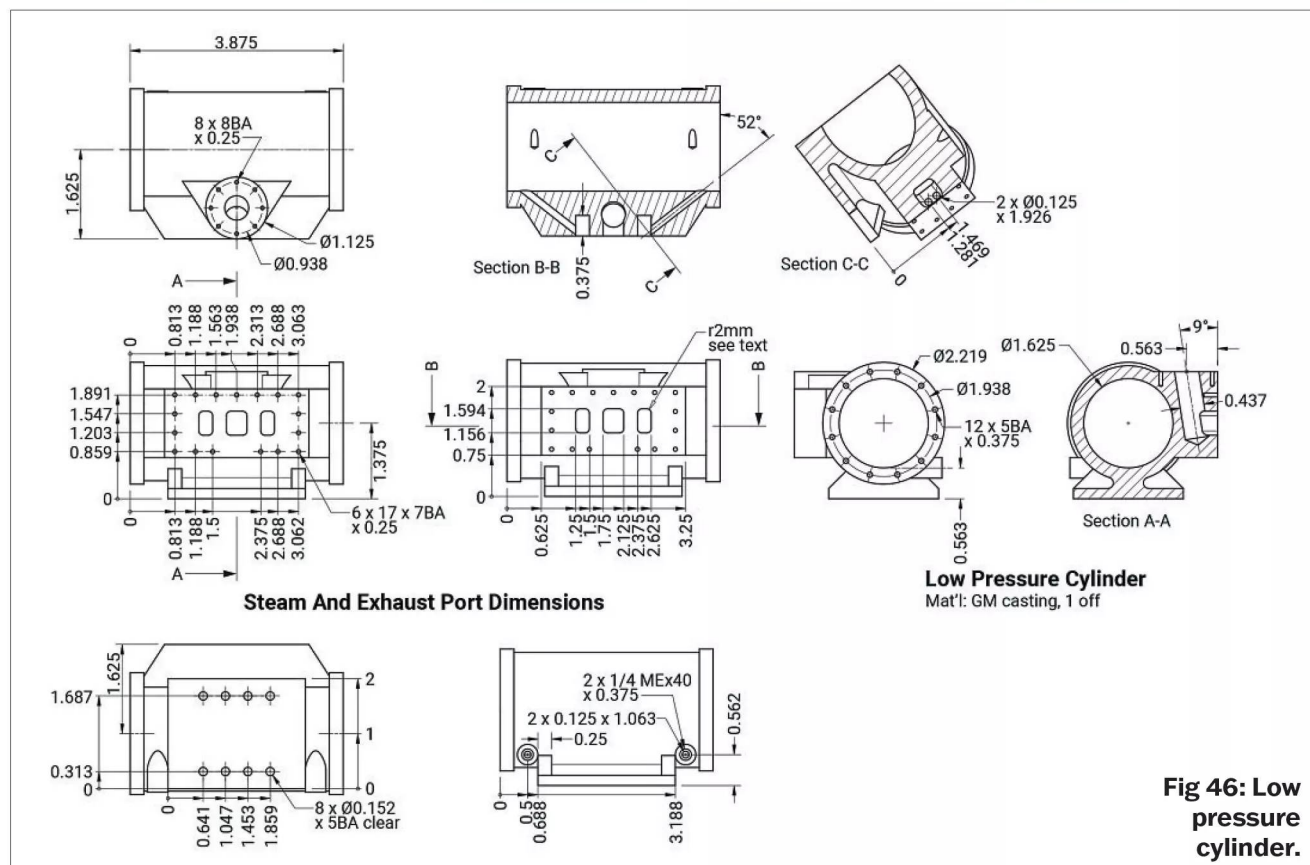
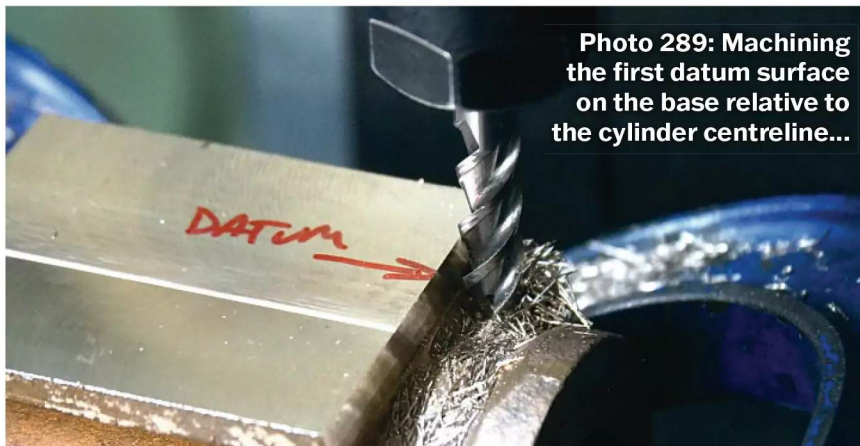


Fig 46: Low pressure cylinder.

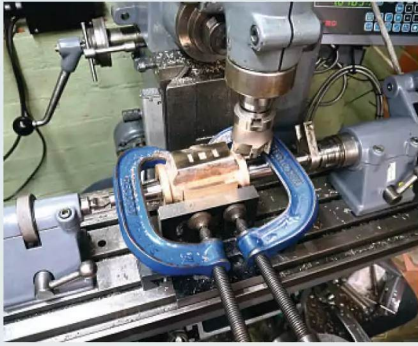


Photo 291: With the casting rotated 90 degrees, the valve face is machined to the correct distance from the centreline.

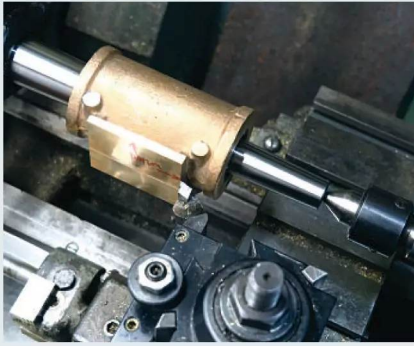


Photo 292: Picking up the longitudinal datum so the end of the cylinder can be turned to length.



Photo 293: One end of the cylinder could now be brought to length and diameter.



Photo 294: And then the other. Unlike most of the other castings there was plenty of machining allowance on this one.

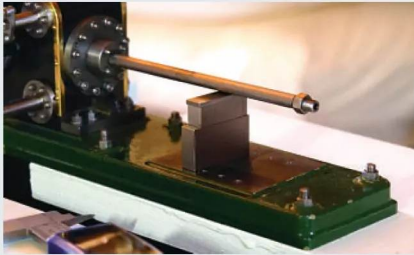


Photo 295: Measuring the actual height of the cylinder centreline above the base. It was only a few thou out but it's good to get things spot on.



Photo 296: Measuring the height of the lathe centre above the after-market boring table.

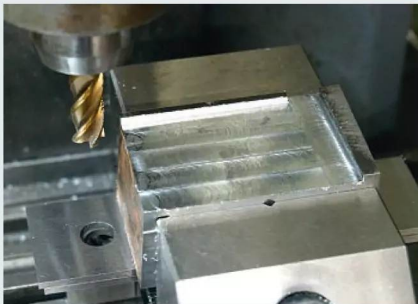


Photo 297: Making a one-off raising block with locating edges gives some certainty to the centre height and makes any movement under cutting forces less likely than with packing.



Photo 298: Not everything went exactly to plan and a bit of very thin shim was needed to get the height right before clamping down. Bringing the casting across from the mill, still on the expanding mandrel, was a part of the plan.



Photo 299: The sanity check with the indicator was encouraging.



Photo 300: The clamps were set to bear on the upper surface of the base to avoid any chance of distorting the cylinder. Standard mill clamps just made it for size, but some one-offs wouldn't be difficult to make.



Photo 301: Happiness is a smooth and parallel cylinder bore.



Photo 302: The expanding mandrel was checked for burrs then used to re-mount the cylinder for drilling the securing holes. The machined valve face was used for angular location.

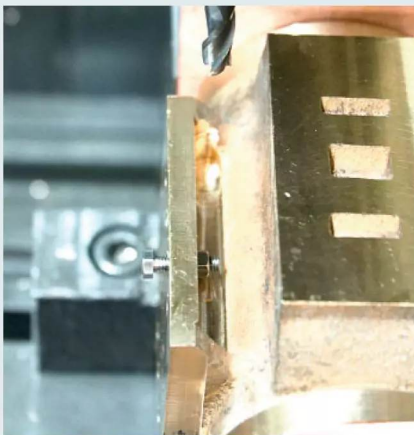


Photo 303: The cylinder base needed milling to thickness which also made space for the nuts.

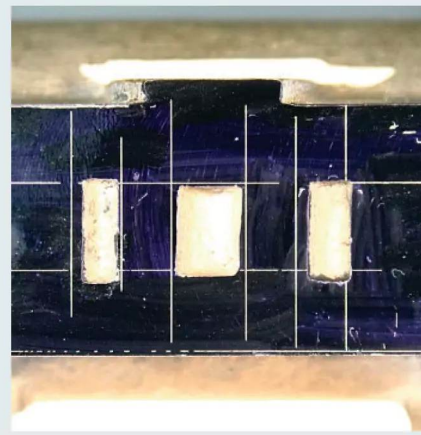


Photo 304: Marking out the ports showed up some sloppy pattern making (or moulding?).



Photo 305: The JB Weld used to correct the port edges can be seen here. The ports have been machined and the stud holes are being spotted out.



Photo 306: Starting the steam passages with a slot drill...



Photo 307: ...and finishing with a long series drill.

The as-made height of the piston rod above the base was measured using gauge blocks, **photo 295**, and this was just a few thou out from nominal. In **photo 296** I'm measuring the actual height of the lathe centre above the after-market boring table. The difference between these two measurements is the height of the packing needed to bring the finished cylinder centreline to the correct height. It would be difficult to get packing to exactly the correct height and even if that was achieved, then the casting would be relying on friction for its location in the other two axes; a machined nest, **photo 297**, makes sure of the security and height. If everything had gone to plan the 0.002" shim visible in **photo 298** wouldn't have been necessary but it wasn't far off. After removing the mandrel, the cylinder was checked for alignment, **photo 299** (once again I've had to go back and dummy a forgotten set-up; the bore looks finished). The boring bar was then substituted for the mandrel, **photo 300**, and the bore completed, **photo 301**, with the gunmetal machining very nicely.

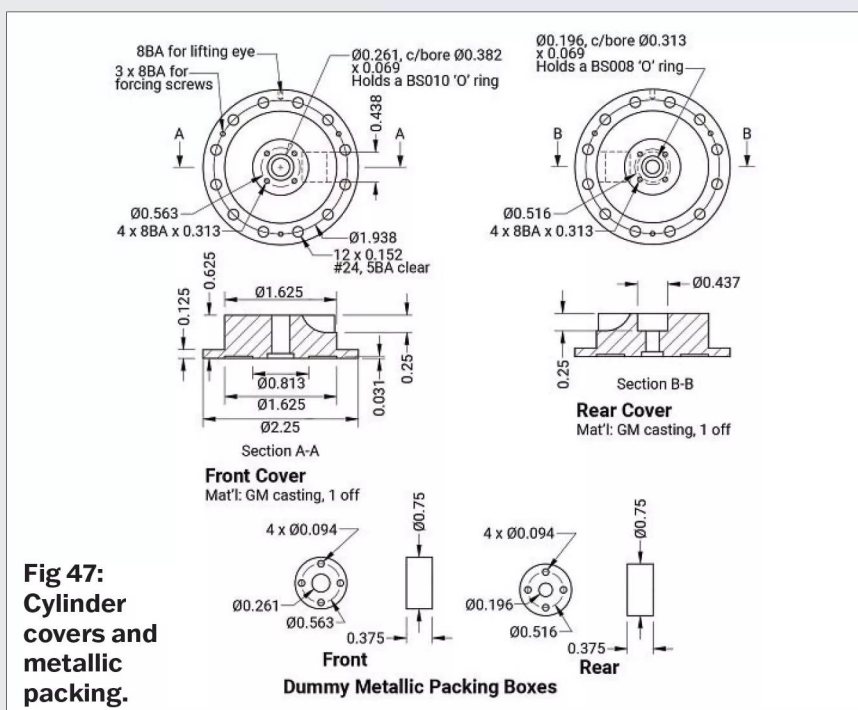




Photo 308: Drilling through for the exhaust.

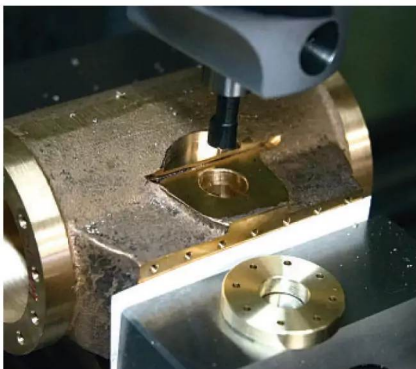


Photo 309: There wasn't enough metal on the casting to make the exhaust flange to drawing height, so I glued in a packing piece; more JBW.

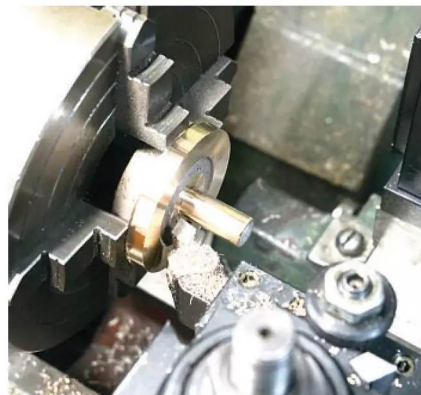


Photo 310: Turning the cylinder covers started in the four-jaw chuck with the chucking spigot and external details...



Photo 311: ...then they were moved to a collet to finish the internal details. This is the rear cover having the clearance for the piston nut machined.

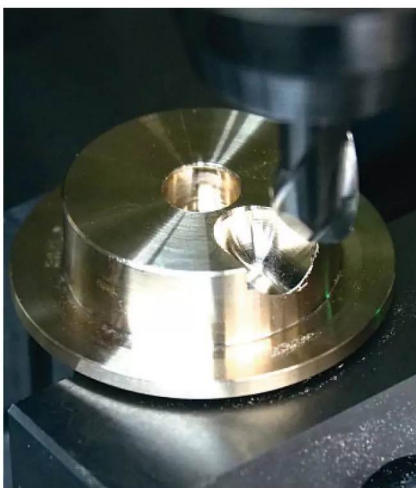


Photo 312: I ignored the drawings for the steam passage past the cover and did it the easy way.

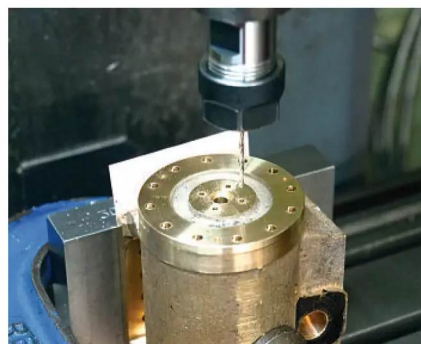


Photo 313: Supergluing the covers to the cylinder before drilling all the holes holds them firmly, removes the need for a second set-up to drill the cylinder and, more importantly, makes sure the holes are in the correct places relative to the cylinder base.

Having checked the expanding mandrel for burrs (there were none) the cylinder went back on and back into the mill for drilling holes by coordinates, **photo 302**. The marking out is there as a sanity check. In **photo 303** the base is being milled to thickness which is noncritical but there must be room to get nuts onto the studs.

Marking out the ports showed up some problems with the casting and **photo 304** shows why it's a good idea to mark things out before machining; the cast in 'ports' were out of place and too large so something needed to be done about the missing material. As I have no intention of running the engine on steam I felt that JB Weld would serve well enough and silver soldering wasn't needed. The engine has now had a few hours of running and the JBW has held up so far. The ports were milled out using a 4mm slot drill which, obviously, left the corners rounded. I chose that

particular cutter simply because it was the smallest one I had that would reach down 3/8" and a smaller long series cutter could be used if desired.

Photograph 305 shows the stud holes being spotted out after the ports have been machined to size. A small slot drill was used to start the drilling of the steam passages to connect the ports to the cylinder bore, **photo 306**, which were drilled through with a long series drill, **photo 307**. The exhaust passage was simply drilled through at the appropriate angle, **photo 308**. There wasn't sufficient metal on the casting to finish the exhaust flange to drawing height, so an extension was made in brass and glued in place with JB Weld, **photo 309**. Yet more JBW faired this part into the rest of the cylinder.

The two cylinder covers, **fig. 47**, differ only in the size of the holes for the piston rod and the O-rings that are the seals for these. The castings were set

up in a four-jaw chuck, the machining spigot trued up **photo 310** and the outer surfaces finished to size. With the spigot now held in a chuck, the inner surfaces were finished and, for the rear cover, a recess formed for the piston securing nut to run into **photo 311**. The drawings show a rectangular slot for the steam to get past the cover and into the cylinder but, as the shape of this isn't particularly important, I used a ball-nosed slot drill, **photo 312**. The pattern of holes in the covers has to be orientated correctly with the cylinder base so drilling the holes with the covers superglued to the cylinder was a good way to go, **photo 313**. In this photo the holes for the studs to secure the dummy metallic packing boxes are being drilled and the recess for an O-ring can be seen. I thought that the dummy boxes looked very plain but that is exactly how the real ones are, with only a very small oiler extra.

On the Wire

News from the world of engineering

Federation of Model Engineering Societies Annual Rally

This year's Federation rally will be hosted by the Rugby Model Engineering Society at their Rainsbrook Valley Railway site on Saturday, 6th September 2025. If bringing a steam locomotive, please remember to bring a current boiler certificate. Proof of club membership and insurance certificates are required for running models at the rally. The RMES boasts an impressive 2½, 3½ & 5-inch dual gauge raised track with a running length of approximately 731 metres. A lifting table enables easy unloading of locos directly onto the raised track steaming bays. A traverser allows locos to join the main line from the steaming bays.

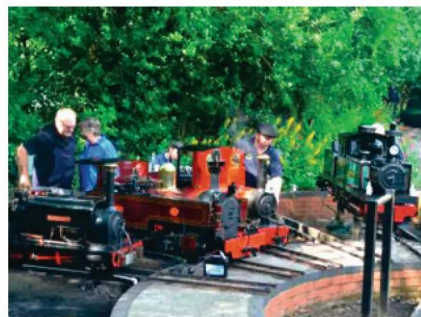
There is an even more impressive 7¼ inch gauge ground-level track of approximately 1 mile. The ground-level track has sidings, passing loops, and station with three platforms that are regularly used during busy times.

Various gradients up to a maximum of 1 in 85 provide interesting experiences for visiting locomotives.

It's not all about railways; the RMES encourages the inclusion of traction engines in a variety of scales, static engines, internal combustion, carriages, 3D printing, and steam road vehicles, examples of which are invited to the rally in September.

Alongside the FMES Rally Competition, there will also be an opportunity for prototypical outline locomotives to be judged in line with the Australian Association of Live Steamers (AALS) rules.

The RMES is based at Onley Lane Rugby CV22 5QD. Anyone who visits the RMES for the FMES rally should be able to enjoy the variety of attractions along with the company of like-minded, enthusiastic model engineering hobbyists. Camping is permitted with pre-booking only by contacting the rally organisers via email george.cannon@hotmail.co.uk with the caveat that all waste be taken home as the site does not have sewage or waste disposal systems.

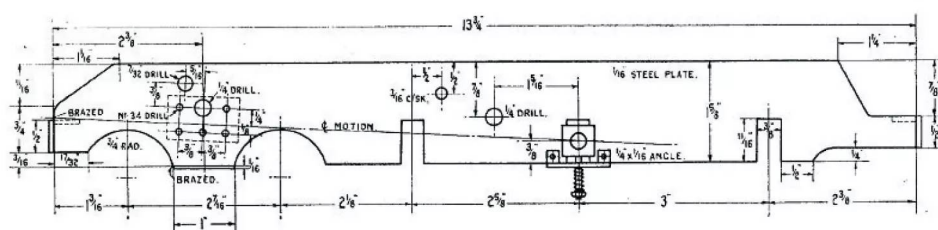
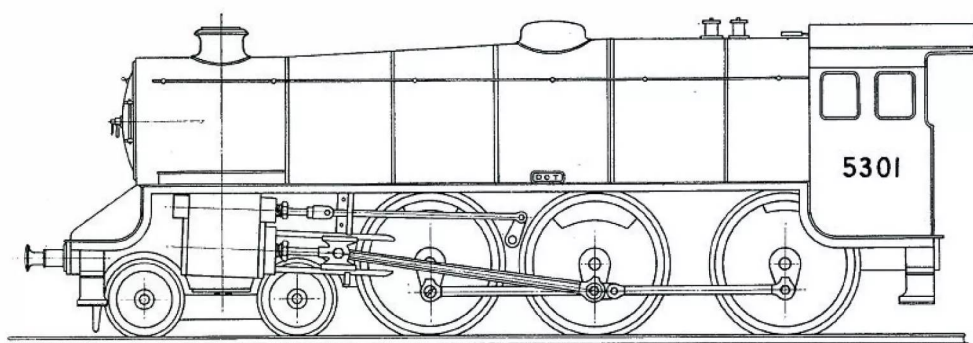


The Curly Bowl 2025

This year's LBSC competition is to be hosted by the North West Leicester club on Sunday 7th September. The competition is open to any LBSC locomotives of 2 1/2", #3 1/2" and 5" gauge that have not won before.

(Our illustration shows LBSC's general arrangement for Dot, a gauge 1 version of the 3 1/2" gauge Doris).

Entries are now invited on a first come first served basis, please send application to eatons182@gmail.com.



Outline and frames for Gauge "1" "Black Stanier"

Wimborne District Society of Model Engineers 50th Anniversary celebrations

This year's Federation rally will be hosted by the Rugby Model Engineering Society at their Rainsbrook Valley Railway site on Saturday, 6th September 2025. If bringing a steam locomotive, please remember to bring a current boiler certificate. Proof of club membership and insurance certificates are required for running models at the rally.

The RMES boasts an impressive 2½, 3½ & 5-inch dual gauge raised track with a running length of approximately 731 metres. A lifting table enables easy unloading of locos directly onto the raised track steaming bays. A traverser allows locos to join the main line from the steaming bays. There is an even more impressive

7¼ inch gauge ground-level track of approximately 1 Mile. The ground-level track has sidings, passing loops, and station with 3 platforms that are regularly used during busy times. Various gradients up to a maximum of 1 in 85 provide interesting experiences for visiting locomotives.





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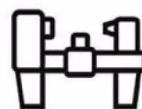
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especially those needing a bit of 'TLC'

These articles by Geometer (Ian Bradley) were written seventy years ago. While they contain much good advice; they also contain references to things that may be out of date or describe practices or materials that we would not use today either because much better ways are available or for safety reasons. These articles are offered for their historic interest and because they may inspire more modern approaches as well as reminding us how our hobby was practised in the past.

GEOMETER suggests ways of avoiding damage to plugs during servicing

SPARKING PLUG SPANNERS

FEW MOTORCYCLE and car owners and not all garages have spanners specifically for dismantling and assembling detachable type sparking plugs. Their construction and proportions render sparking plugs susceptible to damage from inconsiderate treatment. Yet in many cases cleaning is a routine operation.

Difficulties mainly concern loosening and tightening the gland nut. This is slender, screws into a non-too-thick body, and on a 14 mm. plug has flats only 1/8 in. wide. The nut must be secure, however, for the plug to be gas-tight, and after a period of use there may well be carbon or gummy oil tending to stick the threads.

In the absence of special spanners, the least hazardous method is to hold the body of the plug in true vice jaws, sufficiently firmly so as not to squeeze it, and apply a flat-ring spanner to the gland nut-holding the spanner down while turning.

If the body is gripped too tightly, it distorts and grips the gland nut; if an open spanner or adjustable type is used it is likely to distort the nut, and a cranked ring spanner is liable to slip off. Should the gland nut be held in the vice, it too can distort and seize in the body. In such circumstances, dismantling is difficult or impossible; and in the process, the insulator may be damaged.

A simple "special" spanner, A, can be made from rectangular steel 1 1/2 in. X 1/4 in. by about 2 in. long, this having a hexagon drilled and filed to receive the gland nut. The tool is gripped in the vice flush with the top of the jaws, the sparking plug inverted into the hexagon, and a flat-ring spanner applied to the body-avoiding any distortion from gripping across diameters.

A more elaborate service tool, obviating the need for a ring spanner, can be made as B and C. With this, the body of the sparking plug is placed in the main portion, B, which is gripped flush in the vice jaws, and the spanner, C, is applied to the gland nut.

Handles if needed

The main portion, B, is in two pieces of the same material as the simple spanner, A, held by countersunk rivets; and spanner, C, can be made from rectangular section 1 1/4 in. X 1/4 in. by about 12 in. long. In some instances, the ends of such a spanner are reduced like the tangs of files to take handles; or alternatively, four pieces of hardwood (two each side, two each end) 1 1/4 in. x 3/8 in. x 3 1/2 in. can be riveted on to make handles.

The tool at D, devised pre-war by the manufacturer of well-known sparking plugs, employs a pair of discs with hexagons to fit gland nut and body, each disc having a circle of holes, which, different in number, do not coincide or obstruct all together. Thus, it is possible to select a pair of holes not quite in line, enter a taper tommy bar, and lever the discs relative to one another, loosening or tightening the gland nut. One of the discs is usually attached to the ordinary spanner with which plugs are fitted to or removed from the engine, forming a handle, E.

Suitable proportions for the discs are 2 1/2 in. dia. x 1/4 in. thick; pitch circles 2 in. dia.; number of holes,

eight and nine, dia. 3/8 in. Eight holes can be marked off by bisecting with dividers on the pitch circle, and for nine holes, the dividers should be set to a bare 11/16 in. to space round the pitch circle-correcting slight in; accuracies when making the centre punch dots for drilling.

An ordinary tubular spanner can be welded to one disc to accept the body of the sparking plug, and the top disc should then fit the gland nut. Welding should be employed, and not carried deeply to affect the hexagon. Brazing is inadvisable for this reason - it is likely to flow into the hexagon. An old plug body can be used for alignment in welding.

Hexagons can be easily marked by placing body and gland nut on material and scribing round. A centre hole can then be drilled or bored; or if this is not possible, a number of small holes can be drilled, and the piece punched out, F. In all cases, the hexagon is carefully filed.

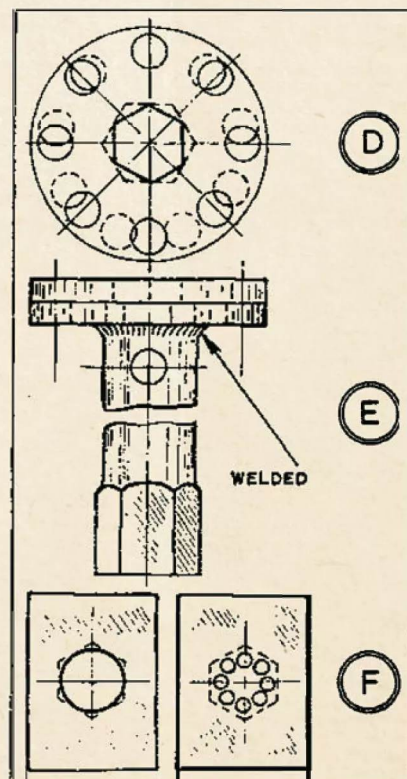
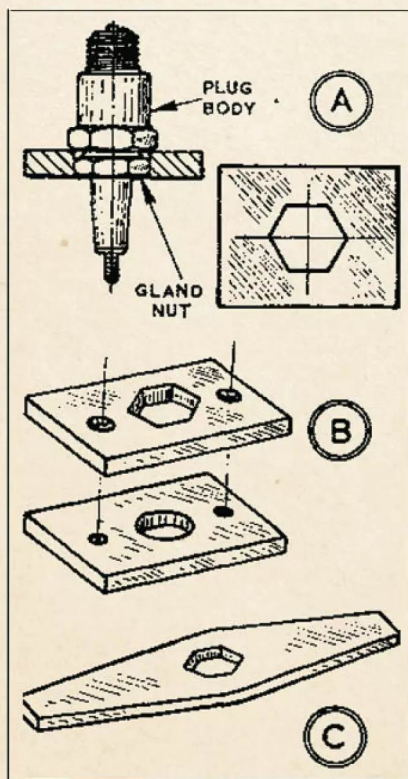


Photo 7: Turning Tufnol.

Cheap Nasty Plastics

Patrick Hendra, Tutor for Eastleigh Young Engineers moves on to thermosetting plastics.

PART 2

THERMOSETS

All the information in the first half of this article refers to the fusible polymers, ones that can be and are, frequently melted and then moulded or extruded but there are polymeric materials in widespread use that are moulded as precursors and then allowed to polymerise in the mould. They produce materials that at the molecular level are made up of 3D networks that cannot be melted. Your domestic electrical fittings are almost invariably made from thermosets. Obviously, a good safety choice because they don't melt and run if they enclose an electrical overheat or fire. Thermosets have a long history; Bakelite, a phenol-formaldehyde polymer, appeared before WW1. Some of the pictures of chemical workers stirring huge smoking pots of toxic reagents heated on coal-fired cookers wreathed in fumes remind us why the dreaded 'elf 'n safety was sorely needed! These polymers are usually loaded heavily with wood flour or chalk, making them almost stone-like but rather brittle. Bakelite has

been followed by many other related materials and more recently by adhesives like Araldite, an epoxy resin. I will not cover adhesives in this article.

This type of polymer soaked into cotton and, more recently, glass fibre then moulded into sheets or blocks appeared in the early twentieth century and is still with us today. Although not used as frequently as it was, Tufnol and Paxolin, two of the trade names for this type of composite, can be machined and Tufnol is particularly useful in 'silent' gear trains, **photo 7**.

Tufnol and related materials are available as sheets, plate and rods and are very useful in model engineering - stiff, hard, resistant to heat and electrically (and reasonably thermally) insulating. Printed circuit boards were and sometimes still are made of this class of polymer composite, **photo 8**.

CERAMICS

Ceramics - why are they included here? Because they are indeed polymers. They are built up of molecular

chains based on silicon and oxygen. Conventional (organic) polymers are based on carbon chains. Silicones are a special class of polymer and I will describe them near the end of this article.

Let's start off with glass. Remember, my background is as a chemist so I am an enthusiast and couldn't possibly be prejudiced.

I have to admit that glass is brittle, shatters easily, broken pieces are dangerous and can fracture if heated so it can't be relied upon and hence engineers only use it if they have to and expect the worst. 'Only used in sight glasses because we can't think of something better' - but...

Glass is transparent and incredibly resistant to almost all chemicals. If handled by skilled, scientific glassblowers, borosilicate (Pyrex) glass can be made into incredibly complex shapes and equipment. Glass is a very effective thermal and electrical insulator and is far more versatile than metal. Once sealed it is TOTALLY vacuum-tight. If sections are flamed and annealed in an appropriate oven, glass can be relied

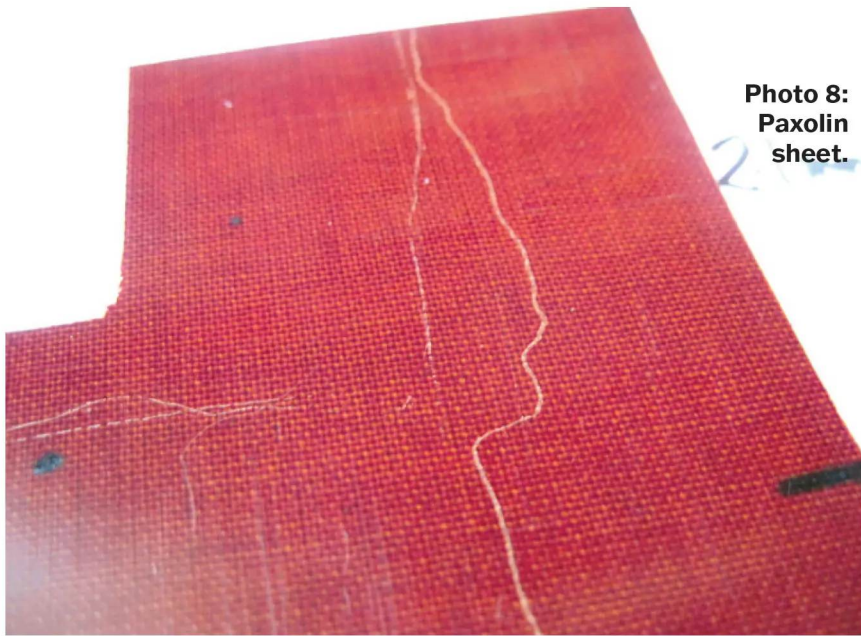


Photo 8:
Paxolin
sheet.

upon. Used in sealed tubes about 25mm in diameter (so-called Carius tubes) chemists carry out high-pressure, high-temperature experiments! Glass can fail if wetted with water while hot. Electrodes can be passed through glass and be absolutely vacuum-tight, for example in the old-fashioned tungsten light bulb or thermionic valves.

Fused Quartz is even better than borosilicate glass but it has to be worked using oxy/hydrogen torches. As a consequence, it is expensive to buy and costly to manipulate.

Glass is heated until soft enough to be bent, joined, stretched and blown. It can be machined at room temperature using diamond saws and drilled or ground with silicon carbide powder.

Okay, I will stop there - but you

engineering lot should think again about using glass. It is *the material* of the 21st Century! I must stop or the Editor will think I'm prejudiced (hmm... Ed.)

There are at least three characteristics that are potentially useful to readers - glass and particularly quartz are non-conducting of heat and electricity. I have used both of these properties when devising and building miniature electrically heated and cryogenic cells for my scientific laser work. Also, the coefficients of expansion are very low indeed. For Silica 0.59 per degree compared with 13 for steel hence it is particularly ideal for clock pendulums.

Many readers will not be aware that machinable glass sheet and bulk is available and is called Macor, **photo 9**. I have found that this material is

easy to turn, mill and drill and, with care, it can be tapped. This material has an incredibly high modulus so the tap must be guided. If handheld, the tap will shatter the threads as they are cut.

One has to remember that glass has a very high tensile modulus so metal screws will inevitably over-stress the upper threads. Exactly the reverse of the situation mentioned above for threads in organic polymers. Like conventional glass, this material can be heated to at least 500 degrees C. The only snag is that it is very expensive. There are cheaper alternatives.

Before the concern over Asbestos dust hit us all, Syndanio, an asbestos/cement material supplied in sheets, was economical and very popular in making furnaces and ovens. However, eBay and others can supply alumina board and rod, a material that has reasonable strength and can be machined. In some respects this material is an excellent replacement for Syndanio, **photo 10**.

Soapstone or Pyrophyllite has been around for millennia. It is very soft, can be machined easily - but not tapped and can be used as supplied or fired (to 1000-1200 degrees C). Once fired this material is VERY hard.

NOTES OF CAUTION

Machining these ceramic materials invariably creates dust and the dust must be avoided at all times. If practical, all machining should be done wet just to prevent the dust. If you

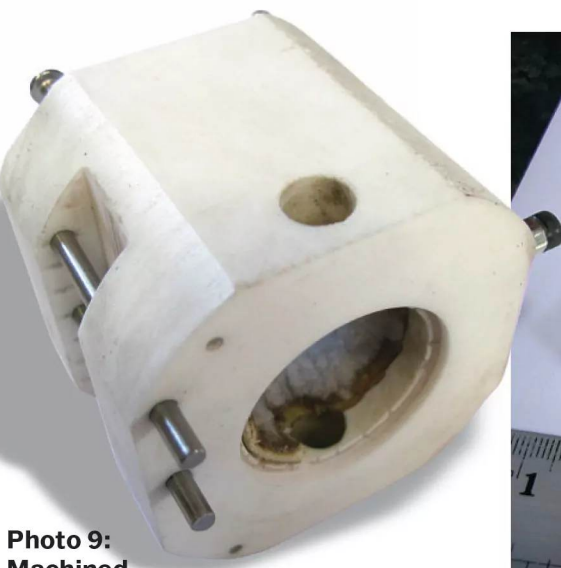


Photo 9:
Machined
glass - a
scrap oven.

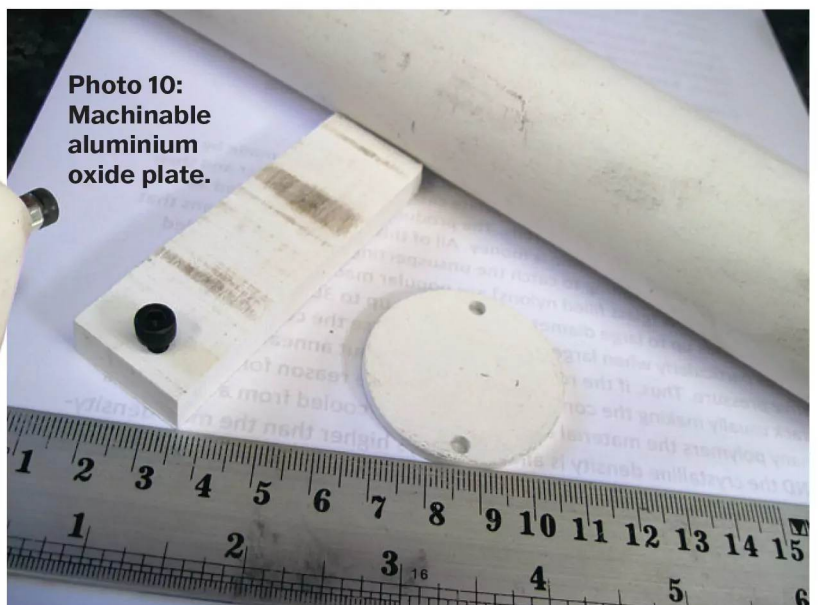


Photo 10:
Machinable
aluminium
oxide plate.

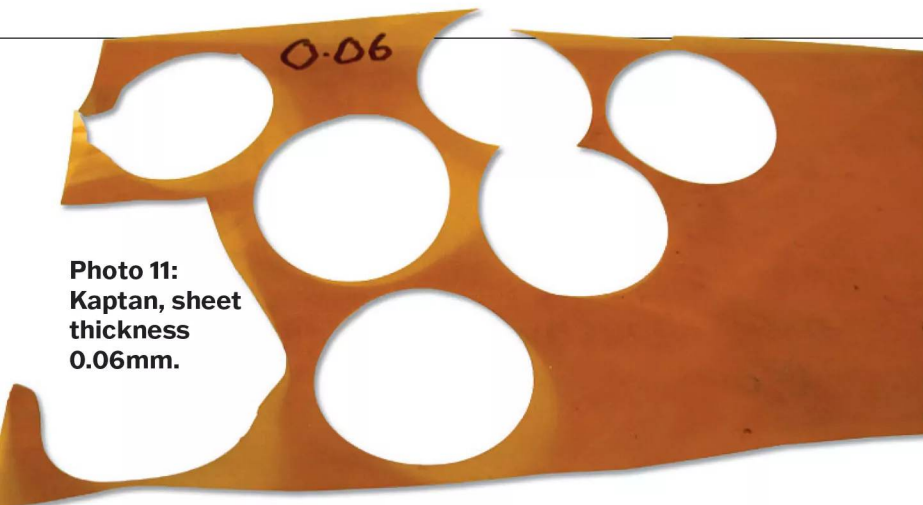


Photo 11:
Kapton, sheet
thickness
0.06mm.

have no facilities to provide continuous water-based cooling, I suggest you are ultra-careful - even over-cautious. Always wear a good quality respirator during machining and clearing up. Also ceramic dusts are abrasive so be very careful to protect your machines.

WHAT HIGH-TEMPERATURE POLYMERS EXIST?

The first question one has to ask is; How high is high? The answer is not very.

We have already discussed polyphenylene sulphide. There are other competing materials that are easily machineable, but their high temperature performance is modest by metal standards. Polyether ether ketones and polysulphones are all widely available and I have machined them already. I am assured that polysulphones are very resistant to steam but have never tried to find out.

One further polymeric material needs special mention. Kapton is a polyimide and is widely available as tape and film, **photo 11**. It is often used as polymeric and hence flexible window in scientific equipment. This film will survive 400 degrees C and even higher for short periods. Polyimides are available in easily machinable rods and plates under the trade name Vespel. This can be supplied virgin or loaded with solid lubricants such as graphite and/or molybdenum disulphide. Vespel really does earn the title 'high-temperature polymer'.

PLASTIC DEFORMATION

This phenomenon has very little use in model engineering but the products thereof you will have encountered. You can demonstrate plastic deformation for yourself. Cut a piece of strip from a high-density

polyethylene shopping bag as in **photo 12**. You need a strip about 15 by 120mm. These films should be thin, rustle slightly and have a low coefficient of friction. Avoid the more common waxy feeling, low-density polyethylene film. Wrap the ends around your thumbs leaving a gap of 50-60mm and pull your thumbs apart slowly and steadily. If you do it properly you can achieve the result shown in the photo. You will notice that once the material starts to stretch, the force you have to apply slightly rises. Since the cross-section is falling, the applied stress is increasing i.e. the polymer is massively increasing its strength to break. In the example shown the cross-section of the undeformed linear polyethylene film was 14 by 0.019 mm. The plastically deformed section has a cross-section of 6 by 0.007mm thus the considerable extension and consequent increase in strength. The plastic deformation process is used very widely to make cords, filaments and high-performance fibres. A wide range of polymers can be plastically deformed but many are treated at elevated temperatures. Most commercial textile fibres are plastically deformed.

If you look carefully at your personal experiment, you will see that the necks where the deformation is occurring are atypical of the bulk. In the necks, the polymer chains pull themselves out of the bulk and form long, crystalline, highly oriented bundles of chains. This highly developed orientation results in the fibres having outstanding strength.

Orientation can be induced in two orthogonal directions. Perhaps the polyethylene terephthalate (PET) fizzy drink bottle is the best example. To make these bottles, a thick-walled closed tube with a screwed neck is fitted into a machine that heats the portion below the neck. Compressed

air then expands the embryo bottle until it fills a cold metal mould. The now two-way stretched PET is now highly oriented below the screwed neck - job done. If you heat a PET bottle in an oven, shrinking will occur. Another experiment you can do for yourself. These bottles will support very considerable internal pressure without bursting.

One of the applications of polymer orientation and subsequent relaxation is the heat shrink phenomenon. The result of heating the supplied sheathing is shown in **photo 13**. To make a tubular heat-shrink product, the manufacturer extrudes a tube and then cross-links it (the polymer chains are made to weld themselves together every now and again along the chains, frequently using electron beams or radiation). The now cross-linked tube is then heated to around its melting point and expanded and then rapidly cooled. Heating the tube results in it relaxing to its unstretched diameter.

Shrink fit is available, made of a great range of materials. Some are incredibly chemically resistant, others are happy to function at high and low temperatures so don't assume that the cheap, familiar products are all that is to be bought.

WHAT ARE RUBBERS (ELASTOMERS, TO WE SCIENTISTS)?

Elastomeric behaviour is, in fact, the behaviour of liquids confined in such a way that they are not able to flow. The molecules in a rubber are cross-linked (see earlier). Either a chemical reagent is incorporated into the liquid mix and then activated to provide infrequent permanent links between the chains or a physical mechanism like radiation is used with the same effect. The point is that rubbers are fluids so cooling a rubber eventually leads



Photo 12: Plastic deformation of polymer film. The un-stretched film and the drawn one.

to it becoming leathery and cooling further it becomes a hard, horny solid. Heating a rubber doesn't melt it into a free-flowing liquid unless it starts to break down – it is ruined. So, strictly, these rubbers are thermosets. Perhaps the height of rubber technology is the vehicle tyre. High-performance tyres are a triumph of selecting exactly the right material to do the job safely and keep on doing it for very long periods.

There are thermoplastic rubbers. To achieve cross-linking, block copolymers are made where at room temperature the run of one copolymer component is solid (below its melting point) whilst the other component is fluid. Heating these materials means that the whole mix can flow and be moulded. Cooling back to room temperature results in a rubber. The process is shown diagrammatically in **fig. 4**.

As elastomers, the thermoplastic rubbers are inferior to their cross-linked competitors. They are not used in tyres. Just as well. On a very hot day the tyre might melt and become a sticky, gooey mess.

MOULDABLE POLYMERS - ONES YOU CAN MOULD IN THE WORKSHOP

These days one can buy a panoply of polymeric compounds that can be cold moulded. Some are very simple. Mix the monomer, or more frequently a very lightly polymerised and hence liquid polymer, with an accelerator and pour the well-mixed blend into a mould and *hey presto*. Isopon is an excellent example. Lightly polymerised styrene mixed with a filler (probably ground clay) is mixed with a small sample of an accelerator, dyed pink so that you can see that it is well mixed. The still viscous blend is used to fill holes, dents or to fill a mould. After thirty minutes or so, the Isopon is hard.

Another example - I have recently used a two-pack polyurethane mouldable rubber called Polytek PT. It is available in various rigidities. In **photo 14** you can see the outcome. The plugs are for the footboards of a 1924 Royal Enfield Motorcycle that I have been restoring.

I could go on for ages, but I must desist. I will finish by describing another of the nasty properties that polymers have attracted to themselves.

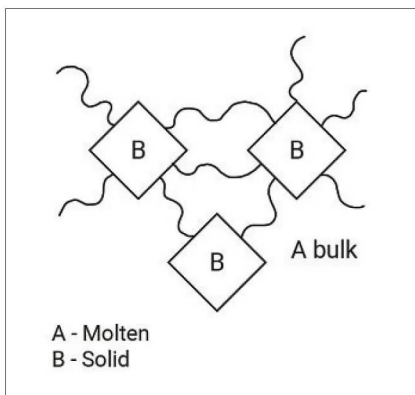


Fig 4: Schematic of a thermoplastic rubber.

PLASTICIZATION, SWELLING AND SHRINKING

Polyvinyl chloride (PVC), a polymer never knowingly to be machined, can be loaded with a filler where it is encountered everywhere as doors, windows, waste pipes, gutters and the like. It can be plasticised by mixing it with a very high boiling point compound with which it is chemically miscible. The mix often contains a large proportion of the plasticiser. The blend changes the PVC from being hard and horny into a flexible material used extensively as plastic tubing, sheet, insulation for electric cable etc. But it is a mix, one component of which is very slightly volatile. This is why your garden hose becomes hard in the winter, like anything rubbery, and only lasts three or four years as the plasticiser evaporates. Oh yes, the

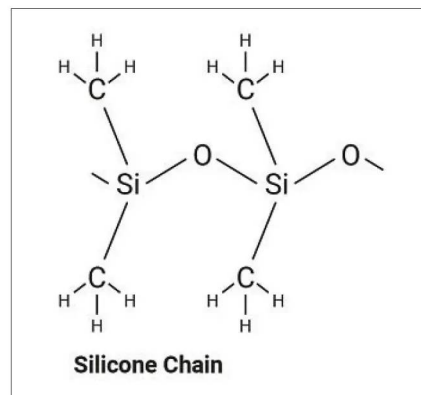


Fig 5: Typical structure of a silicone.

recyclers don't want PVC for a variety of reasons! Over a long period, the plasticiser can leak out, especially if it kept in a warm environment with restricted ventilation, like a workshop **photo 15**.

If your nice new plastic tubing comes into contact with a compound that also happens to be a solvent for PVC, said compound will absorb itself into the tubing, it will swell and eventually fail. Oh dear ... In **photo 16** you can see the process.

Another example is traditional rubber tubing; rubber is chemically compatible with all hydrocarbons - petrol, paraffin, oil etc. - so it swells and inevitably fails.

What about O-rings? Many of us use them and they must be made of the appropriate material otherwise they will swell or melt in the grooves. This is fairly easy to deal with because one can buy Viton O-rings.

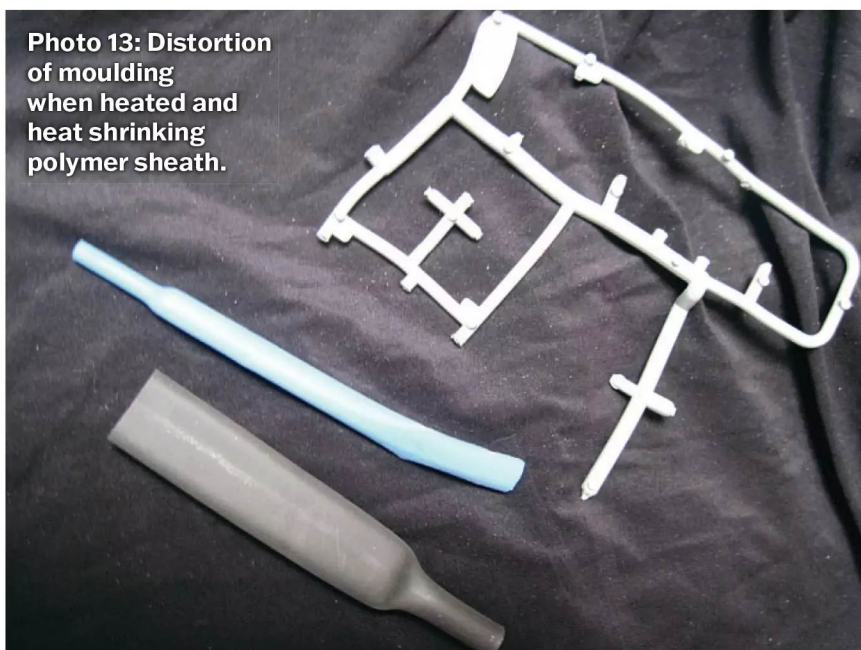


Photo 13: Distortion of moulding when heated and heat shrinking polymer sheath.



Photo 14: Mould and product made in cold moulded polyurethane rubber.

This polymer is a fluorocarbon elastomer and hence incompatible with almost anything found in the workshop. Fortunately, Viton O-rings are cheap and widely available. Silicone rubber and Buna rubber O-rings are frequently offered but my advice is to pay a little extra and always insist on Viton O-rings. They will cope with almost anything thrown at them and they work up to nearly 170 degrees C.

Just as an aside, I notice in many articles in *Model Engineer* that readers use O-rings that are far too thick. That is, the section is too large to be appropriate to scale. There are local suppliers of seals including O-rings all over the country and they can usually supply rings at 1mm or 2mm section over huge ranges of diameters in Viton. I tend to use 1.5mm section O-rings in my models.

SILICONES

Silicone polymers are linear polymers based on the siloxane structure shown in **fig. 5**. To be rather rude, they are unconvincing polymers compared with carbon-based equivalents, but they are invaluable when they show uniquely desirable properties. Silicone rubbers are frequently used as sealants or gaskets and can be bought as O-rings, as sheets and as moulding paste but they really are rotten elastomers. They simply don't have the mechanical performance to compete, but they work acceptably as rubbers over really broad temperature ranges. If your model needs a rubber packing that will keep going down to -100 C, maybe up to +200 C, silicone rubber is for you, but



Photo 15: Self-leaching of plasticiser from PVC.

make sure the section is thicker than the one you would choose for more conventional seals. Silicones also show low water-wetting properties. Once covered with a film of silicone, water will form drops, not a film, on a surface. However, remember what I covered above; a Kaptan shim or seal will perform to much higher temperatures than 200 degrees C. but it won't be a rubber.

Mixed with powdered carbon, silicon-containing monomers can be made into electrically conducting silicone rubber. Just what is needed in your keyboard's switches.

There are some clever ways of using silicones involving deposition from the vapour phase but sadly they are beyond amateur model engineers.

SO TO CONCLUDE

My survey is exactly that, a brief incomplete canter through a huge subject but I hope my piece will answer some questions, suggest what you might research yourselves online and, most importantly, urge you to try more polymers in your future modelling endeavours.

Are plastics cheap and nasty? Yes ... and no. Polymers are cheap if bought in massive bulk and are incredibly versatile. No they are not nasty, but have limitations people often ignore to their cost and, compared with metals, recycling most polymers is a rather poor joke.

One final point; polymers are much less damaging to the environment than many metals and replace metals to the advantage of the poor old planet. We couldn't survive without them and we shouldn't try.



Photo 16: Soaking PVC tubing in methyl ethyl ketone.

Club Diary

Please send your events for Club Diary to meweditor@mortons.co.uk

2025

EVERY SUNDAY

Warrington MES

Running day. Contact : contact@wdmes.org.uk

Wakefield SMEE

Public running day. Contact Denis Halstead 01924 457690

JULY

19 Gauge 1 North

Gauge 1 live steam at Bakewell Agriculture and Business Centre. Gauge1north.org.uk

19/20 July Urmston & District MES

N.A.M.E. Rally (North-ern Association of Model Engineers), 3.5 & 5 inch rail, model Road Steam and static displays.

20 Rugby Model Engineering Society

Public Running, refreshments, free parking - 13.00 to 16.00 - rugbymes.co.uk.

20 Cardiff MES

Public Running Day, Heath Park, 13:00-17:00.

20 Guildford MES

Public open day, Stoke Park. Contact: Mike Sleigh, pr@gmes.org.uk or see www.gmes.org.uk

20 Tiverton & District MES

Running day at Worthy Moor Track. www.tivertonmodelengineering.org.uk/contact

AUGUST

1 Rochdale SMEE

Models running night. Springfield Park, 17:00 onwards. See www.facebook.com/RochdaleModelEngineers

2 Tiverton & District MES

Running day at Worthy Moor Track. www.tivertonmodelengineering.org.uk/contact

3 Guildford MES

Small Model Steam Engine Group meeting, 14:00-17:00, Stoke Park. Contact: Mike Sleigh, pr@gmes.org.uk or see www.gmes.org.uk

3 Cardiff MES

Public Running Day, Heath Park, 13:00-17:00.

7 Guildford MES

Public open day, Stoke Park. Contact: Mike Sleigh, pr@gmes.org.uk or see www.gmes.org.uk

9 Wakefield SMEE

Visiting locos 7 1/2"G only day. Thornes Park Track, Wakefield. Contact: Jacqui Owen jacquie-owen@yahoo.co.uk

15 Rochdale SMEE

Auction Night. Castleton Community Centre, 19:00. See www.facebook.com/RochdaleModelEngineers

17 Guildford MES

Public open day, Stoke Park. Contact: Mike Sleigh, pr@gmes.org.uk or see www.gmes.org.uk

17 Bradford MES

Running Day, public from 1:30 pm to 16:00, Northcliff. Contact: Russ Coppin, 07815 048999.

17 Tiverton & District MES

Running day at Worthy Moor Track. www.tivertonmodelengineering.org.uk/contact

17 Rugby Model Engineering Society

Public Running, refreshments, free parking - 13.00 to 16.00 - rugbymes.co.uk.

19 Nottingham SMEE

Evening Run and BBQ. nsme.org.uk/events/

23 Saffron Walden & District SME

Public running day Down Farm Stud, Elsenham Road, Stansted, 10:30.

24/25 Cardiff MES

Public Running Day, Heath Park, 13:00-17:00.

27 Rugby Model Engineering Society

Public Running, refreshments, free parking - 13.00 to 16.00 - rugbymes.co.uk.

28 Guildford MES

Public open day, Stoke Park. Contact: Mike Sleigh, pr@gmes.org.uk or see www.gmes.org.uk

SEPTEMBER

6 Bromsgrove SME

Open Day. All gauges welcomed 5", 3.5", 2.5", G1 and 16mm. www.bromsgrovesme.co.uk. Contact Doug Collins 07585 524836

6 Tiverton & District MES

Running day at Worthy Moor Track. www.tivertonmodelengineering.org.uk/contact

13 L&NWR Society & Stafford & District MES

Annual Steam Up. The County Showground, Weston Road, Stafford, 10:00.

13/14 Tiverton & District MES

LittleLEC at Worthy Moor Track. www.littlelec.co.uk

14 Cardiff MES

Public Running Day, Heath Park, 13:00-17:00.

19 Rochdale SMEE

Bits and pieces/personal project ideas. Castleton Community Centre, 19:00. See www.facebook.com/RochdaleModelEngineers

20 Bromsgrove SME

Hosting the Rob Roy Rally And 3.5" gauge friends. www.bromsgrovesme.co.uk. Contact Doug Collins 07585 524836

21 Guildford MES

Charity and Heritage Day, Stoke Park. Contact: Mike Sleigh, pr@gmes.org.uk or see www.gmes.org.uk

21 Tiverton & District MES

Running day at Worthy Moor Track. www.tivertonmodelengineering.org.uk/contact

21 Rugby Model Engineering Society

Public Running, refreshments, free parking - 13.00 to 16.00 - rugbymes.co.uk.

27 Bradford MES

Visitors Day - BMES welcomes members and their locomotives from other societies to Northcliff for breakfast & lunchtime butties. Let Russ Coppin, 07815 048999 know in advance, please.

27 Urmston & District MES

Polly Owners Group Rally.

OCTOBER

4 Tiverton & District MES

Running day at Worthy Moor Track. www.tivertonmodelengineering.org.uk/contact

5 Guildford MES

Small Model Steam Engine Group meeting, 14:00-17:00, Stoke Park. Contact: Mike Sleigh, pr@gmes.org.uk or see www.gmes.org.uk

5 Bradford MES

Running Day, public from 1:30 pm to 16:00, Northcliff. Contact: Russ Coppin, 07815 048999.

12 Cardiff MES

Public Running Day, Heath Park, 13:00-17:00.

17 Rochdale SMEE

Annual General Meeting. Castleton Community Centre, 19:00. See www.facebook.com/RochdaleModelEngineers



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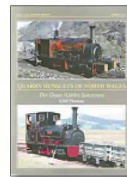
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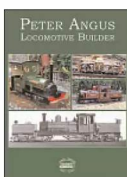
Quarry Hunslets of North Wales - The Great (Little) Survivors • Thomas • £29.90

Reprinted, this is a detail history of all the Hunslet built, mainly 2 foot gauge, 0-4-0 tank locomotives which roamed the slate quarries of North Wales, and especially the good number which have been preserved. Huge amounts of detail, both technical and on service history, numerous B&W photos, a number being of locomotives being restored, which are excellent for detail. These Hunslets are very popular models, in gauges up to 7 1/4 inch, and anybody building a model of one will find this a most useful reference source. 256 pages. Paperback.



Peter Angus - Locomotive Builder - VERY SPECIAL PRICE - Angus • £26.70

If you would like to build a live steam narrow gauge engine in 16mm scale and want ideas, suggestions, hints, tips and the story of the prototypes, look no further than this book from Peter Angus, who has built 100s of such models. A pleasure to read and with 217 A4 size pages crammed with photos, drawings and illustrations, the bulk in colour, it is very good. (Original price - 39.45 inc UK P & P)



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These two 'Digital Editions' may be read on a computer or laptop, and MUST be ordered from our website.

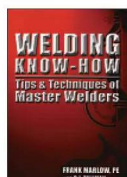
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Cutting a Circular Slot In an Unusual way

As part of a project involving the design of a small tilting table, **Johannes Schiff** stumbled across the need to mill a radiused slot into the bottom of a plate.



Photo 1: Sample plate with two circular slots milled into it.

The cross-section of the slot needed to be part of a circle to allow a ground shaft to be accurately located in the slot. I was hesitant to buy a full-radius end mill or a convex radius cutter for horizontal milling, that might only be used once for a 15-minute operation. While the design of the tilting table later evolved to no longer require the radiused slot, I had already devised a method to produce an approximation of the slot – using ‘standard’ end mills. Hopefully someone else can also benefit from this method. **Photograph 1** shows a sample aluminium plate with two grooves milled in it to fit two ground shafts.

Being aware that mathematical exercises tend to discourage some of us, I will do my best to keep it as

clear and concise as possible. In addition, I have created a simple spreadsheet that can be used without the need to get into all the nitty and gritty details.

METHOD

First of all – the method is only approximate, but within its limitations probably good enough for many applications in the workshop. The whole idea is to approximate the circular shape of the slot by using an endmill (or similar) fed through the work at an angle. When looking in the feed direction, the tilted end face of the endmill takes on the shape of an ellipse. In other words – the whole idea is to approximate part of a circle using part

of an ellipse.

Practically, this can be achieved using a tilted vertical milling-machine head, **photo 2**, but it can also be achieved by holding a cutter in the lathe spindle and clamping the work to the top slide (set at an angle). Other than being approximate in its nature, there are some other limitations to the method:

- The slot must be relatively shallow in relation to the desired slot radius. If the slot depth is increased, so is the error involved in using the method.
- The corner radius of the milling cutter needs to be small, as it really is the endmill corner that generates the shape of the slot. This could rule out the use of standard cutting tools with carbide inserts.

•Cutting a slot using an inclined endmill may lack rigidity, and to maintain accuracy only small depth of cuts can be taken – especially if the material of the workpiece is tough.

THE MATHEMATICS

For those of you not too concerned with the mathematical details, this part can be skipped. For those of you that are – let's dig into the mathematics of the method.

Uppercase letters will refer to the ideal, 'perfect' radiused slot, while lowercase letters will refer to the cutter and ellipse geometry intended to approximate the ideal slot.

Refer to **fig. 1** for a schematic sketch of the setup and let:

$$\begin{cases} R = \text{radius of ideal slot} \\ W = \text{width of ideal slot at surface} \\ T = \text{depth of slot, measured from surface} \end{cases}$$

and

$$\begin{cases} r = \text{radius of endmill} \\ \alpha = \text{inclination of endmill vs. workpiece} \end{cases}$$

Here, the ideal circle is shown with a dotted outline, while the endmill is depicted using solid lines. The width of the ideal slot and slot depth is, of course, directly related, and the slot depth for a given slot width can be computed from

$$T = R - \sqrt{R^2 - W^2/4}$$

For a given slot depth, the slot width of the approximated circular slot will not be identical to the 'ideal' target slot.

Now, let's look at the endmill end face, projection 'A', **fig. 2**.

By letting the centre bottom of the groove being the zero-point, the following parameters are used to describe the line segment of the endmill perimeter within the work piece (segment highlighted in red colour in **fig. 2**):

$$\begin{cases} \Omega = \text{half angle of slot, from center of endmill} \\ \delta = \text{coordinate angle within half angle, } 0 \leq \delta \leq \Omega \\ d_x = \text{coordinate in horizontal direction} \\ d_y = \text{coordinate in vertical direction} \\ w = \text{width of slot at surface} \end{cases}$$

It is the endmill perimeter within the workpiece that defines the as-cut slot geometry. From **figure 2**, we can now write:

$$\begin{cases} \sin(\Omega) = w/(2r) \rightarrow \Omega = \sin^{-1}(w/(2r)) \\ d_x = r\sin(\delta) \\ d_y = r(1 - \cos(\delta)) \end{cases}$$

This means that for any coordinate angle δ , we can compute corresponding coordinates of the as-cut

surface in the horizontal and vertical direction. These coordinates (d_x, d_y) are valid in the plane of the endmill cutter face. To be able to compare these 'endmill coordinates' to that of the ideal circle, we must project them to the plane of the ideal circle.

The projected coordinates (b_x, b_y) and corresponding coordinate angle β can be written:

The following parameters are introduced in the plane of the ideal circle:

$$\begin{cases} b_x = \text{coordinate of endmill in horizontal direction} \\ b_y = \text{coordinate of endmill in vertical direction} \\ \beta = \text{coordinate angle, from center of ideal circle to endmill coordinates } (b_x, b_y) \\ B_x = \text{coordinate of ideal circle in horizontal direction} \\ B_y = \text{coordinate of ideal circle in vertical direction} \end{cases}$$

The projected coordinates (b_x, b_y) and corresponding coordinate angle β can be written:

$$\begin{cases} b_x = d_x = r\sin(\delta) \\ b_y = d_y\sin(\alpha) = r(1 - \cos(\delta))\sin(\alpha) \\ \tan(\beta) = d_x/(R - d_y) \rightarrow \beta = \tan^{-1}(d_x/(R - d_y)) \end{cases}$$

Believe it or not, but we're close now! The coordinates (b_x, b_y) represent as-cut coordinates in the plane of the ideal circle, i.e. along the actual slot. All that is left is to compare these coordinates with that of the ideal circle, which are:

$$\begin{cases} B_x = R\sin(\beta) \\ B_y = R(1 - \cos(\beta)) \end{cases}$$

The error can then be described by:

$$\begin{cases} e_x = \text{error in horizontal direction} \\ e_y = \text{error in vertical direction} \\ E = \text{error in radial direction} \end{cases}$$

and can be calculated from:

$$\begin{cases} e_x = b_x - B_x \\ e_y = b_y - B_y \\ E = \sqrt{e_x^2 + e_y^2} \end{cases}$$

That is essentially it - we now have a method to describe the error in each and every point of the cut surface, that is a consequence of approximating a circle segment using part of an ellipse.

PUTTING THEORY INTO PRACTICE

So, how do we make use of this? We're not helped very much by just knowing the error in one specific made-up angle δ in the plane of the cutter. While it certainly is possible to manually compute the error at a selection of angles, this is the point where it comes in very handy to introduce the computer. Using the computer, it is easy to split the as-cut geometry up in, say, 100 different δ angles, compute the error at each and every angle and let us know how well we have approximated the circle. In fact, we can take it even further, and let the computer find the most optimum inclination angle of the endmill to yield the smallest total error in shape! There are some basic solver tools (through an add-in called 'Solver') available in common spreadsheet software that can be utilised for just that.

I have created a spreadsheet (no macros needed!) for that specific purpose, based on simply specifying a target groove diameter, a cutter diameter and a slot depth. Based on that input, the spreadsheet is able to determine an 'optimum' inclination angle α . The



Photo 2: Cutting an approximated circular slot using an endmill in a tilted vertical head.

Photo 3: Test fitting a ground shaft into a machined slot.



maximum error (according to the formulas above) is also computed. You can download the spreadsheet from tinyurl.com/4x662us9 or use the QRcode.

I have found that, when experimenting back-and-forth, it is often possible to find reasonable setups that yield radial errors smaller than 0.05mm. Of course, it must be made sure that the calculated/ 'optimised' inclination of the endmill is reasonable. I have successfully milled slots with inclination angles of up to 30 degrees, but it is probably possible to push it further than that.

Photograph 3 is an attempt to show the fit that can be achieved using the method. Here, a 14mm endmill was used to allow the 30mm shaft to fit into the slot.

ALTERNATIVE METHOD

The method outlined above is based on retaining a specified slot depth (T in fig. 1). It is however possible to reduce the error in the circular shape even further, if also the slot depth of the approximated circle is allowed to change. This is achieved by simply adding a 'correction' ϵ

to the slot depth T and coordinate b_y :

$$\begin{cases} T' = T + \epsilon \\ b'_y = b_y + \epsilon, \end{cases}$$

When making use of T' and b'_y instead of T and b_y throughout the equations presented above, one additional degree of freedom for finding the best 'curve fit' is available. The spreadsheet 'Solver' functionalities can be employed once again to find the combination of endmill inclination α and slot-depth correction ϵ producing the least error in circular shape.

If playing around and selecting a 'suitable' endmill diameter for the job, the slot-depth correction is typically quite small (in the order of hundredths of a millimetre). To avoid too big of a correction ϵ it is however advisable to find a suitable endmill size using the first method (where only α is 'optimised') and in a second step apply the alternative method where both α and ϵ is 'optimised', using the same endmill size as determined in the first step.

In my spreadsheet, I have included a second tab, where this alternative calculation method is implemented.

CONCLUSION

While I realise that this article probably contains more maths than what most people are interested in wrapping their heads around, I hope someone finds it interesting – or at least useful. Again, the spreadsheet can be used without getting into all the details. I can offer to share my very basic spreadsheet upon request. I would however encourage anyone using it to double check and verify that the computed results are reasonable before any chips are cut.

One of the main advantages of the method, I think, is that it is possible to generate slots with any radius using standard-size end mills – keeping in mind that the shape of the slot is only an approximation of a true circle. For example, metric-size slots can easily be cut using imperial-size endmills and vice versa. Using the spreadsheet approach, it only takes a few minutes of 'playing around' to find a suitable machining setup for milling fair approximations of circular slots.

If anyone has any comments, corrections or suggestions for improvements to the method I shall receive them with utmost gratitude. 🙏

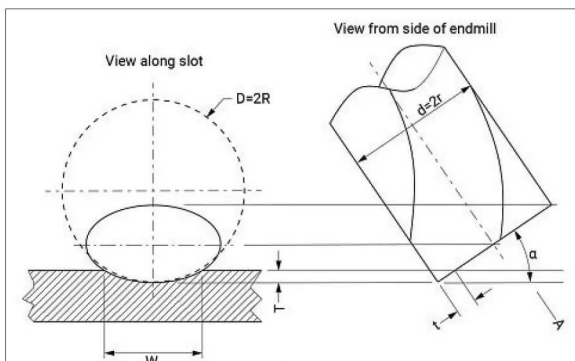


Fig 1: Schematic view along the slot, and a projected view from the side of the slot.

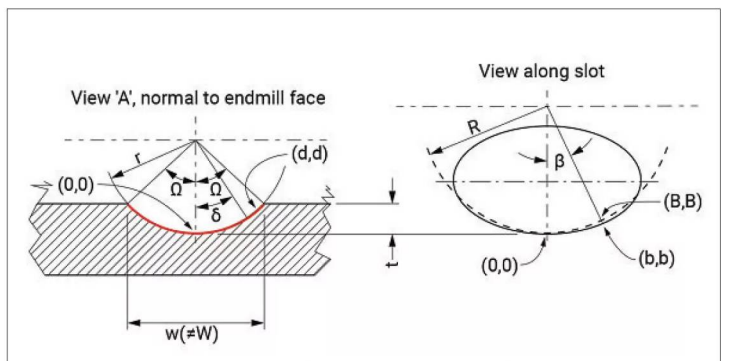


Fig 2: Detailed views, looking in the direction of the endmill face and along the slot.



Club News

Geoff Theasby reports on the latest news from the clubs.



Photo 1: Merlin engine, only used once.

Any one fancy a restoration job? (It could take a while.) Rolls-Royce Merlin engine, one careless owner, **photo 1**.

In this issue, a wizard, the oldest model, a noble car, a quick bridge swap, three wheels on my wagon, sludge, a steam delivery and a book.

In my attendances at the Newcomen Society talks by notable people on engineering matters, one of the other members is Professor Jonathan Ayling, who gave a talk some time ago about Merlin engines being built using a German machine, found on the docks at Dunkirk and appropriated. In questions afterwards I mentioned that the Kelham Island museum in which we were meeting that evening had an example of the Merlin crankshaft and the die used to forge it. Prof. Ayling picked up on this and has spent the last few months writing up his findings. I hope to bring readers more details when he has finished his research (inasmuch as such projects are ever 'finished'). Readers may be interested to learn that YouTube has several videos on the forging of these items.

John Suter, Meetings Secretary of the **Newcomen Society**, South Yorkshire branch, drew my attention to *Salamanca*, the world's oldest

model steam locomotive, built in 1811, 17 years before *Rocket*. The original is regarded as the first successful commercial locomotive but it was destroyed in a boiler explosion six years after being built. There is much online about this vehicle which is kept at Leeds Industrial Museum.

A Classic Car rally at Wentworth Woodhouse featured this Noble M600, A 'rara avis' indeed, **photo 2**. In Sheffield Auctions recently, a number of engineered models including a Stirling Single, Lot 315, plus a Mamod, a Hornby, a 5 inch gauge locomotive (part-built) Trix, Marklin, live steam... only the Stirling went for serious money, £3,600.

Bradford Model Engineering Society's Monthly Bulletin, May issue, included an item by James Barlow, Keighley & Worth Valley Railway civil engineer, on the replacement of Bridge 27, which was completed on time and with the help of a large grant from the local council and all done by volunteers, suitably qualified. The physical installation took only minutes and was watched by about 250 spectators. At the Easter Bunny event, a Junior member, Lennie brought along an electric Ruston 'diesel' which he had just bought, which performed well after a couple of tweaks. David

Jackson's Road Vehicle News features a Sinclair C5, a tuk-tuk and a Swiss Roller (a steam roller in Switzerland) amongst others, with the theme of 'three wheels'. A photographic competition is proposed; entrants should feature any locomotive or boat between May and October this year posed on either of the Club's sites, the Wibsey pool and the Northcliff railway. W. www.bradfordmes.org.

To Conrod, May, from **Otago Model Engineers Society**, welcome back from the wilderness. It has been so long since I last received their missive that I have deleted all my old copies. So, the prodigal returns. What news my fine fellows? Most notable to President, Stuart Reid, in the last few weeks, has been the removal of 10 tons of sludge from the boating pool. Ivan brought to the 'bits on the table' a 3-D printed tool box, made to appear as an accessory to his Volvo loader, whilst in practice housing the transformer supplying the lighting circuits. Murray Wright showed 3-D printed rubber tracks for a vehicle in construction, powered by two cordless drill motors complete with gearboxes and clutches, based on an American 'Ripsaw' armoured vehicle. *Wheels at Wanaka*, was celebrating the centenary of construction equipment. A parade of 242 'Caterpillar' products is claimed to be a world record. Otago Model Engineers is itself celebrating its 90 year history in 2026 and proposals are invited for entries. W. <https://omes.org.nz>

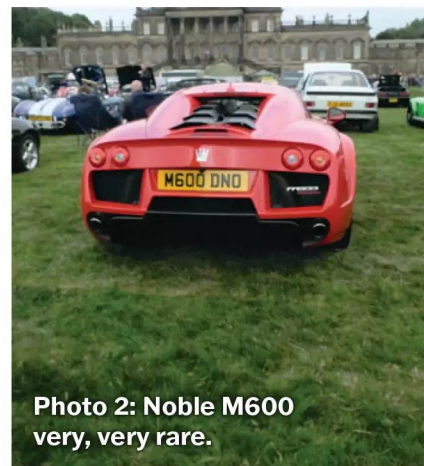


Photo 2: Noble M600 very, very rare.



Photo 3: The engine room of MV Granvin

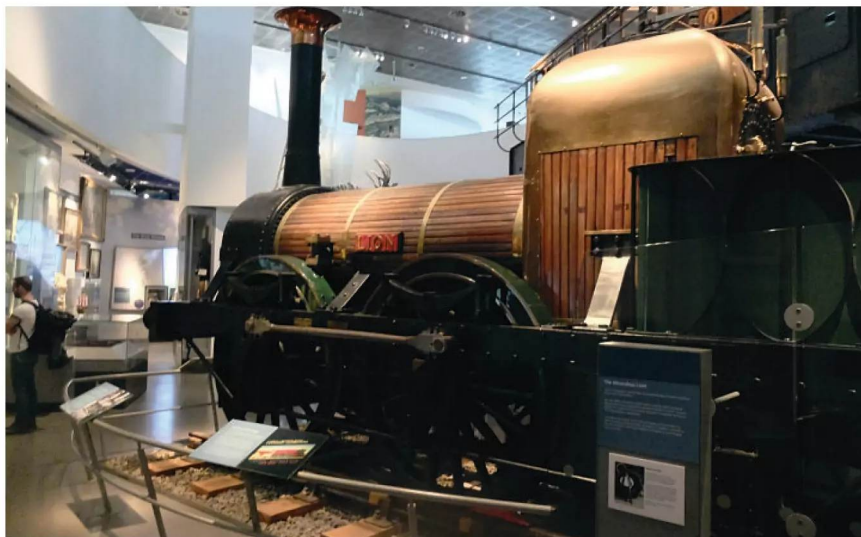


Photo 4: Lion at the Museum of Liverpool.

Reading Model Engineers sends The Prospect, May, in which John Spokes writes of his visit to Taylor's Loughborough bell foundry, as a member of a trip organised by the Society of Model and Experimental Engineers. It is the largest bell foundry in the UK, following the closure of Whitechapel bell foundry in 2017 (an establishment I have visited). John describes the process of melting the bell metal, casting it and tuning the bell when cast. The liquid metal is stirred with a willow pole, such traditional procedures are common in the industry and the machinery in the workshop appears very crude and simplistic but it produces bells of quality and you don't change a winning formula! The bell is tuned to a fundamental

musical note with four overtones, thus the bells 'speak' (technical term) in harmony and this also led to the development of carillons. W. www.rsme.uk

Raising Steam, from the **Steam Apprentices Club**, part of the National Traction Engines Trust, shows an unrestored Marshall Britannia portable engine being manoeuvred into place at an exhibition or show, by an AEC Matador. Editor, Jim Huntley, is working to restore a steam yacht, which he hopes to have ready for the Bristol Harbour Festival in July. Chairman, Paul Stingmore, writes that *Appleford 75* is a celebration of 75 years since the preservation hobby really took off in 1950.

The event involved a race between two engines, *Old Timer*, with owner, Arthur Napper and *Ladygrove*, driven by Miles Chetwyn-Stapleton. The history of the early years of preservation is in the book, *A Wager for Ale*, by Chris Edmonds and see also www.appleford75thanniversary.com The SAC Contract is a guide for everyone in the steam preservation industry. It lays down a code of practice for Apprentices, Owners, Crews, Parents and Volunteers. Apprentice, Elliot Jones, writes on his memorable day at Bedfordshire Steam and Country Fayre. *Lady Sylvia*, the Apprentices' own miniature traction engine, has passed its boiler test. The NTET awards bursaries of up to £500 to anyone who is training for a career which will help to preserve our heritage. Elisha Bell has trawled the archive again to produce more pictures. A Foden underframe, with side-tipping trailer in 1931, an 8 hp Showmans road locomotive, *Mikado* in 1905 and a Foster Wellington tractor owned by a timber merchants and which is notable for the spuds fitted to the driving wheels for use in soft ground. Finally a line up of Aveling and Porter products owned by the French Travelling Theatre, *Theatre National*. Harry Williams writes on his restoration of a Mamod steam car, involving a strip down, some mechanical repairs and a repaint. The result is fabulous! Some loose talk on the legal position of apprentices driving on rally fields is not good for the movement and SAC/NTET have taken legal advice resulting in the position being clarified and it is set down here for general consumption. A Fowler living van with a chequered history has been completed. In a previous life before its repair it was a pheasant rearing shed. It has been rebuilt from the ground up by wood cut on a steam sawmill, therefore it was only fitting that it was delivered to the owner by steam power. Three opportunities for regular crew are publicised for apprentices of 14 years plus, in Waltham Abbey, Warrington and Kent, so if you are interested, form an orderly queue... W. www.ntet.co.uk

Some photos requested have not arrived in time, so here are a couple of pictures from our recent holiday in Norway. This, **photo 3**, is the engine room of the *MV Granvin*, built 1931, operating out of Bergen and powered by a 300 HP 2 stroke diesel engine and here is a picture of *Lion* at the architecturally very striking Museum of Liverpool at Pier Head, **photo 4**.

The Link, from **Ottawa Valley Live Steamers and Model Engineers** March-May, said that in 'Show and Tell', (Round the Table) a book, *How to Run a Lathe*, is to be given away by John Stewart. Guy Cadrin is making a Unimat milling vice, Graham needs replacement gears for a 'Gronk' - it was suggested a 3-D printed set in brass with a hex shaft should do it. David Hayman said, due to house improvements since he moved in, this is the first month on which there has been no model activity. The Safety Policy has been updated. Graham Copley has devised *Copley's Third Law*, 'an object dropped from a height 'h', will, upon hitting the floor, instantaneously beyond human visual detection, vanish to any point upon the compass, horizontally, a distance not less than $N \times h$ where N is an integer 2 or higher'. The proof ...? "I was fighting the front coupling on my Stirling single, putting the final touches to the model when I dropped the coupling spring alignment disc. The disc rolled away right under the bench where the engine was. End of the tape: 96 inches, height from the job to the floor: 32 inches! $N = 3$ in this case." W. www.ovlsme.com

Steam Whistle, from **Sheffield Society of Model and Experimental Engineers**, reports discussion on being registered for VAT. The Society's figures are oscillating around the bottom limits, from year to year. A record number of tickets were sold on 11 May, a public running day, possibly due to the good weather. Pete Nash writes on Manning Wardle NG locomotive, *Abernant*, now at Nottingham SMEE, Ruddington. Robert Collings similarly writes about the newly built Festiniog railway carriage truck. W. www.sheffieldmodelengineers.com



Photo 5: Stan, a 1932 'Standard' Little 9, somewhat modified.

Guildford MES News, May, from **Guildford Model Engineering Society**, contains outgoing Chairman/incoming President's Mike Holman drawing our attention to the massive amount of work that had been done to the signalling system over the winter, mostly by two members. Editor, Peter Shakespeare, mentions the decision not to buy the enhanced version of the website after a vote amongst the members. He says, "This was decided on a majority vote, as is right and proper". In making the usual request for more contributions to the newsletter, he reveals that he is an editor in real life too, so is quite used to submitted copy not being 'page-ready'. Treasurer Chris Phillips muses that the Society's main income source is now the Open Days, the most recent (March) being just short of the figure from July 2023 and £75 short of their best ever, last April. The annual Sweet

Pea rally was held in mid-June and Neil Heptonstall reports the 'Golden Pot' celebration, referring to the markers for access to the signalling cable ducting. This is comparable to the more usual golden spike driven at the completion of other railways. No doubt partly because of the risk to the cables if a spike of any sort was driven in to them. Peter Stage, in 'bits and pieces', is an amateur rocketeer, a very different hobby. At the end of their international competitions, mostly comprising England, Russia and America, to provide a little light relief, they have a novelty rocket competition; Peter produced one made from three Papier-mâché elephants (pachyderms?). It had successfully flown and was only slightly damaged on landing. Look out, Elon Musk! A Custom Car show in Sheffield produced this great car, Stan, a 1932 Standard Little 9, with a 5.5 litre engine, **photo 5**.



Photo 6: Fowler road locomotive, Foremost at Claymills pumping station, Burton on Trent.

This Fowler compound is pictured at Claymills pumping station, Burton on Trent, **photo 6**. There are four beam engines in working order and lots of smaller engines and other machinery. I also bought a book, *Building Model Engines*, based on a series appearing in *Model Railway Construction* magazine between 1947 and 1951, of which I was not previously aware and very good it is too.

And finally, A Sunday School vicar asked his class why he wore his clerical collar. A boy at the back said, "Cos it kills all ticks and fleas in 14 days" 🐞



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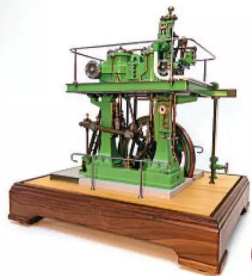
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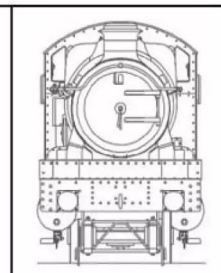
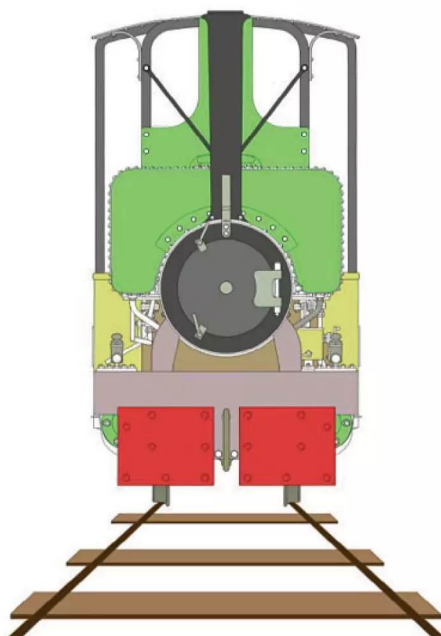
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