

No. 336



DIVIDING PLATES

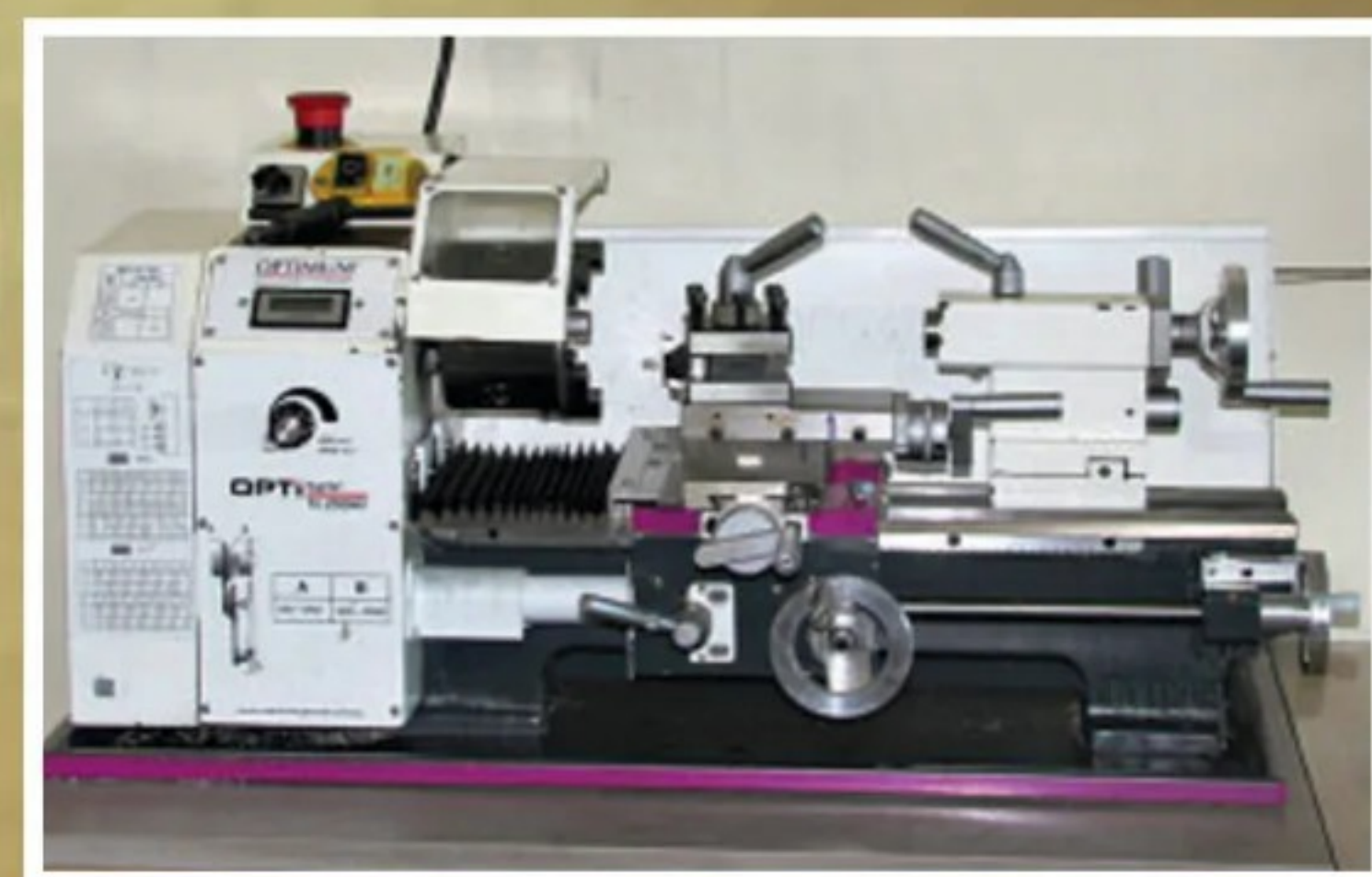
How to use them and make plates for unusual numbers.

MODEL ENGINEERS' WORKSHOP

THE MAGAZINE FOR HOBBY ENGINEERS, MAKERS AND MODELLERS FEBRUARY 2024 ISSUE 336 WWW.MODEL-ENGINEER.CO.UK

A Boring and Facing Head

Detailed plans for Graham Meek's New Design.



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Ideas and improvements for a German-branded lathe.

MAKE A TAILSTOCK STEADY

A safer way to turn long thin stock.



INSIDE THIS PACKED ISSUE:

■ MACHINE LIGHTING – USING LED STRIPS. ■ BIGGER, FASTER 3D PRINTS – THE CREALITY K1 MAX ■ 50 YEARS OF THE UNIVERSAL PILLAR TOOL. ■ ADDENDUM GEAR MODIFICATION. ■ FITTING CORE PLUGS. ■ TOAD5 – ADVANCED CNC CONTROLLER. ■ MAKING A SENSITIVE DRILLING ATTACHMENT. ■ DIVIDING HEAD – THE FINAL PARTS. ■ PLUS ALL YOUR REGULAR FAVOURITES!

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On the Editor's Bench

What do you want to see in Model Engineers' Workshop?

The curious way UK magazines are dated in advance means I'm writing this before we start 2024, I've been reviewing our content over 2023. A number of recent series and articles in MEW generated some interesting feedback from readers. The reprints of historic articles from the last 125 years were well received, and though they won't feature in every issue, I'll look at ways of revisiting particularly good ideas from the past. Readers also like reviews, especially helpful are those of good tooling and machines. Some readers find very technical articles hard going, but these are always balanced by some readers who enjoy working through the calculations and exercising their grey matter.

One recent series generated particular comment – that on the design of a file storage rack. The series was meant as an exposition of various different approaches and techniques (such as automated centre of gravity calculations) and how they can be applied to the process of design of any project. The actual 'product' was relatively unimportant, the file rack itself serving as a straightforward subject to which these approaches could be applied. Perhaps this wasn't made explicit enough, leading some readers to question dedicating so many pages to the making of a simple object.

I also get regular emails about the balance between 'traditional' subjects and topics such as CAD, CNC and the incorporation of modular electronics into workshop projects. They tend to be more positive than negative, though some readers consider any such content a waste of space. Readers will realise 3D printing as a particular interest of mine, but this seem to be less contentious – perhaps because so many of you now have 3D printers or at least experience of 3D printed parts.

Even so, I would like to receive more contributions about traditionally made projects, especially relatively straightforward tooling that can be described in a single instalment. These sorts of articles are becoming scarcer. Perhaps because so many basic tools are now easily obtainable online at relatively modest cost, making your own is a less attractive option.

The content of MEW is written almost exclusively by readers, so it reflects what they want to write about, even if it's not what they want to read about. A problem for me is that very few people will undertake a project and write it up unless it's something they are already planning to do.

I always read and pay attention to reader (and writer) feedback and try to learn lessons from it, so please continue to email me, at meweditor@mortons.co.uk, with your views. However, if you really want to contribute to improving MEW, the best thing you can do is write an article of the sort you would like to see. Don't forget we pay for published articles, so if you have an idea, email me and I will send you the guidelines.

So, in 2024, please consider contributing to MEW, or at least sending me your thoughts of what we could be doing. But most of all, have a happy, safe and peaceful New Year in your workshop.

Neil Wyatt

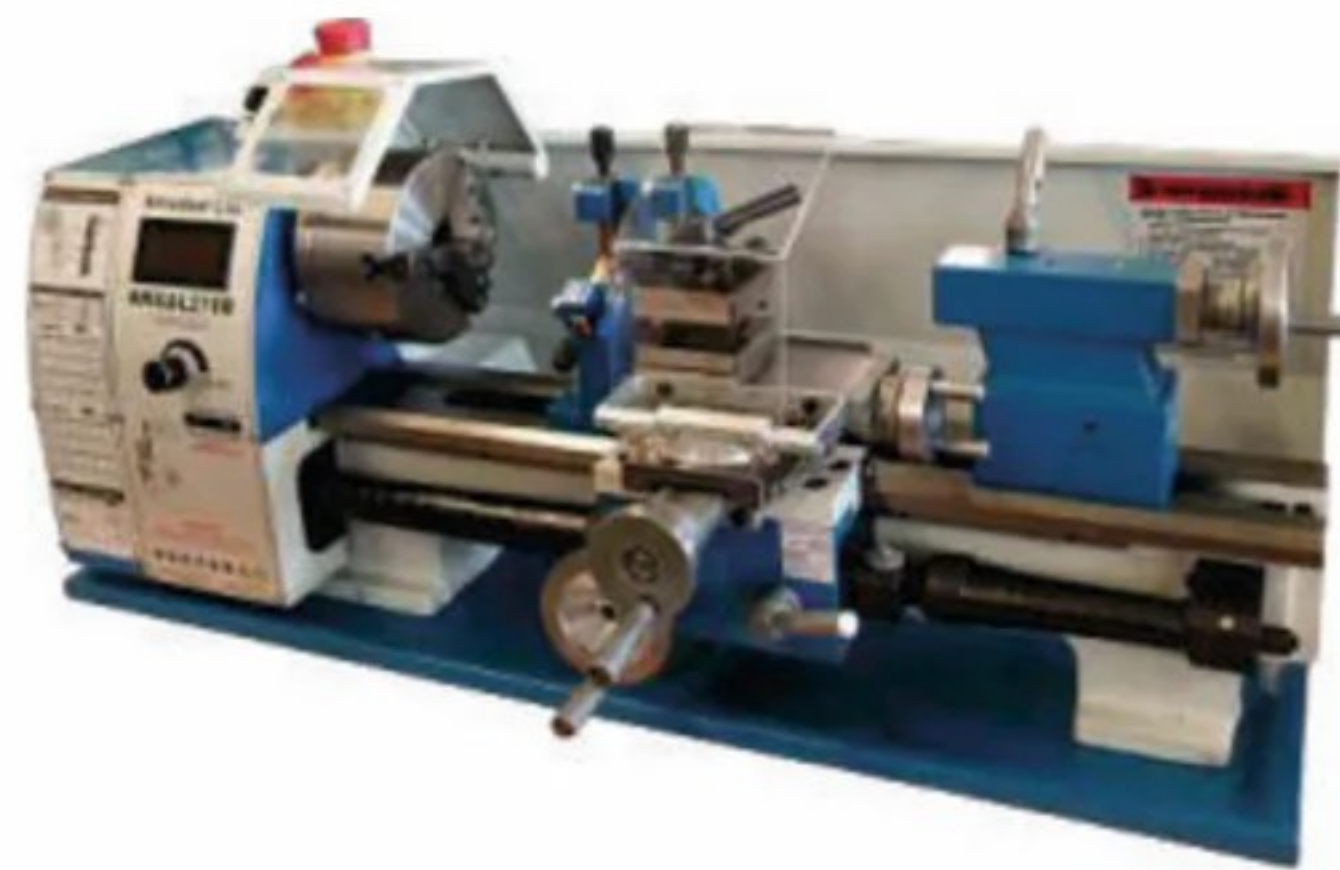


CJ18A Mini Lathe - 7x14 Machine with DRO & 4" Chuck

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Distance between centers: 350mm
Taper of spindle bore: MT3
Spindle bore: 20mm
Spindle speed: 50-2500mm
Weight: 43Kg

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SPECIFICATION:

Distance between centers: 400mm
Taper of spindle bore: MT5
Spindle bore: 38mm
Number of spindle speeds: Variable
Range of spindle speeds: 50~2500rpm
Weight: 65Kg

Price: £1,185



AMABL250Fx750 Lathe (10x30) Variable Speed - Power Crossfeed - Brushless Motor

SPECIFICATION:

Distance between centers: 750mm
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Spindle bore: 26mm
Number of spindle speeds: Variable
Range of spindle speeds: 50~2500rpm
Weight: 140Kg

Price: £1,904



VM25L Milling & Drilling Machine Belt drive & Brushless Motor

SPECIFICATION:

Model No: AMAVM25LV (MT3) / (R8)
Max. face milling capacity: 63mm
Table size: 700x180mm
T-slot size: 12mm
Weight: 120Kg

Price: £1,431

W DRO – Price: £1,921

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SPECIFICATION:

Distance between centers: 700mm
Taper of spindle bore: MT5
Taper of tailstock quill: MT3
Motor: 1.5kw
Weight: 230Kg

Price: £2,782

W 2 Axis DRO – Price: £3,150



VM32LV Milling & Drilling Machine Belt drive & Brushless Motor

SPECIFICATION:

Model No: AMAVM32LV (MT3) / (R8)
Max. face milling capacity: 76mm
Table size: 840x210mm
T-slot size: 14mm
Weight: 240Kg

Price: £2,100

W DRO – Price: £2,537

W DRO + PF - Price: £2,948



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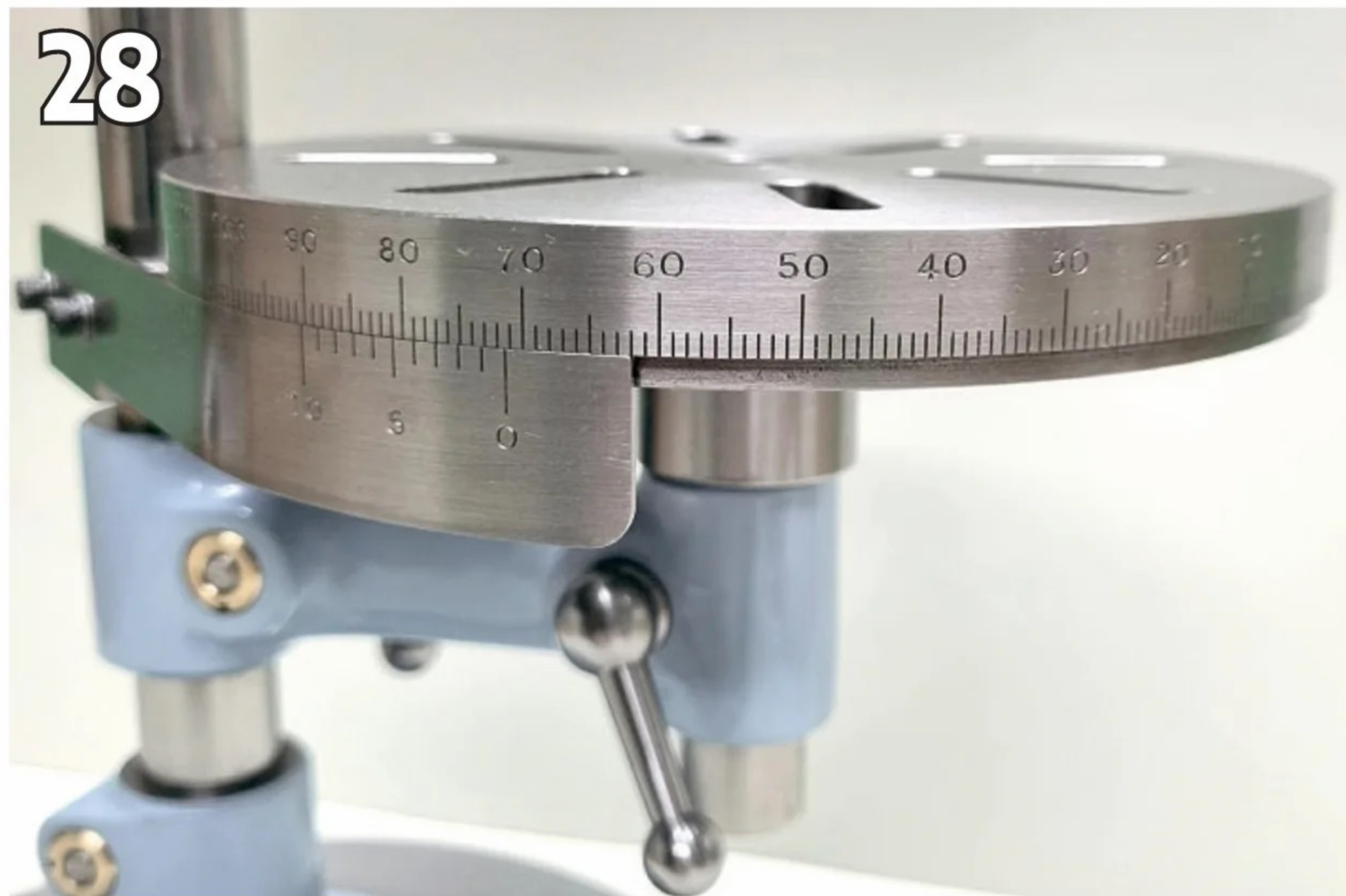
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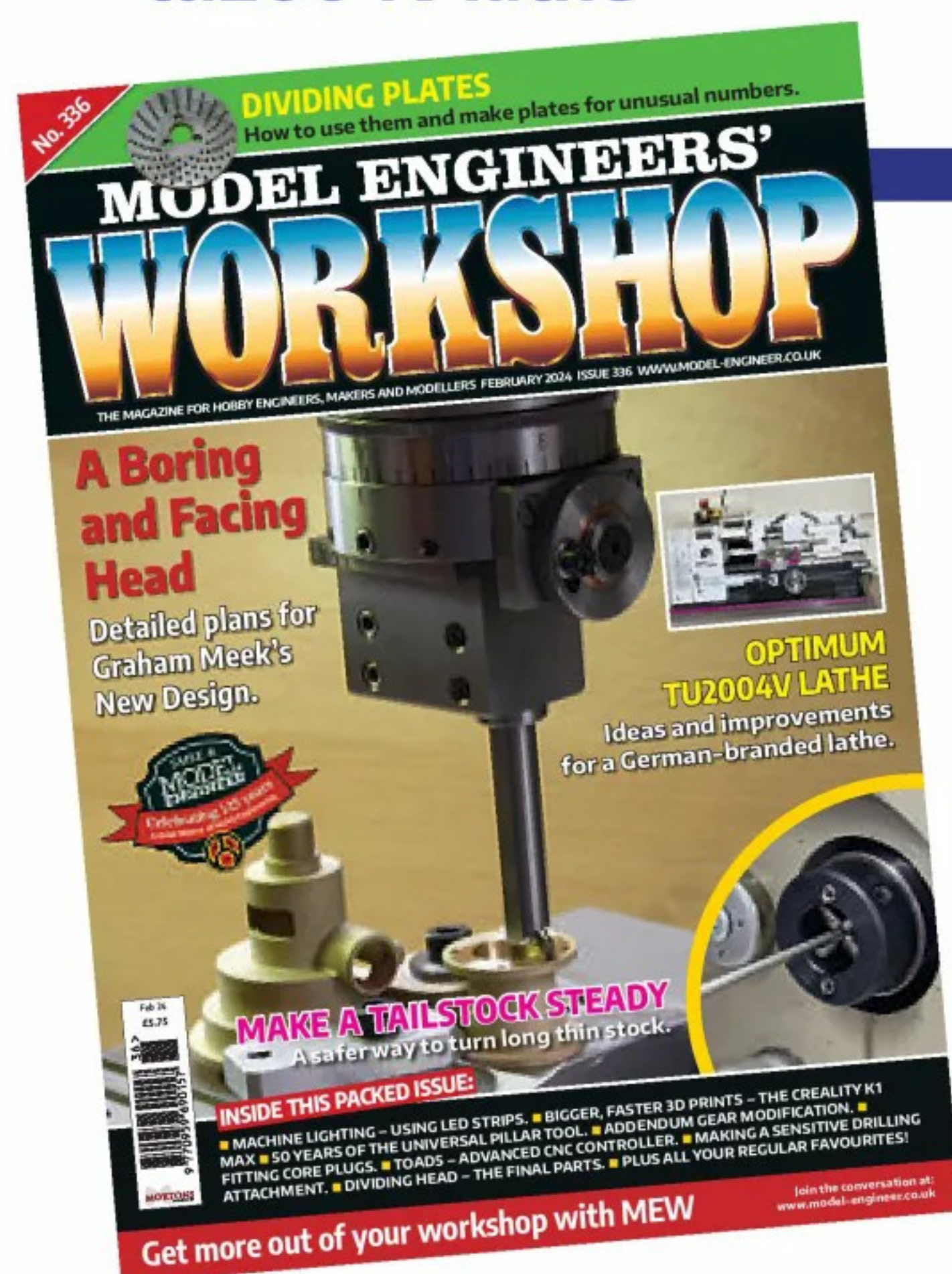
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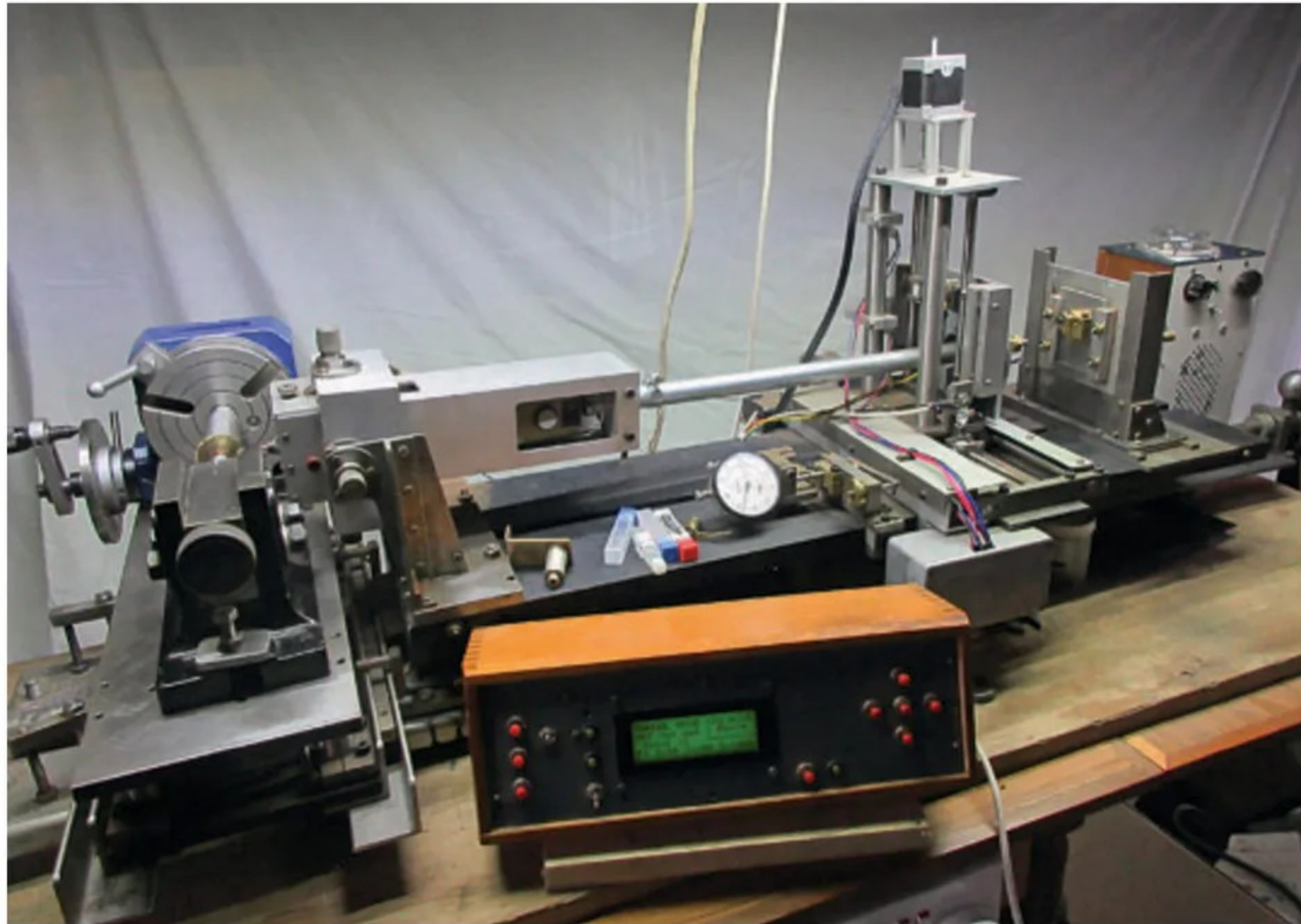
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See page 54-55 for details.

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in our next issue

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ON THE COVER

Our cover features Graham Meek's new Boring and Facing Head design, see pages 9-14.

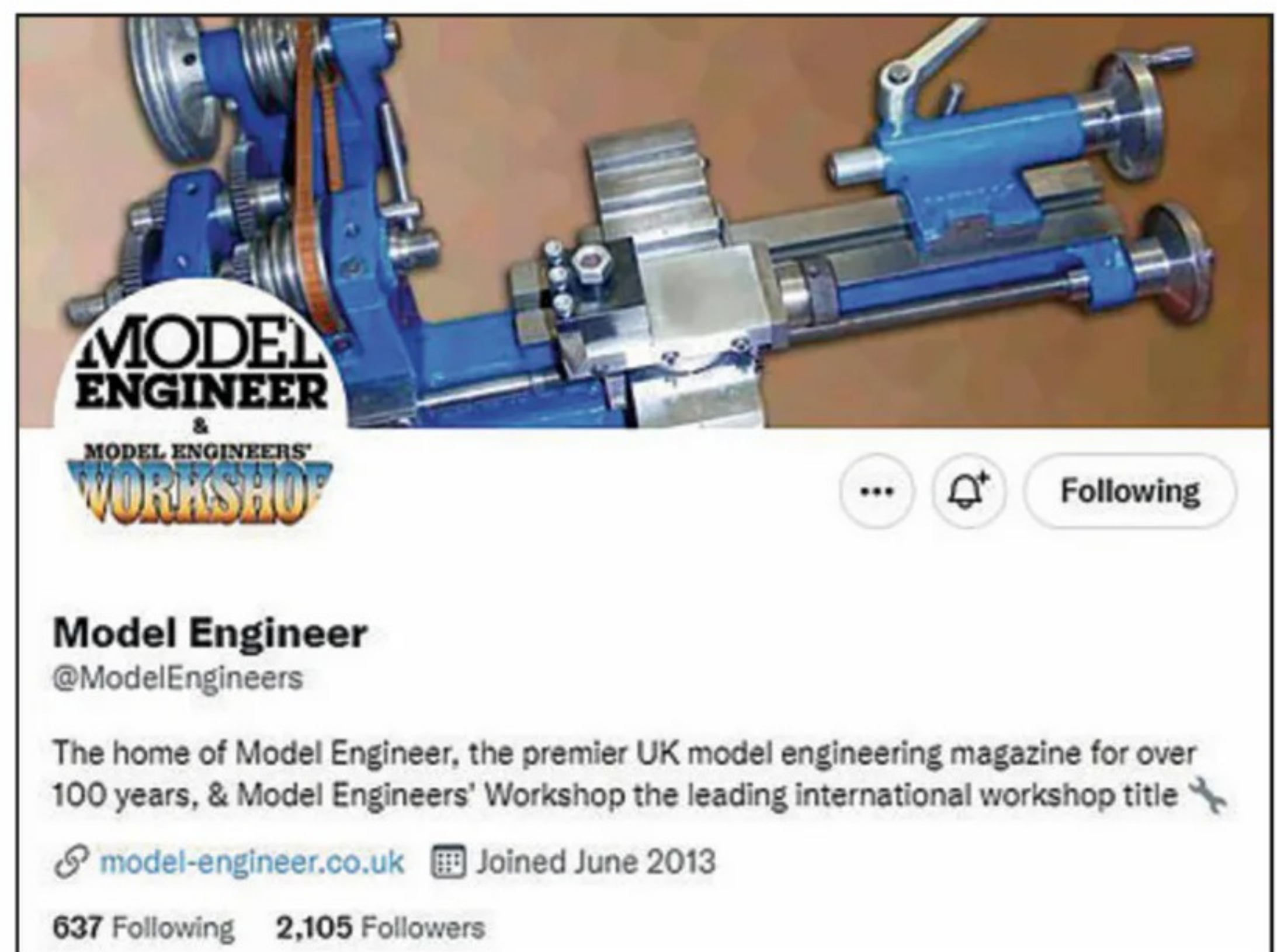


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THIS MONTH'S BONUS CONTENT

The Forum has changed!

You can log on to the new forum using your existing details, you can recover your password to the email address associated with your account. There have been issues with getting the forum working smoothly again, but there is help and assistance available if you have any questions or issues getting to know your way around the new forum software. We have also set up 'practice' threads so you can try posting images and documents. www.model-engineer.co.uk

Hot topics on the forum include:

Pickling Not onions! What do you use to clean up after brazing? By David Deadville.

Where are the shaper users? Revisiting a fascinating old discussion by Richard Green.

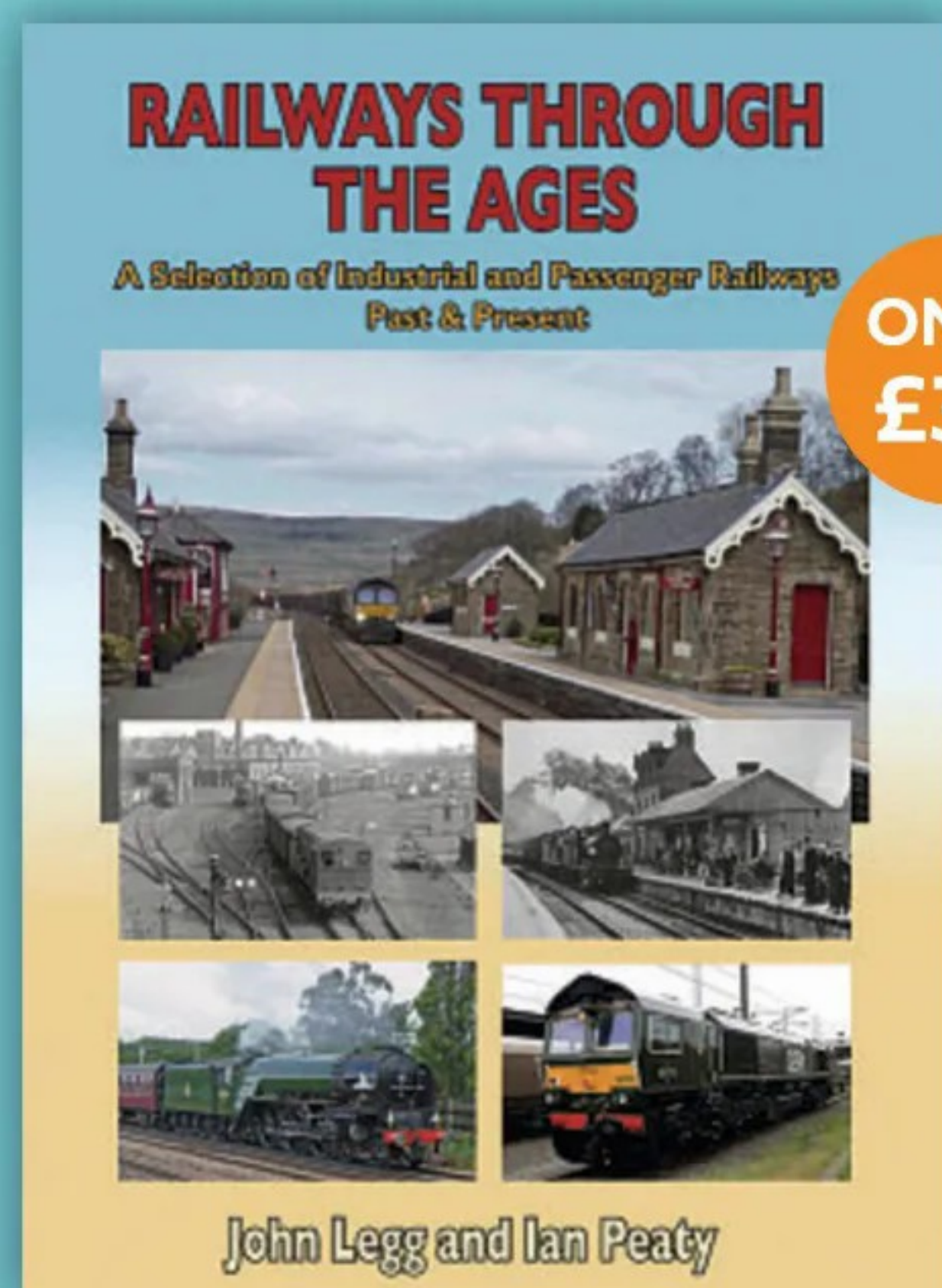
Turning Question: Fine Chatter / Wave Pattern A not unusual issue, by Nigel Graham 2.

Omnimill 00. Starting a classic restoration, by Ian McVickers.

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!

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Railway Through the Ages

By John Legg & Ian Peaty

Dive deep into the history of railways from their early beginnings to today.

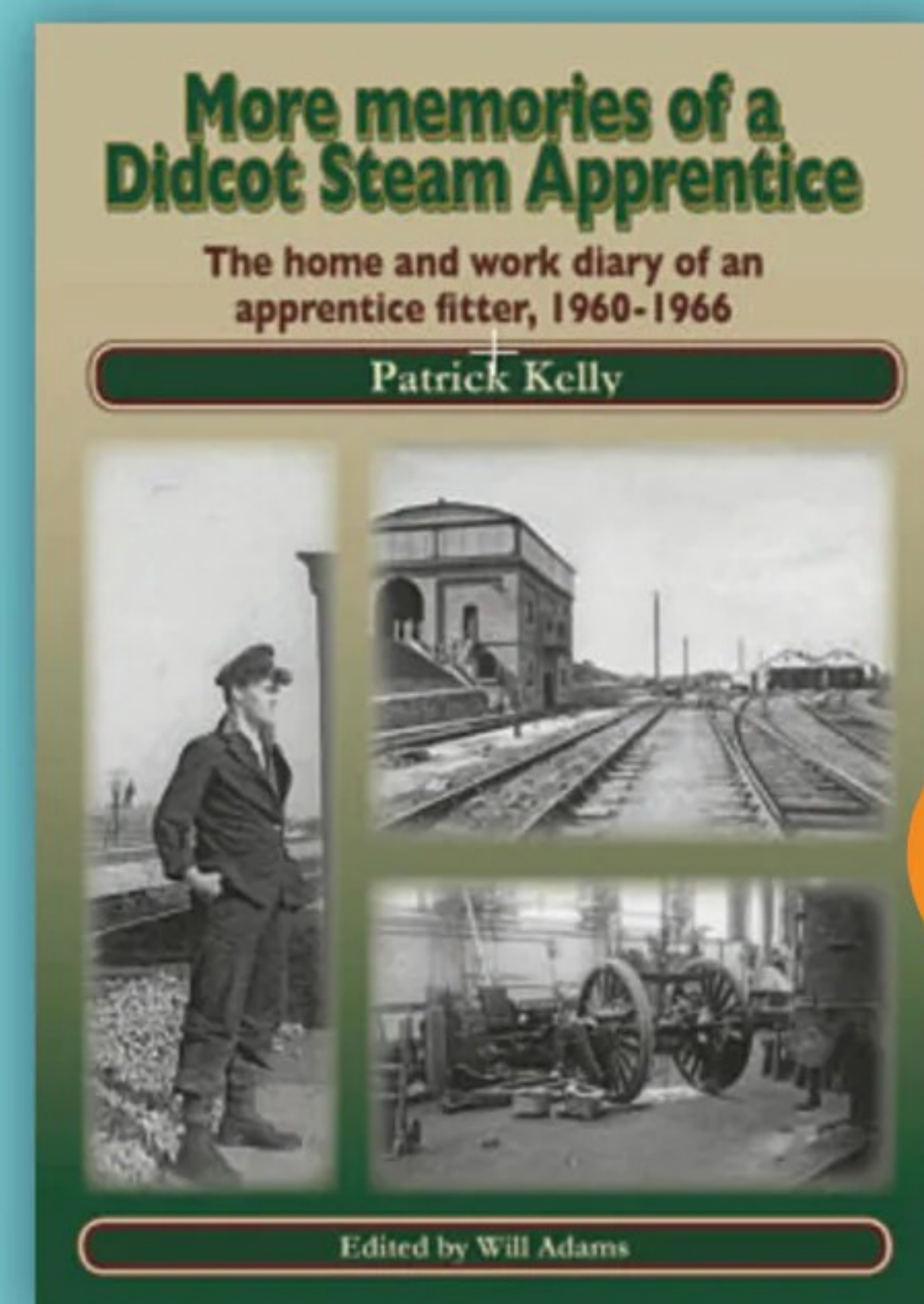
This book features a mixture of standard and narrow-gauge tracks, industrial and heritage lines, and iconic train stations.



Steaming Through the Yorkshire Dales

By Ray Fincham

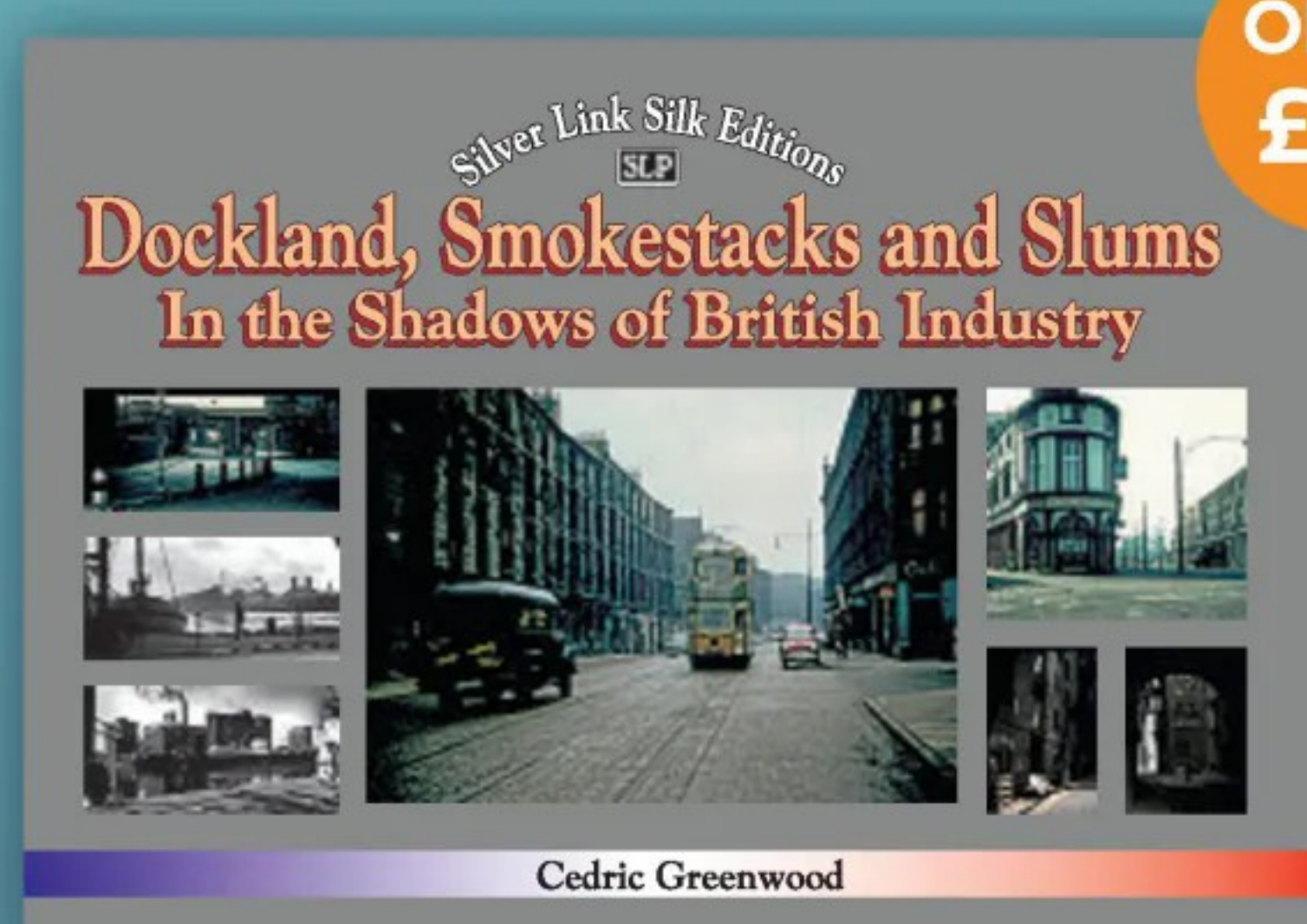
Explore the history of the 73-mile link between Settle and Carlisle that ran through the high fells and dales of Yorkshire and Cumberland.



More Memories of a Didcot Steam Apprentice

by Patrick Kelly

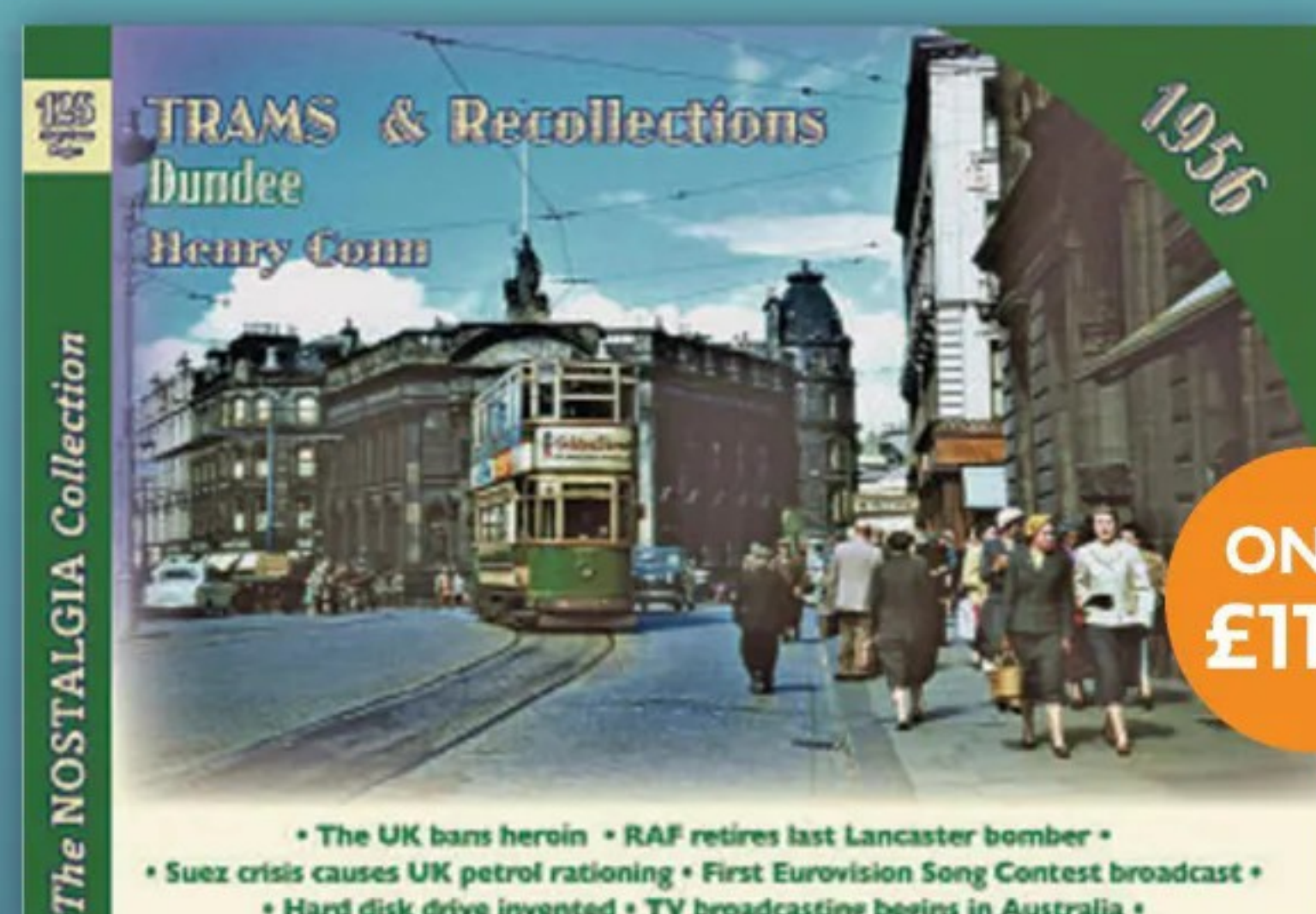
Pat Kelly's day-to-day life at Didcot shed on BR's Western Region in the dying days of steam, as a young inexperienced 15-year-old.



Dockland, Smokestacks and Slums

by Cedric Greenwood

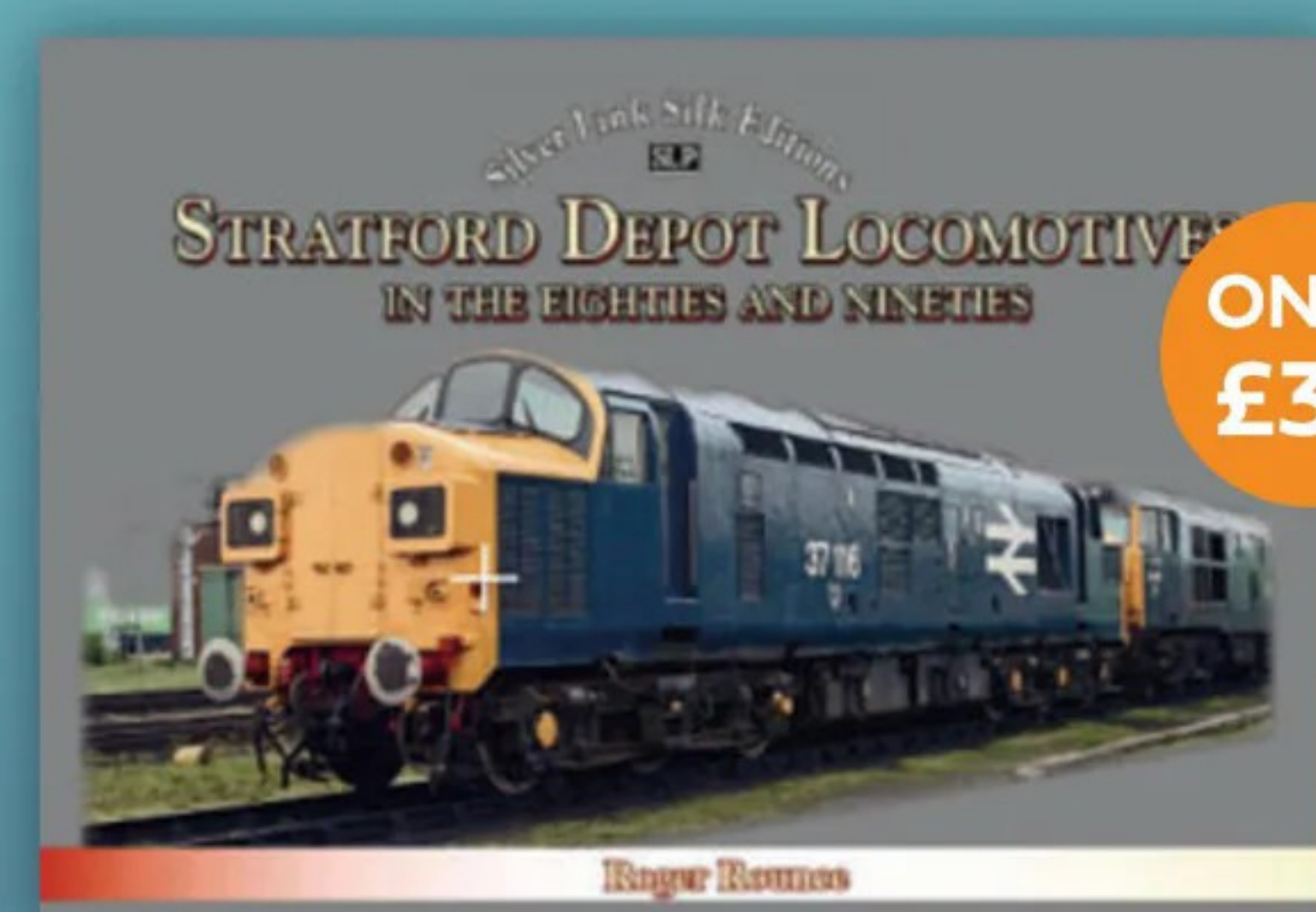
This book provides a photographic study of the 19th and early 20th century British industrial scene from its recovery following the Second World War to its decline in the mid-1980s.



Trams and Recollections: Dundee 1956

By Henry Conn

The third book in a series that explores the tram routes of Dundee in the 1950s.



Stratford Depot Locomotives

By Roger Rounce

Photographer Roger Rounce presents a collection of his own images of diesels and electrics from the days when engines from every region could be found at Stratford TMD.

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A New Boring and Facing Head.

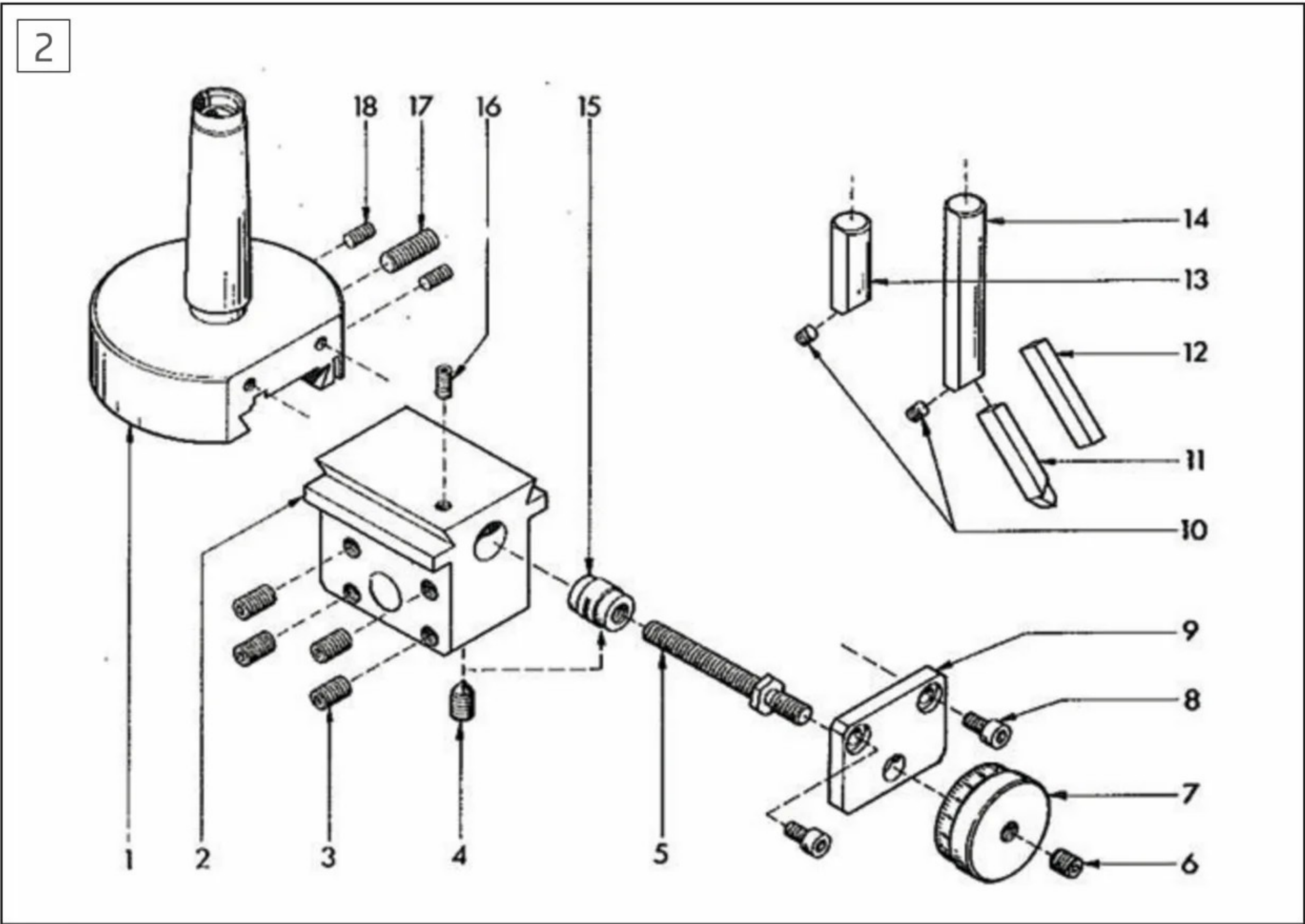


Graham Meek presents his latest design for an advanced boring and facing head. There are six sheets of figures accompanying the series, and two will appear in each instalment.

This short series of articles describes a 'new' design of boring and facing head, **photo 1**, developed in the light of lessons learned and feedback on my previous design. The previous boring and facing head that I designed, HSM July/August & September/October 2016, EiM April-May 2012 and page 7 "Projects for your Workshop Vol 1", leaned heavily on the second generation Emco boring head design. A drawing of the Emco unit is attached at **photo 2**, (reproduced courtesy of the EMCO Group, Austria). The facing facility was added to this design as I was familiar with the Emco head. This seemed a natural route to me to use a proven design. Thereby retaining continuity of operation and the use of existing tooling. This design has been received with some mixed views. Some appreciate the

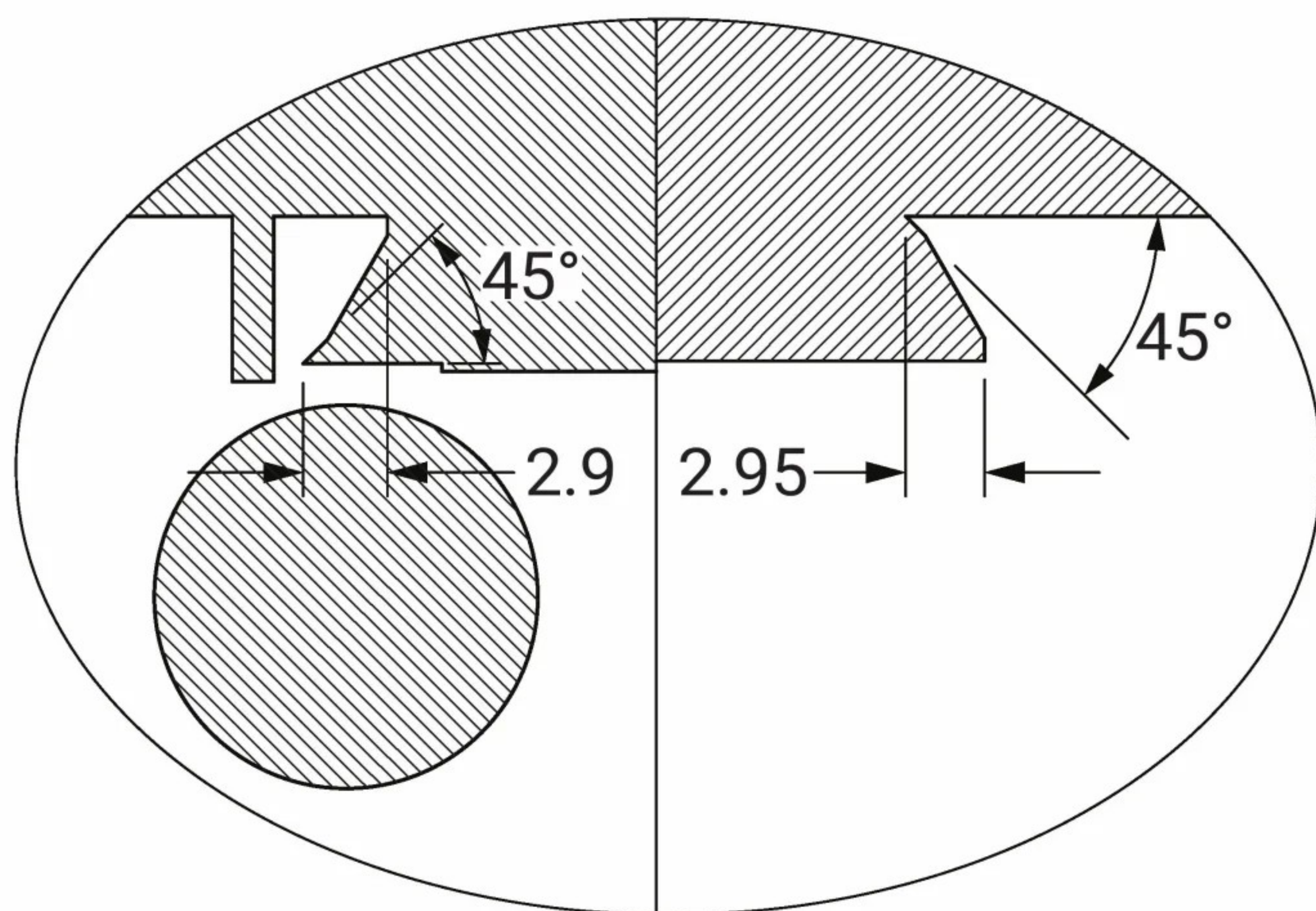


The new boring head



Exploded view of the second generation Emco boring head, courtesy Emco.

facing facility while others like the zero adjustable dial, but some do not like a "the large dial whizzing round". In the original Emco design this large steel dial was in my opinion doing an unseen function, namely helping to balance against the offset tool slide when boring large diameters. It will be noticed that a substantial part of the main body has been machined away to provide the mounting surface for the feedscrew. This had obviously escaped the attention of these critics. Having a larger dial also gives the user a chance to split the 0.025mm divisions for greater accuracy. In an attempt to make the design more appealing and to try a whole new way of continuously driving the feed screw when facing, instead of intermittently as in the old design, a new design approach for the boring head



Enlarged View Of Undercuts

Sketch 1

was therefore contemplated as is shown here. The term "NEW" is used only to differentiate between this design and the previous version. I doubt very much if my approach to this problem is in fact "new", as there is in truth very little in engineering that has not already been done before.

While this new boring head as shown in photo 1, has a body of only 50mm diameter it follows closely the construction of its larger 66mm diameter bodied brother. The Emco-style integral dovetail gib used in my original design has been retained, **sketch 1**. This design to my mind offers greater rigidity and involves one less component to make. While others prefer to use a separate gib strip. Those wishing to do so can add this if they wish but these gib's do have some drawbacks. Unless the separate gib strip is dowelled to stop endwise movement the gib is bound to oscillate slightly on the points or radii, of the adjusting screws. This slight oscillation will in turn affect how closely the slide can be adjusted and its smoothness in operation. Something that the integral dovetail does not suffer from. While the latter dovetail does have to tip over slightly in order to make the adjustment this is in reality a miniscule amount and something I have been unable to detect using Micrometer Blue. Once this gib has been adjusted I

suspect that this adjustment will never need attending to again when used in the average home workshop. The large boring head I originally made is now over 30 years old and despite a lot of work,

both professionally and at home, this has never needed any further adjustment since it was made.

Those boring and facing heads I have used in industry, and from time to time dismantled due to internal failure use some form of epicyclic reduction from the concentric dial, which in turn drives a worm that moves a rack attached to the tool slide instead of an actual feed screw. Trying to incorporate this form of mechanism within the existing body was possible, but the question had to be asked, "how many readers might attempt such a complicated design?". The answer to this question, would I felt have probably been "none". This therefore decided the final design outcome. With these points in mind it seemed a good idea to use the body of the original design as a starting point and reconfigure how the feedscrew was manually adjusted and driven when facing. One thing I did want to do was to get the dial and feed ring concentric with the body of the boring head. This mimics some of those used in industry, which also allows for an easier to read dial, with much larger graduations and

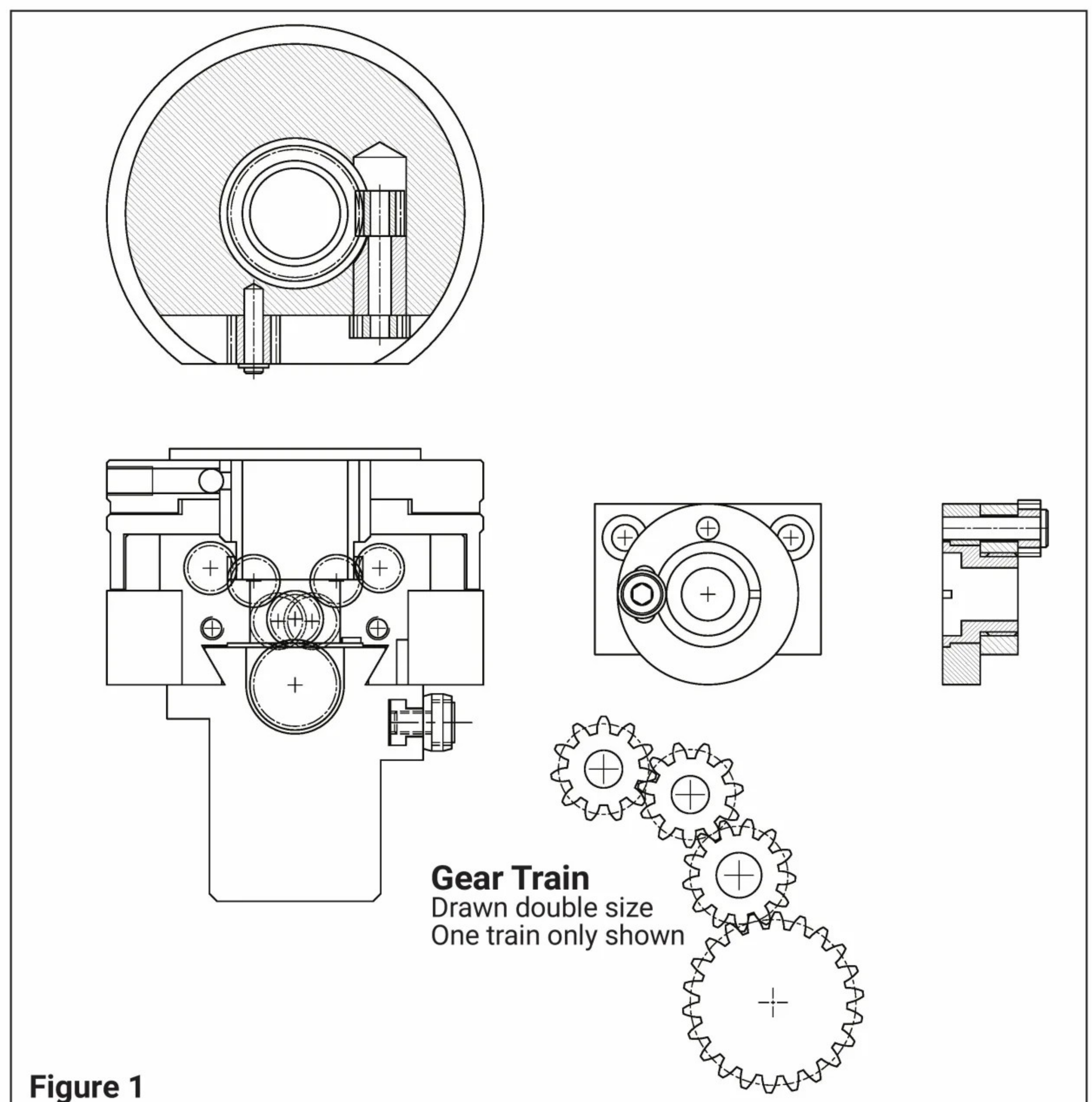


Figure 1

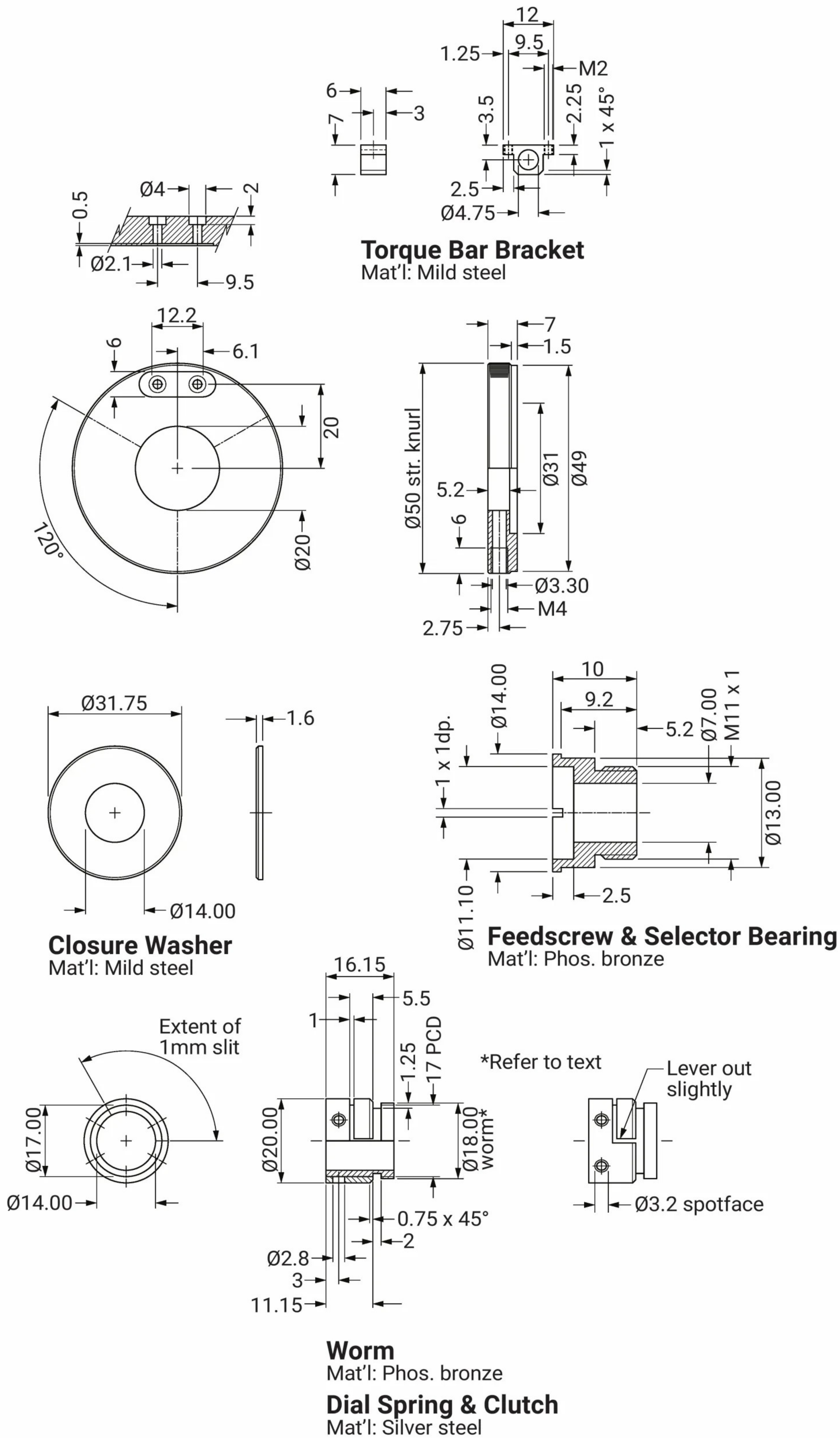


Figure 2



Composite worm silver steel and phosphor bronze.



Output gears and idler gears note E-clip positions to miss endplate.

a possible level of accuracy previously unheard of in the home workshop from a homemade tool, but more on that later. Should any reader prefer a rectangular body then this can be very easily incorporated with this design. With a little ingenuity the rectangular body could be elongated to increase the range of this small boring head if desired. There was one design criterion with regard to the dial and this was it had to be adjustable to give a zeroing facility. Having the dial fixed would have simplified the design no end, but anyone who has worked with such a fixed dial as I have in the past will wish to include a zeroing facility given half a

chance. Some form of locking screw on the dial could have been used, and this arrangement is used in industry, but this was felt to look very unsightly. Plus it would be another “knob whizzing round” so this approach was dismissed. To provide a friction setting for the dial it was originally intended to use one of the crescent shaped Emco dial springs. This is used on all their machine tools and was used in the previous boring head design. Although this new design would have to use a smaller version of the Emco spring. This idea was eventually dropped in favour of a similar spring arrangement to that used on the Myford handwheel dial, (HSM

September/October 2011, EiM March-May 2007, and page 82 of the above book), more on why this was done later.

The drive from the vertical dial and feed ring to a horizontal feedscrew took a little figuring out. This could have been done with a Sun gear, (internal gear), driving a pinion which was integral with a worm which then meshed with a wormwheel on the feedscrew. While this arrangement would work, this did present a rather tedious requirement to repeatedly “wind” the dial during initial setting up. Given the large gearing reduction involved, some form of coarse adjustment would be needed for initial setting up purposes, thereby avoiding this tedious requirement. When the drive mechanism involves a worm and wormwheel there also needs to be some form of clutch provided to disengage the wormwheel during these coarse adjustments, which adds a further complication. Because of the two tool positions in the tool slide, the drive train would also need to incorporate a reversing facility to allow the facing tools to be driven in either direction depending on the size of the diameter being faced. The reader will soon realise things are starting to get out of hand, and it is at times like these that there is a real need to stop, take one pace back and do a rethink.

The problem is the need for a large reduction, especially when facing, but this reduction is also handy to ensure a small incremental increase when sizing a hole. The answer really came when I thought about the placement of the worm gear in the system. If the worm becomes the primary gear, **photo 3**, in the train then the need to disengage the drive for coarse adjustments becomes much easier. Plain spur gears can be used to transmit the drive to the feedscrew after the worm and these can be made to slide or rotate out of mesh to allow for the coarse adjustments. If the worm has a single start, then in one revolution of the dial, (or the boring head when facing), this will only pass one tooth of the gear it is meshed with. Should that gear have 10 teeth, then this will, with a 1mm pitch feed screw give an increment of 0.1mm per revolution of the dial, or 0.2mm off the diameter. Should a further reduction of 2:1 be included in the drivetrain to the feedscrew then

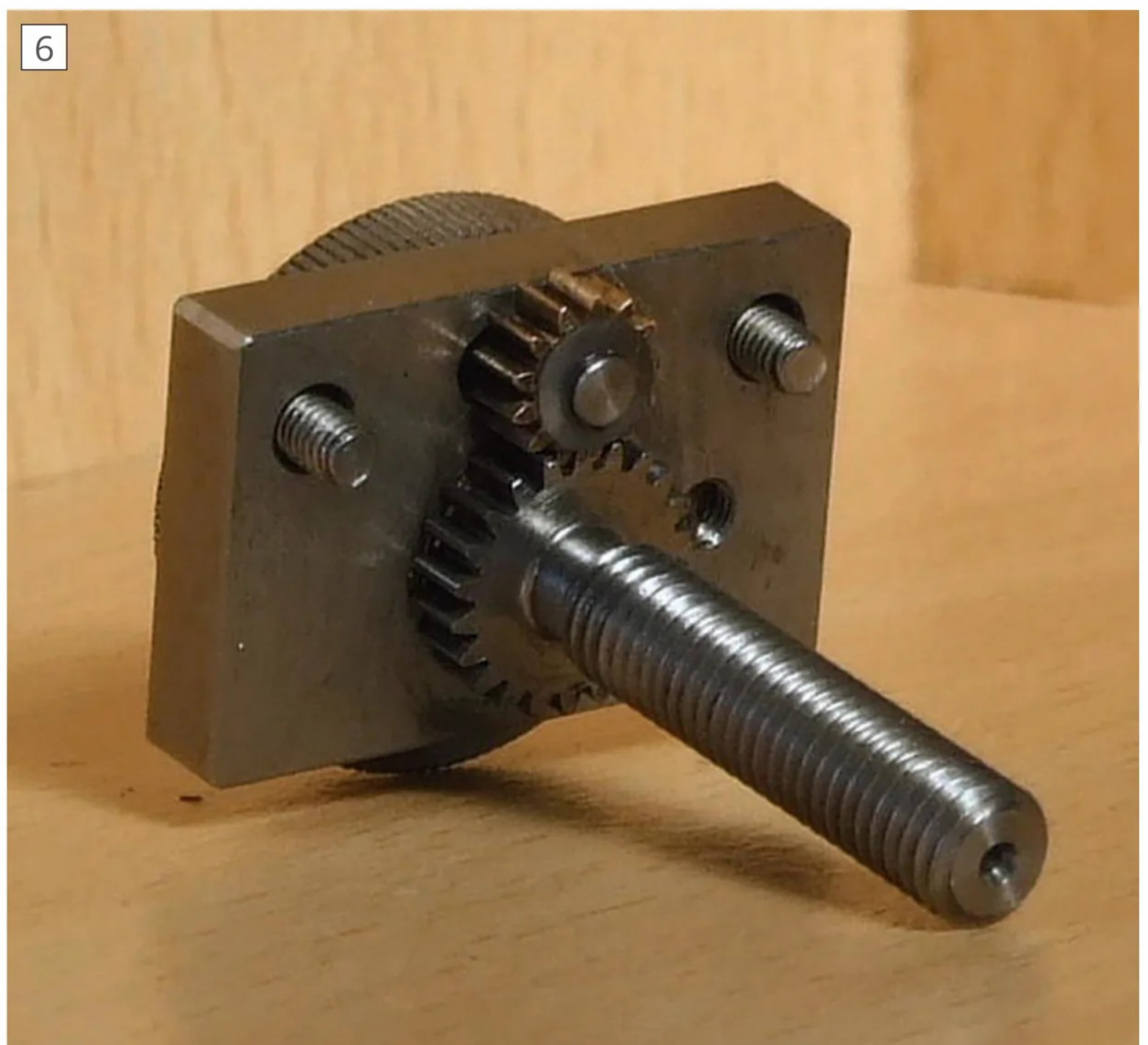


Skew gears in position.

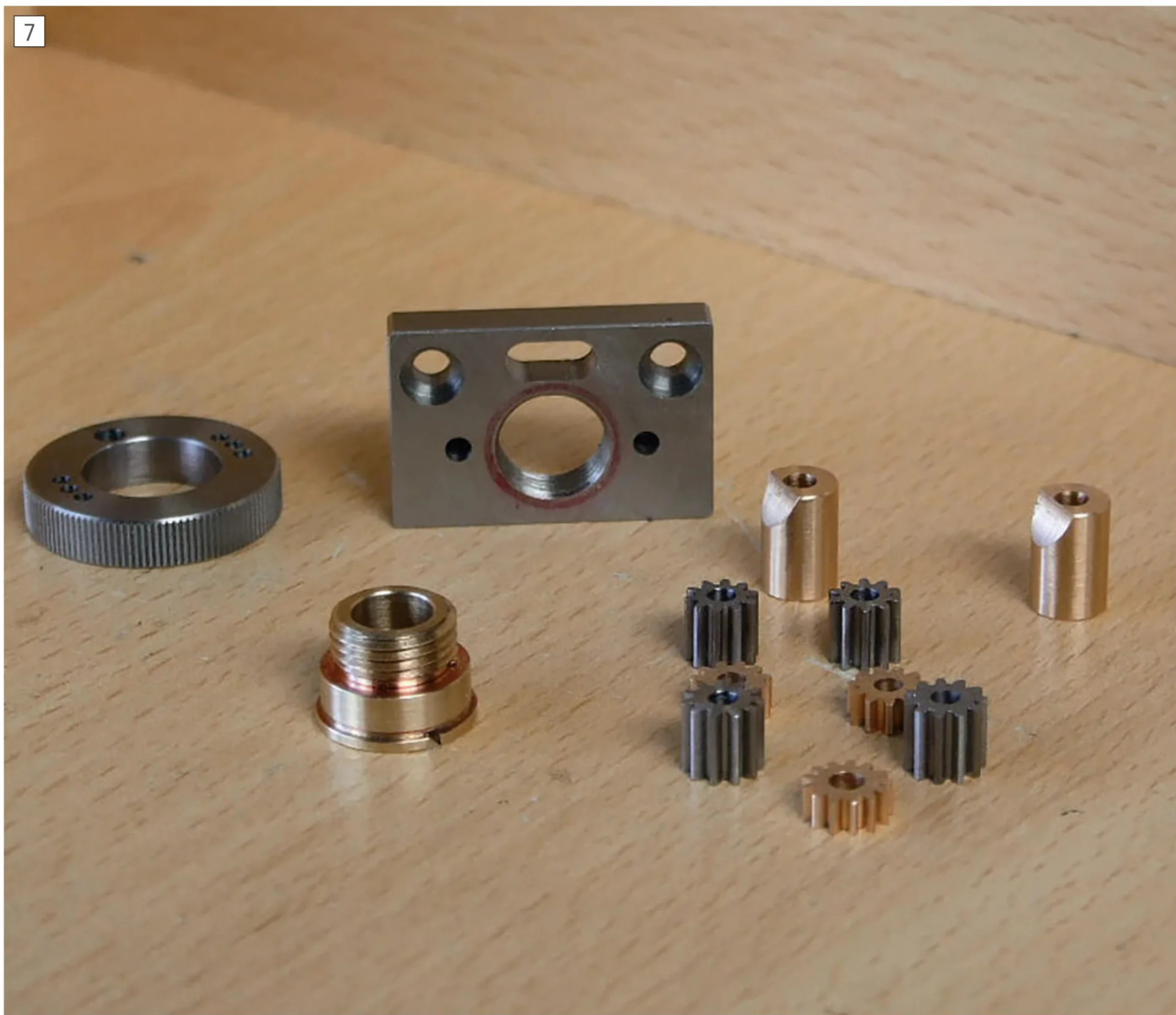
for one turn of the dial the tool slide actually moves 0.05mm or 0.1mm off the diameter. From the experience gained with the original facing head design, which had a two-speed facing arrangement, the 0.05mm feed per rev setting was the one most commonly used. This therefore seemed as though I was heading in the right direction. With the large dial and ten divisions this gives 0.01mm off the diameter per division. Splitting the division in $\frac{1}{2}$ or a $\frac{1}{4}$ by eye would not present a problem but it is not the way I like to work, as this involves some guesswork. As I mentioned earlier the level of precision can be extended depending on personal taste or requirements. The number of divisions can be extended to include 20, 40 or 50, which gives 0.005, 0.0025 and 0.002mm respectively off the diameter per division. However it has to be borne in mind that the reader is never going to remove 0.002mm unless the tool is extremely sharp, correctly ground and in a rigid boring bar. A dial divided into 20 divisions would I feel suffice for most purposes, I merely added the other options to show what can be attained if desired. For those keen-eyed readers, my boring head does have 50 divisions, (the dial looked a little barren with just 20 divisions), and in use it has proved worthwhile, much to my surprise.

With these overall parameters set, the gearing arrangement could be designed, **photo 4**. The next thing was to fit all this in a 50mm diameter body, (this size body I felt was more in keeping with my requirements on the FB2). Initially

the design was first done on the 66mm body and scaled down 0.7575 using the AutoCAD scaling facility. Some slight adjustments were needed to get the gears at the correct centres. Reversing the drive to accommodate the two different tool positions is taken care of by taking the drive from opposite sides of the input worm **photo 5**. While this does involve an extra gear train this does make the reversing arrangement a whole lot easier. As with all things in life this is a “trade-off”, the extra gear train against a complex reversing mechanism. The gears are all made from either EN1A Pb, (Leaded Mild Steel) or Colphos 90, (Phosphor Bronze). This gives two dissimilar materials at each meshed interface. A central tumbler gear in constant mesh with the feedscrew is then used to select which drive is required for each direction, **photo 6**. It has to be remembered the selected drive direction changes when facing is required as the head is now revolving while the feed ring is stationary. The tumbler gear is oriented by the knurled selector knob which is concentric with the feedscrew. This selector was to have two sprung ball detents to retain the chosen selection, but during use it was found the selection



Feedscrew and selector assembly.



Gears endplate and selector.

would on odd occasions “drop out” whenever the rotation of the dial was reversed. **photo 7** shows the original selector with the two sets of detent holes. This state of affairs was not one which I was prepared to live with or allow to go into the public arena. To overcome this annoyance the selector ring now has a slot on the one side and an M3 capscrew to lock the chosen selection, refer to photo 1.

It is advisable to turn up a special washer to go under the head of this capscrew, as commercial washers are usually larger in diameter than the available space allows and look out of place on what is a precision item. Care also has to be exercised to ensure that the head of the central bearing bush for the selector and feedscrew

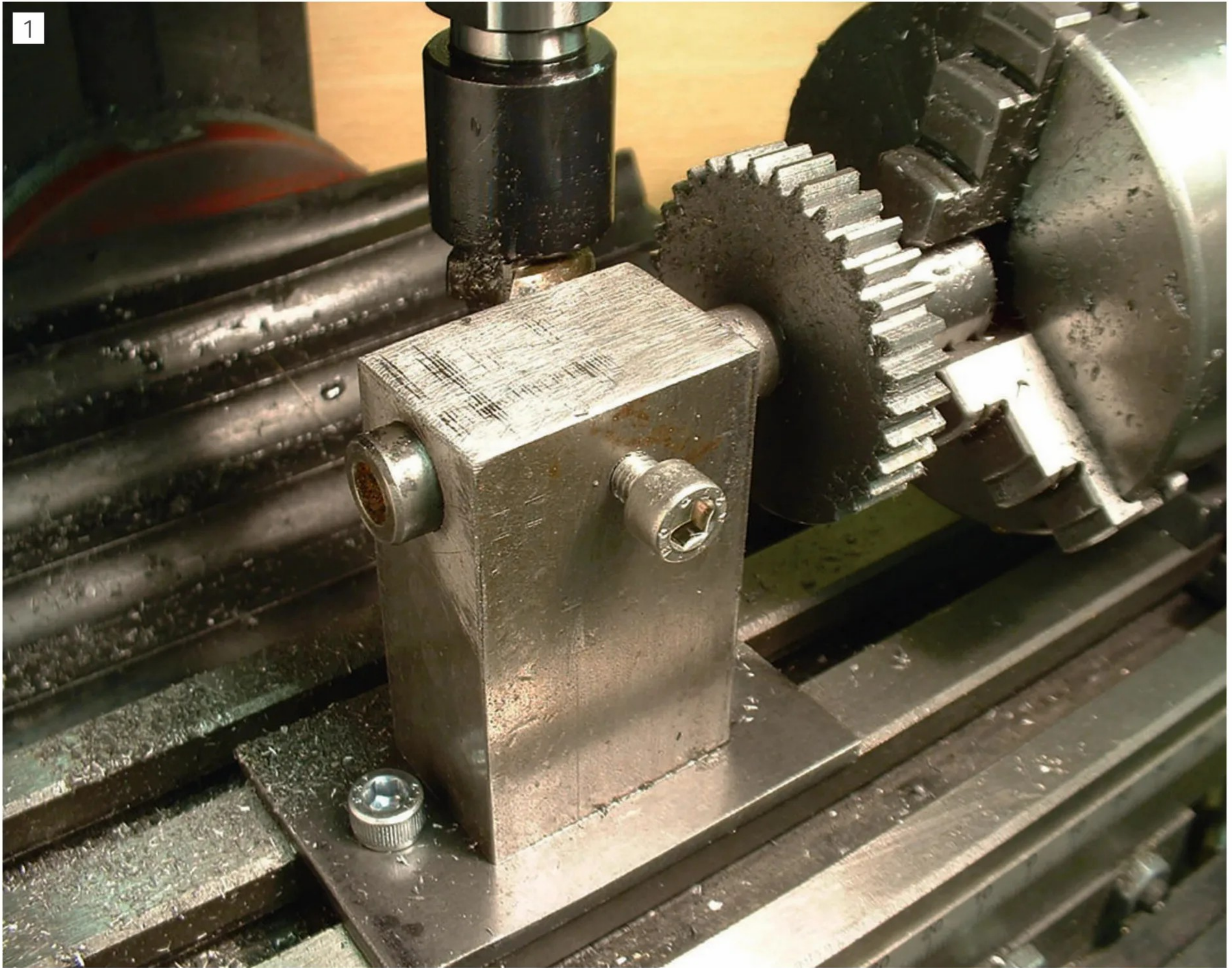
does not protrude above the selector ring. Otherwise the washer under the capscrew will trap this bush. This in turn will tilt the bush and jam the feedscrew. If the dimensions on the drawings are adhered to then this should not be a problem. This selector arrangement does mean that unlike the previous design where the manual incremental inputs could be positive or negative on the dial, depending on which tool location was in use. On this head the feed selector can always be set to give a positive reading on the dial. The tumbler gear also has a neutral position which allows the feedscrew to be turned manually via the Allen key socket in the M4 countersunk screw for initial setting up purposes. This screw is used to lock the feedscrew bearing backlash adjustment,

in conjunction with a micrometer “C” spanner. The M4 size was chosen such that only one Allen key is needed for all the major adjustments on this particular boring head, (3mm A/F Allen key on the 66mm body). Generally I am not a keen user of countersunk screws, but in order to keep the overall height of the protruding masses to a minimum, I could see little alternative. My dislike with the Allen countersunk is the shortness of the Allen key socket. To rectify this the existing Allen key hole is drilled a little deeper to 3mm and the socket elongated using a special hexagonal broach. This gives a much more positive location and more importantly one that will stand up to years of use without weakening the screw.

● To be continued

Using Division Plates

Stub Mandrel looks at using division plates for indexing, and an approach to making custom plates for awkward numbers of divisions.



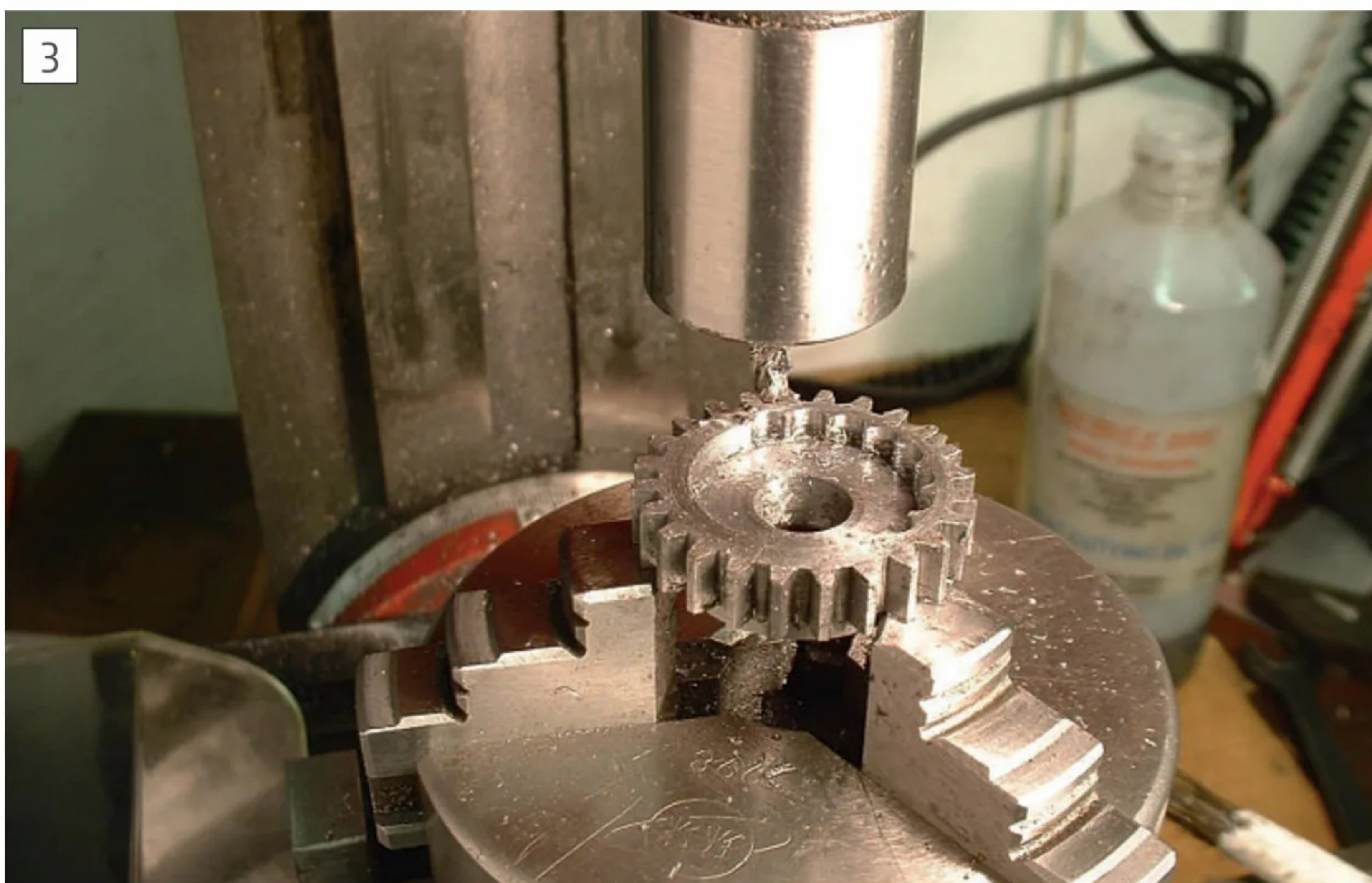
1 Cutting a gear requires accurate repeated angular movements.



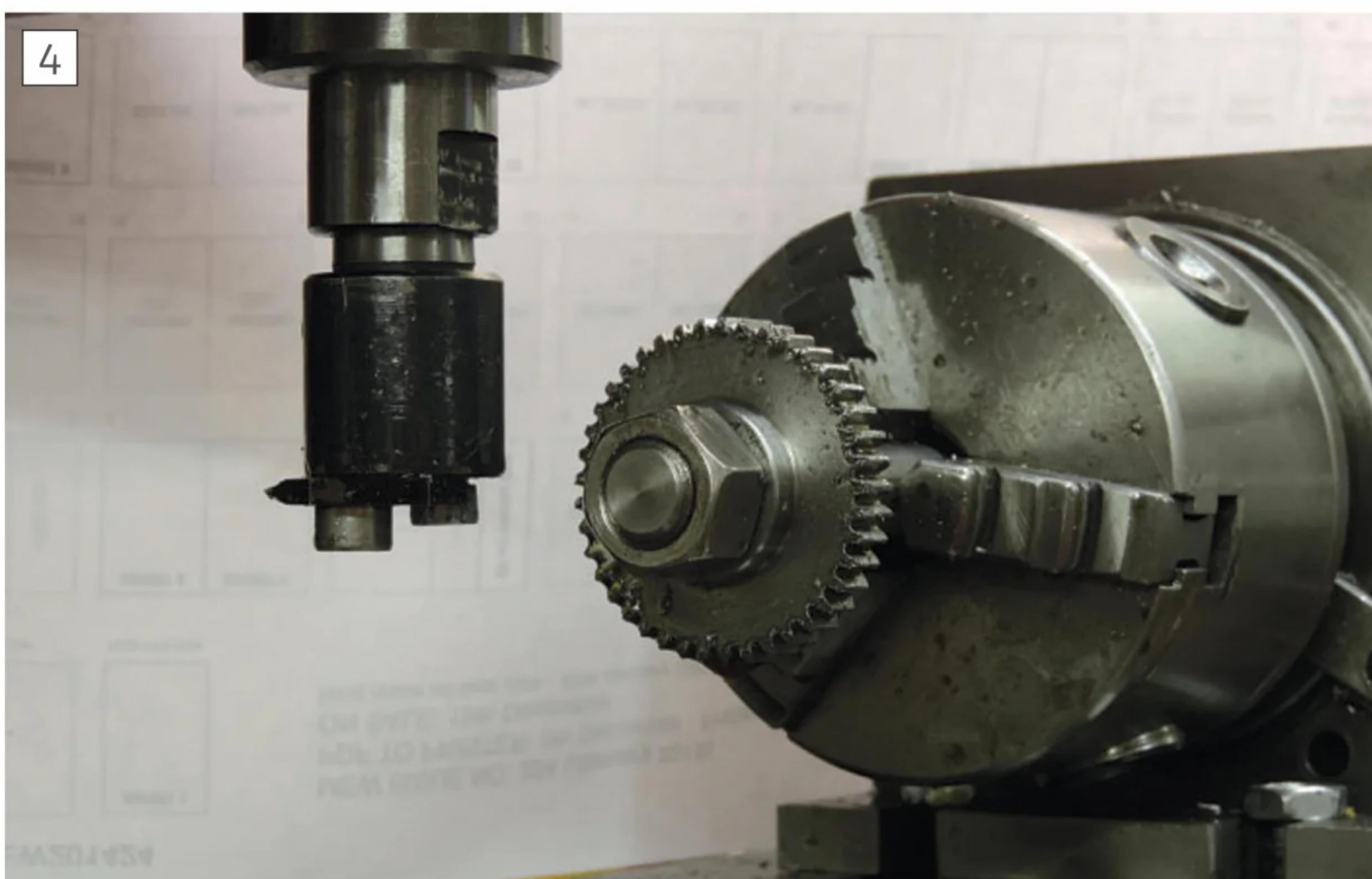
2 Fabricated wheels made using a rotary table.

Rotary tables and dividing heads are tools used to rotate workpieces accurately through various angles. Typical applications are cuts at fixed intervals to make gears or dials, **photo 1**, but other applications include machining curved surfaces and fabricating complex shapes, **photo 2**.

Typically rotary tables are heavily built with a large flat faceplate to which a workpiece can be attached directly, or alternatively chuck can be attached. They can be used with the



Using a rotary table with axis vertical to cut internal 'teeth' for a dog clutch.



Using the same rotary table with the axis horizontal.



Shop made 60:1 worm and wheel in a rotary table.

axis vertical, **photo 3**, or horizontal, **photo 4**. Dividing heads are typically lighter and may use collets or chucks to hold the work. Rotary tables nearly always use a worm gear to provide the primary means of accurate rotation, **photo 5**, while dividing heads are more likely to use direct indexing from gears or index plates, though geared dividing heads are not unknown.

Most (but by no means all) tables and heads have a worm gear, typically with a ratio of 45, 60 or 90. If you want a number of divisions that is a factor of the gear ratio (that is, you can divide it exactly by the number) you just need to make that many full turns of the handle to get each division. For example with a 90 ratio table to get 30 equal divisions, $90/30 = 3$, so you make three full turns between each division.

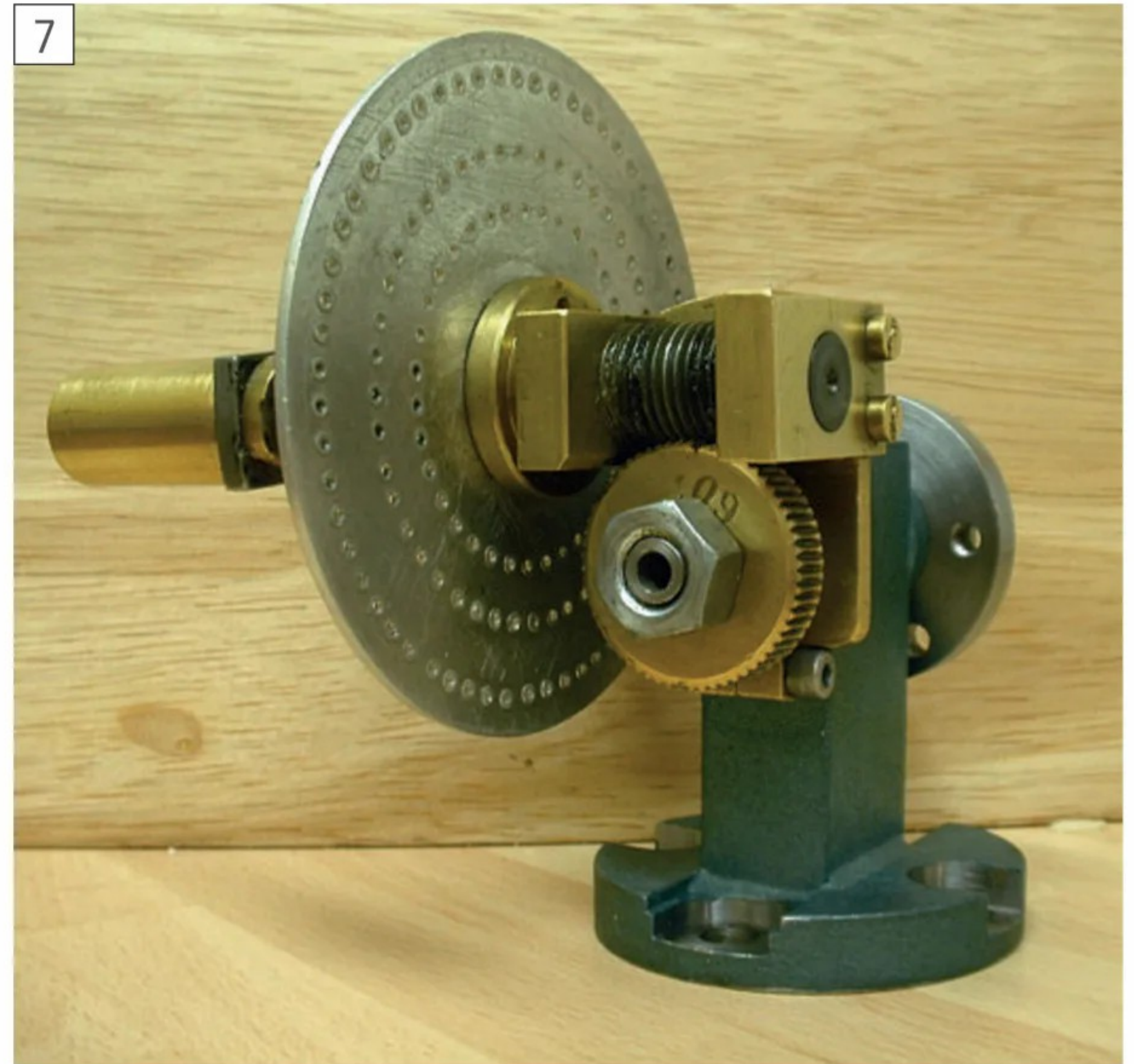
If you need a number, that isn't a factor of 90, it's a bit more awkward. $90/25 = 3.6$ turns. Typically, you achieve this by using a division plate. Such plates have one or more rings of holes allowing you to index round by a fraction of a turn using a retractable pin attached to the handle. **Photograph 6** shows a typical dividing plate for a large rotary table, while **photo 7** shows a lightly built dividing plate attached to a small dividing head.

Using division plates with a rotary table or dividing head in this way can cause a lot of head scratching, and people often resort to using spreadsheets to keep track of what to do. I'll try and explain their use while avoiding any maths more complex than simple division.

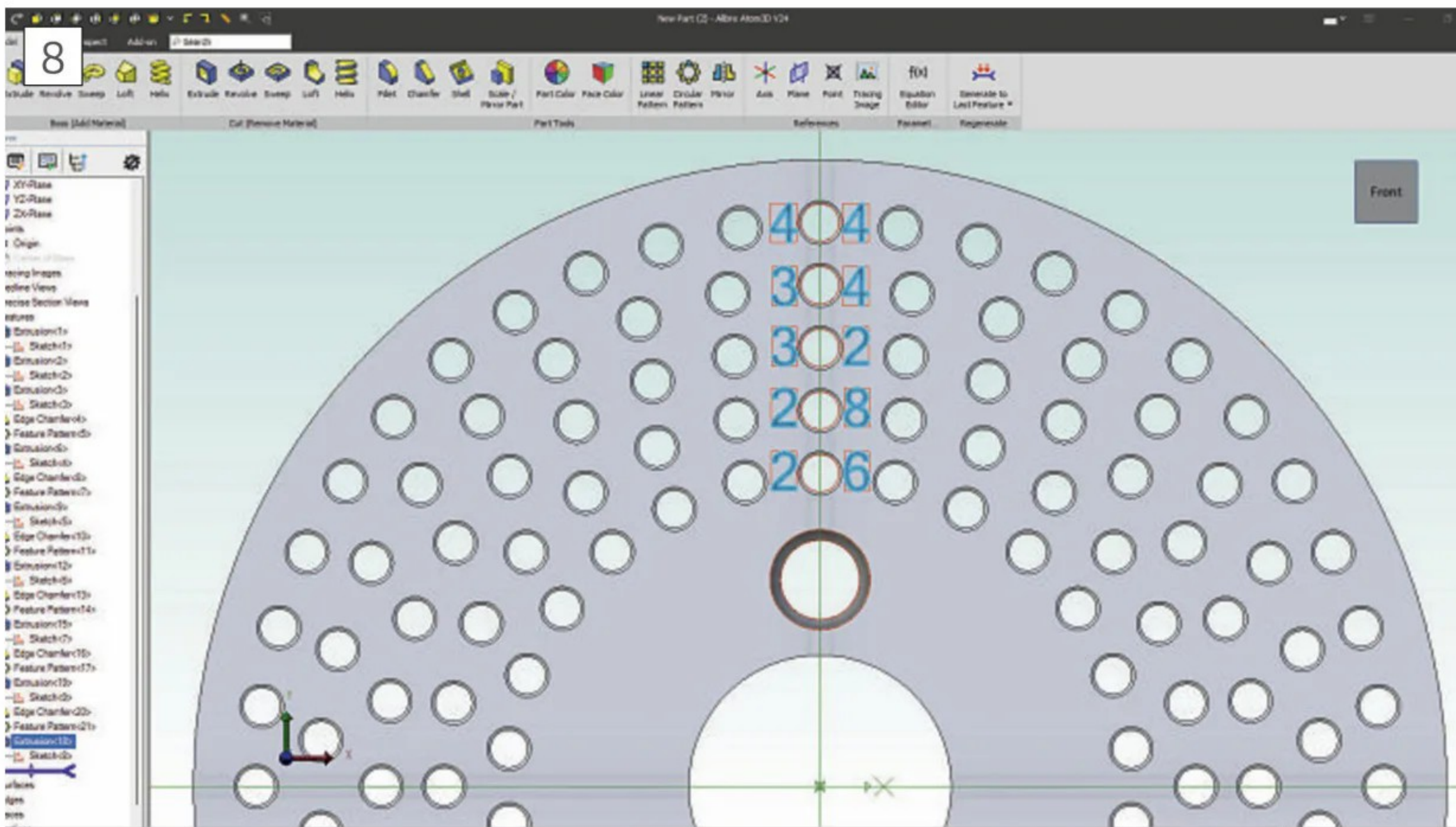
For a typical choice might be a plate with 20 holes. For a full rotation you would need 90 turns of 20 holes = 1,800 holes. 1,800 divided by 25 is 72, so for each division we need to turn the handle by 72 holes, so that's three full turns of 20 holes (60) plus an extra 12 holes. Note that $12/20 = 0.6$. Two turns plus 0.6 of a turn is the 2.4 turns per division we want. Typically metal pointers are used to help you consistently count these holes, be aware that to count the extra holes you need to set the pointers to expose one more hole than the count as the first one is 'zero'. In this example you would expose 13 holes between the pointers to count from 0 to 12 holes.



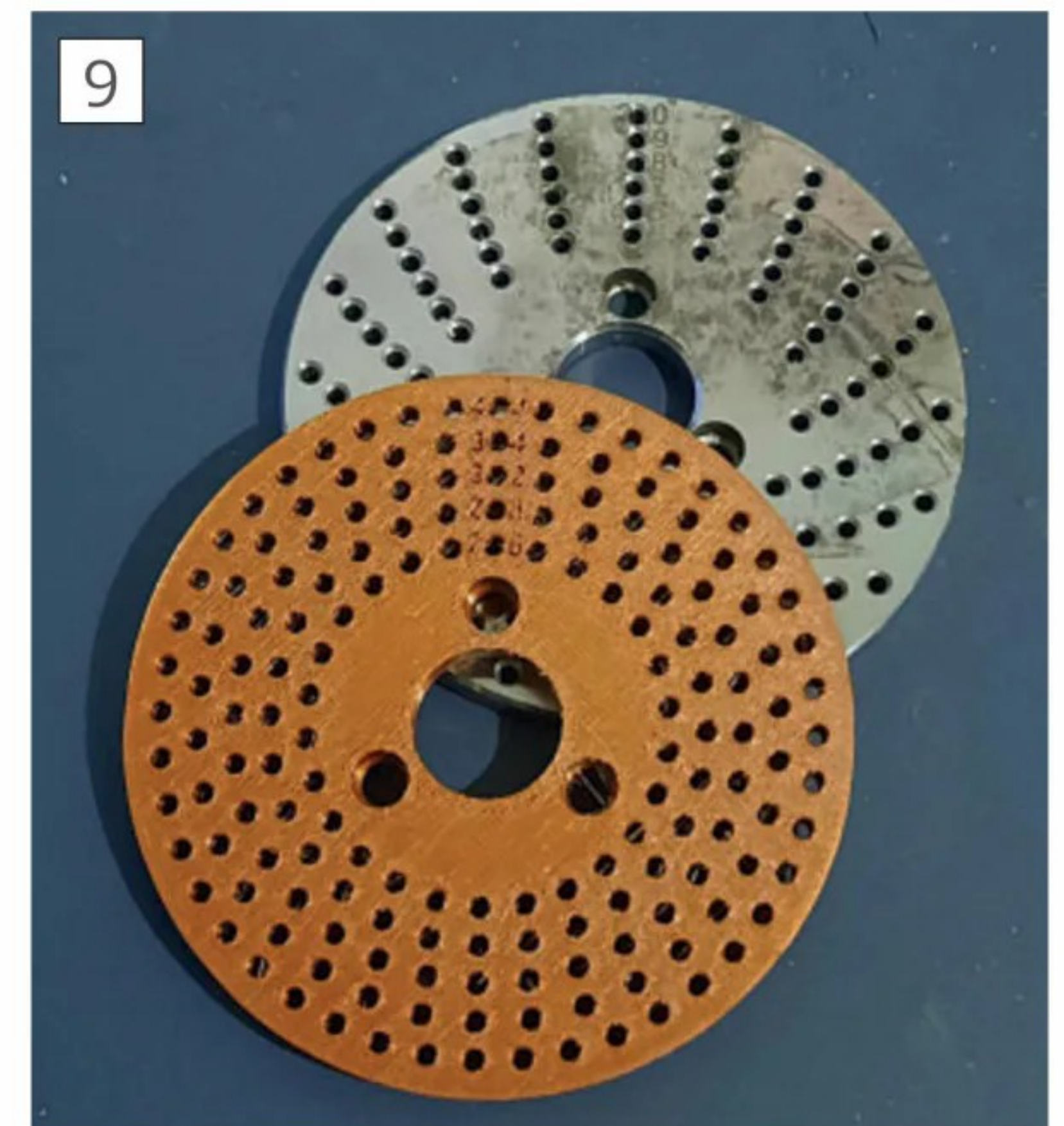
Index plate for an HV6 rotary table.



Index plate, worm and wheel of a light dividing head.



Designing an index plate in Alibre Atom 3D.



3D printed and standard index plates compared.

Not unsurprisingly, many people use tables of division ratios or spreadsheets to calculate these ratios and help keep track of what to do. You can find Howard Lewis's table of corrected index divisions for the popular HV6 (or any other table with a 90:1 worm ratio) on



the Model Engineer forum at inyurl.com/yc6j2bwm or scan the QR code on this page.

Most sets of division plates do not allow you to achieve all numbers, the standard HV6 plates have 22 'impossible' numbers. If you want, say 28 divisions, a solution is a 14 or 28-hole plate.

Making custom division plates is an exercise in division itself. The HV6 would allow you to make a 14-hole plate that could then be used to make 28 divisions. Sometimes it's not possible to do this people typically resort to approaches like making paper scales to index around the outside of a plate or using a CNC mill or co-ordinate drilling to drill out a plate. Temporary plates need not be metal, they can be made

out of wood or plastic to speed things up and reduce tool wear.

This also means 3D printing has made the exercise of producing custom plates relatively trivial. If you have a suitable design program, **photo 8**, it should be easy to design a blank copy of a standard division plate and then create one or more rings of holes to suit your needs. The example plate here opens up several divisions otherwise impossible with the HV6, **photo 9**. It could also be used as a drilling template to allow easy manufacture of a permanent plate, simply by clamping it to a blank. Don't fret too much about perfect accuracy – errors in a dividing plate used table will be divided by the worm ratio, typically making them imperceptible. ■

BEGINNERS WORKSHOP

These articles by Geometer (Ian Bradley) were written about half a century 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 practiced in the past.

Beginner's Workshop

Fitting core plugs

BY GEOMETER

ON THE OUTSIDE of water-cooled engine cylinder blocks and heads are usually several bosses with circular recesses, giving access to the water jackets. The fillings in these are light domed steel discs and are variously called core plugs, welsh plugs or expansion plugs.

The function of the holes they fill is to admit that part of the sand mould called the "core" when the cylinder block or head is in the process of being cast. However, the holes do provide access for flushing later if the waterways get badly slugged and, on occasion, a plug will push out if the water freezes. Hence the term "expansion" plugs—though this is quite incidental and no reliance can be placed on it.

On older engines it is not uncommon for core plugs to leak round the edges, and from the action of water, heating and cooling, complete rusting through can occur in time, necessitating renewal.

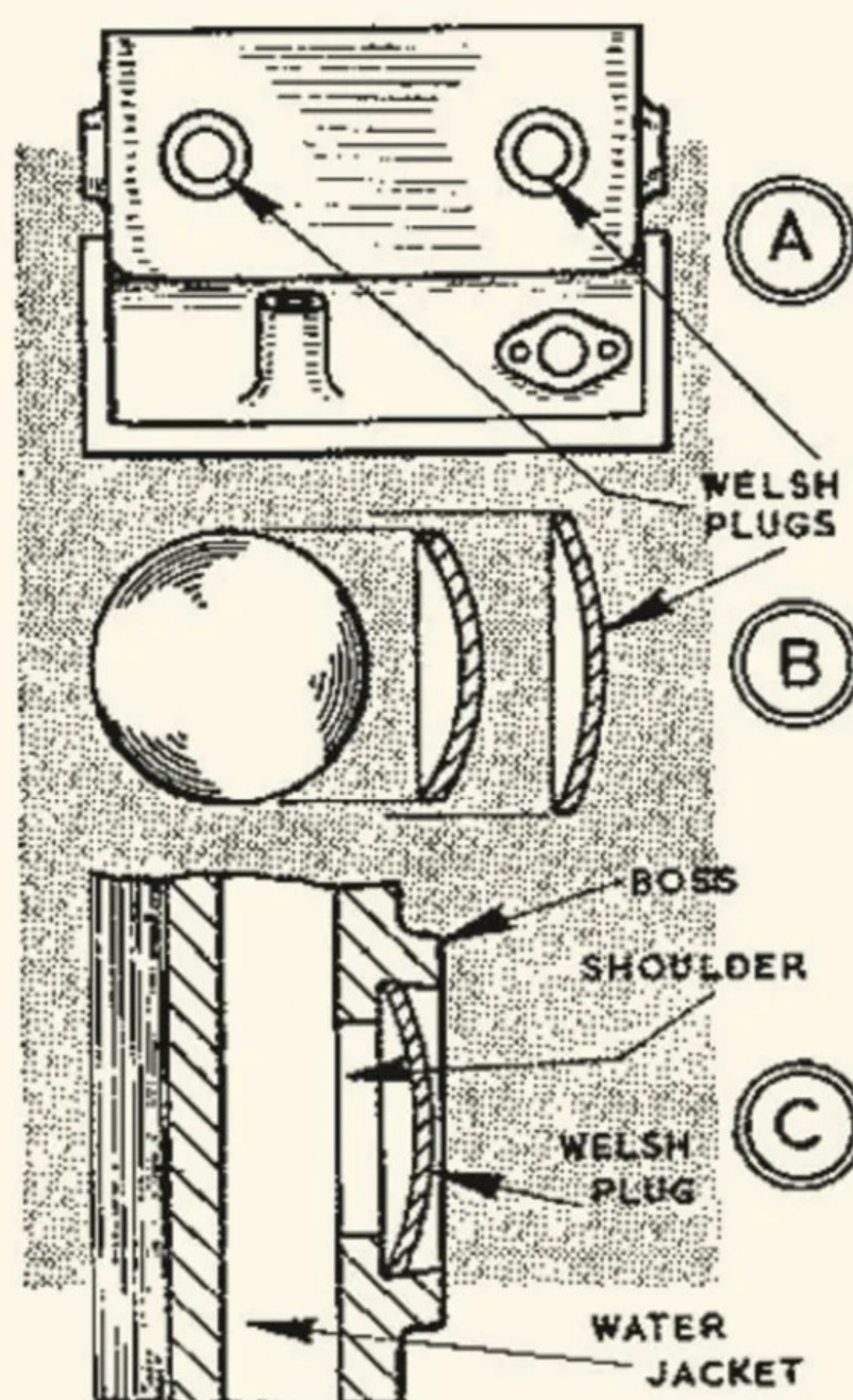
Method of removing

Diagrams A, B and C show locations and details of typical core plugs, which are made in standard sizes and are obtainable ready to fit. The boss on the outside of the water jacket provides extra strength; it is machined circularly to leave an internal shoulder against which the plug abuts to be expanded into position by tapping centrally with a hammer or large diameter flat-ended punch.

To remove a defective core plug it can be drilled centrally, commencing with a small drill and opening out. Then a small sharp chisel can be used to cut and enlarge the hole across the diameter of the plug, after which it can be levered out with a screwdriver.

This is the method if the plug is not badly fretted by rusting. Should the plug be thin and weak a steel-cored screwdriver can be driven straight through, and the plug levered out. An alternative to a large central hole is several smaller ones drilled across the diameter to weaken the plug.

Any water in the cooling system should, of course, be drained before removing a plug. Afterwards the



recess and shoulder should be carefully scraped clean of rust and scale and wiped dry.

For fitting the new plug the recess and shoulder should be lightly covered with jointing compound; then a plug is entered which is of a size to fit comfortably. It is important for the perimeter to be free from burrs and flats otherwise the plug may not seal completely. Small burrs can be filed off, but a plug with flats should be rejected.

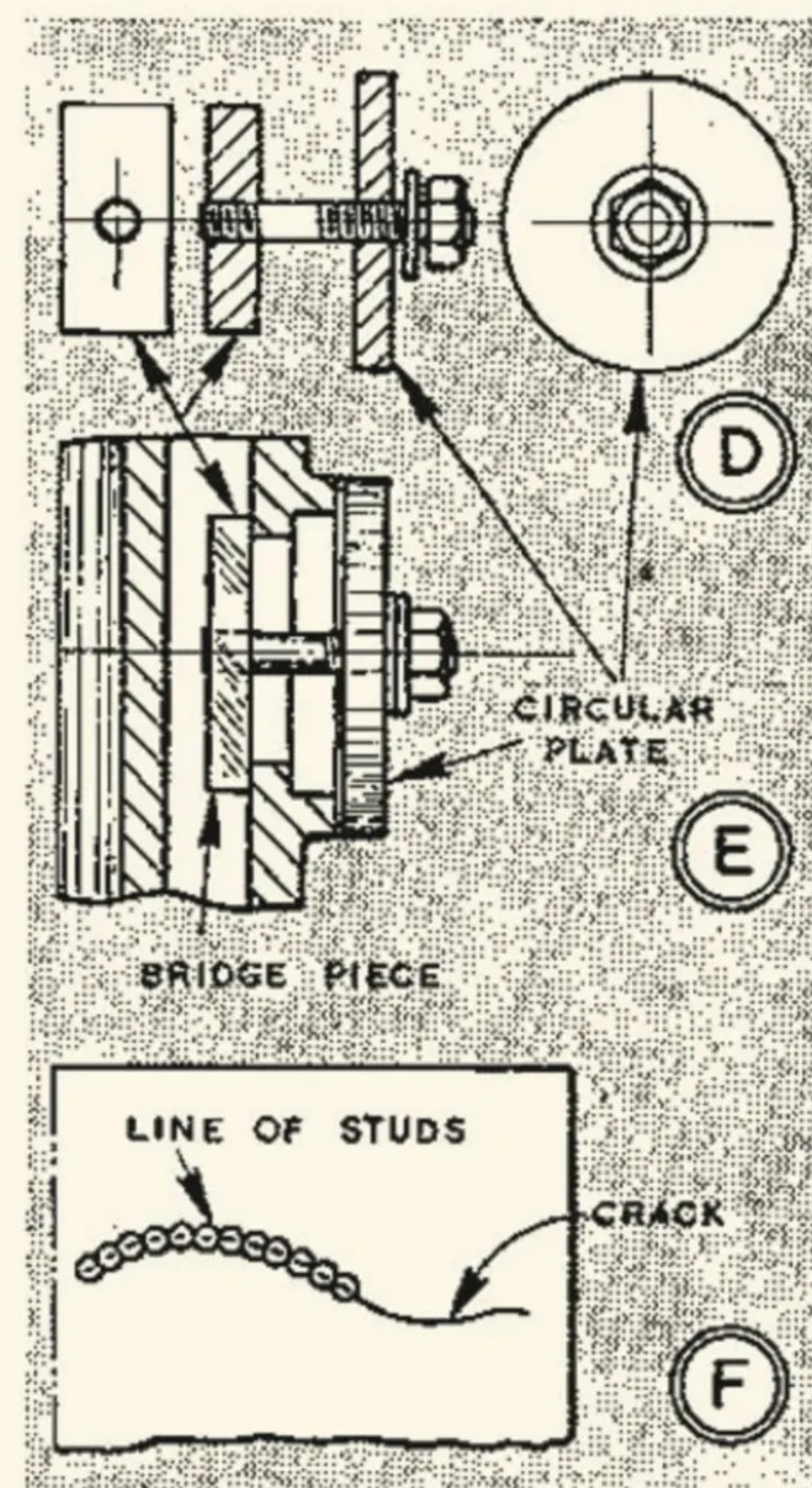
Holding the plug back to the shoulder the centre should be tapped to effect expansion. A large plug may tend to dent in the centre and should be tapped round in circles of increasing diameter—or a flat-ended punch or drift should be used. Should there be slight local leakage, additional tapping in the area will stop it.

It will be realised that an important factor in successfully fitting a plug is accuracy of recess and shoulder. For this reason slight leakage round the edge of a plug should not be neglected or rusting may occur, resulting in a

depression which cannot be filled by fitting a new plug.

When this has happened and there is a permanent leak a repair can often be made by fitting a plate to the seat on the outside of the boss. If uneven the boss should be filed flat and the stiff circular covering plate attached by means of a stud and bridge piece inside the water jacket—D and E. A soft joint can be used between the plate and the boss, and a fibre washer or twist of asbestos string between the plate and the nut and washer.

A single small crack in a water jacket or plate can be repaired as at F. Commencing just beyond one end a hole is drilled and tapped not quite through (second tap) for a piece of studding (3/16 in. or 1/4 in.) to be screwed in tightly. After cutting off, the piece is expanded by light hammering; then another hole is drilled and tapped for the next piece to overlap—and so on to the end of the crack.



Make a sensitive drilling attachment

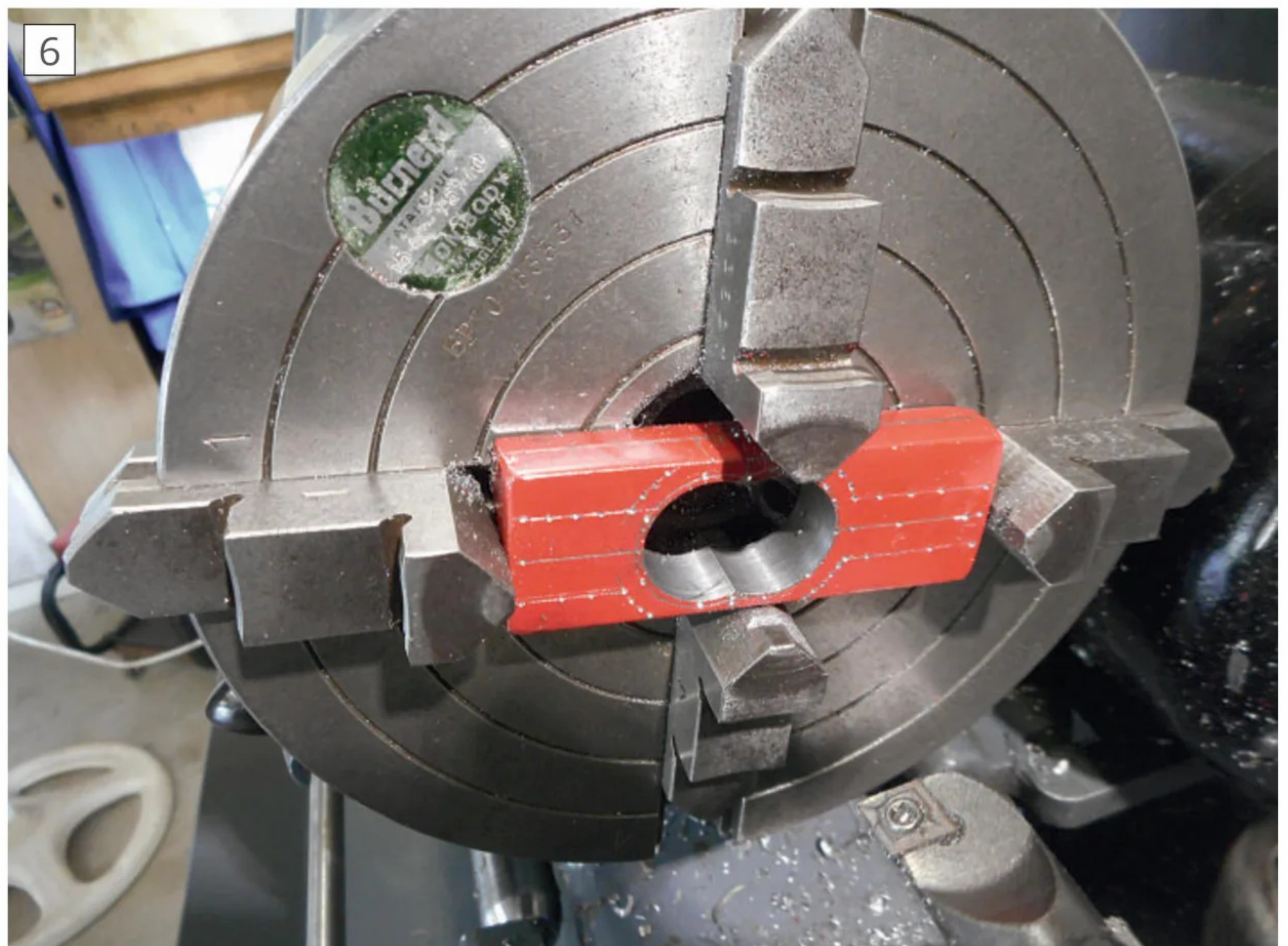
Part 2



Pete Barker completes a useful project that has stood the test of time – for 93 years. This accessory from 1929 makes drilling small holes in any lathe a breeze and not a snap. He uses nothing but the lathe itself and basic hand tools, in the spirit of the age.

I then used a piece of 5/16" tool bit to set one chuck jaw back by that distance, and slid the job along to again touch that jaw before nipping the other three jaws up again. So far still so good. Now to bore the "half a hole" centred 5/16" from the existing one. But alas! How to drill the starting hole for the boring bar in the centre? It can't be done. I tried starting with a smaller boring bar to bore a small overlapping "half a hole" for starters. But it flexed too much under the interrupted cut. So I went back to the large half-inch shank bar and nibbled my way through the job by feeding it in 10 or 20 thou at a time until the heel started to rub, then taking a facing cut outwards with it until it created clearance for the next nibble to begin, and so on until we got through to the other side. Once a slightly undersized hole was sunk all the way through the job, the rest was plain sailing, albeit on a rather choppy sea of interrupted cutting, **photo 6**. Filing flat the small peak between the two holes was left until later, so as to preserve maximum metal for gripping by the chuck in following operations.

Those operations began with drilling and reaming the 5/32" cross hole for the chuck arbor pin. H. Dyer recommends using two worn halfpenny coins as packing so the chuck jaws "have something more than a hole to grip on". In their absence, a couple of bits of 1" flat bar sufficed. Then came holding the job endways in the chuck and setting the marked out centre of the clevis end true. After centre drilling, I held the end



The second "half a hole" is bored after moving the block 5/16" to the left.

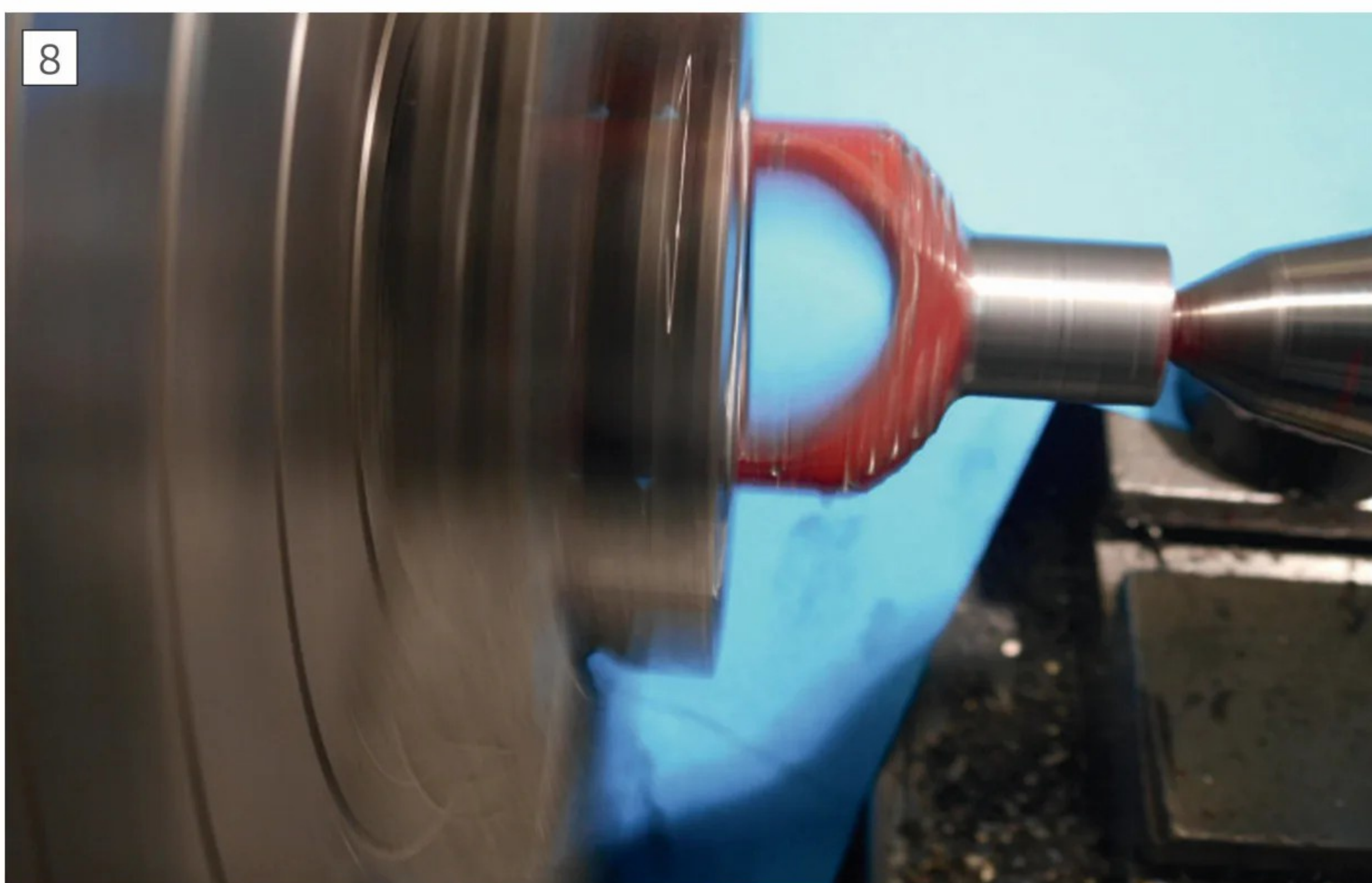
steady with a tailstock centre while turning the body shape. This shape consisted first of reducing the clevis end to 1/2" diameter so the 3/8" square clevis could be filed or machined on it later.

I thought of using a ball turning tool to machine the curved shoulders that follow the shape of the elongated hole in the centre, but either the chuck or the tailstock was in the way no matter what I tried. So, I turned the profile freehand by careful simultaneous manipulation of the top and cross-slide handles. Using the marked out and centre-popped line as a guide, I first turned it as a series of steps close to the line, **photo 7**. Then,

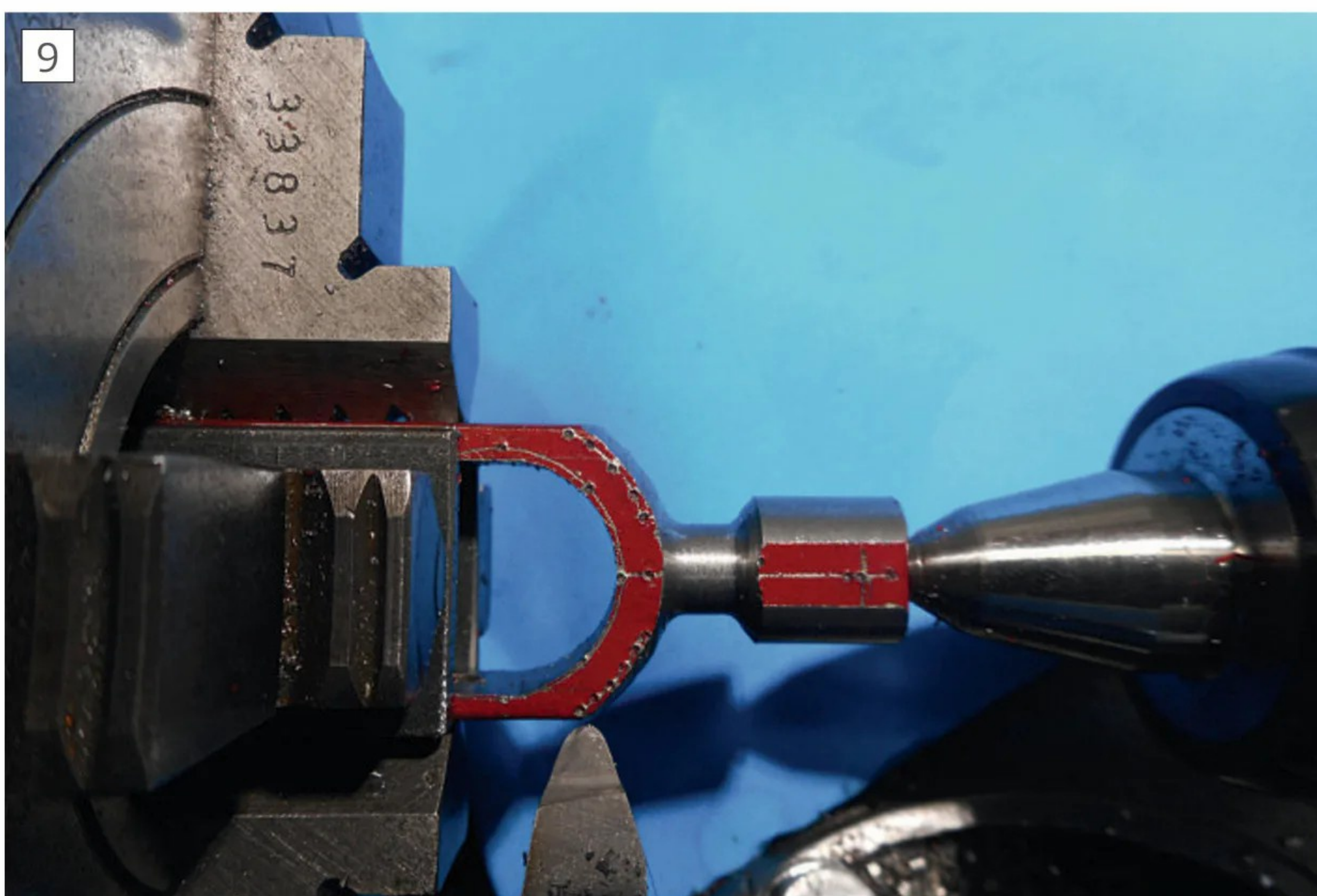


The block's outside profile is turned down to the line in rough steps.

proceeding with caution but improving with practice, I used a round-nosed tool to blend the steps freehand into a



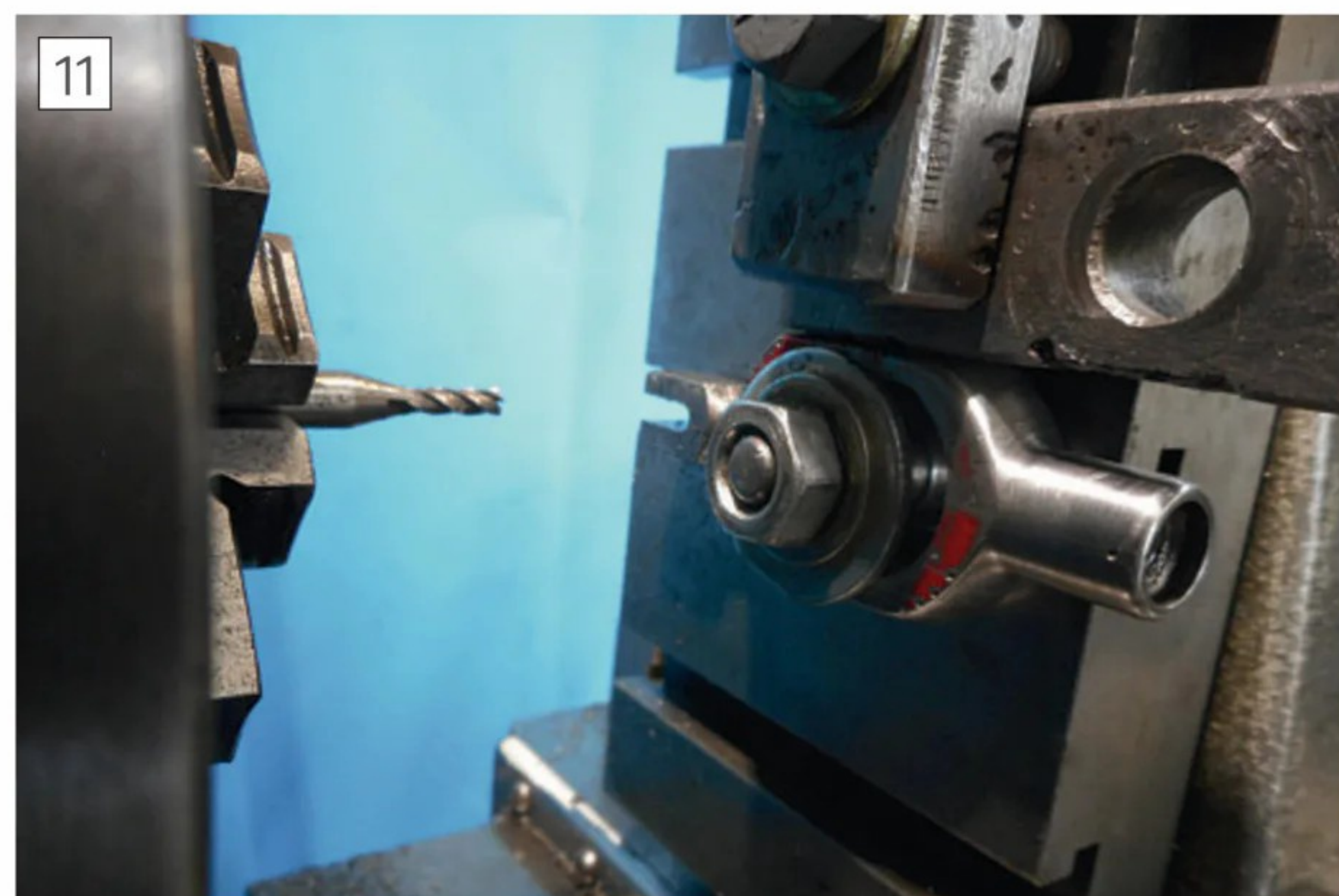
The line can be seen in motion to guide final freehand turning to a smooth curve using cross- and top-slide handles together.



A round-nosed tool is used for the final profiling of the curve and necking down to the future clevis on the end. .



Machining very close to the markout lines is possible, ready for final hand finishing by file and emery cloth.



Tiny 1/8" slot drill is set to run dead true in the four jaw chuck before cutting clevis slots.

flowing curve matching the line which was visible as the job spun around, **photo 8**, if the machine lamp was set at the right angle – and I squinted a bit, and held my mouth just the right way.

The section between the clevis-to-be and the main curve was then turned down to 1/4" diameter and blended in with a round-nosed tool, **photo 9**. With a quick finish with a flat single-cut file and emery tape, the job came up as splendidly curvaceous as a Spanish dancer's bodice, **photo 10**.

After flipping the job around in the chuck, the curve on the other end was done the same way, "ditto repeato" again, this time followed by turning the cylindrical end to size before drilling and tapping the 1/4" BSF thread for the handle.

Bore and shape the fixed member

The fixed member, as H. Dyer calls it, is made much the same way as above, but with only the one hole to drill and bore, this time to a very light press fit on the main shank. There is only the clevis at one end to machine this time. The other end is left square with the corners rounded off for mostly cosmetic effect. Then I drilled the start of the hole for the pin that will eventually pass through the shank to anchor the fixed member. This was completed, and reamed, in situ later.

As a finishing touch, after finishing the clevis ends, I oil blackened the fixed member, actuating link and connecting link to just below a dull red and plunging into clean motor oil. This step is of course optional but does give a rather more "finished" look in my mind.

12



The finished actuating lever link and fixed member have the clevis ends rounded by use of hardened filing buttons.

13



Filing button in use on the connecting link after the fish-belly was filed down to the markout line.

It may be noted that if you are more concerned with making just a functional tool rather than indulging in the decorative style of the Jazz Age in Mousehole, a great deal of time and work can be saved by making the actuating lever link, fixed member and connecting link as simple square-ish blocks with slightly rounded corners, in the current style of the accessory sold by Myford today. These parts could

even be made of suitable aluminium alloy too.

The clevises and pins

Back in 1929, H. Dyer squared and slotted the two clevises by hand with a hacksaw and file. The vertical slide for the home lathe had not yet arrived. But I cheated a little and used mine to mill the flats with an end mill cutter and put the slots in – with careful 15 thou deep

cuts – using a 1/8" slot drill, **photo 11**. The holes for the clevis pins were then drilled and reamed with the job clamped on the vertical slide.

A pair of filing buttons made from silver steel and hardened were used to round the clevis ends. The same buttons were later used to form the shape of the connecting link, which turned out to be a deceptively painstaking job.

But before that, I cut the clevis pins from silver steel rod, doming the ends to give a nice, finished look. H. Dyer made his a press fit by reaming the holes undersized with a tapered hand reamer. But having the luxury of Loctite 638, I used a standard machine reamer and let the pins be a sliding fit.

Finally both parts were filed and emery clothed to final shape and finish, **photo 12**).

The connecting link

This small part required quite a bit of work to get it looking right in the style of 1929, with its fish-bellied centre and circular ends. First, I carefully marked it out on a longer piece of 1" by 1/8" steel flat bar, using dividers to draw the two 5/16" circles at the ends. The longer curve on the fish-belly was then marked out using the lid of a 4" diameter tobacco tin as a template. Old H. Dyer would approve, I am sure. I then drilled and reamed the two holes.

Holding the extra length of the flat bar in the bench vice I was able to gradually hacksaw and then file the link to the marked out shape. The hardened filing buttons made easy work of the ends but the fish-belly section in the middle required great care with some small files to get it to just the right curve while blending with the ends.

The final step was to hacksaw around the last end to separate the job from the rest of the flat bar and then file the circle there down to the button, **photo 13**. Which left only the handle to make.

Turn, thread and knurl the handle

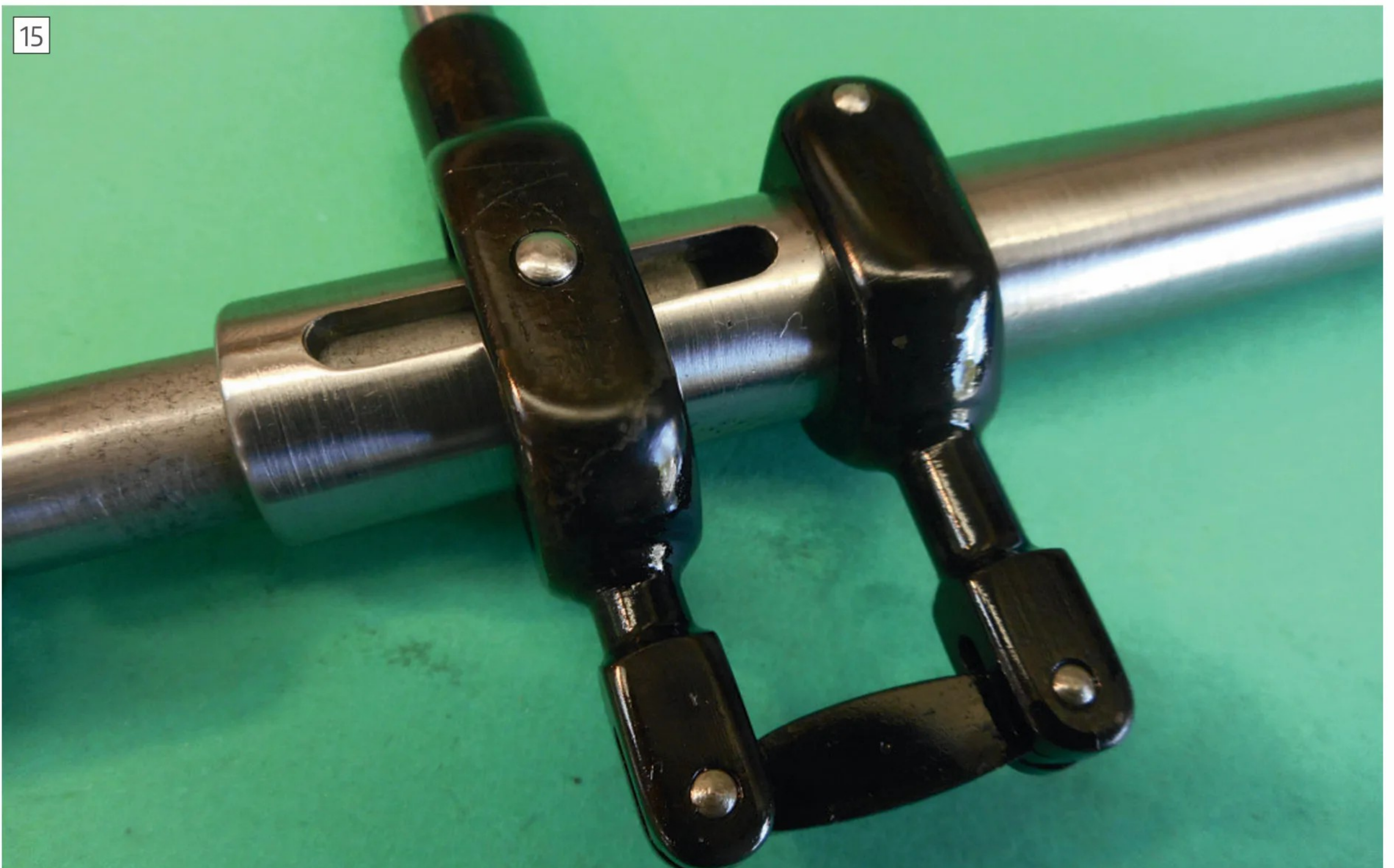
This part needs little explanation. Not shown in H. Dyer's drawings, it is a piece of 5/16" BDMS 5 1/2" long with one end reduced to a 1/4" thread for about 3/8" on one end and then knurled on the other to your liking, with the very end domed

14

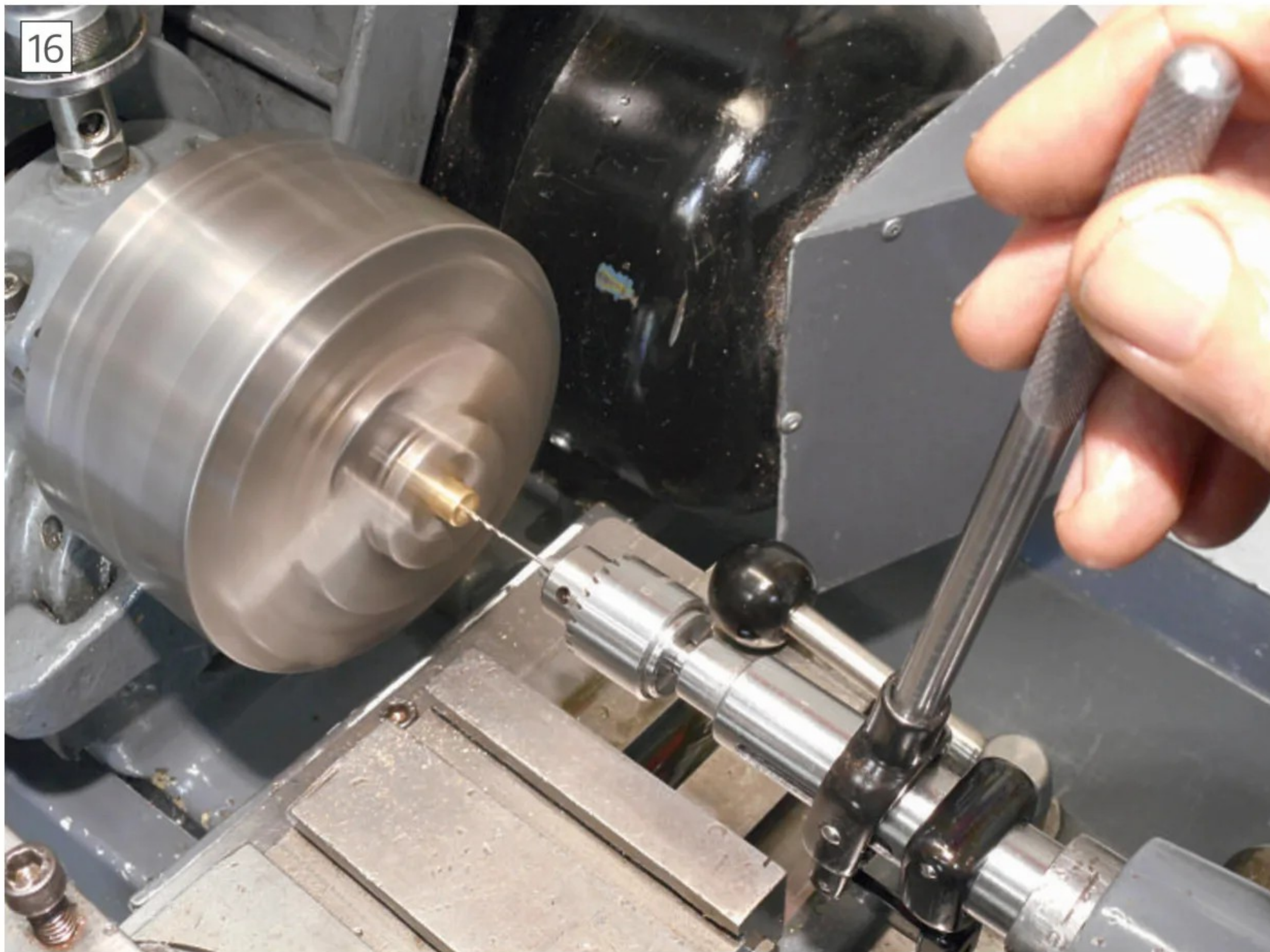


All components are ready for assembly using Loctite to secure the pins.

15



Oil blackening gives a finished look and helps fend off rust. Domed ends on the pins also look more finished than flat ends.



The attachment is quickly fitted to the tailstock when small holes are to be drilled and was tested down to .015" diameter.



All the style of the jazz age: The sensitive driller matches the Myford's classic lines but would be just as useful on a modern machine.

for comfort. I used a clamp-type knurling tool with two wheels.

Tips for knurling:

- Use a tailstock centre to support the end, then turn the centre hole off afterwards.
- Set the knurl wheel centres directly above and below the centre line of the job. Then lock the cross slide.
- Run at below 100 RPM. Use backgear on a Myford etc.

- Oil everything: the wheels, their axles, the job.
- Clamp the wheels firmly on to the job and then feed the carriage along slowly by hand.
- At the far end, increase pressure on the wheel clamping screw and feed back along the job. Do not let wheels lose engagement with the job, or double knurls may result.
- "Ditto repeato" (again), with

judicious oiling and removing swarf with a toothbrush, until the knurls come to a point.

- File the points off with a fine file so they are not like a cheese grater on your hands in use.

Final assembly and use

Assembly of the component parts, **photo 14** is simple and self-evident. After oil-blackening as described earlier, the fixed member is tapped on to the main shank and aligned so the actuating lever and its pin line up with the shank's slot. A drill and then reamer are poked through the previously started hole in the fixed member and the pin inserted to fix it in position on the shank. If you want to make H. Dyer envious, you can put a drop of Loctite on it just to be sure.

The actuating lever link is secured by its pin tapped through the main shank, the drill chuck arbor and back out the other side of the link and Loctited at each end. The connecting link clevis pins are slid into place and Loctited carefully at the outer ends only, **photo 15**.

That's it. Place the shank firmly in your tailstock and a piece of scrap or a job in the lathe chuck at its highest RPM and drill away with the smallest bits you need to use, **photo 16**. I tested mine down to .015" diameter with confidence and success.

Conclusion

I found H. Dyer's sensitive driller to be far superior to the common modern unit that relies on finger pressure on a round knurled collar mounted on a ball bearing, especially when used in these old lathes with their top speed of sub-1,000 RPM. The leverage provided by the handle, **photo 17** gives that extra force required to drill at such low revs yet provides that essential sensitive feel to preserve small drill bits in one piece, whether using treadle power or that new-fangled electric motor drive that H. Dyer was not so keen on in 1929.

Best of all, it's an enjoyable project with the style of a vintage tool from the age of cars with running boards and 10-foot bonnets when style was considered an essential part of substance, something that has been lost in today's ever more efficient world run by accountants, not machinery lovers. ■

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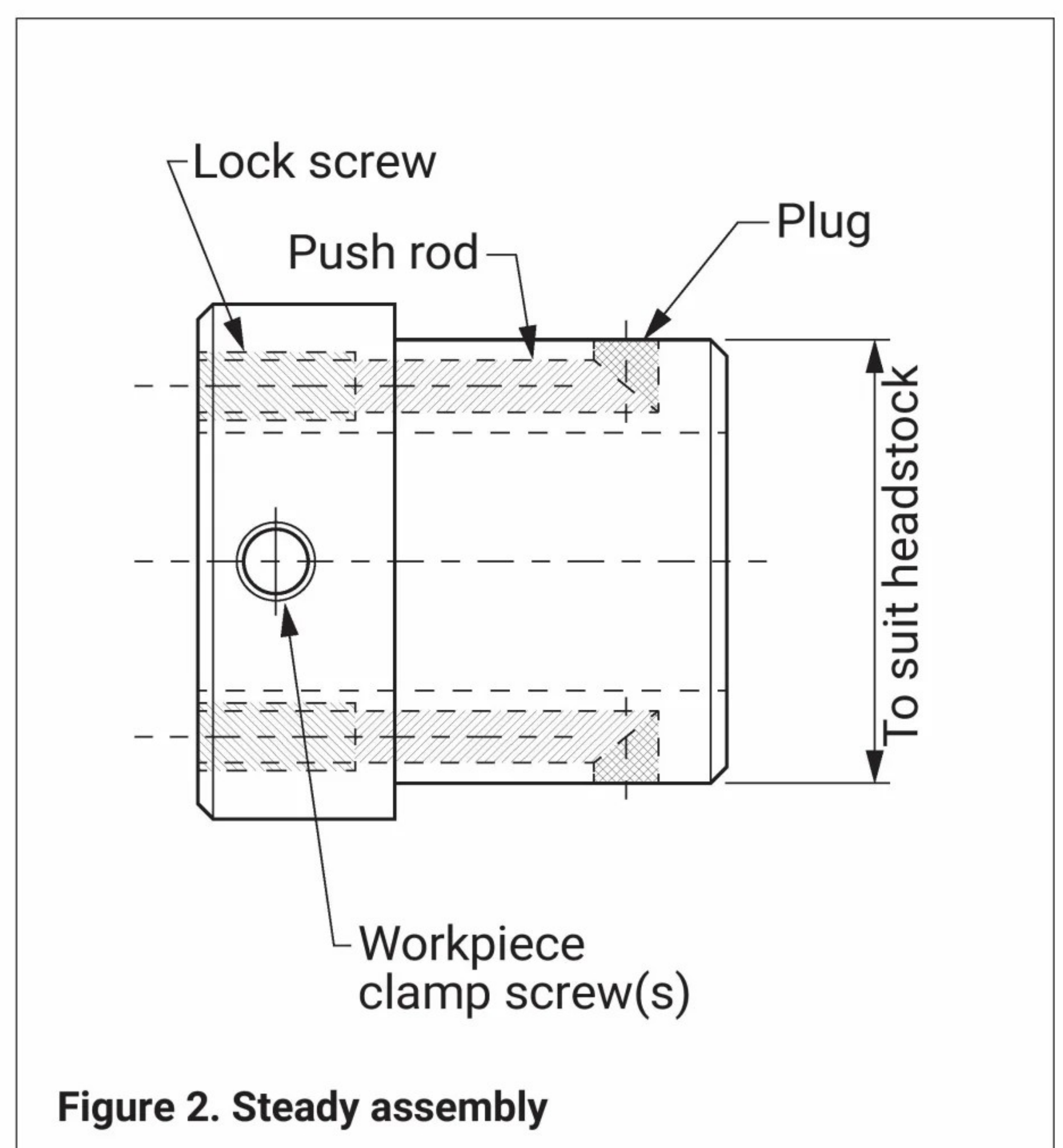
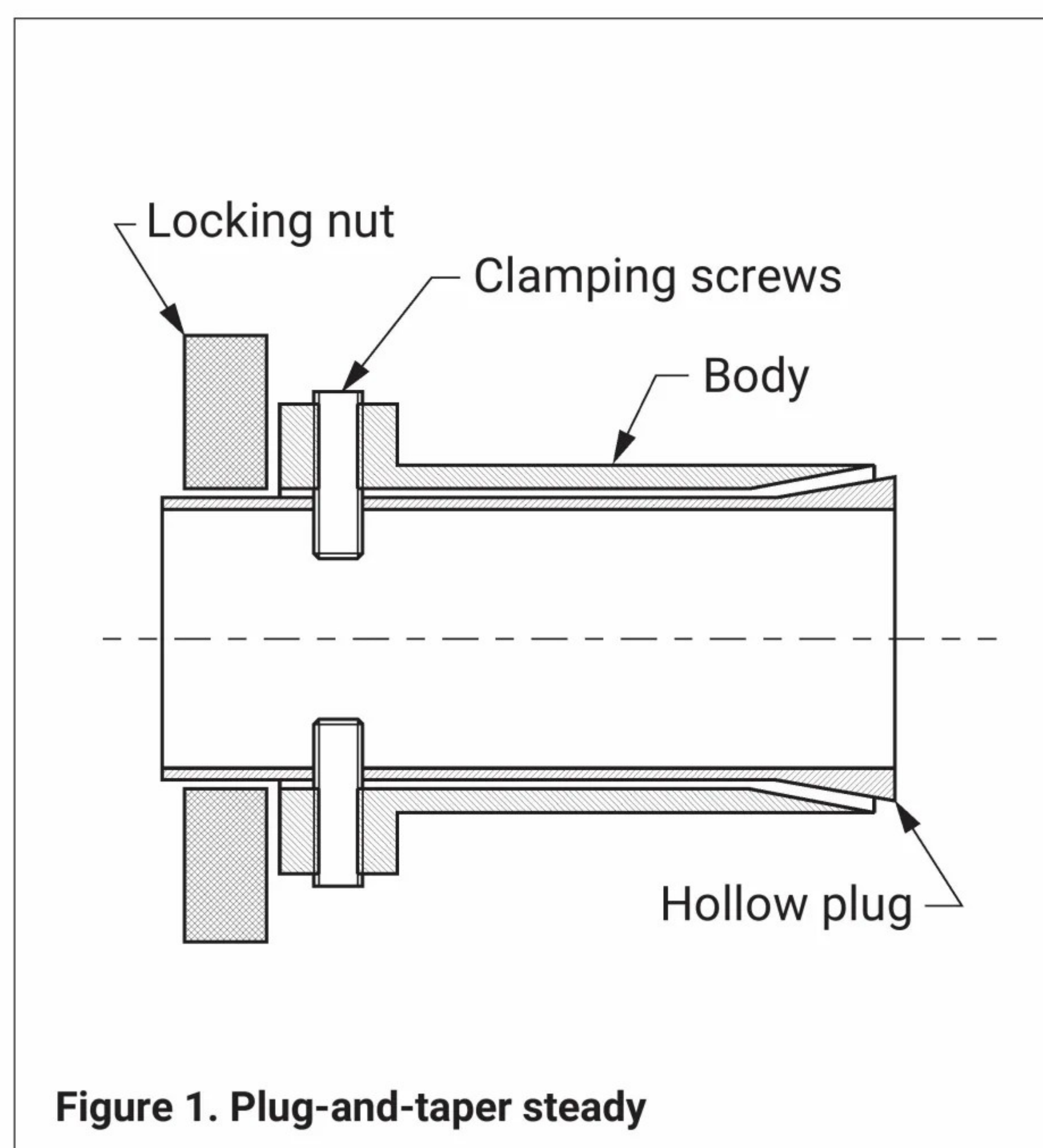
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Alternative Designs for Headstock Steadies



Chris Gill shares two ways of helping make sure long work extending from the back of the headstock is handled safely.



A recent article in MEW 423 ("Safely turning long objects in the lathe" by Brett Meacle) reminded me that I had intended to make something that would handle long workpieces extending out of the back of the headstock. **Photograph 1** shows an example of the problem.

I had already come up with several ideas ranging from a rather fanciful contraption based on the iris in a camera lens (that never made it to the sketch stage) to something very similar to Brett's device. My difficulty is that the end of the headstock tube on my Harrison M250 is almost flush with the casing, as can be seen in

photo 1. I could remove the casing and override the safety switch, but this is hardly ideal.

Instead, I needed something that would fit inside the tube and support the workpiece. Again, two ideas came to mind. The first was based on my headstock hand-wheel which uses a plug drawn into a taper to lock it into place. This is similar to the plug shown in Chris Hobday's recent article ("Lathe speed indication" in MEW 325). My idea was to use a hollow plug that would be drawn in by a large nut on the outer end. To be safe, it would have to be a left-handed thread in order to avoid unscrewing itself and

I simply didn't fancy trying to make one. I also had a feeling that there would be other problems, but I didn't explore them. **Figure 1** shows a sketch of the idea.

My final idea was based on a draw-bar ejector I made a few years ago, as shown in **photo 2**. This is locked into place with a set of three push rods that act on three plugs, pushing them out at 90 degrees. The ejector has to withstand a significant force if the taper is pulled in a bit too tight but the steady only has to stop itself falling out. For this reason, my steady has two sets of push rods, and the arrangement can be seen in **figure 2**.



A long thin workpiece



Drawbar ejector



Two steadies



The 4-axis steady in place

The push rods are 4mm silver steel driven by M5 flat-ended grub screws and the buttons are 5mm diameter but only about 5.5mm long in my case. The buttons were filed to shape once in place and, being short, I stuck them in with a good blob of lithium grease. The workpiece is held in place by three or four M6 grub screws and I turned the ends of one set to about 3mm to

hold thin rods. My steadies can handle rods from about 3mm to 19mm. 20mm might just have been possible.

Photograph 3 shows the completed 4-axis steady with a piece of 3mm rod and the parts for the 3-axis unit.

Photograph 4 shows the 4-axis unit in place in the headstock tube with a thin workpiece on a much better line. The push-rods appear to work well, and the

screws don't need to be very tight for me to be unable to pull the steady out.

I made two of these tools to avoid having the holes for the M6 clamping screws overlap. Under this criterion, a throat diameter of 23mm or more would allow one tool to handle round, hex, square and rectangular work. With that in mind, my next tool will be a version of Brett's design to fit my fixed steady. ■

Fifty Years of George H Thomas' Universal Pillar Tool Part III

Warren Williams continues the correction of errors and introduces some new developments

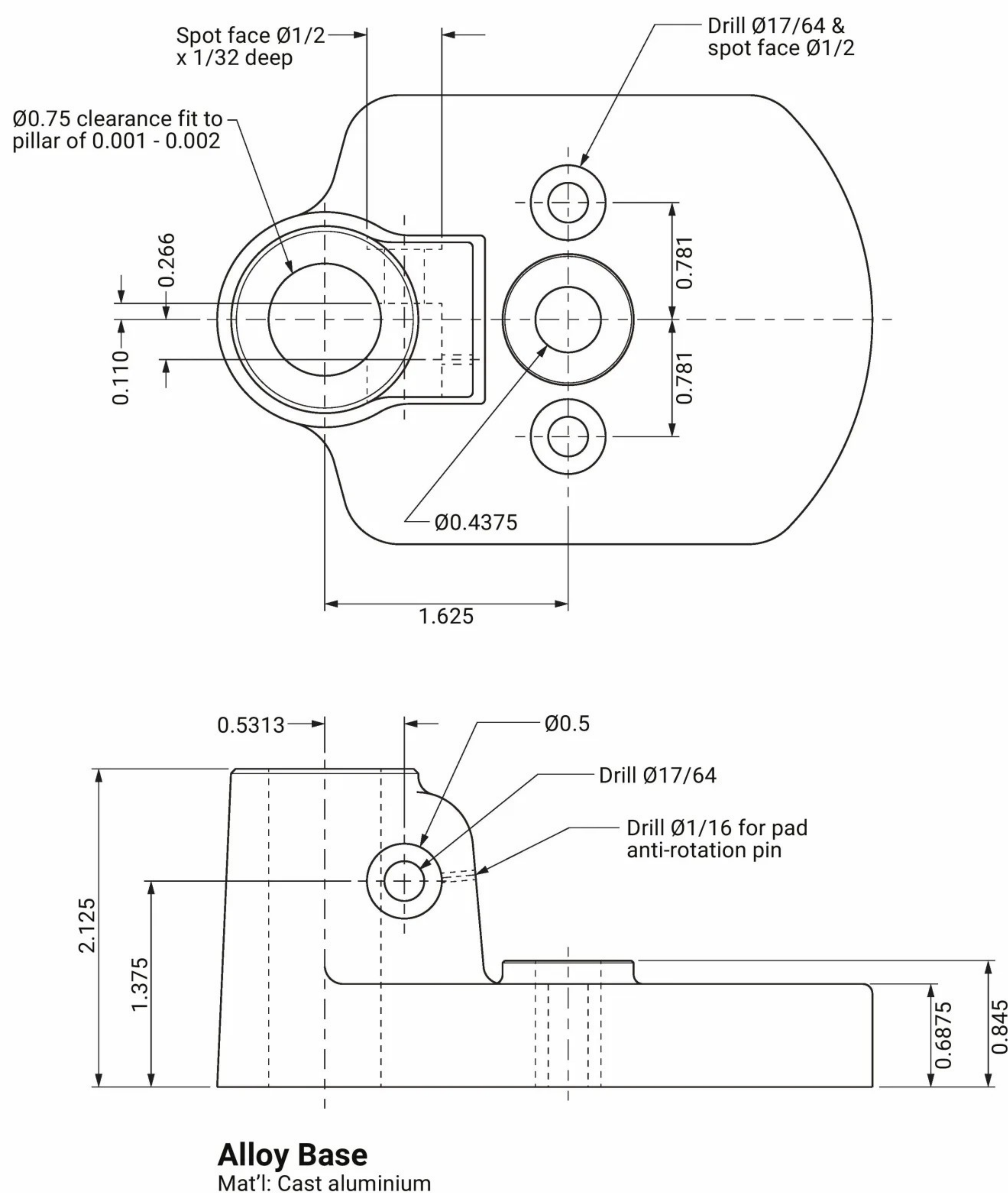


Figure 3. Alloy base machining drawing

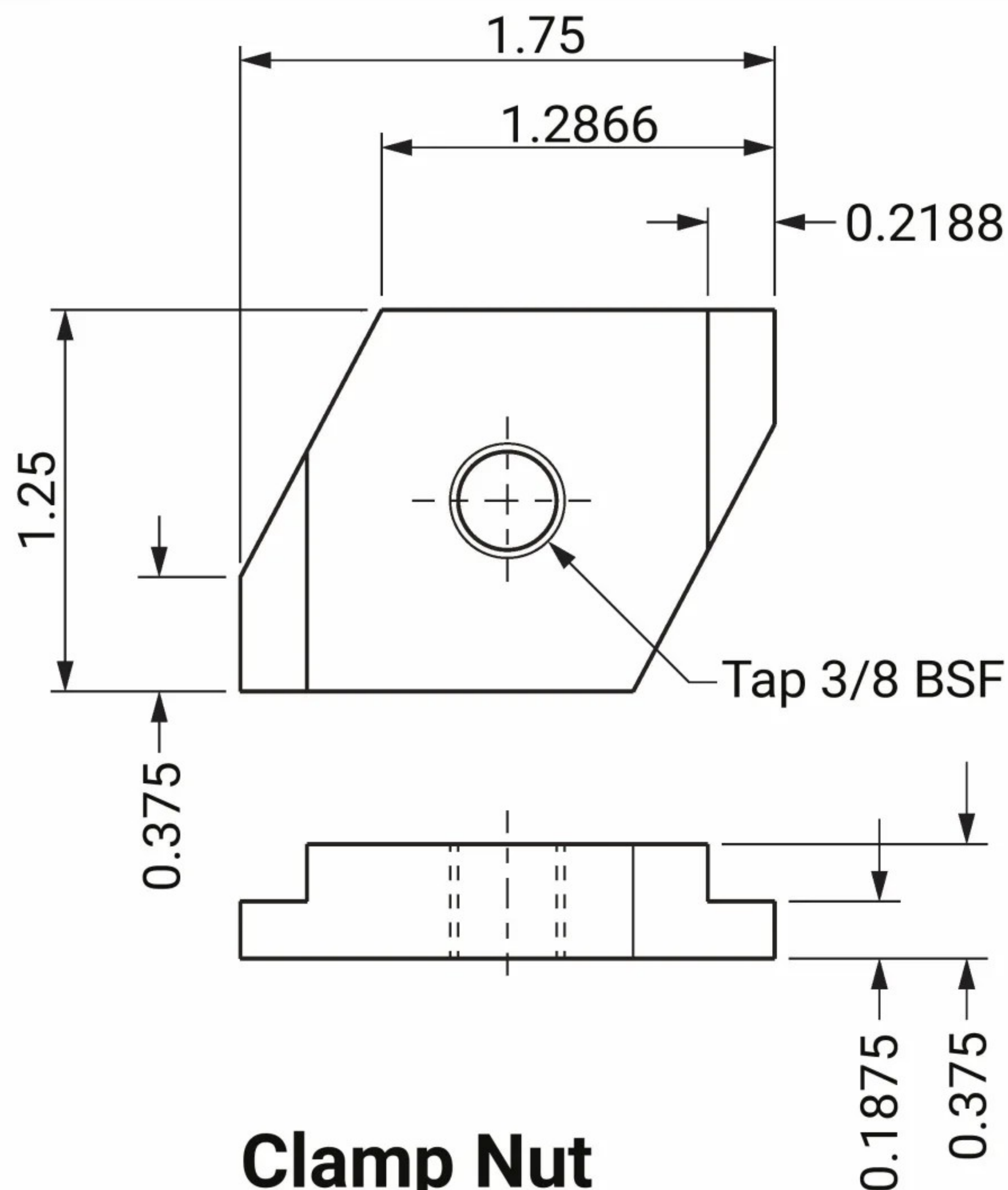
Alloy Base and clamp nut

The drawing of the alloy base, fig. 2.3, is somewhat incomplete. **Figure 3** contains all the information a builder needs to machine the alloy base casting. The drawing does not show the two lugs provided on the casting for holding

down during machining and which are subsequently removed. GHT's design for this component included provision of a step at the pillar end of the base to clear the cross slide of a Myford lathe, a feature which is shown in ref. 1 should that be desired. I preferred to leave the base as

shown in fig. 3 so that base contact area is maximised directly under the pillar.

Again, the radius of the clamp pad which clamps the pillar is machined with the $3/4$ " diameter bore in the alloy base in the same way the clamp pads are machined for the arms.



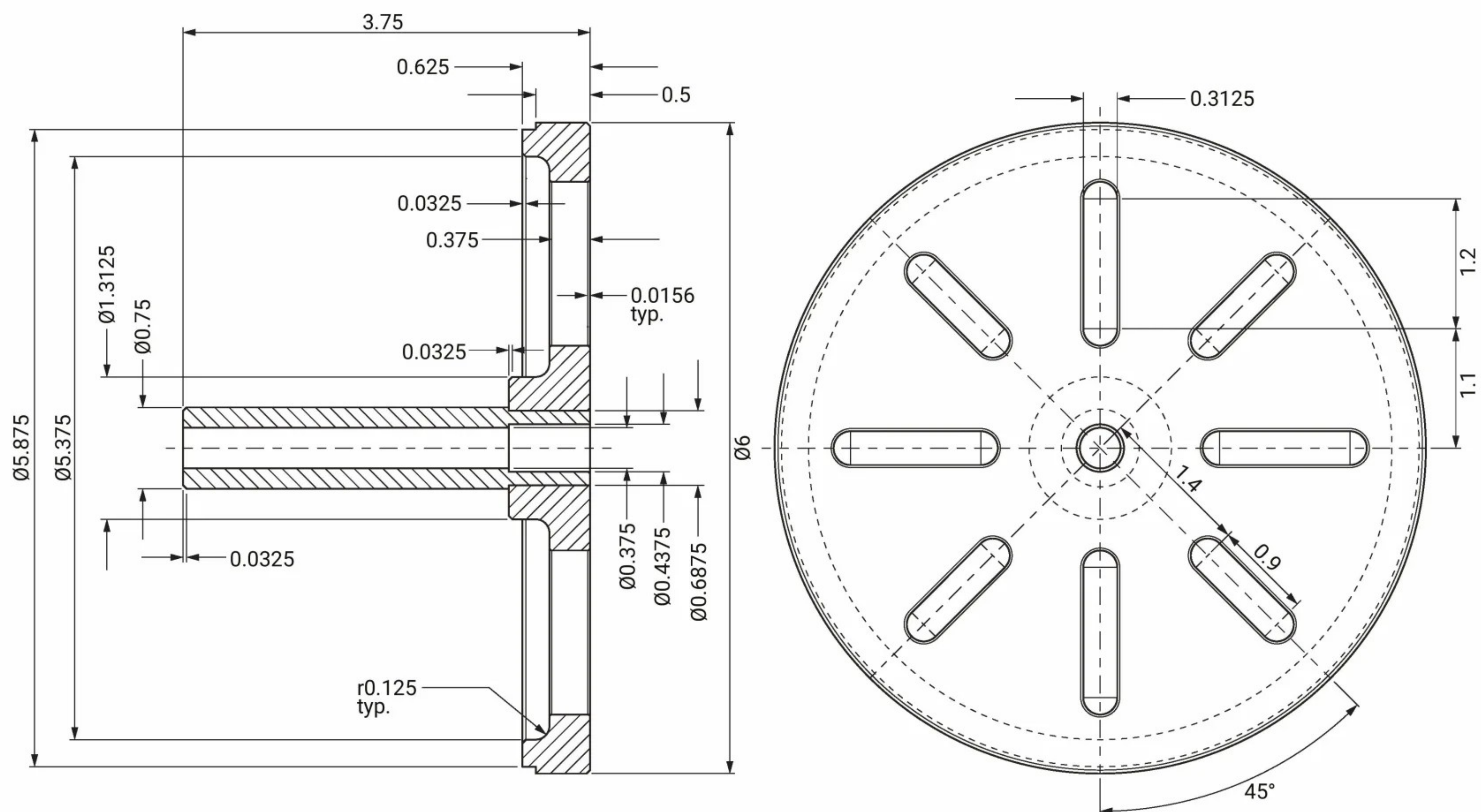
Clamp Nut
Mat'l: Mild steel

Figure 4. Clamp nut

The drawing of the clamp nut for the alloy base, fig. 3.3, is somewhat incomplete. **Figure 4** contains the missing information.

Table – ref. 1, Item 2

The original table design had a stem cast integrally with the table. After GHT added angular graduation to the table a longer stem became necessary to allow the table to be raised, to permit space for the vernier scale to occupy. In any event, the long stem is necessary for operations requiring the table to be mounted in the base. The long stem is a separate item which is permanently attached to the table after the short stem is cut off. The depth of the original table design left very little room for angular graduation marks and their numbering. That problem is solved by making the table 0.125" deeper than the original. Rather than making a new casting, the thicker table is machined from a piece of continuous cast SG (Spheroidal Graphitic) iron, a material which is a pleasure to machine. **Figure 5** shows the deep



Deep Table Assembly And Details

Mat'l: Table - SG cast iron
Stem - silver steel
Press fit stem to table (0.0005" interference fit)
Graduate table as per Fig.15, page 151 of 'Workshop Techniques'
Assembly replaces Items 2 & 13, Fig.2.1, of 'Workshop Techniques'

Figure 5. Table and long stem details and assembly

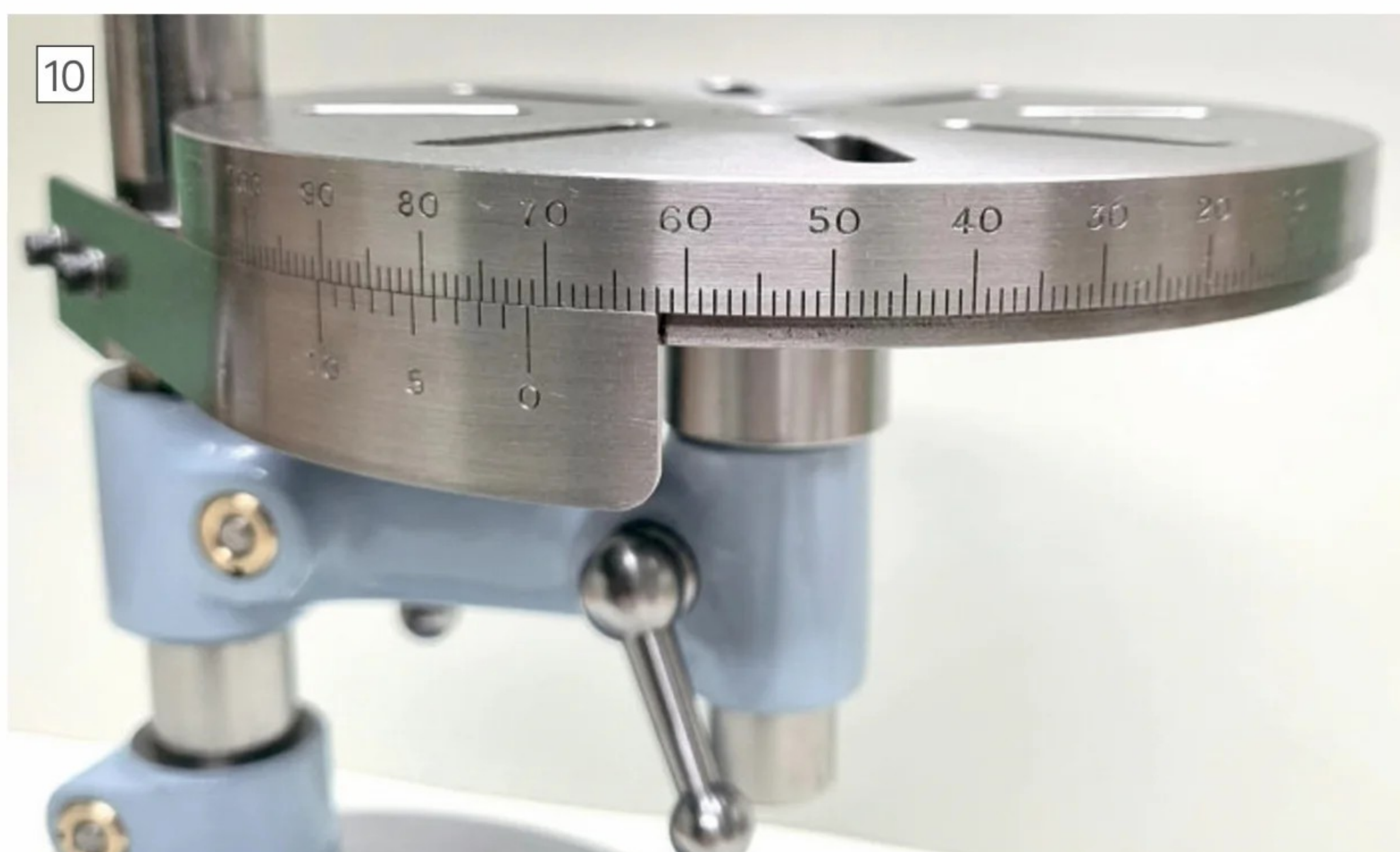


Table graduations and angular vernier

table and **photo 10** shows the angular graduations on the deep table with removable vernier attached.

The deeper table has the incidental benefit of increased rigidity compared to the original. Being made from solid, the clamping slots need to be machined, however the material being a free cutting iron, this is no great task. If the slots are machined accurately, the benefit over cast slots is not merely cosmetic, because accurately made slots can also be used as a setting up aid.

GHT specified a vernier scale for the table, in his fig. 1.15, and showed how this could be used in conjunction with the sensitive drilling arm to make dividing plates. Whilst that operation might be only rarely if ever called for, the facility emphasises that a well-made UPT is not a scaled down common drill press but an accurate machine tool and metrology device in its own right.

The tap holders

GWH specified three kind of tap holders or tapping spindles. The idea is that the three tap holders, between them, cover the range of taps with a 3/8" parallel shank down to about 16BA. The largest holder is made using a No. 32 Jacobs 3/8" chuck fitted to a sturdy spindle which is driven by a cross bar and handles. fig. 4.1 gives two handle designs, a simple type, Item 15, and a more ornamental style, which is also more comfortable to use, Item 15A. I prefer the latter and for the convenience of others who do, **Figure 6** shows the dimensions for making a template to turn the contour

of the handle. A suitable template made from 1/32" brass or similar is shown in **photo 11**. The template includes the shape of the profile and an extension of the centre line of handle is also inscribed. The purpose of the scribed centre line is to enable the template to be oriented correctly on the job, for it is easy to mistakenly turn the correct profile, but for the profile to not be parallel to the handle. The turning itself can be done freehand using a tool of about 1/4" width, the cutting edge being fully radiused with front and rear cutting edges of 1/8" radius. Work on the full length of the profile, repeatedly checking with the gauge, and use a marking pen to identify the high spots to be turned away if necessary. Final finish with files and emery, the lathe bed covered with paper to protect it from abrasive grit.

The two smaller tappers GHT recommended are more of a challenge to make satisfactorily than the largest item. The challenge lies with the imperative for holding the tap concentrically in respect of the bush in which the holder rotates. If the tap wobbles in the holder there is a risk the tapped hole will not be square to the work. A greater risk, especially when using very small taps, is that the tap breaks, because of the bending load being applied by the wobbling tap as it is rotated. Taps are designed for torsional loading, not bending loads. Since the whole point of the UPT tapping facility is accurately tapped holes and fewer broken taps, this challenge must be overcome.

GHT originally, i.e., in the 1974 Model Engineer articles, designed the two



Large tap holder handle and profile machining gauge

smaller tappers to utilize the business end of modified Eclipse pin chucks (also referred to as pin vices), the No. 123 type and the larger, No. 124 type. GHT later, in ref. 1, concluded the smaller type was redundant, and that its purpose would be better served by a very simple tap holder, a piece of 3/16" diameter rod having a 1/8" hole bored in one end, the tap being secured with a 10BA screw in a collar through which the rod passes. This simple tap holder is Item 20 in fig. 4.4 and would hold the smallest taps, provided their shanks were all nominally 1/8" diameter. Taps up to 5BA would be accommodated with the tapper formed using the smaller No. 123 pin chuck.

I adopted a slightly different approach to GHT for the small tappers because of the high degree of inaccuracy of the new Eclipse No. 123 pin chuck I had, and because not all small taps, in my collection at least, have a 1/8" shank. GHT describes in, fig. 4.3, ref. 1, a systematic way of truing an Eclipse chuck, and whilst the method is sound, correction of an error of the size I was dealing with was impossible. My solution for the mid-size tapper was to replace the Eclipse No. 123 pin chuck with a Starrett No. 240C pin chuck, having an opening range from 0.045"-0.135". Whereas the TIR (Total Indicated Runout) for the former was a practically uncorrectable figure (which I omitted to record), the TIR for the latter was about 0.003" before correction, a figure which is practically acceptable in the as-procured condition. For the smallest



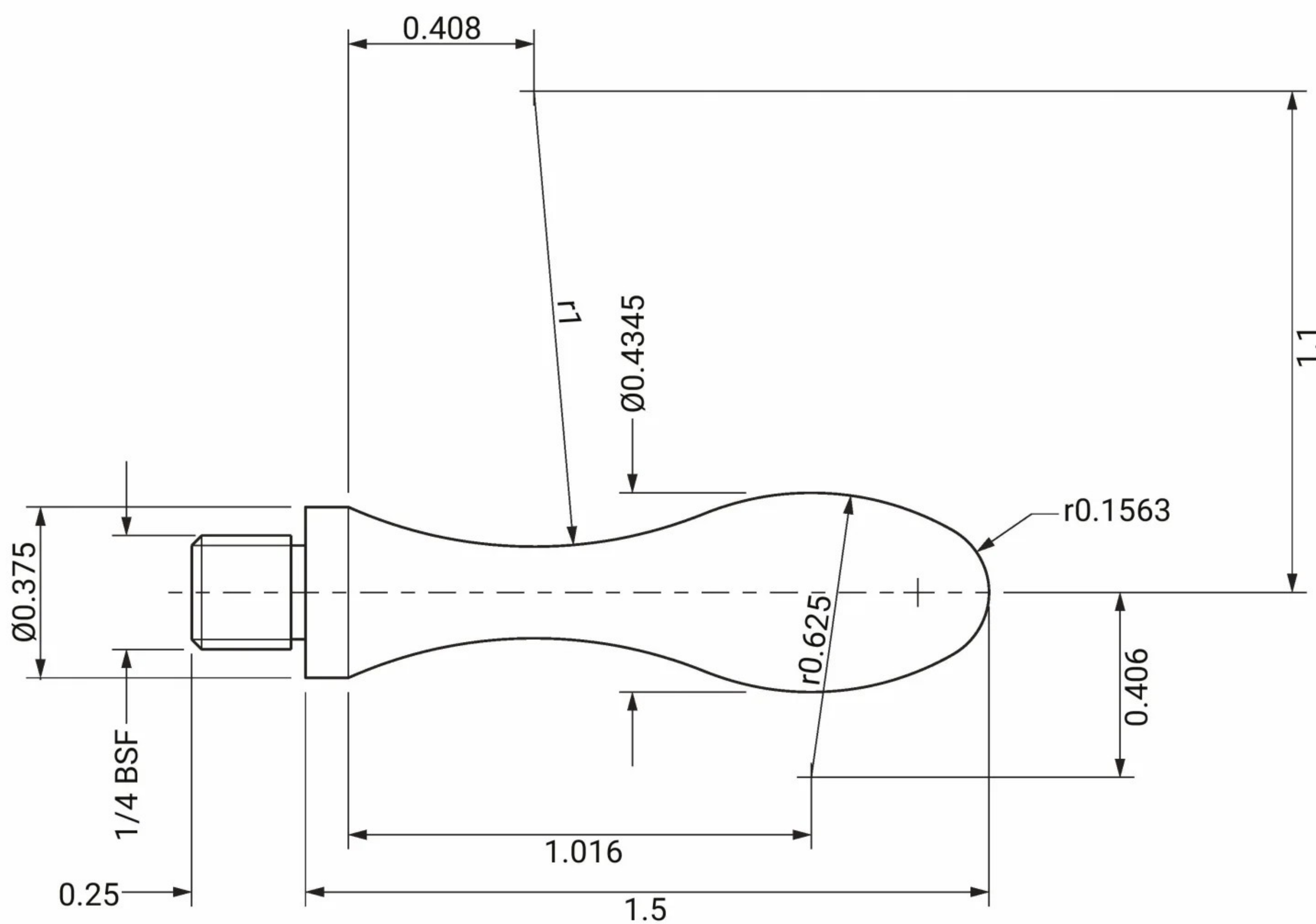
Rotatable stake

tapper I adapted an Eclipse No. 160 pin chuck, which with the smallest of three interchangeable collets fitted, can easily hold the smallest size tap. The three tappers I have described easily cover the whole range of taps from 3/8" diameter down to practically zero. Reamers of the same size range can also be held using the same equipment.

As mentioned in Part I, a very useful feature of the UPT is the two smaller tappers are held in the UPT tapping arm in a bush which, via a controlled friction device, prevent the tap from dropping down onto the work. Another useful feature, for the middle size tapper, is the twin knurled knob. The larger diameter knurl affords sufficient torque for tapping and the smaller diameter results in rapid tap reversal, all very convenient for tapping deep holes in which the tap needs to be periodically withdrawn for chip breaking and cleaning.

Rotatable stake

The rotatable stake is shown, dismantled, in **photo 12**. In addition to



Large Tapper Handle
Mat'l: Mild steel

Figure 6. Large tap holder handle

conventional staking operations the tool can be used to accurately punch holes in gaskets.

The data for drilling the holes in the case-hardened steel staking plate is found on page 63 of ref. 1, under "List of Settings". There are two errors in the list. At 00, the hole should be a No.1 centre drill, not the stated 3/64" diameter hole. The correct position for the 3/64" diameter hole is at 160. The remainder of the data in the List of Settings is correct. The List of Settings is for a recommended generic imperial staking plate and the user may of course amend the design to suit their needs. Odd sizes can be staked by making special purpose stakes which can be held in the single stake holders shown in fig. 5.1.

The base of the staking tool has a 1/16" wide groove in the top face whose purpose it is to engage a pin which prevents the clamping bolt from rotating. The original design has it that this feature is machined using a 1-1/4" x 1/16" slitting saw, a rather particular size which few may have ready to hand. Photo 12 shows an equally satisfactory

result made using a common 1/16" diameter end mill.

Rivet snaps – on their making

The comprehensive range of tooling for the UPT shown in ref. 1 includes various rivet snaps. The usual D-bit plunge cutting method of forming the concave radius, which either holds or forms the rivet head, is proposed by GHT. There is no doubt that method can, when carefully executed, result in satisfactory results. However, making an adequately smooth and truly radial D-bit in the smaller sizes without a tool and cutter grinder is difficult, and even small deviations from the correct spherical profile can appreciably spoil otherwise well executed rivet work. An alternative method is to form the concave shape using the end of a ball nose cutter. Table 1 shows the best fit cutter sizes and cutter plunge depths for common model engineering rivet sizes based on rivet proportions defined in B.S. 641:1951, Dimensions of small rivets for general purposes.

Table 1 – Data for rivet snap profile formation using ball nose cutters

Rivet snap diameter	Ball nose tool diameter	Plunge depth
1/32"	1.5mm	0.023"
3/64"	2.2mm	0.035"
1/16"	7/64"	0.047"

One advantage of living in a dual imperial-metric world is we have twice as many cutter sizes to select from. Although the ball nose tool sizes shown in Table 1 are admittedly uncommon, I was able to obtain the three sizes from internet sources without difficulty. Cutting the concave shape with a sharp cutter, at low speed, and with good lubrication, resulted in mirror finish forming surfaces in silver steel blanks.

Next, in Part IV, a design for an integral variable speed drive for the sensitive drilling attachment is described.

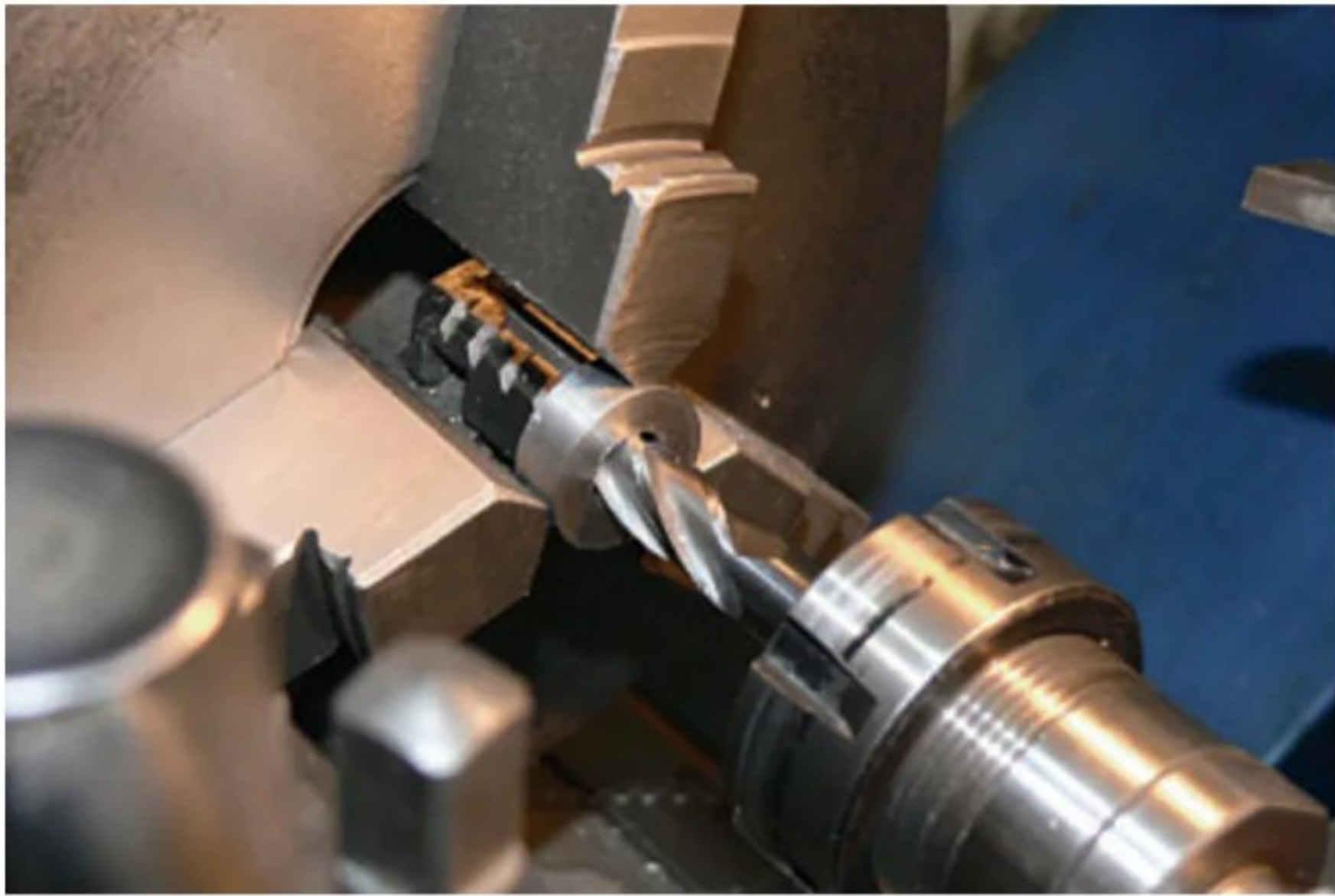
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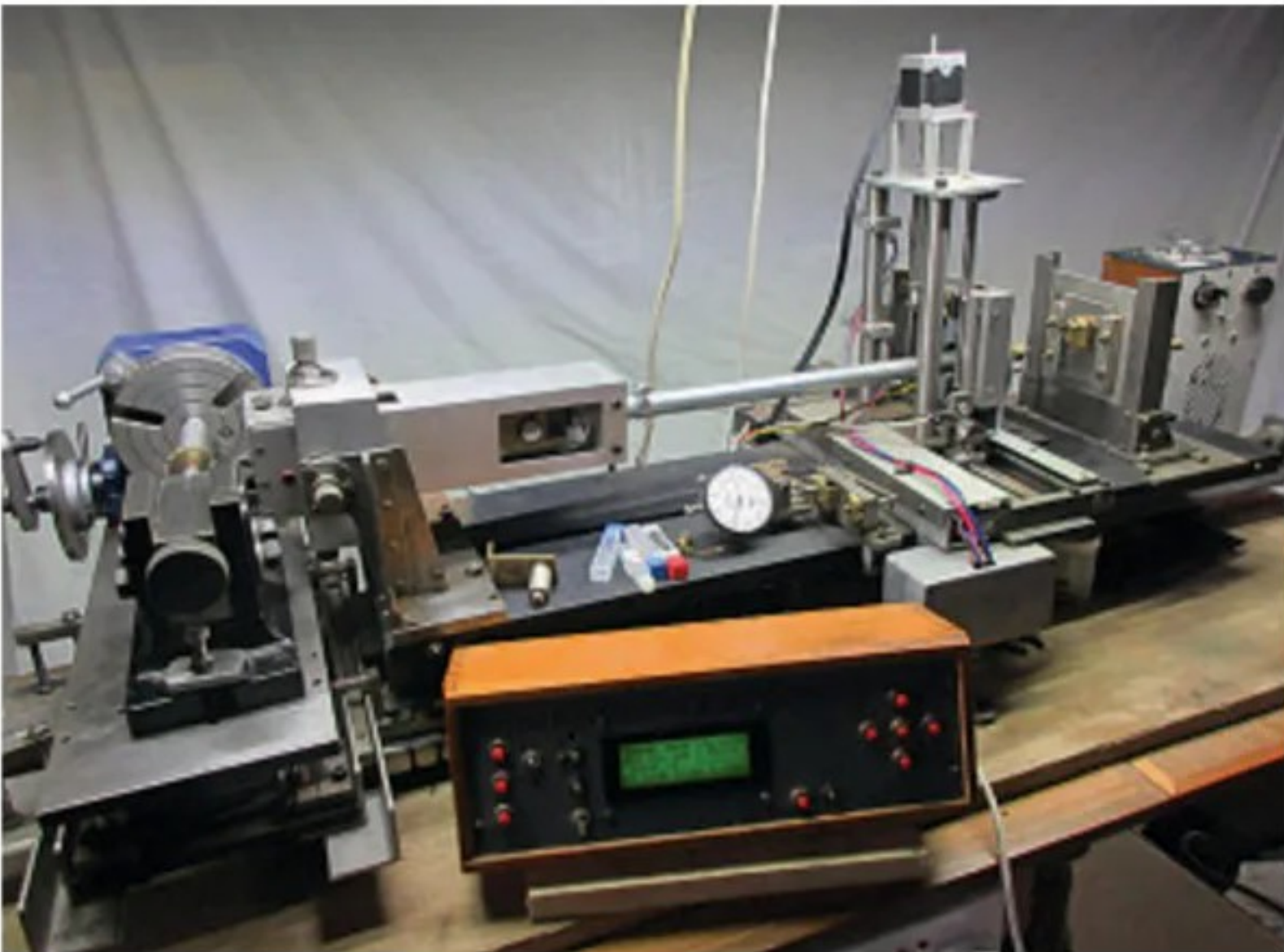
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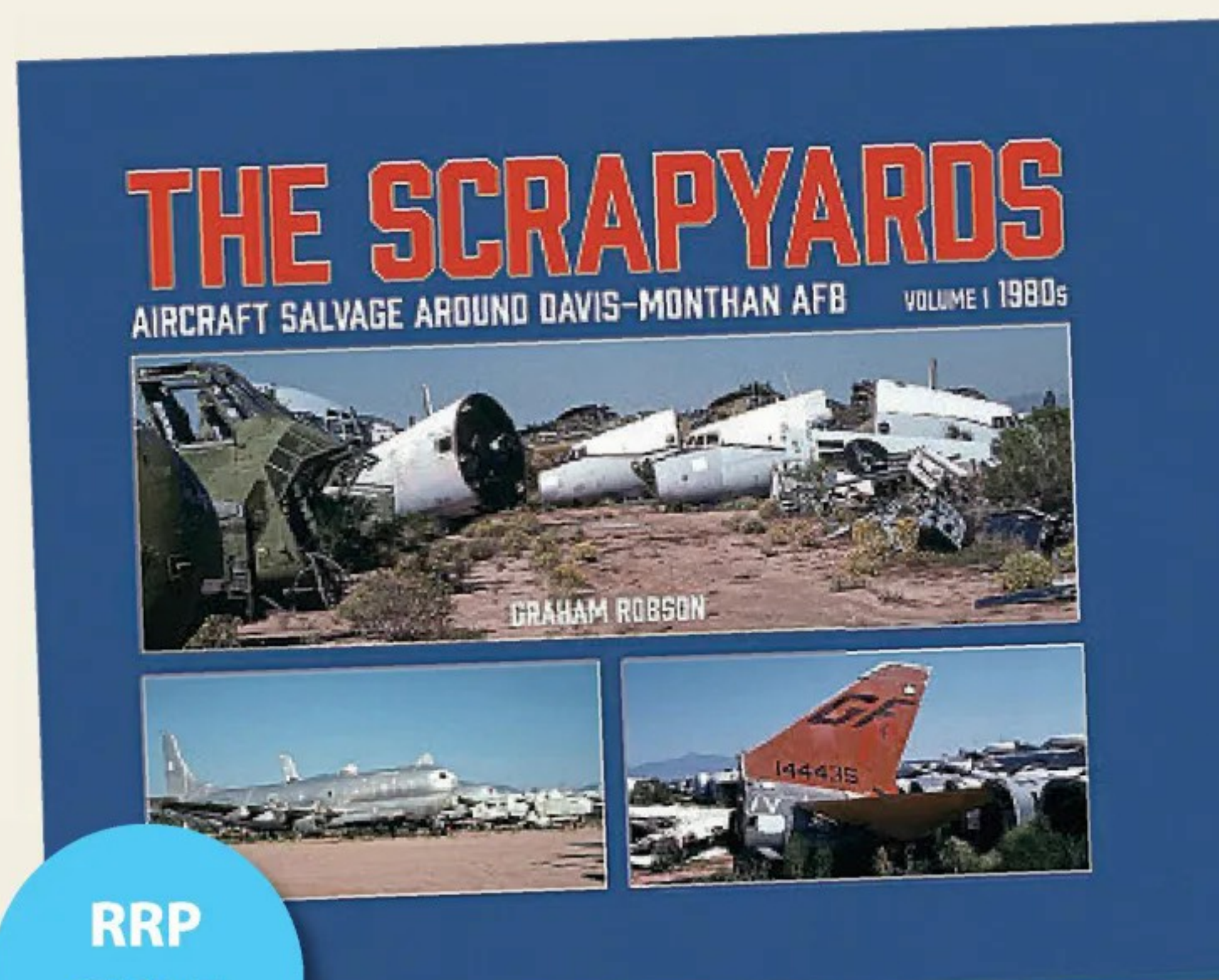


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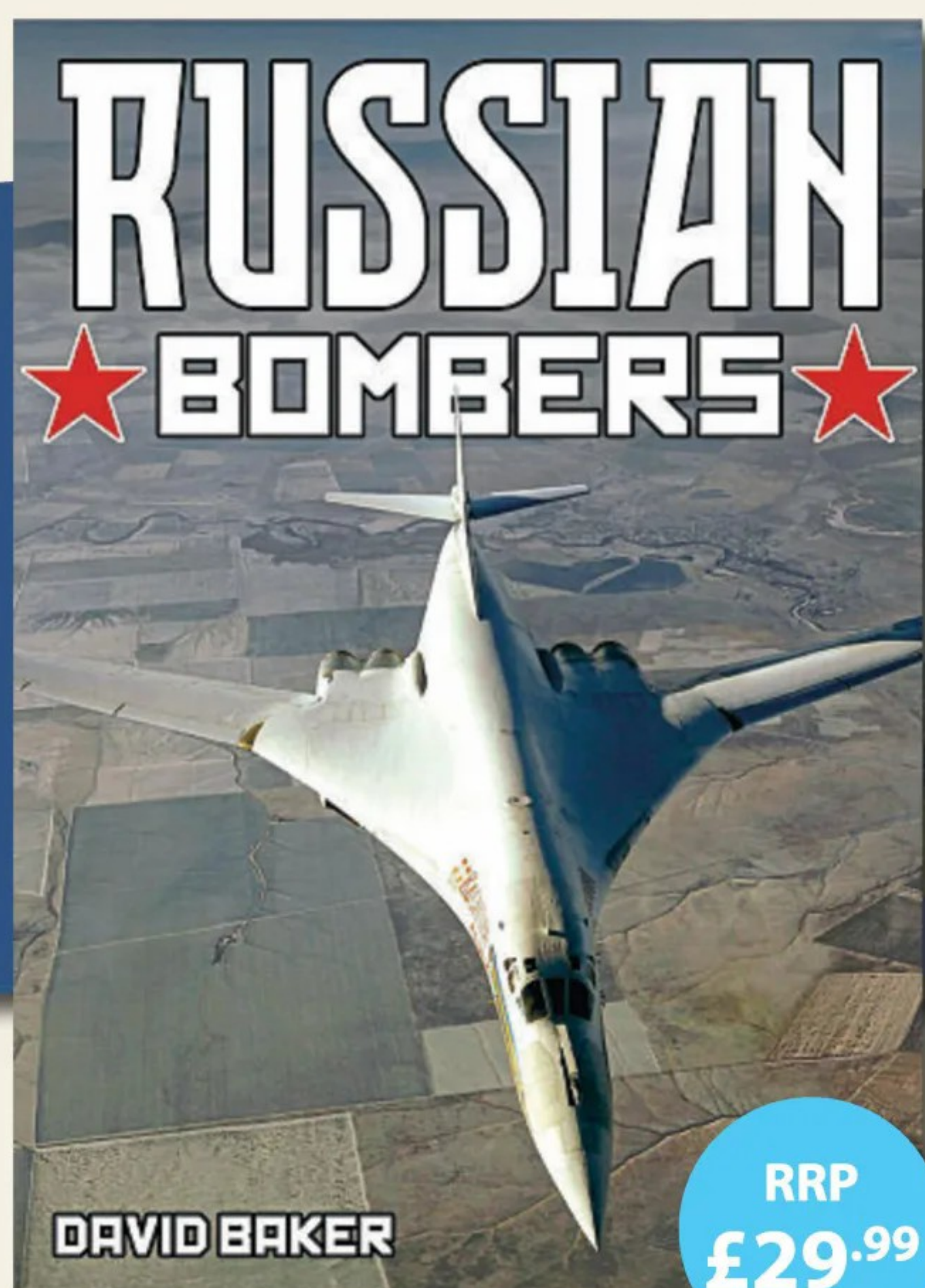
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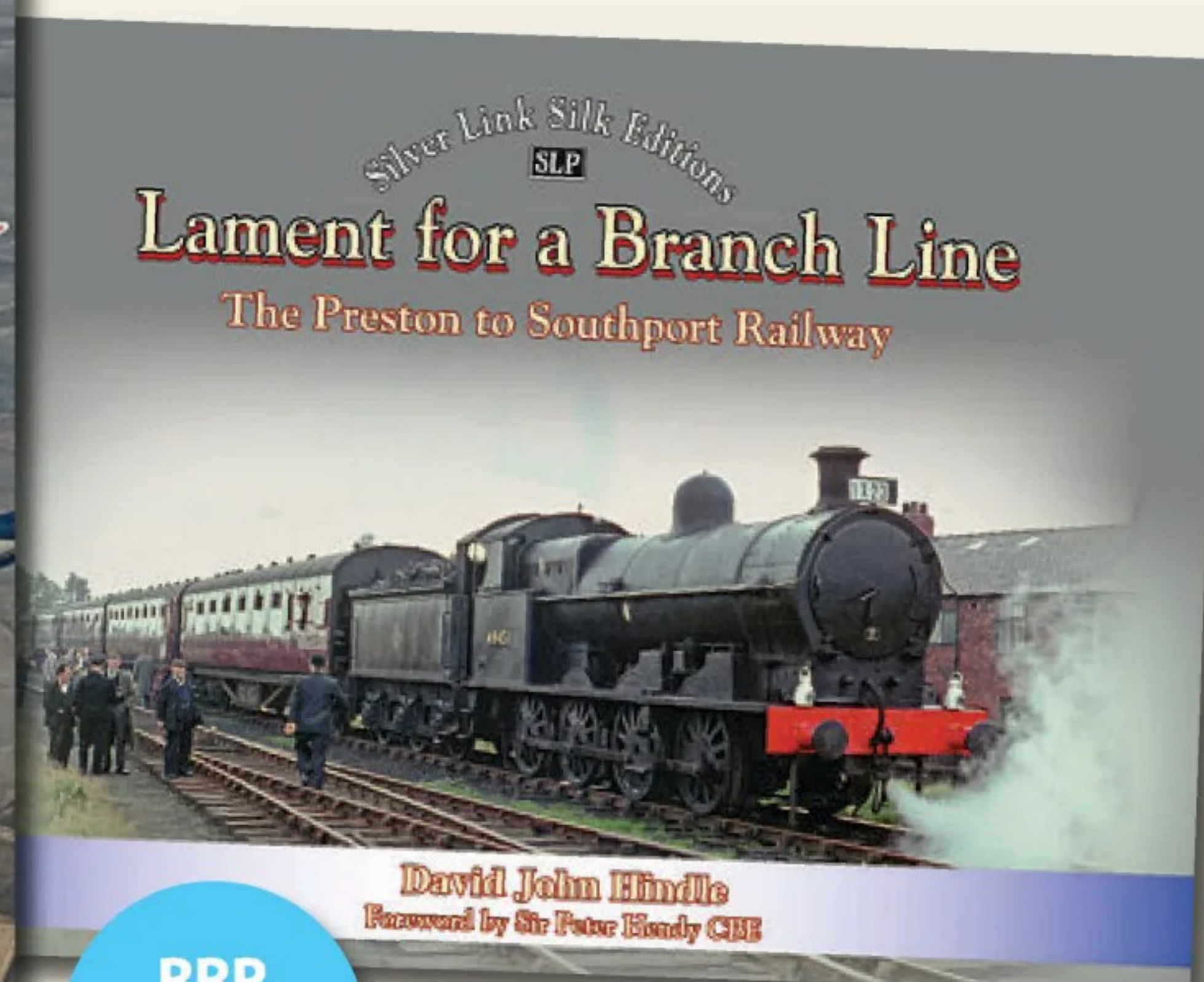
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The Creality K1-Max AI

Neil Wyatt relates his experiences with the fused filament deposition machine he demonstrated at this year's Midlands Model Engineering Exhibition.

Many readers will be aware that I am something of an evangelist for 3D printing. Recently I've been trying out the Creality K1-Max AI (I'll call it the K1-Max for short), one of the largest and fastest hobby-level 3D printers, **photo 1**. This machine has so many interesting features I'd like to put it in the context of my prior experiences in 3D printing.

I got into the technology around the point where reliable and capable fused-filament- deposition (FFD or FDM) printers were becoming relatively affordable. Just to recap, this is the process where a computer-controlled machine extrudes semi-molten plastic in layers to build up 3D objects. Objects can be downloaded from the internet, you can design your own with 3D CAD, or even scan in objects (see MEW 335). Typically objects are exported in STL or a similar format, then 'sliced' by a program such as Cura to prepare them for the specific machine on which they will be printed.

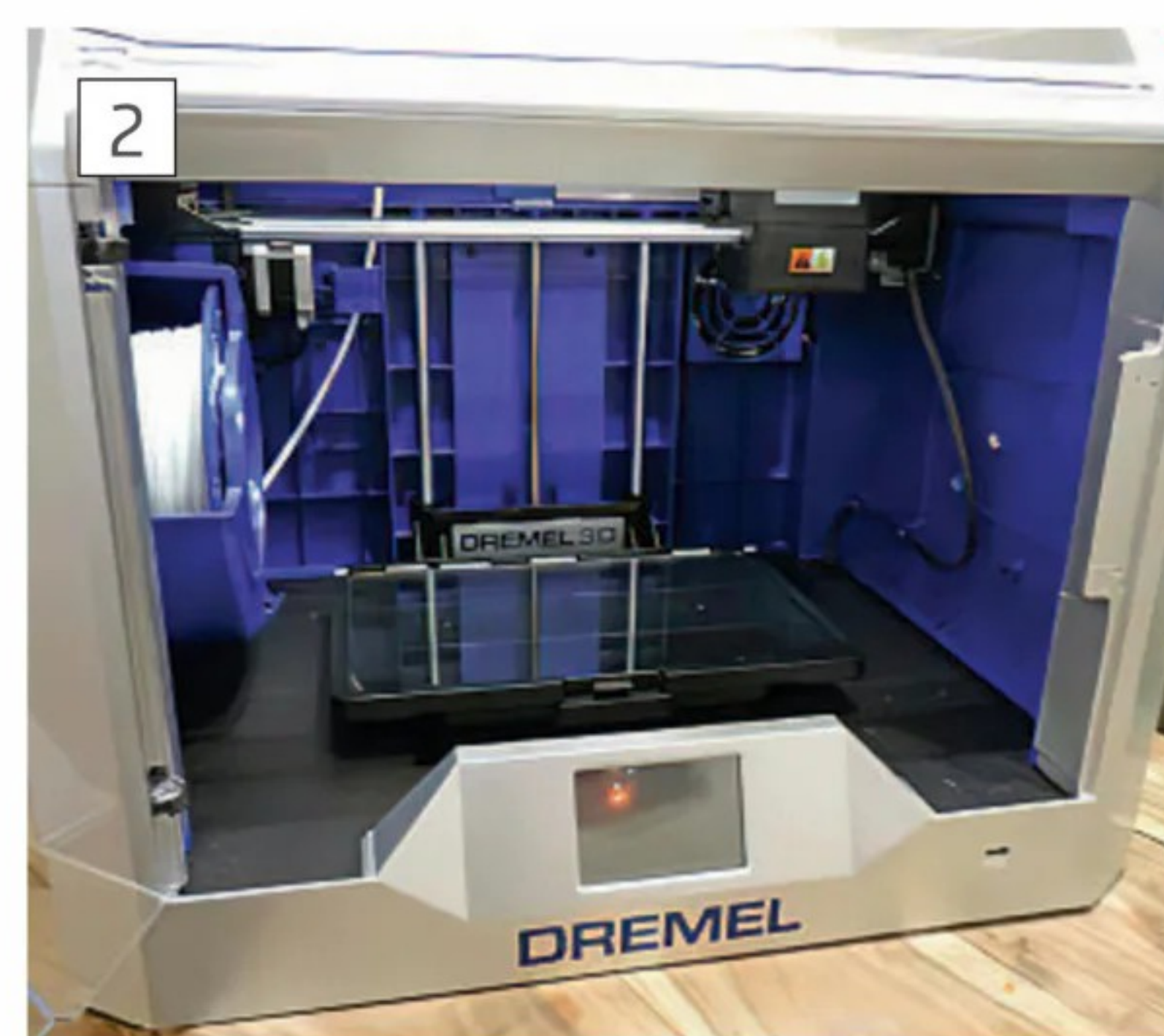
The hobby 3D printer movement started to take off with the ReRap Mendel in 2009, but progress since then has been remarkable. My first hands-on experience of the technology was a Dremel 3D40 Idea Builder which I started looking at in late 2016 (reviewed in MEW 251 and 252, February and March 2017). This was a machine largely aimed at an educational audience with an emphasis on being 'plug and play'. Full enclosed, it used an XY gantry and lifting bed for the z-axis, **photo 2**. It was quite advanced in many of its features, such as automatic loading of filament and automatic assistance with levelling. It did have some limitations, not least it would only readily print PLA and ABS due to a relatively low maximum temperature. The maximum filament reel size was only 500 grams. An unheated bed meant that the biggest challenge was generally making sure the prints stuck to the build plate and getting them off without



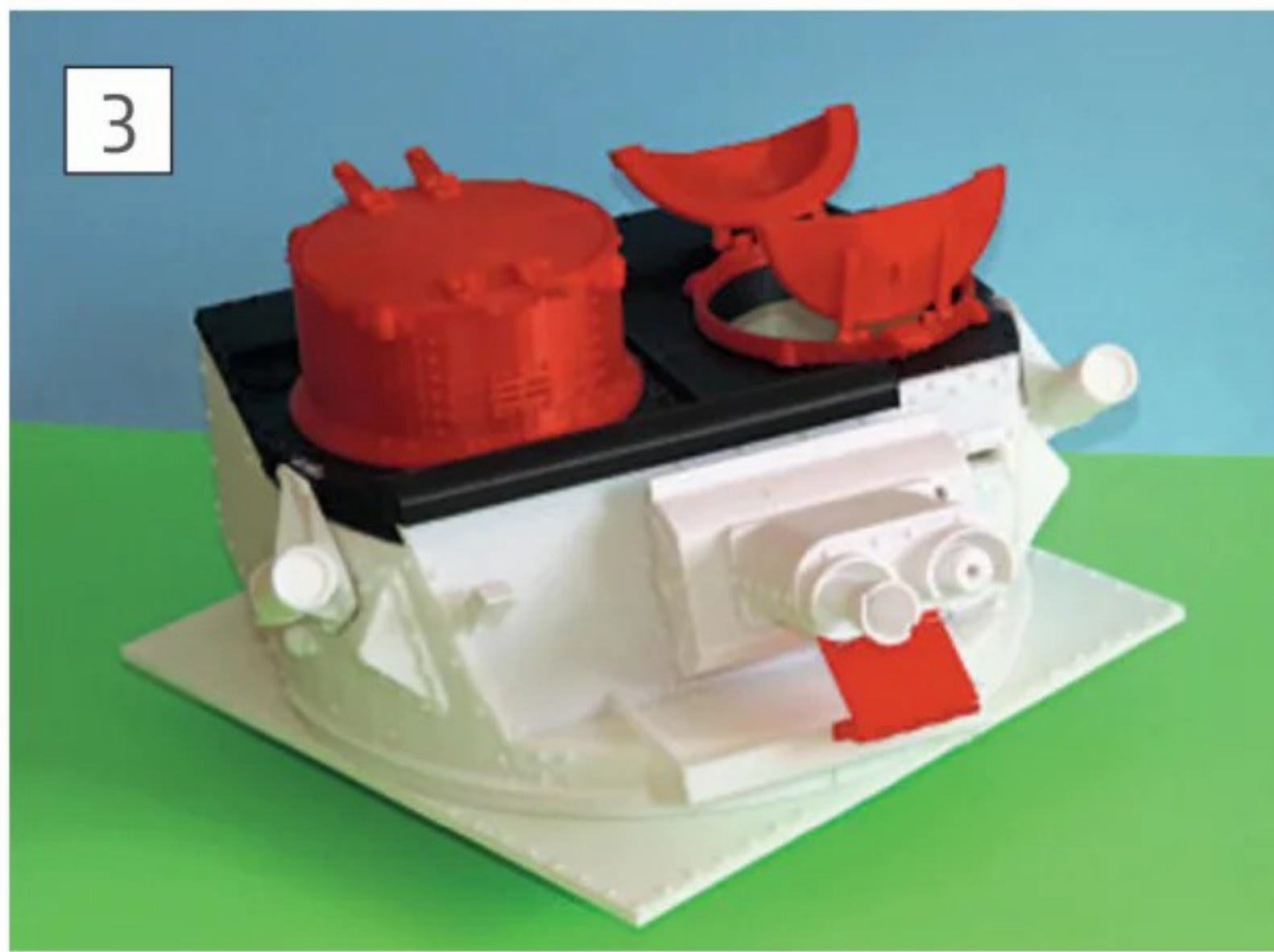
The Creality K1-Max AI.

destroying the 'build tape'. Nevertheless, I was able to produce many great prints on it, **photo 3**.

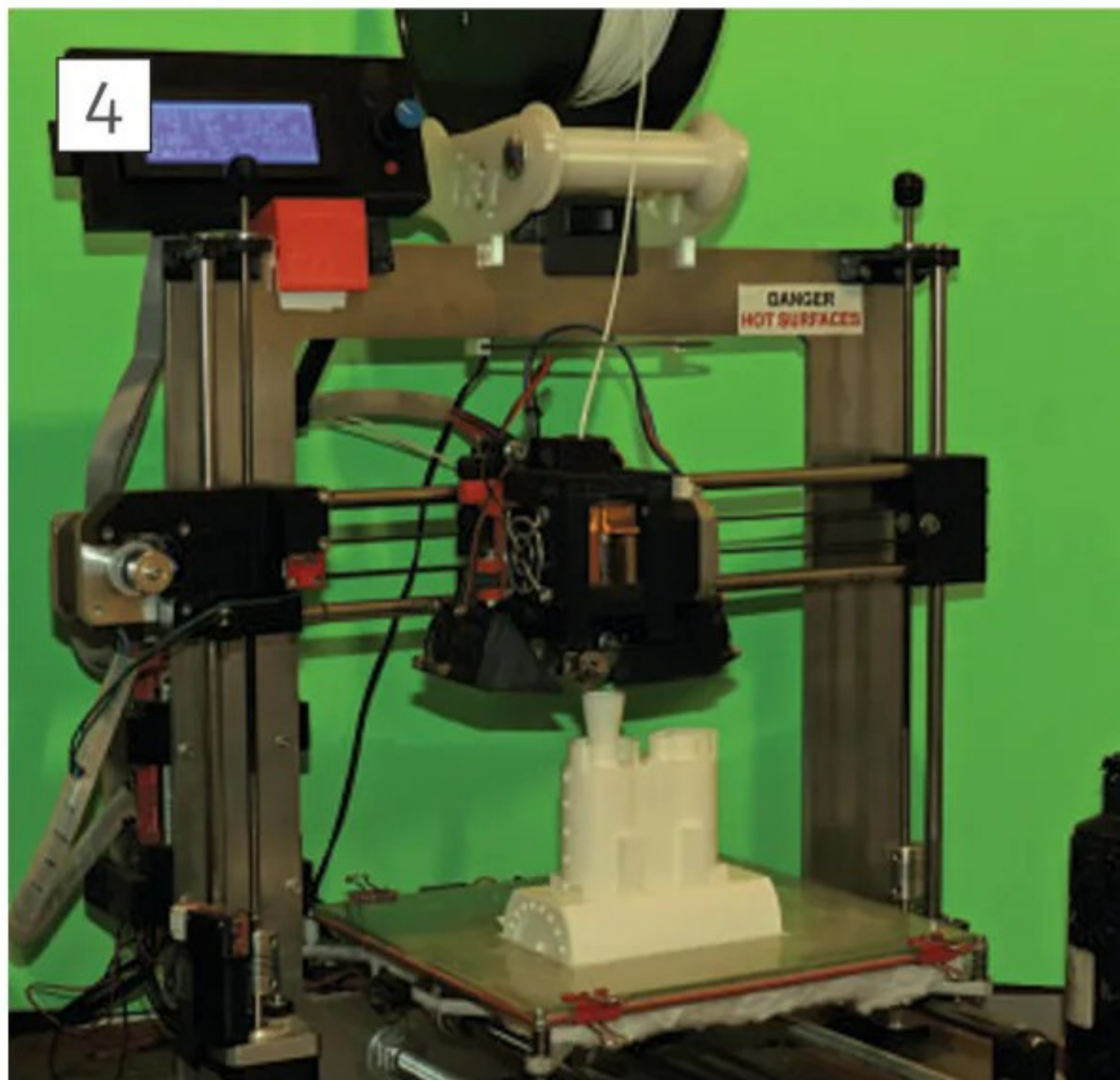
The Dremel certainly got me interested in 3D printing, but also made me aware of further possibilities. After some thought I decided to build my own printer, choosing a kit best described as a Prusa i3 clone, that is it was to the open-source design but not manufactured by Prusa. This machine looked rather Heath Robinson, **photo 4**, and was unenclosed, but it had a heated bed and almost everything about it was



The Dremel 3D40 Idea Builder in 2016, similar footprint but much smaller build volume.



Some of my early 3D printed parts.

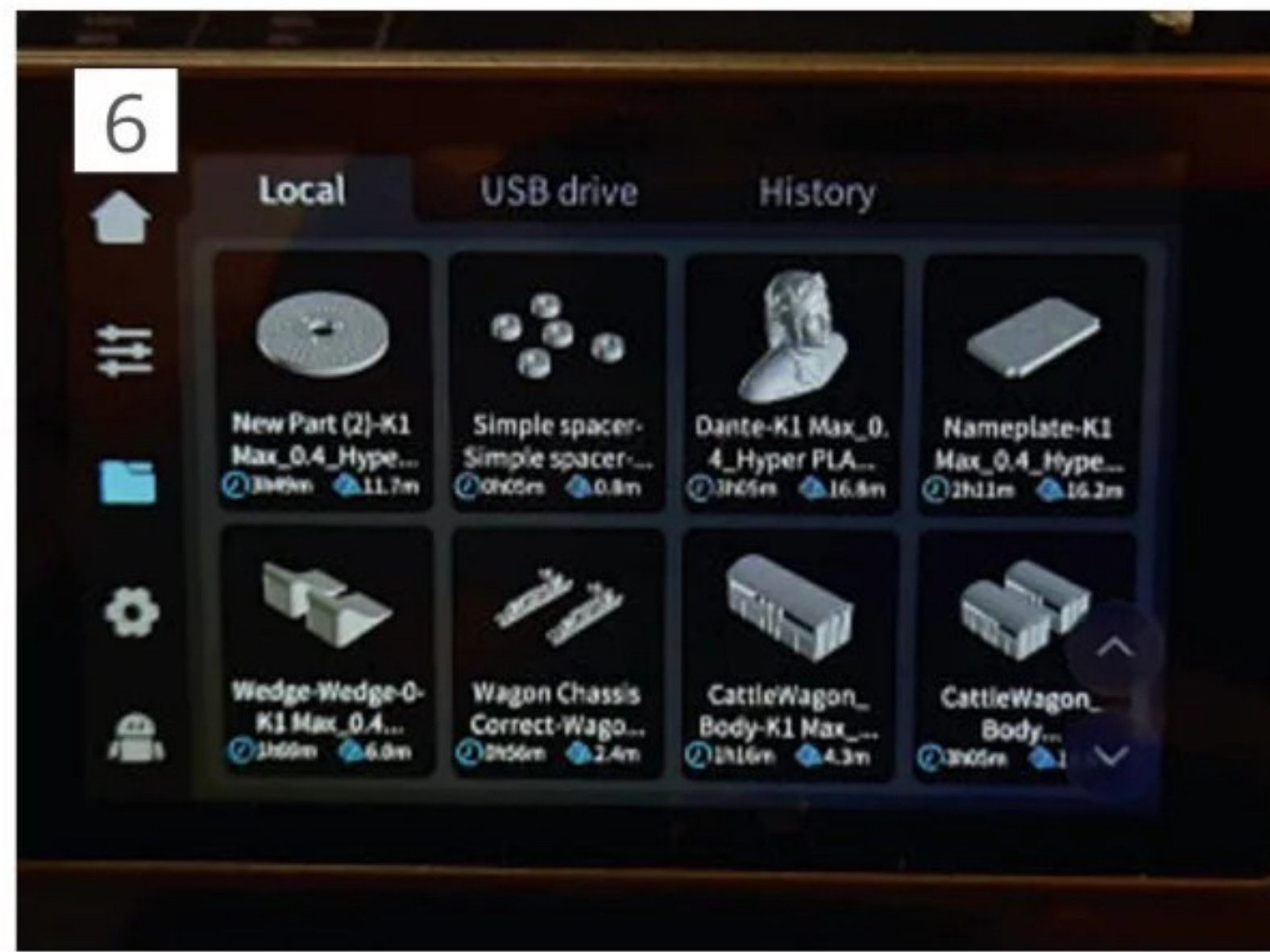


My Prusa i3 clone, built from a kit.

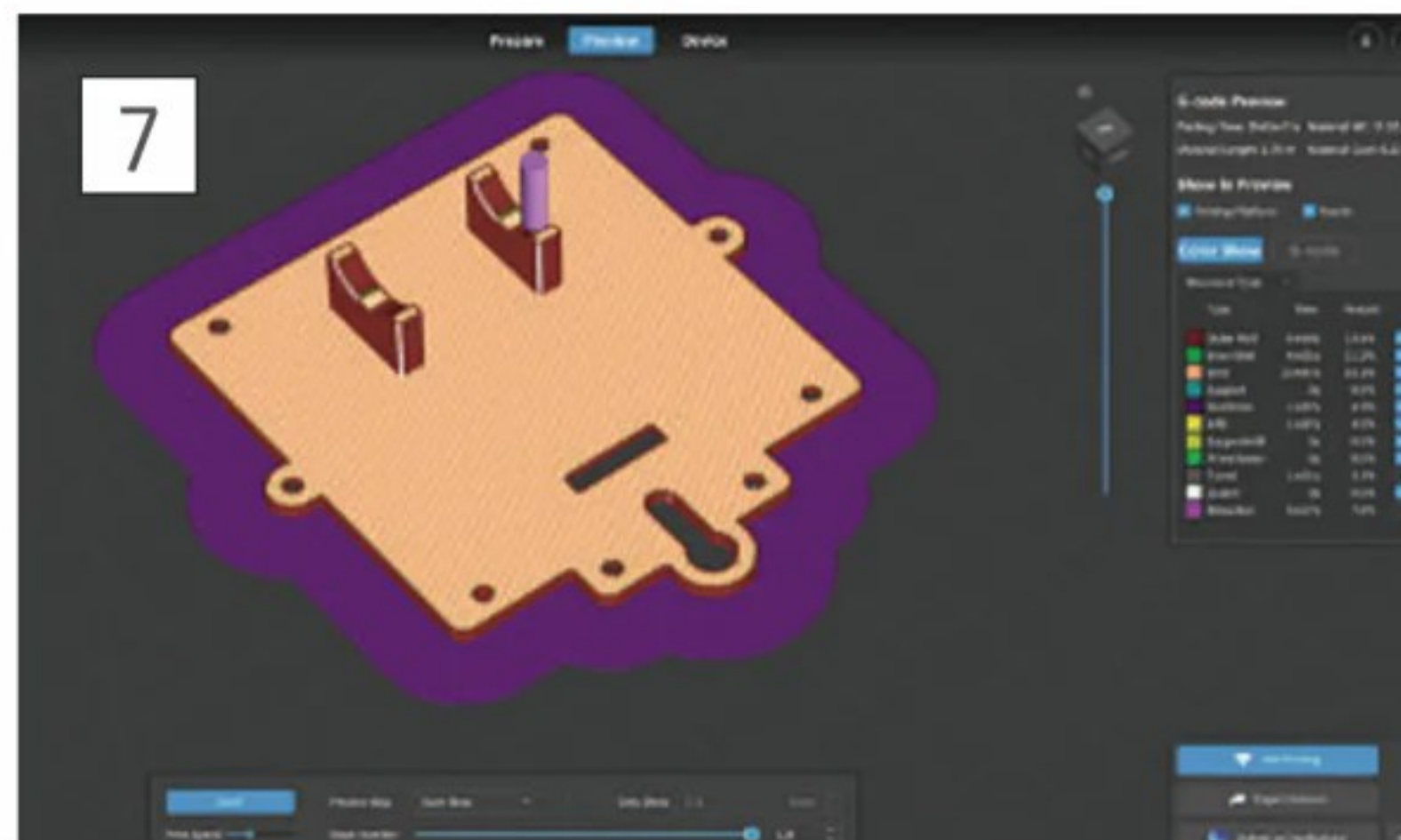


The K1-Max with the door open giving a clearer view of the very neat internals.

easily replaceable or controllable. The heated bed greatly simplified making reliable prints, and I was able to print with higher temperature plastics such as nylon and PETG. It was also very upgradeable, so I did things like fit a high-temperature glass bed, various mechanical tweaks, increasing the Y-travel, adding better reel stowage and greatly improving the filament loading process. Keeping the machine running



The interface screen, this view shows some of my stored projects.



The slicer interface.

has involved some maintenance over the years, mostly replacing worn out nozzles and tasks like lubricating and adjusting the machine. One recurring issue has been that the wires to the print head are rather vulnerable to damage.

In short, the i3 clone was far from a 'plug and play' experience, but it's tunability allowed me to print a far wider range of materials and also push the envelope a lot in terms of speed and quality, it's been an invaluable addition to my workshop.

Last year, some seven years after my first experiences I was offered the chance to try out the Creality K1-Max. Interestingly, this machine has much in common with the Dremel Idea Builder, it's fully enclosed, uses a build plate that moves up and down for the z-axis and has a similar way of feeding the print head/hot end via a tube. It also offers a 'plug and play' experience, but that's about where the similarities end. The K1-Max is bristling with innovations I would not have imagined in 2016. So let's look in detail at what the Creality K1-Max offers as a practical solution for model engineers.

The Creality K1-Max

The basic construction of the K1-Max is a fully-enclosed box structure that is glass on three sides with a door on the front and a lift-off glass lid, this offers a draught free, temperature stable

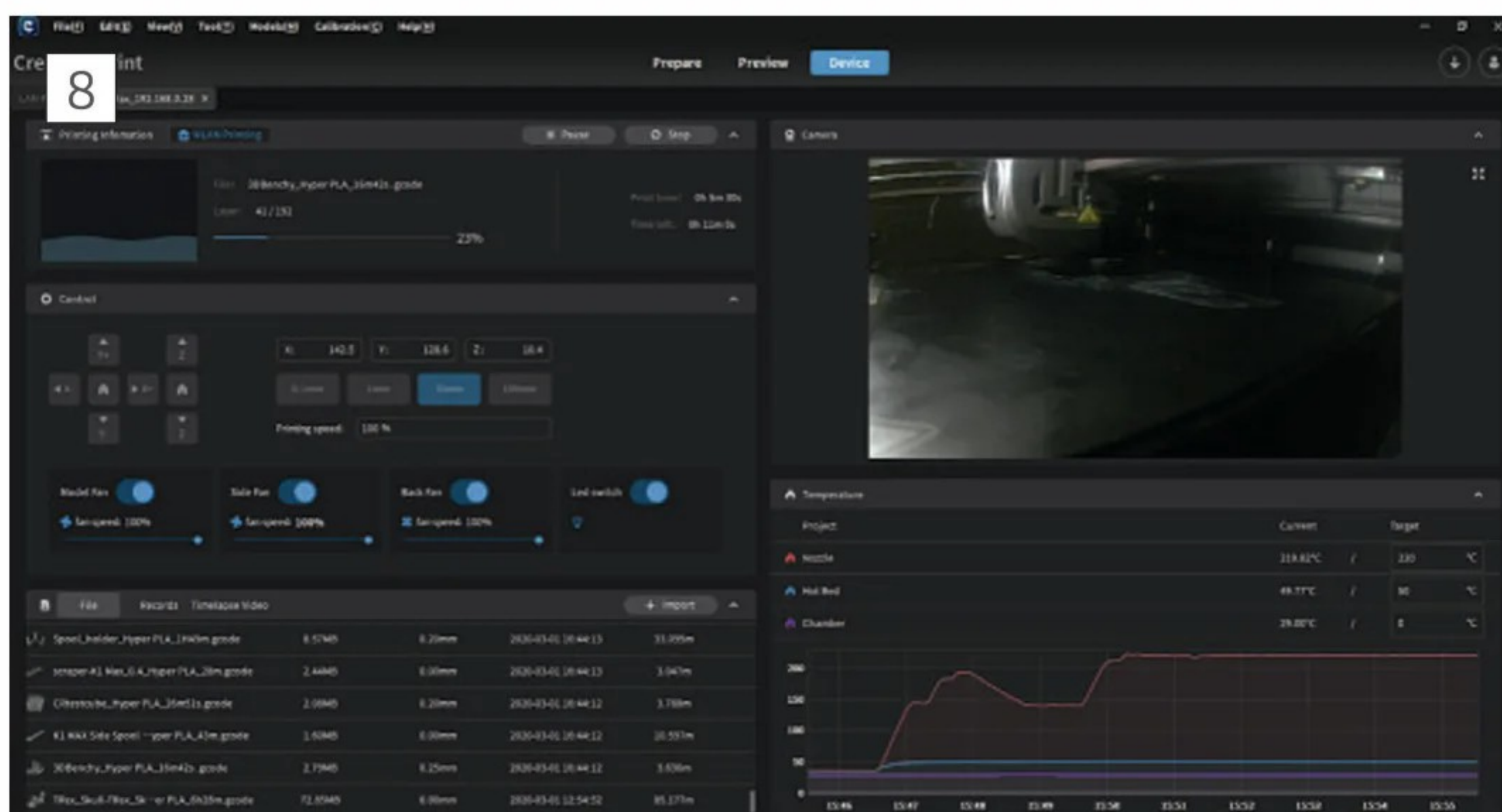
environment helping minimise warping and maximise print quality. It is a large machine, 508mm square and 608mm tall, but will fit comfortably on a standard 600mm deep desk or worktop.

The K1-Max is an enlarged version of Creality's K1 printer, another fast FDM machine. This means the main selling points of the K1-Max are size and speed. The build volume is an impressive 300mm cube, allowing really sizeable objects to be printed in one piece. It also offers print speed of up to 600mm/s, making it practical to use the extra volume to print really sizeable objects. For comparison my i3 has about a 220mm build cube and a practical top speed of about 200mm/s; many printers use speeds well below 100mm/s.

Control of the printer is via a good-sized colour touch screen on the front of the printer, **photo 6**. This comes separately and has to be carefully attached using a ribbon cable. Aside from removing packing material and a few transit screws on the bed and fitting the filament support, that was about all of the setting up the machine required. Once switched on it does a self-test and then you are ready to load filament and start printing.

To print objects you can start with some pre-loaded models, or you can load an STL, OBJ or AMF file into the 'Creality Print' slicer (which is based on the Cura open source slicer) but looks rather different, **photo 7**. The default profiles for the slicer are fast and normal at 0.2mm layer height and high quality at 0.1mm layer height. The slicer offers all the options you might expect such as preparing multiple objects, scaling and reflecting, adding text and cutting objects. It also has access to all of the Cura settings (via a rather more pleasant interface, in my view) including the advanced ones like 'fuzzy skin' which provides a surface texture that effectively disguises the layered nature of FDM prints.

While you can transfer your files to the printer on a USB stick, I was able to get it in range of the domestic wifi, this brings some great advantages. Not only can you upload the sliced object to the printer (which has a significant onboard storage so you can keep a library of objects ready to print), but you can control all of the printer's functions



The remote control interface, including a live view of a print in progress.



Demonstrating the K1-Max at the Midlands Model Engineering Show.



This print used about 200mm of the available 300mm build height.

remotely, **photo 8**. This includes not just self-tests, calibration, movement and heating but also the fans, a light for the build area and also a camera that allows me to sit upstairs and check on progress from my desk! You can even ask the printer to make a time-delay video of your print as it appears.

Print Quality

The big question is, of course, what's the print quality like? With Creality's own PLA filament and also generic 'PLA+' prints are more or less immaculate with great detail, very little stringing. Overhangs are printed well and the default support uses a 'grid' on top of the main support structure for undersurfaces. This is excellent and although these surfaces have a sort of 'knitted' texture they are free of the loose filaments that often spoil poorly supported surfaces.

Photograph 9 shows an impressive 'Godzilla' (a gift for a young nephew,



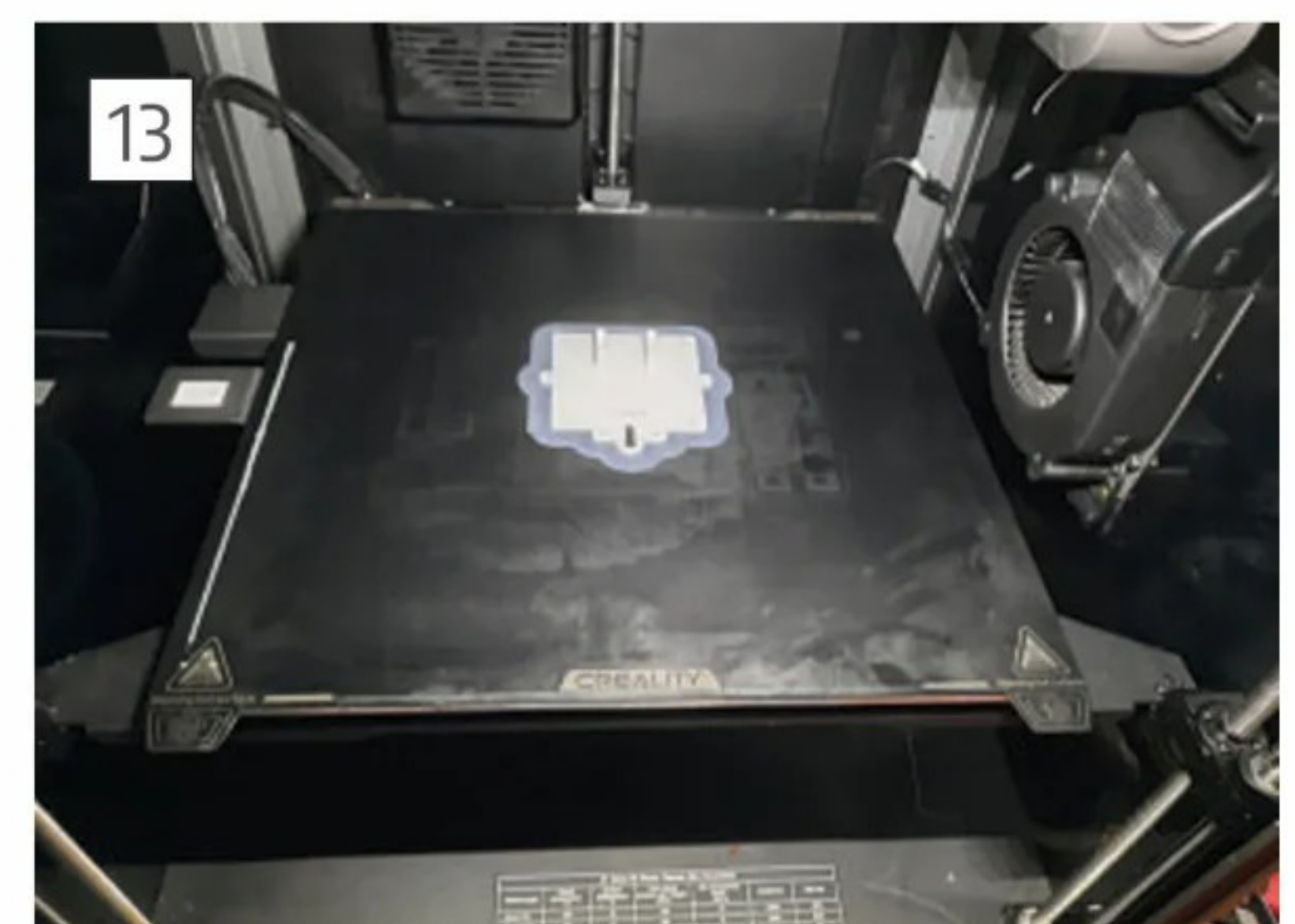
One of the skulls printed in fast mode, £1 coin for scale.



The standard reel support.

downloaded from the Thingiverse website) which makes good use of the K1-Max's build volume. At the Midlands Model Engineering Exhibition I was printing 'Tyrannosaurus skulls' as a demonstration on the high-speed setting, **photo 10**. The one disadvantage of this was that it tended to make the lightly-built folding table rock around. At home I have it on a sturdier desk unit and this is not a problem. Note that it comes with vibration-absorbing feet that are very effective in keeping noise levels low – it is not a noisy machine.

One problem that is often noted with fast machines is that resonances lead to unpleasant banding artefacts; the



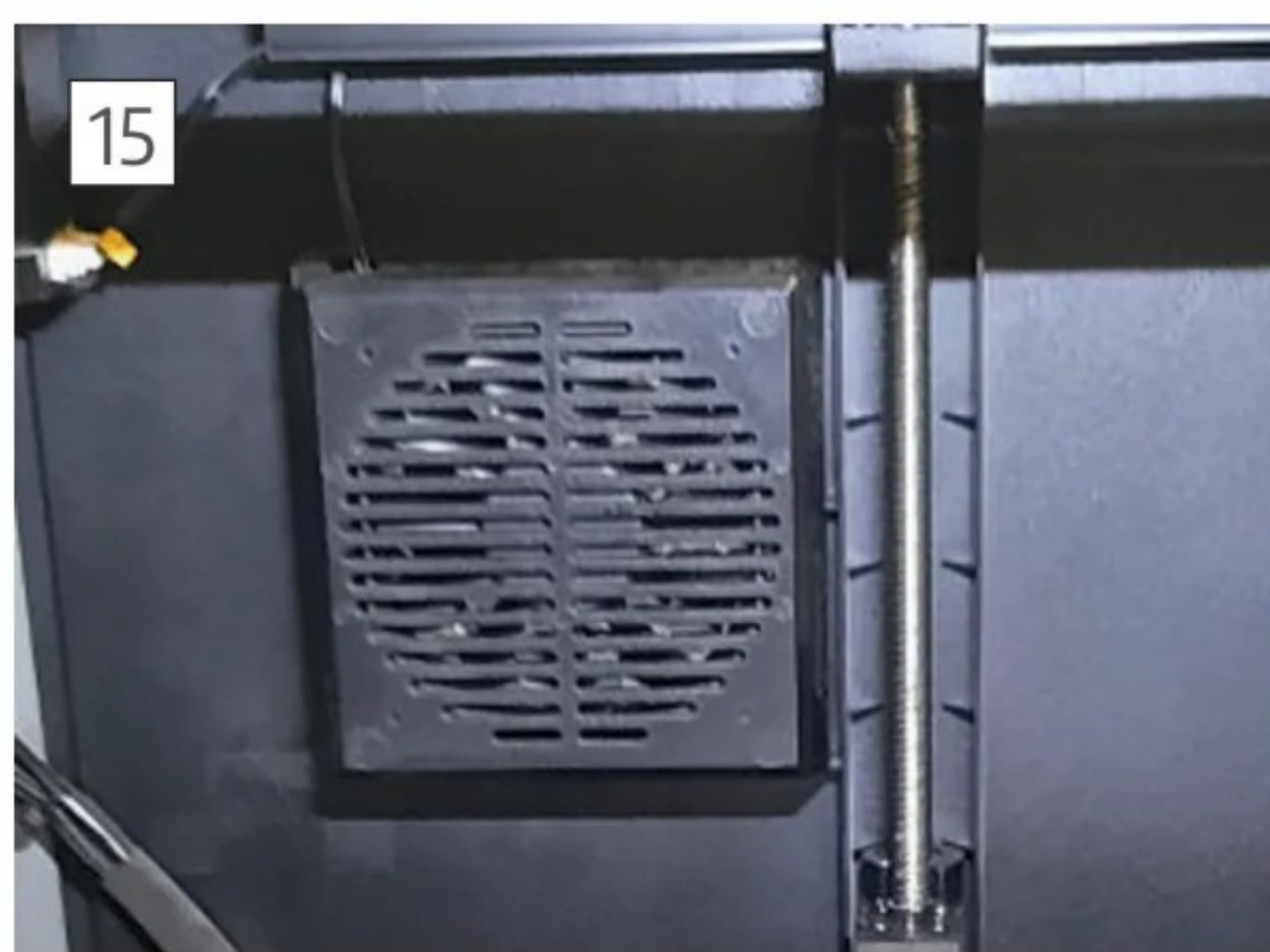
A print on the bed, not 'ghosts' of previous prints in the glue layer.



Peeling a division plate off the flexible bed.

K1-Max has a g-sensor in the print head that detects such resonances, and the machine fine-tunes its speed to avoid this. The 'skulls' printed at maximum speed do not show any such artefacts despite having large smooth areas, **photo 11**.

The printer has external filament stowage on a peg at the back of the machine, **photo 12**, while this works perfectly well, it can be a bit of an annoyance as you have to shift the machine away from the wall to change filament. I have printed off alternative carrier (from a pre-loaded STL) that places the spool at the side of the machine. Filament is fed into the machine via a long tube, but it is not the



The ventilation fan and filter.

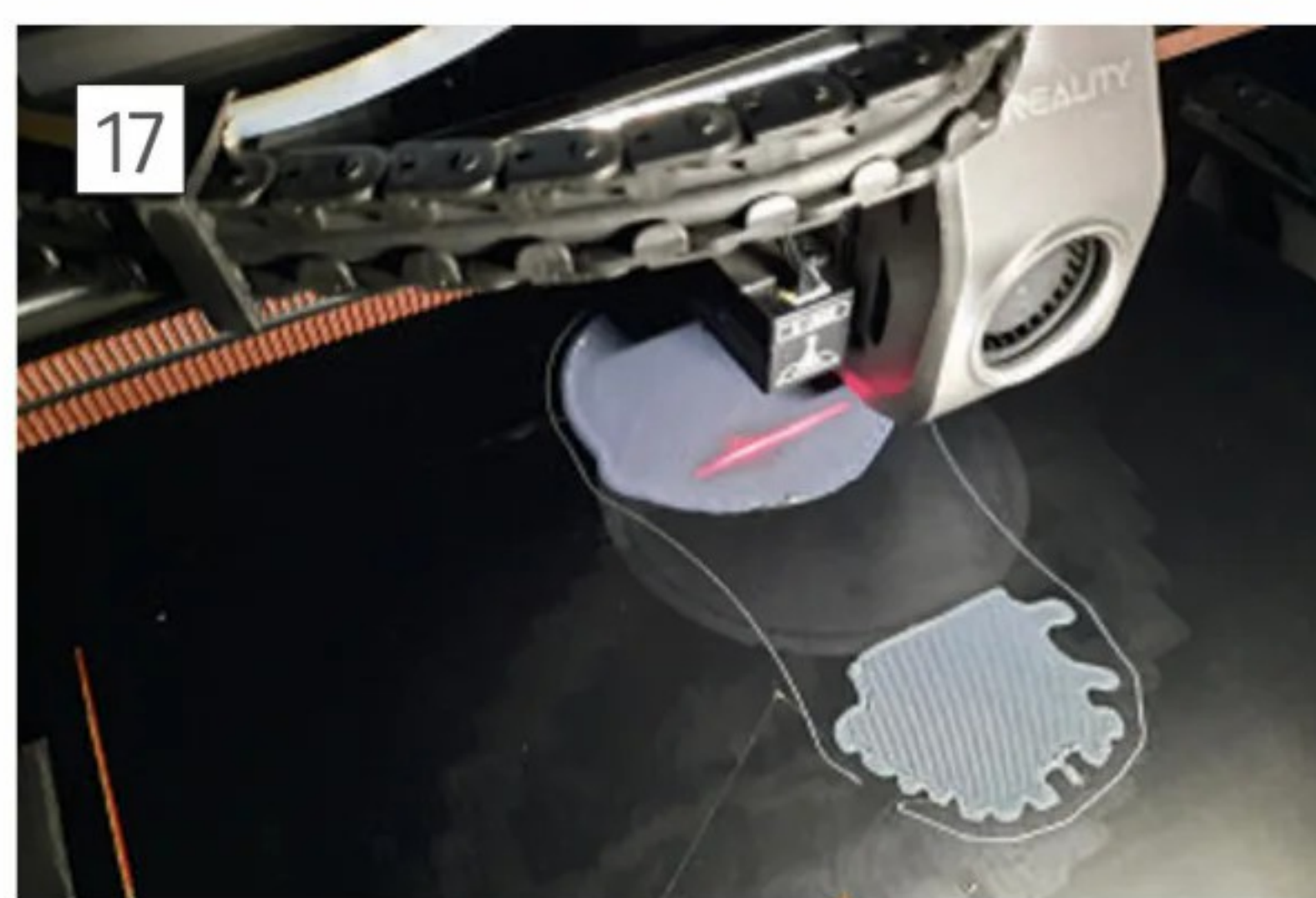


The print head with 'AI Lidar' module.

(less reliable) Bowden tube arrangement some printers use, as the filament is pulled through the tube rather than pushed. One issue is that the tube wears rapidly as it rubs on the glass cover of the printer, I have wrapped the tube in tape at this point to extend its life.

Changing filament is easy; a menu allows you to select 'retract filament', causing it to heat up (rapidly) and wind the filament back. Then you unlock the tube at the top of the print head and pull it out. New filament is simple pushed down the tube until it engages with the drive in the print head. The hot end of the print head is very powerful and heats much faster than that of my old printer. Incidentally, a spare hot end came supplied with the printer, which is a nice touch as heaters do eventually wear out. The printer appears to use steel nozzles and wear so far has been imperceptible – if it had used the brass nozzles I've generally used in the past I would have worn a couple out by now.

The K1-Max has a heated bed in addition to being enclosed and this means that you can print a wide range of filaments. In hot weather it is



Lidar scan of initial layer in progress.

advised to run the printer with the lid removed, especially when using PLA and flexible filaments.

The heated bed warms up very quickly, about 60 seconds. On the heated bed is an easily removed magnetic build plate. Creality recommend using a glue stick to coat the build plate, and this does seem to result in 100% reliable adhesion to the bed. I tried printing without using a glue stick and found the slightly textured surface gave great adhesion until residue built up over a number of prints. While performance can be restored by cleaning down the late with IPA, I have found the glue stick approach more straightforward. You can see the 'ghosts' of printed objects in the glue layer in **photo 13**.

The build plate itself is flexible and can be gently bent to encourage prints to separate, **photo 14**. The only print I have found a bit reluctant to part company with the build plate was itself very thin and flexible.

There is a built-in air purifier with an activated carbon filter, **photo 15**, a useful feature if you are printing ABS or other stronger-smelling filaments. With PLA the machine generates no small whatsoever.

Automation

The K1-Max has a very high level of automation, removing a lot of the tweaking involved in operating simpler printers and also detecting problems to reduce failures and prevent wasted filament. One good feature is genuine auto-levelling. Rather than having an 'assistant' or guide it can be set to calibrate itself before starting a print, and it will probe the build plate area and fully level itself without any manual intervention.

Another useful feature of the printer is that it can remember where it has got to with a print, so if there is an interruption

to the power supply, it offers you the option of resuming the print at switch on. This gives a great deal of peace of mind if you are tackling a big print job. A related feature is that the printer automatically detects when the filament has run out, allowing you to switch to a new roll of filament and resume the print. It's also possible to pause the print manually and switch filaments with little fuss, allowing you to create simple multi-colour prints.

The printer has a number of advanced features. An 'AI Camera' is able to detect if a print object has become detached from the bed or if printing has failed in other ways – in my case it detected when a fragile print broke resulting in a 'bird's nest' of filament and stopping the print. It also pauses the printer if it detects an object left on the build plate before you start a new print, again this is a useful function if you are printing remotely and have forgotten to remove the previous object.

Another AI feature is the 'AI Lidar' which is some sort of 'laser ranging' function. When enabled it scans the initial layers of a print on the build plate with a red laser, to ensure that it has adhered properly, **photos 16 and 17**. Incidentally, this photo shows the 'chain support' for the wiring harness that helps prevent kinking reducing the risk of cable breakages.

Conclusion

I've found the K1-Max reliable and easy to use, delivering excellent results. I've been using it for a few months without any problems, producing prints at various sizes and levels of detail. How such a complex machine will fare in the long term, but it is worth noting that it is designed to be user repairable and that it uses many standard parts. The price of the K1-Max as I write this is £773, from Creality's online UK store <https://bit.ly/3Pq8LDu>, of use the QR code below. ■



The Roll Ranger

When I was offered the chance to review this, I nearly didn't bother, after all it's not an engineering tool. But on reflection, how many times have I spent ages trying to find the end of different rolls of tape in the workshop and elsewhere.

Invented by physicist John Ellis, expectations were high: "Certain inventions solve a problem so easily that you wonder how you ever got through life without it, and the Roll Ranger is one of those inventions! Have you ever struggled searching for the edge of the tape or end up tearing it then opting for a new roll? Roll Ranger has come to rescue, and is the ultimate solution to all your tape troubles."

I have to be honest, this little gadget works wonderfully, reliably finding the end of Sellotape etc. once you have got the knack of moving it along on the roll properly. It uses a metal probe that seems to detect the 'click' as it moves over the end of the tape. Effectively it's an electronic fingernail. The yellow strip on the end is a sharp wedge that does the fingernail's other job of starting the tape, once you have found the end. The only issue I found is that tape with a strong texture, like masking tape, causes too many 'false positives' by not allowing the probe to move smoothly.

I can't say Roll Ranger has been life-changing, but when it effortlessly finds the end of a big roll of sticky tape, it does bring a smile to your face.



New Clarke CMW-8B 8 Drawer Wooden Machinist Tool Chest

Readers who want to use the traditional approach to storing their tools will appreciate this stylish wooden Clarke chest from Machine Mart.

This traditionally styled chest is an attractive addition to workshop, providing storage and protection for fine and delicate tools and equipment, or other small collectibles such as jewellery, coins, medals and shells etc.

The CMW-8B has a stylish stained pine construction with antique brass finish steel hinges and reinforced corners. It also features a convenient carry handles for easy portability.

The tool chest features a felt-lined top compartment with machinist safety mirror, with a front door folding down to provide a work table, ideal for use by jewellers, watch/clock repairers or for hobbyists using delicate equipment.

There are also eight felt-lined drawers to help protect the contents from moisture damage, and to also stop them from sliding if the chest is transported anywhere, preventing further damage.

The Clarke CMW-8B 8 Drawer Wooden Machinist Tool Chest is available now for £107.98 inc VAT in store or from www.machinemart.co.uk.



Is 6G Technology the Future for Cars?

An F-35 fighter plane has 8 million lines of code. A modern car, by comparison, has hundreds of millions of lines of code. The car is on its way to becoming an even more demanding software platform than the cell phone, says Tero Päivärinta, professor of Empirical Software Engineering at the University of Oulu, Finland.

"The car is an IoT device [Internet of Things] and a very software-intensive one. From a researcher's point of view, there is an enormous amount of things to investigate and problems to solve," Päivärinta says.

As society pushes toward smart traffic that's populated with semi-autonomous vehicles—and eventually fully autonomous ones—the interoperability of different systems is crucial. For traffic to become safer, cars and other vehicles must be able to react to their environment and to other vehicles.

"We create huge demands for mobile communications and connectivity if we want cars to be aware of their context. But we also need software for connectivity, for controls that assist the driver, and eventually for work and entertainment applications. All these interfaces will have to be standardised to ensure interoperability," Päivärinta explains.



If we look at mobile phones today, we can get a fairly clear idea of what the car will become in the future. Phones are very complicated devices that nevertheless work together: you can use any manufacturer's cell phone in any operator's network to call any other cell phone worldwide. The infrastructure and interoperability we take for granted when making a phone call or posting a selfie will have to be developed for smart cars driving on smart roads in smart cities. The smart traffic of the future is not only wheels on asphalt; it is also vehicles aloft, up in the air.

"Urban air mobility changes the game significantly. When you can

use elevation, you get quite literally a completely new perspective on any given situation," says Jussi Haapola, an Adjunct Professor at the University of Oulu, who is working on vertical application areas of wireless communications.

6G is not the end goal but rather an enabler of things, something both Päivärinta and Haapola are keen to emphasise. "I want to have 6G be like air or electricity, something that makes things happen but without us having to think about it," Haapola says. And in time, faster and more reliable data transfer and computing will help us create the smart traffic of the future.

Upgrades to an Optimum tu2004V Lathe Part 1

Ron Sharp in Australia downsized after a house move. He recounts his experiences with his Optimum lathe.

Just over two years ago my wife and I moved house, and I lost my practically unlimited workshop space and had to make use of half of a double garage instead. I sold off the medium size lathe and 2 milling machines I had owned for years and purchased a small lathe and mill to replace them. This article will describe my experiences with the lathe and a couple of upgrades I have made to suit my way of working.

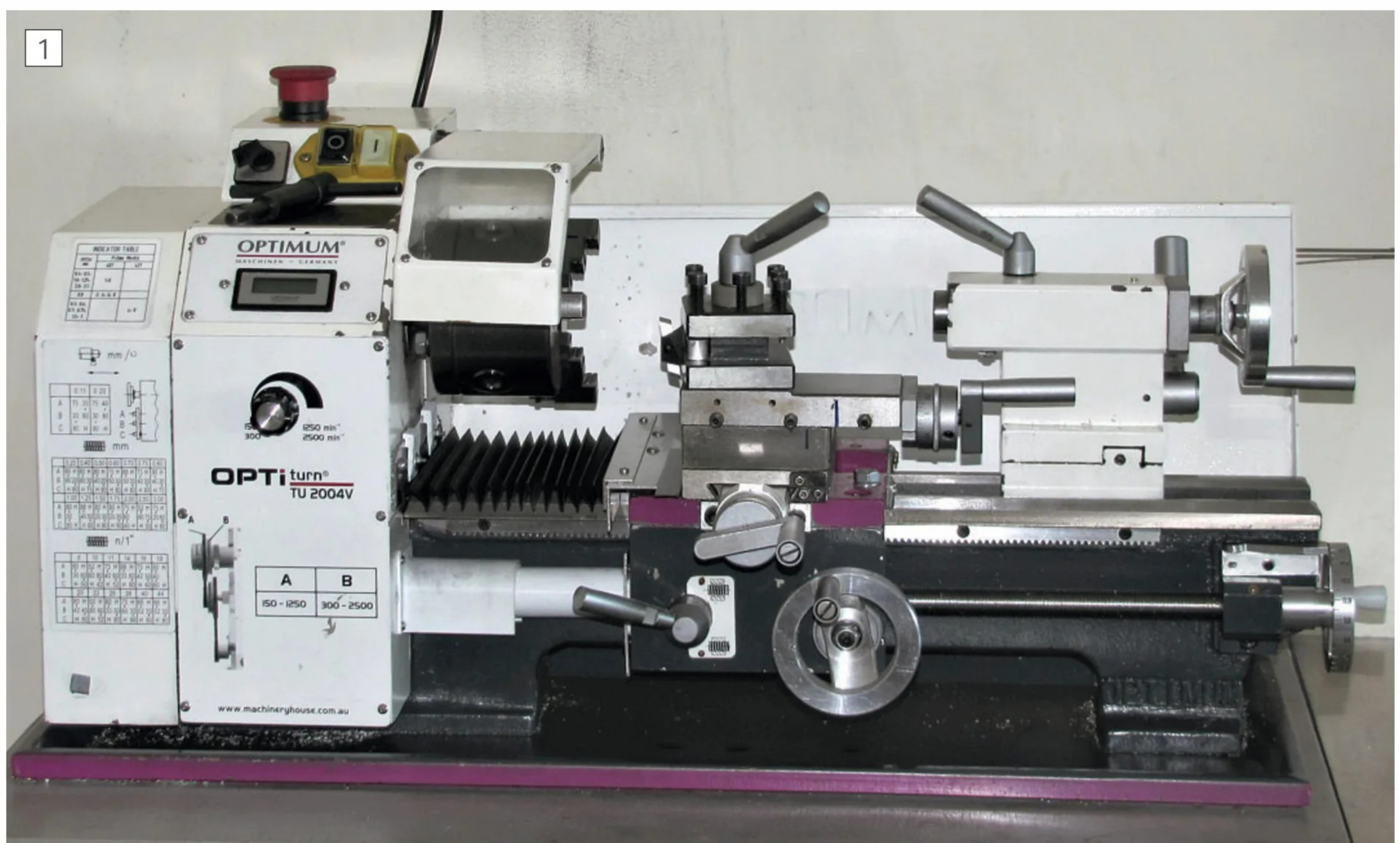
Here in Australia, there is not a great choice of this type of equipment and – partly due to local supplier support – I decided to get the Optimum tu2004V that was available in stock. It is a small benchtop machine weighing 65kg. Centre height is 100mm (200mm swing) and distance between centres is 300mm.

The spindle has a Morse Taper 3 and the tail stock a Morse Taper 2. A fair range of metric and inch size threads can be cut with the supplied gears. A key feature for me is that it is a genuine metric machine, and the hand wheel indices are marked in mm.

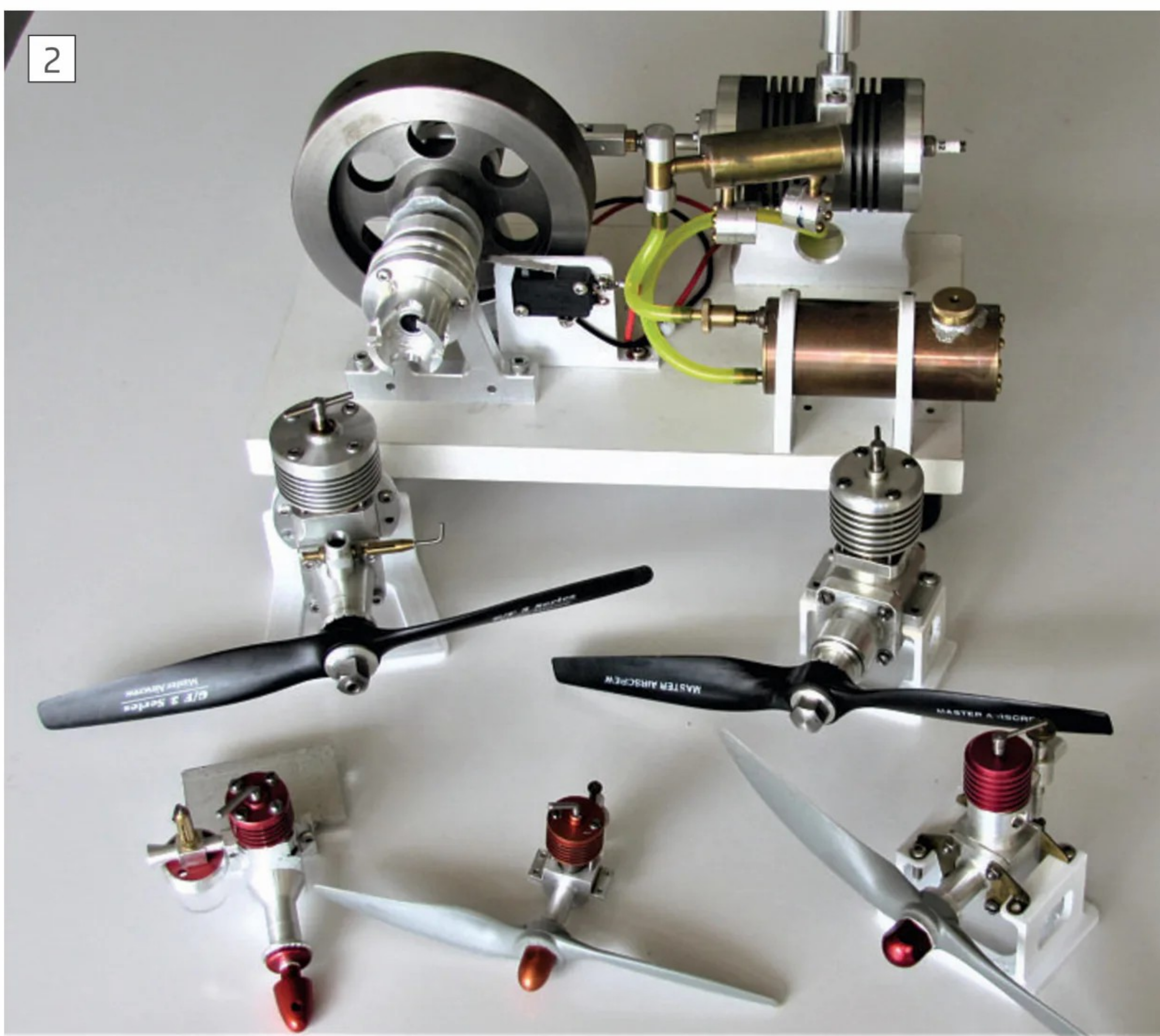
Two features I have particularly enjoyed are the variable speed spindle drive with indication of the actual spindle speed and the calibration of the cross-slide hand wheel to show the effect of a cut on part diameter (if a cut is say 0.2mm the slide shows that the part diameter will reduce by 0.4mm). This seems logical – most turning work is based on work diameter but needs watching when threading or cutting grooves in the work.

The machine is nicely presented and finished in an off-white paint. It is marked “Germany” but is apparently manufactured in China, **photo 1**.

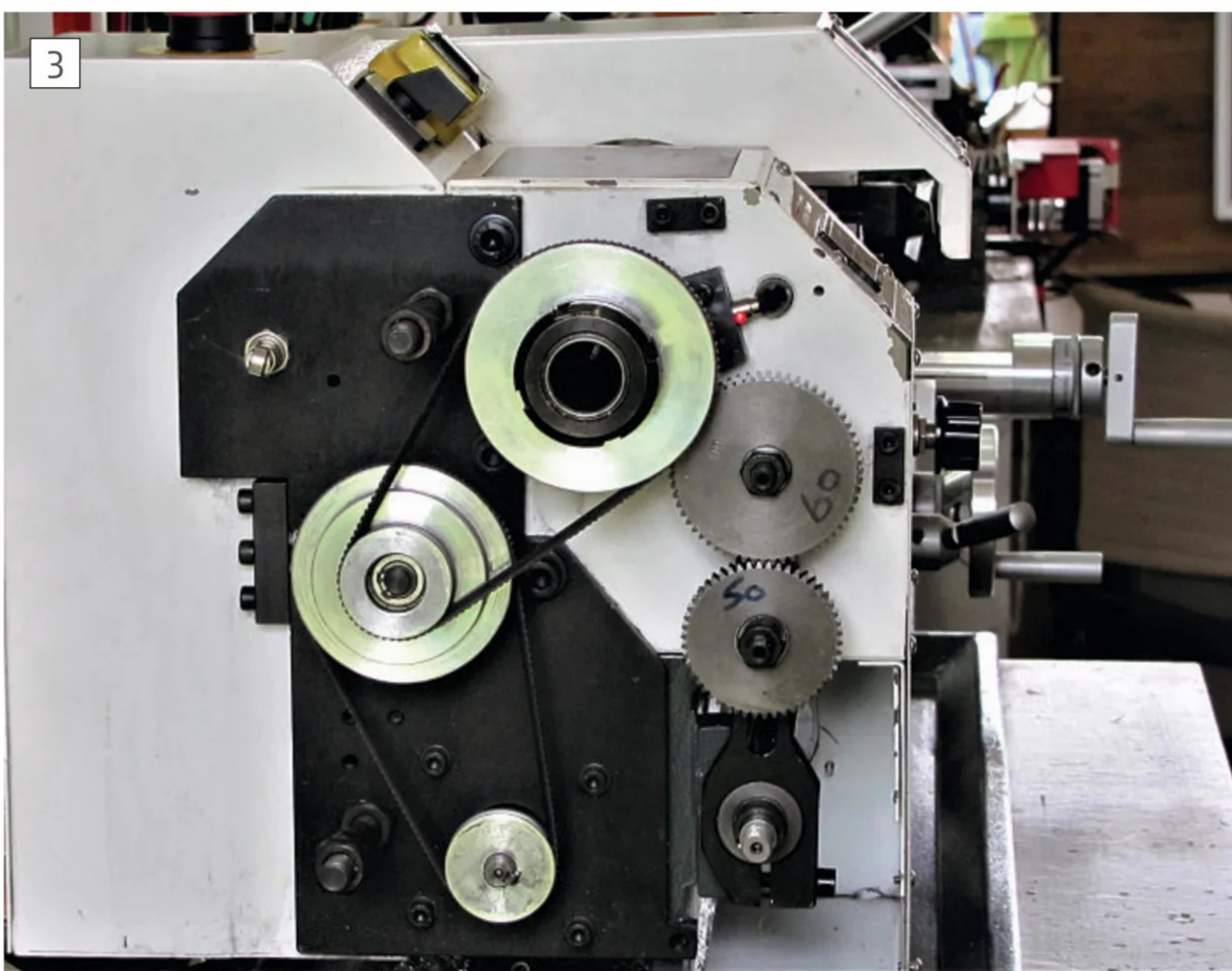
I have used my new lathe very frequently during the past two years on a variety of applications – mainly concerned with making small IC engines, **photo 2**. These engines have all turned out successfully and I have found the lathe a pleasure to use. It is quiet in operation and the controls come easily to hand. The small size – particularly the short distance between centres – takes some getting used to and when not in use the tailstock chuck is best removed. I frequently remove the tailstock as well to provide access for hands and calipers etc.



Lathe general view



Some items made recently on the Optimum lathe. The flywheel on the big engine is 110mm dia and the cylinder is 46 mm dia – both machined from cast iron bar on the lathe. No problems were encountered.



Lathe gearing to the leadscrew. Shows leadscrew gear removed and banjo rotated to clear the spindle gear. These are necessary for hand operation of the leadscrew.

The screw cutting and power feed systems work well, and the change gears seem of good quality in cast iron or steel. The gears are easily changed when required.

Please don't ask what maximum cut can be taken on this or that material. My style of working is to use sharp tools and cuts that are well within the machine capability – and to aim for

the best finish possible. That is how to enjoy the process and the actual turning hours on a small engine are not high.

At an early stage I did identify a couple of areas that I would like to improve:

First, the saddle hand wheel used to feed the saddle back and forth is quite high geared – the saddle moves 25mm per revolution. This is fine for moving the tool into position, but I found it difficult to use when actually making a cut. I decided to fit a lead screw hand wheel to allow easier control of cut feed and distance. These hand wheels are frequently referred to in older publications on hobby lathe work but do not seem to be seen on any but the smallest lathes.

Use of the new hand wheel would require disconnection of the gearing (to the spindle) that would be used to provide power feed or screw cutting but this is a simple matter and can be restored very easily. Disconnection of this gearing results in quieter operation of the lathe. Screw cutting is also not affected, **photo 3**.

Second, the cross-slide screw has a plain collar arrangement to take the thrust when the screw is rotated. This can result in stiff operation – particularly if the slide gib strip is set fairly tight. I decided to fit ball races to take this thrust and improve the feel of the operation.

I would like to emphasise that operation of the lathe was satisfactory before these changes and that I made them for personal preference. I would certainly purchase the same lathe again.

The Lead Screw Hand Wheel.

My aims with this hand wheel included:

1. A generous diameter for easy and sensitive operation
2. Index marking to allow precise carriage movements
3. Hand wheel to rotate without much wobble (there are some shockers on the internet).

I considered a friction index setup to allow setting the index to zero when required. This was discarded as it is generally possible to use the top slide (compound) to provide a similar facility (see below under Operation).

I was lucky to have a short piece of thick-walled aluminium pipe available –

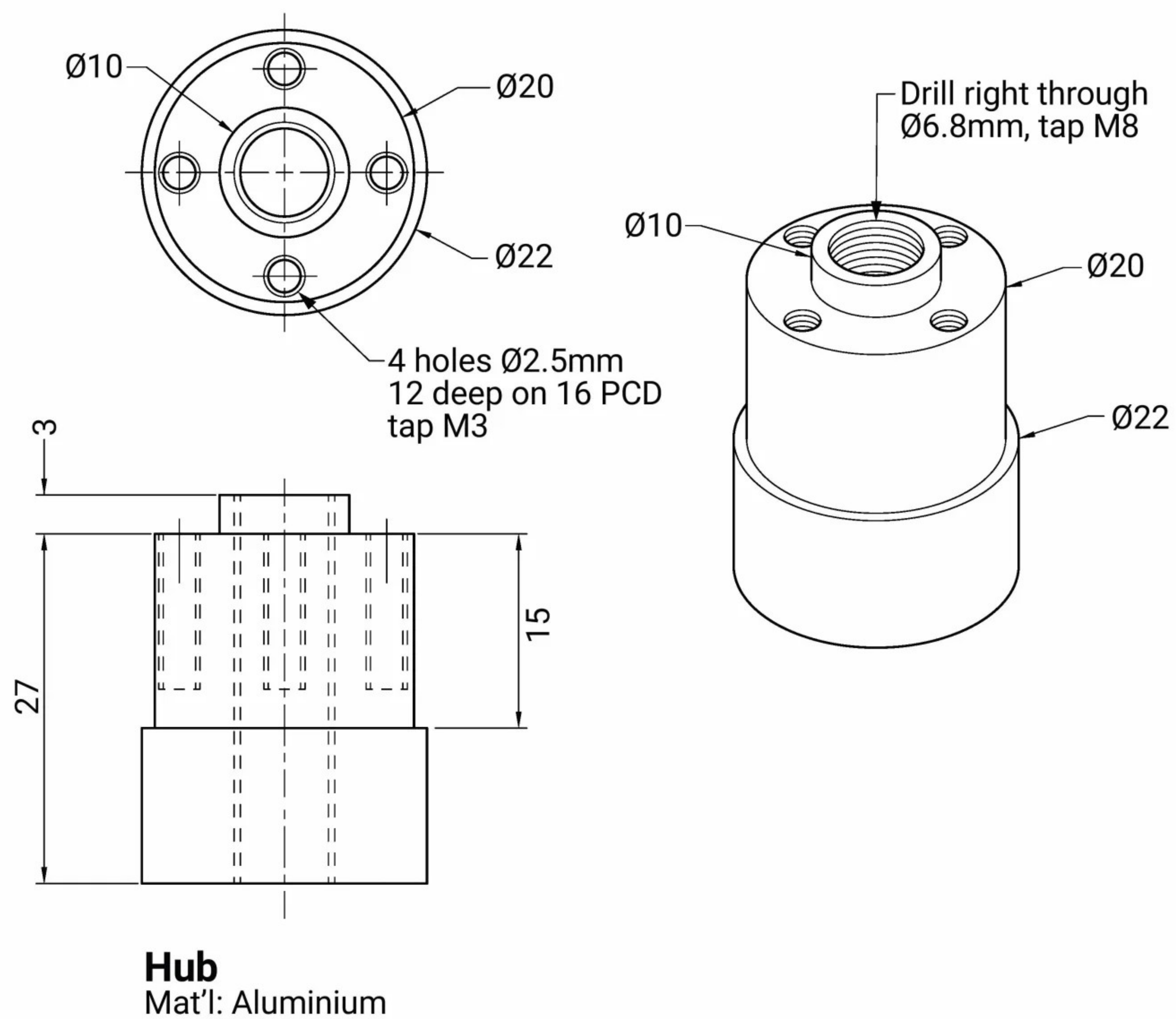


Figure 1

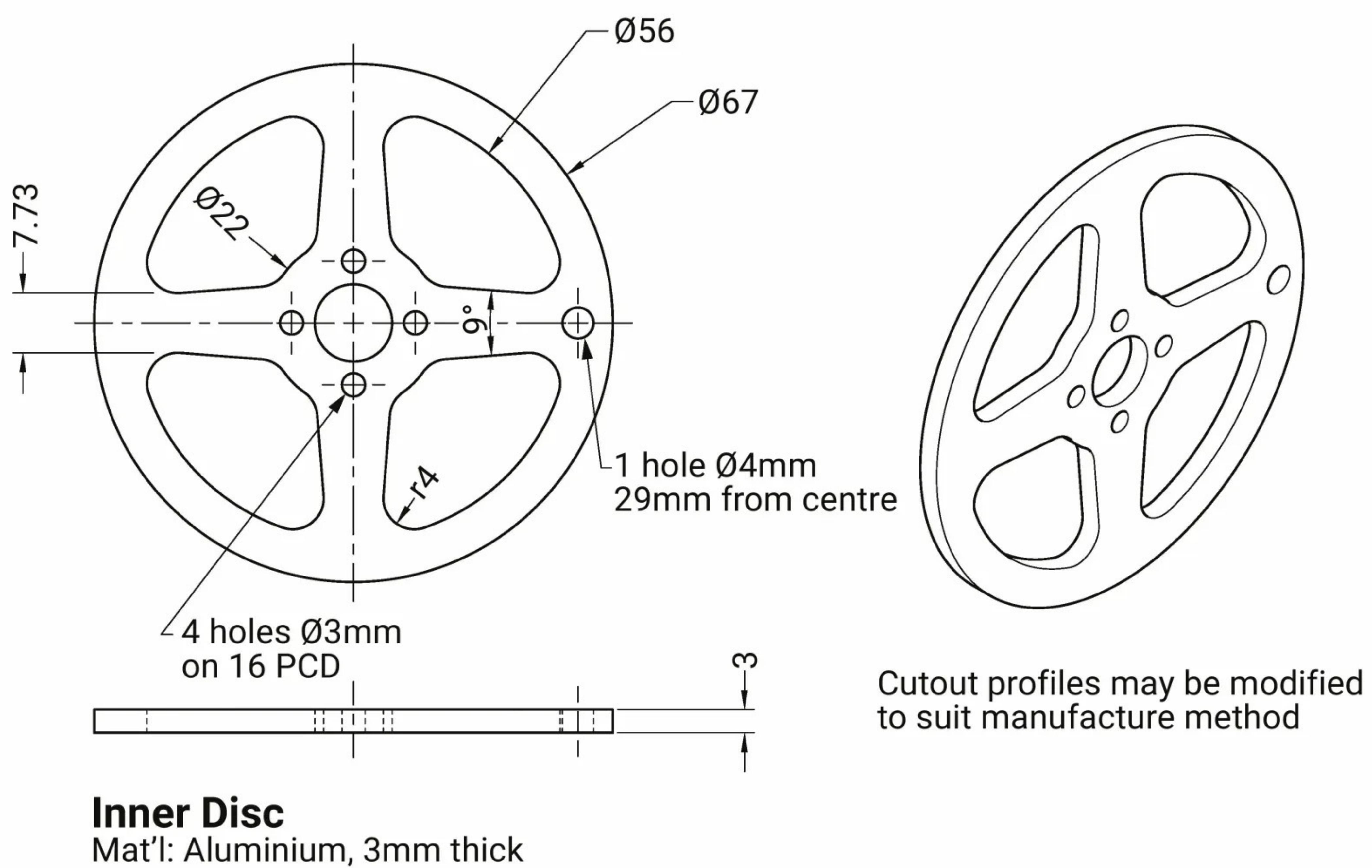
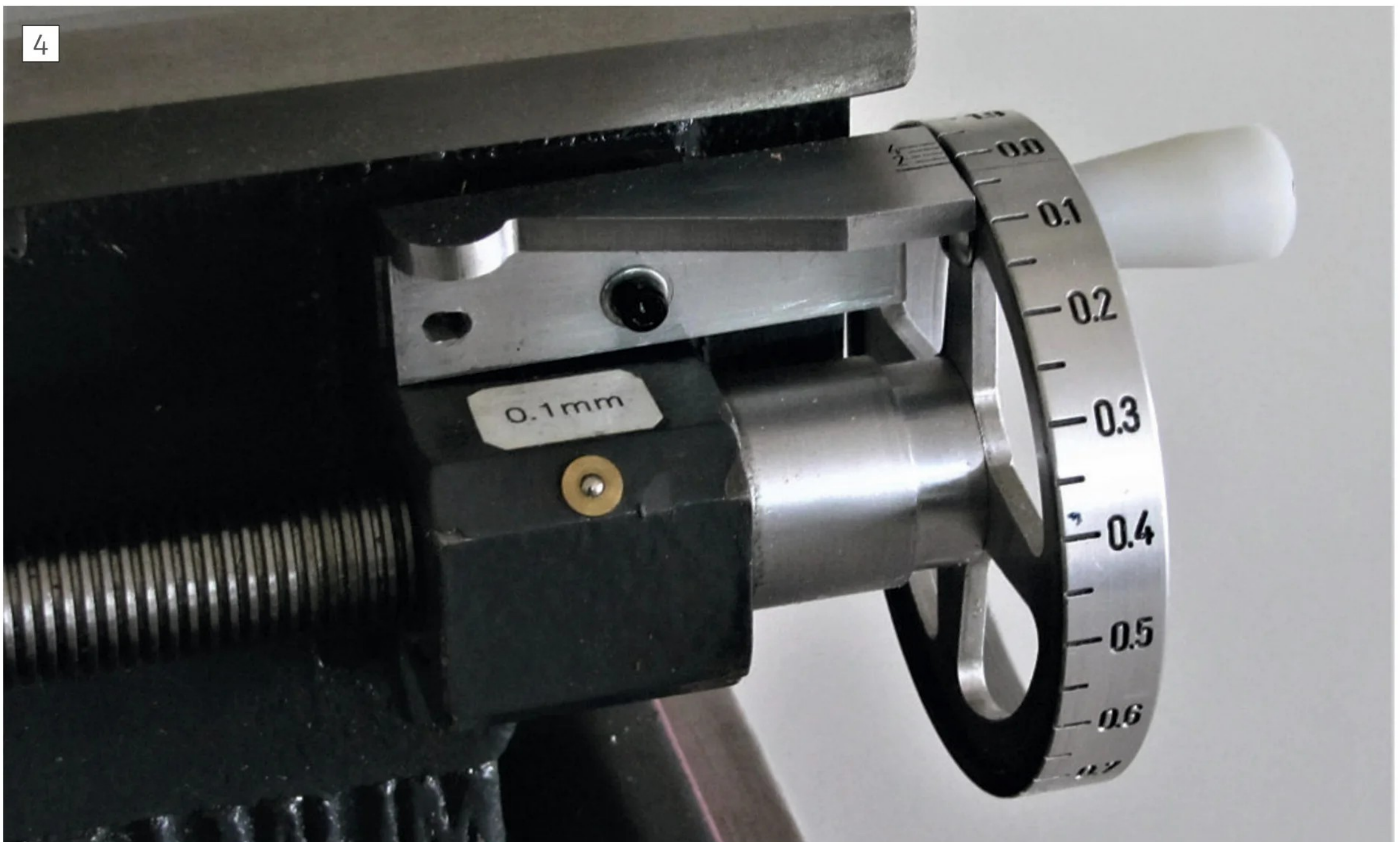
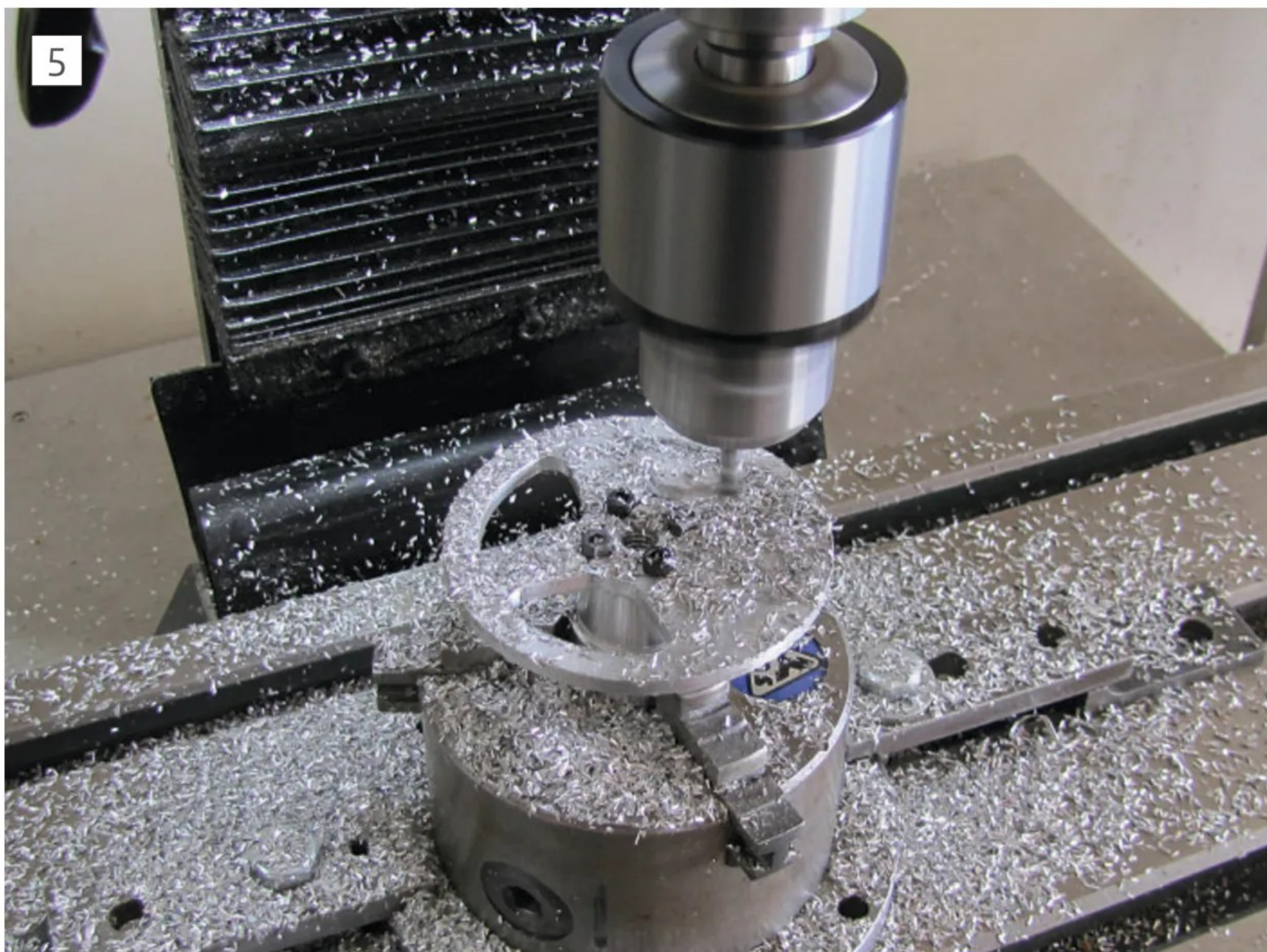


Figure 2



Existing handwheel as made 2 years ago. Division markings by CNC.



Machining the inner disc with Optimum mill using CNC.

it is two and seven eighths inch or just over 73mm and I used a piece of that – finishing nicely to 72mm. I will describe using a piece of this pipe – with brief comments at the end for alternative methods for those without a suitable piece of pipe. A set of drawings and a 3D view are provided, **photo 4**.

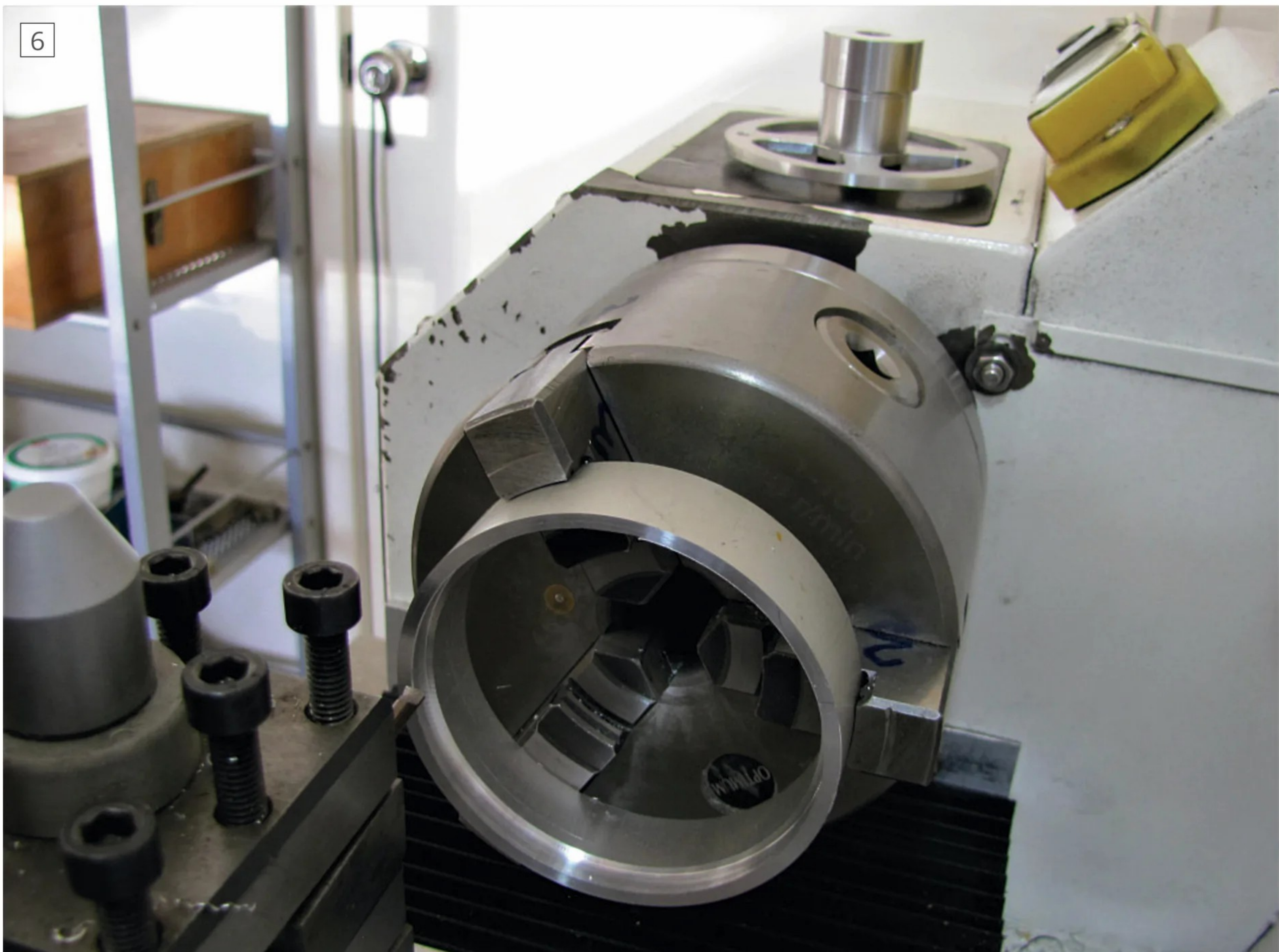
First part to make is the Hub, **fig. 1**. This is a simple turning job from a piece of 22mm aluminium bar. I cut off a piece just over 30mm long and cleaned up the outside diameter for about half the length. While still in position in the chuck I faced the end off true and drilled a 6.8mm hole right through

the bar. This hole was then tapped M8 using tail stock support to ensure the thread was true to the machined end. This is important as the 22mm diameter face will bear on the lead screw thrust bearing.

The part was reversed in the chuck and the 20mm section turned to size followed by the 10mm spigot. It was then mounted in a chuck on the milling table, centralised and the four M3 holes drilled and tapped. The hub was then complete and could be used to hold the inner disc.

The inner disc, **fig. 2**, was made using my Optimum (converted to CNC) milling machine. A piece of 3mm aluminium plate was cut about 70mm square and the centre marked. In the mill it was drilled with the 10mm centre hole as well as the four 3mm holes and a 4mm hole for the handle. This plate could then be mounted securely on the hub piece for machining to profile.

I mounted the assembly in the chuck on the milling table after setting the chuck true under the machine spindle. The aluminium I used was certainly not free cutting and as I do not have coolant to clear the chips when machining I used the following method to get clean machined edges. The outside diameter



Machining the outer ring – well within the chuck capacity.

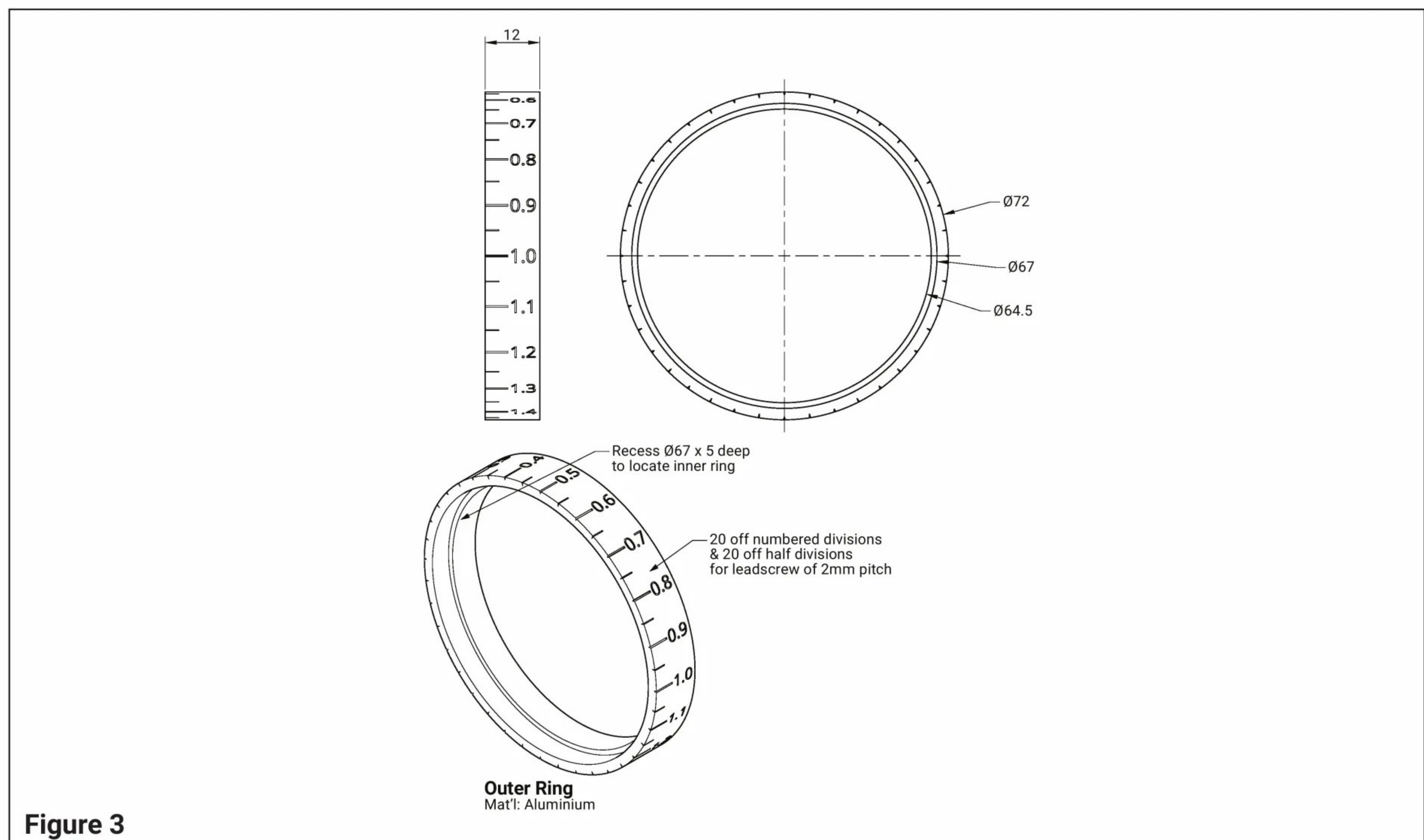
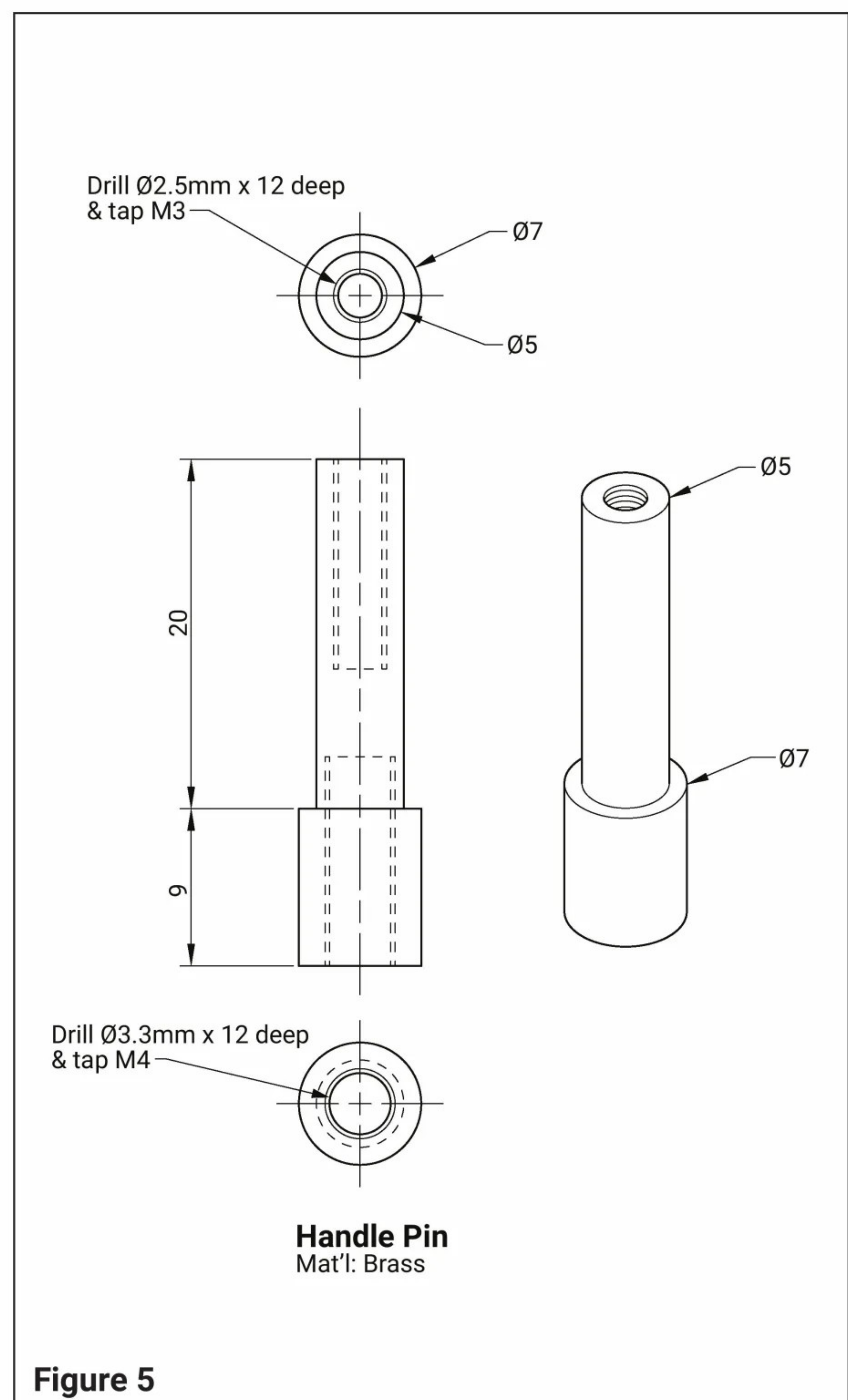
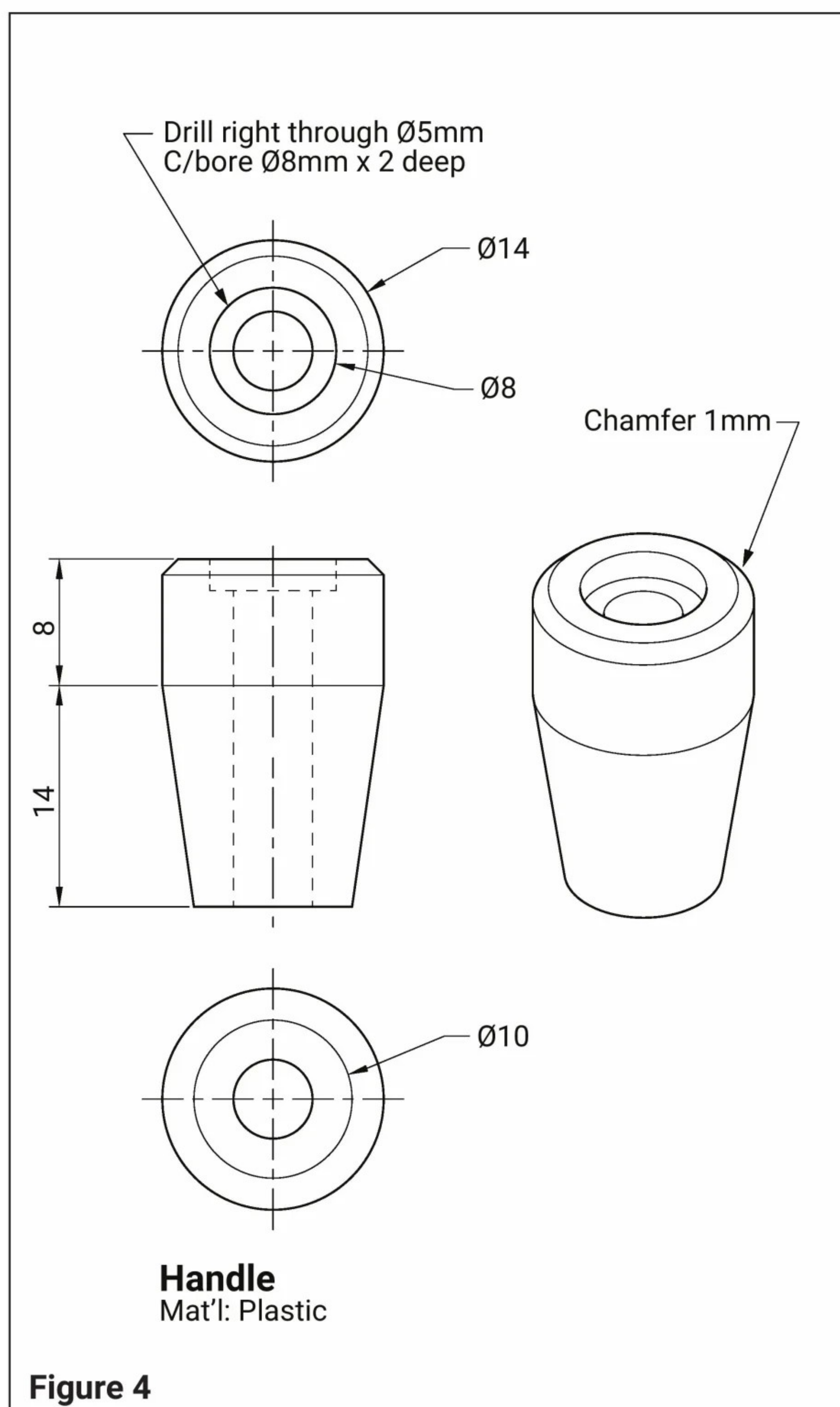


Figure 3



was machined 0.25mm oversize to be cleaned up in the lathe later. The cutouts were all machined at 0.25mm undersize followed by a final cut on the line. After deburring the disc was complete, **photo 5**.

Outer Ring, **fig. 3**, this was cut from a piece of pipe as above. With reversed jaws in the lathe chuck it was set up and the outer end machined true, followed by the 67mm diameter by 5mm deep recess. The balance of the inside surface was left as supplied, **photo 6**.

The inside chuck jaws were refitted and the ring mounted on the outside of the jaws (via the recess) to allow turning to length and cleaning up the outside to 72mm OD. Outer edges were given a very small chamfer. At this stage the outer ring was bonded to the inner disc with a securing compound and left overnight for the compound to fully cure.

Graduations.

The graduations were completed on the CNC mill. As I do not have a CNC rotary table, I used a chuck mounted on a manual rotary table to carry out the dividing. At 20 divisions for the longer index lines and the numbers the move is 18 degrees each step. This is 4.5 turns of the table hand wheel. The table could then be rotated 9 degrees followed by the 18-degree steps for the short lines. I like to draw up a spreadsheet with the angles required to check table position as I proceed.

With the table set to zero degrees the handwheel was mounted in the chuck with the hole for the handle in line with the zero. The first index line was made using a 60-degree point engraving tool. Line length was 4mm and depth of cut 0.3mm. Rotating the table 18 degrees each time, the balance of these lines was cut. The shorter lines (3mm long) were next.

Engraving files in G-code were made with 3mm numerals also for a 0.3mm depth of cut for all required figures. (0.0, 0.1, 0.2 etc). By rotating the table 18 degrees each time and loading each successive file the numerals were easily engraved around the ring.

The assembly was mounted in the lathe and the outside cleaned up with fine abrasive paper and a washing up pad to remove burrs and provide a smooth (nice to handle) surface.

Handle Pin and Handle, **figs 4** and **5**. These are simple turning jobs. The handle was made from a piece of plastic round bar – sold as Teflon I believe. The profile can be modified to choice. Make it first then the handle pin as you will likely find the drilled hole in the plastic is undersized and the pin can then be made to fit and give easy rotation.

● To be continued

TOAD5 for CNC Control

Following on from the last issue's profile of EaztCNC, Kusti Nyholm describes the latest iteration of his TOAD CNC hardware.

I was and still am pretty happy with the overall design of TOAD4. It is minimalistic, compact, and fit for purpose -- a one board system for a medium sized hobby CNC. I had no real plans to revise it anytime soon. But then circumstances conspired against me, and one thing led to another.

I got requests for more axis and more oomph for the axes. Some people wanted 'standard' screw terminals for all the wiring. One or two people had problems with EMI and USB. But the real clinching moment was when the Chinese company JLCPCB appeared on my radar.

Modern product development

JLCPCB offers free assembly of surface mount components on small quantity PCB prototypes if you buy the components from their selection.

Surface Mount Devices (SMD) offer several advantages, they are significantly smaller and cheaper and are specifically designed for mass production fully

automated assembly. The downside is that I don't think they are really suitable for the average hobbyist though some advanced people have the facilities and skills to use them.

I was skeptical at first but all the components I needed were available as SMD and more importantly available from JLCPCB inventory at very acceptable prices for very small PCB quantities. My initial order was for just five boards!

My old PCB design software was no longer available and the DipTrace free edition which I had dabbled with was too limited, so I decided to take the plunge and learn KiCad. It is very different from most other software, so it has a learning curve but with the right attitude and motivation it proved to be actually very good. It can even produce nice renderings of your design which really helps to visualize component and text placement, **photo 1**.

I'm still amazed that we are in a point of history where an individual person

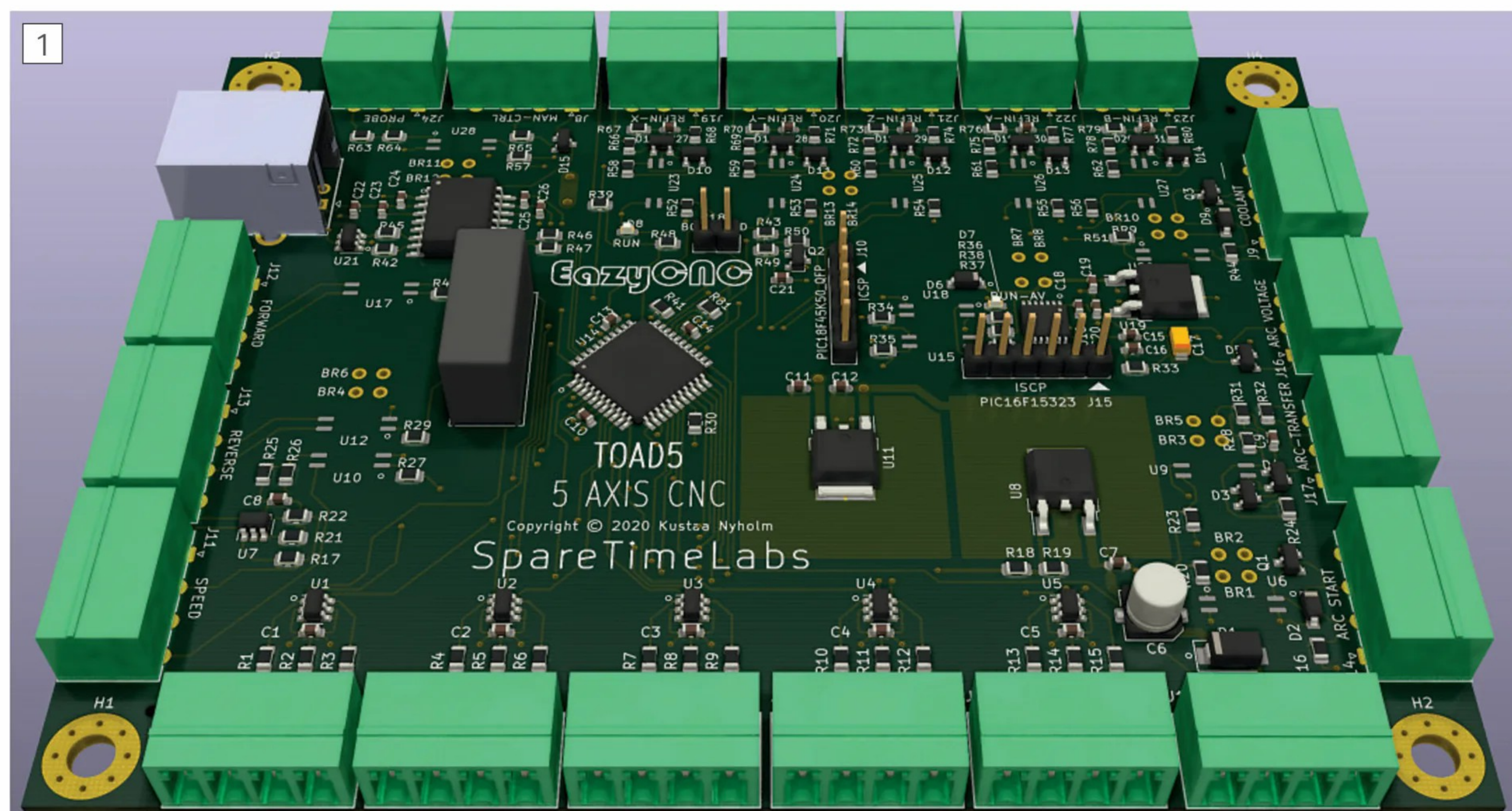
with limited means can design a complex electronic board with free (in every sense of the words) tools sitting comfortably on their lazy-chair and have it delivered on their doorstep in week or two.

That is some holiday activity for you right there!

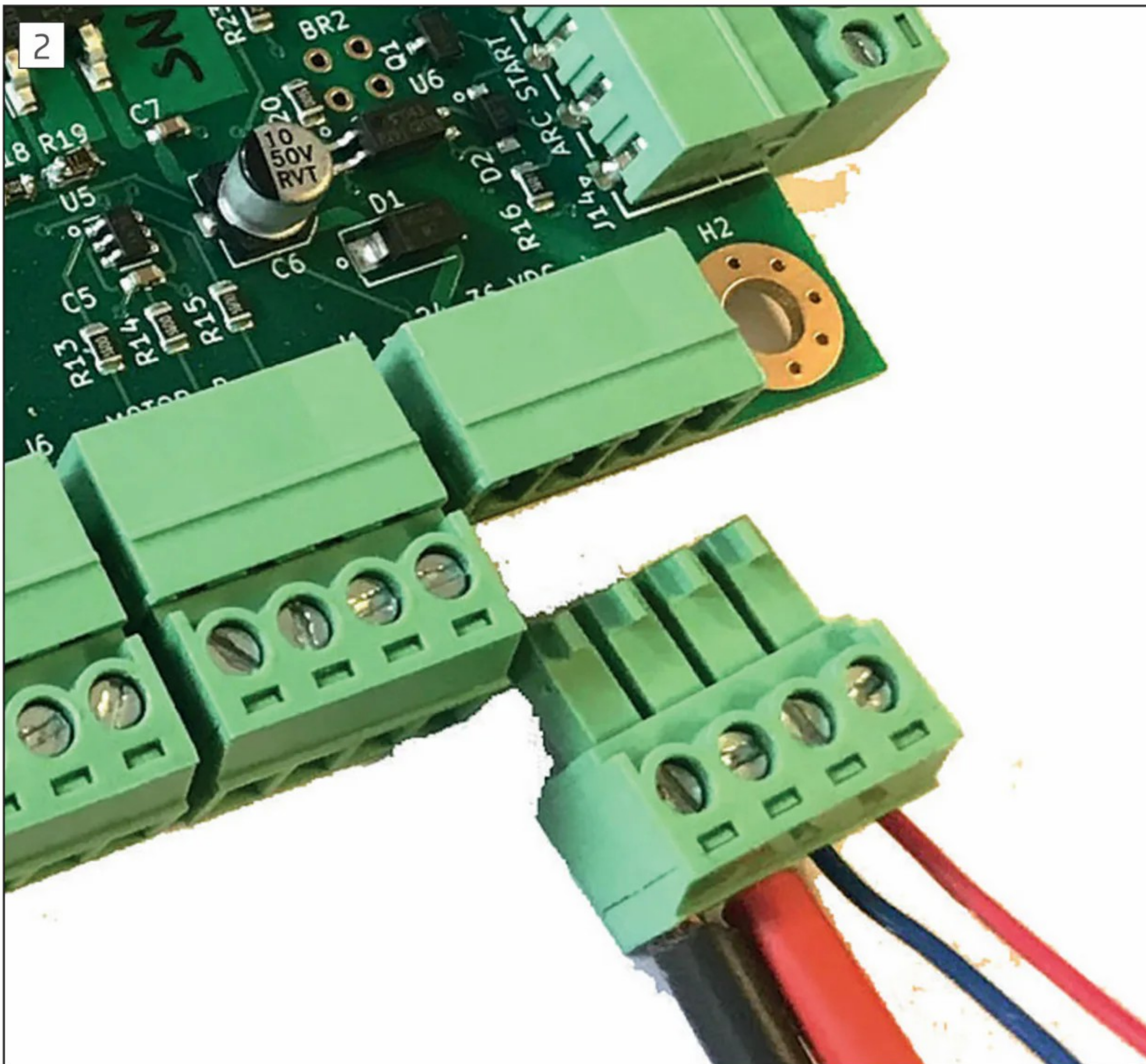
INTRODUCING TOAD5

There is a complete manual of TOAD5 with detailed description of all the features and full schematics on my personal website. In this article I'll discuss some the design decisions and highlight some interesting technical details of TOAD5.

The main difference compared to TOAD4 is that TOAD5 does not have the stepper motor drivers incorporated on to the PCB board. This allows flexibility with the choice of drivers, making it possible to use higher current motors or take advantage of the incredibly cheap Chinese driver offerings or use servo motors as long as they conform to the



A computer rendered image of TOAD5.



Screw and plug terminals.

STEP and DIR method of control. Servo motors are superior to stepper motors in almost every way, except price.

Outputs

TOAD5 board has following outputs:

- 5 x STEP, DIR and ENABLE outputs for stepper drivers
- COOLANT control output, relay compatible
- FORWARD and REVERSE outputs to control a spindle via a VFD
- Analogue SPEED (0..10V) output to control spindle speed
- ARC START output for controlling a plasma torch, relay compatible
- RUN LED output

Inputs

The following inputs are available on the board:

- 5 x REFIN switch inputs, compatible with proximity switches
- Touch PROBE input
- Analogue ARC VOLTAGE input for torch height control
- ARC TRANSFER input to synchronize cut start with arc start up
- MAN-CTRL connection for Manual Control Panel
- ESTOP input to kill all outputs

Stepper Control Outputs

For each axis/motor STEP, DIR and ENABLE signals are provided. These are referenced to ground and protected against electrostatic discharge (ESD) but are not optically isolated because most motor driver modules already have opto-isolated inputs.

Isolation

Except for above mentioned axis control outputs everything else is optically isolated. All outputs are completely isolated from everything else.

All inputs are isolated but are fed from a single on-board DC/DC converter. There are very few use cases where complete isolation is called for. But if necessary they can all be isolated from each other by drilling through vias provided for that purpose on the PCB.

The on-board DC/DC is adequate for most applications but if you need to max out every input and output you may run out of juice in which case an external 12V supply can be used. All the inputs and outputs are on their own 'islands' on the PCB which can be isolated from each other by simply drilling through conveniently placed and clearly marked plate through holes.

Powering the board

The board needs a single DC voltage supply in the range of 24 - 36V DC. This allows operation from common 24V DC switch mode power supplies or from a rectified and filtered 24V AC. In fact, with some additional cooling up to 60V DC can be used, which may come handy if your stepper drivers need that much voltage, saving you the expense and space for a separate PSU for the TOAD5 board.

Careful power balancing allowed me to get away without any heatsink reducing cost and mechanical complexity.

Screw terminals

I was reluctant to use screw terminals for the wiring because I think that service and troubleshooting are better served with connectors. But then I realized that there are pluggable screw terminals which offer best of both worlds, no need to solder or crimp wires and yet you can just un-plug a wire when necessary, **photo 2.**

Isolated USB!

USB is not the best choice for interfacing high current and electrically noisy equipment so isolation is very attractive and should go a long way to reduce EMI (Electro Magnetic Interference) problems.

USB isolation is much more complex than just throwing one or two opto-isolators on the board.

Luckily, I discovered that a USB isolator was available from JCLPCB inventory, which allowed me to incorporate this feature

Plasma Cutter Controls

I use one of my TOAD4 boards to run my plasma cutter. One glaring (no pun intended) omission is that it has no Torch Height Control. THC keeps the distance between the work piece and torch constant, which helps to keep the cut width consistent and is essential if (or when!) the work piece tends to warp.

To remedy this omission, I included an optically isolated analog to digital converter to the design of TOAD5. There is a direct correlation between the arc length and the arc voltage so by measuring and keeping the arc voltage constant the torch is kept at the optimum distance.



Proximity sensor.



Econo probe.

I also added an input for 'arc transfer' signal which is used to signal to the TOAD5 that the initial plasma arc has transferred to the workpiece and thus the optimal time to start the torch movement. All plasma power supplies that are aimed at CNC have the 'arc transfer' output.

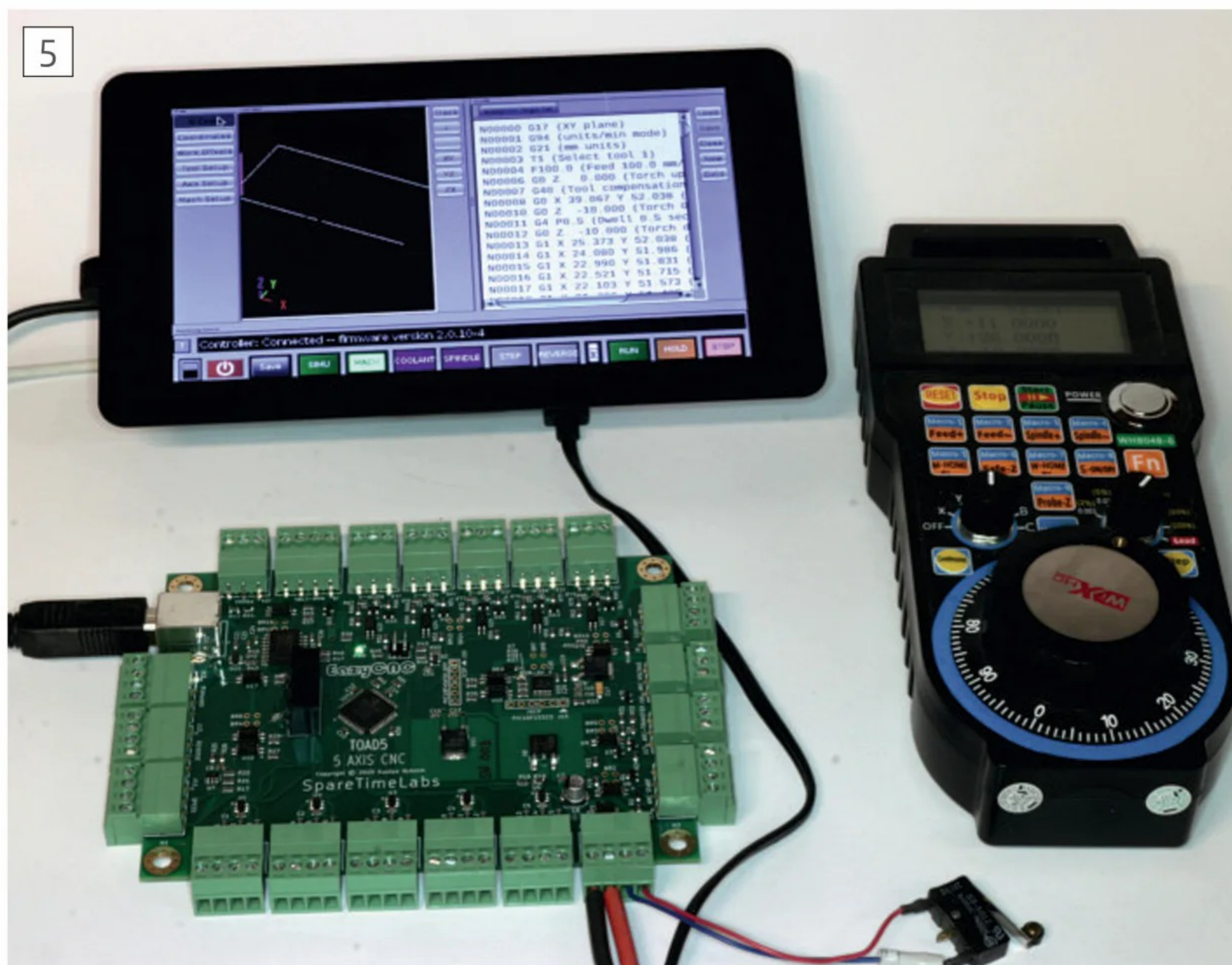
The hardware for these features works but I still have work to do on the firmware, so as of this writing this is a work in progress feature.

Compatible Inputs

Naturally the board also has inputs for reference switches for each axis, a digital probe input and outputs to control a spindle via a Variable Frequency Drive.

The reference switch inputs are interesting in that they are compatible with both mechanical switches and both PNP and NPN style proximity switches and optical forks, **photo 3**. NPN and PNP refer to the type of output transistor in an electronic switch, in practical terms this indicates whether the transistor pulls the output down against ground (NPN) or up (PNP) towards the supply voltage of the switch, which voltage the board also supplies.

This is implemented by a clever little circuit that a good friend of mine supplied, thanks Christian, see **fig 1**. This has quite a few components and it was only feasible to include this feature thanks to the SMD technology. I include a schematic snippet here because I think it is an interesting little detail. To make sense of it you can think that the



Complete control system with MPG pendant.

circuitry treats the input signal as an AC (alternating current) and 'rectifies' it.

Optically Isolated Analog Input

Another interesting detail is how the isolated analog to digital conversion is implemented. It turned out that the most economical way to implement this was to add a single-chip micro-controller just for that.

The MCU I chose costs less than 85 cents and includes 10-bit analog to digital converter and a serial communication port to send the conversion result through an opto-coupler to the main CPU. I find it interesting that a general purpose MCU based solution is cheaper than chips specifically made for the task.

Relay Controls Without External Power

The outputs for coolant pump and plasma power supply can directly control 12 V relays using power from the on-board isolated DC/DC converter and the relay output FET is protected against inductive kickback. The 'raw' output from the opto-coupler is also available, which can be used e.g. to control a VFD driven coolant pump on and off.

Variable Frequency Drive Control Outputs

The VFD control outputs are simple

opto-isolator outputs compatible with both pull-up or pull-down style logic inputs of most VFDs. The ratiometric analog speed output for the VFD speed control is improved compared to TOAD4.

Probe input

The probe input is compatible with 'Econo-Probe' style touch probes or any probe with mechanical switch or NPN -type output.

Econo-Probe, **photo 4**, is a product that utilizes the famous Renishaw mechanical switch arrangement and has a resistor and a LED -in parallel with the switches to indicate a 'touch'. This has the nice property that only two wires are needed but it requires that the input can supply current for the LED.

Option for Manual Milling

Some CNC milling machines retain the manual axis handles and can thus be used for manual milling. But if the spindle is wired to a VFD which is controlled by the computer then it is inconvenient to have to boot up the computer and use a mouse for speed control. For those users I've added an interface that allows you to control the VFD and coolant pump manually.

For convenience and economy this is a separate PCB board that can be mounted to the front panel and requires only three wires to the TOAD5 board.

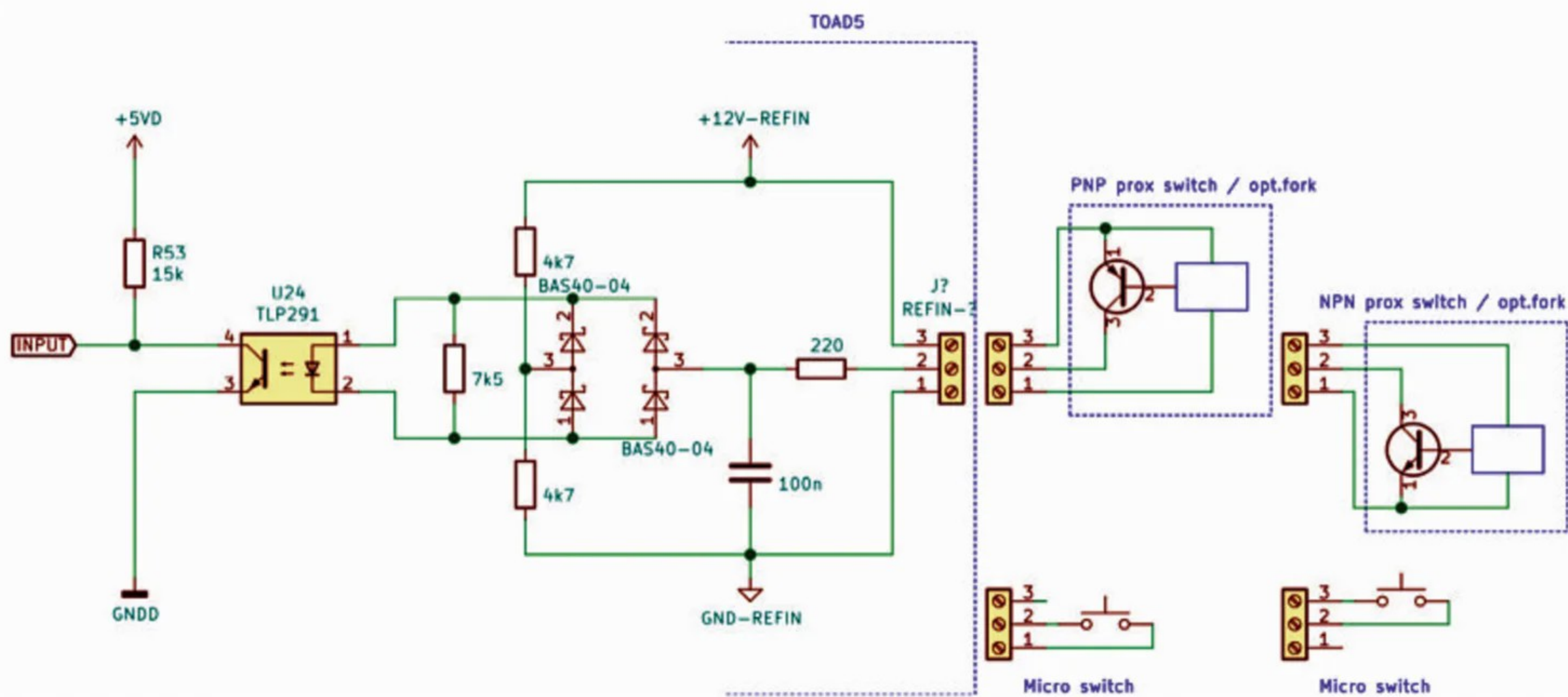


Figure 1

Raspberry Pi

This is an article about TOAD5. But I feel I need to mention some breaking news. Since I originally wrote this article, I've been dabbling with the Raspberry Pi 4 and touch screens. With just a moderate effort I've got EazyCNC up and running and even with the original dismally small 7" Raspberry Pi touch screen it can be used without a mouse or keyboard,

which together with a TOAD board would seem to form a good bases for a small and compact CNC control system, see **photo 5**.

Even the wireless MPG pendant worked out of the box, thanks to Java write once run everywhere technology.

Availability

The boards are available from me fully assembled and tested or the board

with just the SMT devices assembled and MCUs preprogrammed, in which case you need to solder the screw terminals and USB connector yourself.

As this is no commercial operation, I'm quite flexible so don't hesitate to contact me. I can be reached at eazycnc@eazycnc.com. In the final part of this brief series, I will look at using TOAD5 with a Raspberry Pi in more detail. ■

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Contents subject to change.

We Visit Bournemouth

John Arrowsmith takes a trip to the seaside and visits a 100-year old club.

Blackening

Graham Astbury explains the process of blackening small steel parts.

Moving a Garrett

Building a four-inch traction engine is a challenge. Werner Schleidt finds that moving one around is even more so.

Guards

Calder Percival adds safety guards to his milling machine.

LNER B1

Doug Hewson continues with the locomotive fittings for a B1 by describing an 'everlasting' blow down valve.

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YOUR CHANCE TO TALK TO US!

Readers! We 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.

GHT's Universal Pillar Tool

Dear Neil, I was very interested in the article on the pillar tool in MEW 334. For many years I have tapped holes using circular sleeves to hold the taps at right angles but having invested in a mill two years ago, which had improved my ability to work accurately by at least an order of magnitude, I felt that something to hold the taps with a greater level of precision was needed. There are other tapping jig designs, for example Harold Hall's in Model Engineers' Workshop Projects, but in my opinion, none has the elegance of the GHT design.

I recently purchased a copy of GHT's book Workshop Techniques and have been working my way through it and all the references to The Model Engineers Workshop Manual in order to see exactly what is involved and, in particular, whether I have the machinery necessary to build the Pillar Tool.

I feel that in 2023 it should be built to metric standards. Both machine

tools and materials are becoming less available in Imperial units as time passes and if, in years to come, the Pillar Tool requires refurbishment the ability to obtain the correct materials to do this will be much greater. There are many manufacturing processes for which the use of a mill is more sensible than using a lathe as GHT originally envisaged and I will use this where possible as my 3½" lathe of WW2 vintage no longer has the accuracy or repeatability to produce pairs of components where an accurate fit is required.

You asked me about a full redesign. If I may be permitted to paraphrase C E M Joad (BBC Brains Trust 1941 - 1948) It all depends on what you mean by "a full redesign". I hadn't done any drawings as my outline thoughts were to take the existing Hemingway castings and to machine these to metric integer dimensions as far as possible. This depends on how much "meat" there is on the rough

castings. The pillar can be 22mm without a problem and I was hoping that the arms could be machined to 40mm high instead of 1.5" by 32mm wide instead of 1.25" and the spacing between pillar and outer bore could be 90mm instead of 3.5". The small boss in the arms would be 20mm ϕ and the clamp pads 12mm ϕ . This would require the position of the clamp pad holes to be altered. These changes seem to me valid tweaks to GHT's design.

If the small changes to the castings cannot be achieved then, these days, it is relatively easy to redesign/redraw the components in 3-D to metric dimensions and mill from a solid bar. I don't have a CNC mill, but my son does and is fluent in G-code. But with this approach we have possibly a better tool, but I feel that no longer would we have a GHT Pillar Tool.

Chris Gardiner, Chelmsford

Content of MEW – 1

Dear Neil, I have received my latest copy of MEW (issue 335) and I have to say how disappointed I was to find the first six pages full of a project that I believe should be in an electronics magazine. As I read further, I found more non-engineering articles on 3D scanning and woodwork projects.

Come on, we need to focus and try and keep to model engineering workshop articles.

I have been looking back over some of my earlier magazines when Harold Hall was editor, and every page was full of engineering articles and modifications and improvements on tools in the workshop. These earlier copies also featured quick tips and it would be great if you could include some new ones or even refresh the old ones.

If it is because of a lack of engineering articles, I'm sure some of your readers could help out and provide something, including myself.

Please, let's get back to making the MEW for model engineers.

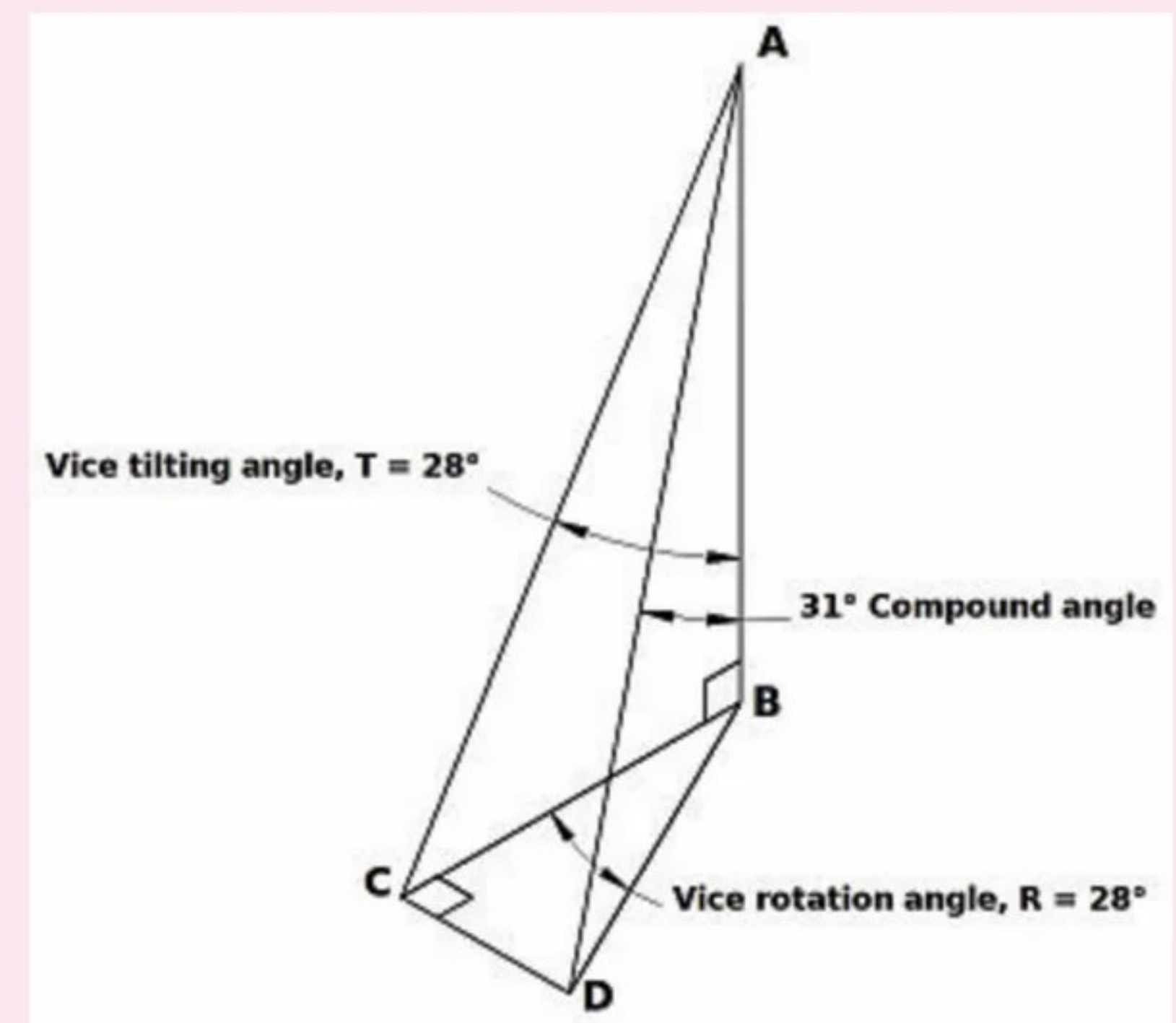
Don Ballard, by email.

The Compound Angle Problem

Dear Neil, with regard to Nigel Beal's article, which followed mine, on the subject of The Compound Angle Problem (Model Engineers' Workshop Issues 331 and 335), I am pleased that at least one person read my article! I thank Nigel for pointing out my errors and providing the correct solution. I found that Nigel's rigorous and comprehensive analysis of the problem far exceeded my meagre attempt and provides a generic methodology for the problem however it arises. He had

obviously gone to a lot of effort, not only to derive the correct analytical equations to solve the trigonometrical problem, but also to demonstrate that his theory was correct by making the 3-D models out of polystyrene. At this point I must don my sackcloth and ashes and confess that the errors discovered by Nigel in my analysis were totally my fault because the drawing of the angles (in my original Figure 1) were incorrect. I append a corrected version. I also append a revised Figure 2 where the vertex 'D' was indeed missing - unfortunately I cropped it off by mistake whilst exporting the image from my draughting package.

After my carrying out the analysis and completing the machining, a considerable time elapsed before the writing of the article and unfortunately, I did not check my drawing for publication properly, so it showed one of the 31° angle to be achieved, incorrectly. The tip angle is not actually specified on the original drawing - only the splay angles and the slide bevel angle. It was entirely my mistake by incorrectly transposing the relevant details onto the drawing for publication. Consequently, the errors that Nigel found were entirely



my own mistake and for that I apologise. As a result of this, I think that my original analysis using the revised drawing will achieve the desired objectives. For Nigel's information I have measured the tip angle that I achieved with the 31° splay and bevel angles, and it is indeed 28° as he predicted.

I sincerely hope that Nigel will accept my apology. I shall keep his article in my "File of Useful Information" as I am sure that a similar Compound Angle Problem will occur again at some time in my Workshop. As a final note, I shall write out 100 times "I must check my drawings properly before I issue them".

R. Finch, by email

Content of MEW – 2

Dear Neil, in issue 334 December 2023 I read of some individual dismay about content in the magazine. I have to tell you the reason I moved from Model Engineer to Model Engineers Workshop was the variety offered in the latter.

As a qualified Electrical Fitter and Mechanic I know well the importance of ancillary trades and how they can be taken for granted. Carpentry for example is a fundamental skill for pattern making, cabinet making, building workshops and much more.

Another that is underrated is 3D printing. It has great use in prototyping, checking fit for purpose, sacrificial jigs and brackets and more. I have had great success in printing angle blocks to an accuracy of .01 degrees, if I drill through one, I print another. The real kicker to 3D printing is that you cannot print your own work unless you can use CAD. Having a printer has forced me to learn CAD where I had given up on it in the past. Any articles on using CAD, particularly a generic program like Freecad would be greatly appreciated and may be an eye opener for some. Thanks for the great work.

Robert Walker, by email

The Editor's Response.

I think these two letters perfectly sum up an Editor's dilemma perfectly! I'm sorry Don found some of the last issue disappointing but glad that Robert appreciates those topics. I hope you've both read my editorial in this issue.

Since Harold Hall's time our hobby has changed considerably, and although they don't find a place in everyone's workshop, things like CNC machines, laser cutters, 3D printers and scanners are now commonplace alongside lathes and mills. You'll even find an article musing on the future of CNC in the hobby by Stan Bray, our first editor, in an early issue.

MEW has to reflect the changing nature of our hobby and the balance between old and new will swing back and forth in different issues. I can't see any issue ever striking an ideal balance for every reader! I appreciate the suggestion that those who want more traditional skills and topics covered write contributions themselves, I'm always keen to see such content.

Neil Wyatt, Editor.

Readers' Tips



Reinforcing Cardboard

TIP OF
THE MONTH
WINNER!



This month's winner is former MEW editor Dave Fenner, who has devised a handy way to make cardboard more durable.

Most of our workshop activities involve the use of metals, plastics and wood. As an alternative to wood, MDF may be used, and in the model railway world, extensive use of cardboard for scenic items is encountered. Some time ago I experimented with the use of MDF to produce a timing belt pulley. After cutting the teeth it was liberally coated

with Ronseal Wood Hardener (RWH) which was allowed to soak in. While the device has seen occasional rather than intensive use, the pulley has nevertheless survived in good shape for a number of years.

Moving on to OO gauge items, I had been fiddling about with a short length of folded cardboard angle strip, and wondered whether the application of RWH might be beneficial. The angle was dipped about halfway lengthwise in the can

and left to dry. This then gave one end treated and the other not. Using the "calibrated finger squeeze test" it was clear that the treated section was now considerably more rigid. The strength is probably not equal to the plastic extruded sections but may make treated cardboard a viable alternative for some applications.

I am guessing that the action is similar to that of resin with fibreglass in providing reinforcement, and may be of use to others.

We have £30 in gift vouchers courtesy of engineering suppliers Chester Machine Tools for each month's 'Top Tip'.

Email your workshop tips to neil.wyatt@mytimemedia.com marking them 'Readers Tips', and you could be a winner. Try to keep your tip to no more than 600 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* will win **£30 in gift vouchers from Chester Machine Tools**. Visit www.chestershobbystore.com to plan how to spend yours!

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.

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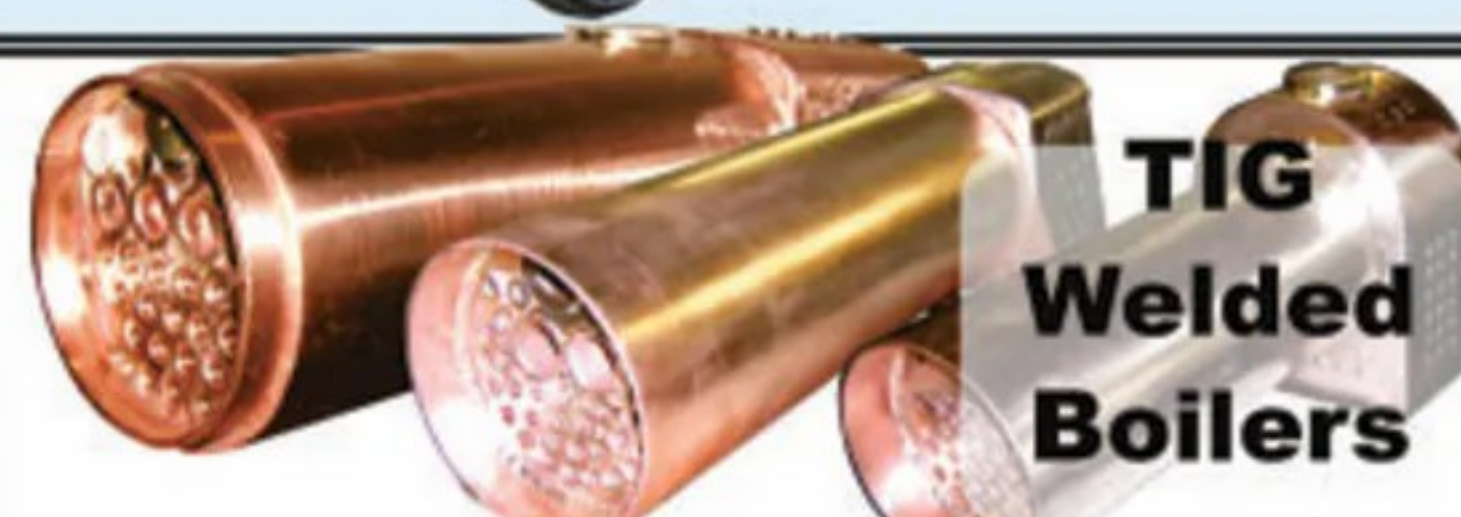
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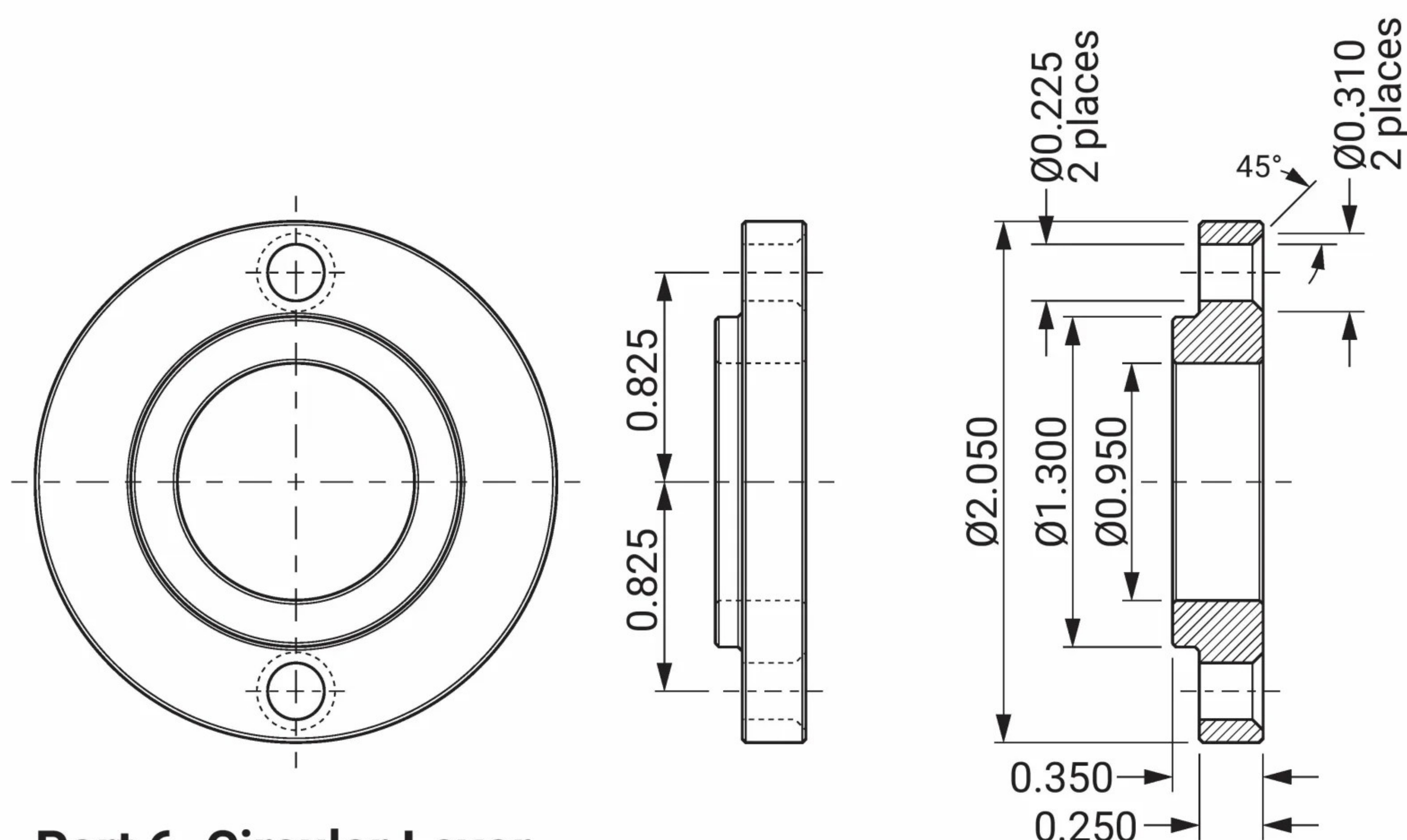
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Compact Dividing Head Part 5

Chris Hallaway designed and made his Compact Dividing Head (CDH) about thirty years ago for use with hobby size milling machines.



Part 6. Circular Lever

Mat'l: 6082T6 or similar aluminium alloy

Figure 31

Figures 31 to 40 show the parts required to complete the CDH not described in detail in the text due to their relative simplicity. Their location can be deduced from figures 1-7 in Part 1.

Some errors occurred in redrawing the figures. Marked up versions will be put on the MEW forum, figures needing amendment are marked below:

Part 1, MEW Issue 332

Page 15, Figure 7, Part 1, Body Stage 1. Top right view, 0.690 dimension

wrongly ascribed. Top left view, 0.750 dimension lacks a brother arrow, 0.525 dimensions wrongly ascribed. The recess around the three through holes is intended on both sides. Recesses have been specified so that areas of contact reacting clamping loads are spread out giving a more secure fixing.

Part 1, Body Stage 2. View shows holes for clamp bars in full instead of dotted and recess on face in dotted instead of full.

Part 1, Body Stage 3. As above regarding full and dotted lines. In

addition tapped holes shown dotted at the left hand end are removed.

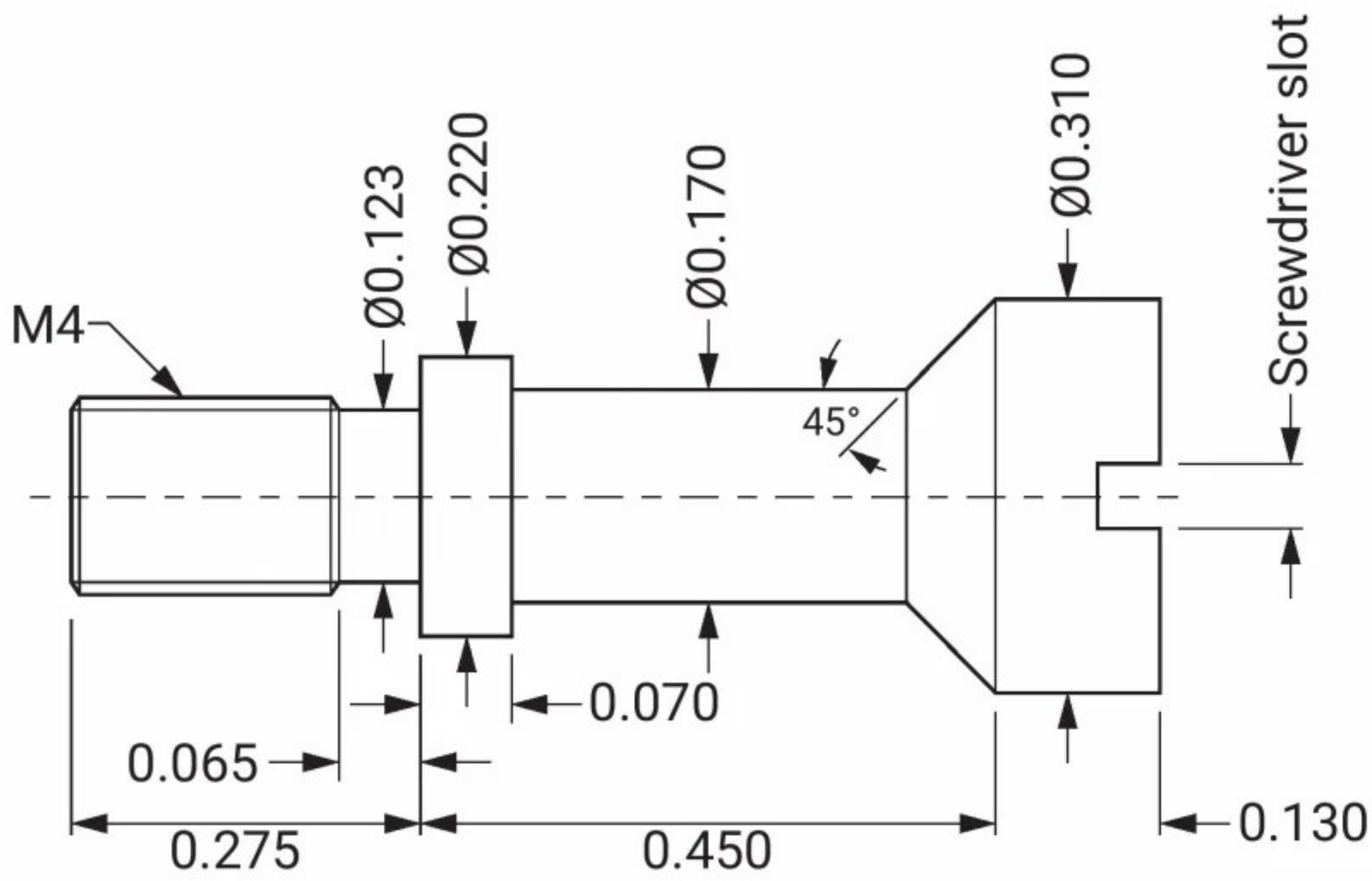
Part 2, MEW Issue 333

Page 30, text first paragraph fig 10 should read fig 12.

Page 30, Figure 12, Part 33, Worm Shaft, Figure number reference list below image is incorrect due to reassigned numbers.

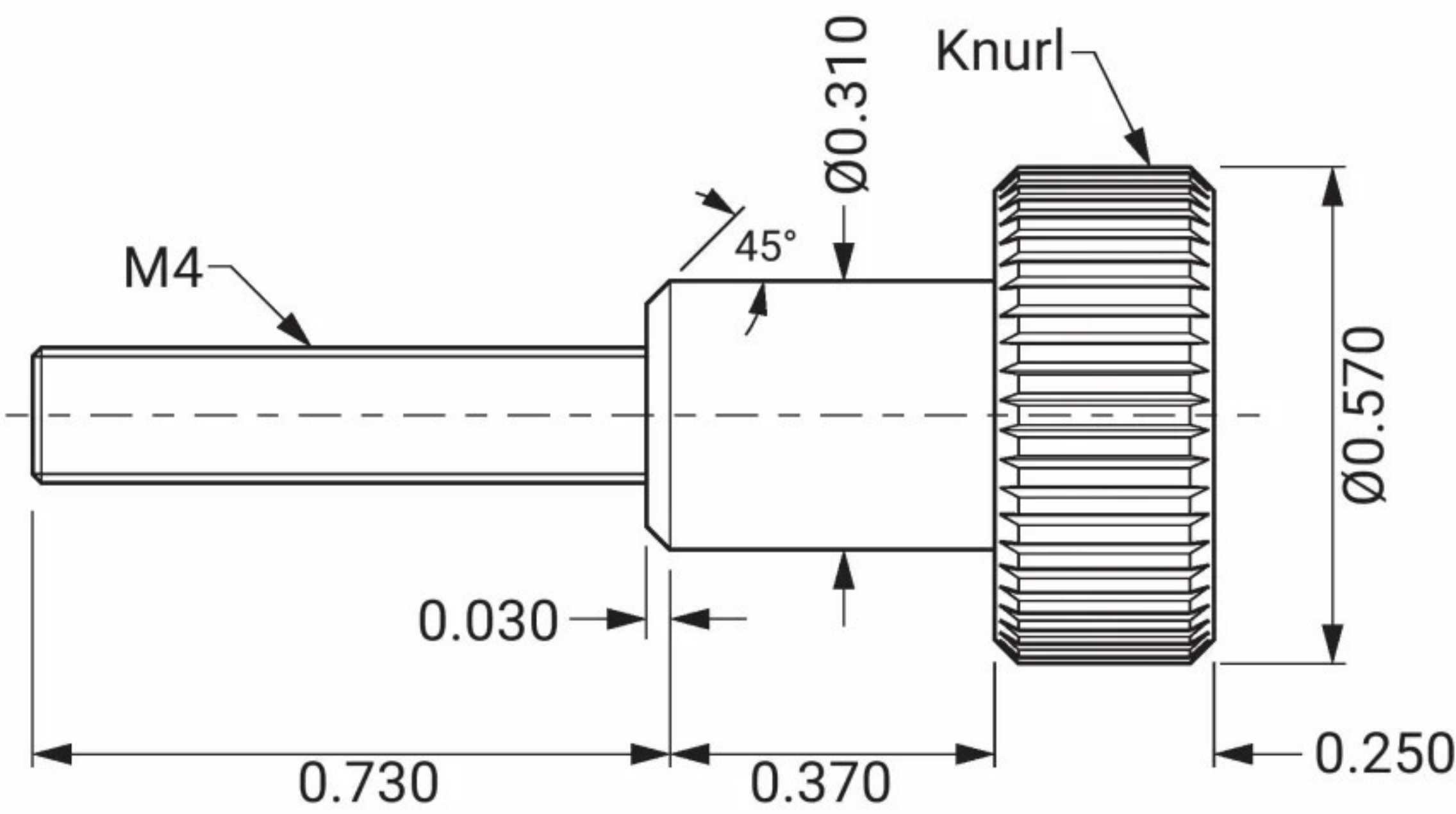
Page 32, Figure 15, Part 8, Wormwheel, 2.784 nom should read 0.784 nom.

Page 32, text, penultimate paragraph, final sentence, 1.370 should read 1.300.



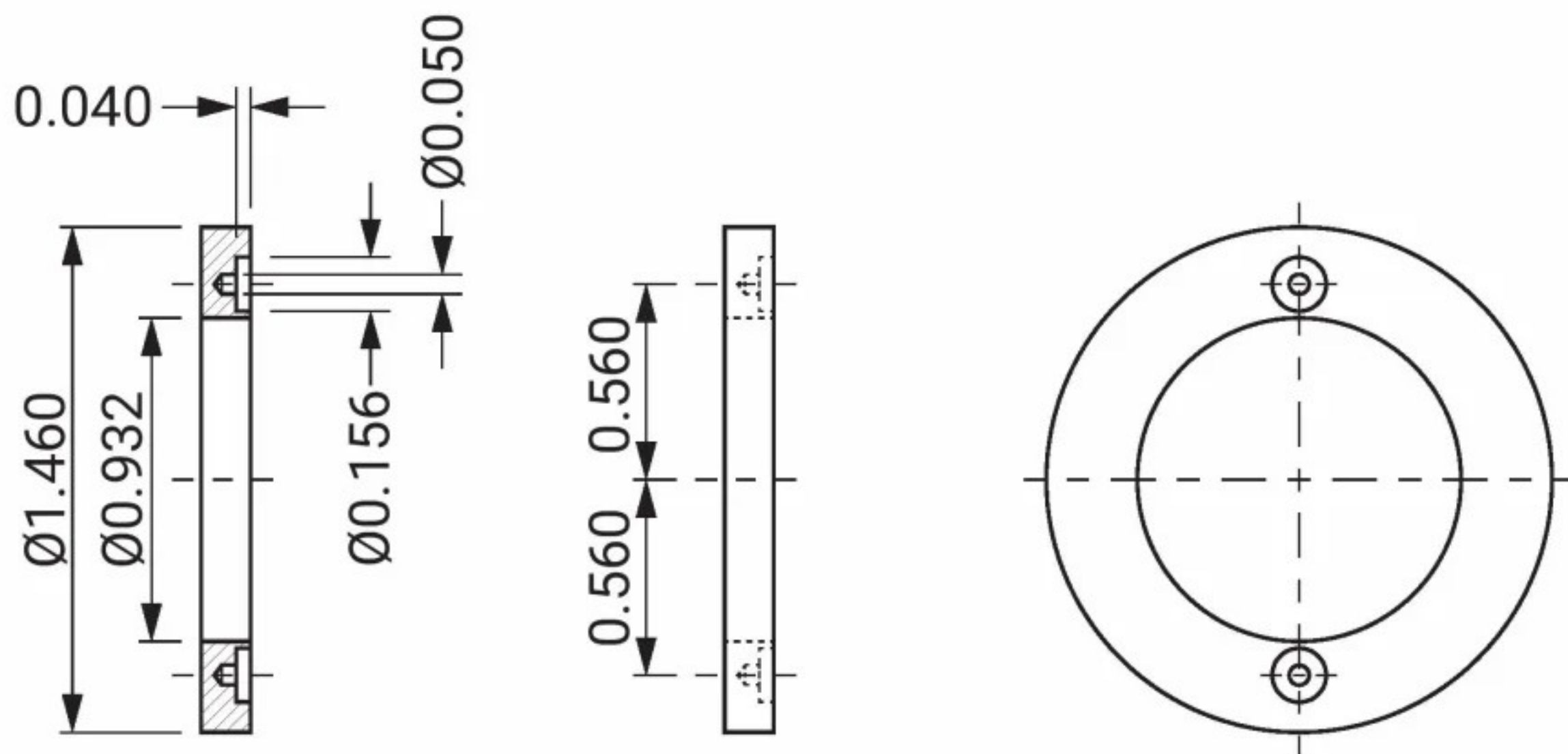
Part 9. Pivot Screw
Mat'l: Mild steel EN1A or similar

Figure 32



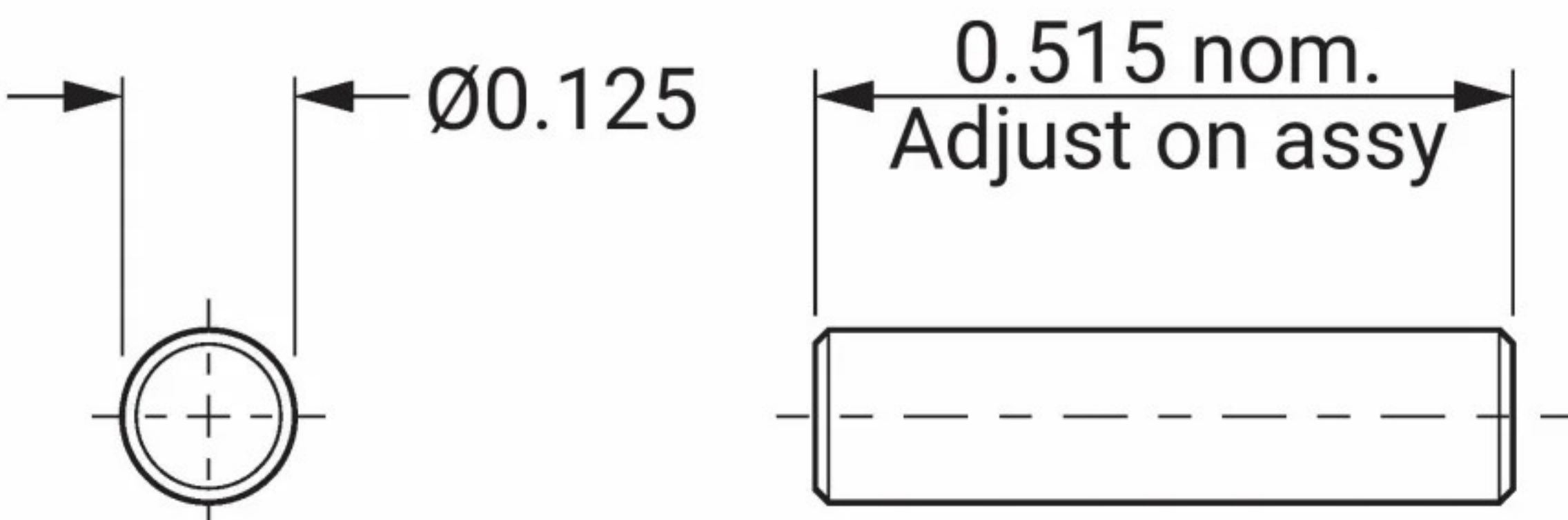
Part 10. Thumbscrew
Mat'l: Mild steel EN1A or similar

Figure 33



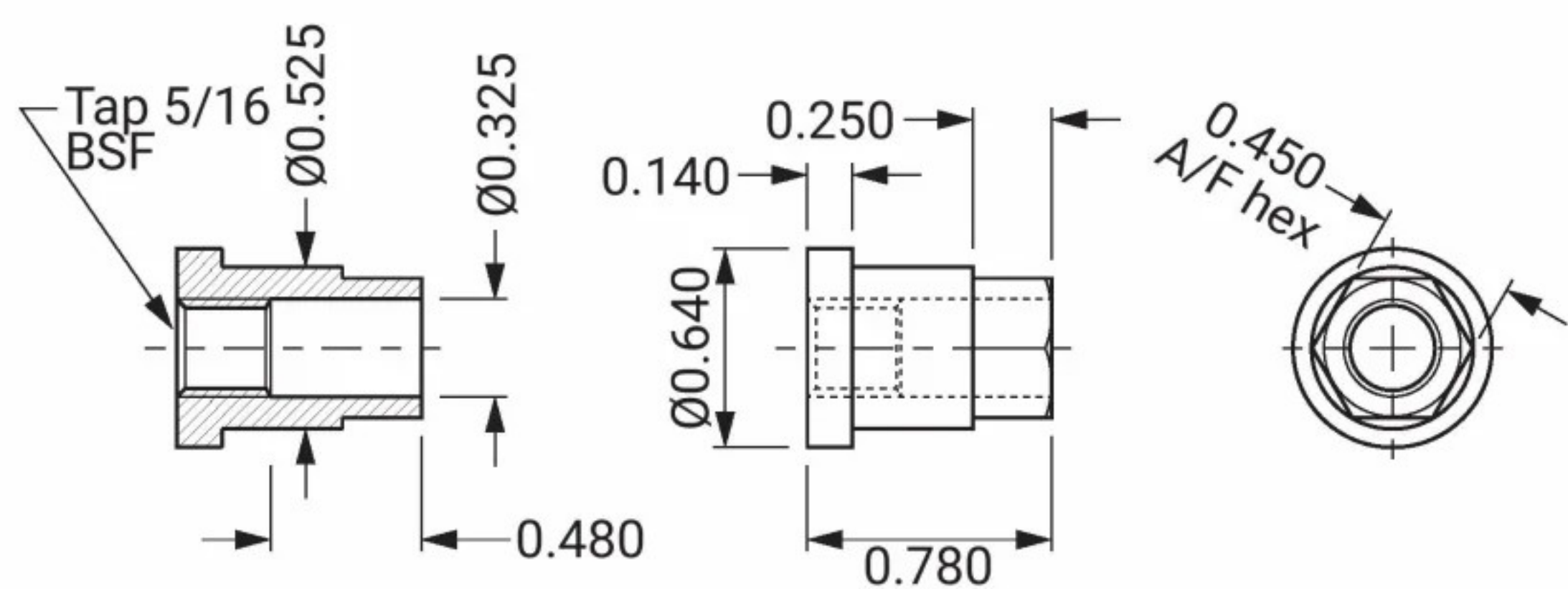
Part 11. Thrust Washer
Mat'l: Mild steel EN1A or similar

Figure 34



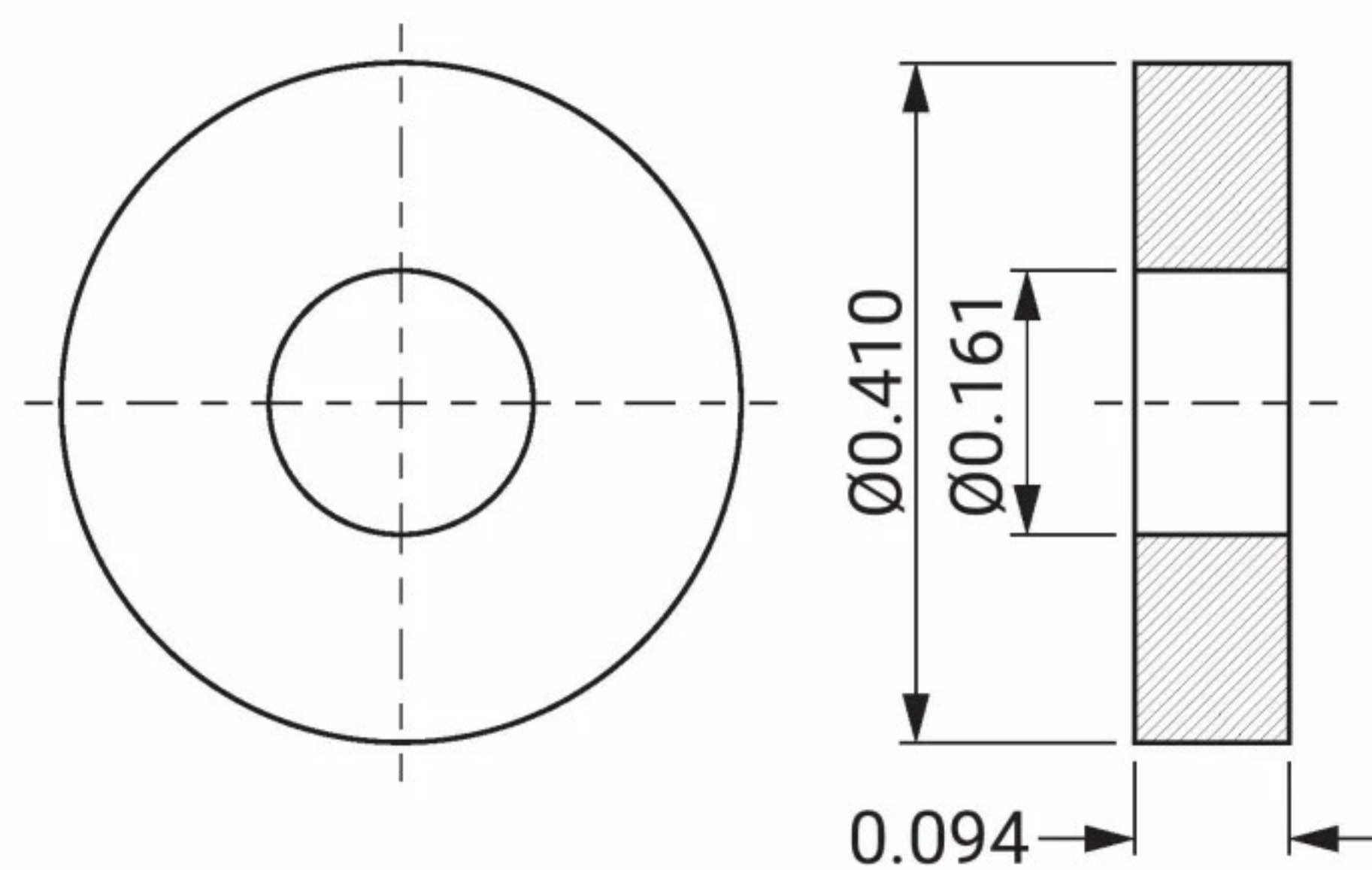
Part 14. Thrust Pin
Mat'l: Mild steel EN1A or similar

Figure 35



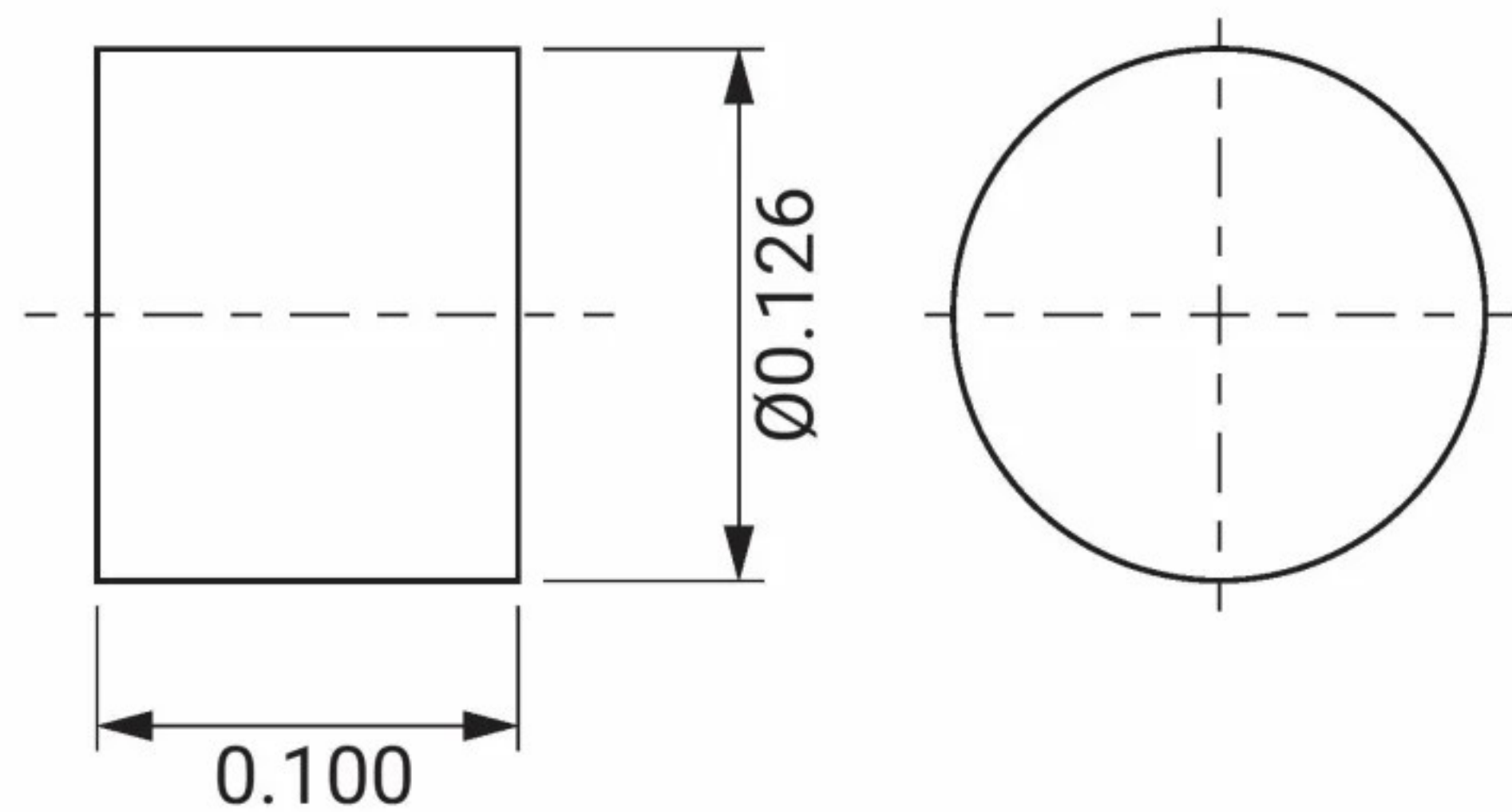
Part 16. Drawbar Sleeve
Mat'l: Mild steel EN1A or similar

Figure 36



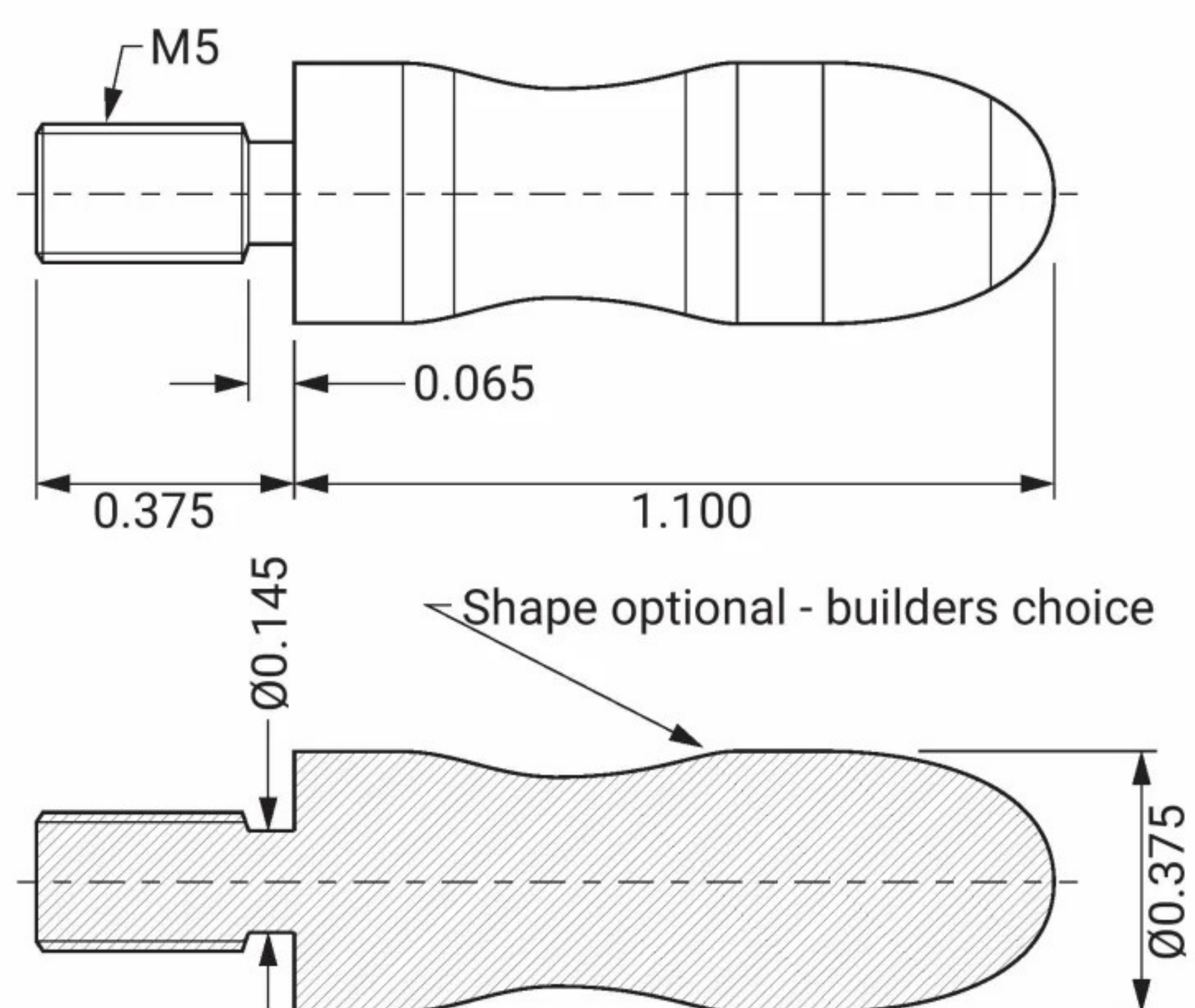
Part 21. Retainer
Mat'l: Mild steel EN1A or similar

Figure 37



Part 29. Plain Nylon Plug M4
Mat'l: Nylon

Figure 38



Part 34. Handle
Mat'l: Mild steel EN1A or similar

Figure 39

Part 3, MEW Issue 334

Page 26, Figure 17, Part 18, Worm Bracket. Main view, top RH corner, 0.400 dim. should read 0.440.
RH view, "1.250" dim. refers to step, not hole CL.
Page 28. text, second column "photo 5" should be followed by "prior to parting off".
Page 28, text final paragraph. "Figure 23" should refer to the gear trains shown in Figure 41 below.
Page 30, photo 6 actually shows an example gear train.
Page 30, Figure 24, Part 37. Correct title is "Handwheel Dial Collar". 0.475 dim. should read 0.450.
Page 31, Figure 25, number is Part 36 not 37, "Handwheel Dial". ■

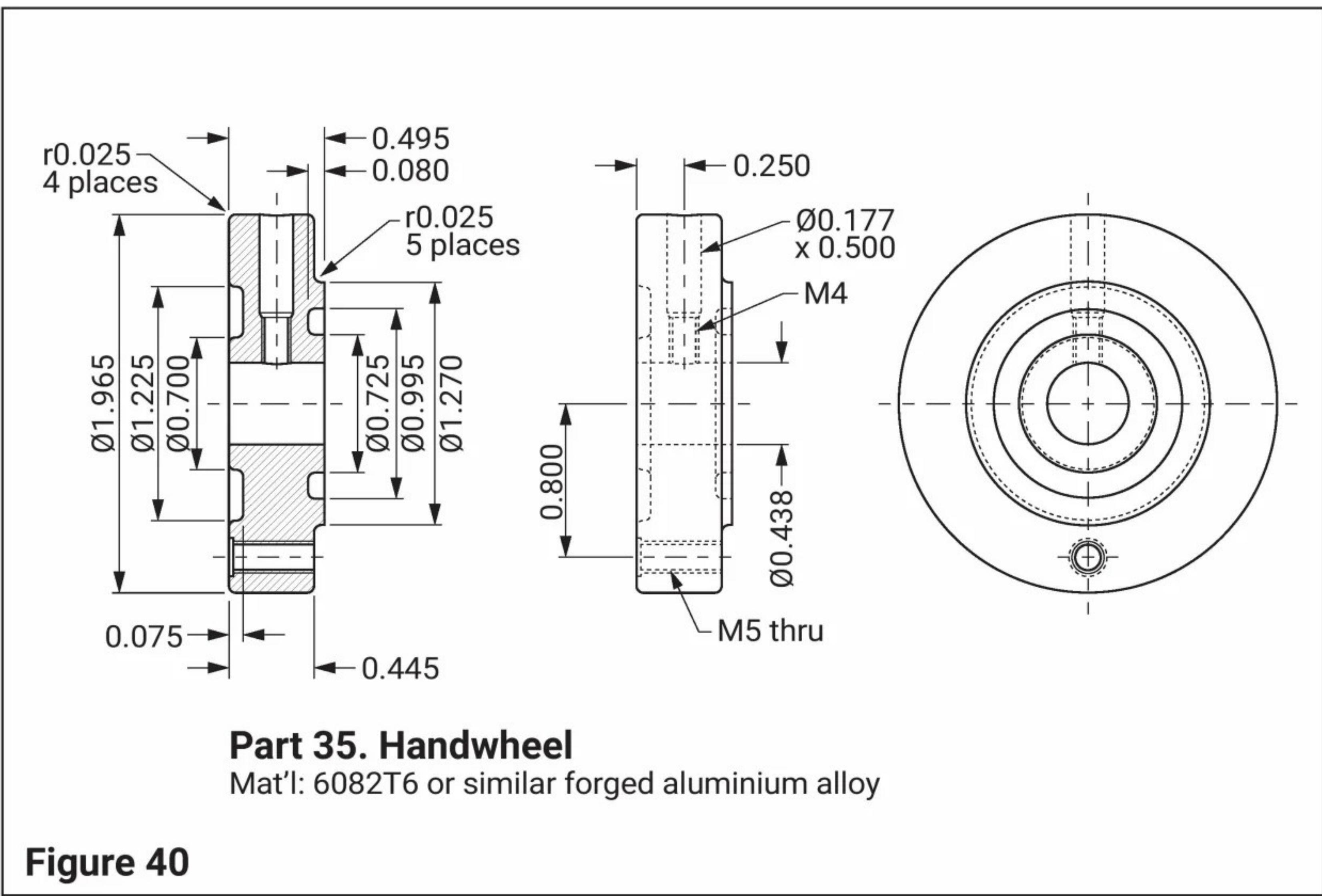
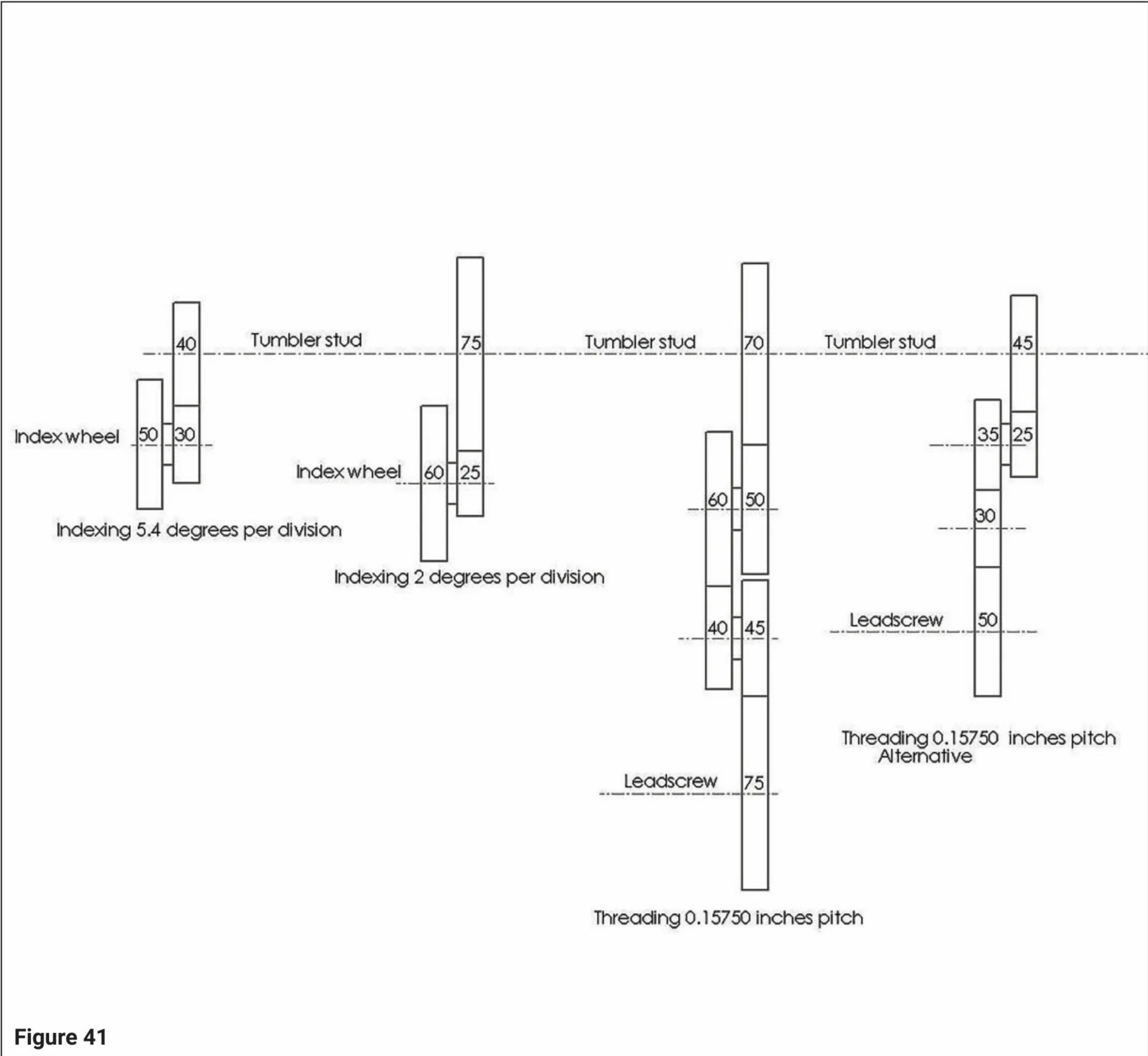


Figure 40

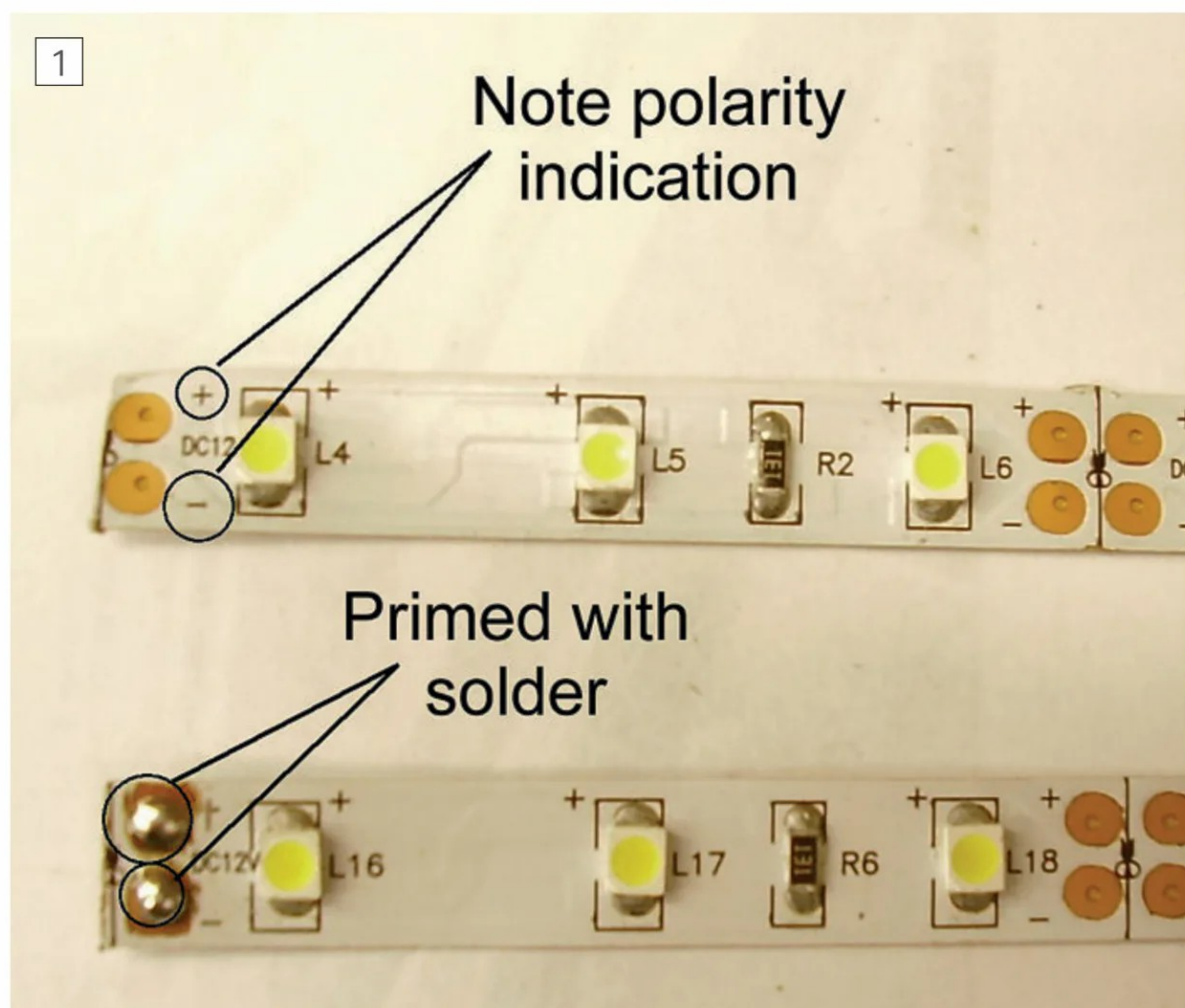


Lathe Cabinet Lighting

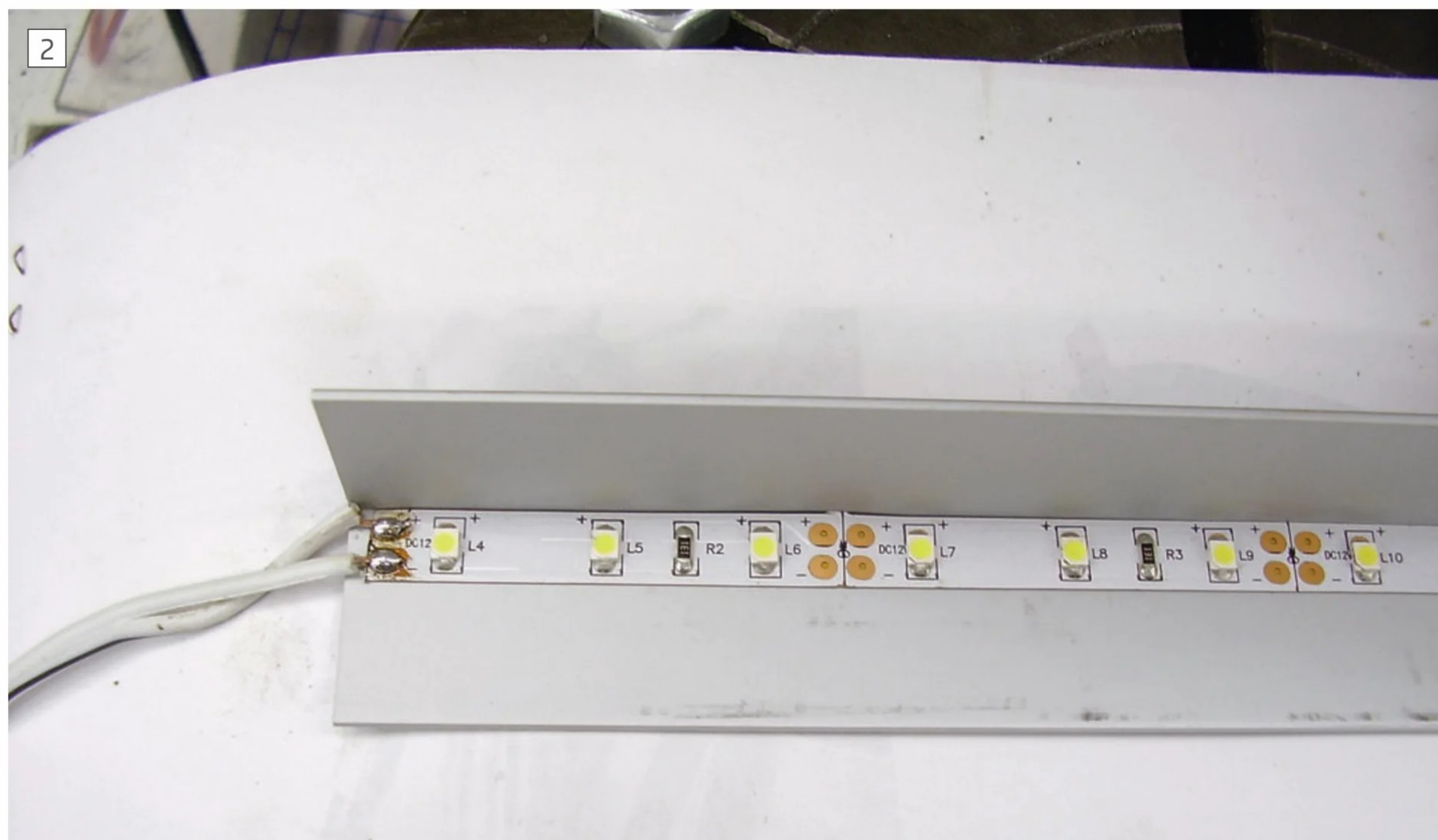
Mike Joseph explains how to use 12-volt LED strips for workshop lighting.

Being a creature of the night, I like to walk to the pub via the country paths without artificial illumination (torch). It is a great walk over fields in the depths of a good frost with moonlight and it is surprising just how much light there is and not just background glare from street lighting and how active the soundscape is. However, there are limits: I like to see just what I am plunging my hand into (unlike vets).

So now we get on to illuminating the lathe cabinet: I am not keen to plunge my mitt into a cavity wherein there may be mains voltages astray, I now have a state pension and wish to remain a burden upon the state for as long as possible hence the use of 12 volts wherever I can. So after some years of unsatisfactory lighting using magnetic round battery driven 'things' I decided that tempus is fugitting and I had better do something. I do claim to be a retired electrician after all.



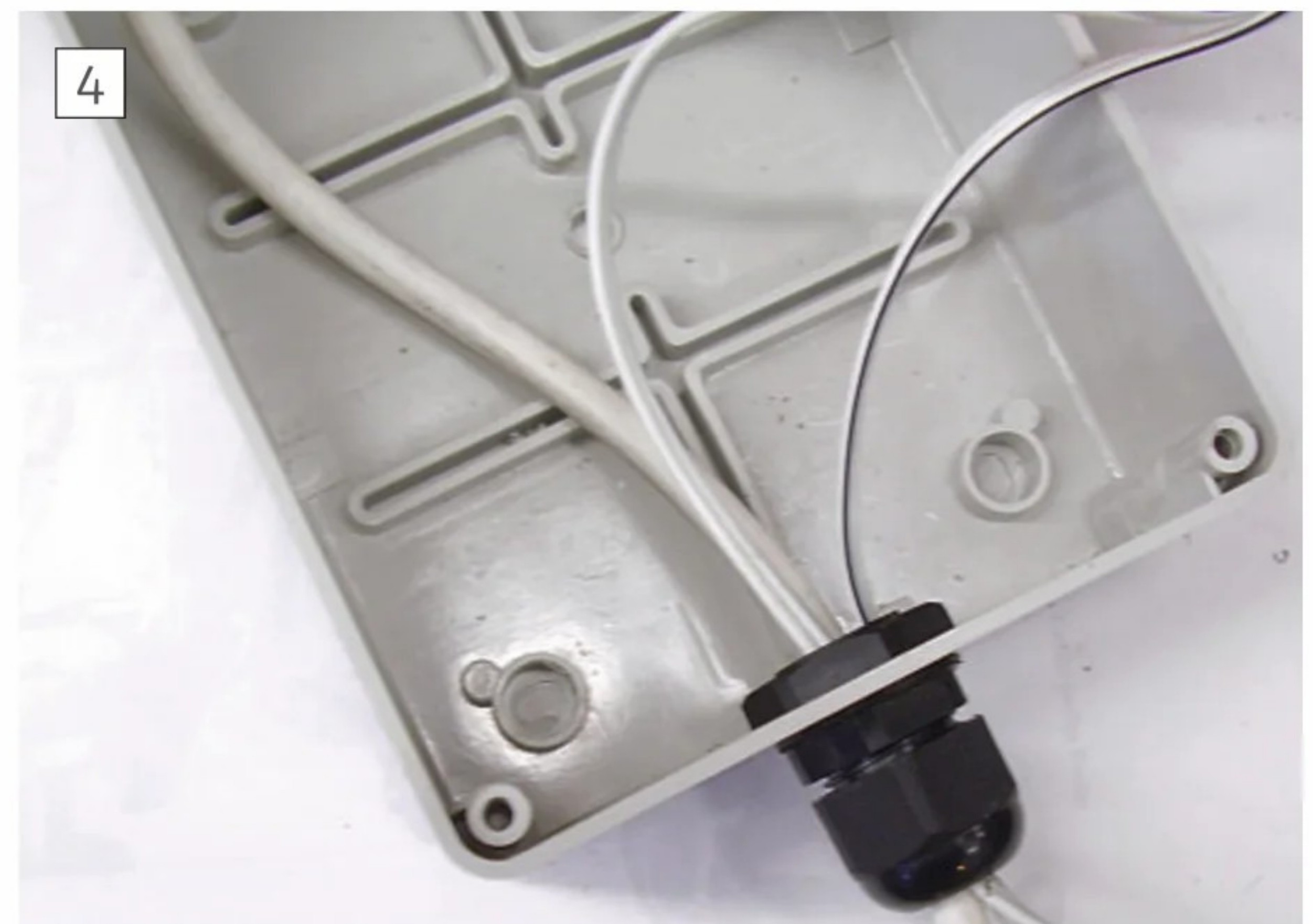
Typical LED strip showing connections.



Soldered connection and aluminium mounting.



12 volt LED driver.



IP56 rated box with gland.



'Wago' connectors – lift the lever, insert stripped wire and close lever.



Lighting installed on lathe.

LED strip lighting: self-adhesive LED strips are available and I had two metres remaining from some job or other, using some aluminium angle and a 'driver' – LED strips need a DC supply, ordinary lighting transformers simply will not work (AC). I know, 'cos I tried one and, lo, verily is shone about as brightly as an extinguished match and it was not good, **photo 1**.

The little round dots are for either push-on connectors (not great in my experience) or when cleaned can be used for a soldered connection – polarity is important! The black striped cable I use as the negative. And after soldering do run a triangular file between the solder blobs to ensure there is no short circuit.

I also stick the strips on to aluminium angle to help reflect/disperse the light around, **photo 2**. (I used this trick to illuminate the

innards of my work van – incredibly useful in the dark and of course the 12V supply came straight off the pathetic little centre light in the back. The extra amperage is minimal and is ignored but the extra light is not!) The lightweight LED cable is bell wire, quite satisfactory for 12V and the tiny amperage required. It might need support at the soldered joints, either a cable tie or laced through a couple of holes.

The LED driver is enclosed in an IP56 rated box, **photos 3** and **4**, with gland primarily so that no fingers can get anywhere near a 240V bit, but also to restrain the cables and arguably 'wet' protection because I use cutting fluid. Please note that there is an earth on the flex even though the driver does not need one. This is to help protect the *flex*. And remember

to use the black strip wire as the negative on the driver.

Finally, once the flex was fed around the lathe, mount the units in the lathe cabinet, attach plug and off you go except that I had miscalculated and once I had fixed the driver box inside the cabinet, I had to cut the lead to the lower strip and use Wago connectors to do the join, **photo 5**. Note that one connector is use to join two or more wires, one wire per lever.

And now there is loadsalight, **photo 6**. I just have to fit a flex switch sometime. The LED strip and driver were from gil-
lec.co.uk – they run a mail order business as well as a couple of conventional outlets, Chesham and Milton Keynes. The aluminium angle was from Wickes

My other machine tool cabinets may be modified too. I will not be labelled a latheist! ■

Eight Ways to Get More Out of Your Workshop

1. Do a drawing first

We may encourage readers to try out 3D CAD, but in practice any kind of sketch or drawing will help you make better designs and waste less materials. Why? Chiefly because when we make things up as we go along, we tend to over-engineer them. The ubiquitous fag-packet may be banned, and envelopes are rarer than the used to be, but remember even the tommy gun was designed on a napkin!

2. Use the right materials

A classic beginner's shortcut is to use oddments and scrap as a supply of materials, and even the experienced hobbyist has a scrap bin (see below). But if you spent a few hundred pounds on a lathe and some lathe tools, it is really worth saving a few quid on some quality metal bar to get you started? For those first practice cuts some free-machining EN1a Pb is inexpensive and will reward you with predictable results while if your scrap bin find turns out to be a chunk of hardened axle you might only find frustration and blunt tooling.

3. Go Large!

If short lengths of materials always seem expensive, that's partly because we pay a premium for people to stock large quantities of obscure sizes and materials, and also it's a lot more work to cut, package and send out twenty 15cm lengths of rod instead of the one 3m bar things are usually supplied as. So next time you are about to order a short end of something, see what twice the length will cost. It might be less than you think, making buying double a great way to stock up.

4. Buy Wisely

It's often said, buy cheap, buy twice, but there are times when buying budget makes sense. So the answer is 'buy smart' A good example is if you need special sizes of taps and dies to suit a particular

project, or a set of number drills. It makes sense to buy a relatively inexpensive set of carbon-steel taps and dies or budget drills if you are only likely to use a small proportion of the sizes. When you see which sizes are starting to wear out through plenty of use, upgrade to HSS taps and dies or better-quality drills.

5. Become a Hoarder

No, we don't think you need to fill your home ceiling high with unopened boxes, but before you chuck anything in the recycling, think about whether it contains any useful materials or parts. Old computer printers (especially very old ones) are packed with precision gears and rods as well as a host of fixings. But do beware odd chunks of metal of unknown provenance – if it's tough to turn to a decent finish, you may be best off recycling it!

6. Consider Second Hand

You have to balance the pros and cons of buying used machinery: on one hand many older machines built in the UK, Europe and the USA are of good quality,

but on the other the best machine in the world is no use if it is worn out. That said, if you can get a good old lathe or mill in good condition at a good price you won't regret it. Check out some of the used machine dealers advertising in MEW. Never buy a big, expensive machine without seeing it first hand, and if you are a beginner, take along a knowledgeable friend to help you spot a 'lemon'.

7. Don't be afraid to ask the advice of others!

The website www.model-engineer.co.uk is a friendly and supportive forum full of like-minded people who are always ready to help and assist beginners with advice, tips and fault finding when things don't go quite as planned. No question is stupid when you don't know the answer, but not asking is definitely foolish!

8. Read Up!

Finally, take a out a subscription to Model Engineers' Workshop – the best source of ideas, advice, tips and techniques there is – but of course we would say that!



This piece of a broken vice could be a useful source of cast iron, as well as a large ACME thread screw.

Addendum modification for involute gears



Jacques Maurel explores the theory behind the gear modifications used in his earlier articles about the Filengrene gear design software.

The aim of this article is to give some information about this gear tooth form modification (also named “profile shifting”) that can be very useful for avoiding undercut, getting a desired centre distance between shafts, increasing the tooth strength and more. This modification can be made easily with “generating” machines, the hobbing machines which are now quite common in model engineer’s shops. It’s nevertheless possible to make form cutters to do this.

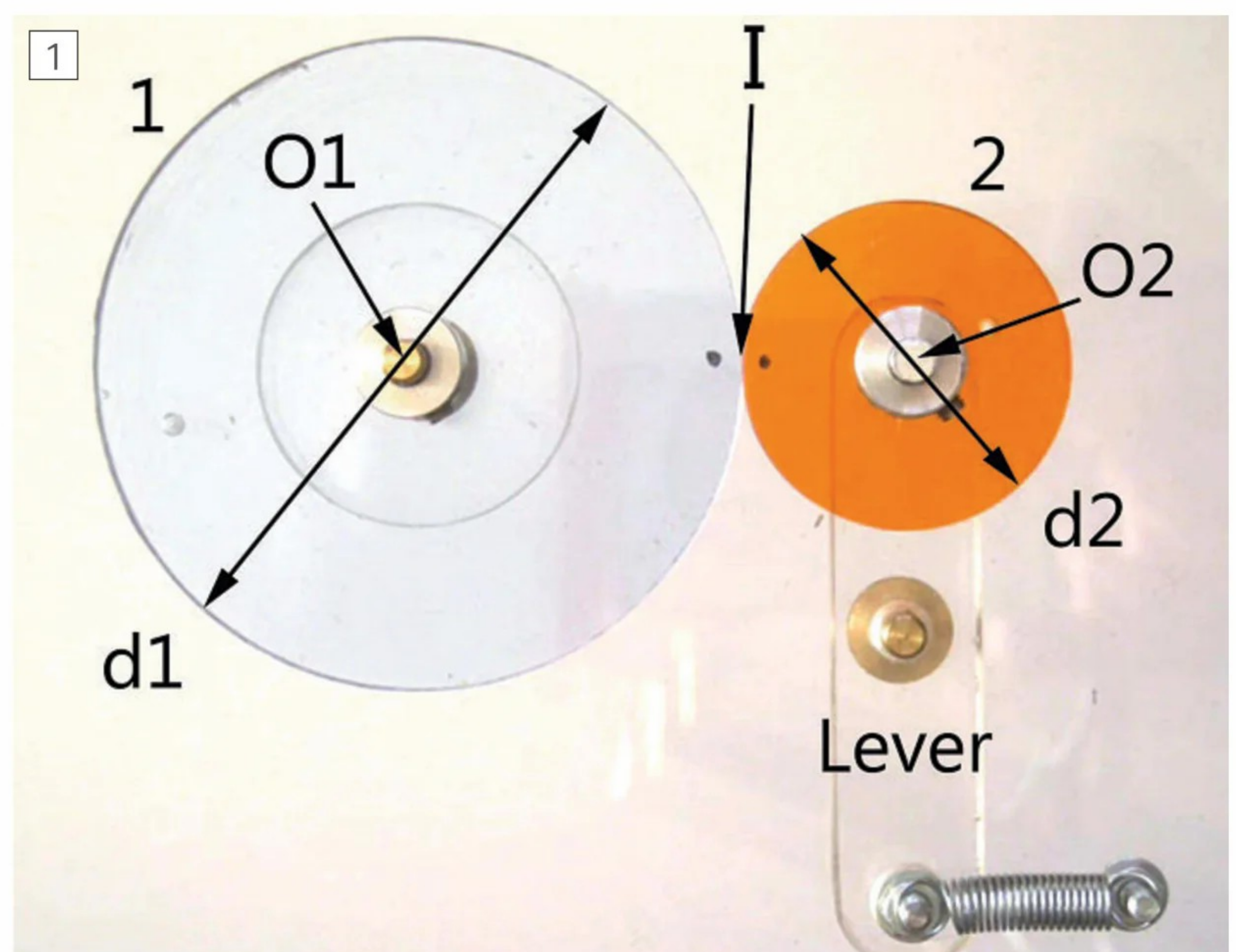
The free software “Filengrene” described in an earlier article (MEW 331, 332) can be used to solve all the gear definition problems with no calculation, and do even more for those with 3D printers.

How and why of the involute profile

From friction wheels to gears (Sketch1 and video ref. 1)

If power is transmitted by friction between two cylindrical wheels, the spring and lever giving a radial contact force, the wheels are tangent at point “I” and rolling without slipping. You use this system everyday as wheel/road or wheel/ rail contact when moving by car or train, your wheels being rolling on a sphere (the earth!)

The **transmission ratio** is $U = N2/N1 = d1/d2$, the **centre distance** $a1/2 = (d1+d2)/2$. Unfortunately slipping can occur hence the idea of using teeth, **sketch 2**. In this Sketch, gears are pinned on the friction wheels to avoid slipping. The circles C1 and C2 are the pitch centre circles, diameters $d1$ and $d2$, are

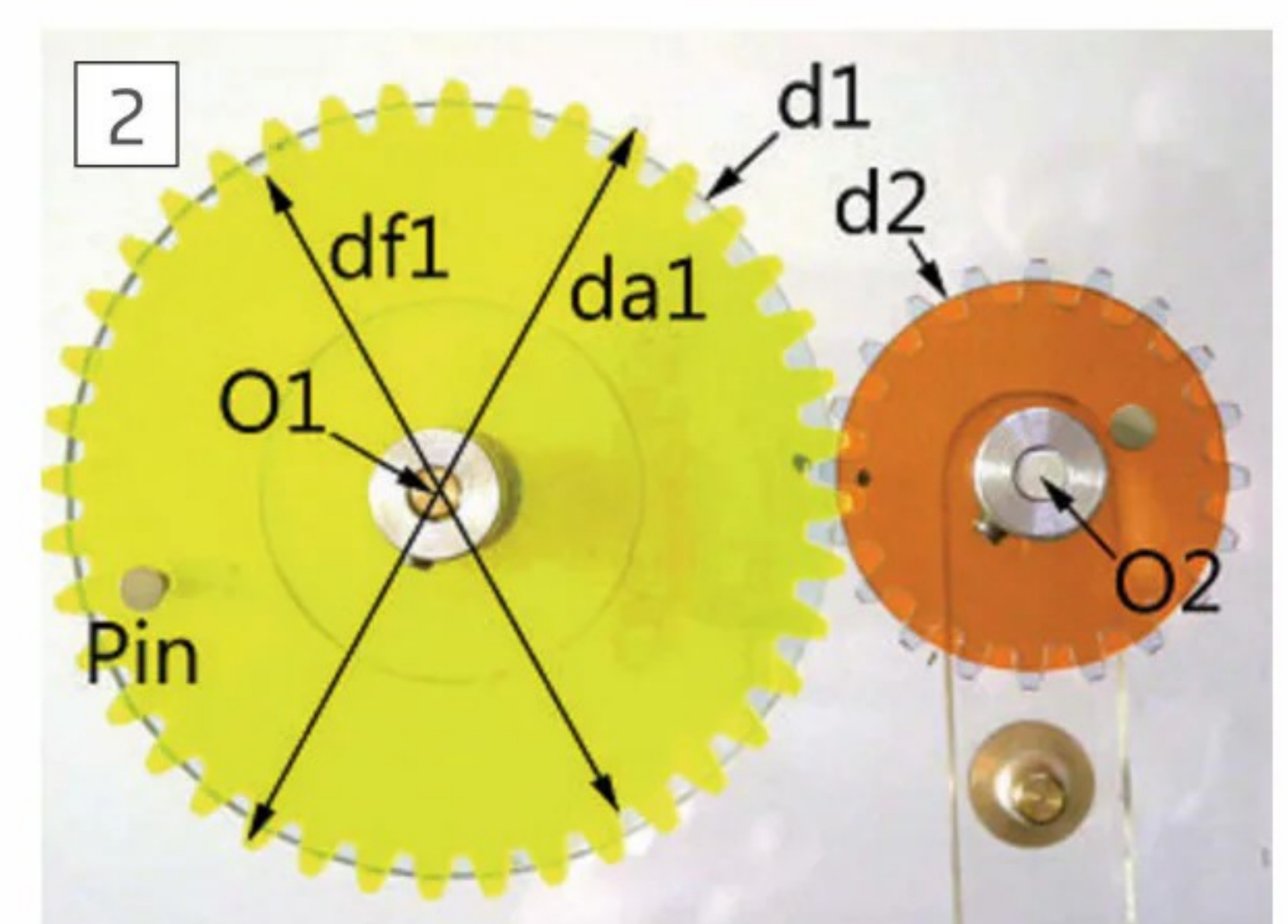


named the “pitch centre diameter” or **PCD**, with Z being the number of teeth, the pitch (distance between successive teeth measured along the pitch circle circumference) is $p = (\pi \cdot d)/Z$. Usually we use the relation: $d = (p/\pi) \cdot Z$. To have a round number for “d” (because of $\pi = 3.14159...$). The relation $(p/\pi) = m$ is named the “**module**” this being the normalized dimension for gear teeth.

The imperial system uses the “diametral pitch” DP, the relation between diametral pitch and module is $m = 25.4/DP$.

Hence the centre distance: $a1/2 = (d1+d2)/2 = (m/2) \cdot (Z1+Z2)$

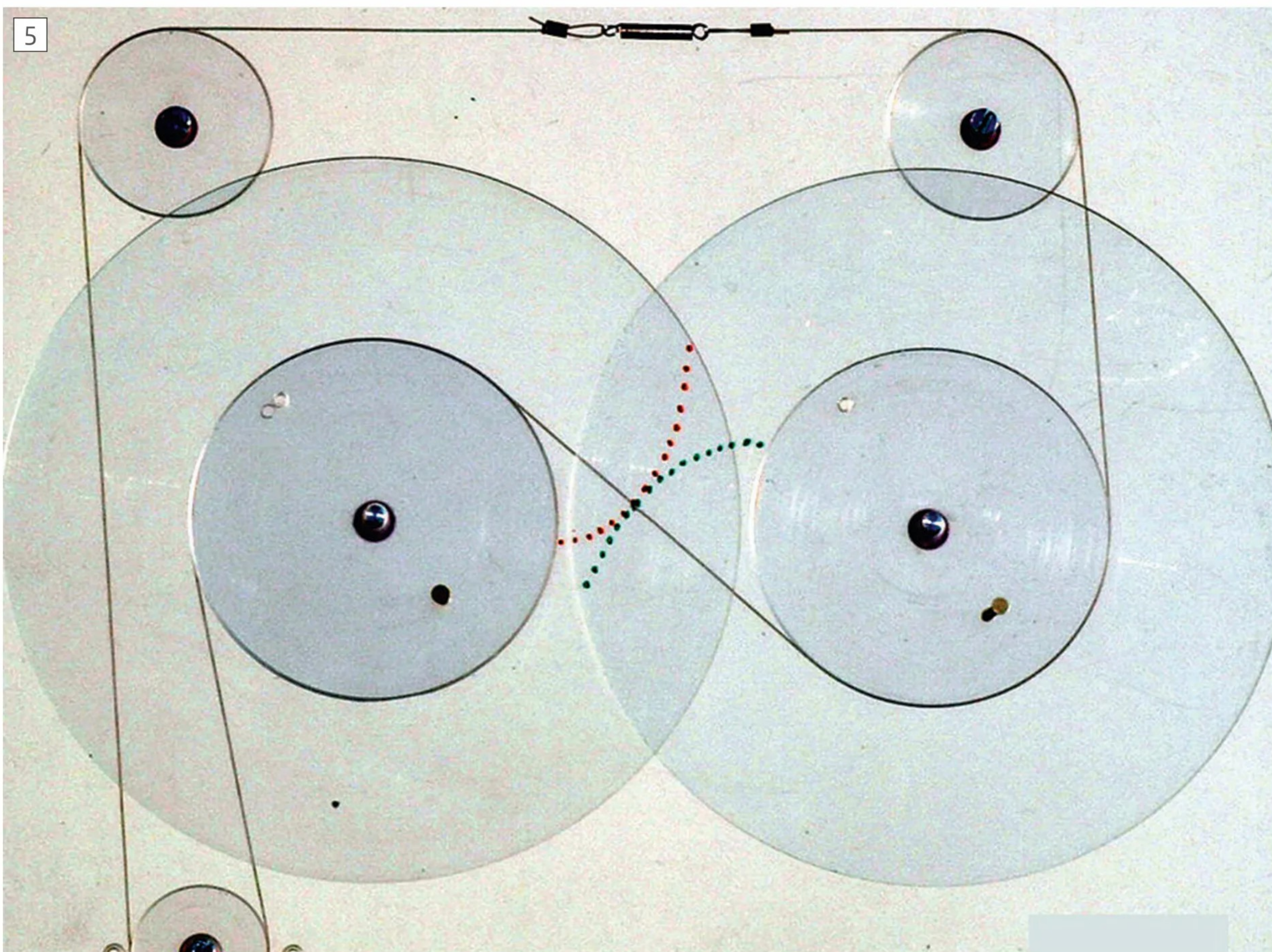
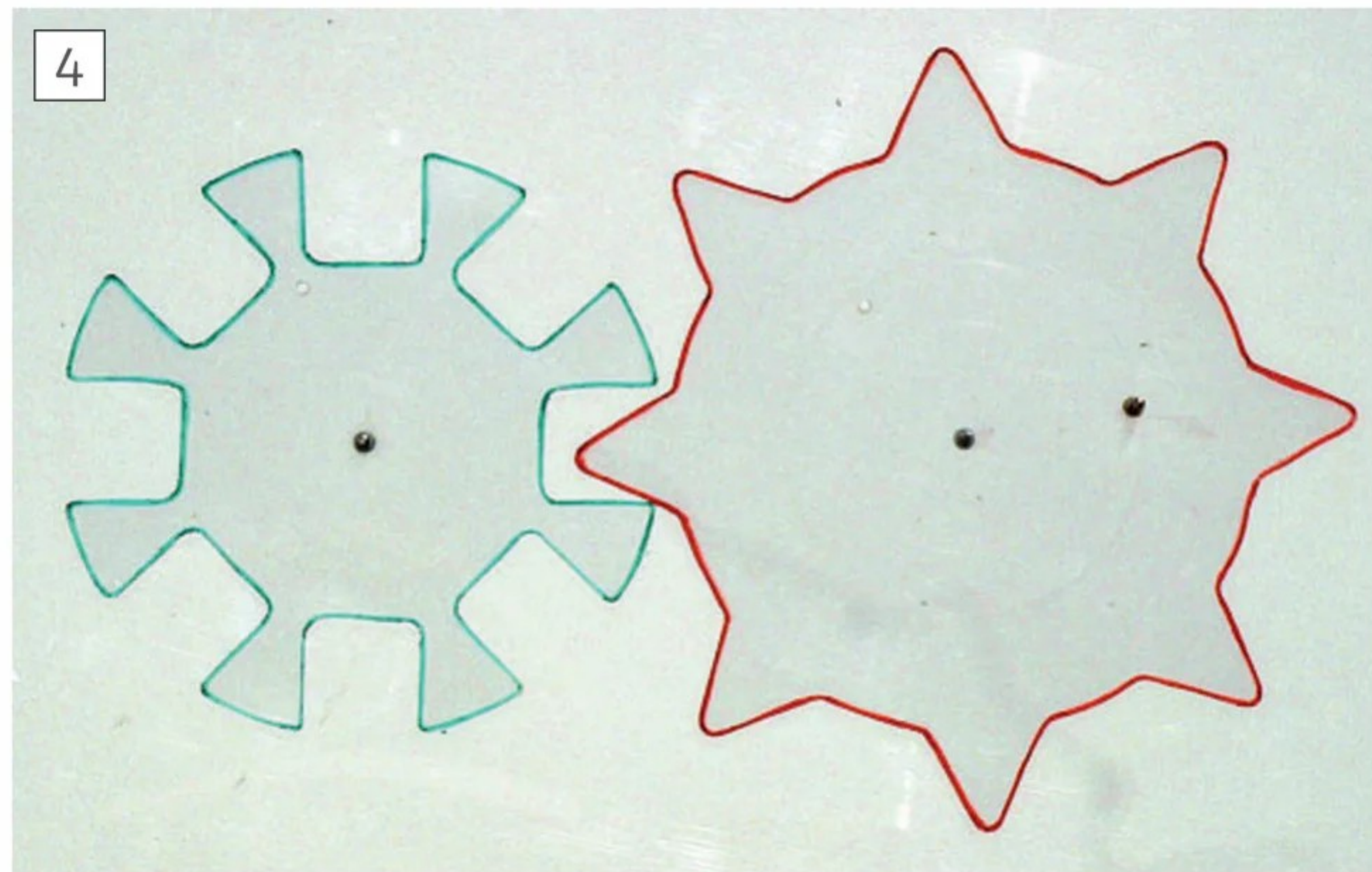
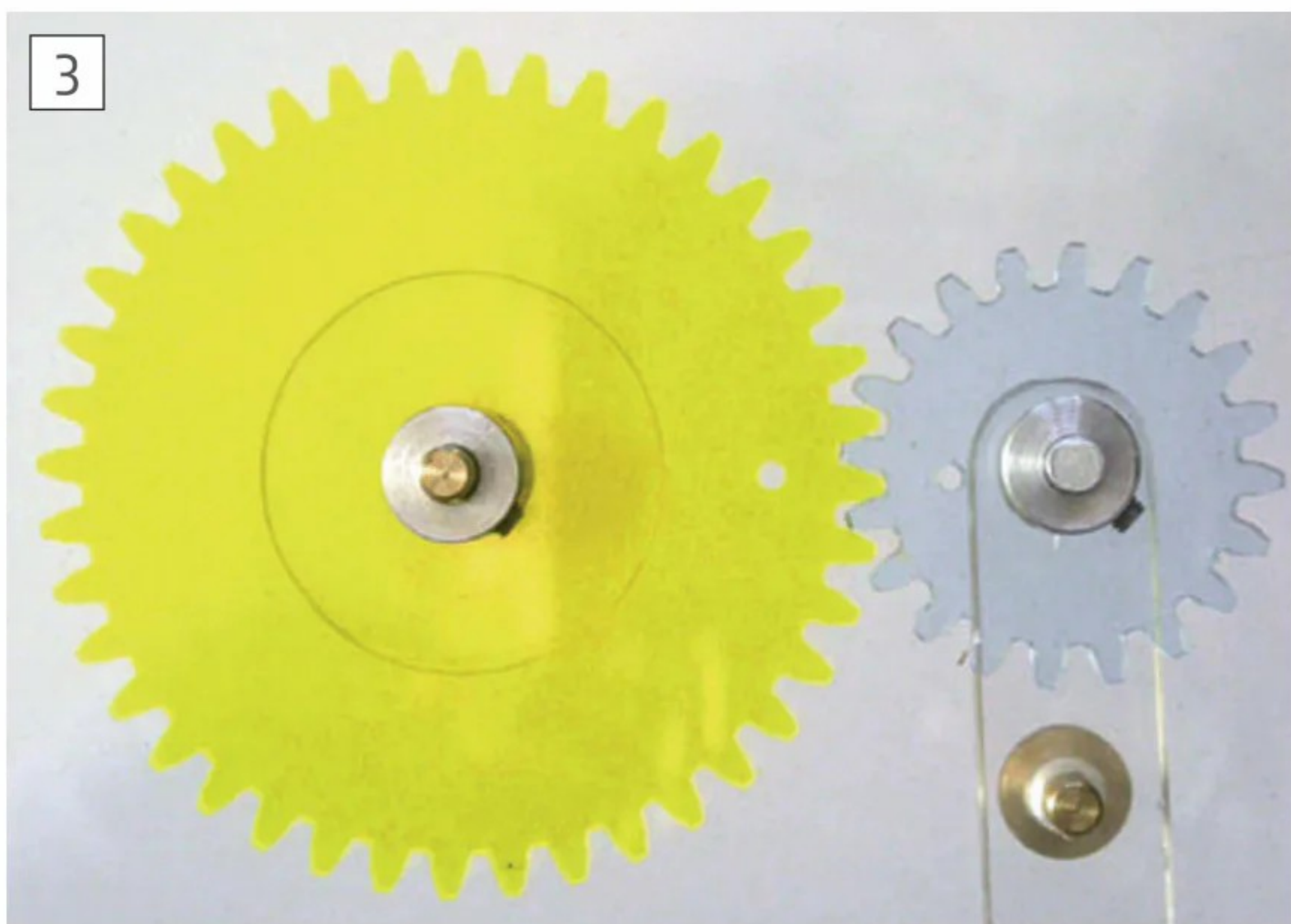
There are two new circles appearing (see Sketch 2):



The outside circle **Ca**, diameter **da**, and the base circle **Cf**, diameter **df**.

The standard values are:

$da = d + 2m$, as the tooth is one module protruding out from the PCD, this part of the tooth is named “addendum”.



$df = d - 2.5m$, as the tooth is extended 1.25 module under the PCD, this part of the tooth is named "dedendum".

So the tooth height: $h = 2.25m$.

Sketch 3 shows the gears only as the friction wheels are now of no use.

A bad gear set using an odd shape for the profiles (see **sketch 4** and video **ref. 2**)

The tooth contact varies from a sharp point to a flat, the direction of the

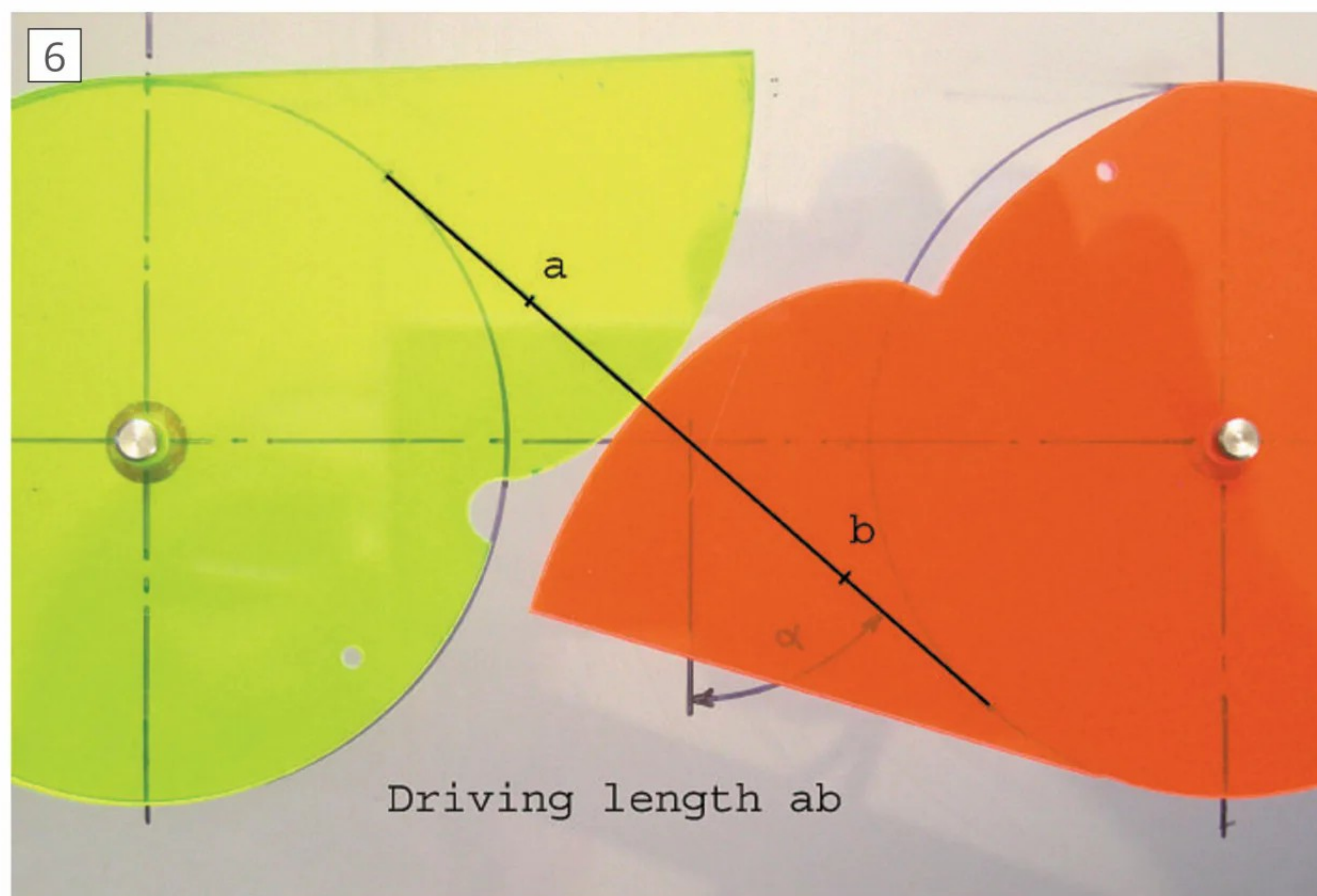
contact force is changing, and at one point there is a loss of contact.

The transmission is not homokinetic; if the input $N1$ (rpm) is constant, the output $N2$ is variable, while the average ratio is $N2/N1 = -1$ as the tooth number ($Z=8$) is the same for the two gears turning in opposite direction (hence a negative number for the ratio). This would create strong vibration at high running speeds.

The transmission is irreversible: gear 1 can drive gear 2 but gear 2 is unable to drive gear 1. So, an odd shape can't be used for the tooth profile.

From pulleys and belt to a good gear tooth profile: (see **sketch 5** and video **ref. 3**)

Sketch 5 shows two pulleys with a crossed belt (fishing line) carrying a knot identifying a point on the belt. Using a felt pen, it is possible to mark out the



locus of this point on a disc locked by a pin to the left pulley (red dots) and afterwards, on a disc locked to the right pulley (green dots). These dotted lines are the “involute” curves which will give the profile of the teeth.

These two profiles are tangential, they are named “**conjugate profiles**” the common “**normal**” (line perpendicular to the tangent) is along the belt and named the “**line of action**” as this is the

(constant) direction of the contact force. At the contact point the teeth are rolling and slipping (but just rolling without slipping at point “I”).

As we have previously got rid of the friction wheels, it's time to abandon the pulleys and belt and to materialize the profiles (see **sketch 6**).

This gear set is now running with the pulley and belt's good properties: Constant direction for the contact

force, homokinetic, reversible. A new vocabulary is appearing:

The pulley diameter is named the “**base diameter**” (**db**).

The angle between the line of action and a line perpendicular with the centers line is named

the “**pressure angle**” (**α**) the smaller the better (for low contact force) it is normally set at 20° (but is 50° on the sketch and it was often 14°30' in the past).

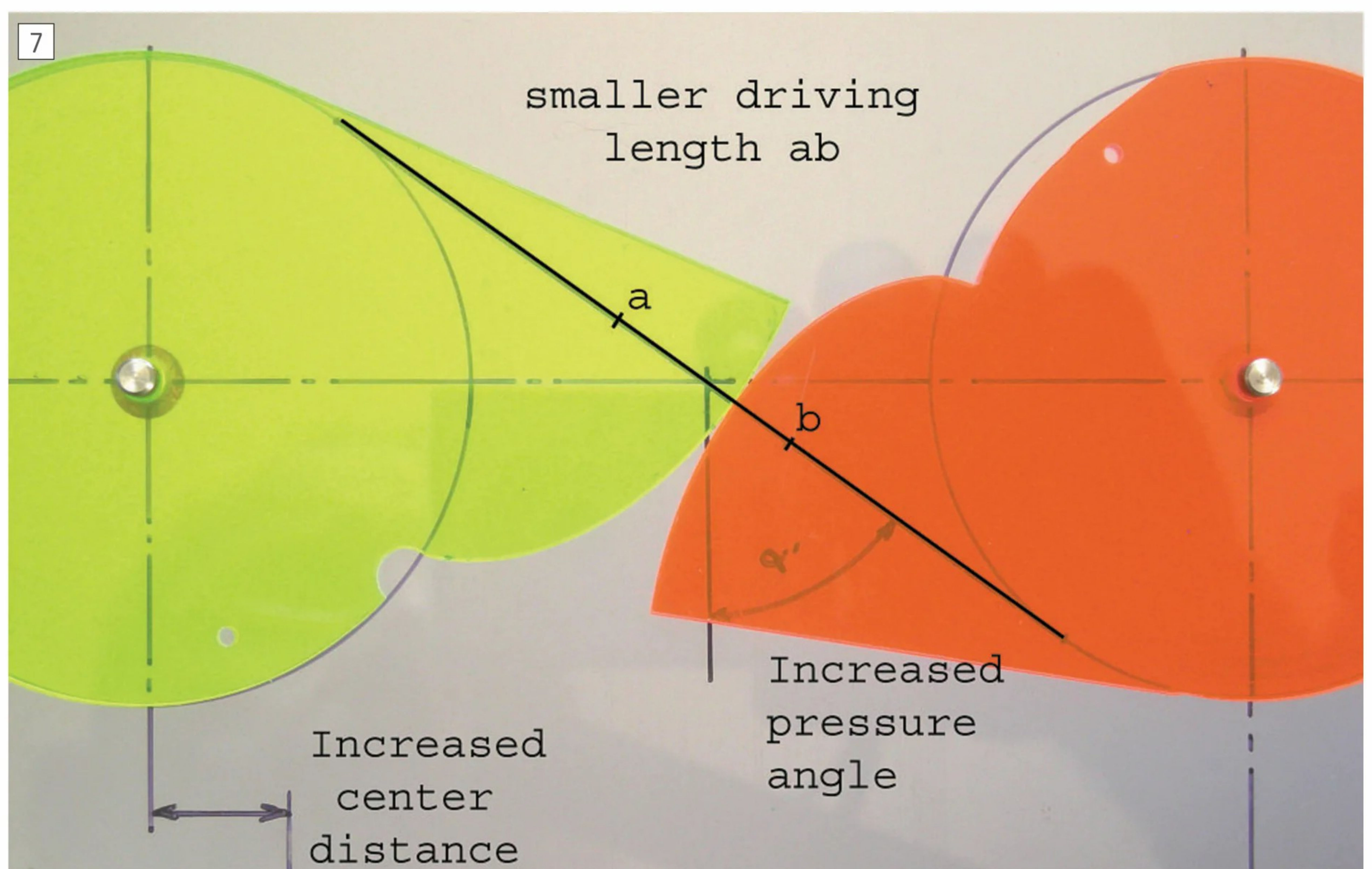
The belt length during which the profiles can be in contact “ab” here is named the “**driving length**” the longer the better (for a silent gear set, see later).

Relation between d (PCD), db (base circle diameter) and α (pressure angle):

$$db = d \times \cos \alpha$$

But there is a wonderful “must”, look at **Sketch 7**, the profiles are now working with an increased center distance but yes they are still running quietly! With some drawbacks: increase of the pressure angle and decrease of the driving length.

Note: This property is fundamental for high-speed running gear sets, lacking this, no other profile can be used at high speed, because of vibrations, although other profiles are used (epicyclic ones) in horology where typically the speed



is very low (the reason for this will be explained later).

Multitooth gear set: (see video ref. 4)

Figure 1 shows two $Z = 17$ teeth gear meshing, only 3 teeth of each gear being seen for the demonstration, it also shows:

- The PCD circles $C1$ and $C2$ diameters $d1$ and $d2$ (were the friction wheels) are tangent at point "I" and give the center distance $a1/2 = (d1+d2)/2$.
- The base circles $Cb1$ and $Cb2$ diameters $db1$ and $db2$ (were the pulleys).
- The line of action (was the belt) $T1T2$ are the tangent points on the base circles.
- The points $t1$ and $t2$, beginning and end of the teeth contact, they are the intersecting points between the head (outside) circles "Ca" and the line of action.

The meshing motion detailed:

The tooth contact is starting at point $t1$ (2 pushing 1), one pair of teeth is so in contact.

Later, a second tooth contact takes place (see **note 1**). We have now 2 tooth pairs in contact. Later the first tooth contact will stop and a new one will occur. So when meshing there are one/two/one and so on teeth pairs in contact, each new contact giving a slight shock and some noise!

The successive teeth contacts are following along the line of action that is then "wrapped" on the base circle (like a toothed belt), the distance between these profiles being so the "**base pitch**" $pb = (\pi \cdot dp)/Z = m \cdot \pi \cdot \cos \alpha$ (the tooth belt equivalent pitch). This is the most important feature of an involute gear, and is

defined (and normalized) by two numbers, the module m (or the DP) and the pressure angle α (see **note 2**).

Contact ratio: named " $\epsilon\alpha$ " is the driving length (length during which the teeth are in contact: $t1t2$ on **figure 1**) divided by the base pitch. This ratio must be more than 1 (only one tooth pair is in contact in this case, a new contact coming just after a lost one). It should be 1.3 minimum for a good gearset and the bigger the better for a silent gearset (this gives smaller shocks as the teeth contact).

Note 1: This is not actually the case, in fact in the video due to the teeth having a circular profile in place of an involute one, the contact is occurring slightly later, this is a good property as under load the teeth are bending and the contact occurring at the right time; a good profile would give shocks in that case.

Note 2: This explains why two gears with the same module but not the same pressure angle cannot mesh correctly.

All the already defined dimensions can be found on **figure 2**.

Multitooth pinion and rack system: (see fig. 3)

The rack is considered as an infinite diameter wheel, no problem as the pitch line of the rack (equivalent to the PCD) is rolling without slipping on the pinion PCD.

The puzzling thing is that there isn't any "base line" (it is shifted far away in the infinite...) and so no convenient pulley and belt comparison is possible. It's well known that infinite is very far, mostly when you are nearing the end! See **appendix 1** to know more about the pinion and rack meshing.

● To be continued

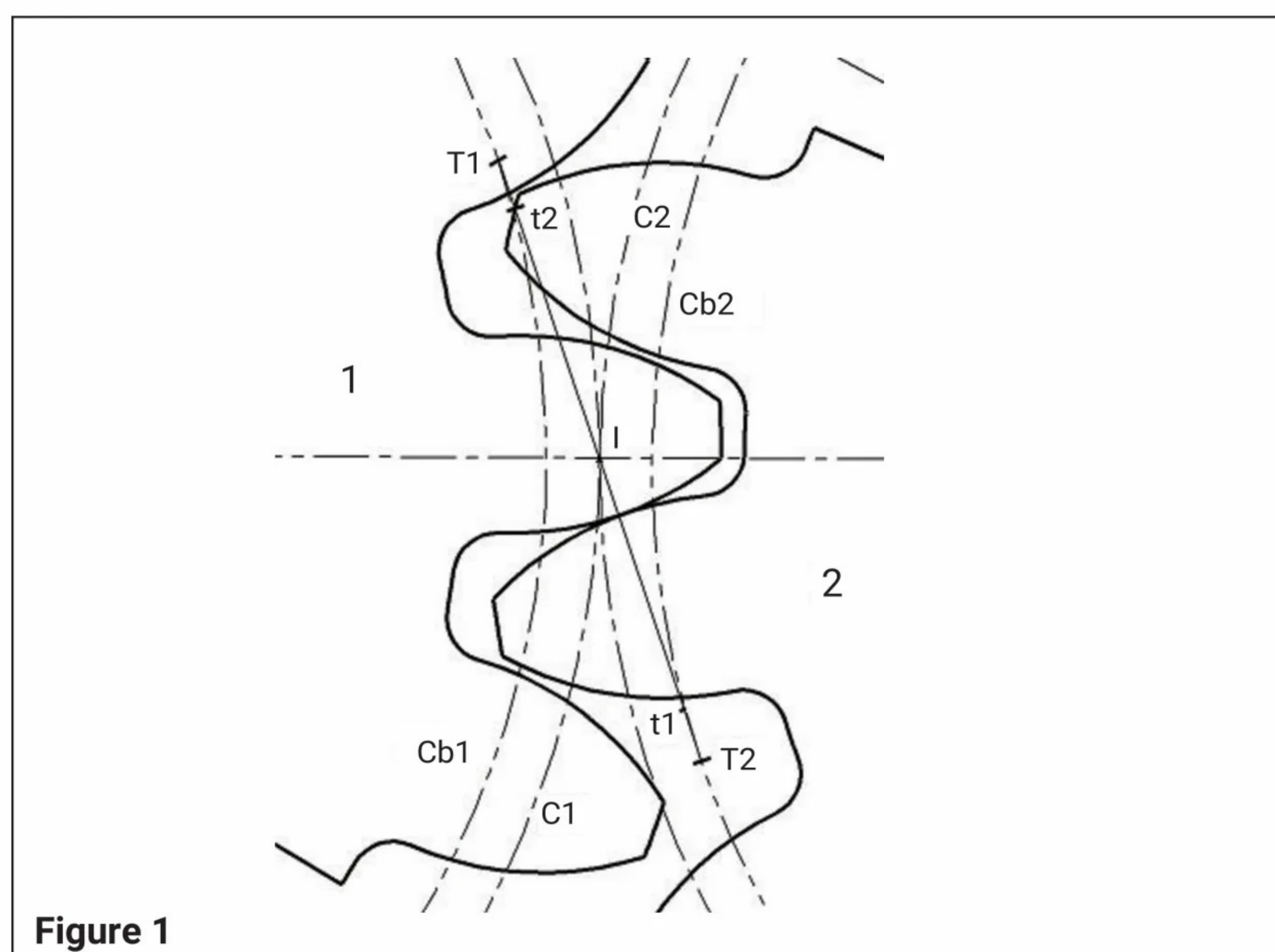


Figure 1

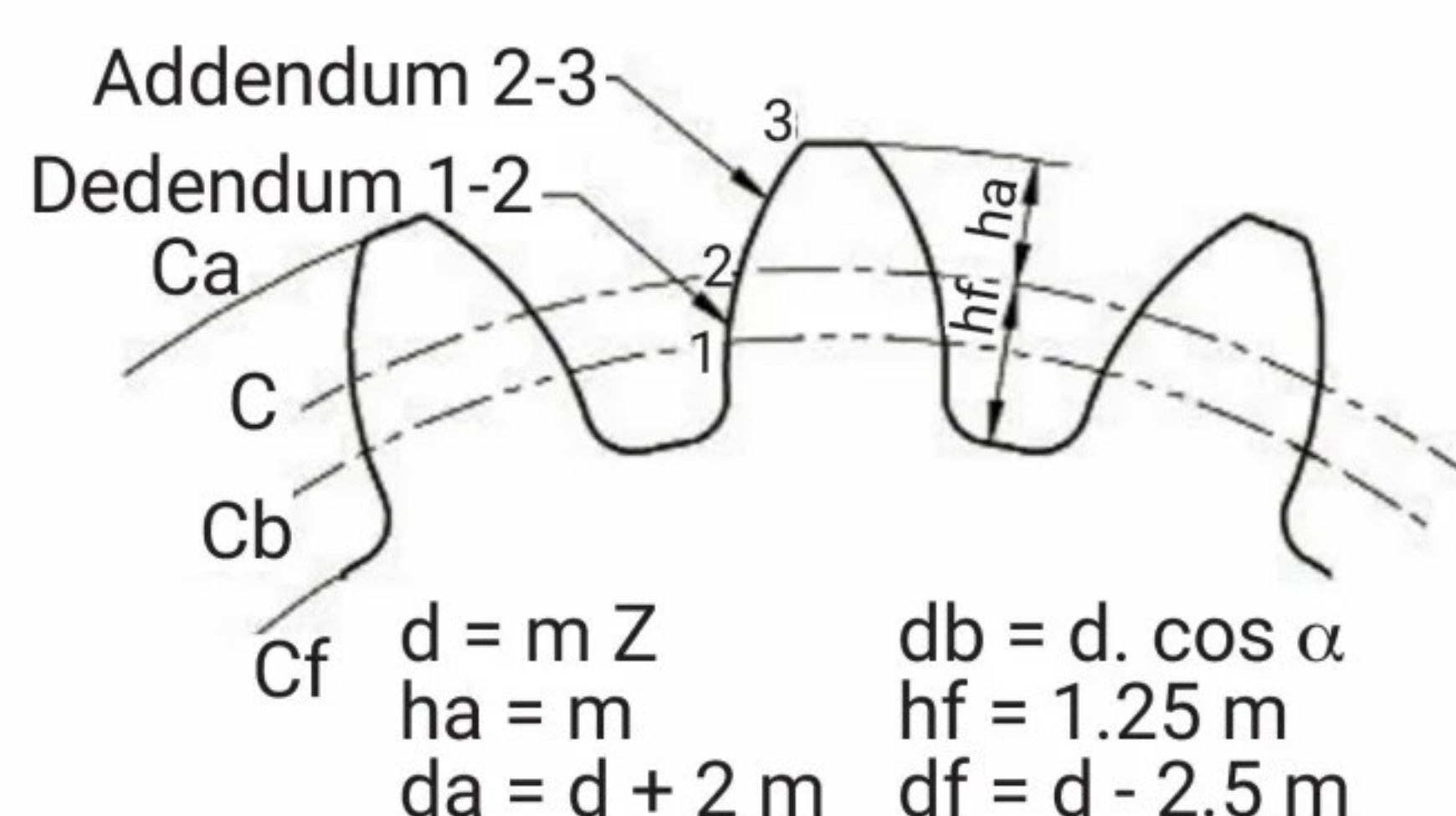


Figure 2

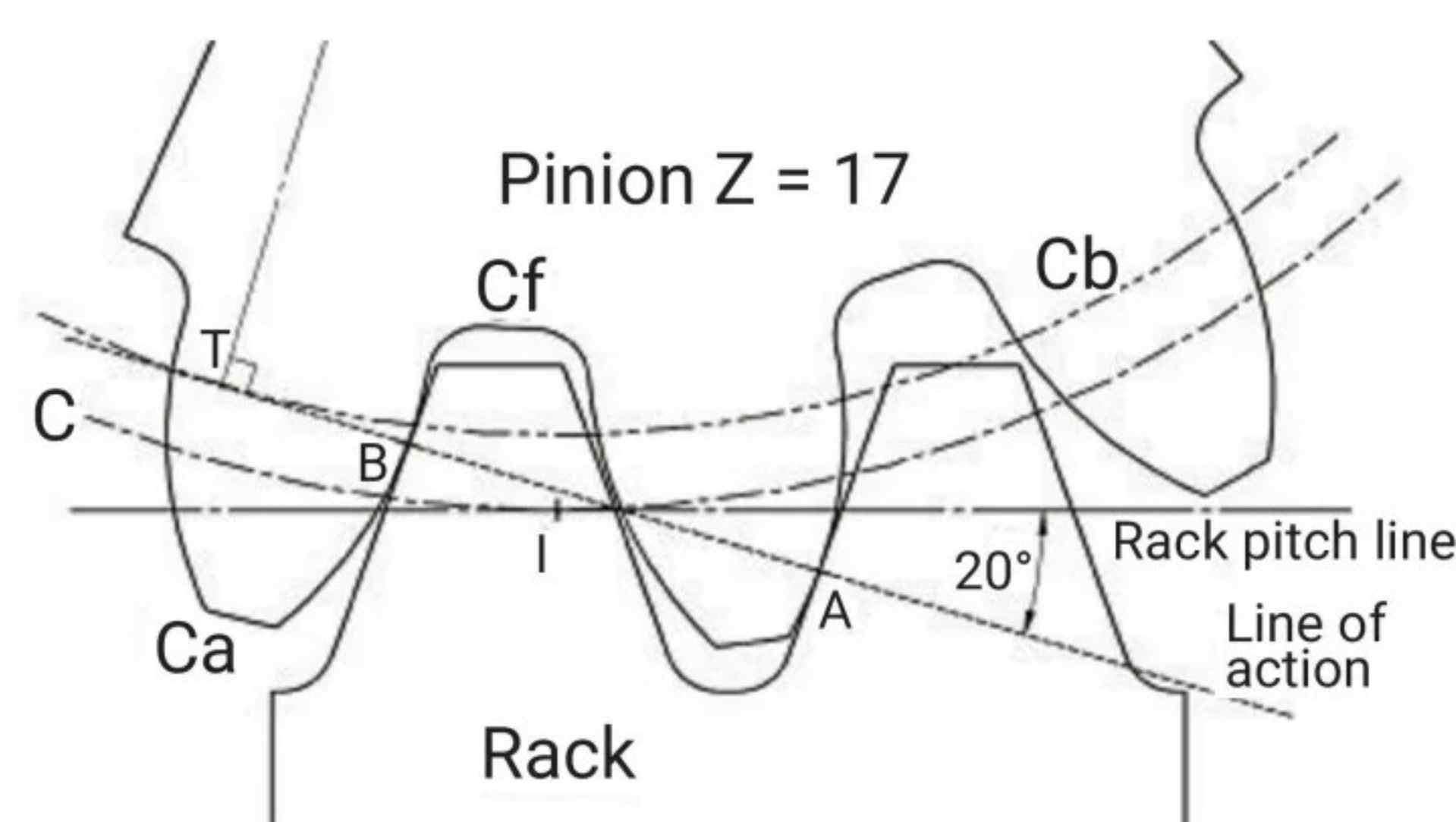


Figure 3

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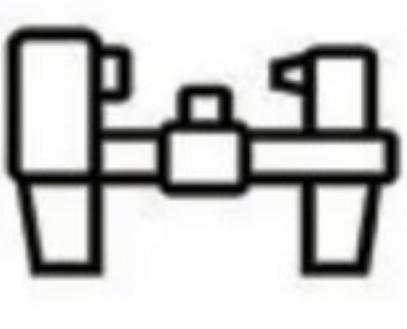
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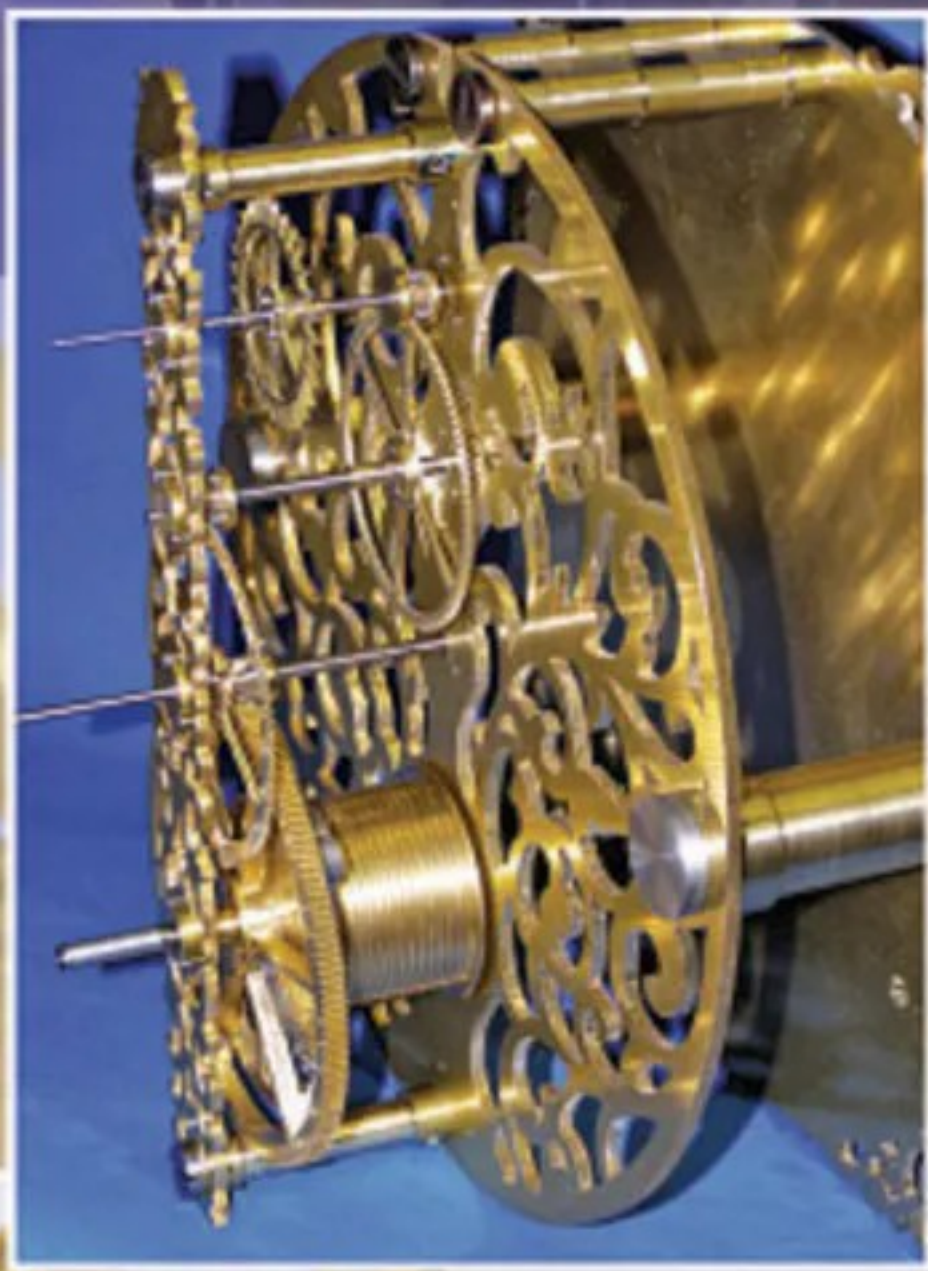
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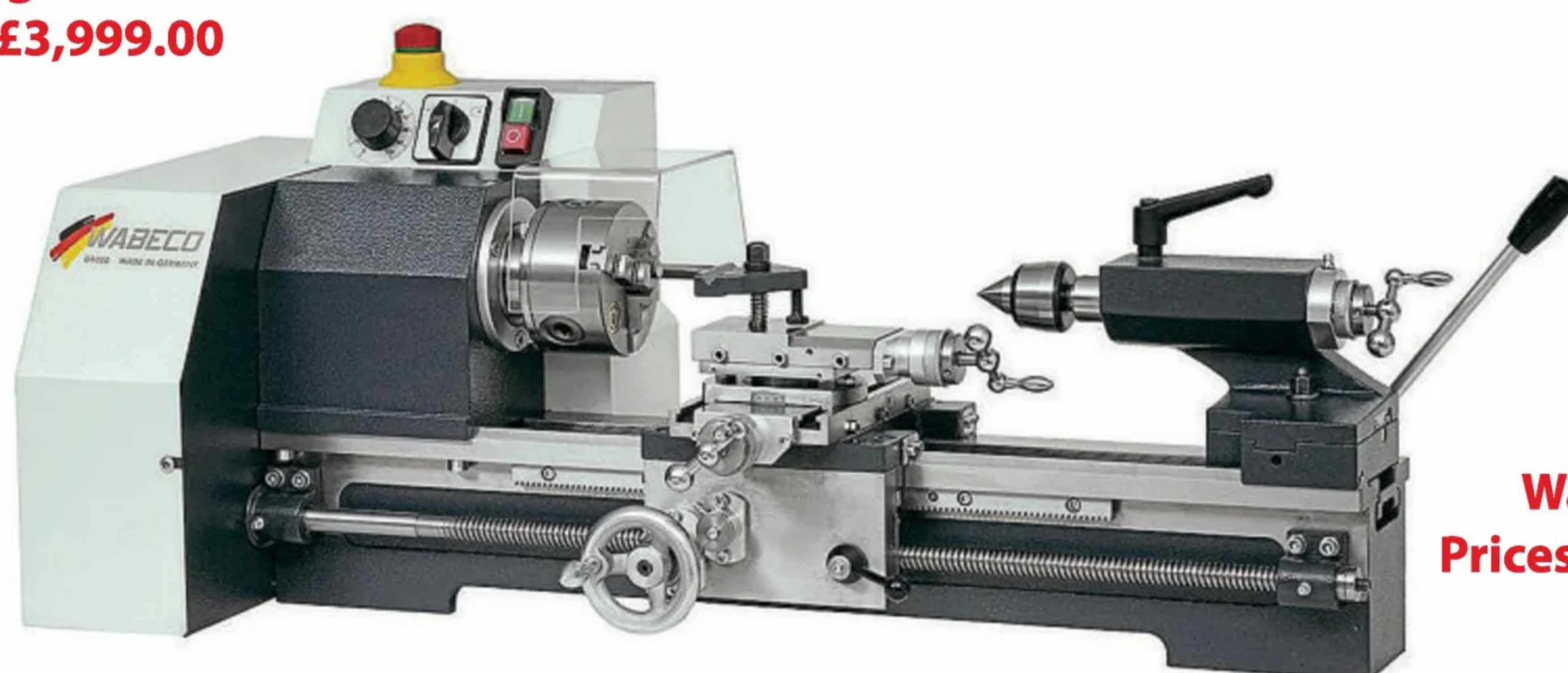
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