No.2 Morse taper facing tools

Guy Gibbons

Introduction

Shortly after the acquisition of one's first lathe or vertical milling machine it becomes obvious that it is of little use without some tooling. One of the principal operations needed in the home engineering workshop is a means of facing a piece of metal ('the work') that cannot easily be held in the lathe chuck in order to create a plane (flat) surface. With the work held on the milling machine table or lathe cross-slide, the simplest and arguably most useful of these is the flycutter, but this has limitations in that it does not offer a radial feed facility for facing around, say, the bore for a spindle. To do this, one needs an automatic radial feed facing head, which is a variation of a plain boring head.

This article presents two of my regularly used own-design tools: a simple flycutter, and a No.2 Morse taper radial feed boring and facing head. Both can be manufactured in the home workshop, but the latter presents some challenges in requiring cutting a scroll plate* and some fluency with epicyclic gearing.

* A scroll plate (or scroll) is essentially a spiral thread cut on a flat circular plate (a disc) rather than a helical (screw) thread cut on a cylinder. It is most commonly found in 3-jaw self-centring lathe chucks.

A No.2 Morse taper Flycutter

Design

Shown being used in the author's Westbury vertical milling machine in the introductory photograph and Figure 1, the design has a No.2 Morse taper (MT) shank and is fitted with an extraction ring based on the 'damping ring' supplied by Clarkson's for their No.2 MT S-type collet chuck. It takes a $^{5}/_{16}$ inch or 8 mm square single point lathe tool and is relatively simple to make. It can also be used in the Myford Series 7 lathes with a No. 2 MT spindle bore and can, of course, be made with other shank forms such as a No.3 MT.

The flycutter is not balanced as I have not found this to be necessary even at 1000 rpm.

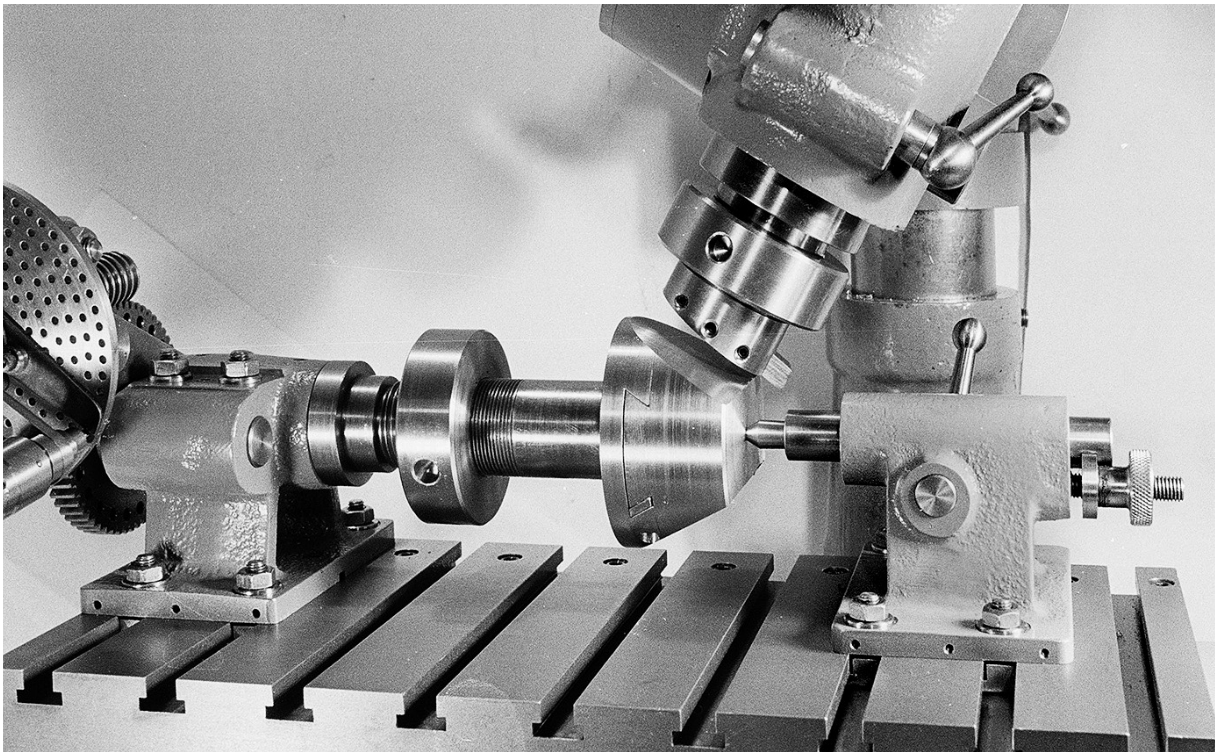


Figure 1 The flycutter being used in the Westbury vertical milling machine to taper the sides of a boring head body and associated cross-slide. The body is held by its integral No.2 Morse taper shank in the author's variant of the Geo. H Thomas dividing head and tailstock.

Manufacture

Manufacture is straight-forward, but those who have so far shied away from No.2 Morse Taper turning have now got to bite the bullet. While the taper shank could perhaps be pressed, glued, pinned or screwed into the flycutter body, the damping ring will put the joint under some axial load during taper extraction; consequently, it is preferable for the taper shank to be turned integrally with the head. I used a taper turning attachment, but a No.2 Morse taper can just about be turned using the Myford topslide. Care should be taken over the truth of the damping ring threads and associated faces.

One thing to note is that the head is handed; the tool slot is asymmetric in relation to the 10° face and the direction of rotation in normal use. The $^5/_{16}$ inch square toolbit (not shown on the drawing) is ground just as if it were a lathe tool with a small $^1/_{16}$ inch radius at the tip.

De-burring of the edges is essential on any rotating attachment. This should be done carefully and precisely; for a high quality finish, de-burring is a job in itself. Finishing

No painting is involved, though some constructors my choose to heat blue or chemical black some components.

The Drawbar

A lathe (and milling machine) spindle drawbar will be needed. The drawing shows my Myford Super 7 drawbar, and adjustments will be needed for one's vertical milling machine and dividing head – see Figure 2.

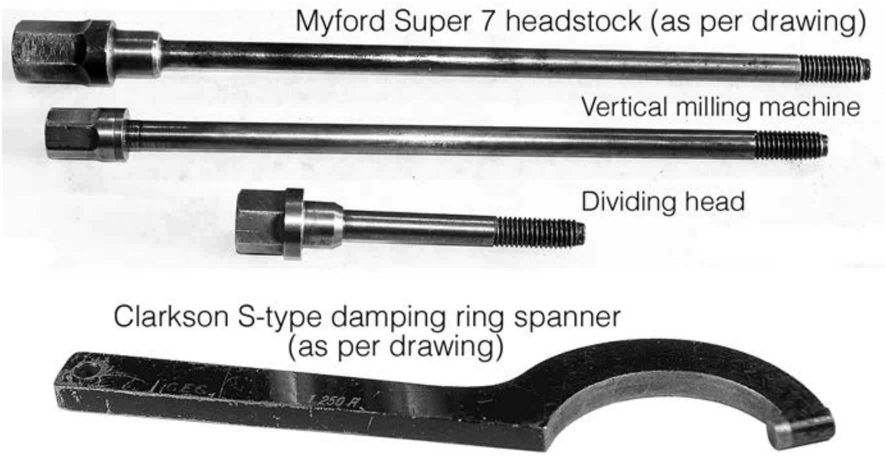


Figure 2 Three drawbars used by the author, and (below) the pin-spanner to suit the Clarkson S-type damping ring

I have developed this design of drawbar from at least two earlier and less successful designs, and it has been found not only capable of taking a lot of punishment but also convenient to use. The extended hexagon permits the Super 7 drawbar to be tightened with the change wheel cover closed, though this does have the slight disadvantage that the cover cannot be opened again without removing the drawbar. I include a 0.1 inch thick brass washer under the hexagon head to give a 'softer' pressure surface, and it is convenient to secure it with an anaerobic adhesive in order to save it from dropping off and getting lost*. But it is optional.

* Subjected to both (drawbar tightening) compression and (torsional) shear, adhesives are massively strong in shear so in-service failure of the adhesive is unlikely (and has not occurred in the author's example after thirty years' use).

At the time of construction, $^3/_8$ inch Whit. was the standard, No.2 Morse taper thread and is far more robust for repeated use than a fine (BSF) thread; nowadays a M10 thread is the standard size. Removing the end two threads protects the thread from burring over should the drawbar be carelessly thrown into the toolbox (surely not!) and helps to locate and start the thread into the shank.

The damping ring C-spanner

The spanner – Figure 2 – is a clone of the Clarkson 'S' type small Autolock chuck damping ring spanner, the Clarkson standard product having a finish of which they should not be proud. After rough sawing the blank, I recommend machining both external and internal radiused edges using the milling machine and careful manipulation on the rotary table.

Figure 3 shows a C-spanner being machined on the milling machine rotary table to suit the damping ring* alongside, after which the peg is silver-brazed into position.

* The Clarkson description (see box) of the damping ring emphasises its benefits in conferring stability rather than its benefits as an extraction ring to avoid having to free the Morse taper with a soft-faced hammer on the end of the drawbar. I leave readers to decide which is the more important purpose.

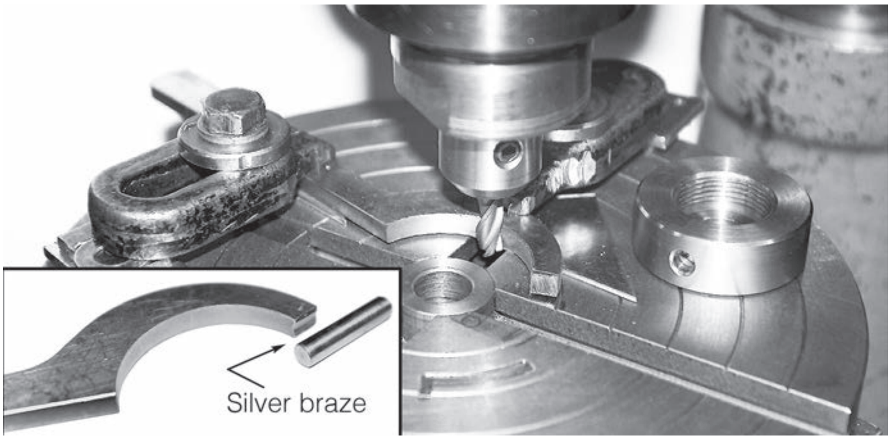
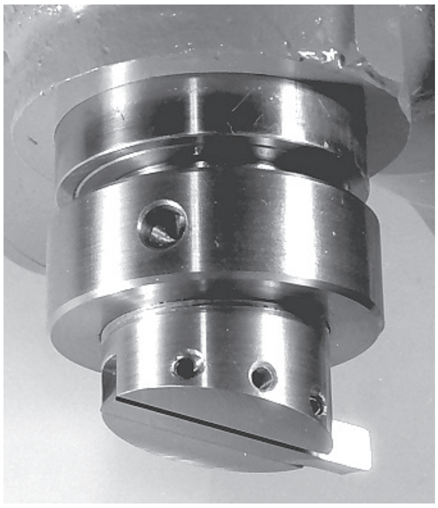


Figure 3 Machining the inner radius of the C-spanner


We recommend that the Autolock Chucks listed below are used in conjunction with a damping ring (see illustration). The purpose of these rings is to give added stability to chucks which have small tapers and a relatively large overhang below the machine spindle. The chucks listed are supplied with a left-hand thread on the back face of the body to which the rings can be fitted.
When a damping ring is screwed onto the chuck and tightened back against the machine spindle nose it greatly improves the stability of these particular chucks.

Extract from the Clarkson catalogue Ca. 1975

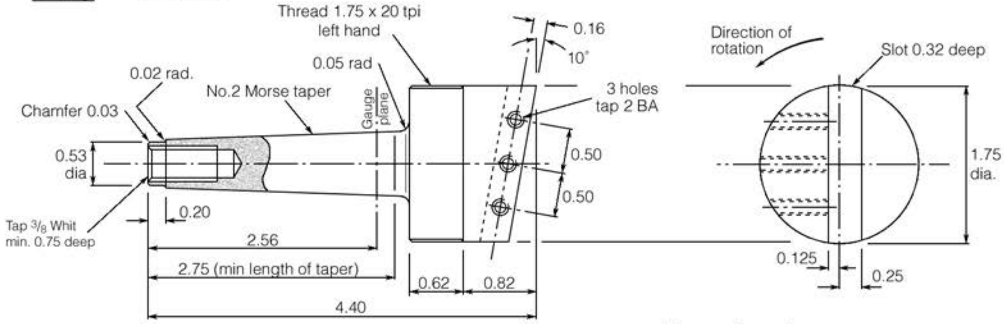


In the next Section starting on page 6, I continue with the design and construction of a No.2 Morse taper radial feed boring and facing head

No.2 Morse taper Flycutter

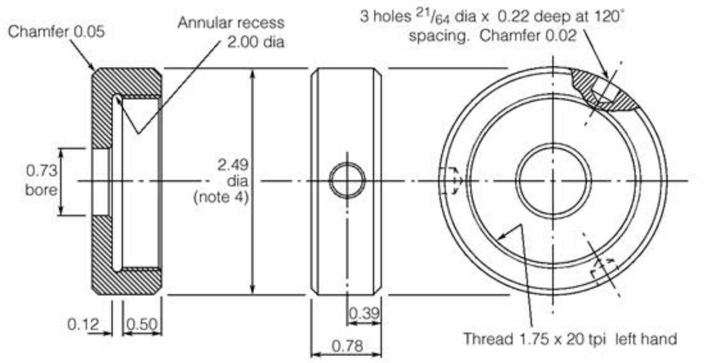
Body

1 off mild steel



Damping ring

1 off mild steel



NOTES

1. No.2 Morse taper to BS1660:1972. Diameter at gauge plane 0.7000, taper on dia 2°51.68'
2. Drawn to suit $^5/_{16}$ sq. single point tungsten carbide or HSS lathe tool
3. Standard parts: 2 off 2 BA x $^1/_2$ hex skt set screws
   1 off 2 BA x $^3/_4$ hex skt set screw
4. Damping ring outside diameter and pin holes the same as Clarkson S-type Autolock chuck with No.2 Morse taper shank.

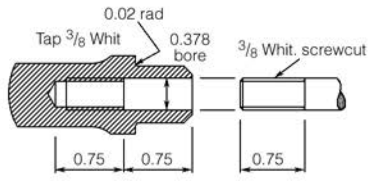
Third angle projection. All dimensions in inches unless stated. GEG 12/87(1)

Myford Super 7 Drawbar and Clarkson C-spanner

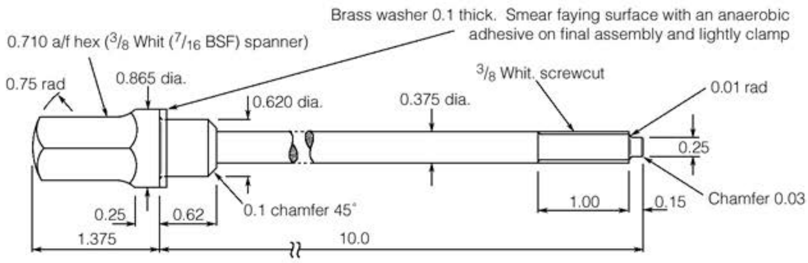
Drawbar

1 off mild steel assembly. Drawn to suit Myford Super 7 lathe (overall spindle length approx 11.75)

Assembly detail

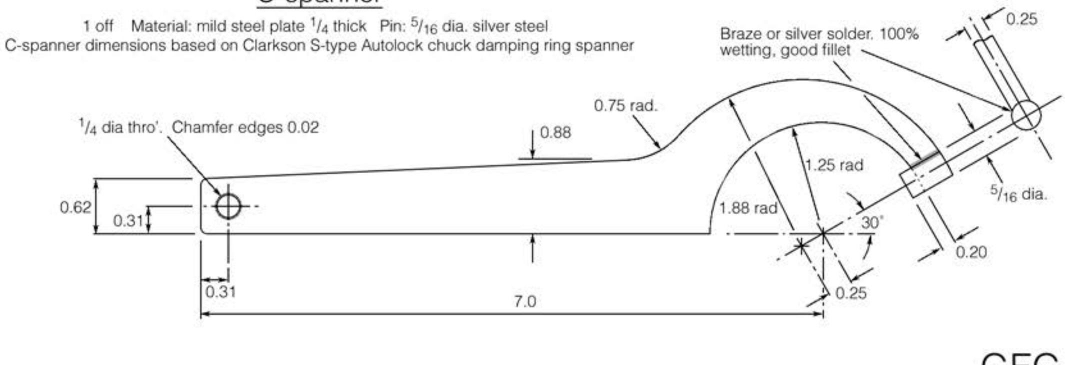


Assemble with high strength anaerobic adhesive and screw to refusal while liquid



C-spanner

1 off Material: mild steel plate $^1/_4$ thick Pin: $^5/_{16}$ dia. silver steel
C-spanner dimensions based on Clarkson S-type Autolock chuck damping ring spanner



Third angle projection. All dimensions in inches unless stated. GEG 12/88(1)

A No.2 Morse taper automatic radial feed boring and facing head

This boring and facing head is based on the principle that, by gripping and holding stationary an outer knurled ring while the spindle is in motion, a radial feed motion will be imparted to the tool slide – Figure 4 inset. Alternatively, the outer ring can be left alone and the slide locked to bore a hole so that boring and facing,can be cut at one setting and be both truly concentric and at right angles to one another. Feeding stops the moment the knurled ring is released.

Although shown being used in the lathe, this tool is equally useful in the vertical milling machine. But I should mention that the device does require one to have fingers very close to rotating parts and, while I see no real danger for a competent person, the device may not be appropriate for inexperienced persons.

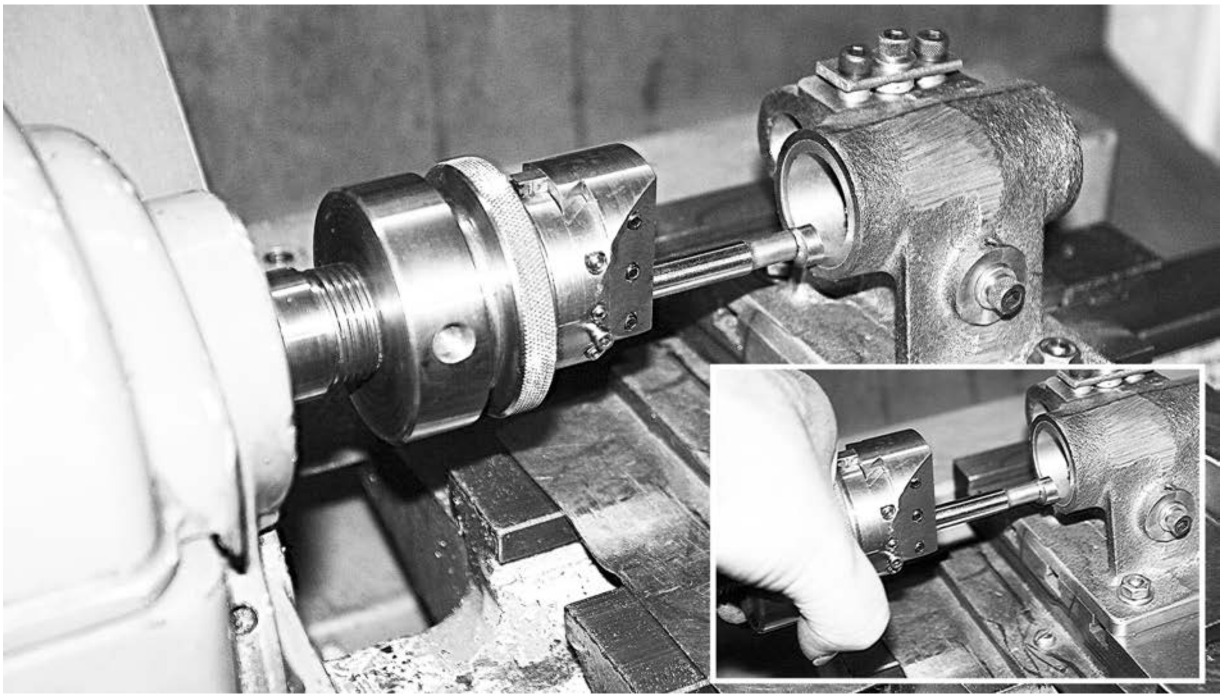


Figure 4 Using the automatic radial feed ring to face the end of a casting. Finishing the face with the casting at the same cross-slide setting ensures it is truly at right-angles to the bore. Radial feed also permits the faced end to be recessed, which cannot be achieved with a flycutter

Design

Being wholly dissatisfied with the clunky finger wheel and striker mechanism design presented by Mr Westbury that appears to be the first choice of many toolmaking model engineers (including me), it took me literally years to get this device into the compact form shown. An earlier attempt had an automatic quick return, but it was too fast and rather cumbersome.

In overall appearance, the design is based on the Wohlhaupter UPA2 boring and facing head, but it differs in several respects:

- for compactness and simplicity no quick return is incorporated,
- the head has just one radial feed ratio of approximately 1.5 thou (0.04 mm) radial feed per spindle revolution,
- no 'Tommy bar' facility is included, and
- the radial feed is smooth and continuous rather than being incremented in tiny steps.

The key to a compact radial feed facing head of this type is in the use of epicyclic gears, and for a full understanding one may need to spend some time thinking about the mathematics of epicyclic (sun and planet) gearing. To assist, an isometric sketch together with the equation for the gear ratio is shown on drawing Sheet 6 (sheet GEG 12/89(6)).

The epicyclic gearing is combined with a scroll of the type normally found in 3-jaw lathe chucks; as the geometry of the scroll 'nut' is not entirely straight forward an explanation is provided on drawing Sheet 8. Each side of the nut 'threads' needs to be cut separately, the 'threads' needing to be cut at the mean tangent to the scroll spiral.

The same No.2 Morse taper drawbar(s) and damping ring C-spanner as described for the Flycutter earlier are used.

Manufacture

The dovetail slide can be cut using a cross-slide milling attachment in the lathe – Figure 5. Alternatively, the body can be set up in a dividing head on the milling machine (vertically mounted if a vertical milling machine is used).

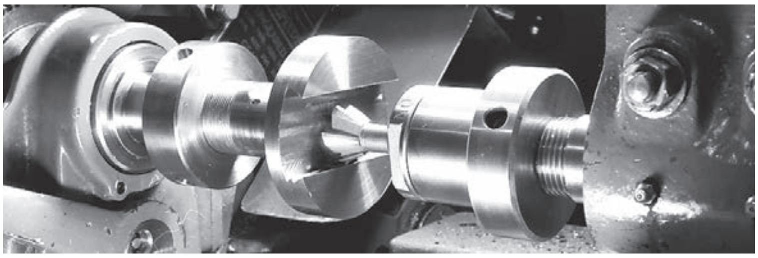


Figure 5 Cutting the dovetail slide using a motorised cross-slide milling attachment. It is a far from rigid set-up, but with careful cuts and a little hand-fitting (scraping) a very good sliding fit can be achieved

It is vitally important that the $^3/_{16}$ inch hole for the sun wheel securing key is accurately located along the body length; at only 0.197 inch wide, there is only 5 thou. clearance either side of the sun wheel. Indeed, axial dimensions are generally critical if trouble-free operation is to be achieved and adjacent gear teeth are not to clash. Similar considerations apply also to the dimensions of the tool slide, and it is best to make and fit the gib strips and adjusting screws and so fit the slide to the body for final shaping and machining together.

A start can now be made on the moving parts. I know of no other way of making the planet carrier accurately other than by co-ordinate drilling and taking extreme care in the planting of the planet wheel pivots. As drawn, there is but half a thou. over-spacing of the gear centres and it is essential that this is got right if the gears are to run freely. For this reason, it is probably best to increase the PCD by 2 to 3 thou. as I did in order to ensure smooth running even if at the expense of a little extra backlash. While we are talking of the planet carrier, it is important to get a smooth knurl that is free from sharp edges; remember, you must be confident enough to grip this rotating ring with no fear of cuts to your fingers.

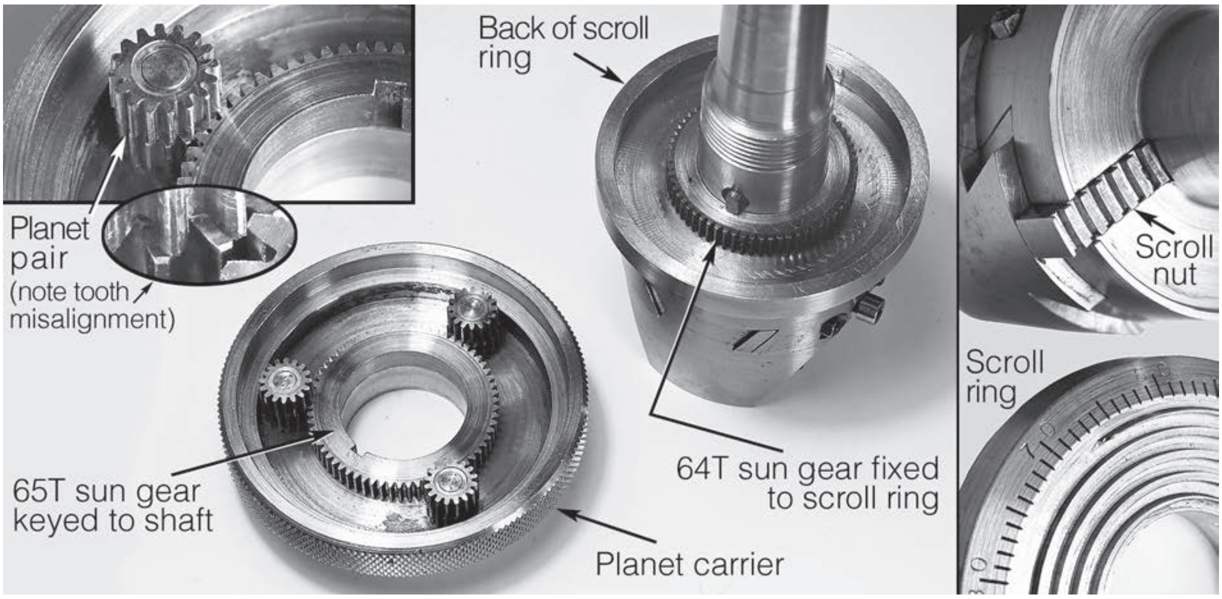


Figure 6   Showing the disassembled planet gear pairs, the sun gears (see drawing Sheet 6), scroll nut teeth and scroll ring (note the direction of the scroll spiral)

The gearing

For this attachment I purchased commercial stock gears. Having to mesh wheels with a different number of teeth (64T and 65T) with 16T pinions on an identical centre is accommodated by mixing module and diametral pitch pinions (see Drawing Sheet 5). This results in a negligible pitch centre error that is well within an acceptable tolerance, though one must remember to allow for the slightly increased tooth width of the 64 DP pinions by increasing the pitch centres a fraction.

Concentric machining the bores of commercial gears with their outside diameter is, I find, best done in machined-up soft jaws of the 3-jaw chuck. The keyway in the 65 tooth gear wheel requires the use of a slotting attachment; I made mine to J A Radford's design – Figure 7 (see *Model Engineer* magazine, 3 January 1969).

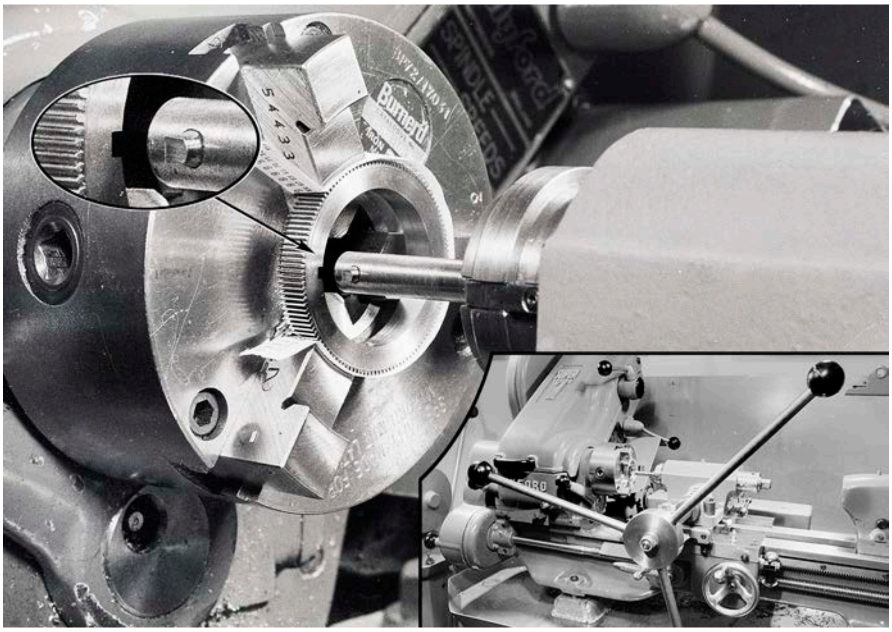


Figure 7   Slotting the keyway in the 65T sun wheel held in soft jaws in the 3-jaw chuck

And do the three planetary gears all transmit torque equally? I doubt it as there is no torsional flexibility between the two 16T planet gears, but I couldn't bring myself to fit just one planetary gear set - it didn't look right. With three shafts and only one tooth difference, the pinions on the planet shafts have to be spaced in-line, $^1/_3$ and $^2/_3$ tooth spacing, and I found no more accurate way of achieving this than by eye. This, of course, immediately throws into greater doubt the equality of load sharing between the planet gears, but by using gear teeth in an unhardened (soft) condition, my experience with these gears has shown that they do bed-in (bruise) with time which will lead to improved load sharing.

The scroll

Cutting the 10 tpi scroll is far from easy, and at the very least requires a suitable power cross-slide feed arrangement geared from the lathe spindle – Figures 8 and 9. My Super 7 has no power cross-slide, so before embarking on the manufacture of this boring and facing head, I designed and made a scroll cutting attachment, but this is perhaps for a later time.

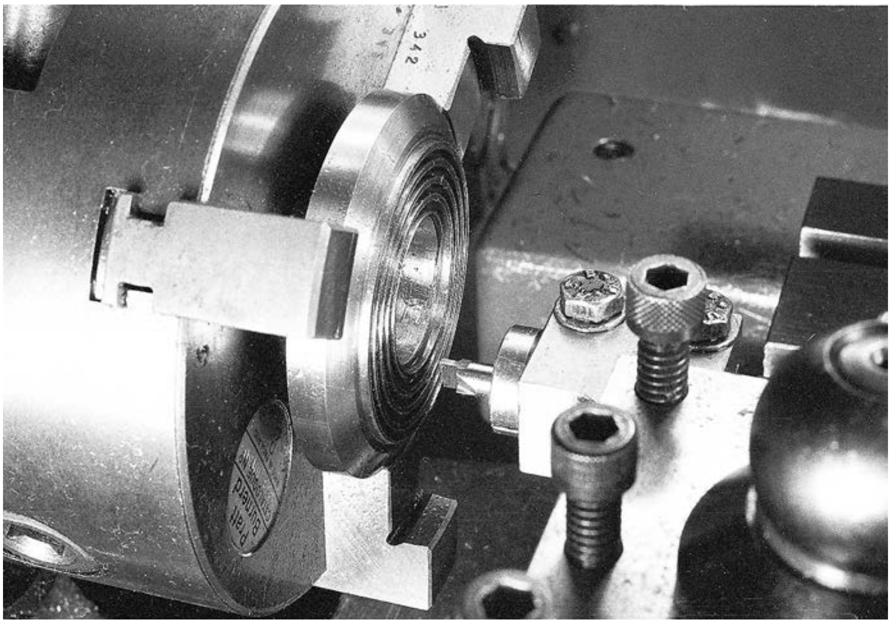


Figure 8 Cutting the scroll on the Myford Super 7 lathe using the author's own-design power cross-feed attachment (Figure 9)

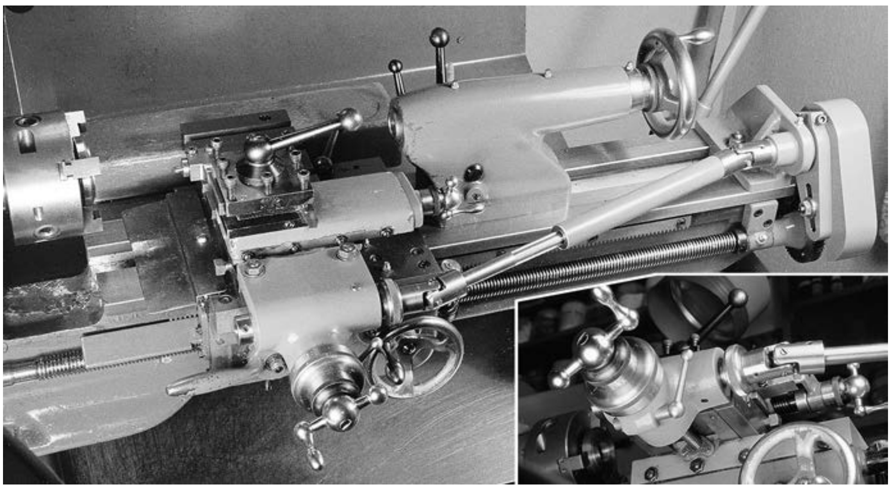


Figure 9 The author's power cross-feed attachment

Needing an automatic feed cross-slide on the lathe, the scroll is cut with a square tipped single point lathe tool at 10 tpi. This should be done in two stages: firstly, a roughing cut with an under-width tool, which is then repeated twice with the tool ground to a fine finish to bring the scroll gaps to the exact width. Make sure the scroll is cut in the correct spiral direction.

To digress for a moment, I have cut scrolls both using a power cross-feed Myford Super 7 lathe and my earlier Super 7 fitted with my own design and manufacture power cross feed attachment. Perhaps I am biased, but because my scroll cutting attachment incorporates a fine radial positioning device (Figure 9, lower right), I did find it the easier to use for this application, primarily for shaving the sides of the scroll teeth to the correct width and finish. Without it, and with the topslide in its normal position, one has no facility to put on the tooth width shaving cut. And setting the topslide at 90° is no solution (even if the topslide feed handle does not foul the cross slide) where the cross slide is powered by the saddle feedscrew as one no longer has a means of adjusting the tool cutting depth (feed).

No attempt at hardening the scroll teeth is made; for occasional use I do not think this necessary and it will certainly create problems of distortion. A smear of grease on the scroll will give it a more than adequate life for home workshop use. Numbering the ring (taking care to get them the right way round) is done using the Geo. H Thomas approach of engraved fiducial lines and stamped numerals followed up with a very smooth (but sharp) flat Swiss file.

The scroll nut

I did wonder about making the scroll 'nut' from bronze, but settled on steel for no particular reason other than because lathe scroll chuck jaws are of steel. The scroll nut teeth do not form part of a spiral but are a series of parallel 'fences' which require cutting either on the vertical slide in the lathe or on the table of the milling machine. To cut them, a single point cutter is held in a boring head* which is set in turn to cut the outer and inner radius – Figure 10.

* Figure 10 shows the Westbury boring and facing head which, while perfectly good for tasks that do not require a radial feed, I find rather 'home-made' in appearance.

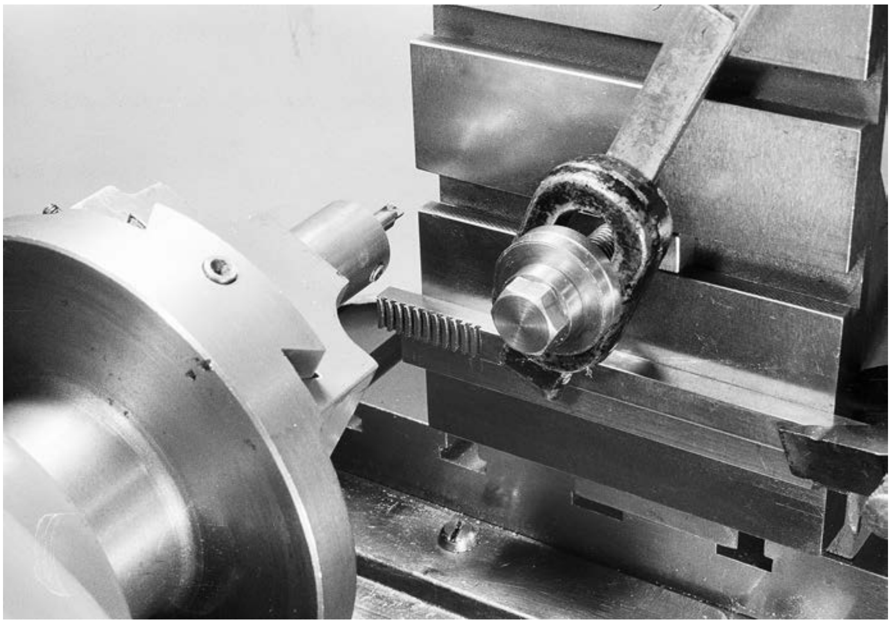


Figure 10 Using a Westbury boring head to cut the scroll nut teeth

The outer convex tooth radius must be as tight as the smallest (inner) radius of the scroll, and the inner concave tooth radius must be as large as the largest (outer) radius. The nut teeth lie along the local tangent to the spiral which varies across the nut width, and this in turn is dependent on the radial position of the scroll teeth.

Marking and drilling for the dowels and securing screw is done in-situ after engaging the nut in the scroll, and it is important not to break through into the nut teeth roots. Shims between the scroll nut and slide may be used to adjust for maximum tooth engagement with the scroll.

Figure 10 The completed boring and facing head with a selection of tools and sleeves alongside

Final assembly and use

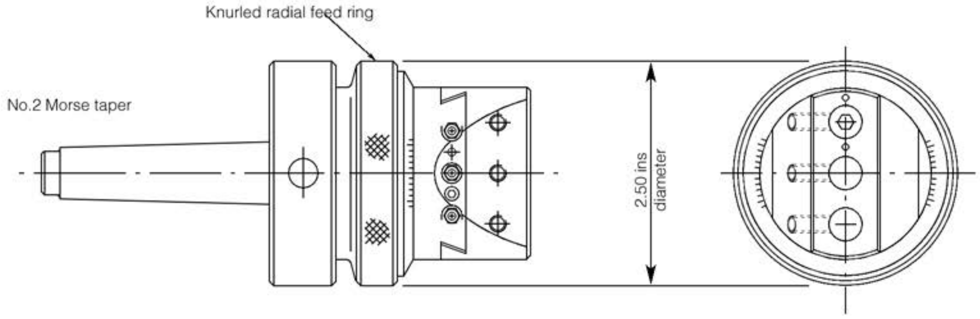
Assembly is easy if accurately made, and a smear of molybdenum disulphide grease helps all run smoothly. The facing tools can be commercial single-point tools but can also be made, and are much the same as for those for a boring head. The feed direction can be out-to-in or in-to-out depending on the position of the tool in the tool holder.

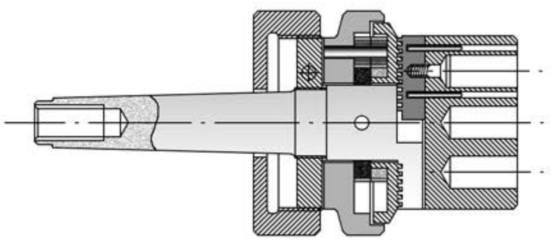
By locking the slide between each cut, the graduations mean that it is quite possible to use the head as a boring head as well as a facing head, though personally I have found a dedicated No.2 MT boring head with hexagon socket screw adjustment a little more convenient.

Guy Gibbons, OBE, MIMechE

Bath, 2024

No.2 Morse taper radial feed boring and facing head

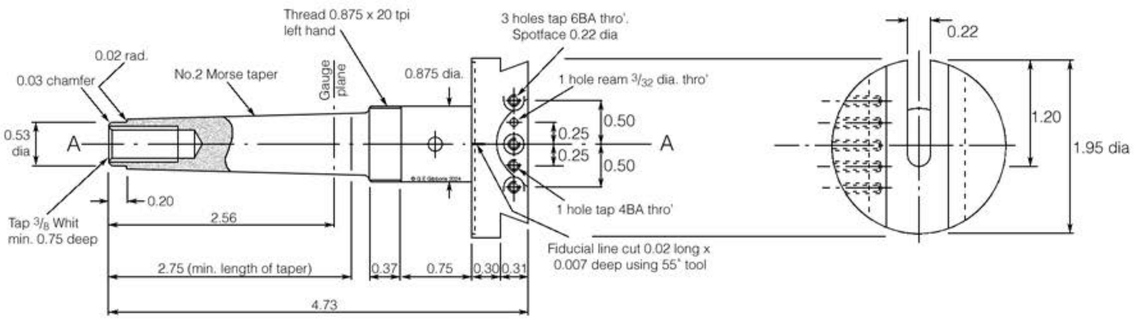




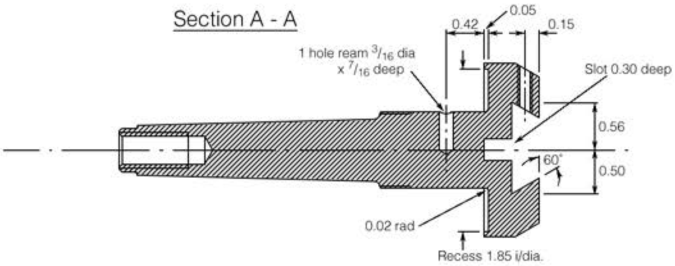
Max. radial slide travel: $^5/_8$ inches (16 mm)
Max. facing dia using simple tools approx. 2 $^1/_4$ inches (55 mm)
Radial feed per revolution approx 1.5 thou. (0.04 mm)

Third angle projection. All dimensions in inches unless stated. GEG 12/89(1)

Boring and facing head - body



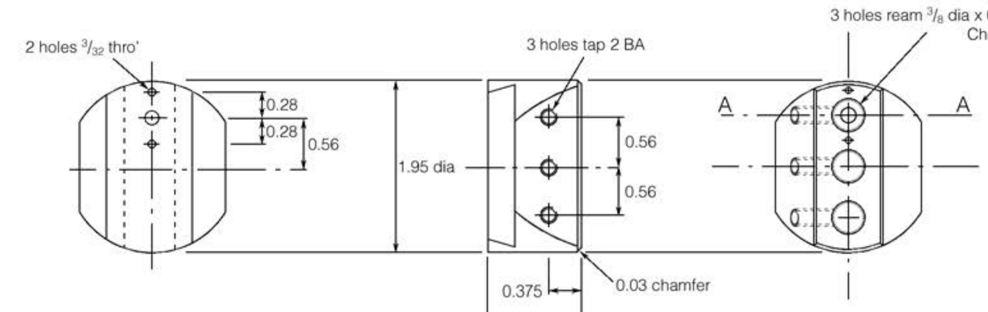
Section A - A

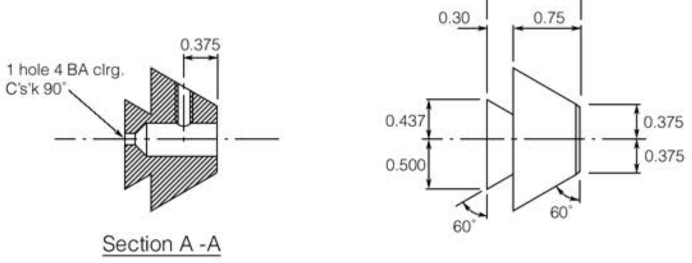


NOTES
1. Material: steel EN8 (080M40) or similar
2. No.2 Morse taper to BS1660:1972. Dia. at gauge plane 0.7000, taper on dia 2°51.68'

Third angle projection. All dimensions in inches unless stated. GEG 12/89(2)

Boring and facing head - tool slide

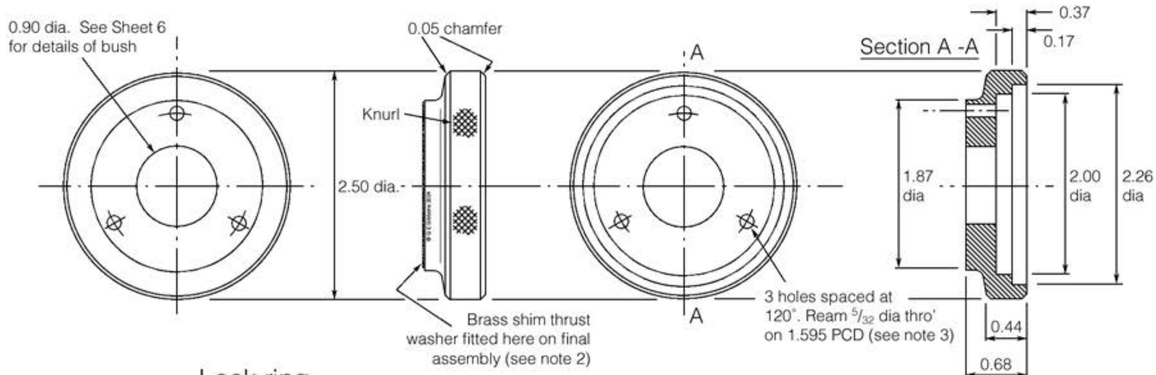


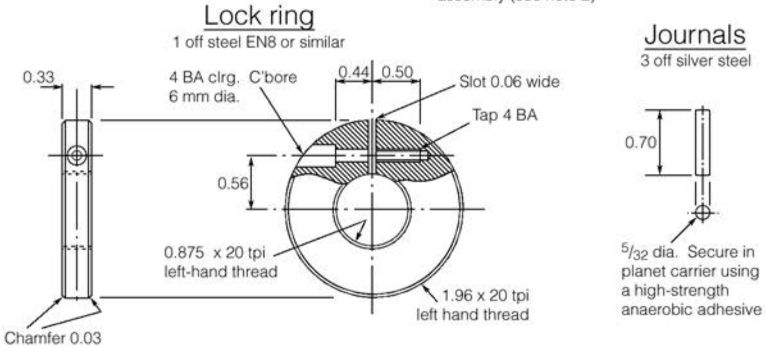


NOTES
1. Material: Steel EN8 (080M40) or similar
2. Standard parts: 3 off 2 BA x 7/16 hex skt set screws
1 off 6 BA x 7/16 hex skt csk screw
2 off 3/32 x 1/2 roll pins

Third angle projection. All dimensions in inches unless stated. GEG 12/89(3)

Boring and facing head - planet carrier





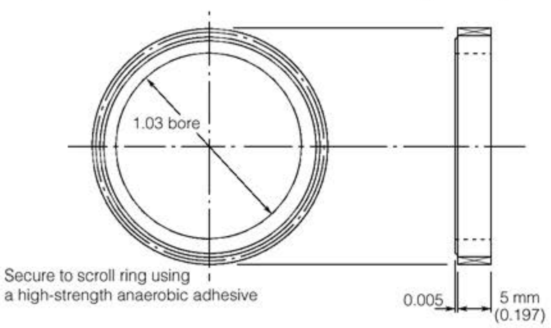
NOTES
1. Material: Steel EN8 (080M40) or similar
2. 1 off brass shim thrust washer: 7/8 i/dia x 1.80 o/dia x 0.01 thick
3. PCD: See note 2 on Sheet 5
4. Standard part: 1 off 4 BA x 7/8 hex skt cap screw

Third angle projection. All dimensions in inches unless stated. GEG 12/89(4)

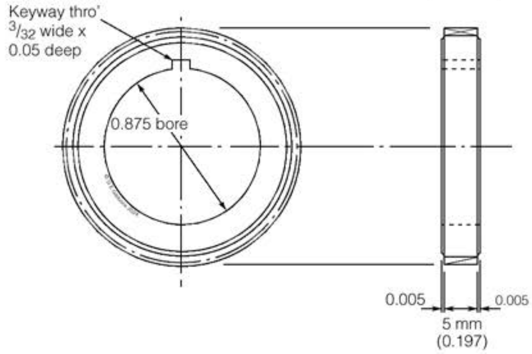
Boring and facing head - gears

All gears 20° pressure angle involute tooth form

64 teeth 0.5 mod. PCD 32 mm (1.260)

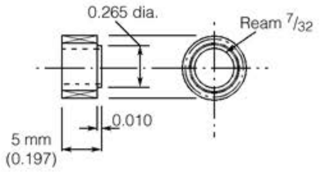


65 teeth 0.5 mod. PCD 32.5 mm (1.279)



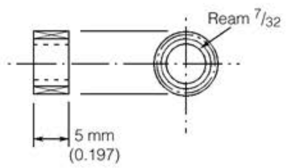
16 teeth 48 DP PCD 0.332

3 off steel



16 teeth 0.5 mod PCD 8 mm (0.315)

3 off steel



NOTES

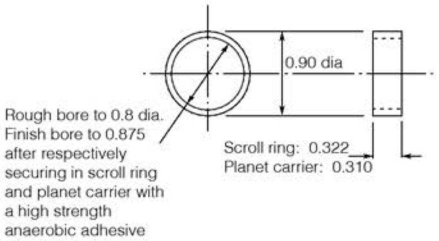
1. Secure pinions to pinion sleeve (Sheet 6) using a high strength anaerobic adhesive. The pinion teeth must be phased during assembly:
   - pair #1: teeth in line
   - pair #2: teeth 1/3 space out of phase
   - pair #3: teeth 1/3 space out of phase
2. 64 tooth wheel meshes with 48 diametral pitch (48 dp) pinion, 65 tooth wheel meshes with 0.5 mod pinion. Using involute teeth, this results in negligible (± 0.1%) pitch centre errors; however the 48 DP pinion may need the tooth width slightly reduced (by up to 0.003 inches) for free meshing. Alternatively, the pitch centres could be increased by 0.003 inches as shown on Sheet 4.
3. Nomenclature: PCD = Pitch Circle Diameter
   DP (inches) = Diametral Pitch = No. of teeth/PCD
   mod (millimetres) = module = PCD/No. of teeth
   mod = 25.4/DP

Third angle projection. All dimensions in inches unless stated. GEG 12/89(5)

Boring and facing head - gear details

Bushes

1 off each size (2 in total). Bronze



Key

1 off silver steel

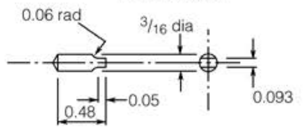
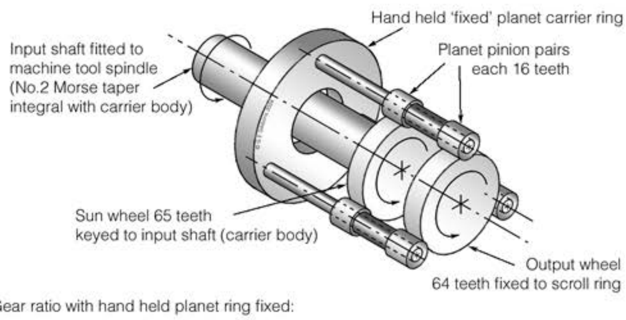


Diagram of sun and planet epicyclic gearing



Gear ratio with hand held planet ring fixed:

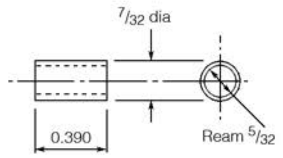
Scroll ring : carrier body = $\left(\frac{65}{16} \times \frac{16}{64}\right) : 1 = 1.015625 : 1$

Scroll ring : machine tool bed = $(1.015625 - 1) : 1 = 0.015625 : 1$

With a 0.10 tpi scroll, radial feed of 0.015625 $= \frac{0.015625}{10} \approx$ 1.5 thou per spindle revolution

Pinion sleeves

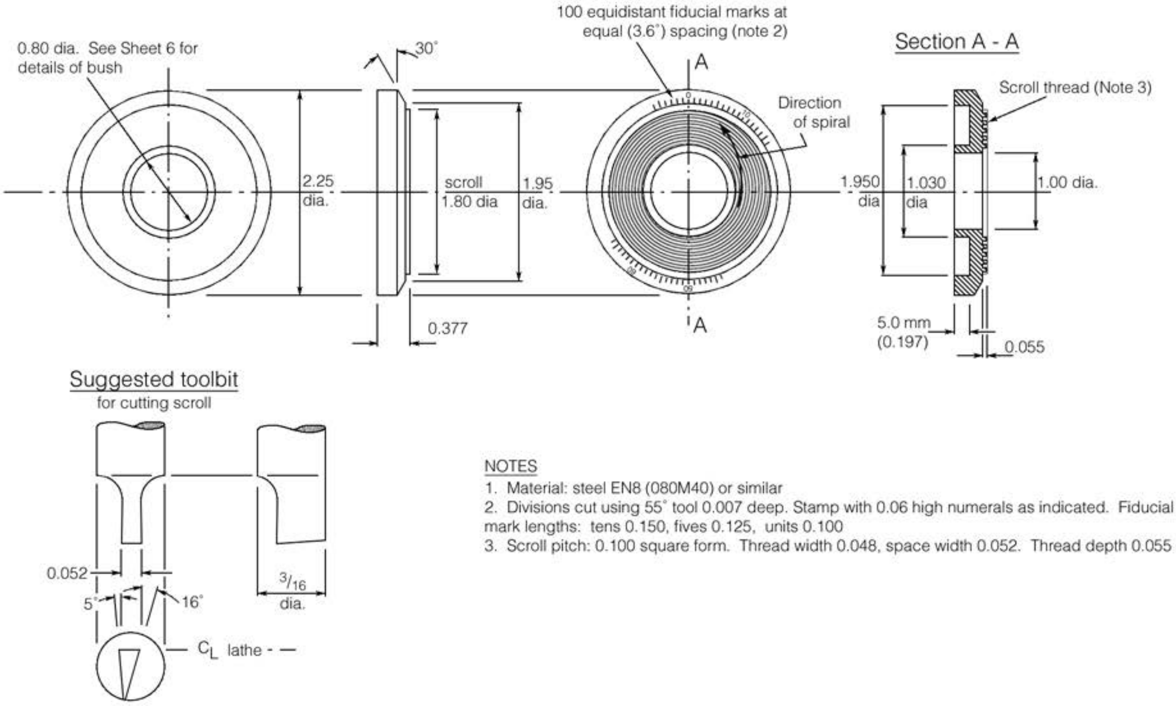
3 off Bronze



For fitting, see Note on Sheet 5

Third angle projection. All dimensions in inches unless stated. GEG 12/89(6)

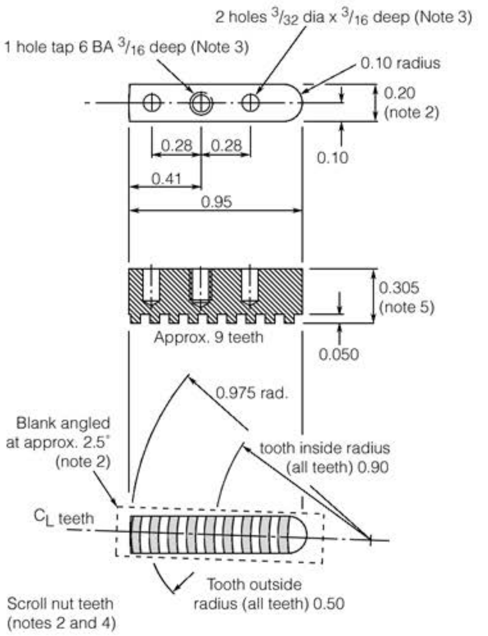
Boring and facing head - scroll ring



NOTES
1. Material: steel EN8 (080M40) or similar
2. Divisions cut using 55° tool 0.007 deep. Stamp with 0.06 high numerals as indicated. Fiducial mark lengths: tens 0.150, fives 0.125, units 0.100
3. Scroll pitch: 0.100 square form. Thread width 0.048, space width 0.052. Thread depth 0.055

Third angle projection. All dimensions in inches unless stated. GEG 12/89(7)

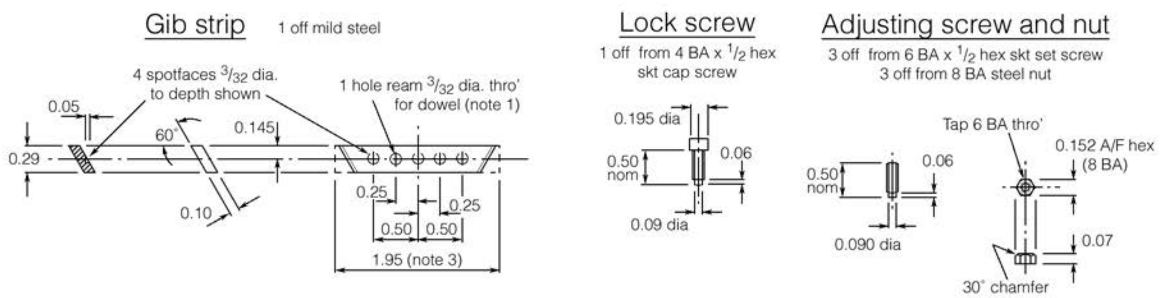
Boring and facing head - scroll nut

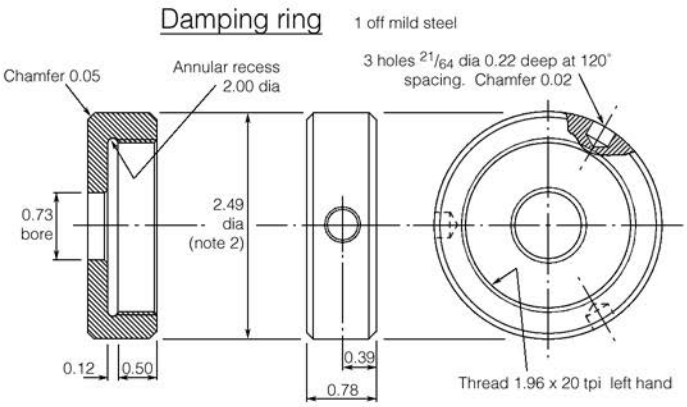


NOTES
1. Material: steel EN8 (090M40) or similar.
2. The scroll nut teeth ideally need to be set parallel to the tangent of the scroll spiral. This varies at each scroll thread, so in practise is not possible, and the specified tooth inside and outside radii stated work well (0.90 and 0.30 respectively).
   While it is theoretically possible to calculate the angular offset of each nut tooth (approx 2°), an alternative is to cut the teeth on an over-width blank (say 5/16) and then machine to the 0.20 width and angularity (approx 2.5°) after trial fitting. To do this:
   (i) using the slot in the body as a guide, the nut is engaged with the scroll thread and the back of the nut is scribed along the edges of the slot width,
   (ii) after removal, the width of the nut is machined to its correct width and angularity.
3. On completion of machining (2(ii) above) and the nut has been brought to its finished width and angularity, the two dowel holes and 6 BA thread are located from the tool slide by spotting through the holes in the tool slide.
4. Scroll nut tooth pitch 0.100. Tooth width 0.050, space width 0.050.
   Tooth depth 0.050 square form.
5. The 0.305 dimension (height of the nut) may be reduced by up to 0.030 on its back, and the best depth of engagement achieved by steel shims between the nut and the tool slide (Sheet 3).

Third angle projection. All dimensions in inches unless stated. GEG 12/89(8)

Boring and facing head - details

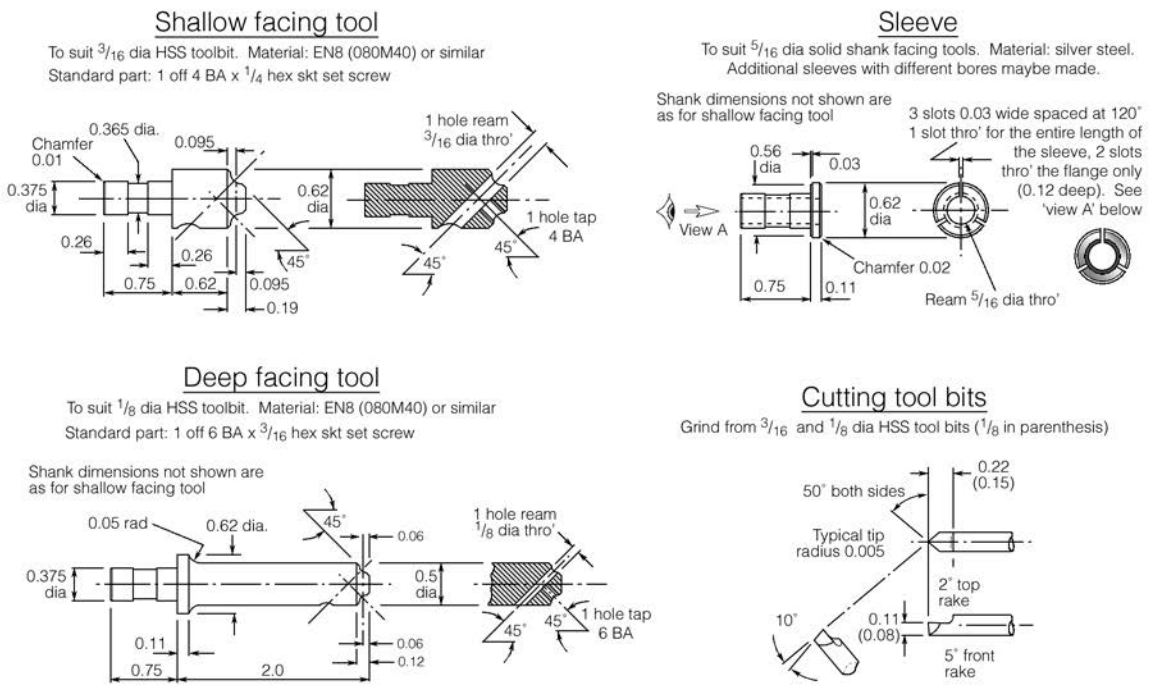




NOTES
1. 1 off dowel silver steel $^3/_{32}$ dia x $^1/_2$. Chamfer end 60°
2. Damping ring outside diameter and pin holes the same as Clarkson S-type Autolock chuck with No.2 Morse taper shank
3. Machine to length in-situ after fitting to boring head.
4. Standard parts:
   1 off 4 BA x $^1/_2$ hex skt cap screw. Reduce head diameter to 0.195
   3 off 6 BA x $^1/_2$ hex skt set screw modified as shown
   3 off 8 BA steel full nutrs modified as shown.

Third angle projection. All dimensions in inches unless stated. GEG 12/89(9)

Boring and facing head - tooling



Third angle projection. All dimensions in inches unless stated. GEG 12/89(10)