# WORKSHOP BENDING ROLLS

**by George H. Thomas**

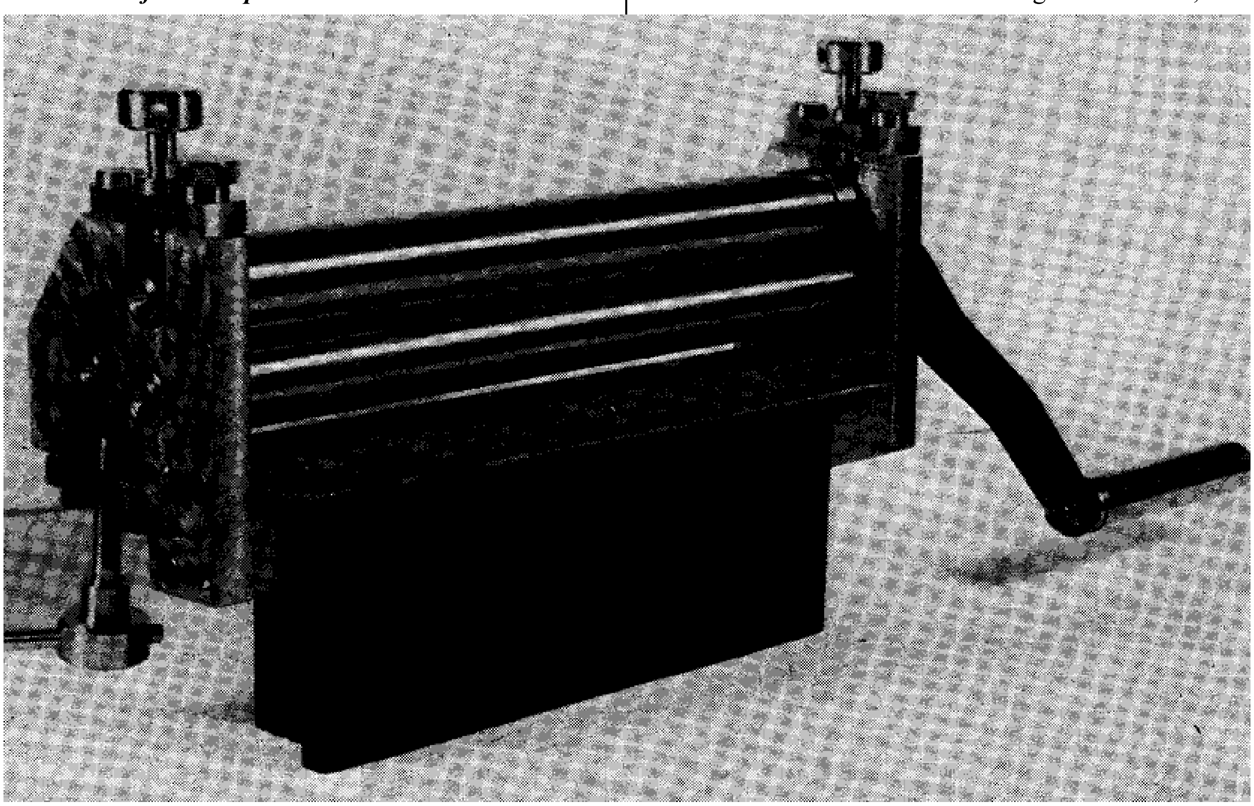
*This article first appeared in the October 1976 issue of Model Engineer in Britain. Some comments have been added in [brackets] to add ANSI specifications, or other comments.*

Two or three years ago, after having tried my hand at bending sheet-metal around beer bottles and pickle-jars I decided that the time had come to make a proper tool for the job. I knew several people who had made sets of rolls of the "pyramid" type in which the material is carried on a pair of rollers, front and rear, which are geared together so as to turn in the same direction and the desired curvature is obtained by pressing a third roller down into the gap between the other two.

Whilst it could be claimed that rolls of this form are simple to make, they do possess some serious drawbacks in operation, the worst of which is that the starting and finishing ends will be left straight and have to be hand-worked afterward - or cut off - due allowance being made for this when planning the work. The action of these rolls will, I hope, be made clear in Fig. 1(A) where the piece of material is acting as a beam freely supported at the ends and having a load applied at the centre. Under these conditions, the maximum bending-moment, and stress, will occur at the centre and when the stress exceeds the yield-point of the material, permanent deformation will occur at this point. Bending will take place progressively along the material as it passes under the central roller until the end slips over the supporting roller. It will be clear that, for a distance equal to approximately one half of the span of the supporting rollers, at each end the material has not been subjected to the maximum bending stress and these ends will, therefore, remain comparatively straight.

After considering a number of possible (and impossible) arrangements it was decided to go ahead with the system shown in Fig. 1 B & C. Here, the material is gripped by screw-pressure between a pair of rollers and driven forwards on to a deflecting roller at the back. The material is no longer a freely supported beam with the load at the centre but a cantilever with the load at the end, the anchorage of the cantilever being represented by the powerful grip of the pair of rollers and maximum stress will occur at this point. Thus far conditions are somewhat similar to those of the previous case *but* as the work is fed through the rolls, bending will occur progressively right along until the end passes out through the rollers so that, although the front end will be left straight as before, the

***Front view of the completed rolls.***



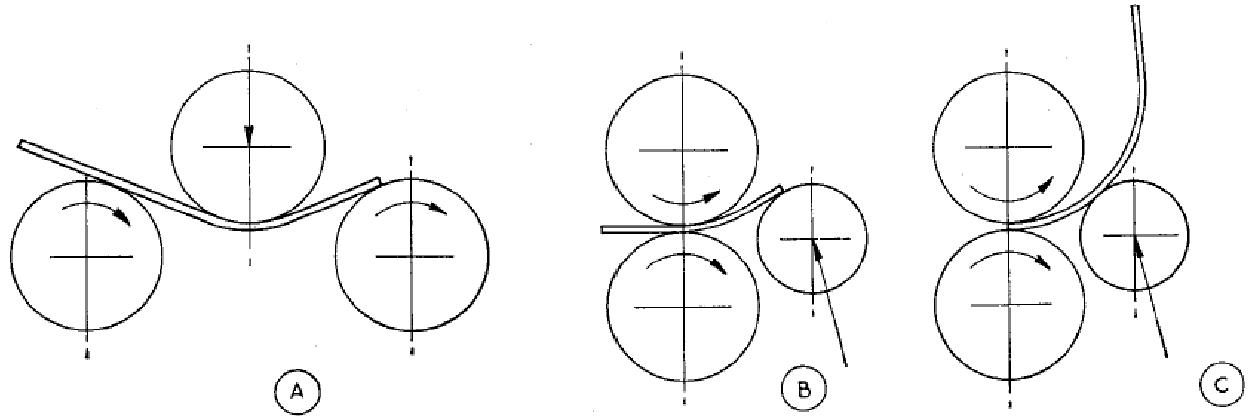


Fig. 1

curvature, when it starts, will continue right up to the other end. Now, if the material, after passing through once, is reversed end-for-end, the short straight portion will now be the last to pass through the gripping rollers and it will be curved in a similar manner to the rest.

Another trouble experienced with the “pyramid” type of rolls which has been reported from several users is that the material being worked upon will frequently refuse to travel forward, the supporting rollers merely skidding on the underside. It is possible to increase the friction between the driving rollers and the material only by increasing the pressure on the deflecting roller which, in turn, increases the resistance to movement. As I have not used this type of rolls myself, I cannot say what gives rise to this slipping condition; it might be brought about by an attempt to do too much bending at one pass or by screwing down the deflecting roller when the material is already in position underneath. The "pinch" rollers do not suffer from this disability as the pressure required for driving the work forward can be adjusted independently of the resistance of the deflecting roller.

For the type of work which I contemplated, which did not include rolling large boiler barrels, a capacity of 10 inch width was considered ample and, at this span, pinching rollers of l-1/8 inch diameter looked quite sturdy. As the loads on the deflecting roller would be considerably less than those on the pinch rollers, this was reduced in diameter to ¾ of an inch bearing in mind that the smaller this roller can be made the more closely can it approach the work emerging from the pinching rollers.

The final point to be settled was whether or not to provide gearing between the pinch rollers. Owing to the amount of rise and fall of the upper roller, equal to the thickness of the heaviest material to be worked, in relation to the roller diameter, an ordinary pair of gears was out of the question; the simplest alternative seemed to be a train of four gears between the two rollers. With a pair of rollers geared together each of them will, by friction, apply an equal driving force to the material the amount of which will depend, among other things, upon the pressure applied by the rollers. If the gearing be disconnected, the lower roller will apply its quota of driving force but the upper roller will now be merely a follower and contribute nothing. Moreover, as the bearings of the upper roller are carrying the full pressure load between the rollers there will be a resistance to rotation of the upper roller which must be subtracted from the frictional force applied through the lower roller so that the net forward driving force will be less than one half - probably 35 to 40% - when compared with geared rollers. However, in view of the fact that considerable pressure could be applied through the screws (and also that I wanted to make the rolls that week!) it was felt that it would probably be safe to go ahead without gearing and, in use, to apply such pressure as was necessary for the job in hand. On this basis I went ahead with construction and four days later I was able to confirm that some, at least, of the guesses had come out right. There are occasions, which I shall mention later, when it might be desirable or essential to work with the smallest possible pressure between the pinching rolls and in these instances gearing is called for.

## Construction

The constructional features are shown in the G.A. Fig. 2, on which the upper position of the bending-roll and of its jacking-screw are indicated in dotted lines. The view in the lower left-hand corner shows how the latches can be swung aside for the purpose of lifting out the top roller. This G.A. should appear full-size so that any details not drawn separately can be scaled off.

The main frame consists of a bar of b.m.s., 1 inch x 1-½ inch x 10-3/16 inch long with its ends brought square and parallel. The two end plates of ½ inch thick b.m.s. 3 inch x 4 inch should have their reference edges, front and top, milled square after doweling together at two corners, using 5/32 inch diameter dowels. These two dowels are shown, at top right and bottom left on the detail, Fig. 3. Mark out in accordance with the detail drawing. The line of the slot for the rear roller is at about 9 degrees to vertical and

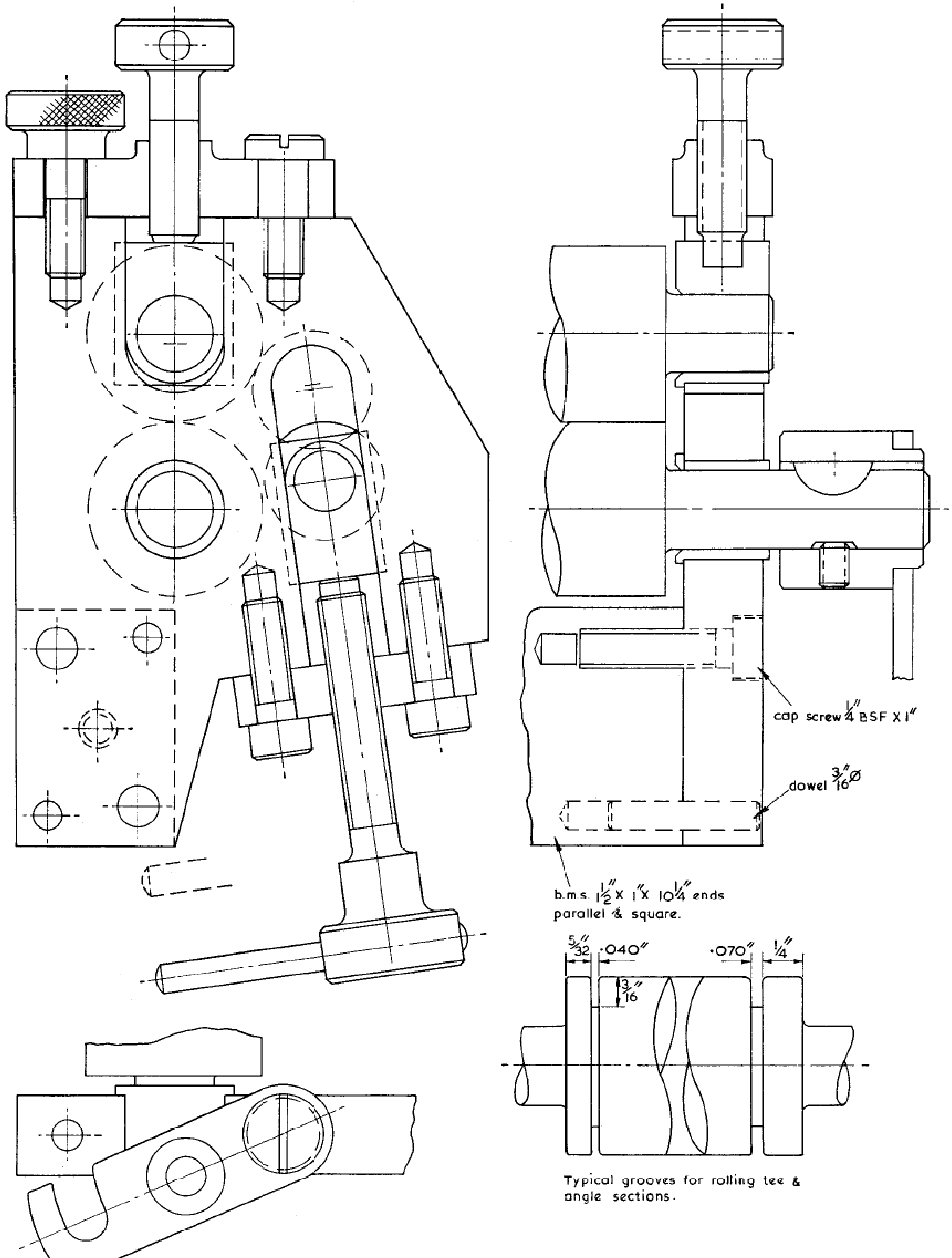
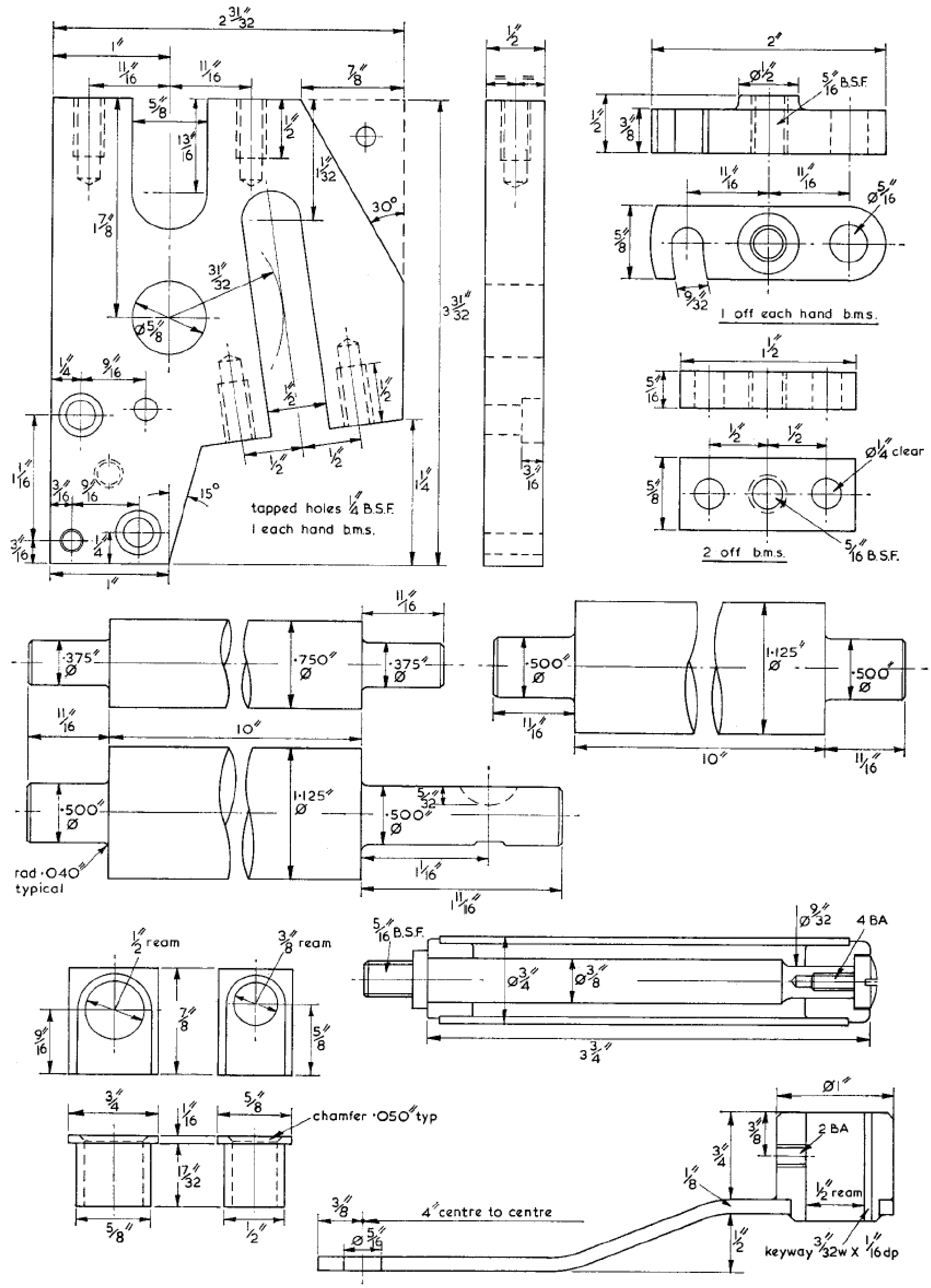

cap screw 1/4" BSF X 1"
dowel 3/16" Ø
b.m.s. 1½" X 1" X 10¼" ends
parallel & square.
5/32"
.040"
.070"
1/4"
3/16"
Typical grooves for rolling tee &
angle sections.

Fig. 2



tapped holes 1/4 B.S.F.
1 each hand b.m.s.
5/16 B.S.F.
1 off each hand b.m.s.
Ø1/4 clear
2 off b.m.s.
5/16 B.S.F.
rad ·040" typical
1/2" ream
3/8" ream
5/16 B.S.F.
4 BA
chamfer ·050" typ
2 BA
1/2" ream
4" centre to centre
keyway 3/32w X 1/16dp


Fig. 3

the easiest way to mark this out is to carry a line from the 1-11/16 inch diameter from the front (which is the centre of the latch pivot screw) to form a tangent to a 31/32 inch radius struck from the centre of the lower roller.

Mount the pair on the faceplate and bore the three holes, one for the lower roller (5/8 inch diameter ream) and the other two being the ends of the slots. Now cut away the unwanted metal at bottom right and saw out the slots but leave, for the time being, the top corner which carries a dowel. The sawing was done quickly and accurately on my band-saw which is a Myford ML 8 woodworking band-saw borrowed (permanently) from my woodwork shop and mounted up with a worm reduction gear bought on the surplus-market from one of our advertisers. While still together, clean out the slots to dimensions with an end-mill and mill the sawn edges.

The next job is to attach the two end-plates to the main bar in correct alignment and the simplest way to tackle this job is probably as follows:

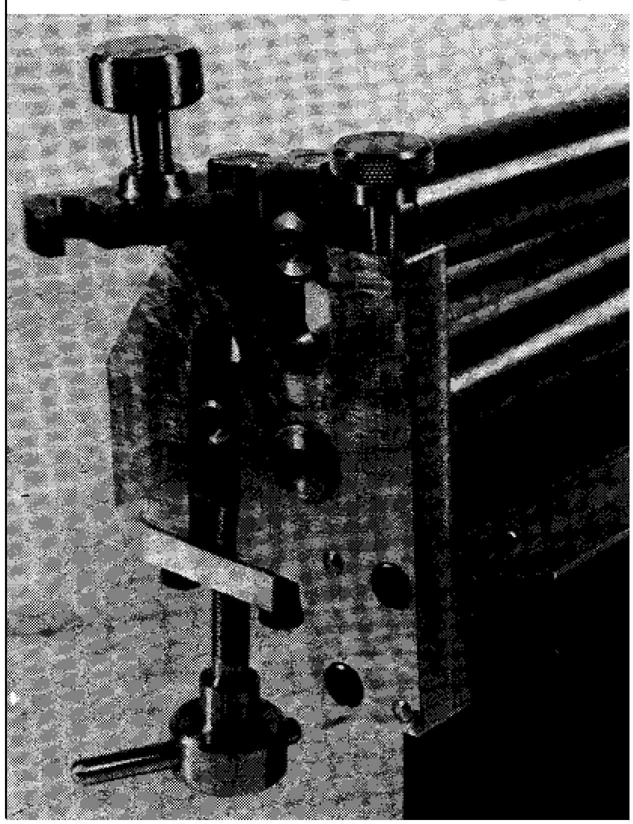
First mark out for the screws and dowels (one dowel already existing u/s [undersize?]), and also for a hole in the centre of the group as indicated on the detail drawing. Drill through both plates #4 (1/4-26 BSF tapping [use #3 for 1/4-28 UNF tapping]) for the screws and #14 for the 3/16 inch diameter dowel. The central hole can be drilled a good clearance for 2 BA [use 13/64 inch drill]. Mark out for a hole at each end of the bar to correspond with this central hole in the plates; drill No. 22 and tap 2 BA (use #25 for 10-24 UNC tap or #21 for 10-32 UNF tap]. The end plates can now be attached, accurately lined up and securely clamped to the bar using a 2 BA [10-24 or 10-32] socket screw and washer. It is now possible to transfer the #4 and #14 holes through the plates into the bar. Ream the dowel holes (the original 5/32 inch hole will now have been opened up) 3/16 inch before taking apart to open the screw holes in the plates to #F and counter-boring for the heads - don't forget that these c-bores hand the plates.

The rollers need to be carefully made; they must be parallel and straight but, even more important, the end bearings must be truly concentric with the body of the roll. Mine were turned between centres from 1-1/8 inch bar, the rolls finishing a trifle under the nominal dimension, but I would strongly recommend this, especially for those whose lathes are not quite up to scratch, that they be made from 1-1/8 inch precision ground bar. Unless you know of a better one, use the following procedure: After cutting to length, hold the material for about ¾ inch in an accurate self-centering chuck (if it doesn't live up to its name, use a four-jaw) and get the far end running true to indicator. Support this end in a three-point steady-rest, pushing the fingers in very gently so as not to disturb the position of the bar. Check again with the "clock", there should be no movement whatever; if there is movement the fingers are not all in contact with the bar. Face the end; put a suitable centre-drill in the tail-stock chuck with its two cutting edges in a horizontal plane, i.e. one towards the operator and one towards the back. Put a piece of plain bar or any blunt instrument in the tool-post; start the centre-drill into the end of the bar and then bring up the blunt ended "tool" and cause it to bear with slight pressure on the centre-drill whilst it is being fed in. Ease off the pressure gradually as you finish feeding the drill.

### *Part II*

The method described in the last issue will produce a true centre even on lathes that leave a lot to be desired and readers might be interested in the results of a test carried out today on my own lathe, the alignment of which is beyond reproach. A 10 inch length of 1 inch diameter P.G.M.S. [precision ground rod] was set up exactly as described above and, after facing the end, a #2 BSS centre-drill was carefully fed in to produce a centre about 3/16 inch diameter. The work was then supported on a fixed centre and all support from the steady-rest removed. I obtained an indicator reading (total) at 1/8 inch from the end of the bar of .0007 inch. The steady-rest was replaced and a larger centre-drill fed in a little way under side pressure as recommended after which I obtained a T.I.R. of .0003 inch, in other words the centre was within one and a half tenths (of a thou.) of its true position. I have

***An end view with the latch open and the top roll lifted.***



no doubt that it could be brought closer than that.

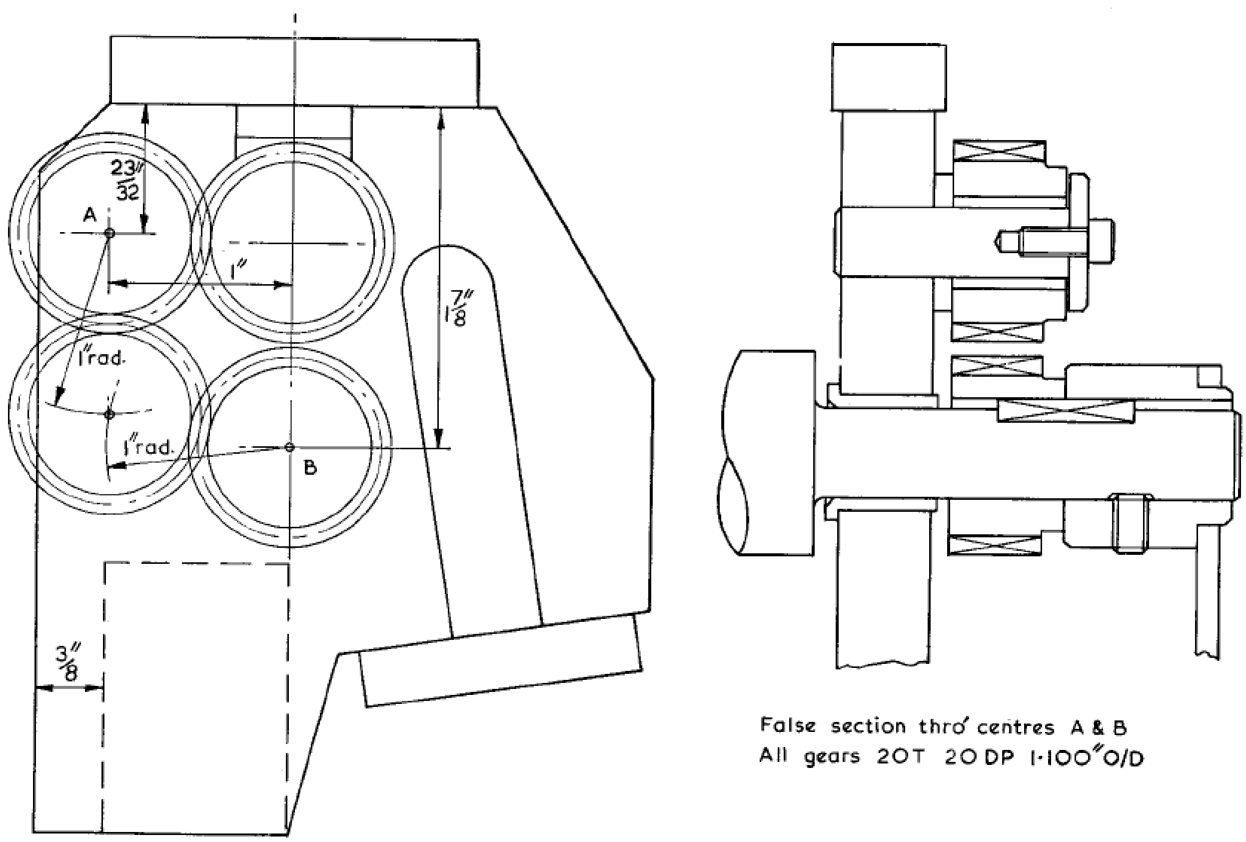
If desired, the spindle ends of the rolls could be roughed down whilst supported in the steady and the centres used only for final finishing to size. There is no necessity for such care with the making of the deflecting roll which can be turned from ¾ inch b.m.s. The making of the straps and latches should present no difficulty and after dismantling the end-plates from the bar all the necessary holes can be drilled and tapped to receive them.

The lower roll runs in P.B. [phosphor bronze] bushes which are press-fitted into the plates with the flanges inside, but flangeless oilite bushes could be substituted if they were left standing 1/16 inch proud in the inside. All the sliding bearing-blocks were machined from drawn P.B. [phosphor bronze] bar and the holes bored whilst clamped to an angle-plate on the faceplate using my normal axle-box technique which ensures absolute accuracy. All the sliding blocks have slugs of steel let into their faces where the pressure screws abut. After starting off the holes for these with an ordinary drill they were finished off to depth with a "D" bit to give a flat bottom. The various small turned items are all straightforward and have not been separately detailed. Do *not* drill the holes for the short permanent tommy-bars in the raising screws yet.

The handle could, of course, be anything capable of turning the lower roll, but as mine has proved to be comfortable in use it is drawn exactly as made though it might, with some advantage, be made a little longer - a throw of say 5 inches. The quill portion is ¾ inch outer diameter x 18 SWG brass tube with brass ends sweated in and I sometimes borrow this for use on other handles.

Before final assembly of the main frame, it might be as well to tap the now unwanted central hole so that it can be used for a jacking screw to force the ends off the bar. Another small item not shown on the drawings is the folded steel angle attached to the front of the main bar. This can be seen in the photograph and is useful to prevent the rolls dropping - with possible damage - when the vice is opened.

After final assembly of the main frames with the driving and rear bending rolls in place, the latter should be raised by its jacking screws until it is parallel with the driving roll which can be checked by sighting from the front across the two rolls or one might rest two short rules across them, one at each end, and bring these parallel to each other. The heads of the jacking screws can now be marked for their tommy holes (3/16 inch diameter handles, a drive fit). The two handles will now point always in the same direction when the rear roller is parallel to the front ones. Number all the screws, straps and bearing blocks.




Note: Gear centres shown as 1" nom: should be made 1·002" to 1·005"

Fig. 4

## Tests and Conclusions

As soon as the rolls were completed a test piece was made by rolling a length of 18 SWG CRCA [cold rolled, close annealed] strip, 1-½ inches wide, to form a complete circle about 3 inch diameter. Initially, the rear bending roller was raised by about one turn of the screws for each pass, the work being reversed, end-for-end, at each passage through the rolls, care being taken to feed it in square. The amount of lift given to the bending roll at each pass was progressively reduced as more curvature was given to the work. When the gap between the two ends became too small to pass over the roller, the top roll had to be lifted from time to time to enable the work to be removed and replaced the other way round. The whole process of rolling until the edges met took but little time and it was very gratifying to find, on checking with a slide-gauge, that the piece was circular within .01 inch.

Everyone who has bent a piece of sheet metal will be familiar with the phenomenon which, for want of a better term, I will call "edge lift". When the bend radius is small compared with the metal thickness, e.g. a 1/16 inch internal radius with material of 1/16 inch thickness, the extreme corner lifts and is drawn back away from the general level of the edge. See Fig. 5 (5). When the bend radius is much larger the effect is not so marked and is as shown in Fig. 5 (4). The reason for this behavior is that the metal on the inside of the bend is in compression whilst the outer surface is in tension with the result that the inner surface tries to flow outwards at the edge whilst the upper or outer surfaces pulls the edge back. I have often found this "lifting" to be annoying because a considerable amount of filing and dressing is sometimes necessary in order to remove it and restore the correct form. It was hoped that the pinch rolls would, due to their ironing action, reduce this effect to some extent and in this I was not disappointed. By standing up the original test-piece on the surface plate it was just possible to nip a ¼ inch wide strip of cigarette paper .001 inch thick) in the centre of the width. A piece of the same strip material was bent by band, to the same radius around a bar and the "lift", which was very noticeable, was measured against the surface plate with feelers and found to be .005 to .006 of an inch.

I have, so far, made no mention of the grooves at the ends of the rolls shown in the lower right hand of Fig. 2. These are provided to enable angles and "T" sections to be rolled. In order to roll one of these sections with its web standing inwards a groove will be required in the upper pressure roller but if the web is to stand outwards there must be grooves in the lower and the bending rolls. I have indicated the dimensions which I used and these grooves will handle sections up to 1/16 inch thickness. Remember that when the web stands inside it will tend to thicken up slightly as

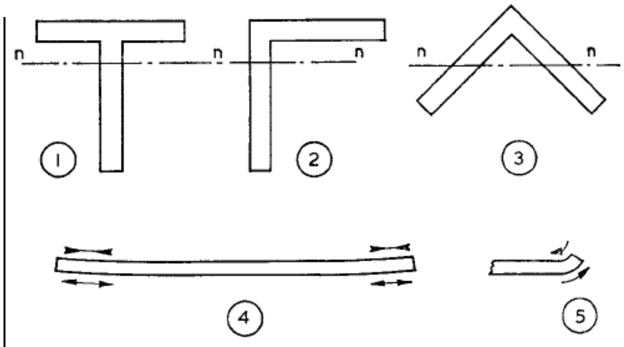
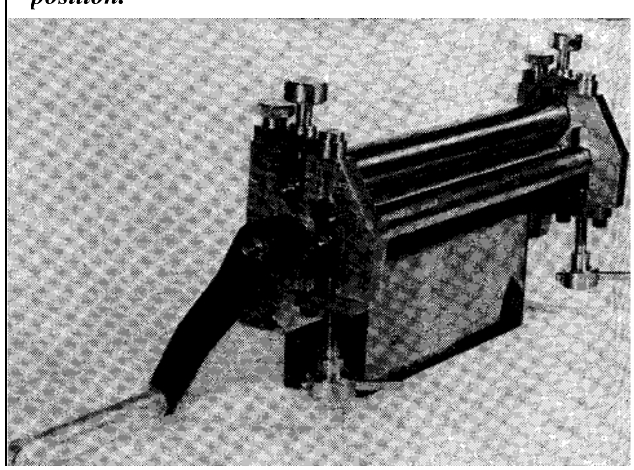


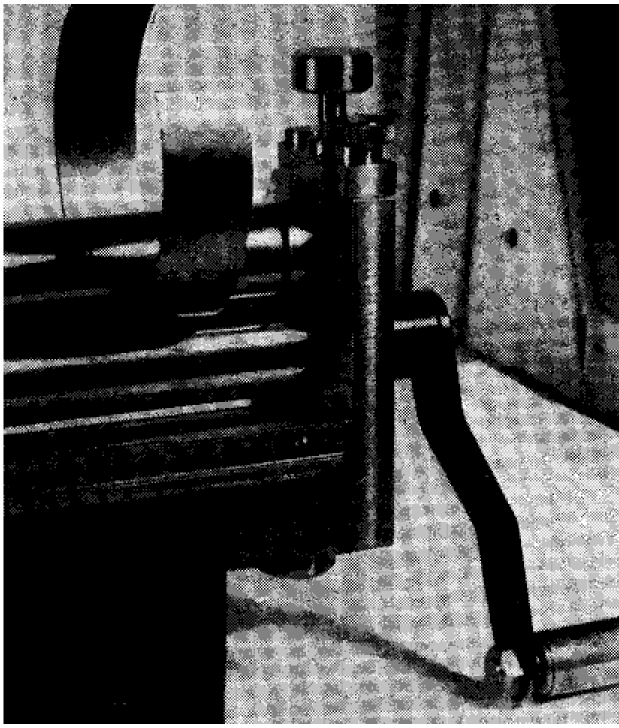
Fig. 5

bending takes place and some allowance should be made for this in the width of the groove.

Rolling "T" sections has not presented any difficulties. If the web is standing inward it will be in compression and the flange in tension; a little extra pressure on the pinching rollers will, therefore, be beneficial as this will tend to stretch the flange and so assist the operation. When a curved "T" is required with the web standing outwards, the reverse will apply and the operation should be carried out with the minimum of pressure on the feeding rolls. Angles are a different kettle of fish altogether because they do not like being bent with the neutral axis "nn" as shown in Fig. 5 (2). In this attitude the modulus of section is greater than in the case shown at Fig. 5 (3) so the angle tries to twist round into the symmetrical attitude. This can give rise to some horrible results resembling corkscrews. On the whole, I have found it easier to bend angles with the web standing outward - possibly because the web will more readily stretch than compress. Even so, the job is by no means straightforward and is best done in stages, first rolling until distortion is becoming apparent then anneal and knock down with a mallet and wooden "punches" until sitting flat on a surface plate, then roll again, anneal, flatten, etc. This method sounds - and is - laborious but it has produced some very satisfactory curved work and beyond this I have no advice to give and await

***Rear view of rolls, showing deflecting roll in lower position.***





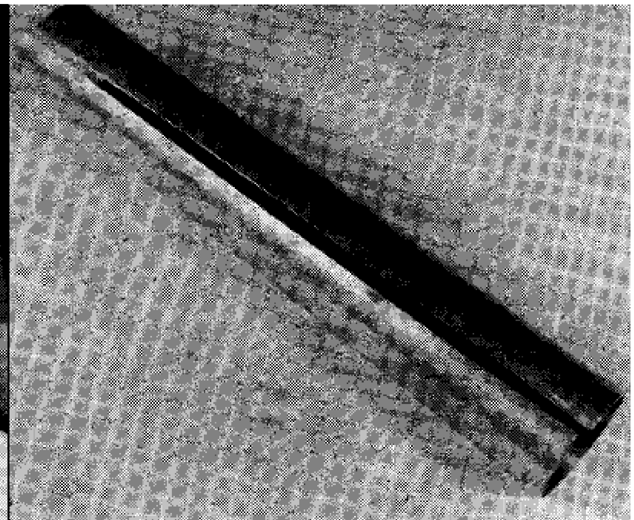
***Bending narrow work near the end of the rolls.***

enlightenment from those more expert than myself in this field.

So far, the rolls, as made, have carried out all the normal work for which they were designed with little or no trouble but, before writing these notes, I decided to conduct a few tests on rather more demanding jobs. First I tried to bend some b.m.s. strip ½ inch wide x 5/32 inch thick into a curve of 1-½ inch radius. Full stop! This obviously needed a bar-bending machine, similar in action to a tube bender. I got as far as a 14 inch radius and geared rolls would have taken it further but never to 1-½ inch radius. I tried to make a tube 1-½ inch diameter by 10 inch long, using an off-cut of aluminum. When nearing closure (see photo) it was found that the pressure of the feed rollers had stretched the two ends of the material by .10 inch (about 2%) so that the gap was not parallel. Whilst this would not have happened with steel and probably not with ½-hard brass, the indication was that geared rollers might have done the job without stretching the material. On the other hand, I might have applied more pressure than was necessary.

## Gearing for Rolls

For those who might like to incorporate gears and thus be prepared for all emergencies, I show in Fig. 4 a simple and convenient arrangement which includes, apart from the gears keyed to the upper and lower rolls, a pair of idlers which run on fixed studs on the main endplate. This layout still allows the upper roll to be lifted out at will.

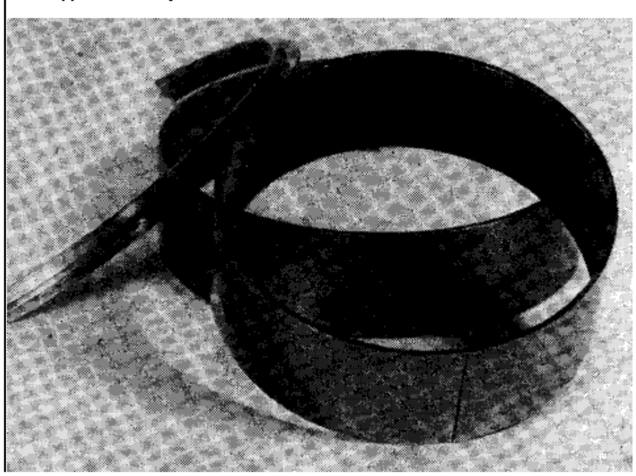


***1 ½ inch diameter aluminum tube, showing closing of gap at ends.***

The end frames are made, as before, from b.m.s. 4 inch x ½ inch but a width of 3-3/8 inch is necessary in place of the 3 inch. The two ends are preferably made to the same external dimensions as this will facilitate lining up on the bar. I have shown the gearing at the same end as the handle as this reduces the possibility of getting a finger in the works! An interesting feature of the proposed gear drive is that any increase in the resistance to movement of the work through the rolls is accompanied by an automatic increase in the pressure between the driving rolls.

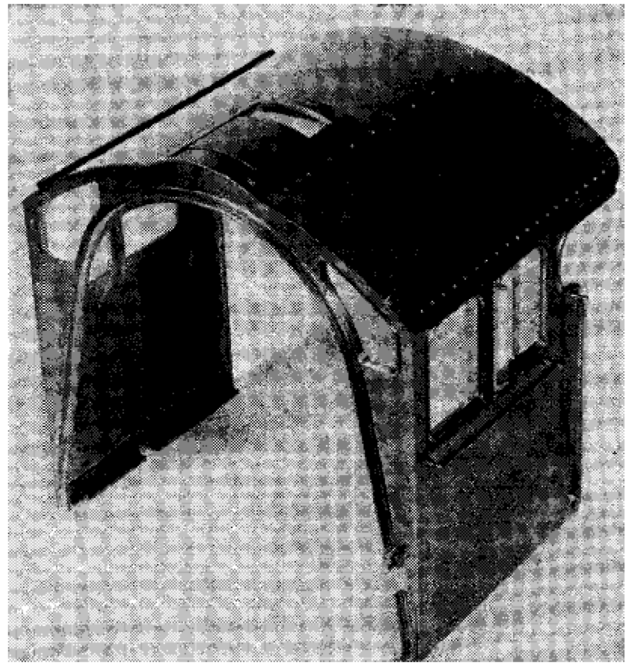
The arrangement is based on the use of four gears having 20 teeth, 20 DP [diametral pitch], with a face width and bore of .500 inch which are obtainable from Messrs. S. H. Muffett Ltd., Mount Ephraim Works, Tunbridge Wells but I am hoping to be able to arrange for an alternative source of supply at probably, a lower cost. [Part #36682011 from mscdirect.com is a close equivalent manufactured by Boston Gear - but with a 3/8" bore and 3/8 inch face] [note: closest metric

***Specimens of rolled work. That in foreground is original test piece.***



equivalent is a 20 tooth spur gear with a 1.25 module] As supplied by Muffett, the bosses are ½ inch long and these can be reduced to 1/8 inch as shown. Two of them will need keyways 1/8 inch wide and the others can be bushed with brass or G.M. to run on the steel stub axles which are 1/8 inch diameter. The latter can be made a press-fit into the end plate or, better, fixed with Loctite. Perhaps the best method of fixing the gear to the upper roll would be to leave the boss ¼ inch long, instead of reducing to 1/8 inch, and tap for 4 BA grub-screw [use 6-32 UNC set screw] - this in addition, of course, to the key which would take the drive.

I have no hesitation in saying that I believe the geared form of rolls to be superior to the simpler arrangement and if I had not already made them and found them capable of doing the jobs for which they were intended, I would include the gearing as a form of insurance against the unknown and unforeseen job, but a friend has made a suggestion for something simpler. He is going to make the two pinch rolls exactly alike, i.e. each having one end extended to take a handle. On the odd occasion, if the drive from one roller proves to be insufficient, he will attach a handle to the top roller also - at the opposite end - and so obtain maximum driving power by turning both handles!



***Locomotive cab, showing various curved work on plate, angle and tee.***