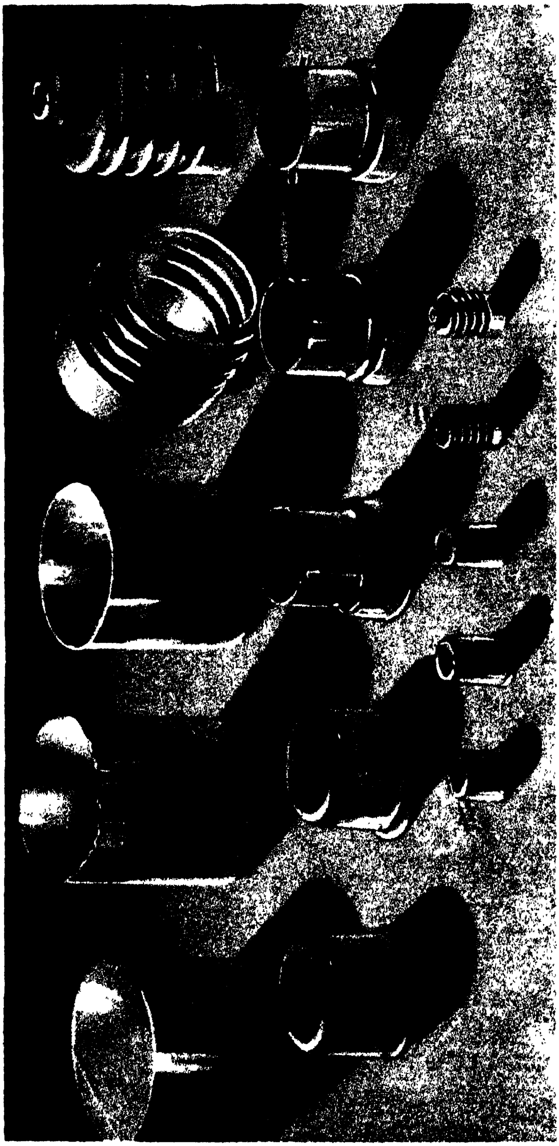
# JIGS, TOOLS AND FIXTURES



LAMPHOLDER COMPONENTS FROM BRASS STRIP

FRONTISPIECE

# JIGS, TOOLS AND FIXTURES

COVERING THE DRAWING AND DESIGN OF EQUIPMENT FOR PRACTICALLY ALL MODERN MACHINE TOOLS, WITH CHAPTERS ON SPECIAL EQUIPMENT AND DRAWING OFFICE PROCEDURE: ALSO GIVING NUMEROUS EXAMPLES FROM PRACTICE

WITH

FRONTISPIECE

NUMEROUS ILLUSTRATIONS DIAGRAMS AND TABLES

BY

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# PREFACE

In preparing a second edition of this book the opportunity has been taken to introduce a chapter on materials, a subject very closely related to jig, tool, and fixture design.

Yet another feature is the inclusion of a series of plates illustrating recent practice, which should prove instructive.

Specialized subjects like bakelite moulding and die casting mould designing have been purposely omitted—a volume would be necessary for these alone. The author has endeavoured to deal with the subject in a simple manner, covering at the same time as wide a field as possible. It is hoped that the fully qualified draughtsman will not look askance at it because the beginner, as well as the man in the shop, has been considered.

The author also desires to remind the reader that there exists such a diversity of opinion on some points that any method or design mentioned here is not necessarily the only way out. As it is possible that this work may pass into the hands of one who is not conversant with the rules of machine drawing, it was thought desirable to include this in Chapter I.

The author desires to express his thanks to National Automatic Tool Co., Indiana, U.S.A., for permission to use Fig. 155, to the editor of *Machinist* for the use of illustrations facing pages 66 and 142, and to the editor of *Machinery* for those facing pages 16, 128, 169, 175, and 206.

## PREFACE TO THIRD EDITION

THE success which has attended the disposal of the 2nd edition of this work has made essential the publication of a third. Fortunately the basic principles of jig, tool, and fixture design remain unaltered, interest becoming centered rather upon their ingenious exploitation.

In this edition, except for a note upon the use of indiarubber, of which more may be heard later, the text remains unaltered.

We have, however, taken the opportunity of increasing the instructive value of the book pictorially by the inclusion of thirteen additional plates.

## PREFACE TO FOURTH EDITION

BEFORE issuing a fourth edition of this work, Chapter I, which deals briefly with Mechanical Drawing, has been entirely revised and the proposals made by the Technical Committee of the British Standards Institute and embodied in their publication No. 308, have been adopted. Also Tables No. 16 and 16A, which were becoming obsolete have been replaced.

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# JIGS, TOOLS AND FIXTURES

# JIGS, TOOLS AND FIXTURES
## THEIR DRAWING & DESIGN

## CHAPTER I

## MECHANICAL DRAWING

Drawing Equipment—Selecting Views—The Completed Drawing—Lines—Machining Indicators—Dimensioning—Sections—Representation of Screw Threads and Gears—Breaks—Abbreviations.

It is not suggested that this subject can be fully considered in one short chapter. The information given, however, will serve as an introduction before proceeding to more specialised literature. Readers are advised to make themselves acquainted with the recommendations made by the British Standards Institute No. 308, upon which this chapter is based.

**Drawing Equipment.**—Like the tools in most trades and professions those of the draughtsman have been improved and this facilitates the production of good drawings. The simple drawing board and stand has been replaced by the drafting machine in various forms, one pattern being seen in Plate No. 1A.

With regard to the proper grade of pencil, different people will get different results with the same pencil, but for general work a good class H, or 2H, will be found satisfactory. For outlines or bold work and lettering, an HB will be useful. The correct sharpening of a pencil is a great help to neat and accurate work, the conventional shape being that of a long wedge, the flat side of the lead being used against the rule edge, this produces a line of unvarying thickness. To assist in maintaining the point a 4″ or 6″ flat smooth file is a useful addition to one's kit though there are now available small glass paper pads, layers of which can be stripped when worn. There is a wide choice of scales, but *printed* celluloid should be avoided because the marking wears off after a week's contact with the paper, also, check the straightness of the edge. For jig and tool work graduations in one-tenth of an inch as well as the usual divisions will be found suitable. For the purpose of taking measurements of machines, etc., a 6" and 12" steel flexible rule and a slide gauge or calipers will be most useful. With regard to drawing papers it will be found that practice varies in different offices, but there are three that can be mentioned as being in general use, these are: Cartridge Paper, Detail Paper, and Tracing Paper. The former is generally used where the drawing is to be permanent or may be subject to many alterations necessitating much erasion. Detail paper is a finer and cheaper paper much used for small drawings or for roughing-

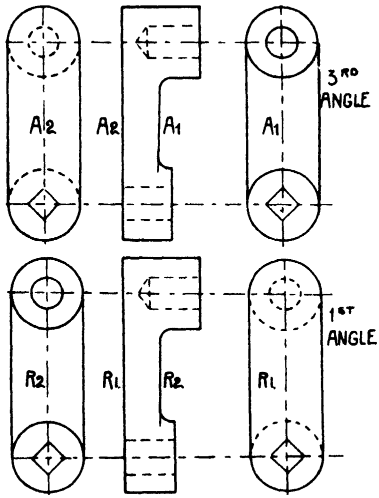



FIG. 1.

FIRST AND THIRD ANGLE PROJECTION.

out ideas generally, although extra good quality paper is sometimes used for all permanent drawings. Blue prints can be taken from such drawings if the lines are exceptionally bold. Tracing paper is very useful when taking out a certain portion of a permanent drawing where modifications are to be made, rough ideas being carried out on the tracing paper.

It may appear superfluous to mention drawing pins, but select those having a head of large diameter, remembering that the head holds the paper, not the pin.

Drawing instruments should be purchased from a maker of repute and after being used with ink, take care to clean *thoroughly*.

**Selecting Views.**—As the essential point of a mechanical drawing is that it should convey the ideas of the draughtsman to the mechanic as clearly as possible, the selection of the correct view becomes important. To draw an unnecessary view is both wasteful and misleading, to give insufficient views will give rise to innumerable queries. As to the correct method of showing plans and elevations there exists some difference of opinion, American draughtsmen adhering to what is known as third

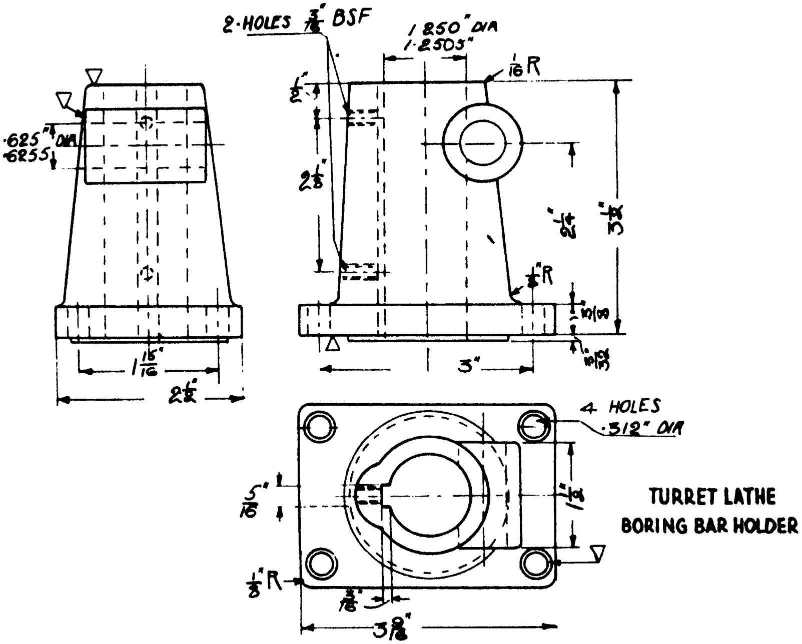



FIG. 2.

DRAWING TO B.S. SPECIFICATION 308.

angle and English to first angle. While the practice of any particular drawing office should be followed, it matters not what arrangement of views is given as long as what is intended is made perfectly clear. Where the ordinary plans and elevations are not sufficient, section or part section views can be added, see Fig. 4. Fig. 1 will make clear the difference between first angle and third angle projection. In the upper group the component shown in the centre is turned so that its face A1 becomes *adjacent* or A1 in the view to its right. The same twist, but in the opposite direction, will bring face A2 *adjacent* as seen to the left. In the lower group the component is *rolled* to the right or left thus making the respective sides R1 or R2, become *remote* in the views thus produced.

**The Completed Drawing.**—Fig. 2 is a drawing of a cast-iron holder suitable for a certain size turret lathe and the drawing embodies the recommendations made by the British Standards Institute. The title block in which the draughtsman prints the drawing Title, Firm's Name, Drawing Number, etc., is omitted. The principles of mechanical drawing are similar whether drawing engine parts or jigs and tools, but in the latter case, a different technique is often possible. When the size of the component for which equipment is to be designed permits, it is an excellent plan to draw one or more views of the component to scale in red ink and then, it is very interesting and certainly simpler to, as it were, "erect" the jig or fixture round it.

**Lines.**—For indicating the shape or profile of an object the bold line A, Fig. 3, should be used. This prevents the general shape from becoming lost in the maze of other essential lines. The line B is used for dimensioning and the projection of views, etc. For hidden outlines the line C, consisting of regular *short* dashes is used, but should not be confused with the short *chain* line E, which would be used to indicate an alternative position of a unit such as say the position of a crank at different positions of its path. Very important is the chain line D. This indicates the centre of bores, holes and important parts, and it is customary to insert these at an early stage and then to build round them.

**Machine Indicators.**—At one time it was customary to place against a surface which was to be machined a letter "f". It is now recommended that this should be replaced by the triangular indicators as seen at F, Fig. 3. Also, by inserting a letter inside the triangle the nature of the operation is made apparent. The "f" can be inserted with greater facility but the lettered triangle is more informative.

**Dimensioning.**—Some draughtsmen dimension from the centre lines shown in the *vertical* dimension H, Fig. 3, others work from a certain face of the object as seen in the *horizontal* dimensions. It is frequently desirable to do both. Take care that the arrow heads touch the line intended so that no misunderstanding can occur. When an overall dimension is included it is recommended that the last dimension X, be omitted. Dimensions indicating limits should be printed as at G.

**Sections**—Sections are useful to show internal construction and shape. At one time the type of line used for this purpose also indicated the class of material, but the variety of material used

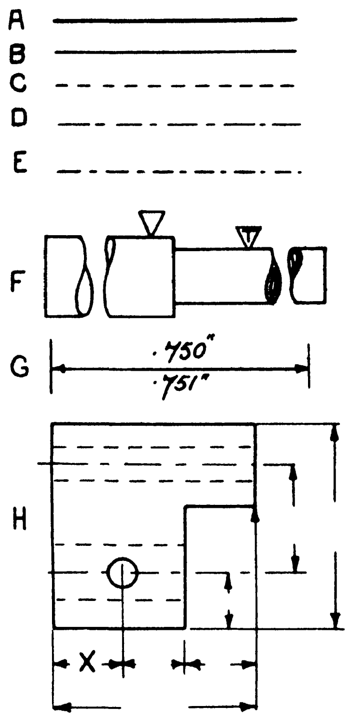



FIG. 3.
LINES USED IN ENGINEERING DRAWING.
BREAKS.
MACHINING INDICATORS.
CORRECT DIMENSIONING.

has grown to such an extent that this method has been abandoned in favour of plain lines drawn at 45 degrees and spaced according to the area being covered. Section lines can be omitted to allow a dimension to be inserted as at C, Fig. 4. Half sections A, and part sections B, are also very instructive and may sometimes avoid the necessity for drawing other views. Where a member is cut completely through, for sectional purposes, the direction from which the section is viewed should be indicated as shown at D, Fig. 4.

**Representation of Screw Threads and Gears.**—As drawing office charges are all added to the cost of a given job, unnecessary work must be avoided, thus such items as screw threads and gear teeth are not drawn in detail. The former are shown as seen at A and B, Fig. 5, and a threaded hole at C and D. It is recommended that where a plain drilled hole is tapped, the depth of the drilled hole apart from the tapped portion, should be also dimensioned as at C. A piece of tube having an external thread

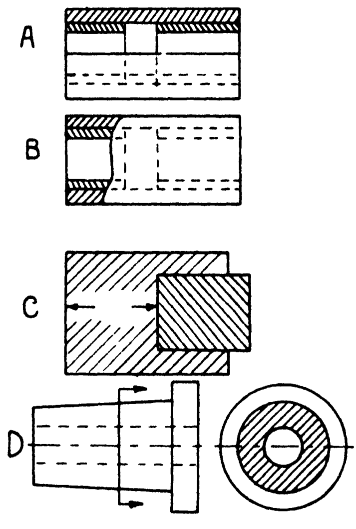



FIG. 4.
HALF SECTION.
PART SECTION.
DIMENSION IN A SECTION.
VIEW POINT OF CROSS SECTION.

is indicated as at E. A brief statement of thread size, form, etc., is added neatly as near as possible without causing confusion. With gear wheels it is sufficient to draw plain circles representing the Outside Diameter and the Pitch Circle, and then to insert the necessary tooth information in the circle or nearby.

**Breaks.**—It is very desirable where a unit or a view of a unit is disproportionately large to make use of a "break". These are seen at F, Fig. 3, where, to the left is the method of showing a broken solid bar, while a broken tubular item is seen to the right.

**Abbreviations.**—Apart from actual dimensions, it is necessary to add further information and to accomplish this in a simple manner a group of abbreviations have been standardised and are here given:

| | | | |
|---|---|---|---|
| C.I. | Cast iron. | In. | Inch. |
| M.S. | Mild steel. | RH. | Right hand |
| T.S. | Tool steel. | LH. | Left hand |
| H.S.S. | High speed steel. | Rad. | Radius. |
| Phos.B. | Phosphor bronze. | MC. | Machine. |
| A.L. | Aluminium. | B.S.F. | British standard fine. |
| CCpr. | Copper. | U.S.S. | United States standard. |
| G.M. | Gunmetal. | B.S.P. | British standard pipe. |
| Mang.B. | Manganese bronze. | B.A. | British Association. |
| Br. | Brass. | B.S.Whit. | British standard Whitworth. |
| C.S. | Cast steel. | Thd. | Thread. |
| W.I. | Wrought iron. | Hex. | Hexagon. |
| H.T.S. | High tensile steel. | csk. | Countersink. |
| Dia. | Diameter. | cbr. | Counterbore. |
| C.H. | Case harden | | |
| ch.hd. | Cheese head. | | |
| t.p.i. | Threads per inch. | | |
| Sq. | Square. | | |
| Std. | Standard. | | |

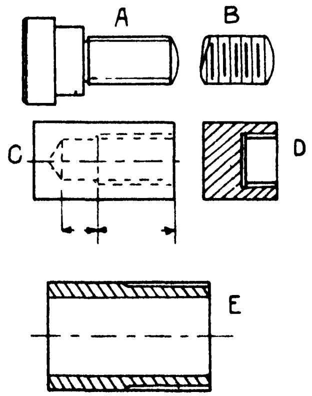



FIG. 5.

REPRESENTATION OF SCREW THREADS.
REPRESENTATION OF INTERNAL THREADS.
SECTIONING OF EXTERNALLY THREADED TUBE.

## CHAPTER II

# SKETCHING

The Value of Sketching—Proportion—Duplicates—Tabular Drawings—Oblique Projection.

**The Value of Sketching.**—Ability to make rapid and fairly accurate sketches is essential to the successful draughtsman, in fact it has been truly described as an auxiliary language.

Often it may be necessary to go into the machine shops, which may not be near at hand, to take details of a machine or tool, and to do this the machine may have to be stopped, obviously then the draftsman must not only be quick but reliable, for the forgetting of a point would entail another visit and stoppage which would not be viewed with pleasure.

It is also of great value when discussing the pros and cons of equipment, a few rapid sketches making one's ideas immediately clear. It might be mentioned that sketching is one of the finest ways of learning and remembering the construction of machine tools and details, many people would be surprised to find how weak is their detailed knowledge of various constructions, having looked at, passed by, and perhaps used a certain mechanism, quite certain that it has been understood, yet when called upon to put the idea on paper, difficulty is experienced.

On the machine bed with chalk, on the wall, on the palm of one's hand, many are the arguments settled by means of a few telling sketches.

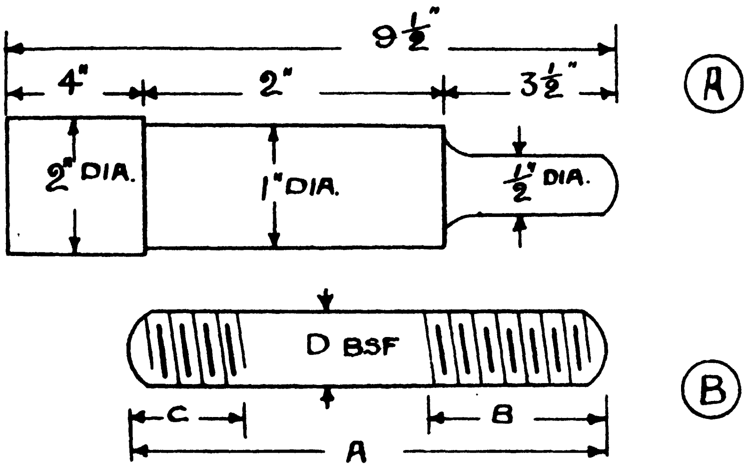
**Proportion.**—There is one point that should be carefully observed, and that is that the various parts should be in correct proportion. In attempting to make a neat sketch this is often overlooked, and while it might be said that if the dimensions thereon are stated right, that is sufficient, it is very deceiving and often leads to a misunderstanding.

When turning a job in the lathe or working on the shaper the mechanic gets into the habit of allowing the machine slide to travel till the piece looks something like the drawing, and then applying the rule or other instrument.

A, Fig. 6, is an example of this where the shortest length is marked 4" and a part considerably longer 2", the diameters also being deceiving.

It will also be noticed that only one view is given, this is permissible when no error can possibly occur, which certainly is so in this case, the word or abbreviation for diameter being distinctly written after the figure.

Sketching pads made up of paper ruled in tenth of an inch




| A | B | C | D | E | | |
|---|---|---|---|---|---|---|
| 10 | 4 | 2 | ¾ | | | 6 off |
| 7 | 3 | 2 | ¾ | | | 10 off |
| 6 | 2½ | 1½ | ⅝ | | | 32 off |
| 4 | 1½ | 1 | ½ | | | 18 off |

FIG. 6.

A.—IMPORTANCE OF SKETCHING IN PROPORTION.
B.—TABULAR DRAWINGS.

squares are exceedingly useful, but the draughtsman should practise so as to be able to draw under any circumstances.

**Duplicates.**—Where rough sketches are called for in cases of great urgency the draughtsman will be well advised to lay a sheet of carbon paper between the sheets of his pad, so as to secure a duplicate, because such sketches, in their passage through the shops, generally become unreadable and in the event of a mistake occurring due to this, the value of the duplicate is obvious.

**Tabular Drawings.**—It is often necessary to call for a number of parts very similar in form but differing perhaps in one or two dimensions. This is overcome by making one sketch of the part, but instead of putting the usual dimensions, letters are added as at B, Fig. 6. Below or near the sketch is then made out a tabular statement of the sizes required.

This is particularly useful where a number of parts of varying

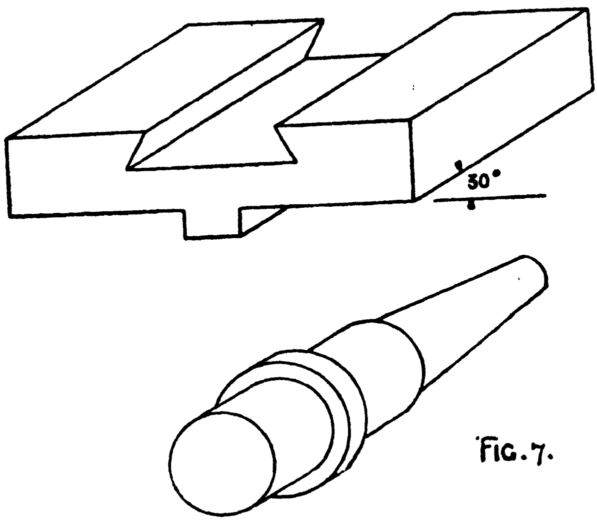



FIG. 7.

OBLIQUE PROJECTION.

size are called for quickly, it being only necessary to fill in the figures.

**Oblique Projection.**—The method of laying out an object showing views in a certain relation as in Fig. 5 is termed orthographic projection, and while it is the usual method adopted, it is sometimes necessary, particularly when sketching an awkward piece, to make its general form obvious at once.

To do this, what is known as Oblique Projection is employed as shown in Fig. 7. The reader will observe that it has the appearance of perspective drawing except that lines going in the same direction are parallel.

With this style of drawing it is possible to explain a point to anyone unacquainted with mechanical drawing and it also enables three dimensions to be given in one view.

To become skilled in the rapid sketching of objects thus projected, should not be difficult with practice.

The best results are obtained by placing the longest side of the piece horizontal, this prevents a distorted appearance, then draw one of the edges upright, following with a side at 30 degrees to the horizontal.

After this, if *all the lines running in the same direction are made parallel,* there should not be the slightest difficulty in producing quite lifelike sketches.

To appreciate fully the value of this projection one has but to attempt to show by ordinary methods a complicated piece of pipe work with branches in different planes, or any rather elaborate piece of smith work.

## CHAPTER III

# FIRST CONSIDERATIONS IN THE DESIGN OF JIGS, TOOLS AND FIXTURES

Difference between Jigs and Fixtures—Their Value—Looking Ahead—Cost of Equipment—Quality of Product—Class of Labour—Single or Multiple Equipment—Remember the Tool Room—Elaboration—Co-operation—Properties of First-class Equipment.

**Jigs and Fixtures, the Difference.**—Clarity of expression and description is as important in the world of engineering production as in any other trade or profession, so that a few words on the relation between jigs and fixtures will be helpful.

One would be safe in saying that a jig is a device having suitable guides through which are passed the necessary tools to operate on the particular component held in that jig. The latter, as in the case of a drill jig, might have guide holes or drill bushes through its various faces, thus making it impossible to clamp it on the machine in any one position.

In the case of a fixture, however, as the name suggests, it could be described as a device clamped to a machine table, into which the component to be dealt with is locked. In the latter case a certain amount of skill may be necessary to set the tools in relation to the fixture, whereas with a jig it is correct to assume that very little skilled attention is called for.

**Their Value.**—The use of jigs and fixtures is extending and developing daily, having had its beginning in the production of small and medium-sized articles; to-day, however, one sees large engine and machine tool builders employing them, and the economies effected thereby are unquestionable.

To mention a few points in their favour, there is :—

(1) Quicker production, due to the removal of measuring operations, etc.

(2) Cheaper production, it being then possible to employ unskilled labour.
(3) Interchangeability, thus facilitating assembly and also helping future upkeep.

The old mechanic who laboriously marked off each part has gone, to be replaced by the tool maker responsible for the manufacture of jigs and fixtures. It must not be assumed, however, that the system of employing jigs, etc., is infallible, because, in the case of castings which vary considerably in form, much trouble often occurs.

A compromise is sometimes effected in such cases by centre lining or roughly marking out the important points of the casting and then locating them in the fixture. The latter remark applies particularly to heavier work such as automobile components, cylinders, etc.

**Looking Ahead.**—The successful designer is not only an ingenious person, but one who has developed the habit of looking well ahead, and the field that he should scan before making any decisions will be indicated.

In these days of "Payment by Results" there might not always appear the necessity for giving special attention to rapidity of production but as it has been found that sometimes an operator or clique of operators will "nurse" a certain job with a view to maintaining or increasing its price, the design of what might be called "compelling" jigs and fixtures is necessary.

By "compelling" the writer means equipment, that by watching points in its general design such as method of loading, cleaning, clamping, etc., the opportunity for any such form of slacking is removed.

By attention to the points mentioned an indirect increase of production is obtained, for without entering the field of "Motion Study" it is obvious that the operator can work continuously, or at least with less fatigue, when the number of his movements are limited. It is a fatal mistake for the designer to complete the design of jigs, tools, etc., for one operation on a component, without giving a thorough consideration to the operations to follow. The order, "layout," or sequence of operations for a certain part may be handed to the designer by his chief, but even then he should mentally follow the operations in order to make quite sure that there exists no hidden "snags," because it has often been found that, paradoxical as it may sound, to add one or two extra operations on a component has, in the end, reduced the total time of production very considerably.

To give an example, a casting may be varying in form, or be very roughly cast at an important locating spot. To work from this point under these circumstances would probably result in many being spoilt entirely, a great number being doubtful, and others would require an expenditure of labour to save them from the scrap bin, whereas by introducing an extra operation to clean or true up this locating spot, in the first instance the work would have passed through successfully with satisfaction to the people concerned, and without interrupting "progress,"[1] a very important point in a well-organized factory.

**Cost of Equipment.**—The scale on which production is to be carried out, or the number of a certain article called for, will naturally decide the expense to be incurred in producing the necessary equipment. When dealing with turned work it would be necessary to decide between arranging for the tooling of an automatic as against a capstan lathe, or between the tooling of a capstan with cheap labour, and avoiding special tools altogether by putting the job in question on a centre lathe and employing skilled labour.

Where the material is of thin section, the question of press or drilling machine would arise, but whatever method is adopted, if the quantity to be produced is small, the tools, etc., should be made with as little expense as possible. With press tools the hardening process might, in some cases, be avoided, with the drilling operation the body of another jig might be utilized temporarily by adding the necessary extra parts. The main point to bear in mind, then, is that any profits accruing from a small job must not be consumed by the cost of the equipment.

**Quality of Product.**—Quality of the finished product, by which, as far as the tool draughtsman is concerned, is meant accuracy and finish, comes next for consideration.

[1] It is necessary to explain to the beginner that "Progress" occasionally referred to is the systematic control of components, etc., from the rough stores till they reach the shipping department, in a finished state, by which means waste time is avoided and the efficiency of the works increased.

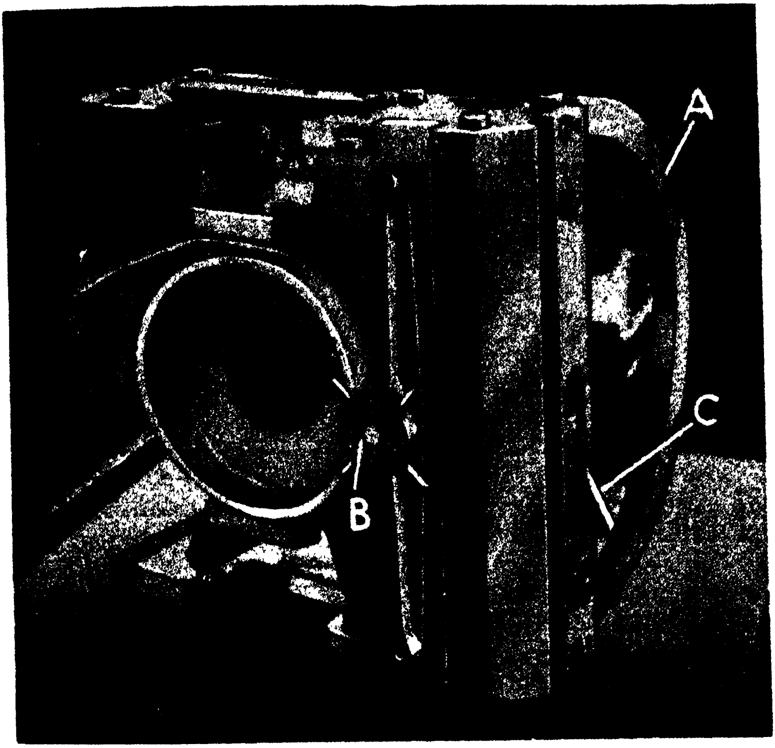



**Plate 1.**

**Handling Heavy Jigs.**—The importance of designing jigs which are convenient to handle has already been dealt with and here is seen one way of dealing with a heavy or awkward jig. The component is a piece of a " Hoover " cleaner and is clamped on to its machined face by means of nut and bar B. The trigger C is used to force the component into its seating in the jig.

The rockers A enable the operator to *roll* the jig from one side to the other for further drilling operations, thus reducing fatigue and saving time.

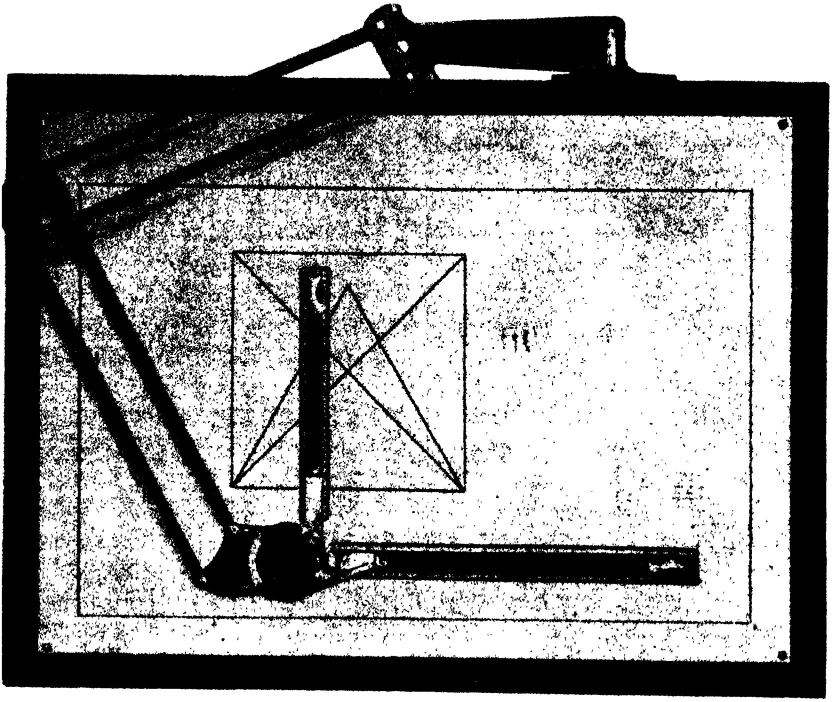


Plate Ia.

Work in the jig and tool office is facilitated by the use of modern equipment. Here is a drafting machine rightly described as "Universal". The protractor is the controlling centre of the machine. It is held in the left hand, and from this position all the motions of the machine are readily controlled. The right hand is left free for drawing. This machine is supplied by Messrs. B. J. Hall Ltd., Dacre Street, Westminster.

[*Facing page 17*

The greater degree of accuracy called for, the more care must be expended both in the designing and making of the jig or fixture.

The machine available for the particular operation must be selected, and assuming that this machine has defects, which cannot be, or possibly it may not be convenient to have remedied, the equipment must be so designed as to produce accurate work, and at the same time to remove any danger introduced by these defects in the machine tool itself. It may sound somewhat unfair to thrust the responsibility of overcoming machine faults on to the designer, but he must regard it as excellent practice and remember that unusually successful results often bring their reward; on the other hand, when connected with a firm whose plant is very doubtful, to ignore this would certainly end disastrously.

The finish of a product is often affected, indirectly, by the method of machining which, in turn, is controlled by the design of the jigs or fixtures.

If the various operations are so arranged that burrs or "rags" are thrown up excessively, or surfaces are not finished sufficiently fine, extra expense is entailed in correcting this, and the final finish is sometimes affected. The removal of burrs often provides the designer with an interesting though difficult problem, the cost of their removal often being out of all proportion to that of the remainder of the work.

**Class of Labour.**—After considering the type and quality of the machinery in general, the class of labour employed must be remembered. If a firm are content to pay sufficient wages to encourage a somewhat higher grade of labour, the necessity for extremely accurate and foolproof equipment might be avoided; again, some firms are very slow to change their methods—to replace an operation employing a file and template by a profiling operation might not always meet with the approval it should. The continual change of operators necessitates the design of what might be called super-foolproof equipment.

The writer remembers a concern situated in an agricultural district, the management of which regarded with dread the approach of the pea and strawberry seasons, because the operators, being mostly females, were attracted to the fields on the work of picking, which meant engaging new people, and in cases where certain operations required a little practice to accomplish, an amount of scrap work and delay resulted. A jig or fixture having clamps, the design of which were quite successful when operated by male labour, may not meet with the same success with female labour.

The method of loading a component into its fixture is another point, and the designer will do well to imagine himself in the place of the operator, especially where the weight is rather high and the operator a female.

It might be said that it is the duty of the shop foreman to select his operators for the particular job, but the designer should remove the necessity for any such selection by attention to the point in the manner indicated.

**Single or Multiple Equipment.**—In these days of high production the draughtsman should resist the temptation to design all fixtures on a high production scale, that is to say, to design fixtures capable of holding a quantity of parts at once.

Careful examination will often show that better results are obtained by handling each piece singly.

The writer remembers a very elaborate fixture for milling slots in the periphery of some steel rings 4" diameter, $3\frac{3}{4}$" bore, and $\frac{5}{16}$" thick. It consisted of a steel mandrel about 12" long to fit the bore of the rings, the latter being threaded thereon and nuts finally locking them in position.

The loaded mandrel was then to be lifted into a cradle on the machine, but as the price of this job only allowed for female labour the lifting was found to be more than a female could accomplish, which necessitated re-designing this fixture.

Another factor to be considered is the supply of components. If this is from outside sources and is insufficient, or perhaps the preceding operation is not fast enough, it does not pay to set up an elaborate equipment, so it is obvious that a simple fixture which can be easily set up and taken down is best under such circumstances.

The same question applies to the designing of jigs and fixture for use on multiple spindle drilling machines, etc., for here again, if the supply of work is inadequate, it scarcely pays to set the machine which would probably remain standing idle in preference to continually setting and resetting it, this in either case being very expensive.

**Remember the Tool Room.**—This might, with advantage, be hung on the walls of many drawing offices as a text, for certainly, judging by some designs produced, tool makers are regarded as wizards. It is worth mentioning here that for a person to produce designs for equipment satisfying all points he must have had tool-room and machine-shop experience.

Though, of course, the points already mentioned must be

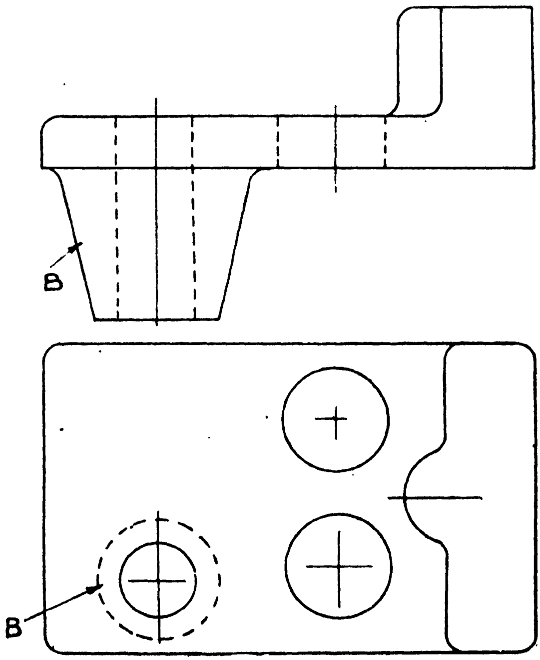



FIG. 8.

ALLOWING FOR MACHINING WHEN DESIGNING.

considered first, it would be wasteful to introduce a design that would occupy the time of skilled and consequently expensive tool makers when the same result could have been effected in a much simpler manner.

Fig. 8 is an example of this, where a hole is wanted through the boss B at fixed centres and square with the other holes in the plate.

The tool maker would probably clamp this casting on to the lathe face plate for boring the hole, but the presence of the boss B would make this exceedingly difficult, as the four corners would have to be packed up equally as high as the boss, and it is doubtful whether, after many vexatious attempts, the holes would all be parallel.

If, however, the designer had called for a separate boss, a quicker and more reliable result would have been obtained, even allowing for the extra work entailed in fitting the boss afterwards.

The length of reamers, spindles, etc., which are to be finally hardened should be kept as short as possible, for it is quite possible that in getting over the difficulties caused by warping of long pieces when heat-treated, two will have to be made to ensure getting one.

**Elaboration.**—A person whose work brings him continually in touch with mechanical drawings gradually becomes something of a connoisseur, and it may be this, coupled with the desire to produce something pleasing to the mechanically trained eye, that tempts some draughtsmen to introduce extremely elaborate and therefore expensive designs.

Jig and tool offices and similar non-productive departments are regarded as necessary evils, therefore it is necessary that the results of their work should show in a favourable light. The cost of special equipment should be kept as low as possible, and this can most easily be done in the drawing office. Where iron castings form part of a design it is very tempting to include webs, bosses, lugs, and numerous other refinements which certainly make the finished fixture look very workmanlike, but what has been the cost? The extra bosses, etc., all made work for the pattern maker, the moulder found that the casting needed care in moulding, the tool maker had to think how he could best tackle such an awkward piece, and finally, when the cost department figured it all out, that designer had no reason to be pleased with himself. It is quite possible that a plain iron casting would have accomplished the same results, even pieces of channel and girder sections should not be despised.

The designer who judiciously uses materials at hand, and is ever ready to adapt old discarded parts, shows a breadth of experience and indicates the profit-making servant.

**Co-operation.**—In the writer's opinion there is one essential to the successful production of a commodity, and that is co-operation between the designer of the commodity, the planning department or jig and tool office, and the machine shop.

Often, and with expensive results, do these people "plough a lonely furrow," thinking that it is hurtful to their dignity to alter or moderate their ideas at another's suggestion. When drawings of a component or the component itself is handed to the designer, it is often immediately obvious that by slight modifications the arrangements for tooling and subsequent production can be greatly facilitated.

As, however, it is not within his province to make such alterations, and the point in question may be very vital, he should consult with the people responsible for the design of the article, who should agree any alteration that would make for cheap production.

Having got so far, though the draughtsman may be an expert mechanic, there may be many hidden difficulties in the particular machine shop into which the tools will go for use, so again it will be advantageous to consult with the shop foreman or charge hand before proceeding.

Another very good reason why the policy of allowing the machine-shop people to express their opinion is that if eventually there is a slight hitch in the tooling arrangements, they will do their very best to get over the difficulty with the minimum of trouble, feeling that they have a share of the responsibility.

On the other hand, no matter how well equipment is designed and produced, it is remarkable the difficulties and troubles that can develop when these designs are not to the liking of the machine-shop executive.

To illustrate how co-operation resulted in economy, Fig. 9 is given. It shows the flange of an oil pump, the four holes, A, B, C and D being fixing holes and E an induction hole. It is obviously a job suitable for a multiple-spindle drilling machine, piercing the five holes in one operation, but as it was only possible to adjust the spindles of the machine to drill holes with 1" centres, this was impossible, as it will be seen on examining Fig. 9 that the centres of the induction hole and the nearest fixing hole are ¾". After arranging with the designer of the pump to widen these centres the five holes were drilled at once, otherwise this piece would have required two operations.

**Properties of First-class Equipment.**

(1) The cost of designing and making should be in proportion to the price and quantity of work in view.
(2) Should be perfectly reliable as regards accuracy, and production therefrom should be up to the estimate.[1]

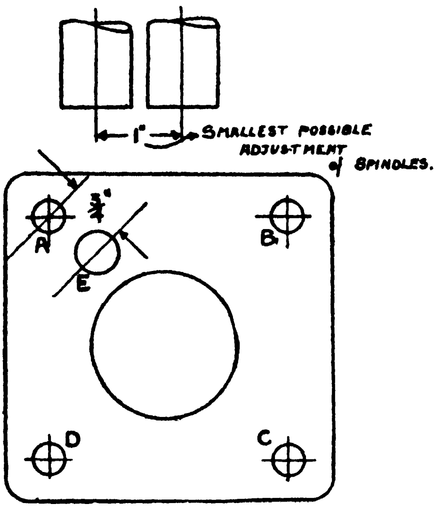



FIG. 9.

ADJUSTING DESIGN TO FACILITATE PRODUCTION.

(3) Should be light and easy to handle and manipulate.[2]
(4) It should be foolproof.
(5) Parts subject to heavy wear should be designed to facilitate removal.
(6) The equipment should not constitute a danger to the operator.
(7) All parts should be standardized where possible.

[1] The writer remembers a designer who would sit with eyes closed and mentally carry out movements necessary when operating the jigs or fixtures of his design, and it was very surprising how accurate were the results obtained when estimating production.

[2] The operators should not have cause to complain of fatigue.

CHAPTER IV

# DRILL JIGS

Holes through Diameters—Location—Self-Centring Mechanisms—Locating Rough Components—Adjustable Supports—Clamping—A Simple Drill Jig—Drill Jig for Pistons—Jig for Use on Double Spindle Machine—"U" Washers—Jig Feet—"Jigging" a Component—Multiple Drill Head—Simplicity of Design—An Indexing Jig—A Jig Indexing in Four Planes—Continuous Drilling.

In this and succeeding chapters the design of various equipment will be considered, and so as to enable the reader to thoroughly grasp the various points requiring attention, it is proposed, in some cases, to introduce sample components and then to design the equipment for a certain operation. Attempts have been made to classify the various types of drilling jigs, but the dividing line is so faint that it is in many cases indistinguishable. For preference it would be better to classify the operation such as drilling raw castings, half-machined components, parts machined to coarse limits, parts finished to very fine limits, etc., a somewhat different type of jig being wanted in each case.

**Holes through Diameters.**—In the engineering world there is an enormous variety of parts such as rods, tubes, pistons, etc., having holes passing through their diameters, and though this may appear very simple, it is not so when extreme accuracy is required. To illustrate this Fig. 10 is given showing a piece of steel tube having ¼" holes each end and running at 90 degrees to each other.

It will be noticed that the holes are expected to be accurate within ·002". The first consideration then will be, how to maintain this accuracy.

It is at once obvious that a drill starting on a convex surface will always have a tendency to run off, which of course would be fatal, therefore the bushing that guides the drill must not only be as near as possible to the tube, but must be extra long so as to provide an extended bearing surface, because the continual tendency of the drill to run wears the bush considerably, this wear can be further reduced by making the bush a good fit on the drill.

Seeing that the proper guidance and control of the drill presents no difficulty, the method of holding the piece will next be considered.

**Location.**—The question of the correct locating point is very vital, for it is obvious that the accuracy of the hole cannot be greater than that of the locating point. The usual method for drilling single pieces is to lay them on a vee block as shown at A, Fig. 10, these blocks being very successful where the holes to be drilled are in one direction only, but

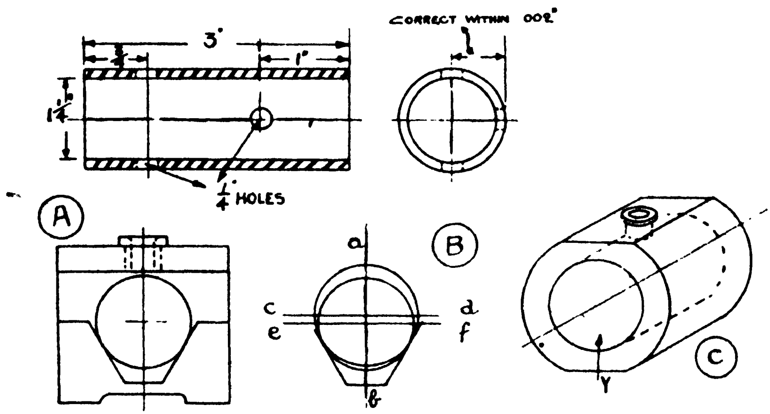



FIG. 10.

A.—VEE BLOCK LOCATION.
B.—ACCURACY AFFECTED BY VARIATION OF DIAMETER.
C—CHEAP JIG FOR SMALL QUANTITY.

where the holes are in different planes another factor enters. This factor is the accuracy of the diameter of the rod or tube both externally and internally.

A glance at B, Fig. 10, clearly shows that if the external diameter varies accuracy is impossible, because while the line *a*, *b* is correct, whatever the variation, when turning through 90 degrees and drilling, the lines *c*, *d* and *e*, *f* show that the hole position would vary with any difference in diameter. It can therefore be at once decided that while this condition exists, vee block location must be discarded.

On the other hand, had the external diameter been finished to limits as accurate as those called for in the hole to be drilled, a jig embodying a vee block would have been quite successful. It must be remembered then that if the two diameters are unreliable, the method of holding must be such that this absence of accuracy is avoided, and this can only be done by utilizing a device that will centralize the tube or rod in all planes.

The drawing indicates that the holes must be correct within ·002″ in their relation to the outside diameter. This allows the inside diameter to be ignored, a very useful concession, seeing that the particular piece is from the tube in its raw state, under which circumstances the bore may not be concentric with the outside. A certain path is therefore indicated to the designer, i.e. the jig must centralize the tube, and for this purpose the outside diameter must be made use of.

Having determined the conditions that must be fulfilled to produce the requisite degree of accuracy, the method of securing this will raise the question, What expense can be incurred in making the jig ?

Assuming that only a few dozen are wanted, it may be possible to introduce an operation of turning or grinding the outside diameter at each end, finally resorting to vee blocks as already mentioned. If that is impracticable, another method of getting through a small quantity would be to measure accurately the outside diameters and group these, after which a simple drill jig as shown at C, Fig. 10, could be made. The hole Y would first be made to suit the tube of smallest diameter, and when this batch is finished the hole could be ground out to suit the next size. This method would, of course, make the jig useless for future work, but where the job was known to be the last this would not matter.

**Self-Centring Mechanisms.**—Quite a number of these will suggest themselves and a few are indicated in Fig. 11. A is a pair of vee blocks arranged to slide, without any "play" and actuated by a right- and left-handed screw. If this method is adopted, the length of the blocks should be sufficient to stand considerable wear and also provide a long bearing surface, because the tendency is for these to lift when tightened. B shows two coned plugs, one of which is fixed and the other provided with a screw or cam lever enabling it to be withdrawn or closed on to the tube. This is quite good where the ends of the material are perfectly square; if this is not so, it is obvious that the tube will not lay parallel. If the tube being drilled is of thin section, care must be taken to see that the gripping mechanism is not powerful enough to distort it. The method shown at C employs a coned plug one end and an ordinary small three jaw chuck at the other.

D and E, Fig. 11, show the principle of two devices, the former for gripping on the outside and the latter internally. Taking

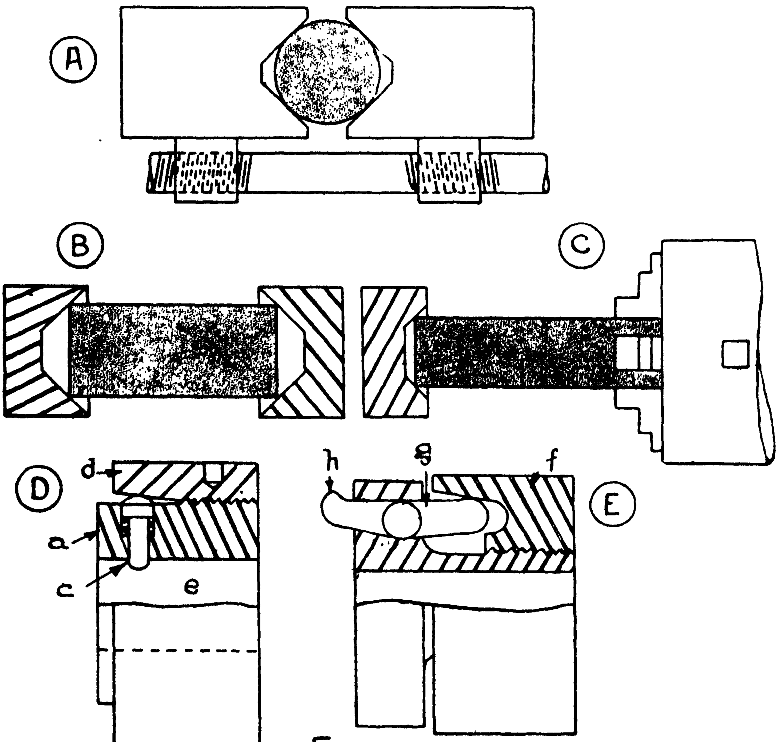



FIG. 11.

SELF-CENTRING MECHANISMS FOR DIAMETER DRILLING.

D first, it consists of a body piece *a* on to which is screwed the coned nut *d*. Equally spaced round *a* are three hardened steel pegs or jaws *c* of equal length, capable of a sliding motion, so that on inserting a rod or tube in the bore *e* and turning the nut *d*, the pegs are depressed centrally and so grip the rod. The pegs are provided with small helical springs to assist them on their outward motion. E is very similar, except that the pegs are replaced by three pivoted levers *g* equally spaced round, which tilt when nut *f* is screwed up enabling their ends *h* to grip internally.

Other than these there are spring collets as used on capstan lathes and also various types of expanding mandrels (see Chap. VI).

**Locating Rough Components.**—In deciding from which point to locate a component the greatest care should be exercised, for upon this the accuracy of the finished work will depend, at the same time excessive operations introduced to provide a suitable locating point should be avoided if possible. Once an operation has been performed on a piece the question of location is simplified, but it is with the rough component that the difficulty arises.

Forgings, stampings and die castings are generally produced uniform in shape, but ordinary castings vary considerably and it will be found in dealing with these that an elementary knowledge of pattern making or foundry work will be of great value, for it will be appreciated that it would be fatal to locate from a point that was continually changing, and the knowledge referred to enables this to be avoided.

In the case of a casting with bores calling for machining, the bores will probably be " cored " out in the casting, leaving a certain amount of metal to be removed. Now in the production of the casting the cores are very liable to move and so produce eccentric bores, whereas the main pattern which produces the mould from which the castings are taken, if well proportioned, should give uniform results.

The correct location point for a casting, then, can be best found by an examination of the method of producing the casting. In locating a piece of irregular form, or when providing a seating for a component, what is known as " three point " location is best. The best illustration of this exists in the comparison of a three-legged stool and an ordinary chair. The latter, when placed on irregular ground, will invariably rock on two diagonal legs, whereas the former will adjust itself under whatever conditions it is placed. The diagrams in Fig. 12 indicate several methods of locating components when in their rough state as for the first operation.

Taking A first, where the component is shown shaded, the operation required is to drill the holes *a* equidistant from the outer rim. In this case it is obvious that though the holes might be drilled more central to the bosses by locating therefrom, this is not essential, and though the finished piece might have a better appearance when so drilled, the important

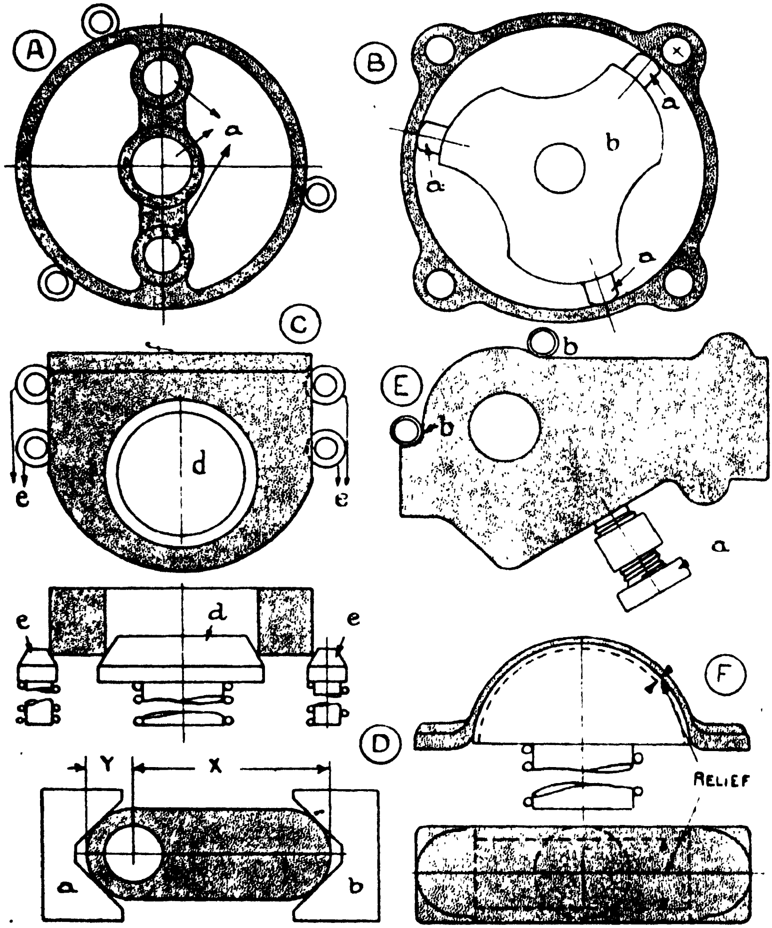



FIG. 12.

LOCATING METHODS.

point, i.e. the relation of the holes to the outside rim, would have been missed and probably a quantity of work wasted.

One form of location shown can be employed where three-coned studs are provided equally spaced round the rim at such a radius that the rim seats on the cones, the latter being provided with springs below, which enables them to drop or lift to suit the component; the latter is by this means centralized, and if the drill bushes are fixed on the jig in correct relation to these coned pegs, accurate results will be obtained. The angle of the cone on these pegs is generally about 60 degrees, and they can be arranged to suit the inside or the outside of the component according to which is most desired.

Another form of location is shown at B, where the rim again enters into the question. In this case correct location is secured by three hardened steel plungers *a*, behind which are fitted springs, and actuated by means of the cam *b*, a partial rotation of which will force out the plungers equally, thus locating the piece. The springs cause the plungers to fall back when the cam is released.

At C a component having a cored hole calls for machining on the horizontal face indicated, and at a certain distance from the centre of the hole, so that it is necessary to fix the piece with the sides vertical. Two relationships are necessary then, first, the centre of the hole to the top face, second, the latter to be square with the sides.

This can be overcome by having a coned centre *d* capable of a sliding motion and fitted with a spring, and at the sides four coned pegs similarly fitted, so that on pressing the component down on to the coned centre, the latter recedes, the spring being compressed until the component comes in contact with the coned studs *e* which set the sides to the vertical, after which the piece is clamped.

There exist an endless variety of levers and plates having holes a certain distance from the end, and a form of location for this is shown at D.

For locating pieces having a radius, the vee method already mentioned is quite satisfactory, one vee being fixed and the other adjustable, the latter also providing a means of locking the component. In the case of the piece shown the relation of the hole to the vee blocks is important. The accurate dimension must always come between the fixed vee and the drill bush, that is, assuming that block *a* is fixed, and the dimension is given at *y*, the component is correctly located, but if as at *x* the component should be reversed so that the end from which the dimension is given butts against the fixed vee.

Parts having an exceptionally irregular outline are very difficult to locate, one method is as shown at E where the component is forced by the screw *a* against the two pegs *b*, the latter being arranged at the most clean and reliable parts of the casting, also at points that govern the important dimensions. In cases where the piece is so irregular that it has proved impossible to use pegs, the difficulty has been overcome by having the outline of the piece accurately marked or engraved on a jig plate, and then clamping the piece on

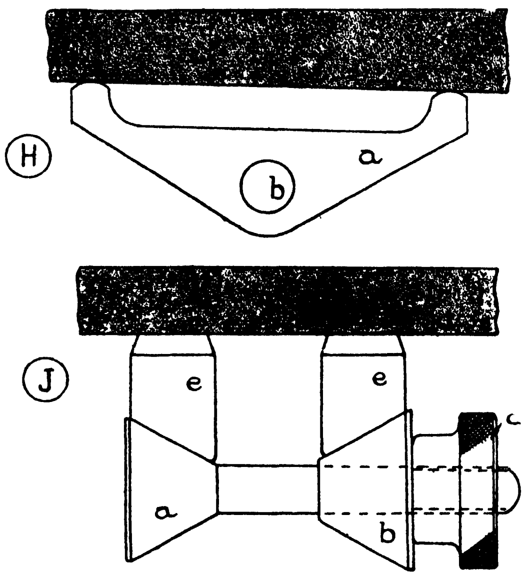



FIG. 13.

ADJUSTABLE SUPPORTS.

to it over the outline. Naturally a smart operator will be necessary for this job, but it will be found that the extra time taken or expense incurred by adopting this method will be outweighed by the small amount of scrap, and also by the time saved by not having a jig with pegs to adjust to suit the varying castings.

Where the position of a radius is important, the semi-circular pad provided with a spring seating, indicated at F, is quite successful. To avoid the roughness of the concave shape, the pad is cut away or relieved so that only two or three points of the pad are in contact with the component.

**Adjustable Supports.**—It is frequently necessary, after a component has been located in a jig or fixture, to swing or adjust the piece square irrespective of its section and at the same time to provide support. H, Fig. 13, is a form of support where the component is located in a jig at a slightly varying angle so that the support *a* pivoting at *b* will adjust itself to the angle. At J is another very useful form of support which also sets a component horizontal in the fixture. It consists of a coned bolt *a* on which is a sliding cone *b* having a similar angle to the bolt. By turning the nut *c* the two are drawn together thus causing the pegs *e* which are provided with angular flats on their bottoms to move upwards equally at the same time correcting the component should it not be horizontal.

**Clamping.**—Having correctly located the component, the next thing is to see that it is clamped in an efficient manner.

A large amount of time can be wasted and work spoilt by having unnecessary clamps, or ones that are awkward or complicated, by having them placed in awkward positions, or by making them removable so that they get mislaid. The first point is that the gripping should take place immediately over or as near as possible to the locating spots, otherwise the work may distort. It has often been found that work, after it has been machined and checked in position, is correct to size, yet on releasing the clamps an entirely different result is obtained. It should also be remembered that the clamping method should take into consideration the operation being performed. If it is horizontal milling, where the tendency is for the work to be lifted up from the machine table, the clamps must be so arranged as to prevent this; if it is vertical milling where the tendency is for the cutter to swing the work off the table, the clamps should be assisted by projections or pegs to take up this thrust.

A variety of clamps are illustrated in Fig. 14, and the designer must see that while the clamp is effective it is not too elaborate. The simplest form is seen at A and no apology is offered for mentioning this old method, because even to-day it is possible to find it being applied in a faulty manner.

It should be arranged so that the pressure of the nut is as near as possible to the work, so that the latter gets the full value of the leverage. The inclusion of a spring beneath the clamp plate will assist wonderfully in its manipulation. The plate *a* should err rather on the thick side and should

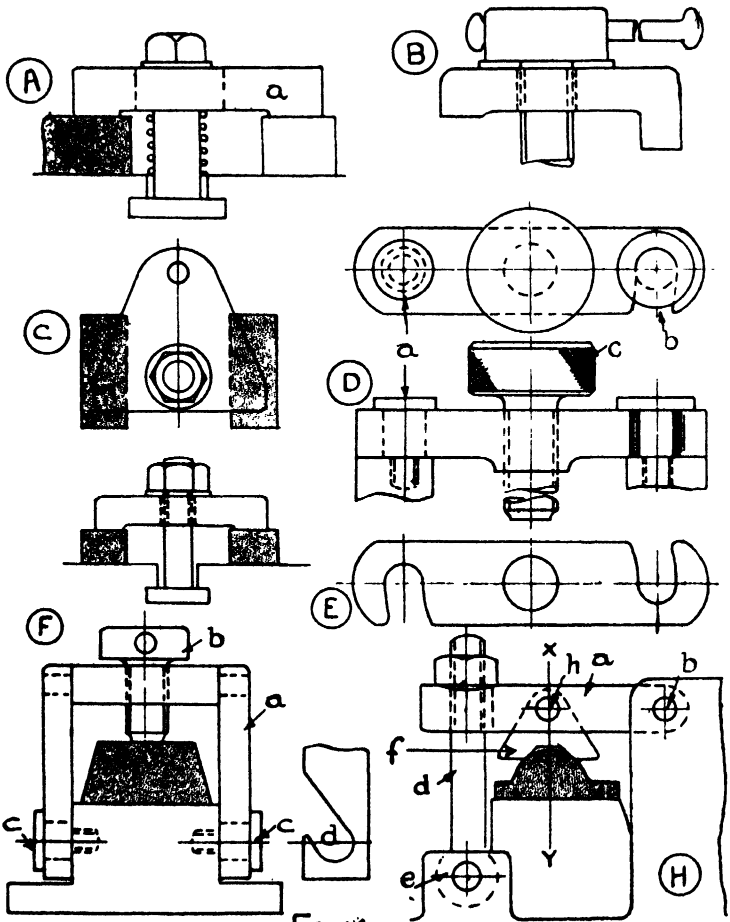



FIG. 14.

TYPES OF CLAMPS.

be provided with an elongated slot enabling it to be slipped back to facilitate the removal of the component.

At B is seen the same type of clamp, but the hexagon nut is replaced by a round-headed one provided with a loose tommy bar which obviates the necessity of the operator using a spanner, the use of the latter should be always avoided where possible. The opportunity of clamping more than one piece at once as at C should be watched for.

Favourite clamps for holding components in drill jigs of box formation are shown at D and E. In the former the end *a* is pivoted so that the clamp swings clear to enable the jig to be loaded, and when ready for clamping the hooked end *b* passes under the head of a stud as shown so that the plate is effectively held while the clamp nut *c* is screwed home.

That at E works in a similar manner except that the clamp plate is removable.

At F is seen another pattern, the link *a* swivelling about the studs *c*, the bolt *b* gripping the work. The disadvantage of this type of clamp is that it occupies three faces of the jig, thus making it impossible to turn in any but one position, without the use of legs of excessive length, and the latter should be avoided.

It can, however, be made removable if this form of clamp is unavoidable by slotting the pivot hole as shown at *d*.

Where the component varies slightly in shape, the clamps shown at H are very useful. The plate *a* being hinged at *b* and provided with a slot as shown, thus enabling the bolt *d*, which is also swivelled at *e*, to be swung clear, forming a very quick method of holding. The pad *f* is suspended at *h*, so that it swings ready to adjust itself to any variation in the form of the piece. The plate *a* should be of generous proportions, as it will be seen that the tendency is to bend it across the line *x*, *y*.

As it is essential that the minimum time must be spent on the clamping of the piece, the employment of long lengths of thread should be avoided. Particularly in the case of finished or semi-finished work, where there exists a portion having a constant shape, clamps in the form of levers or toggles provided with a cam lobe are an advantage. At J, K and L will be seen three types of cam lever applicable to various cases. That at J is shown in use in Fig. 16, and it is usual to have the centre thrown eccentric by a distance varying from $\frac{1}{32}''$ to $\frac{1}{16}''$. This amount is described variously as the " lead," " throw," " rise," or " lift."

The cam on the lever at K is drawn as indicated, and the portion at *a* must be sufficiently wide to prevent it bending when the lever is thrust home. That at L is of slightly different pattern to the others and is not so well known, but used in the proper place it is very successful. The cam *a* is fixed to the spindle *b* which is operated by turning the handle *c*, the cam applying pressure to the bolt *d*, the latter being

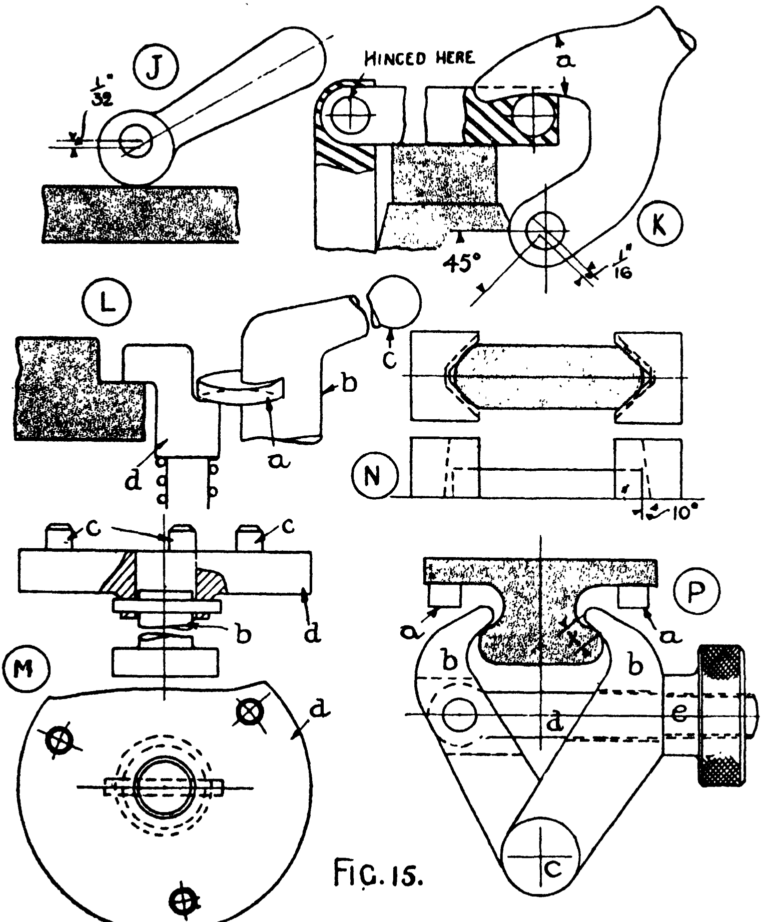



FIG. 15.

TYPES OF CLAMPS.

provided with a spring to lift it when the pressure is released.

To grip a component having a fairly large area which is not at right angles to the clamp bolt, the method shown at M will be found satisfactory, with the advantage of having only one bolt to operate. The plate *a* is pivoted at the end of the bolt *b*, and the former has three hardened pegs *c*, so that at whatever angle the face of the component may be, the three points are enabled to reach and lock it, the clamp screw being equidistant from them.

Forgings of small levers, stampings, etc., are not always easily gripped, but N indicates one method where the component is seen held by two vee blocks, one being fixed while the other is actuated by a clamping bolt. To keep the piece from lifting it will be noticed that the vees are not cut at right angles to the face of the blocks, but at about 10 degrees which prevents the component from lifting due to the action of the cutting tool. The movable vee should be accurately dovetailed into the foundation plate of the fixture to prevent it lifting when pressure is applied.

The designer will often meet components that will tax his ingenuity to devise suitable clamps, and as has already been mentioned this may be overcome by consulting those responsible for the design of the piece in question, with a view to making a slight alteration to assist clamping.

At P is a clamp of special design holding a forging of awkward shape. The latter is located on pads at *a* and held by the claws *b*. These are pivoted at *c* and the locking is effected by screwing up nut *e* on bolt *d* which passes through one limb and swivels on the other.

The length of the lip *x* should be as short as possible, otherwise time will be wasted in opening the claws wide enough to permit of removing the component.

The magnetic chuck and the introduction of compressed air for operating clamps will no doubt make a great difference in the future, but as the sphere of usefulness of the former is limited and the latter merely applies the necessary force, the question of the method of holding still remains.

The reader is advised, however, to make himself acquainted with the theory of these two introductions.

**A Simple Drill Jig.**—Fig. 16 gives different views of a simple yet highly successful jig, for rods or tubes where the holes are in one plane. The rods lay on the vee block and a single motion of the lever *a* locks the rod centrally. The construction also allows of easy removal of the work. Plenty of room also exists for the operator's brush when removing the cuttings, a very important yet much neglected point.

As this jig is shown fully detailed (see Chap. XIII), no further description will be necessary.

**Drill Jig for Pistons.**—The increase in the production of motor vehicles has brought to light a very interesting machining proposition in the form of pistons, and the points

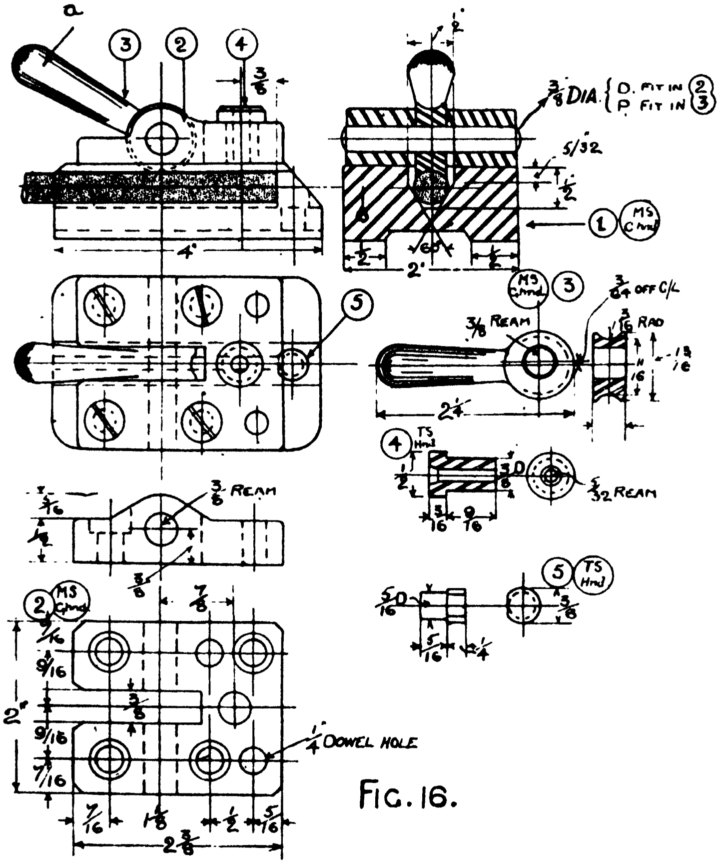



Fig. 16.

A SIMPLE DRILL JIG.

already mentioned in connection with drilling through diameters apply to this component.

Fig. 17 shows a piston in section, one is also seen in position in the drill jig illustrated. To get these pieces machined quickly a horizontal machine having two spindles opposed to each other and capable of being fed in simultaneously is often used.

It will be at once seen that the drilling time is halved and also by drilling through from opposite sides greater accuracy is obtained. For the piston to function properly when complete it must be correct to size, a certain weight, and with its walls of sufficient thickness to give the necessary strength.

To secure this evenness of wall special precautions are adopted when turning the diameters (see Fig. 42), and to

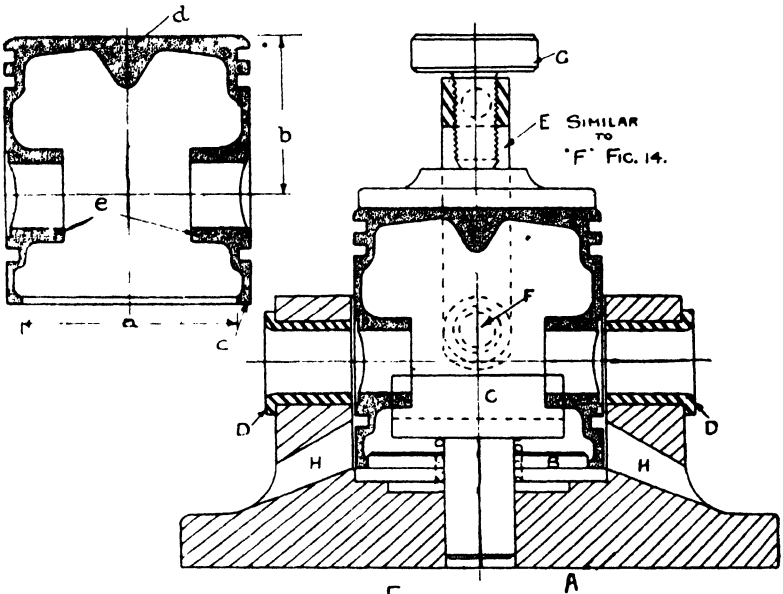



FIG. 17.

DRILL JIG FOR PISTONS USING HORIZONTAL DUPLEX MACHINE.

assist when putting in the grooves and also to provide a locating place when drilling, the inside diameter *a* is machined to rather close limits. The hole to be drilled, which is for the gudgeon pin, must be central, at right angles to the axis of the casting, and at a certain distance from the top of the casting, because if the latter varied it would cause a variation in the compression when working.

As the face *c* and the diameter *a* is turned when locating from the top *d* if the hole about to be drilled is located from *c* the dimension *b* should be maintained correctly. Examining the jig then it consists of a main casting A which is clamped to the bed of a horizontal duplex drilling machine, B is a hardened steel locating pad, C is a 60-degree vee block, mounted on a peg and capable of a vertical sliding motion, but being provided with a key to keep it in position, that is, so that the vee forms a seat for the two bosses *e* and locates them central with the drill bushes D.

Beneath the pad is a helical spring which presses the pad upwards, thus assisting the location. The clamp E (see F, Fig. 14), which swings about F locks the casting securely in position. With such a delicate casting the locking nut G should not be made so as to provide too much leverage, otherwise the casting may be distorted. With any form of jig that suggests a box or receptacle there arises the difficulty of cleaning, or getting rid of the cuttings, which if allowed to remain will interfere with the accuracy of the jig.

To ensure that this does not happen considerable thought should be given, because even if the cleaning is successful, the time taken to accomplish it should not nearly approach that taken for the actual drilling. In Fig. 17 at H are two outlets cored in the body casting just beneath the bushes, so that the cuttings will, when falling, work out of the jig, also the cuttings that may accumulate in the vee piece can be easily swept out in the same direction.

To prevent, as far as possible, any cuttings getting on the main location B, and under the piston, the former is relieved so as to leave but three points for the latter to rest on. The space between the vee block and the pad should also be kept wide enough to avoid the possibility of cuttings interfering with its free movement.

**Jig for Use on Double Spindle Machine.**—Fig. 18 shows a jig for drilling the component seen in position in the jig. This component, which is a part of an agricultural machine, is a steel forging which has passed through its first operation, which consisted of boring the centre hole and then facing the boss *b* of the latter and also the bosses *a* and *c*, leaving the two holes *x* and *y* to be drilled.

The most important point to be observed in the drilling is that the holes are the correct distance apart and that they run parallel with the centre bore. Seeing that the latter is finished and faced as also is the two small bosses, the method of locating as shown should give the desired result.

As the jig is intended to have a long life the seats on which the bosses rest are made of hardened steel. The arms D, carrying the drill bushes *d*, should be as close as possible to the forging so as to keep the length of the drill protruding below the bush as short as possible, thus minimizing the risk of the drill deflecting from its true course. To locate the bosses *a* and *c* central with the bushes *d*, the vee block *f* operated by the lever *g* is used, a spring *h* being provided to keep the block in contact with the component when locking nut *r*.

The height of the vee *f* should be such that it touches the forging just below the centre line of the boss, thus avoiding

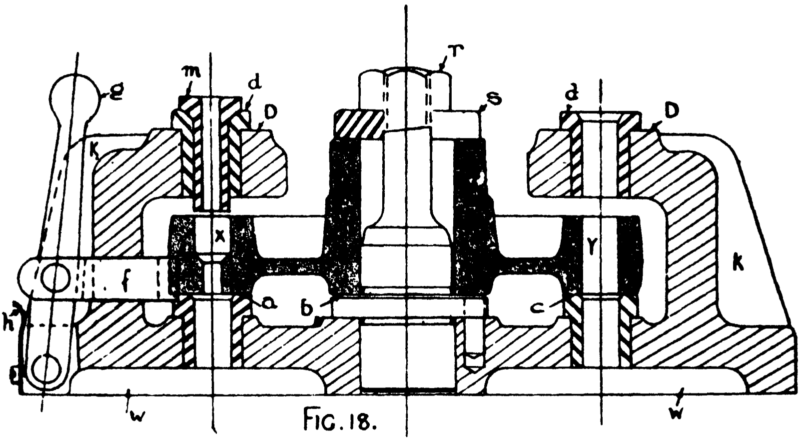



FIG. 18.

DRILL JIG NECESSITATING A DOUBLE SPINDLE MACHINE.

the "flash" or burr which generally exists on forgings due to their being formed between two half dies.

The cast-iron arms bearing the drill bushes, it will be noticed, are strengthened by arms *k*, which while adding the necessary strength do not add excessive weight. The reader is warned that while the inclusion of webs, fillets and other strengthening devices is often necessary they considerably increase the cost of the fixture, because of the extra work entailed when making the foundry patterns.

It is assumed that the jig would be used on a double spindle machine, drilling boss *c* right through and boss *a* half-way, after which the small bush *m* is slipped in position and the small hole drilled through. Had both holes been the same diameter the job could have been dealt with on a single spindle machine or a multiple spindle machine, in the latter case taking half the time.

**"U" Washers.**—To facilitate the removal of components that are located on a screwed stud, the method adopted in Fig. 18, is very successful. The nut *r* is made slightly less in diameter across the corners than the hole in the component, so that the operator has merely to loosen the nut and slip off the U washer *s* when the component can be lifted off, the nut remaining in its place. Though loose pieces are condemned the washer described should be introduced wherever possible in connection with hexagon nuts, even if it is chained or otherwise anchored to the machine to prevent the operator dropping or losing it.

**Jig Feet.**—It will be at once seen that if the holes are to be kept accurate, the jig must lay quite flat on the machine table. Pieces of cuttings under one side of the jig would tilt it slightly, thus causing the drill, when entering the bushes, to be strained out of the vertical, which would gradually wear the bushes large and finally produce faulty work. To avoid this, jigs are provided with feet sometimes consisting of hardened steel pegs, at other times the legs are formed by machining a recess in the centre of the base of the jig, thus leaving the corners standing clear as in Fig. 18, w, though in this case the recess was cast.

**"Jigging" a Component.**—It is worth while halting at this point to indicate a common method of procedure when designing a jig or fixture. Assuming that the various points mentioned in Chap. II. have been decided, the draughtsman takes a blue print of the component, and fixing it squarely beneath his detail or other fine drawing paper, traces it, using red ink for this purpose and including only the outline of the piece and its centre lines. With the component before him, the locating points are considered and lightly drawn in, as also are the methods of clamping. At this point it is well to examine closely an actual component both finished and in the raw state, for when a jig has been designed entirely from the component drawing it is remarkable how many irritating points can crop up after it is made and ready for use.

Having got so far it only remains, as it were, to build the body of the jig or fixture round the component, bearing in

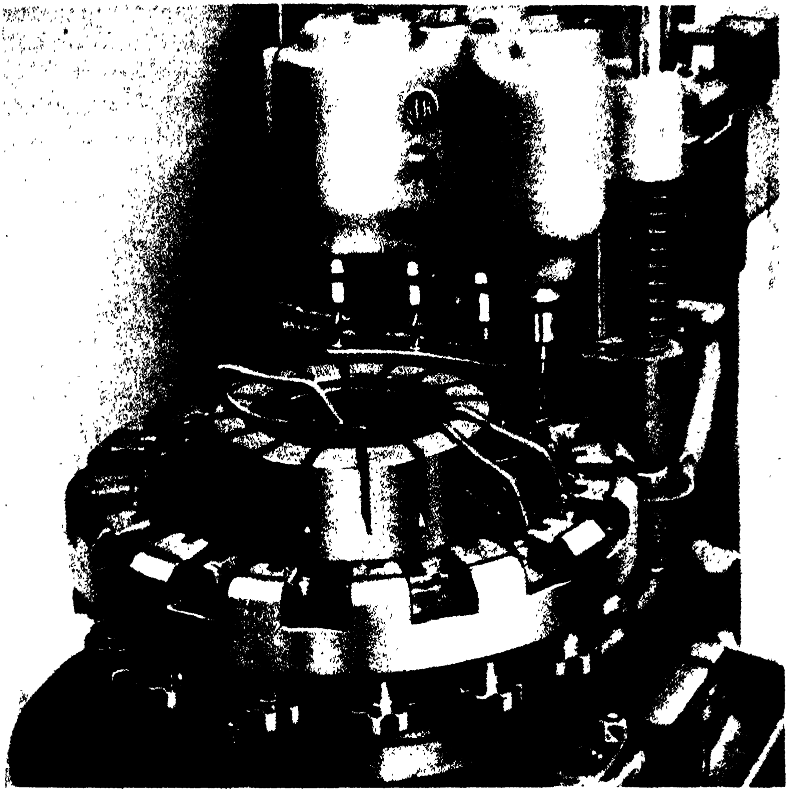


Plate II.

**Continuous Drilling and Tapping.**—This fixture was designed specially for the drilling and tapping of weaving-machine parts. The cam which controls the indexing table also operates the spindle feed. The table first indexes into drilling position, next into tapping, and finally into loading position, thus two pieces are completed at each indexing. The machine is by Messrs. Alfred Herbert, Ltd., of Coventry, and is a standard design.

Note the convenient clamp knobs, the generous chip clearance, and the arrangement of the lubricant pipes.

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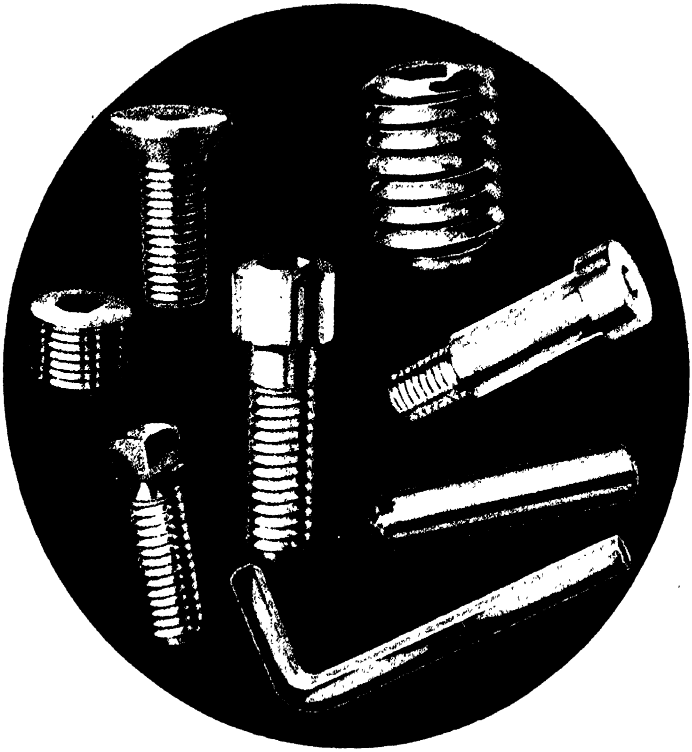


Plate IIa.

In the fabrication of jigs, tools and fixtures ordinary screws and bolts are being displaced by specialised products. The spanner and screwdriver are also superseded by the hexagon key which fits the female cavity in the screw head. They are made of special alloy steel, are more convenient, and will outlast ordinary hardware. The progressive designer should keep these in mind. Those shown are of the "Allen" variety, whose agents are S. Ralph Golding & Co. Ltd., Beaconsfield, Bucks.

[*Facing page 41*

mind strength, chip capacity, lightness and finally the pattern maker!

**A Multiple Drill Head.**—Though there are in existence many designs of multiple spindle drilling machines, there is another field which has been developing recently, and that is the design of multiple spindle heads of various sizes and spindle centres to suit certain components, the heads being attached to radial or other single spindle machines. The great advantage of these is that no setting of the spindles is necessary, being made for a single purpose, and simply require clamping on the sleeve of the machine. Fig. 19 shows a sectional elevation of one with two spindles, which would be quite suitable for use in connection with a drill jig of the type shown in Fig. 19, drilling the two holes at once.

As there is a bright future in front of these, time will be well spent in examining the construction.

The body is built in two parts, A and B, of cast iron which should not be too heavy, the use of thin section and the introduction of ribs to add strength is advisable. The drill spindles C, which are of mild steel, are integral with the pinion by which they are driven, and run and are supported by the phosphor bronze bushes D. The upward thrust of the spindles is taken by the ball thrust washers E which, it will be noticed, are dropped into a seating in the spindle pinions, and are further retained by the rod F.

The drills are gripped by the spring collets, G being forced up into the coned portion of the spindles by the nut H, the latter being provided with holes or flats to assist when tightening.

The gears are lubricated through the plug hole J, though if the gears are filled with good solid lubricant when assembling, a long time should elapse before further attention is necessary. The two spindles are driven by means of the central pinion K which runs on the peg L and is in turn driven direct by the drilling machine spindle. This is effected by cutting a slot about $\frac{3}{8}''$ square centrally across the end of the machine spindle which engages the square peg shown at M, the latter being fixed centrally across the centre pinion. Another method of securing the drive is to arrange for a tapered spindle to be integral with the centre pinion and allow it to fit the tapered spindle of the machine.

The complete attachment is slipped on to the sleeve of the

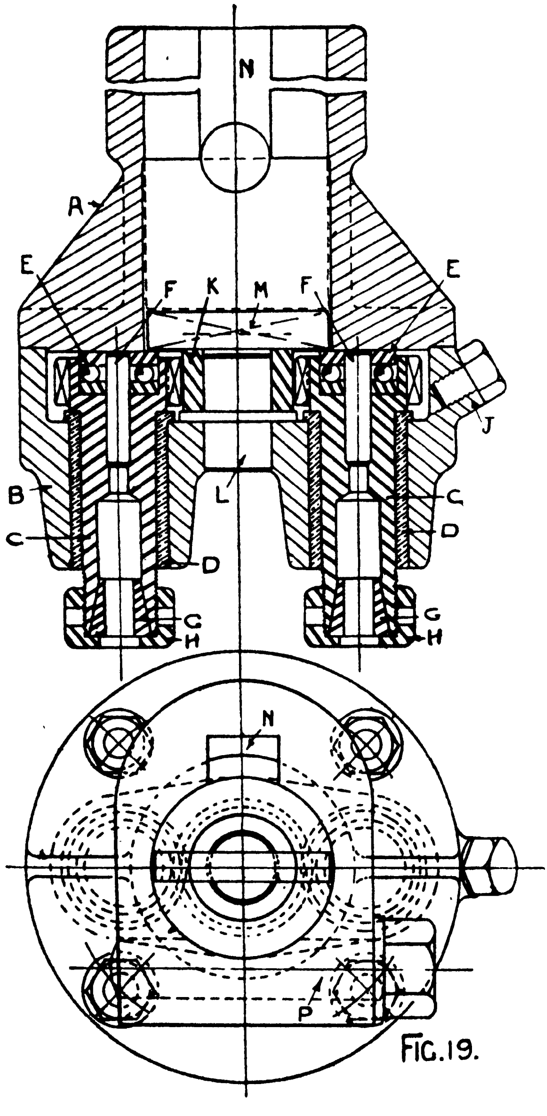



FIG. 19.

MULTIPLE SPINDLE DRILL HEAD.

drilling machine, the rack attached to the latter fitting the slot N and on tightening up the bolt P the head is securely held. From this simple example the reader will see that it is quite easy to design another head for any arrangement or number of holes. If the holes are to be closer together it will mean that the gears must be of smaller diameter.

The centre pinion in Fig. 19 had 19 teeth of 12 pitch, while the two side pinions had 17 teeth of 12 pitch. If desired the spindles can be bored to take morse taper shanks instead of the small collets and nuts as shown.

**Simplicity of Design.**—It has already been mentioned that mass production does not necessarily call for elaborate and multiple tools, in fact sometimes the simplest equipment will give the best results. It is possible to design a single drill jig to include in it bushes for every hole in the component, and while this method is very safe, ensuring the correct relation between the holes, it is possible that production may be hampered by waiting for one operator to complete the drilling, whereas had a more simple jig been designed, the work could have been split up among different operators and production facilitated.

Fig. 20 shows a group of drill jigs for drilling the necessary holes in a brass motor-car wind-screen bracket. This component contained a number of holes in various planes, and to include them in one jig would have resulted in a very awkward piece of work, so that it was decided to make simple jigs as shown.

The three parts of the complete bracket are seen standing behind the group, and the chief one is shown at Fig. 21.

The jig A is for drilling a hole through the lug *f*, and for this purpose the component is held vertically by means of a hook-shaped clamp B operated by nut *c*, and located from the holes *e*.

These two holes are made use of for this purpose throughout all the drilling, they being in turn located from the hole *v* which is drilled first, so that it may be said that all holes are measured off from hole *a*. As the lower fork of lug *f* is tapping size and the upper clearing, the bush D was made to suit the latter, so that when drilling, the clearing drill is set to pass through the upper lug and make a centre hole in the lower, after which a tapping size drill is used, starting in the centre made by the larger drill this necessitates the use of a two-spindle drilling machine.

As the larger of these holes was only ¼" diameter, and the brass was of very soft nature, no support was found necessary underneath the lug to take the thrust of the drill.

For drilling the hole *h* the jigs E and F are used, one being left- and the other right-handed to suit the two opposite handed castings. It will be seen that they are very simple in construction, being plain angle iron castings.

The components are located from the hole *a* on the stud

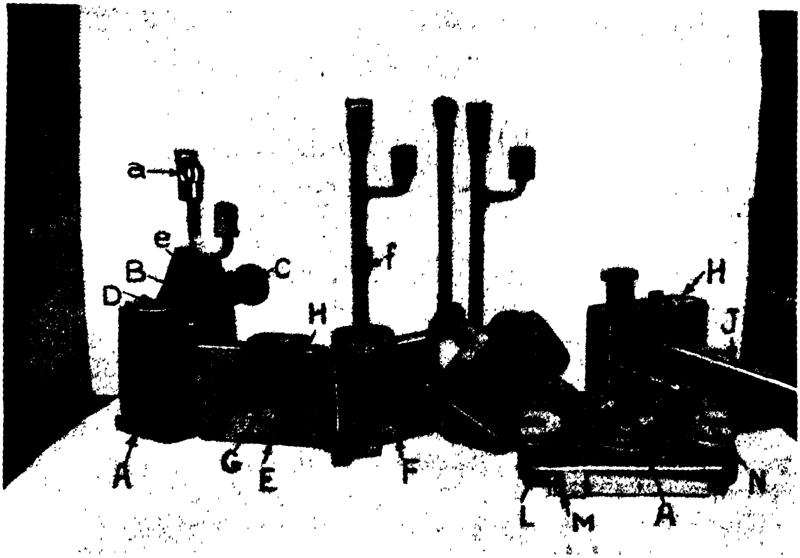



FIG. 20.—SIMPLE JIGS FOR WIND-SCREEN BRACKET.

H, the machined face *k* of the component butting against the shoulder seen on the stud. The latter is of hardened steel, and is a push fit (see Fits, Chap. IX), and is provided with a nut for locking purposes. To facilitate loading and unloading the nut G is of smaller diameter than the hole *a*, thus enabling the component to be removed without taking the nut from the stud, the U or clip washer seen at the foot of the jig enabling the clamping to be effected.

The extra thick base of this jig, not visible in the illustration, prevents any possibility of the jig tipping over when drilling, and it would have been an improvement to have made this base of inverted tee section.

As a general rule the feet or foundation of a jig should be equally balanced about the area bounded by the holes to be drilled.

The jig H is for drilling and reaming the main hole *a* where it will be observed that the component, which is semi-circular in section, rests in a vee block J, and is located by two short pegs which engage in the slot *m*, Fig. 21, at the top of the component. No clamping is necessary, because the thrust of the drill, which is about 1" in diameter, keeps the component in position. For reaming, the drill bush is removed, being

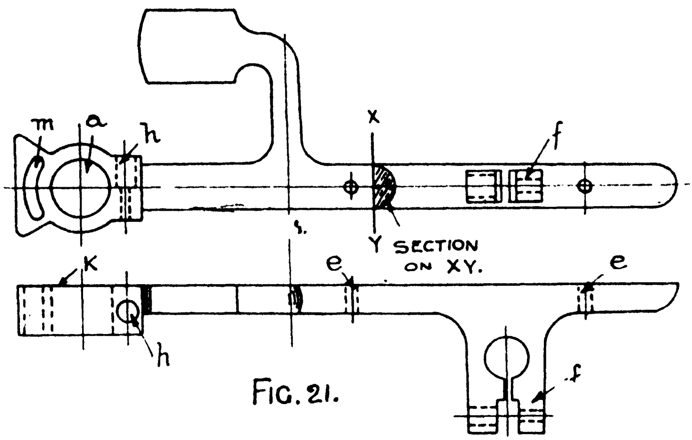



FIG. 21.

WIND-SCREEN BRACKET CASTING (SEE FIG. 20)

specially designed to facilitate this, and a bush of the reamer size inserted. The bush and its locking screw is seen in the illustration, and the reader is reminded that these bushes as well as the clamps, nuts and various parts of jigs are standardized in various drawing offices and the designer should follow any procedure laid down. Fig. 164 shows a drill bush, and its proportions are given in Table No. 14. Fig. 165 shows a reamer bush, and Table No. 15 gives suitable proportions. To prevent wear and consequent inaccuracy due to the constant removal of the bushes, the cast iron or mild steel part of the jig holding the bushes, is generally provided with a hardened steel liner or sleeve; a close examination of H, and also Fig. 165, will reveal one such.

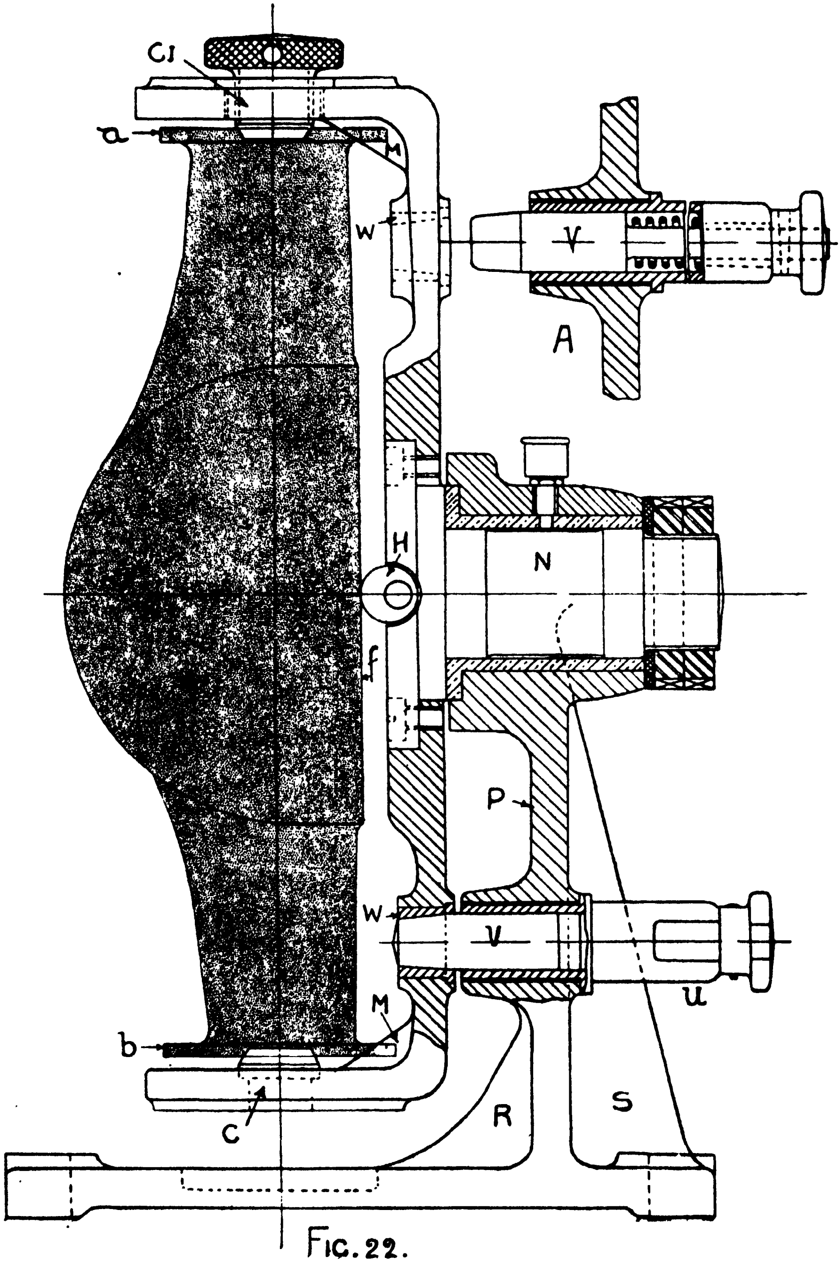



FIG. 22.

INDEXING DRILL JIG.

The face *k* of the component is finished by what is known as a spot-facing operation, and is carried out on the plate L. The hole *a* fits the plug A of the plate, and the pilot pin of the cutter M is a running fit in the small hole seen in this plug. The peg N is merely to prevent the component from swinging round, which is rather dangerous when the cutter is at work. The plate itself is of cast iron, provided with two slots cast in it for fixing purposes, and the centre plug is of hardened steel a force fit into it.

**An Indexing Jig.**—Fig. 22 shows the drill jig for a component which is the centre portion of an automobile rear axle. The holes to be drilled are six in number, equally spaced round the flanges *a* and *b*, and as a horizontal multi-spindle drilling machine was not available, the fixture was designed to be used under a vertical machine as shown in Fig. 25, the table being removed.

The component was located from its cored hole, the flanges having been previously turned from this point on a mandrel similar to the one shown in Fig. 37, on a coned stud C and a similar stud $C_1$ provided with a screw at the opposite end completing the location and also acting as a clamp.

To set the face *f*, which was about 10″ diameter, square, a rod provided with cams is arranged at H so that before tightening $C_1$ this cam rod is brought into contact with the face of the piece and so retained while the clamping is effected. The fixture consists of a cast-iron cradle, which is kept as light as possible and strengthened by webs and fillets at M and revolves on a steel spindle N in the pedestal P. The latter has a bronze bearing, which should be kept as long as possible; the webs R and S support the pedestal, which is subject to considerable strain due to the six holes being drilled at once.

The plunger for indexing the cradle in its two positions is shown in position at U and in detail at A. The plunger pin V, and the bushes W into which it fits, are of hardened steel to prevent wear, and the former is kept reasonably long together with its bearing so as to prevent it working slack with resultant faulty indexing. The plunger is provided with a tapered nose which enables any wear to be taken up by allowing it to drop further into the bush which, of course, could not be done with a straight plunger.

**A Jig Indexing in Four Planes.**—Another design of indexing jig is shown at Fig. 23, the component in this case being an automobile gear box casting. The jig is seen in position on an ordinary radial drilling machine, and of course, as only one hole can be drilled at a time, unless a head designed on the principles of Fig. 19 be employed, production will be limited. This could be overcome by mounting the jig on a steel truck and passing it beneath the various drilling machines each set for operating on the different faces of the casting—this principle is illustrated in Fig. 155.

The main cradle of the jig is of cast iron, and pivots on steel

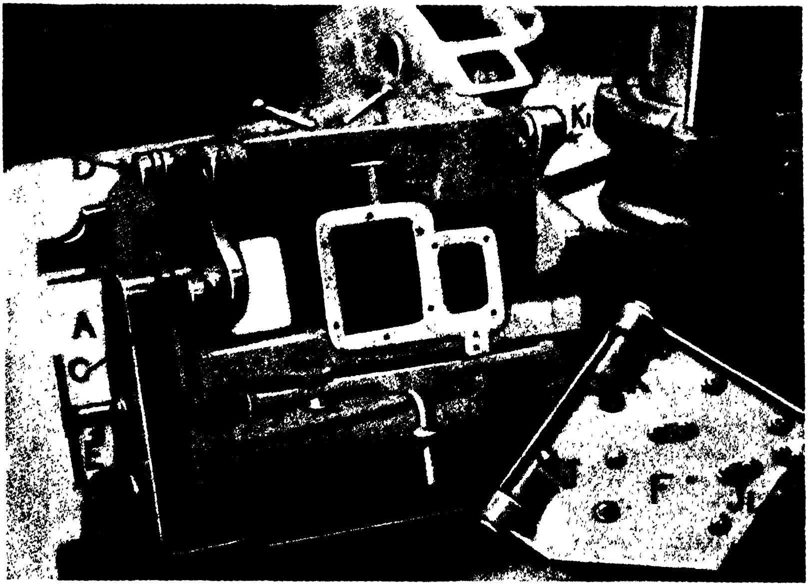



FIG 23 —DRILL JIG FOR AUTOMOBILE GEAR BOXES INDEXING IN 4 PLANES.

studs in the standards A. It has four steel indexing bushes, three being visible at B, C and D, and the plunger for them is seen at E.

To enable the component to be loaded and removed easily, the top plate F is made so that it can be detached from the jig. To hinge this plate as in a box would have necessitated widening the cradle, which must be avoided, as it is essential that the drill bushings be kept as near as possible to the component. The plate was therefore located on the fixture by the plungers J, K and L, which engage in the bushes $J_1$, $K_1$ and $L_1$. The lug seen at P inside the casting also required to be drilled, so that, as it is impossible to bring the drill bush near to it, an auxiliary bush is introduced to support the drill, which would otherwise bend and " wander " due to its unsupported length.

This is accomplished as shown in Fig. 24, where A is the lug to be drilled and B the drill bush through which the drill will enter, the bush C is attached to another removable part of the jig and acts as a support. In the illustration, Fig. 23,

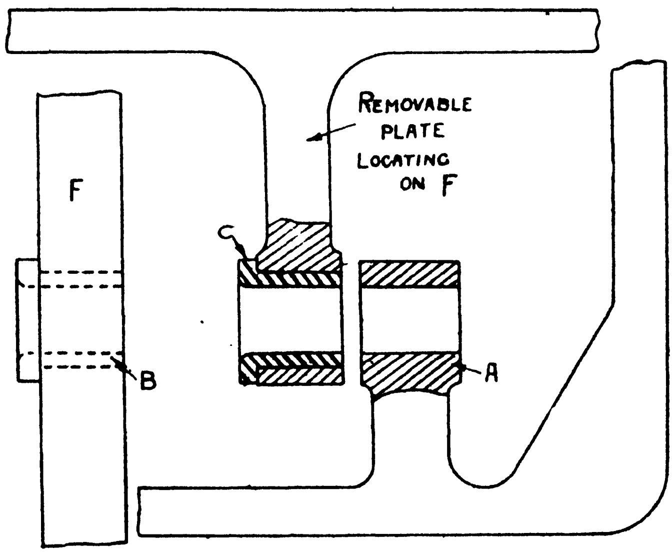



FIG. 24.

SPECIAL GUIDE PLATE TO SUPPORT EXTENDED DRILL.

the plate F is provided on its other side with an arm carrying a supporting bush as described.

**Continuous Drilling.**—Making use of the automatic feed of a drilling machine continuous drilling can be accomplished by using two identical jigs, and locating them on a revolving plate arranged on the machine table.

This method has been developed in connection with multiple spindle machines, and Fig. 25 is an illustration of this, where components from harvesting machines are being drilled.

The two necessary fixtures are seen built in one, and it will be noted that while one is in operation the other can be loaded. The jig plate A carrying the drill bushes is hung on

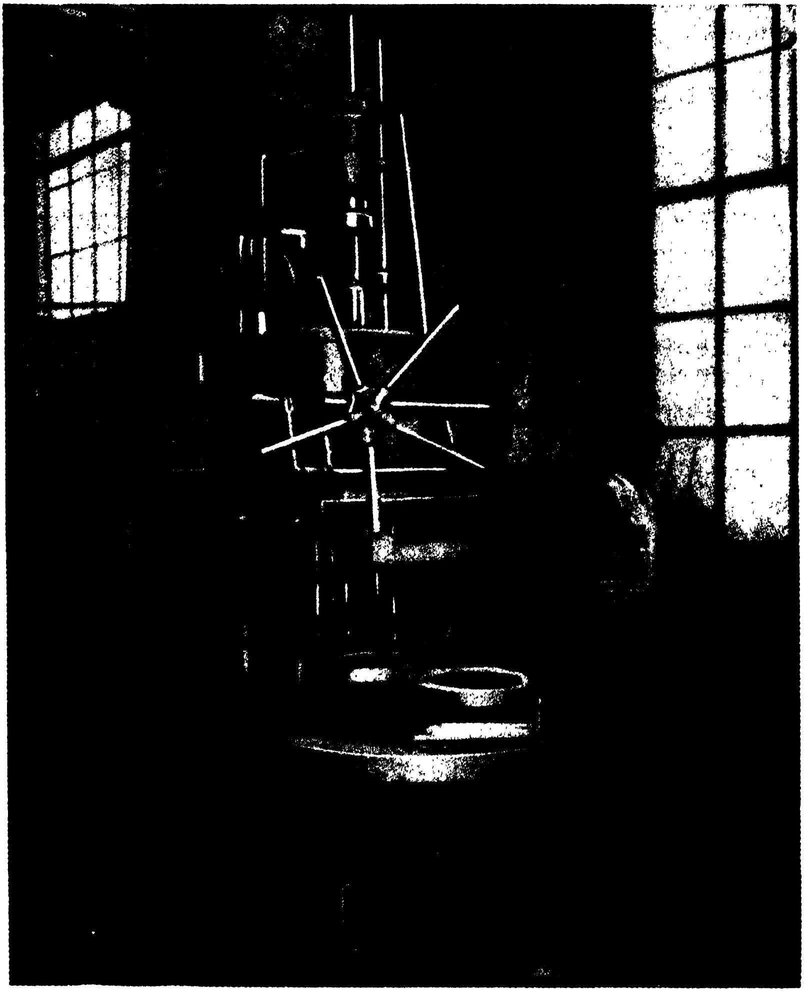


FIG. 25.

four steady rods so that as the spindles are brought down to or lifted from the work the plate follows.

The correct location of the plate on the jig is secured by means of the pegs B. The spiral springs seen on the steady rods keep the plate in position at the bottom of the rods as the spindles are lifted after drilling.

If a reaming operation is necessary three jigs can be employed, equally spaced round the table, and the machine spindles arranged in two groups, one holding the drills and the other reamers, so that while one component is being drilled the other is being reamed and a third being loaded into the jig.

The revolving table is generally purchased with the machine, though it can be made quite easily. The plunger for indexing can be seen at C.

In some cases where high production is called for, to save time and more effectively remove the cuttings, a compressed air pipe is attached which blows away the cuttings as they are made.

## CHAPTER V

# MILLING FIXTURES

Choice of Machine—Setting Spots—A Simple Fixture—String Fixtures—Continuous Milling—Indexing Fixtures—Clamps and Location (see Figs. 11–15, Chapter IV).

THE competition in connection with the finishing of surfaces is very keen, the milling machine vieing with the planer and the grinder for supremacy. Where the work is other than a plain surface, however, the milling machine still stands first, but the designer must consider well if the decision of the actual operations is left to him, before fixing on the method. Having decided that the milling operation is best for a given job, the question arises as to whether the fixture is to be a multiple one, that is, to hold a number of pieces at once, or only to operate on one piece at a time. This will naturally depend on the number of components passing through the shops, also whether the operation is a permanent one or not.

**Choice of Machine.**—The selection of the type of milling machine for a certain operation also calls for care, though in many cases a job is put on a certain machine because another and more suitable one is hard pressed with work. The designer should always consult the shop foreman as to the best machine for any job, and having done so should see that, especially in the case of "string" fixtures, the capacity or length of traverse of the machine table is considered (see Tables Nos. 16 and 16A).

The milling machine of the "Plano" or "Ingersol" type is undoubtedly very valuable for medium and heavy work, especially where large quantities of components are available, but as this type is not known to every shop, time will be better spent on a consideration of the more common machines, seeing that the different points to be watched when designing apply equally to all. Assuming that a component calls for plain surfacing, the choice may rest between horizontal and vertical milling as at A, Fig. 26. If the surface is very wide, using roller mills (see Fig. 62) on a horizontal machine will probably be quicker than using an inserted tooth cutter in a vertical machine. Should the area be small, however, a vertical operation will be the quicker.

In the case of the component at B calling for "straddle" milling, the fixture can be made adaptable, so that in the case of horizontal machines being pressed with work, the fixture could

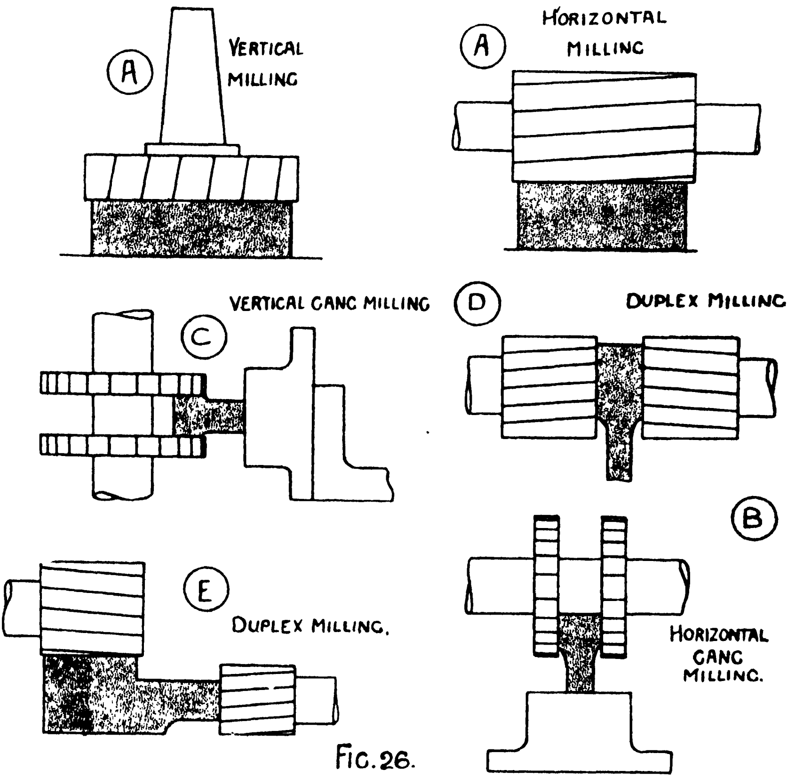


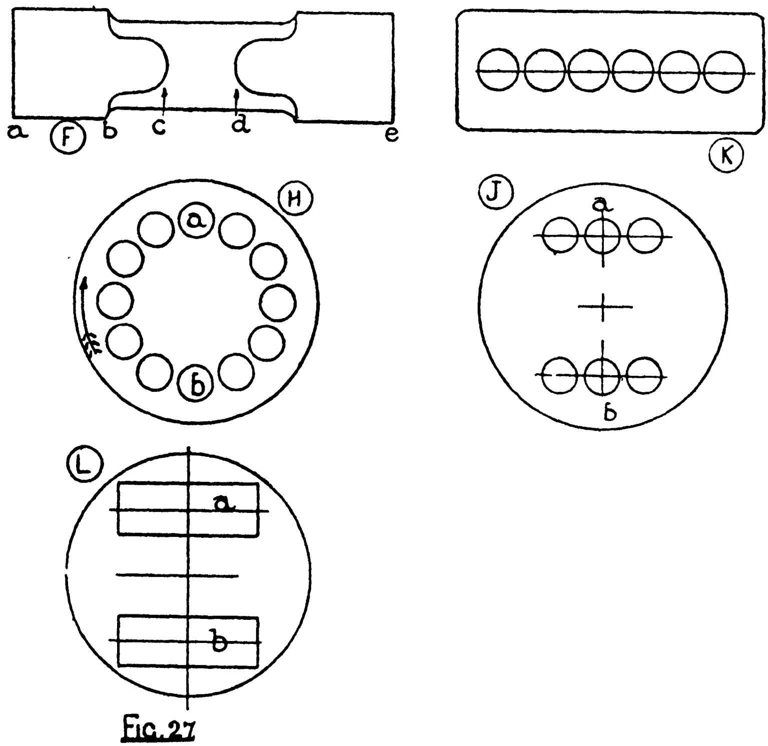

FIG. 26.

MILLING METHODS.

be arranged on an angle plate as at C and vertically "straddle" milled, though, in this case, as the end of the arbor is unsupported, in some machines, a slower feed must be used. Here also the "Duplex" type of machine, that is, where the two spindles are horizontal and opposed to each other as indicated at D could be employed, and, in the writer's opinion, this method is ideal.

Where the component is of medium size, with machining operations necessary on the side and face, the "Duplex" machine again proves its value, and it is being used with advantage at E, one spindle being adjusted to mill the top face and the other the side.

At F, Fig. 27, is seen a component having a face to be




MILLING METHODS.

machined which varies in width, there being a space in the centre before again machining at the opposite end. For work of this class, in order to avoid waste of time due to—

(1) Table traversing during the blank, or
(2) Operator winding the table across the blank, or
(3) Inability to conveniently alter feed and speed to suit the reduced area,

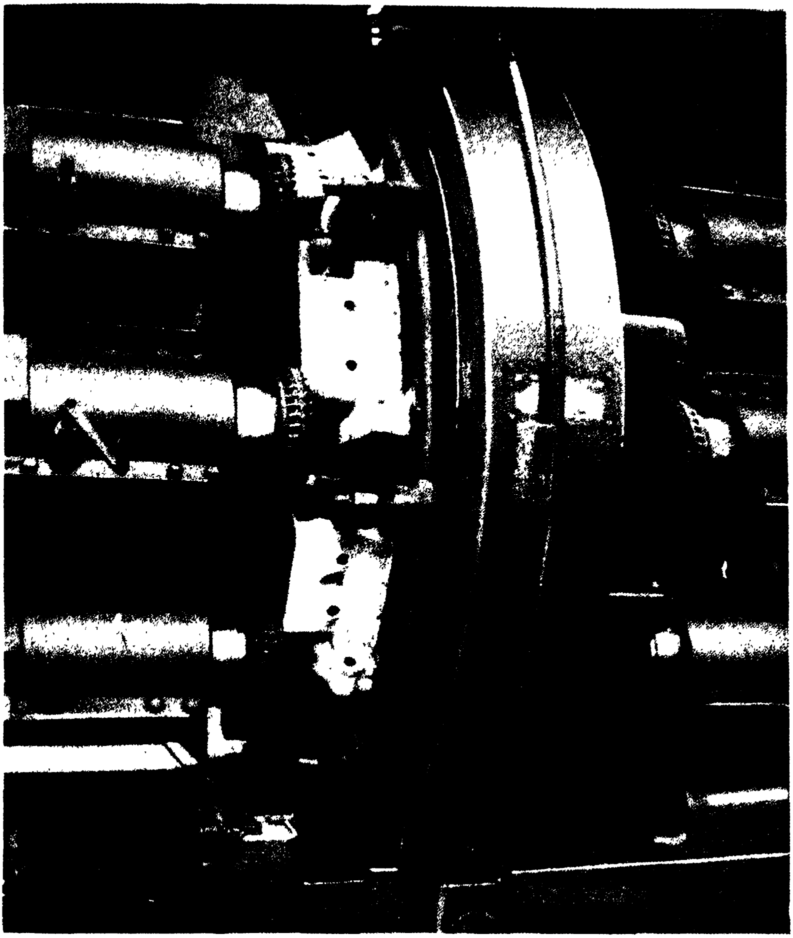


Plate III.

**Continuous Milling.**—A machine by Messrs. Holroyd, of Milnrow, Lancs, is shown operating on cylinder blocks. Four high-speed cutters are used, two roughing and two finishing. The components are removed as they are finished and replaced by the operator at the rear of the machine. The carrying drum rotates at 18′ per minute.

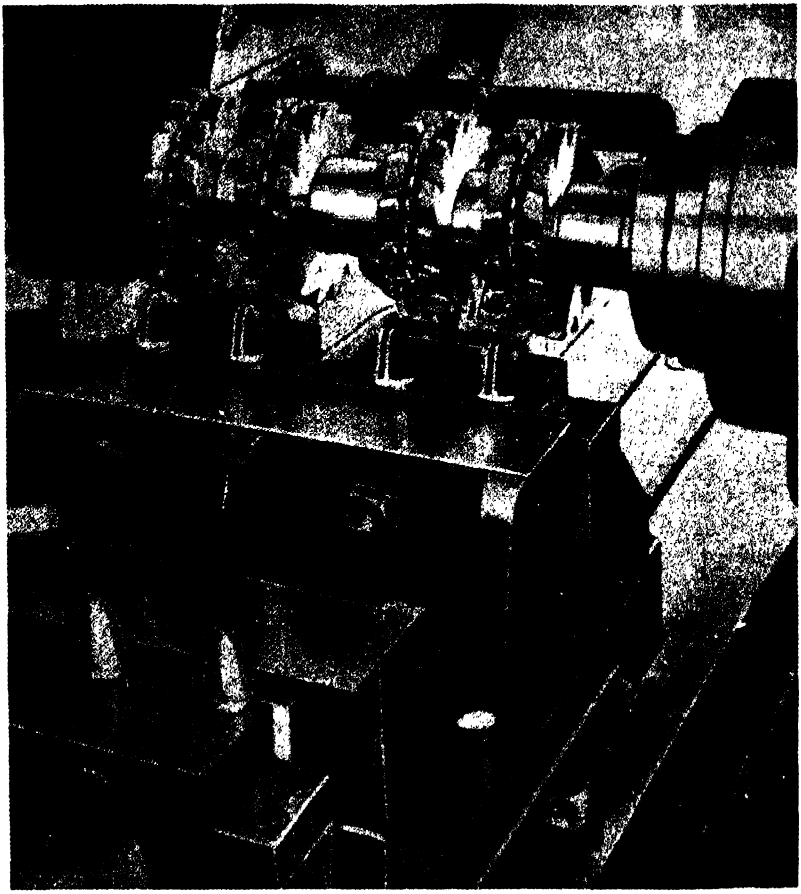


Plate IIIa.

A multiple fixture is seen here mounted on a Cincinnati milling machine manufactured by the Cincinnati Co. of Tyburn, Birmingham. By locating the pieces in multiple abreast, the number of pieces completed per table cycle increases the machine loading.

[*Facing page 55*

a special type of machine has been introduced which possesses a number of " dogs " clamped to the side of the table, which automatically trip the feed mechanism. So that in the case of the component at F the table would traverse at a certain rate from *a* to *b*, the feed would then be tripped to, a faster one from *b* to *c*, and from *c* to *d* the table moves past at a rate of 100 feet per minute, being again tripped into the correct feed at *d* as before, finally, when arriving at *e* the table is tripped once more, the table running back to its starting place at 100 feet per minute, when the component is removed.

For continuous work the parts are arranged on a fixture H of circular form and fixed to a rotary table used in conjunction with a vertical machine. The table is loaded and the revolving mechanism put in gear, so that while the cutter is at work at *a* the operator is unloading the finished pieces at *b* and replacing them by raw ones. Semi-continuous work can be carried out on the horizontal machine by means of the fixture at J where the components *a* pass under the cutters while those at *b* are being loaded. On the completion of those at *a* the horizontal table is run back and the rotary table turned through 180 degrees, bringing those at *b* into line for machining, at the same time allowing for the removal and replacement of those at *a*.

Another and more common method is to employ what is known as a " string " fixture, that is a fixture holding a number of components in a line as at K. With this fixture, though the pieces can be removed as fast as they pass under the cutters, they cannot be replaced until the fixture has completed its traverse, and has been returned to its original starting-place. In this case a small waste of time occurs, but the operator can load the first one or two pieces into the fixture and then set the machine in motion, loading the remainder as the cutting proceeds.

One other machine caters for semi-continuous work, where the main table of the machine, circular in form, rotates carrying upon it, equally spaced from the centre, two tables capable of longitudinal traverse, as shown at L.

The parts are clamped in the fixture on the slide *a*, and while these are passing under the cutters the fixture *b* identical with that at *a* is being unloaded and loaded; here again, however, a small leakage of time occurs when revolving from *a* to *b*.

**Setting Spots.**—To facilitate the setting of the cutters relative to the fixture, setting spots are introduced. These vary according to the nature of the operation, but briefly, they consist of hardened steel pieces, generally permanently. attached to the fixture in such a position that, by measuring from them, the correct position of the cutter is obtained without trouble.

A usual method is to fix upon a standard amount of space

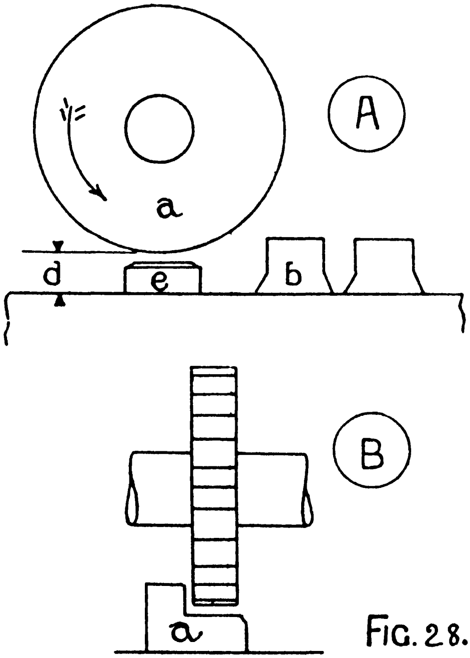



FIG. 28.

THE USE OF SETTING SPOTS.

that is allowed beneath the spot and the cutter for the latter to be located correctly. For the information of the setter when no standard amount is fixed, the amount decided upon for a particular fixture should be plainly marked thereon.

A and B, Fig. 28, makes clear their use, where at A is seen a cutter milling the piece *b* to the height *d*, and the latter is determined by placing between the cutter a and the setting spot *e* a feeler having a thickness of ·010″, so that any guesswork is eliminated.

At B is a slotting cutter which has to be located correct for depth and also lateral position. This is obtained easily by means of the setting spot *a* which enables a feeler of calculated thickness to be inserted below the cutter and also at its sides.

**A Simple Fixture.**—The word simple is used in this case to mean a fixture holding only one piece, and from this a multiple fixture could be made by including a number of similar fixtures in one and possibly making one clamp hold more than one component.

At Fig. 29 is shown a fixture for holding an aluminium cover plate which is shown shaded in position. The fixture is intended for use on a vertical spindle milling machine where, as already mentioned, the tendency of the cutter is to fling the component off the machine, so that the small fixing holes previously drilled round the edge of the component are made use of to assist in holding. At *a* will be seen a mild steel pillar surmounted by a small stud, enabling the component to rest on the pillar, and the stud entering one of the drilled holes locates the piece previous to clamping.

As the piece calls for machining on its face, the question of clamping becomes difficult, seeing that it is only ¼" thick and of aluminium. This difficulty is overcome in the manner indicated, provided that too much strain is not put on the nut H.

Describing the fixture it consists of a cast-iron base A provided with four steel pillars as at B and two pads C into which fits slide J. To hold the component down the nut H operates the sliding wedge J seen better in the sectional elevation.

The component is dropped on to the fixture and the knob L passes through the hole K in the wedge, after which the nut H is turned, causing the wedge to be drawn forward, drawing the narrow slot M of the wedge under the knob L thus preventing the component from being lifted out. As this may not necessarily lock the component firmly, the under side of the slot in the wedge is tapered slightly as at P, so that as the wedge is drawn across, it jambs or draws the knob L downwards, the latter being thus firmly held.

To prevent undue leverage being applied to H it should be made with a small head knurled, or a larger head left plain. If tommy pins are fitted to it they should be left very short. In cases like this holes for tommy bars or flats for spanners should never be called for, for there is nothing to prevent the operator of little intelligence from inserting a bar of extreme length, or as is sometimes done, adding a length of steel tube, thus increasing the leverage and either breaking the fixture

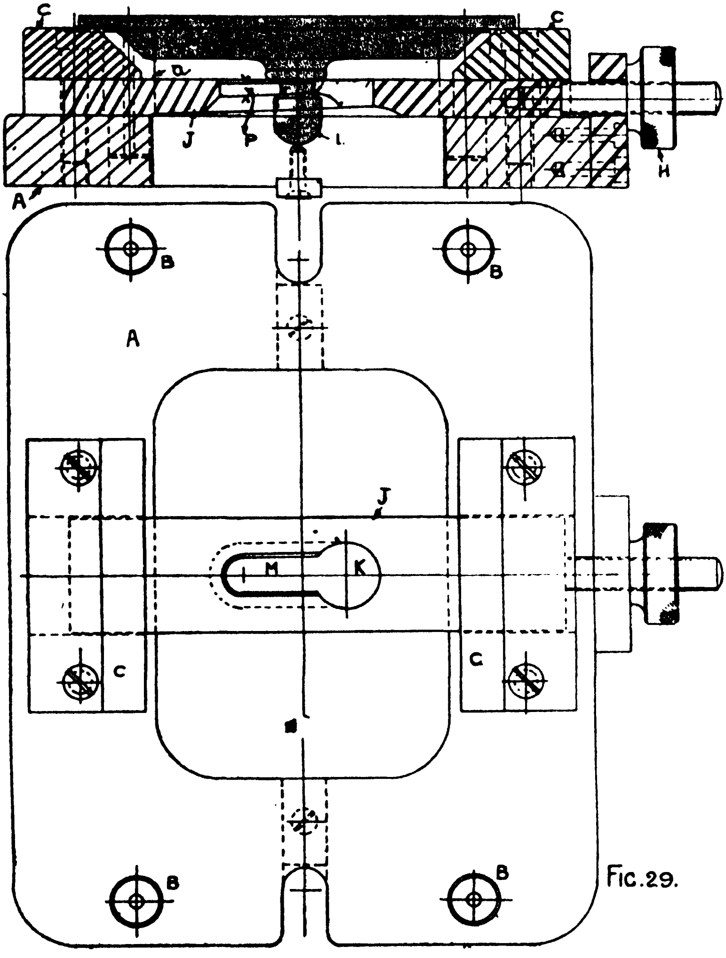



FIG. 29.

SIMPLE MILLING FIXTURE FOR AN ALUMINIUM COVER PLATE.

or spoiling the work; in a few words, every endeavour should be made to render the fixture foolproof.

Fig. 30 shows a milling fixture for a component calling for machining in two planes—this illustration could also represent the end view of a "String" fixture, dealt with later.

Unless a machine of the duplex type indicated at E, Fig. 26, is available, or a milling machine of very heavy pattern, it will be necessary to finish the operations separately, which is not to be recommended.

The component is located in the fixture by means of the vee block A and the studs B and C. By locating under the flanges at B and C their correct thickness is assured, and by carrying out the operation on a duplex type of machine the two flanges will be machined at right angles. The clamp D is of the pattern shown in Fig 14, C. The setting spots are

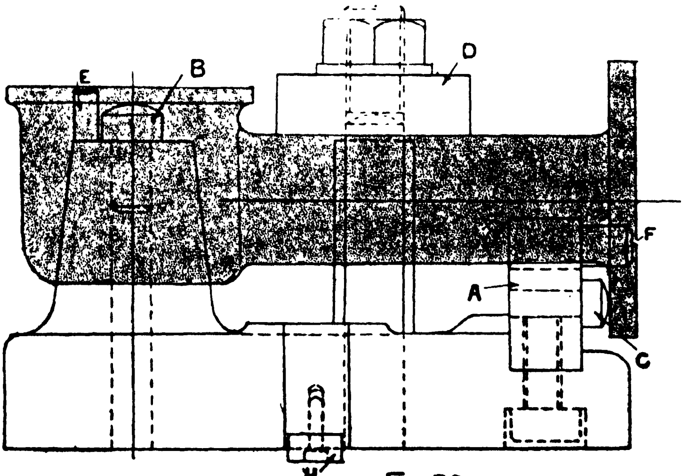



FIG. 30.

MILLING FIXTURE FOR COMPONENT REQUIRING MACHINING IN TWO PLANES.

located at E and F and require a "feeler" of ·01" to ensure the cutter being in the correct relation.

The tenon H is fitted with screws, making it possible to change to another size should it be necessary to transfer the fixture to another type of machine.

**"String" Fixtures.**—As the name suggests, this type occupies a considerable length of machine table and holds a number of components in a line. Unless the machine is provided with a tripping mechanism enabling the table to pass rapidly the blank spaces between the components, care must be exercised in arranging them so as to reduce this space to a minimum.

Needless to mention, that unless the operators are instructed to handle any fixture to the best advantage, the efforts of the jig and tool department will be wasted.

Fig. 31 is a fixture of this type, the components being bronze eccentric straps for small pumps and the operation to mill each side of the lug. Advantage is taken of the shape of this piece to arrange a double row, employing two pairs of straddle milling cutters. The important point in the milling of the lug is the accuracy of its thickness, the depth not being so important. This being so and the component having had its large hole bored, it is located by this on two plugs A and an extra support is given by the pegs B.

To facilitate loading and unloading the head of the bolt

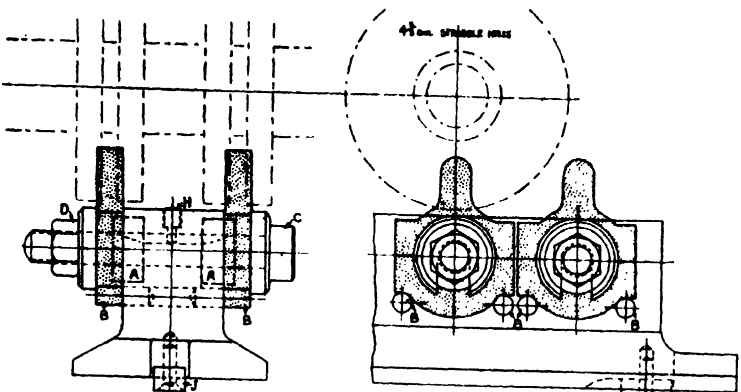


FIG 31

STRING FIXTURE.

C and the clamp nut D are made smaller than the bore of the component, enabling the latter to be removed without having to take off the nut. To operate then, the components are slipped on each end of the bolt, the U washers are placed behind them and on tightening up the nut D the bolt C is drawn up, locking the pieces in position.

To prevent the bolt turning round when moving the nut, the former has a slot milled along it, and the grub screw H with the pin at its extremity is adjusted to allow the bolt to slide yet not revolve. The tenon J ensures the fixture being set at right angles to the machine spindle.

The body of the fixture is of cast iron and broadened at its base to give rigidity. The pegs B are made from drill rod

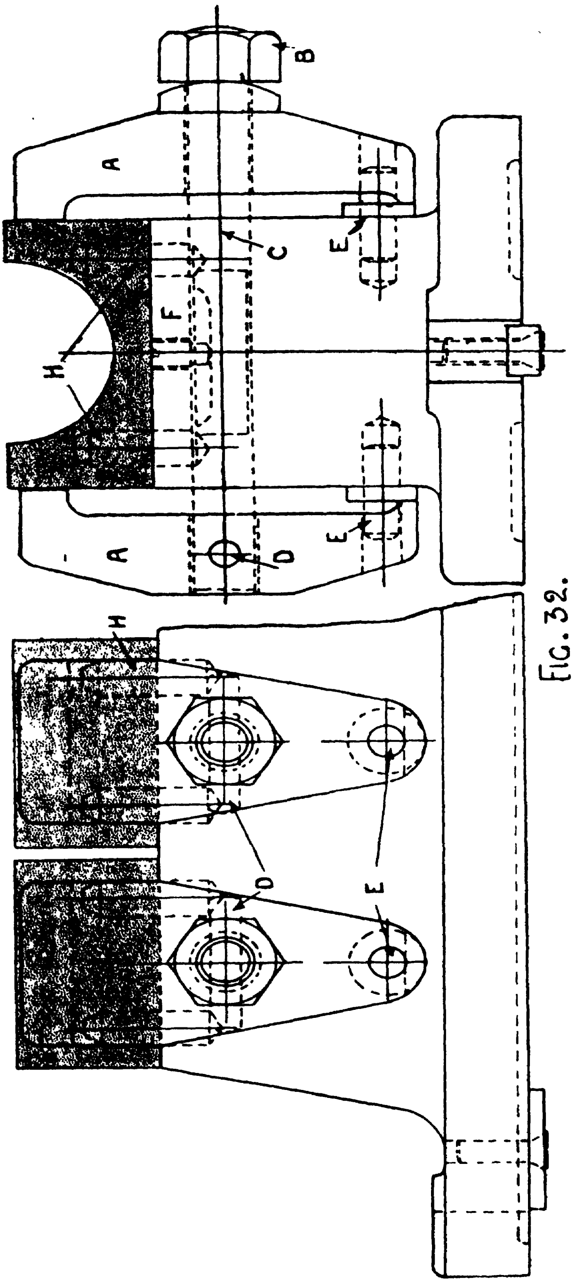



FIG. 32.

STRING FIXTURE FOR CAST-IRON BEARING CAPS hardened and tempered, the locating plugs A are of carbon steel left hard. The bolt C, nut D and screw H are turned from case-hardening steel, and after hardening the bolt is ground.

It is good practice when laying out some classes of fixtures, if not all, to indicate the milling cutters required; this tends to prevent anyone in the machine shops using unsuitable cutters and so not getting full productive value from the fixture. Another useful design is shown at Fig. 32, where cast-iron bearing caps for petrol engines are being rough milled before boring. The bolt holes are drilled previous to this operation and these holes are used for purposes of location. Though four holes are drilled in each piece, only two are used, these being at opposite diagonal corners.

The method of clamping on this fixture is interesting, being effected by the two jaws A operated by the nut B on bolt C. The latter passes through the body of the fixture and the nearest jaw into the further jaw, the hole in which is about $\frac{3}{32}''$ larger than the diameter of the bolt.

A small pin D passes through the bolt and jaw, thus providing a pivot. The bolt should be arranged as near as possible to the object being machined.

To prevent the jaws from swinging out of position they are provided with a hole into which fits the guide pin at E, the hole being about $\frac{1}{8}''$ larger than the pin. The pins also have a shoulder upon which bears the jaw. As the outside of the components are in a rough state, the upper ends of the jaws are serrated or roughened to make their grip more effective.

As with the previous fixture, the locking bolt is slotted and kept from rotating by means of the screw F. The base or body of this fixture is of cast iron, the jaws of mild steel case hardened, and pegs H are of carbon steel hardened and tempered, and the bolt, nut, and studs E are of case-hardening steel. Fig. 33 shows another string fixture in operation milling the stub axles of automobiles. The rigidity of this fixture will at once be noticed, and this is particularly necessary in this case, for the components are forged from steel of 30-ton tensile strength and the whole width of the gap is being machined in one cut. The cutter is of the interlocking pattern, that is, it is made in two pieces which are located side by side, the teeth being so cut as to overlap or interlock, enabling the two halves to be separated slightly when the width of the gap gets small due to the wear of the cutter or resharpening, and this without leaving a gap where the halves part. The zig-zag or "staggered" parting line can be seen in the illustration.

The previous operations on the components was to turn the stem seen at A and drill the holes at B; these are therefore used for locating purposes. The gripping and location of these pieces is effected as follows. The stem of the component, which is turned at a slight angle to the base of the slot, visible at F, is passed through the slot in an adjustable wedge H, and

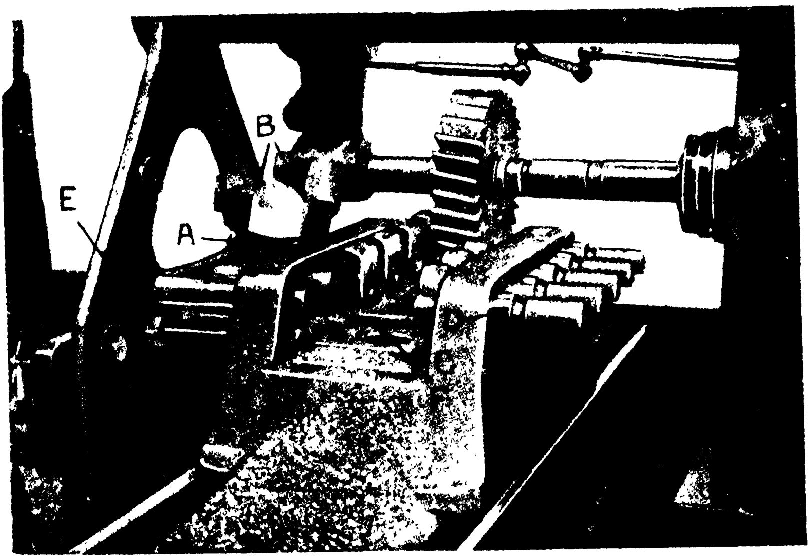



FIG. 33.—"STRING" FIXTURE USING AN INTERLOCKING CUTTER AND MILLING AUTOMOBILE STUB AXLES.

the hardened steel plugs D are pushed into the holes B, thus locating the forging square.

To lock it the bolts E are turned clockwise, thus forcing up the wedge H and jambing the component firmly.

The plugs D are an accurate fit in steel liners forced into the main casting, the liners preventing wear.

An advantage would have been to have replaced the hexagon headed bolts E by another form not requiring the use of a spanner, though when the use of the latter is unavoidable, those of the tube or "box" pattern will be found most convenient.

The three fixtures just described could be easily duplicated and used on a machine of the type indicated at L, Fig. 27.

**Continuous Milling.**—It is impossible to carry out continuous milling on a horizontal machine, but with a vertical spindle machine and a fixture located on a revolving table,

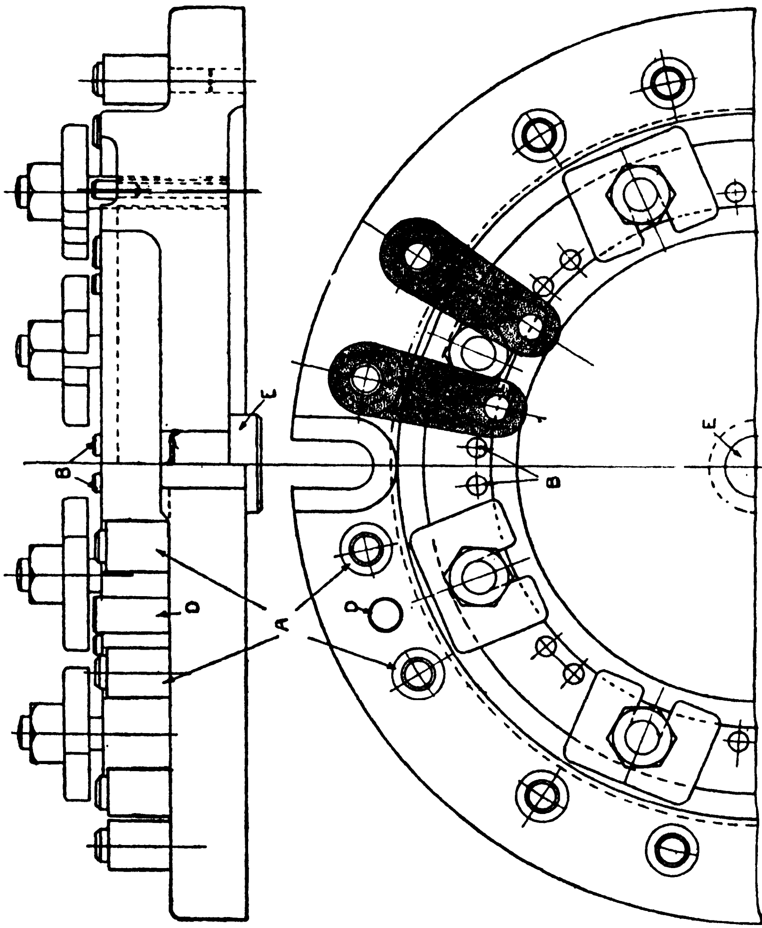



FIG. 34.

FIXTURE FOR CONTINUOUS MILLING USING REVOLVING TABLE ON A VERTICAL MACHINE.

it is quite simple. Generally speaking the output by this method is regulated by the operator's ability to unload, clean, and reload the fixture while slowly revolving, and except for the sharpening or adjusting of cutters there need not or should not be an unproductive moment. A portion of a circular fixture is shown in Fig. 34, where the small levers indicated are to be machined on one face of the larger boss. It will be seen that the components are arranged radially round the fixture as close as possible together, each pair being held by one clamp, the latter being a U washer held by a nut.

A hole previously drilled in the centre of the boss of the levers makes a suitable locating point, for which purpose the shouldered pins A are arranged round the fixture. The opposite ends of the pieces are kept in position by the pegs B.

The setting spot is placed at D, and it is not unusual to add one or two of these equally spaced round the fixture for the convenience of the setter. The steel peg E in the centre of the fixture is a push fit in the hole found in the centre of the revolving table, and is to ensure the fixture being located central thereon.

The body of the latter is of cast iron, the various pins of carbon steel hardened and tempered, while the washers, etc., are of mild steel case hardened.

A fixture of this pattern could be employed, if necessary, on a horizontal machine, and while it could not revolve continuously, a portion of one-half could be loaded and passed under the cutter, during which time the opposite portion of the fixture could be loaded. When the first loading has been milled, the table is run back and the fixture rotated through 180 degrees, bringing the next batch into position in front of the cutters. The cut is then started while the last batch is unloaded, etc.

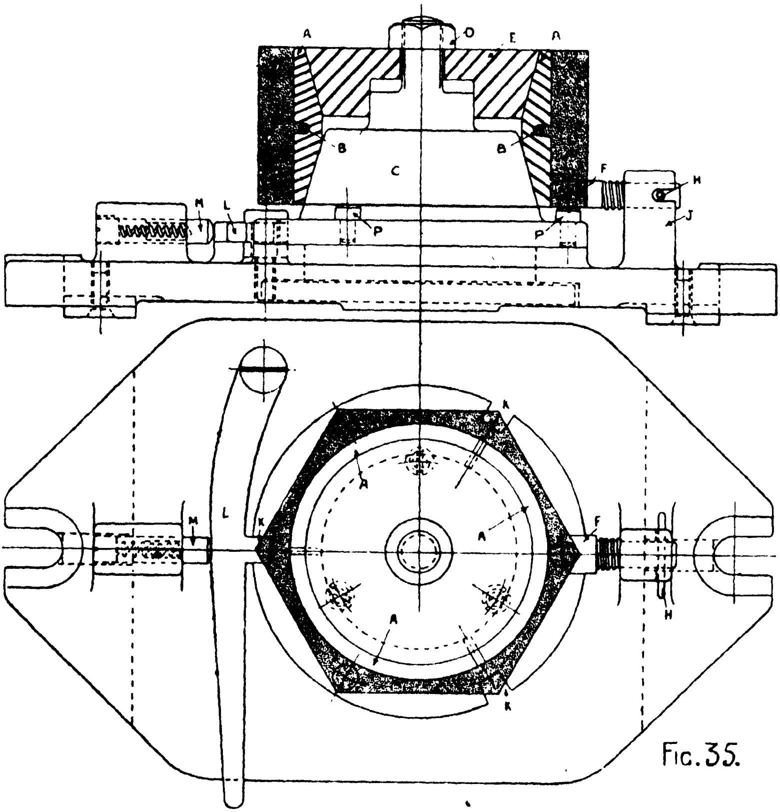
**Indexing Milling Fixtures.**—In many cases it is necessary to repeat an operation on another portion of the same component, in which case the fixture is provided with a mechanism to ensure the relation between the two machinings being kept uniform. Fig. 35 is an illustration of such a fixture, where the component, an hexagonal iron casting, requires machining on six sides, having previously been bored and faced. The operation is performed on a duplex machine so that only three indexings are necessary.

To locate the casting an expanding mandrel is introduced, consisting of three segments A held together by means of the steel spring ring B. They rest on a cone piece C and on screwing down the nut D the upper cone E descends, thus forcing out the segments. To assist in arranging the faces of the component square in the first instance, the vee piece

F is released, which engages the corner of the casting while the expansion takes place.

This vee is held when rotating the component, by means of the peg H which, when drawn back, and given a half-turn, catches on the boss at J.

The lower cone C is provided with a wide base which acts




INDEXING FIXTURES.

as a platform, and the component being clamped thereon revolves with it. The outer edge of this platform has three slots K milled 120 degrees apart into which drops the lever L, the latter being retained there by the spring plunger M. The three studs P are provided to form a seating for the component. The base of the fixture is of cast iron ; the remaining parts, except springs, are of case-hardening steel.

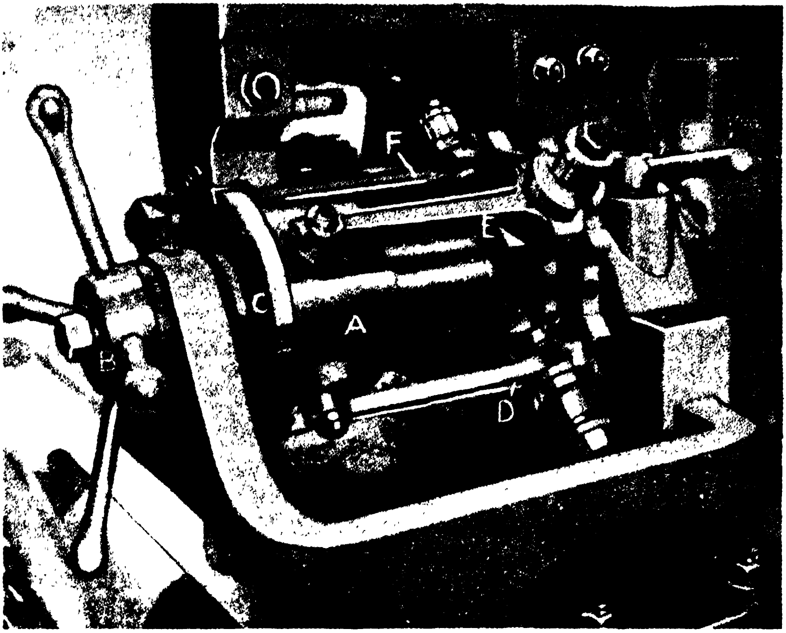



**Plate IV.**

**Continuous Milling and Splitting.**—Here the big end of automobile **con** rods are having their bolt faces machined and end bearing caps sawn through. Handwheel B rotates the drum A, which is indexed by plate C. On the machine arbor is a slitting saw spaced between two side and face cutters. At one movement of the table one half of two rods is finished, i.e., when the drum is next rotated, the visible side of rod F and the neighbouring side of rod E will be machined. After that, one side of E and D will be dealt with.

One rod is completed per minute, the cutters operating at 60′ per minute and the feed being 2″ per minute.

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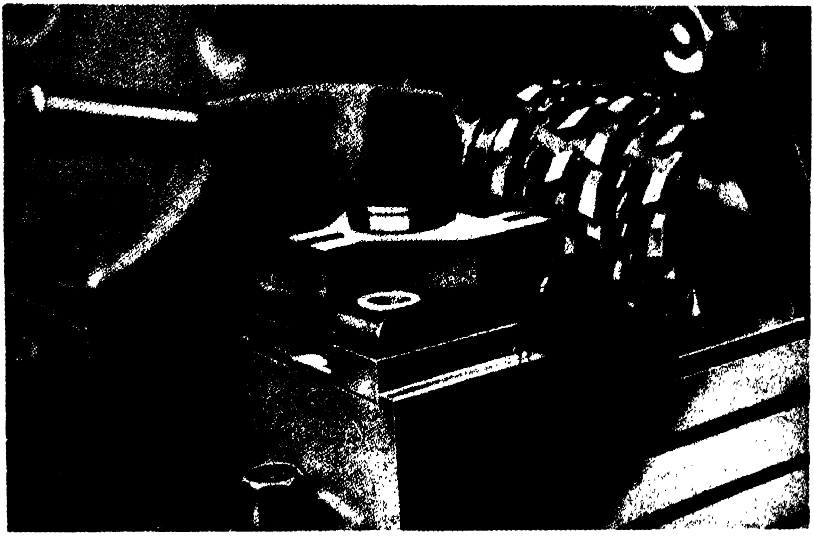


**Plate IVa.**

Another machine by the Cincinnati Milling Machine Co. of Tyburn, Birmingham, demonstrating "Plunge" milling. The cutters go straight into the work eliminating cutter travel or approach, and often great reductions in machining time results. Note the quick and effective cam lever on the fixture.

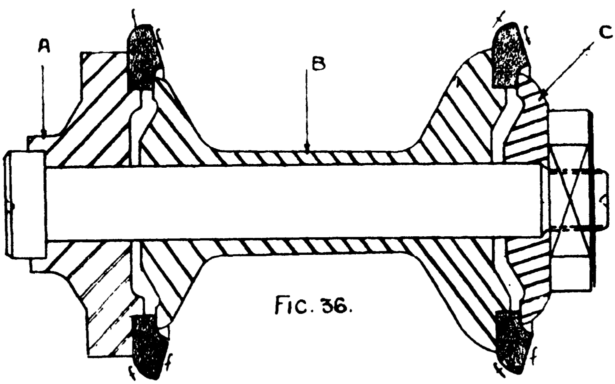
[*Facing page 67*

## CHAPTER VI

# CHUCKS AND TURNING EQUIPMENT

Mandrels—Expanding Mandrels—Special Purpose Expanding Mandrel—Spring Collets—Thread Chucks—Turning Fixtures—Indexing Fixtures—Cross Slide Tool Holders—Circular and Dovetail Form Tool Holders—End Working Tool Holders—Plain Holders—Bushes for Holders—" Floating " Holders—Tap Holders and Die Adapters—Turning Tools—Cutter for Box Tool—Flat Form Tools—Circular and Dovetail Form Tools—Shaving Tools.

WHILE the tendency is always in the direction of quick and cheap production, which means the elimination of old machinery and methods, the centre lathe in various improved forms is still with us, there being some classes of work that




MANDREL FOR MULTIPLE TURNING.

can only be successfully carried out on this machine. This being so, the favourite method of handling work on the lathe will be mentioned first.

**Mandrels.**—Though the manipulation of mandrels is at least the work of semi-skilled operators, their construction should be as simple as possible. Fig. 36 shows a mandrel for use on a " Fay " automatic lathe, the components being shown shaped in position, consisting of steel ring bevel gears, the operation being to machine the rim and face indicated, the former by means of a dovetail form tool (see Fig. 60) and the latter using ordinary turning tools.

The gears were about 6″ diameter, so that the r ther large mandrel was made in several pieces, the parts A, B and C being steel forgings.

The operation being fixed for this particular lathe, which is arranged for multiple turning, two components were machined at once, and for this reason the correct relation of these must be maintained on the mandrel.

The mandrel would be best made of case-hardening steel, hardened and then ground.

Where the casting is long in proportion to its diameter and it is to be turned from its cored bore, a cheap form of

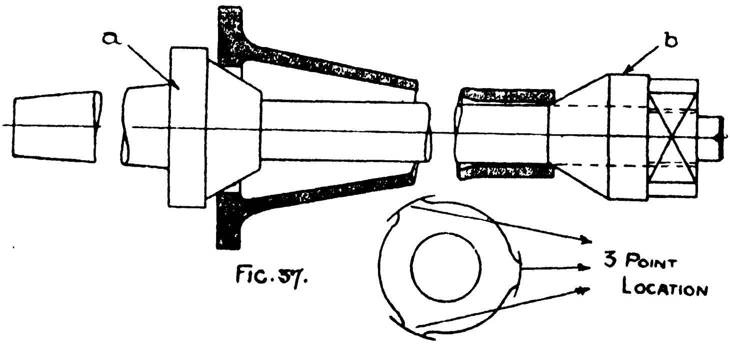



FIG. 37.

MANDREL FOR TURNING OUTSIDE CONCENTRIC WITH CORED BORE.

centring mandrel can be made as shown in Fig. 37, the component in this case being an automobile axle sleeve, where the rough-cored hole must be reasonably true with the outside diameter.

The coned boss A is integral with the shaft, which is provided with a taper to fit the nose of the machine.

The coned piece B has the same angle as A, i.e. 60 degrees, but is free to slide on the mandrel.

To help to overcome the difficulties caused by any irregularities of the ends of the bore, the two cones are relieved, leaving three points to engage the casting. By having at least one of the cones capable of revolving assists greatly in getting the component to run concentric.

For automobile work a large quantity of gears have to be turned which have a splined hole of the form shown at A, Fig. 38. These are broached out, and so form a reliable point to work from, yet care must be exercised.

Fig. 38, end view, shows a section of the splined mandrel with gear in position, and it will be noticed at a that the *top* of the spline of the gear seats on the *bottom* of the mandrel spline. This is purposely exaggerated in the drawing, and as this is the condition under which the gears work when finished, the final result should be quite satisfactory.

In all cases the chucking method adopted should be as near as possible to the final working position of the component. The designer must see that the size of the spline on this turning mandrel takes this point into consideration,

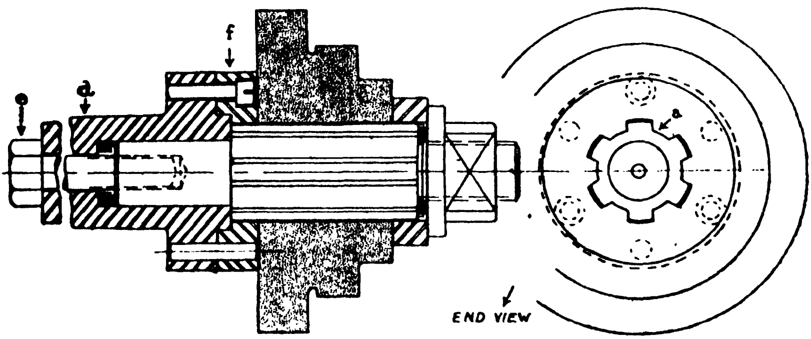



FIG. 38

MANDREL FOR SPLINED GEAR BLANKS.

that is, the gear blank, when on the mandrel for turning, must also have its spline top resting on the bottom of that of the mandrel.

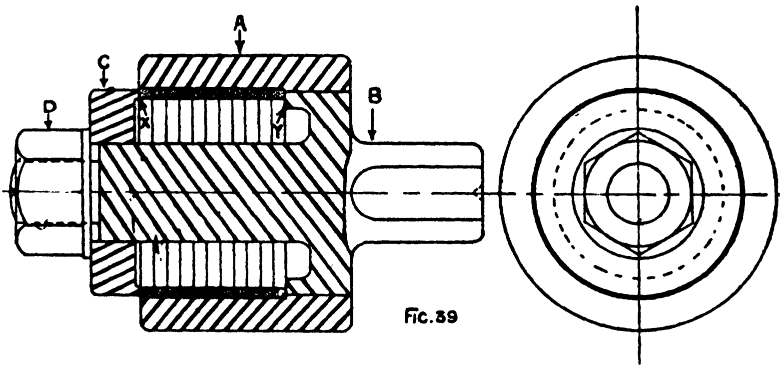
It might be considered possible to have a good round mandrel without the spline, but apart from assisting as a positive drive when turning, the final concentricity of the gear is almost assured by using the splines, for the reason already mentioned.

With the mandrel shown, the tapered part *d* is arranged with a draw-bolt *e*, making it possible to attach any other mandrel. The pad *f* is of hardened steel, to take any wear which would cause the component blanks to run eccentrically.

The mandrel shown in Fig. 39 is really intended for grinding the outside diameter of piston-rings, which are indicated in position, the rings having been previously split; but the principle of the mandrel may be adapted for turned work when necessary.

The method of using this tool is as follows: The rings, in clean condition, are placed together in the sleeve A, a little pressure being needed as the slots must be compressed to get them in. The sleeve thus filled is slipped on to the mandrel proper B, after which the washer C is put on the opposite end. When the nut D is tightened up, it will be seen that the rings are effectively clamped between the rims X and Y, the sleeve A being then removed.

The sleeve A should have a very long bearing surface, and be a sliding fit without any slackness on the mandrel B, otherwise the rings would not be loaded concentrically.




MANDREL FOR SPLIT PISTON RINGS.

The washer C also must fit the mandrel accurately and have its outside diameter as large as possible, yet allow for the amount of metal to be removed from the rings.

**Expanding Mandrels.**—The use of expanding mandrels finds great favour among designers, especially where the work is second operation or rechucking work, that is, where a previous operation affords a machined surface of sufficient accuracy to locate from.

They are not, however, suitable for very heavy turning, that is, where the metal to be removed is excessive or the diameter is very large in proportion to the width of the article, because the absence of a positive drive will allow the component to turn round on the mandrel and become loose when the tools commence to cut. Fig. 40 shows one form that has proved quite successful, consisting of a hood or nose-piece A made of mild steel, carbonized and hardened, which fits the screwed nose of a capstan lathe.

The steel segments B, three in number and of a diameter to suit the component *x* being machined—in this case a piece of switch-gear—are made of hardened steel to prevent wear, and slide up the coned portion of A when actuated by the coned bolt C. The latter is moved either by a rod passing through the machine spindle and operated by a hand-wheel, or else the usual clutch toggles fitted to the machine are adapted to give the necessary pulling motion.

To retain the segments on the cones, they are provided with a groove, into which fits a round steel spring which,

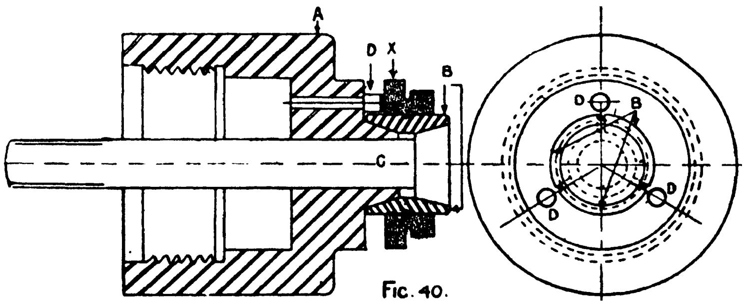


FIG. 40.

EXPANDING MANDREL USING DRAWBACK MOTION.

while holding the segments in position, allows them to expand when necessary.

To assist the component to adjust itself squarely on the mandrel, and also to give a positive seating from which to work, three hardened steel studs D are fitted equidistant at a suitable diameter, the component being held firmly up against them with one hand while operating the lever with the other. The angle of the cones should not be too great, about 30 degrees being considered suitable.

The nose-piece A can be made of cast-iron where the diameter is, say, over 5″, but the coned portion must be fitted separately, and be made of hardened steel.

Another form of expanding mandrel utilizing the ordinary or "push-out" motion of the capstan is given in Fig. 41.

It will be observed that the expanding portion and the nose-piece are combined, the expansion being effected by means of a plunger A, which is forced into the coned nose. It is noticeable also that the nose does not expand parallel as in Fig. 40, but pivots at X and Y, causing the front to be of larger diameter than the back, indicated by the lines *a*, *b*.

If the bore of the component is fairly accurate, this will not be sufficient to cause trouble, but if the bores are varying the component will only be held on the edge, thus reducing the grip, and the piece will work loose directly the tool touches it. If the component can be provided with a hole

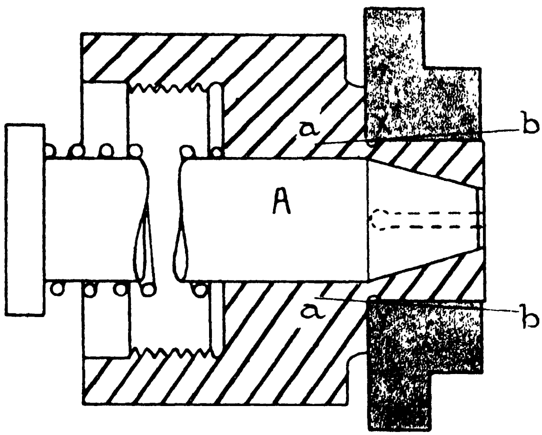


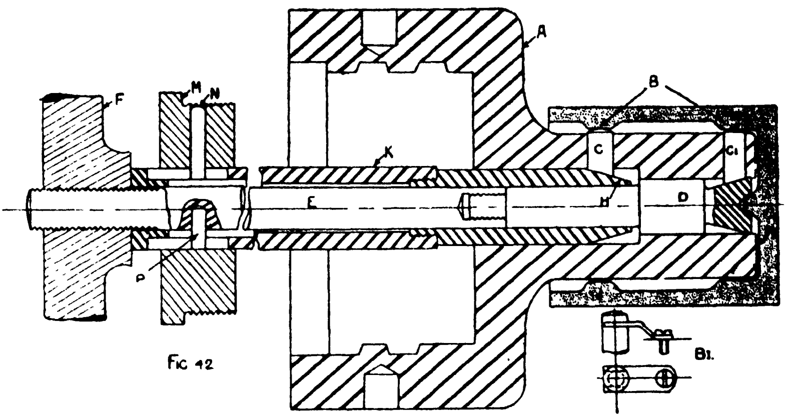

FIG. 41.

EXPANDING MANDREL USING PUSH-OUT MOTION.

through its face and the nose-piece drilled for a steel peg a positive drive can be obtained.

The writer remembers the case of a soft brass tube, $\frac{3}{4}''$ long, $1\frac{1}{4}''$ bore, and about $\frac{1}{16}''$ thick, which had to be threaded on the outside about 26 per inch. In so doing about 70 per cent. were pulled off the mandrel when the die reversed and had to be chipped out of the die with a chisel, and others twisted on the mandrel after a few threads had been cut, using a self-opening die, the rings appearing to expand with the mandrel and so would not be gripped. The trouble was removed in a very simple way. Permission was obtained to make a rather heavy centre punch-mark on the outside of the rings which would not interfere with their final use, and when putting the rings on the mandrel the " pimple " on the inside of the rings caused by the centre punch-mark only allowed the rings to go on by letting the " pimple " set in one of the slots of the mandrel, and when the latter was expanded it provided a very successful positive drive, with the result that the rings were threaded quite easily.

**Special Purpose Expanding Mandrel.**—It has already been mentioned that components with cored holes present difficulties where expanding mandrels are concerned, and under such circumstances if possible they should be avoided ; but in some cases it is essential that this method of holding




SPECIAL EXPANDING MANDREL FOR PISTONS.

should be adopted, therefore a special mandrel must be designed. Fig. 42 is an instance of this, being a mandrel designed for holding cast-iron pistons while they are being turned.

With this component it is essential that the outside be reasonably concentric with the bore, which is rough as cast, therefore some form of gripping device that will work from the inside walls is necessary. The thick part of the component at B, where the grooves will come, are inconveniently placed for locating purposes, as they are some distance apart, so that the ordinary methods of cone expansion will not be of use.

An examination of Fig. 42, however, will show how this is overcome. A is the main body screwed internally to suit the nose of the machines; the nose portion of the body has six holes drilled radially and equidistant round its circumference, through which protrude the gripping pegs C and $C_1$, two only being shown to avoid confusion.

The front pegs $C_1$ are expanded by the drawing back of the coned bolt D, which is effected by means of the rod E and wheel F, on turning the latter the bolt being drawn back. The pegs C are by the same movement forced out by the cone H, which is connected to the sleeve K.

Therefore by turning wheel F cone H is pushed forward and that at D drawn in till the pegs grip the casting. The boss M is fixed in the rear end of the spindle to support and centralize the sleeve and rod E and K.

To prevent either of the latter from turning round when operating the mechanism and yet allow end motion, the sleeve K is fitted with a retaining pin N and the rod E with a pin at P.

To assist the six pegs C and $C_1$ to return when the wheel F is released, they are each provided with a spring, shown only in the detail drawing at $B_1$, which is just sufficient to cause them to return far enough to clear the component as it is drawn off.

The piston butts up against the three small projections R at the end of the nose A, thus ensuring that the piston tops are of uniform thickness.

There is another type of mandrel where the pegs are replaced by two segments expanding on the double-cone principle as here described; but should the inside of the castings vary in form or be very irregular, loading and unloading is very difficult.

To add strength to the rather weak nose part of A, the radius at their junction should be made as large as possible, also the diameter of the nose should be made as full as possible—only the radius of the pegs need show above it.

**Spring Collets.**—These are employed in a variety of machines, and vary from the simple form shown in Fig. 19 to the more elaborate ones fitted with adapter pads as used on automatics. The most common type seen on capstan lathes are too well known to need any description here, but as special ones are often called for one is given in Fig. 43. This is described as an extra capacity collet, because it will hold a diameter larger than the capacity of the machine, i.e. the size of the spindle bore.

Examining Fig. 43, it is seen to consist of a nose-piece A, made of mild steel, case hardened and ground on the coned portion *a*, and threaded at the opposite end to suit the particular machine. The collet B is usually of carbon steel and hardened, the rear portion being finally tempered to give the necessary spring.

Mild steel case hardened has given fairly good results, but it does not retain the springiness necessary for free working. As these collets are very expensive to produce, the draughts-

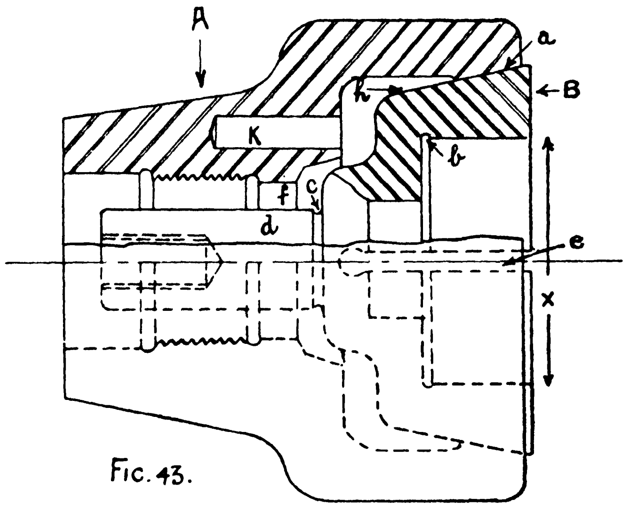



Fig. 43.

EXTRA CAPACITY SPRING COLLET AND NOSE-PIECE.

man must watch carefully the design, for a large number are spoilt in the hardening and in use, due to very thin section and also allowing sharp corners to exist.

The shell must be of as even thickness as possible, any sharp corners must be avoided, and if a square corner is unavoidable the danger should be minimized by putting in a small radius as at *b*. The small radius at *c* is to enable the grinding wheel to work right up to the back of the collet when grinding the stem *d*, and the latter must also be a good sliding fit in the machine spindle. The slots *e*, which give the necessary spring, in this case are four in number, equally spaced round the collet, and extending to the rear face of the collet, and, as already mentioned, to avoid the chance of the collet breaking at their termination a hole is drilled for them to open into.

To ensure the true running of a chucking mechanism of this type, where it can be done, the draughtsman should call for the principal diameters to be ground when in position on the machine.

That is to say, after the nose has been threaded and hardened it should be screwed in position on the machine it is intended to be used, and by means of a portable emery-grinder the cone *a* should be ground perfectly concentric, because it is upon this part that the collet depends to assist it setting true. When the collet has been ground on the parts *h* and *d* it can be fitted to the nose-piece by whatever " drawback " mechanism is to be employed and the diameter *x* ground, thus securing perfect concentricity.

When making the collets, to prevent them closing in or opening out, which generally happens when heated and quenched for hardening purposes, the slots are not allowed to break completely through the front face of the collet, but a thin section, about $\frac{1}{8}''$, of metal is left, which retains the shape of the collet while being hardened and ground, the small piece of metal being finally removed by means of a thin elastic emery-wheel.

One difficulty with this type of chuck is that a slight variation in the diameter of the component will not allow the collet to draw back so far in its seating, and where the operation on the piece may be turning or grinding to a certain length or thickness this variation in diameter will cause a variation in thickness also.

One way of overcoming this trouble is to insert steel pegs into the holes placed as at K, which can either protrude through the slots in the collet or through holes specially drilled therein, and so form a positive seating for the component.

It might also be mentioned that in the hole K, or upon the pegs that may be used, can be placed an helical spring, which will assist the collet if it is inclined to stick when released.

**Thread Chucks.**—With some components that have passed through one or more operations, one of which is threading, it may be necessary to perform further operations which must be perfectly concentric with the threaded portion.

In this case it is clear that unless the operations can be arranged so as to combine the threading with this later operation, the threaded portion must be made use of for purposes of gripping. Though this practice is not generally recommended, it is sometimes unavoidable, and if carried

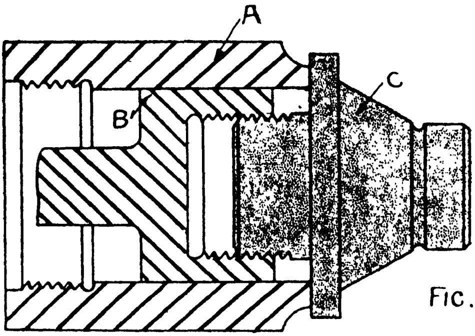



FIG. 44.

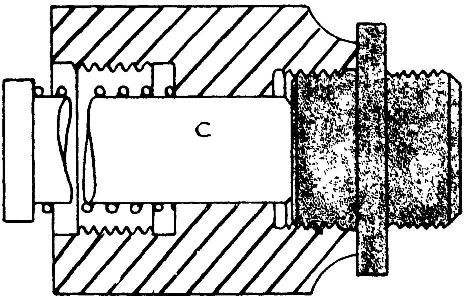



FIG: 45.

THREAD CHUCKS.

out carefully no trouble should result. Figs. 44 and 45 show two designs for holding from a previously screwed part, the former making use of the drawback mechanism of the capstans and the latter the "push-out."

Taking Fig. 44 first, A is a hardened steel nose fitted to the machine, into which slides the plunger B, the latter being threaded to take the component. To operate this, the component C is screwed into the pad while the chuck lever of the machine is released until the component butts against the face of the nose A. Upon closing the chuck lever the pad is drawn back, thus effectively locking the component in position.

To remove it, the operations mentioned are reversed.

Fig. 45 works on similar principles, except that the pad C is thrust against the component, giving a seating which helps to take up some of the cutting thrust.

The latter, however, though simpler to arrange, should be avoided, as the thrusting of the component away from its seating is bad practice. In both cases it will be seen that if the component was screwed into a plain nose without any pads, when the cutting tools in the machining operation had finished great difficulty would be experienced in releasing the component, due to the tightening effect of the tools.

In both cases, however, the fit of the component into the nose or pad must be good, otherwise in the jambing action when locking the threads will get distorted ; also the adjustment of the clutch on the machine must not be too heavy.

It will be noticed that both Figs. 44 and 45 can be also arranged to take components having female threaded parts.

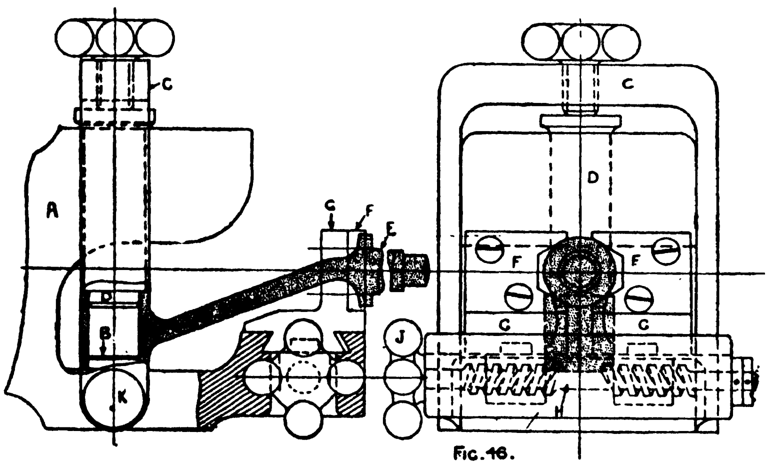
**Turning Fixtures.**—The numerous awkward-shaped pieces that exist and call for turning operations necessitate the design of special holding devices to save time, and also to obviate the necessity of employing a fully skilled man, which otherwise would be necessary. To give a survey of the huge variety of such fixtures would require a separate volume ; but to give some idea what is meant by a turning fixture Fig. 46 is shown, where the piece, a steel forging, is indicated in position, and the extreme awkwardness of it will be noted.

This fixture was designed for a capstan lathe, the body A being screwed to fit machine nose. The boss of this component was previously milled on both sides and a hole drilled through, providing a good locating point by seating on the stud B, and being finally locked thereon by means of the swing clamp C, which holds the plunger D into the other side of the boss.

To centralize the round stem of the component E some form of self-centring clamp is necessary, and this is secured by introducing two vee-pieces F, F fixed to the slides G, G, which are actuated by the screw H, the latter being provided with a left- and right-handed thread. Thus, on turning the knob J, the two slides are drawn together, thereby centralizing the stem.

The clamp C, swinging on its stud K, not only partly holds the component, but also acts as a binding unit on the necessarily peculiar-shaped chuck, the clamp screw and the mass of metal about it further acting as a counter-weight to the other half of the chuck casting.

**Indexing Fixtures.**—With components having a number of holes in the same plane the question arises as to whether they should be finished on a boring machine, drilling machine, or capstan lathe. Where the piece is exceptionally heavy




TURNING FIXTURE FOR AN AWKWARD FORGING.

and of large dimensions, the boring machine will be best; if of rather small size, a good drilling jig will get over the difficulty.

For work of medium size and weight, especially where the bores in question call for the use of several tools, such as boring, recessing, threading, etc., the capstan lathe undoubtedly is best. An interesting example of one of this class of fixtures is shown in Fig. 47, where an aero engine crank case is being machined.

The cast-iron body A is screwed to the machine nose in the usual way, the mass of metal at the top part being added to balance the fixture when running. The crank case is located on a platform B, being held by three plain clamps locked by means of a box spanner, the platform being provided with nine index holes, that is, one for each hole being bored.

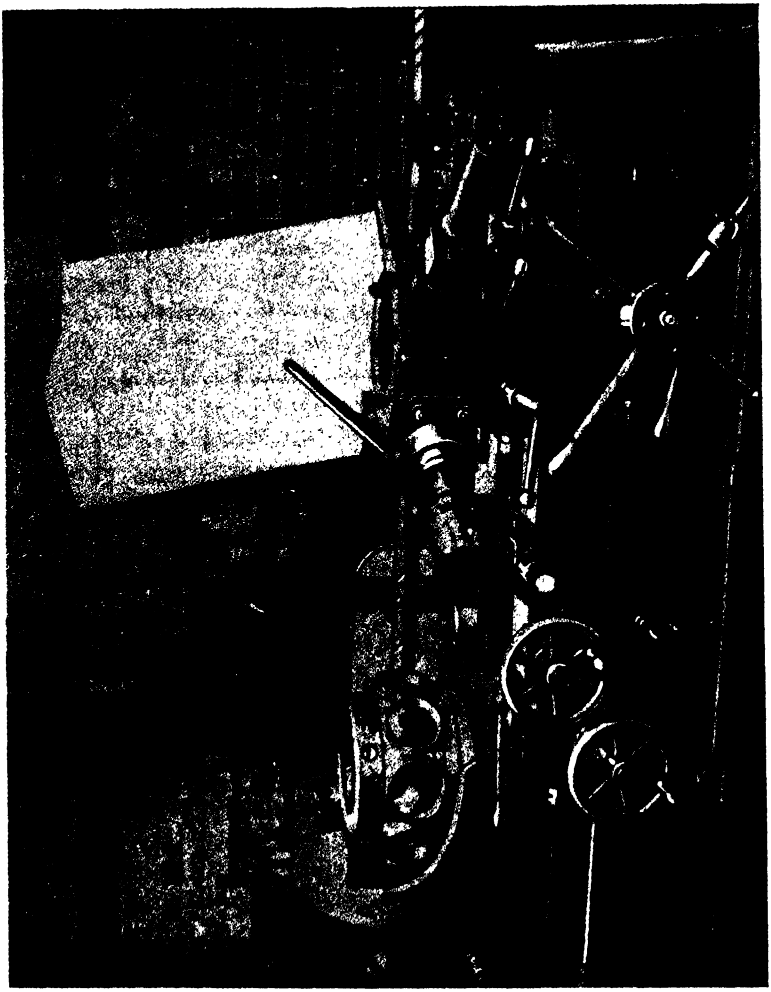


FIG. 47.—INDEXING FIXTURE FOR OPERATING ON NINE BORES OF AN AERO ENGINE CRANK CASE.

The form of index plunger is rather important, the pattern shown in Fig. 22 being very satisfactory.

The tapered form of pin finds its location easier and automatically adjusts itself to the hole, thus preventing any slackness and consequent rocking of the work being operated on. With fixtures that revolve, care should be exercised to see that any plungers, clamps, etc., are not so arranged that the centrifugal force will tend to loosen them, which, of course, would be very dangerous.

Nevertheless, the value of the fixture may be lost if the indexing and locking mechanism are too complicated.

The one illustrated was responsible for reducing the time per piece from 14½ hours to 4, the operation being to rough bore, finish bore, face and screw nine holes to a limit of ·001″.

Another form of indexing fixture allows of a lateral movement instead of revolving, an instance being the boring of a twin-cylinder motor casting, or the two bores of a water-meter, the slide carrying the work in this case being operated by a rack and pinion, and indexed for each hole by a plunger as usual, means also being provided to lock the slide before the fixture is allowed to revolve.

**Cross Slide Tool Holders.**—The designing of tool posts for holding ordinary turning tools of the flat type does not often become necessary, they being generally supplied with the machine. As, however, those in general use vary greatly in their degree of usefulness, a few remarks may be of value.

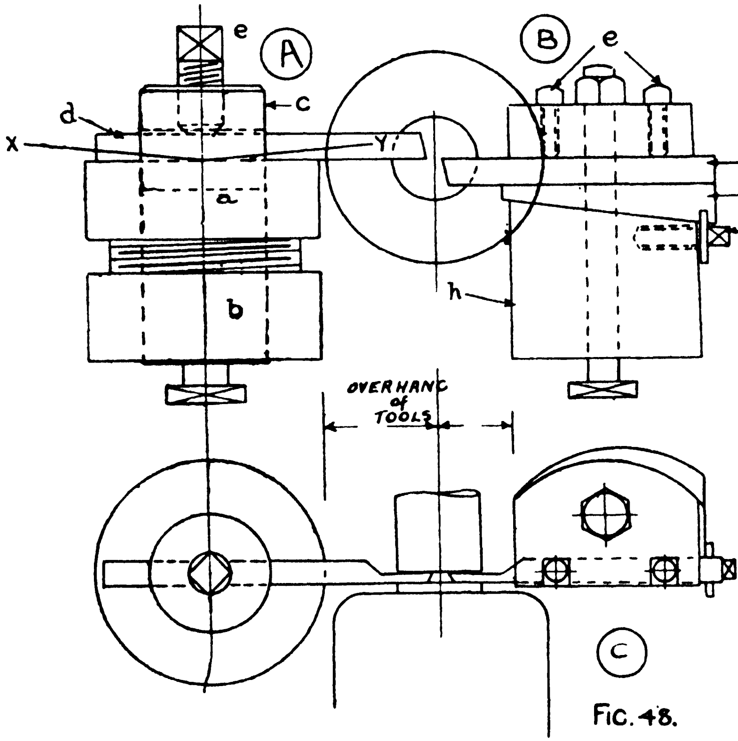
The first essential is that, having set the tool accurately, it should remain so under ordinary conditions. It should also be easily clamped and provided with some form of fine adjustment.

A comparison of the two types shown in Fig. 48 is interesting.

Taking A first, the tool *d* passes through the column *c* and rests across the top nut *a*, which screws into the lower nut *b*, these nuts making it possible to adjust the tool up and down.

It will be seen, however, that there exists a weak point, because the tool is being held by one screw only, which allows the tool to pivot when under cutting strain, and further, instead of having a solid foundation, this clamping screw is directly over the hole through which the stem *c* passes, with the result that if the tool happens to be somewhat soft in the shank or of thinner section than is general for that post, on tightening the screw *e* the tool will tend to bend to the line XY, shown exaggerated.

It will also be seen in the view C that it is impossible to set the tool near to the machine nose without excessive overhang, whereas with the other post, shown in position, the tool can be arranged both near the nose and with very little overhang. The post shown at B is an exceedingly good design, the body *h* with base broader than its top gives rigidity, and the tool is also held by two screws *ee*,




TOOL POST DESIGN.

and therefore cannot swivel. Adjustment is secured by means of a screw *b* engaging the wedge *a*, a movement of the former raising or lowering the tool *d*, a further advantage being that as the tool lays flush with the side of the tool-post it can be brought within $\frac{1}{32}''$ of the spindle nose, as shown in the view C.

**Circular and Dovetail Form Tool Holders.**—To hold these types of tools special holders are required, for unless they are correctly held considerable trouble will result. Not only must they be held well, but a means of fine adjustment is essential, especially with circular tools (see Fig. 59).

There are numerous patterns of these holders, but a very useful pair are shown in Fig. 49. Taking the circular tool holder first, it consists of a cast-iron bracket A provided

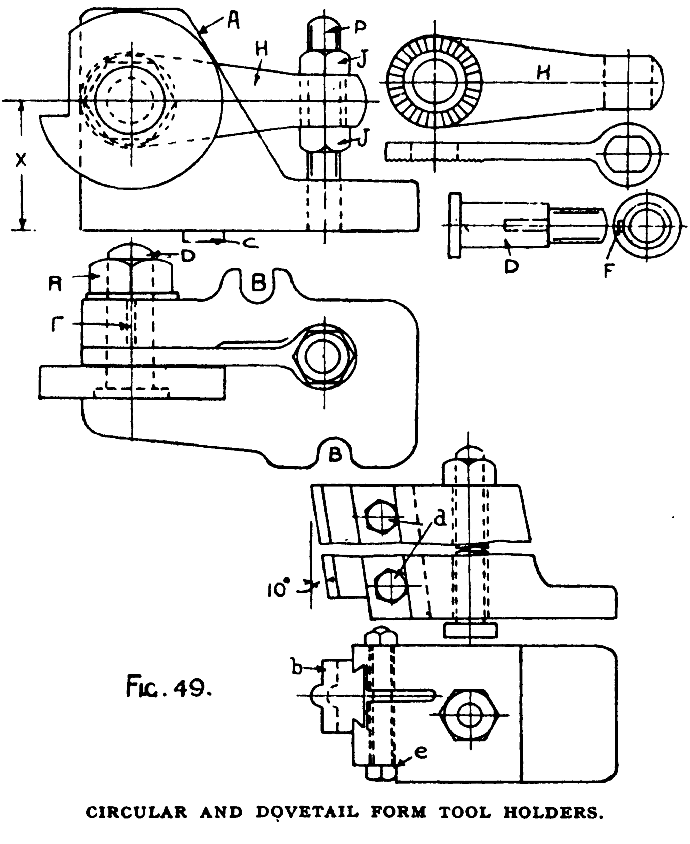



Fig. 49.

CIRCULAR AND DOVETAIL FORM TOOL HOLDERS.

with slots B for holding-down purposes, and a tenon C to fit the slot in the machine cross-slide, thus ensuring the bracket setting at right angles to the machine spindle.

The bolt D also passes through the bracket, and to enable the tool to be used close up to the machine nose the bolt-head is sunk into the tool; the bolt is also keyed as at F, so as to prevent it turning round when tightening up.

Fine adjustment is secured by means of the plate H and nuts J, J. On examining the detail drawing of the plate H, it will be seen that one side is perfectly flat, while the other is provided with a serration.

At the tail of the plate is a boss, through which is drilled a hole that clears stem P, and the boss is arranged between two nuts J, J thereon. The form tool itself being provided with similar serrations to those on the plate, is assembled with the latter, so that the two serrated faces meeting form a secure lock.

To make a fine adjustment it is only necessary to loosen the binding nut R and then raise or lower the plate H by means of the two nuts J, J.

In some cases the serrations are replaced by equally spaced holes in the plate, and a peg fixed in the side of the tool, but the former method is best. The fine adjustment is also secured by replacing the stem P and nuts J, J by a lever and nut, the latter being provided with a cam, a movement of which raises or lowers the lever. In making Fig. 49 care must be taken that the plate H is ground perfectly flat, otherwise the tool will not set square with the spindle.

The height X is less with tool brackets designed for the rear side of the cross slide by twice the amount the tool-cutting edge is cut below centre (see Fig. 59).

The holder for dovetail form tools can be made either of mild steel or of cast iron. The angle *a* is made 10 degrees or whatever angle is adopted in the particular works.

It will be seen that the body is slotted, thus enabling the tool *b* to be gripped by tightening the bolts *d*, and to prevent the latter turning the body is cut away at *c* to engage the bolt head. A good method of obtaining fine adjustment has yet to be devised ; but the mechanic sometimes overcomes this by putting a short bolt fitted with a nut under the tool, so that by unscrewing the nut the tool is forced up. This also acts as a positive stop should the tool have a tendency to work down, due to it taking an excessive cut or perhaps the fit of the dovetail being bad.

The dovetail should, of course, be to a standard form.

**End-Working Tool Holders.**—Holders for end-working tools, that is drills, taps, counter-bores, etc., are generally purchased from the machine tool builders, but, in the writer's opinion, it is cheaper to make even a small quantity if the

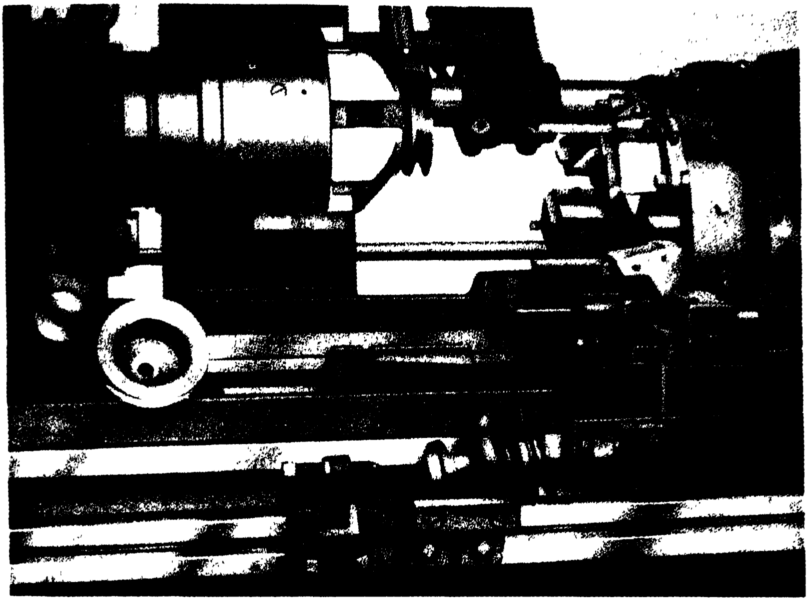


Plate V.

**Turret Lathe Accommodating 16 Tools.**—The " Pitler " lathe supplied by Messrs. Dowding & Doll, Ltd., of London, is seen here machining a vee-belt pulley. In its robust two-jaw chuck soft jaws can be machined to suit any shaped component. The design of the turret makes it possible to accept 16 separate tools.

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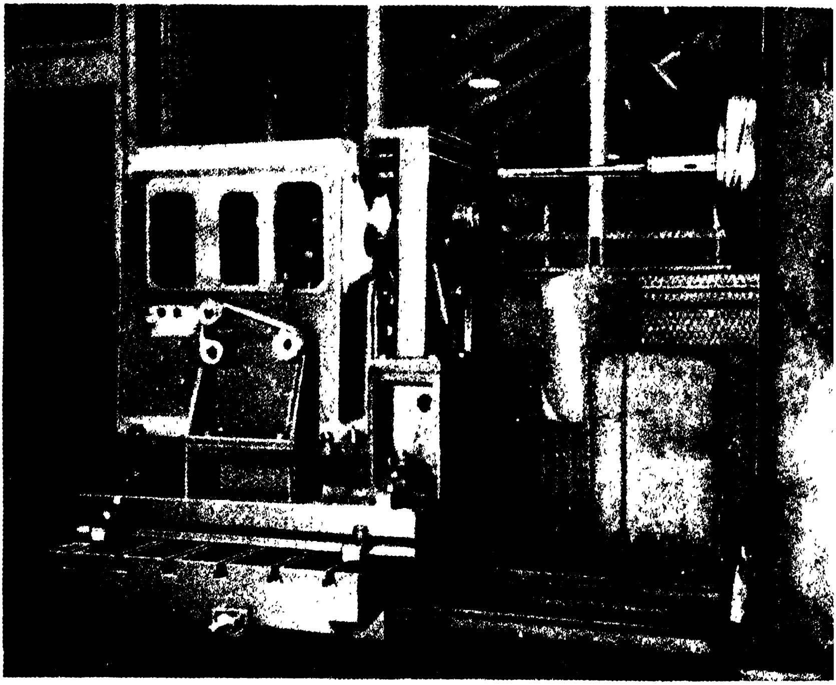


Plate Va.

The casting of a Wickman automatic main housing located in a jig on a horizontal boring machine, at the works of John Lang & Sons Ltd., Glasgow.

[*Facing page 85*

*Courtesy Associated British M/c. Tool Makers Ltd.*

points really calling for attention are watched and the non-essentials neglected.

**Plain Holders.**—The simplest possible type of holder is shown in Fig. 50, and is quite satisfactory provided it is kept in good condition. The body A is made of case-hardening steel, and is ground on the stem and in the bore as indicated ; to add a fine finish anywhere else is a waste of time. The stop-screw B, though generally omitted, is of great value, preventing any possibility of the tool pushing back, and when short ends of tools are being used up a piece of steel of suitable length can be inserted to fill up the space.

A small point, though very important, is the end of the

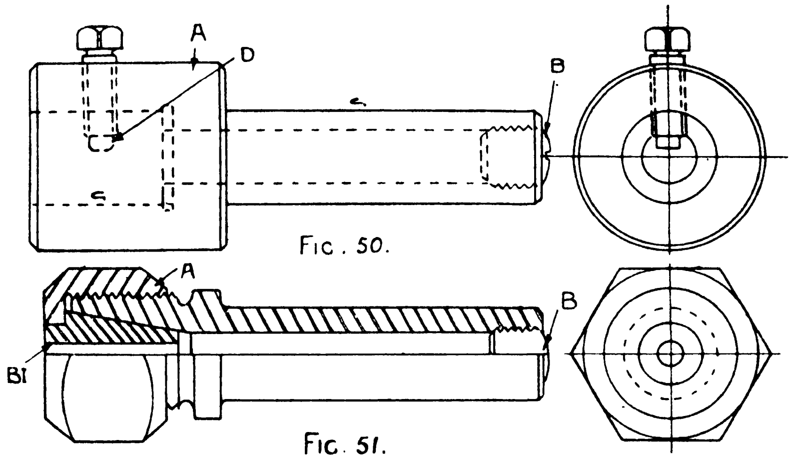



FIG. 50.—PLAIN END-WORKING TOOL HOLDER.
FIG. 51.—COLLET TYPE END-WORKING TOOL HOLDER.

screw D, which should have about two of its end threads removed and be hardened, to prevent it spreading or flattening due to continual tightening up.

The front bore must be ground perfectly concentric with the stem.

The collet type (Fig. 51) is a favourite for drills of small size from $\frac{7}{16}''$ downwards, but with this method of gripping the stop-screw B should not be forgotten.

The body of the holder should be hardened, and both this and the coned mouth ground, making them both concentric and well finished. The cap A is of the same material as the body, and, as it is subject to hard wear, should also be hardened.

The collet $B_1$ should be made as long as possible, so as to give a good bearing surface and a better grip. The practice of splitting it into separate segments should be avoided, but if the reader has ever attempted to find a small part of a tool among the oil and "swarf" in the machine bed this warning will not be necessary.

**Bushes for Holders.**—These unimportant-looking pieces go a long way towards making a successful holder and are worth a little consideration. The one shown at A, Fig. 52, is split through one side and partly through the other, and the bottom of the slot is in the form of a radius to prevent the bush breaking.

The one at B has two splits, one opposite the other, both commencing at opposite ends and finishing a short distance

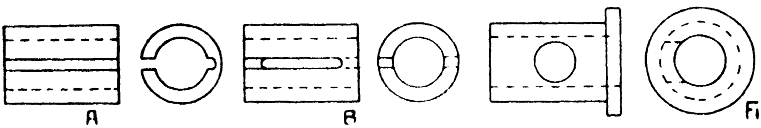


Fig. 52

BUSHES.

from the other end. With very large bushes a number of slots are introduced in a similar manner.

The bush C is, in the writer's opinion, the best, having a hole drilled half-way through clearance size for the holder screw, which grips positively on the tool itself, a small flat being ground thereon to assist this. The flange on the bush is also of assistance when it is being removed from the holder, a point much appreciated by tool setters.

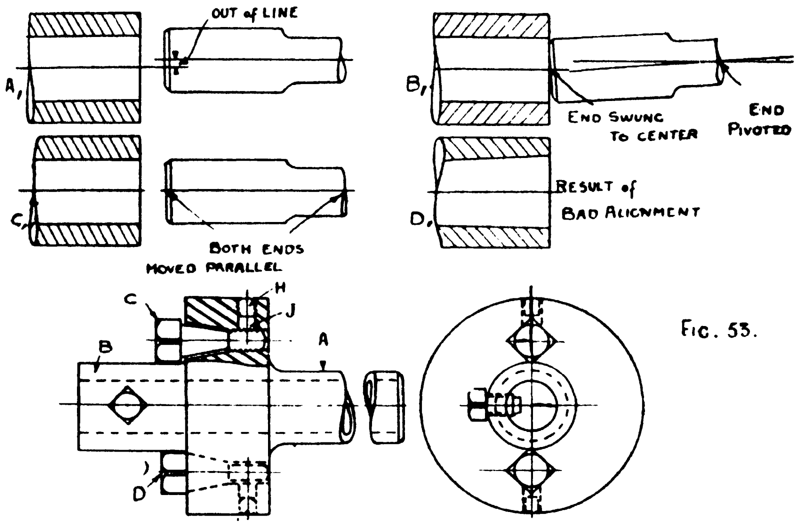
Where the holder screw binds direct on to the bush, the latter should always be provided with a flat, otherwise the burrs thrown up by the continual tightening of the screw will make it impossible to remove the bush when necessary.

**Floating Holders.**—The object of this type of holder is to provide a means of allowing the tool to avoid an error due to the non-alignment of the machine spindle with the turret tool holder or turret itself.

The weak point with some forms of "floating" holders is that the movement or "float" is not parallel to the centre line of the machine. A glance at Fig. 53 will make this clear, where $A_1$ represents a piece of work with a hole to be reamed and the reamer is shown out of line. $B_1$ shows the wrong method of " floating " the reamer to bring it in line, where it will be seen that the end of the tool only has been moved. $C_1$ is the correct movement where the entire length of the reamer has been moved parallel to the centre line of the machine.

The result of reaming with the tool out of line or with the " float " incorrect is indicated at $D_1$, the hole being tapered or commonly called " bell-mouthed."

A very useful and simple pattern holder which fulfils



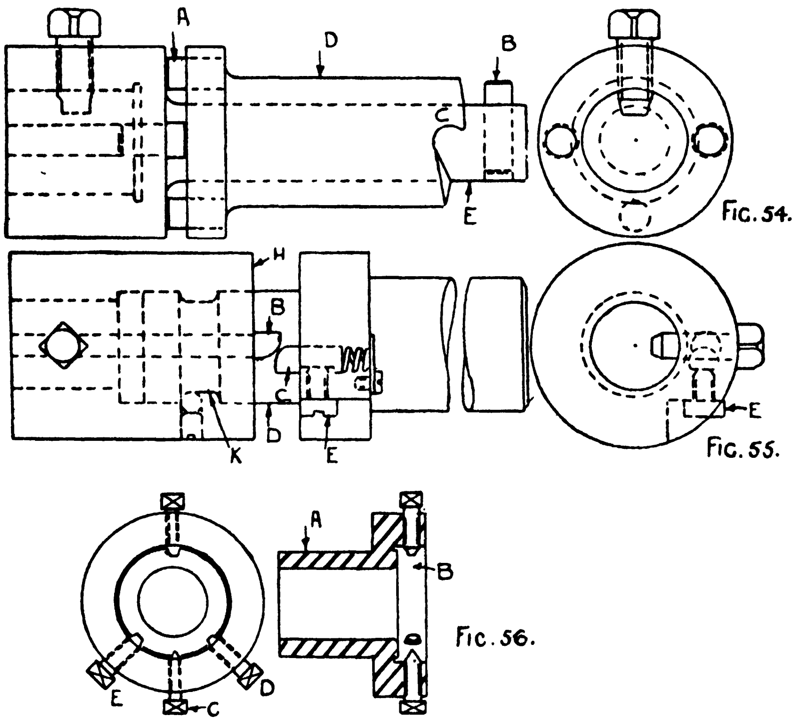

" FLOAT " AND " FLOATING " HOLDERS.

the necessary condition is given in Fig. 53. It consists of two main parts, the shank A and the nose B, the latter being held against the former by the two screws C, D, which are provided with a coned portion.

It will be seen that the nose can either be locked firmly against the body part A or given " float " according to how far the coned screws are released, in which case the " float " will be seen to be quite parallel. To prevent the screws working loose they are locked by means of a small screw H bedding on the brass pad J.

**Tap Holders and Die Adapters.**—There still exists much room for a good and simple design of releasing tap holder. Many are on the market which are both expensive and elaborate, and it is thought that the same results could be obtained with much simpler equipment.

Two are shown in Figs. 54 and 55, the former being a very old pattern and the latter a much simpler and more useful




FIGS. 54 AND 55.—TAP HOLDERS.
FIG. 56.—DIE ADAPTER.

type. The chief faults with that at Fig. 54 are that the wear is excessive, the pins A and B, also the end of the catch C, quickly wearing or breaking. The jarring that takes place when the pins disengage and when C engages is objectionable, especially with fine threads. Also, when using a tap of large diameter it is necessary to grip the sleeve D very tightly, and it will often happen that by so doing the sleeve closes slightly, gripping the stem E with disastrous results.

With the holder shown at Fig. 55 absence of vibration and accessibility to the parts that wear are its strong points. In the position shown, the nose is out to its fullest extremity, and on reversing its direction of rotation the two pegs B, C will engage quite smoothly, C being provided with a spring to take the thrust. To retain the nose H on the shank D a race K is ground and a steel ball put in.

Peg B is fixed in its correct position, and C is provided with a flat which enables screw E to prevent it turning round yet allowing sliding motion. Both pegs have their tops shaped like a tooth to assist the release and to favour smooth working. The peg C is made as simple as possible, consisting of standard drill rod, so that if it wears or breaks the tool-setter can replace it in a very few minutes, this not being possible with the general design of holder.

The hole into which the peg B is driven should be continued straight through the nose, so that the peg, which is driven in, can be removed without much difficulty when necessary.

**Die Adapters.**—Though holders on the same principles as have already been described for taps can be bought or made, it is common practice to employ adapters of the pattern shown in Fig. 56. These are made of mild steel, and case hardened to prevent them getting damaged. The shank A, which fits into the bore of a standard tap holder, and the recess B, which takes the button die (see Chap. VIII), must both be quite concentric, and the shank should be a good push fit in the tap holder.

The recess is also better for the narrow channel removed from its corner, which prevents dirt or cuttings lodging therein and causing the die to set at an angle.

Three screws are fitted, the one at C having a coned point of about 60 degrees to open the die, and the remaining two, D and E, help to both close and hold the die, the latter generally having small hollows round its rim for the screws to engage in. As the wear on these screws is heavy, they should be made of tool steel and properly hardened and tempered; also, if there is sufficient room between the cross slide tools, the screws should have thin heads in preference to the grub type generally used.

**Turning Tools.**—As the question of turning tools as used on the centre lathe has been dealt with in so many works already published, it is not proposed to include them here. It is, however, worth mentioning that tool designers are getting much bolder with regard to cutting angles, especially those for use on capstans and automatics.

**Cutters for Box Tools.**—A cutter from a box-turning holder is illustrated in Fig. 57, which is intended for soft steel, aluminium or iron. The top rake is 35 degrees, which will enable the cuttings to sheer off with the minimum of friction, and the front clearance of 4 degrees is quite sufficient otherwise the strength of the cutting angle, which is 51 degrees, would be jeopardized.

In designing any tools the steel called for should be of standard section, so as to avoid extra machine work necessitated in reducing a piece perhaps from a large standard size to a smaller size which is out of standard.

To assist the tool setter, it is advisable to indicate on the drawing that the base of the tool must be ground flat; this will facilitate setting, and also the production of accurate work.

**Flat Form Tools.**—This type of tool is only used where a small quantity of a component are wanted and where accuracy is not of first importance. Their life is short, due to the fact that they can only be ground on their top face, and of course the form alters every time this takes place. Fig. 58 shows one of these tools, and the clearances will be noted are in violent contrast to the tool in Fig. 57.

In settling the amount of clearance a compromise must be effected between the material being machined, the width of the face being formed and the anticipated quantity of work to be accomplished. An average front clearance might be 4 degrees, and side clearance, which is not always put in, about 2 degrees. If the face being formed is wide, the tool must be kept as massive as possible, and in any case, while lack of clearance will produce friction which will spoil the tool at the point it takes place, excessive clearance will cause "chatter" or vibration, and so render the tool almost useless because of the badly finished work that results.

**Circular and Dovetail Form Tools.**—To maintain accuracy of form and avoid expense caused by the continual making of flat form tools, circular tools, i.e. tools of circular shape having the desired form on the periphery and with a portion cut away to form a cutting edge, are employed.

Standard diameters are fixed for these by firms to suit their machines, and here again a size should be selected that will not necessitate the reduction of a bar of material when making.

For machines like the popular Brown & Sharp Automatic the size of the largest diameter of the tool for use thereon is determined by the makers, and tables are also supplied by them to assist in the design of the tools.

The design and production of these tools would be greatly

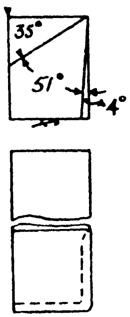


FIG. 57.

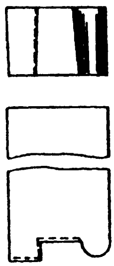


FIG. 58.

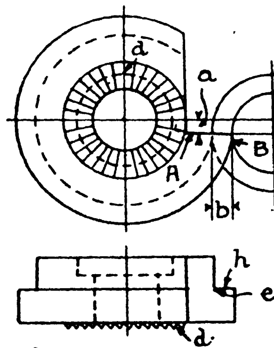


FIG. 59.

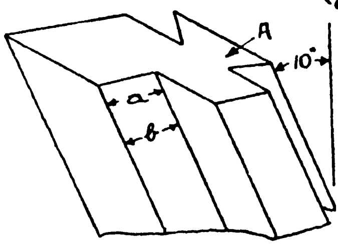


FIG. 60.

FIG. 57.—FORM OF CUTTER GENERALLY USED IN BOX TOOL HOLDERS.
FIG. 58.—FLAT FORM TOOL.
FIG. 59.—CIRCULAR FORM TOOL.
FIG. 60.—DOVETAIL FORM TOOL.

simplified if it was possible to make the cutting face A, Fig. 59, on a level with the centre line of the work and the tool; but a glance will show that to do this would provide no clearance at B, with the result that rubbing and not cutting would take place. To get over this difficulty the cutting edge of the circular tool is arranged a certain distance, *a*, below the centre. In so doing, however, another difficulty is introduced when the tool is stepped to form more than one diameter.

It will be easily seen that the depth *b* increases as the cutting face A is lowered, so that this must be taken into account when designing and producing the form of the tool in the first instance.

For the purpose of calculating the diameter of the tool to allow for this, the following formula is given, where—

R = Largest *radius* of tool.
H = Amount cutting edge is below centre.
D = $\frac{1}{2}$ difference in diameters of work being turned.
*r* = *Radius* of smallest diameter of tool.

$$r = \sqrt{(\sqrt{R^2 - H^2} - D)^2 + H^2}$$

To give an example. The diameter of the tool blank is, say, 2″, to suit the machine and tool holder, the cutting edge must be, say, $\frac{3}{16}$″ below centre, and the diameters to be turned 1″ and $\frac{3}{4}$″ respectively.

Then—

$$R = 1''$$
$$H = \cdot 1875''$$
$$D = \cdot 125''$$

The smallest diameter of the tool will equal 2*r*, and inserting these values in the formula, we have—

$$r = \sqrt{(\sqrt{1^2 - \cdot 1875^2} - \cdot 125)^2 + \cdot 1875^2}$$
$$= \sqrt{(\sqrt{1 - \cdot 03516} - \cdot 125)^2 + \cdot 03516}$$
$$= \sqrt{\cdot 731025 + \cdot 03516}$$

So that $r = \cdot 8775''$.

This means that the diameter of the tool is 2 × ·8775″ = 1·755″, from which it will be seen that the allowance necessary to make good the dropping of the cutting edge is ·005″.

Side clearance should be also given as indicated in *e*, Fig. 59, though in the writer's opinion side clearance should end at *h*, leaving a flat surface of about $\frac{1}{16}$″ according to the heaviness of the work and the degree of finish required, it being found that this tends to reduce the scoring of the work when the tool is withdrawing.

The serrations shown at *d*, Fig. 59, are intended to mesh with those on the plate H, Fig. 49, to prevent the tool turning and assist fine adjustment. Some designeis, however, prefer a number of equally spaced holes of about $\frac{1}{4}''$ diameter, the tool being provided with a steel peg to engage therein.

**Dovetail Form Tools.**—These take their name from the part A, Fig. 60, which enables them to be held firmly in holders of the type shown in Fig. 49. The points mentioned in regard to circular tools have a bearing on these also, for to secure satisfactory cutting action they must be tilted at an angle which affects the relation of one diameter being turned with another.

The cutting edge *a* is longer than the dimension *b*, which is taken at right angles to the tool face, and will vary according to whatever angle the tool is inclined. Where more than one diameter is to be turned, as with the circular tool just dealt with, allowance must be made for this, and the depth of the shoulder *b* is obtained from the formula—

$$D = d \text{ (cosine C)},$$

where $d = \frac{1}{2}$ difference of diameters to be turned,
$C$ = Clearance angle of tool,
$D$ = Depth of shoulder required.

Giving an example, suppose the diameters to be turned are $1{\cdot}250''$ and $\cdot 875''$ and the clearance angle is 10 degrees. Then—

$$d = \cdot 1875$$
$$C = 10^\circ$$
$$\therefore \cdot 1875 \times \text{cosine } 10^\circ$$
$$= \cdot 1875 \times \cdot 98481$$
$$= \cdot 1847''$$

So that the step *b* must be machined to a depth of $\cdot 1847''$ to produce a shoulder on the work of $\cdot 1875''$.

**Shaving Tools.**—As the name suggests, these tools are designed to remove a very light cut, thus securing extreme accuracy and fine finish. This is effected by giving the tool a certain amount of " float," and a glance at Fig. 61 will make its application quite clear.

The shank A is held in the machine tool holder, and pivoted about the bolt B is the cradle C.

The cradle has a fixed seat at D and an adjustable one at E, the latter being adjusted by the screw G.

A dovetailed recess is machined in both seats to take the tool and its steady.

The cradle C is " floated," and steadied by means of the screw H and the spring K.

In the view Fig. 61 the tool is seen shaving to size a shoulder, the work being, as it were, sandwiched between the tool and the pad, the latter being always a little longer than the tool, enabling it to secure a seating before the tool

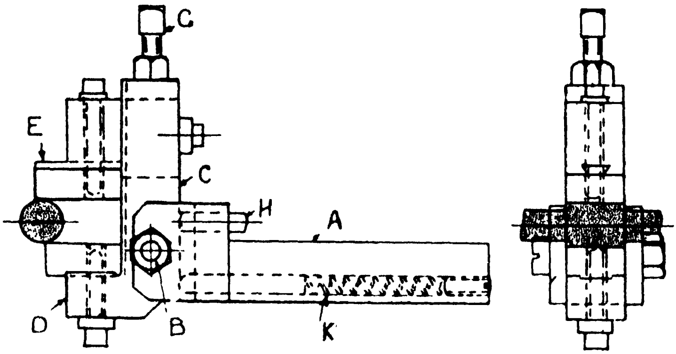



FIG. 61

SHAVING TOOL.

commences to cut. The tool should be provided with about 2 degrees top rake and 5 degrees front clearance.

The tool shown in Fig. 61 is arranged for an " Acme " multi-spindle machine, the spindles of which run anti-clockwise; and this point should not be forgotten by the tool designer, otherwise expensive losses will be the result.

Parts A and C, together with the screws, are of mild steel case hardened, and the tool and pad are of high-speed steel.

## CHAPTER VII

# CUTTERS

Roller Milling Cutters—Inserted Tooth Cutters—Relieved Form Cutters—Hollow Mills—Running Stops—Cheap Type of Hollow Mill—Reamers—Expanding Reamers—Special Purpose Reamers—Boring Tools and Holders—Boring Cutters of Special Form—Flat Bits—Counter Bores and Spot-facing Cutters—Countersink Cutters—Spot-facing Cutters—Trepanning or Spirally Relieved End-Working Tools—Broaches.

As it would be impossible to deal individually with the vast number and variety of tools coming under this heading, those that form a basis for the design of others will be dealt with, and the word cutter will mean any cutting tool other than those already mentioned.

**Roller Milling Cutters.**—Standard cutters of this type

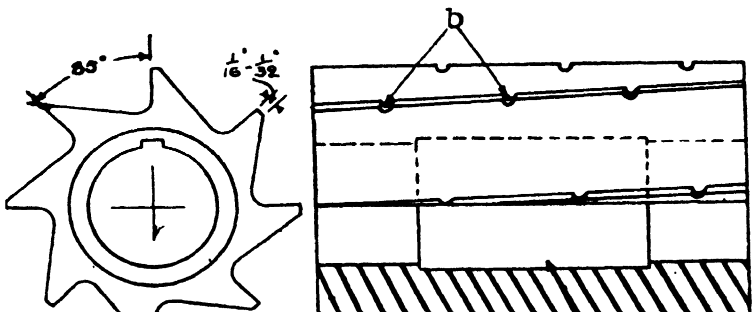



FIG. 62.

ROLLER MILLING CUTTER.

cannot be made profitably in small quantities by a firm not specially laid out for their production, but as sizes out of standard and of special form may be called for, their consideration will be well worth while. Fig. 62 shows one form of roller milling cutter, such as is used for heavy work on broad surfaces.

Assuming that the outside diameter of the cutter, which should be as small as possible without making the shell too weak, has been fixed, the next point will be to decide upon the number of teeth. With facing or "slabbing" work where a heavy cut is generally taken and where the escape of cuttings from under the cutter is difficult, a coarse pitch cutter, i.e. one with few teeth, thus leaving plenty of room between them, is best.

While it might be argued that the cutting strains would be reduced by dividing the work between a greater number of teeth, it should be remembered that the finer the pitch the more teeth would be in action at once. The chief objection to fine pitch cutters, however, is the lack of room for the escape of cuttings, sometimes called clearance or chip capacity, which, offering resistance to the cutting action, develops friction. In securing the full chip capacity, the strength of the teeth must not be sacrificed, a tooth of sufficient strength is obtained by allowing about $\frac{1}{32}''$ for land at the cutting edge and then making the clearance angle about 85 degrees as shown. The "land" referred to here, of course, has a back clearance of anything between 2 to 5 degrees, in addition to the major clearance of 85 degrees. Tooth spacings that have been found by experience to give satisfaction are given in table No. 1.

TABLE No. 1.

MILLING CUTTERS.

| Diameter. | Bore. | Number of Teeth. | Key Slot. |
|---|---|---|---|
| In. | In. | | In. |
| 2 | 1 | 8 | $\frac{5}{32} \times \frac{3}{64}$ |
| 2½ | 1 | 8 | — |
| 3 | 1¼ | 8 | $\frac{3}{16} \times \frac{3}{32}$ |
| 3½ | 1¼ | 8 | — |
| 4 | 1¼ | 9 | — |
| 4½ | 1½ | 9 | — |
| 5 | 1½ | 10 | — |
| 5½ | 1½ | 11 | $\frac{1}{4} \times \frac{1}{8}$ |
| 6 | 1½ | 11 | — |
| 6½ | 2 | 12 | — |
| 7 | 2 | 12 | $\frac{5}{16} \times \frac{5}{32}$ |

The spiral tooth is preferable to the straight one as the cutting action is greatly eased by the gradual shearing action due to this formation, especially where the material is of a tough fibrous nature. As with the majority of questions arising in connection with tool design opinions vary considerably, but an average angle for a spiral tooth would be from 10 to 15 degrees, and with cutters of less than 1½″ in length the teeth are generally left straight.

With all milling cutters of over ¾″ wide the bore is undercut

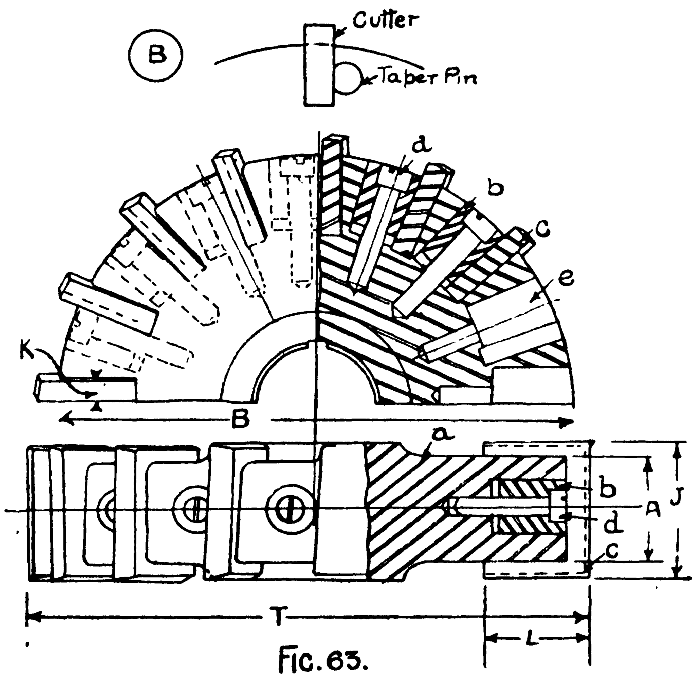



FIG. 63.

INSERTED TOOTH CUTTER.

as shown at *a*, Fig. 62, the length of the undercut being between one ½ or ⅔ of the width of the cutter. This undercut facilitates grinding the bore of the cutter when being made and in no way interferes with its strength.

The table No. 1 gives proportions for roller mills, and it might be mentioned that the key slots are not always put in for special cutters, its absence allowing the cutter to slip on the arbor should any excessive cut or other strain be put upon it, thus preventing the breaking of the teeth. On no account should any sharp corners be allowed to occur on a cutter, for this will greatly help in the breaking of the cutter when working, though it may never get past the hardening process for this reason. With cutters of $1\frac{1}{2}''$ length the nicks *b*, Fig. 62, known as chip breakers are employed. It will be seen that the cutting is broken up by this means, and the strains somewhat relieved. These nicks should be of concave form and of a depth equal to about twice the "land."

**Inserted Tooth Cutters.**—Milling cutters of whatever type should be kept as small a diameter as possible, because apart from the cost of the steel the life of these tools is very limited, also there is always the risk of the cutter breaking in the final hardening process—thus making the expense heavier. When, therefore, a cutter of large diameter is essential, it is well to introduce the inserted tooth type, one of which is shown at Fig. 63. The body *a* is generally of mild steel and the bushes *b* of tool steel. These bushes are provided with about 2 degrees taper, thus acting as a wedge holding the cutter blades *c*, which are of high-speed steel, in position.

The screws *d*, which hold the bush in its seating, are also made of tool steel for strength.

The holes *e* into which the bushes fit have a taper corresponding to that of the bushes, the latter being provided with a flat to effectively grip the cutter blade.

Table No. 2 shows some proportions for designing satisfactory cutters.

TABLE NO. 2.

INSERTED TOOTH CUTTERS.

| T. | A. | B. | J. | K. | L. | Number of Blades. |
|---|---|---|---|---|---|---|
| In. | In. | In. | In. | In. | In. | |
| 5 | 2 | $4\frac{5}{8}$ | $2\frac{3}{8}$ | $\frac{15}{16}$ | $\frac{3}{8}$ | 10 |
| 6 | 2 | $5\frac{5}{8}$ | $2\frac{3}{8}$ | $\frac{15}{16}$ | $\frac{3}{8}$ | 12 |
| 8 | 2 | $7\frac{5}{8}$ | $2\frac{3}{8}$ | $\frac{15}{16}$ | $\frac{3}{8}$ | 14 |
| 9 | 2 | $8\frac{5}{8}$ | $2\frac{3}{8}$ | $\frac{15}{16}$ | $\frac{3}{8}$ | 16 |
| 10 | 2 | $9\frac{5}{8}$ | $2\frac{3}{8}$ | $\frac{15}{16}$ | $\frac{3}{8}$ | 18 |
| 12 | 2 | $11\frac{5}{8}$ | $2\frac{3}{8}$ | $\frac{15}{16}$ | $\frac{3}{8}$ | 22 |

Another and cheaper method of gripping the blade is to drill holes at right angles to the face of the body as shown at B, Fig. 63, these holes being tapered to take standard taper pins which, having a flat machined on them, are driven home, thus securely wedging the blade.

**Relieved Form Cutters.**—With cutters relieved or backed off in the ordinary way, it is obvious that, as the cutting face is ground, the form produced is altered, and as it is essential with some cutters that their form must be accurately maintained, the cutter must be so designed and finally kept, in such a way that grinding does not alter this form, and form relieving is a method that gives the necessary clearance while fulfilling the qualification mentioned.

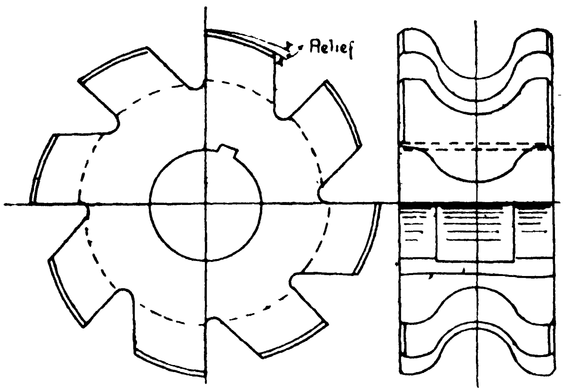



FIG 64

CUTTER FORM RELIEVED TO ALLOW FOR GRINDING.

This relieving is accomplished in a special lathe or machine, and it is necessary that the designer should indicate on his drawing that this method is required.

Fig. 64 shows a cutter of special formation with relief indicated. The latter must not be excessive, otherwise a weak tooth will result at the same time; if insufficient the cutter will rub rather than cut, which will quickly destroy the tool. A reasonable relief is obtained by striking an arc from a centre $\frac{1}{8}$ to $\frac{3}{16}$ offset from the true centre of the cutter as indicated. It will be noticed that the clearance angle is in this case only 45 degrees, this being done to increase the length of the tooth, thereby prolonging its life. As it is unusual for form cutters to take heavy cuts, the angle giving chip capacity need not be so great as with the roller mill just dealt with. These cutters are, however, often provided with chip breakers in a similar manner to plain cutters.

**Hollow Mills.**—These are used plentifully on screw machines and capstans, though in some cases they can be employed with advantage on drilling machines. The most common pattern is shown in Fig. 65, and Table No. 3 gives two dimensions having a bearing on the diameter of the cutter bore.

This tool is usually provided with either three or four teeth milled straight as at A and suitable for brass, or at an angle as at B, thus giving rake and enabling mild steels and ductile materials to be machined with ease.

Their lengths will be about two to three times the outside diameter of the mill, though this must be altered to suit any special conditions prevailing.

To prevent the material seizing or getting jambed in the bore *c* the latter is tapered about $\frac{1}{8}''$ per foot for a length as shown at Fig. 65.

The length for this part is indicated in Table No. 3, where

TABLE NO. 3.

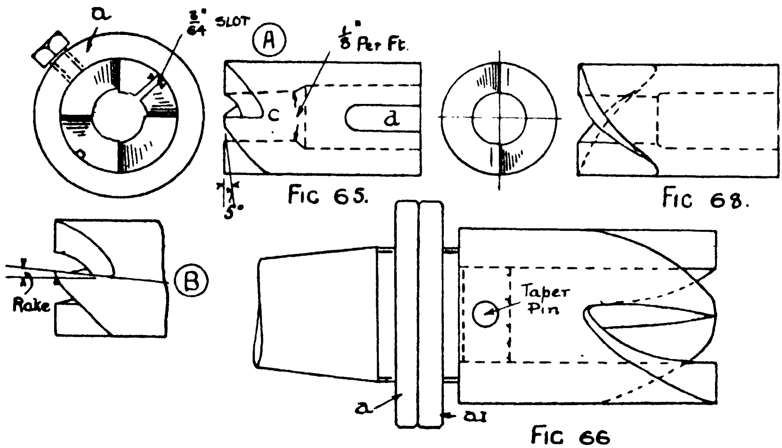
HOLLOW MILLS.

| Bore. | Outside Diameter. | Taper Portion. |
|---|---|---|
| In. | In. | In. |
| $\frac{1}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ |
| $\frac{3}{16}$ | $\frac{1}{2}$ | $\frac{7}{16}$ |
| $\frac{7}{32}$ | $\frac{5}{8}$ | $\frac{1}{2}$ |
| $\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ |
| $\frac{3}{8}$ | $\frac{7}{8}$ | $\frac{3}{4}$ |
| $\frac{1}{2}$ | $1\frac{1}{4}$ | $\frac{3}{4}$ |
| $\frac{3}{4}$ | $1\frac{9}{16}$ | 1 |

also will be found the outside diameter of the cutter. If the latter is kept too small, and the teeth made extra long, the tendency is for the mill to open out at the mouth as it is fed on to the work, thus producing a taper on the latter. A flat *d* is machined on the outside diameter to enable the holder screw to grip properly.

The front clearance on the teeth is about 5 degrees, and this amount should not be exceeded, otherwise they will chip or "chattering" may ensue.

As the grinding of these cutters must necessarily produce



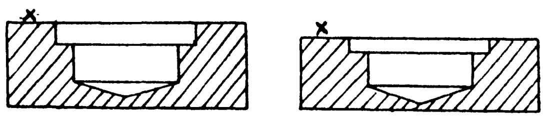



FIG. 67.

FIG. 65.—HOLLOW MILLS.
FIG. 66.—LARGE HOLLOW MILLS.
FIG. 67.—RUNNING STOPS.
FIG. 68.—CHEAP TYPE OF HOLLOW MILL.

work of enlarged diameter due to the tapered bore, some means of adjustment is often provided, and this is accomplished in two ways. The mill is either split as shown in Fig. 65, the slot breaking into the bore on one side and a nick being made opposite this on the outside, which enables the clamp collar *a* to be used as a means of opening or closing the mill. In this connection it is well to mention that unless the tool has been properly hardened and tempered, while the mill will close under pressure of the screw, the lack of spring in the tool will prevent it opening when the pressure is released.

The second method is to make the teeth of increased length and fitting a clamp collar as before, by which means the teeth are closed or opened at the front. The same remarks in regard to the correct hardening will apply here also.

Hollow mills have been used very successfully in drilling machines, being guided through steel bushes in the same manner as drills. Fig. 66 is a large type of mill used in this way, and to avoid the waste of expensive high-speed steel, it will be seen that the mill is separate from the shank, the latter being made of mild steel. They can be assembled by either making the mill a light push fit on the shank and then driving a tapered pin through them both, as shown, or providing them with threads and screwing them together.

The stem can be straight or be made to a standard taper to fit the spindle of the drilling machine.

**Running Stops.**—In the particular cutter illustrated at Fig. 66 it was found an advantage to introduce a running stop, that is, the two collars $a$ and $a_1$, being locked together on the shank, were adjusted at a certain height so that when the mill had reached its depth they butted on the top of the bush through which the mill was passing, the usual machine stop being rendered unnecessary. This principle can be used to great advantage in drilling and boring, where the depth dimension is very particular and the height of the component varies. Fig. 67 will make this clear, where it will be seen that if the height of the component varies by however small an amount, if the cutter is dependent on the machine stop, the length of the portion machined will vary, but if the tool is provided with a running stop, which it is obvious, fixes the distance from the cutting edge to the stop face, and the latter butts against the face $x$ of the component, the length of the machined portion will be kept constant.

**A Cheap Type of Hollow Mill.**—A hollow mill which for small work can be made much cheaper than other types is shown in Fig. 68. The cheapness lies in its being provided with only two teeth.

The teeth are formed by the milling cutter which should have an angle of about 50 degrees making two gashes at opposite sides, after which the front clearance angle can be put on by means of a file.

As there are only two teeth there is more of the cutter bore in contact with the work, and it is claimed that for this reason the diameters produced are more cylindrical. The proportions for these are as for the mills already described.

**Reamers.**—As with milling cutters the chief point with reamers is the teeth and their clearance. Naturally the size and form of the teeth will depend on their number, and standard reamers contain a larger number of teeth than the

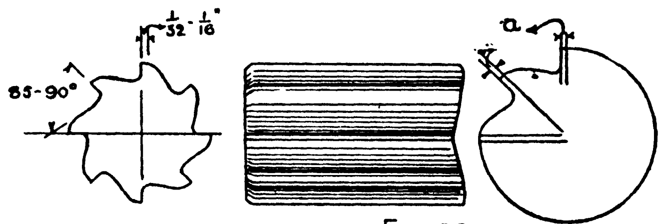



FIG. 69.

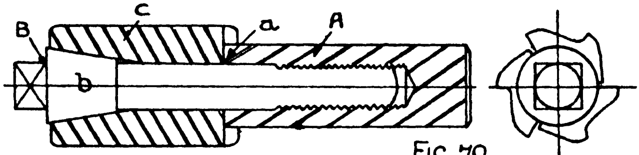



FIG. 70.

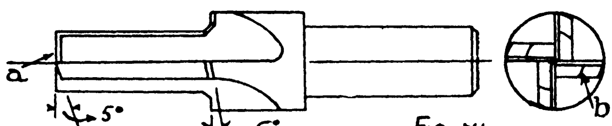



FIG. 71.

FIG. 69.—TOOTH FORMATION OF PLAIN SOLID REAMERS.
FIG. 70.—EXPANDING REAMER.
FIG. 71.—SPECIAL REAMER AND COUNTERBORE.

designer usually calls for in special ones. The number of teeth are given in Table No. 4 for various diameters.

Special milling cutters are made for cutting the flutes in reamers, the angle of the teeth of which are generally about 85 degrees ; this size will be found to leave a substantial form of tooth, and at the same time provide a groove of sufficient size to facilitate the escape of cuttings. It has been found that when reaming bronze, brass, etc., the reamer produces a much finer surface if the teeth are not made radial, but slightly ahead of the centre as shown at *a*, Fig. 69, the amount *a* being $\frac{1}{64}$" for reamers between $\frac{1}{4}$" and $\frac{3}{4}$" diameter and about $\frac{1}{32}$" for those above this. In the writer's opinion, however, if the clearance is correct and cutting lubricant used the teeth can be cut radial with every chance of success. "Chatter," the great enemy of the machinist, is often caused by the reamer being too keen, the remedy for which is in his own hands; excessive clearance on the outside is another cause of this trouble, and the designer should see that sufficient land is left which will act as a steady for the reamer, the width of this land as indicated in Fig. 69 should vary from $\frac{1}{32}$" to about $\frac{1}{16}$". Rose-chucking reamers, that is, reamers reserved for use on capstan lathes for "hogging" out rough holes, are provided with cutting edges at 45 degrees on their front edge, the flutes being milled as usual to assist in getting rid of the cuttings, but no side clearance is provided.

It is the practice in some works to make reamers with teeth unevenly spaced, it being claimed that this prevents chatter, but the idea does not meet with general approval. The teeth are generally milled straight, but a large quantity of standard and special reamers have teeth either left- or right-handed spiral. It is claimed for these that the shearing cut due to the spiral formation produces a better finish. The left-hand spiral prevents the reamer being drawn into the work which would occur with a right-hand spiral if hand fed. As, however, in most cases the reamer is fed in by power, this point does not arise, and a right-hand spiral which will assist the withdrawal of the cuttings from the hole being reamed will be found an advantage.

**Expanding Reamers.**—To avoid expense caused by the scrapping of reamers when they are worn undersize, various methods have been introduced, and the majority patented, for expanding them. A very simple yet successful form is shown in Fig. 70, consisting of stem A, a screw B, and the shell portion C.

The stem, which is made of mild steel, has a tongue at *a* which engages in a slot milled in the bottom of the reamer C, forming a positive drive, and a hole is bored and tapped to receive the screw B. The latter is made of case-hardening steel and has the thread of fine pitch, about 26 threads per inch to avoid working loose, and the coned portion *b* is ground after hardening. The shell portion is of high-speed steel bored to fit the plain part of the screw B and with a female

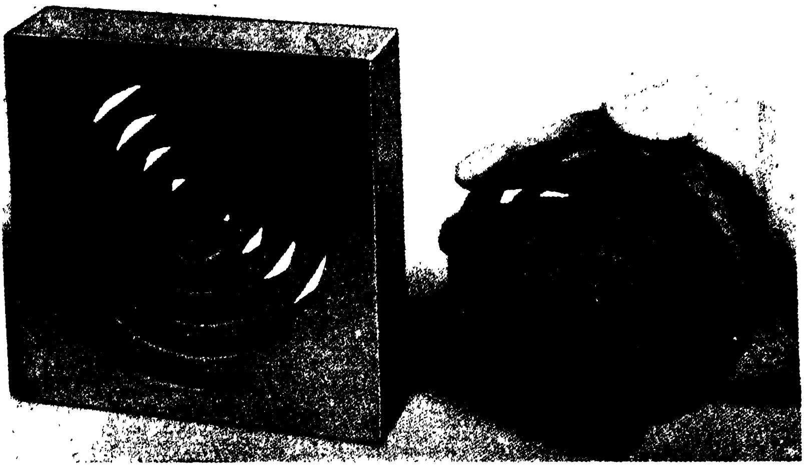


Plate VI.

**Contour Machining.**—The cutting of elaborate shapes in thick plates has always proved a lengthy and expensive job. Messrs. Geo. Alexander & Co., Ltd., have, however, introduced a machine known as the " Doall " metal master which is designed to deal effectively with this work. The plate shows one difficult example.

Actually it is a very efficient bandsawing and filing machine. Where pieces have to be cut with no entrance from the edges, the band saw is passed through a previously drilled hole and then butt welded. A special device for this purpose as well as a grinding device for trimming the saw previous to welding and for trimming it afterwards is incorporated in the frame of the machine. An additional feature is known as the " Job Selector." A dial indicates the correct cutting speed for sawing or filing 48 different materials giving also the correct pitch, temper, and set for saws for each one.

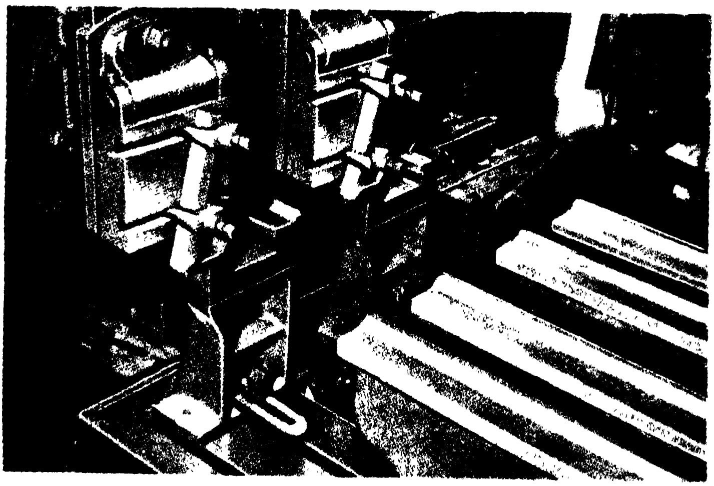


Plate VIa.

Setting gauges mounted on the planing machine bed to facilitate tool setting when machining the famous "Lang" lathe beds at their works in Glasgow. The lathe beds are visible in the foreground.

[*Facing page 105*

*Courtesy Associated British M/c. Tool Makers Ltd.*

cone of 15 degrees. To allow of expansion it has three slots equally spaced round its circumference, breaking into the bore and terminating about $\frac{3}{8}''$ from the rear end. So that on turning the screw B by means of the square end, the male cone of the screw forces open the reamer.

Though the expansion is not parallel, as only the front of the reamer expands, this is by no means objectionable as a back clearance or taper is thus provided which is, in some classes of work, a distinct advantage.

**Special Purpose Reamers.**—While standard tools, which can be bought cheaper, should be introduced wherever possible, occasions occur when the design of a special tool is essential. Fig. 71 shows a reamer and counterbore combined in one tool, a method often adopted on turret lathe work when there are more tools than the turret can accommodate. If the hole is to be reamed to very accurate limits this combination is best avoided, because if the front cutting edges of the tool are unevenly ground or are allowed to become dull, the cutter will tend to spring away from the work, thus enlarging the hole. The method of relieving or backing off the reamer as indicated at *b* where the outer edge is convex in form instead of having a flat, tends to strengthen the teeth and also prevents "chatter."

TABLE NO. 4.

REAMER TEETH.

| Diameter. | Number of Teeth. |
|---|---|
| In. | |
| Up to ½ | 4 to 6 |
| ½ to 1½ | 6 to 8 |
| 1½ to 2½ | 8 to 12 |

The clearance on the front end of the reamer and on the teeth of the counterbore should not exceed 5 degrees, otherwise the tool may "dig" in and possibly break. This particular cutter is used to ream a "blind" hole, i.e. a hole blocked at one end, and also to make the bottom of the hole square, the latter being accomplished by the teeth on the front part of the reamer. Fig. 72 is another reamer specially designed, and to avoid expense and hardening difficulties due to its length the main body of the tool is of case-hardening steel, the reamer portion *a* only being made of high-speed steel. The stem is provided with a tongue *b* which engages in a slot in the top of the reamer.

The sleeve *c* is bored out to slide on the stem *d*, the last $\frac{3}{4}''$ of which is provided with a screw for holding purposes. Four holes *e* are drilled round the end of the sleeve to enable a tommy bar to be inserted when unscrewing the sleeve.

As the reamer *a* is hollow, the grooves for forming the

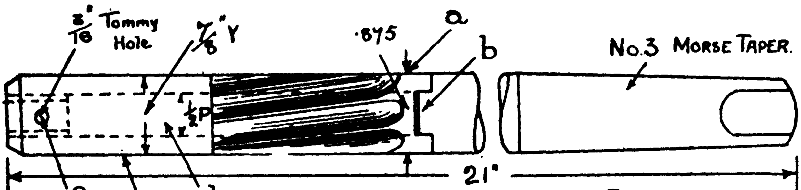



Fig 72

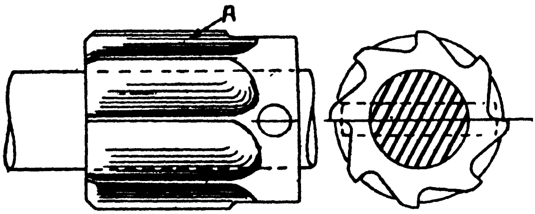



Fig. 73.

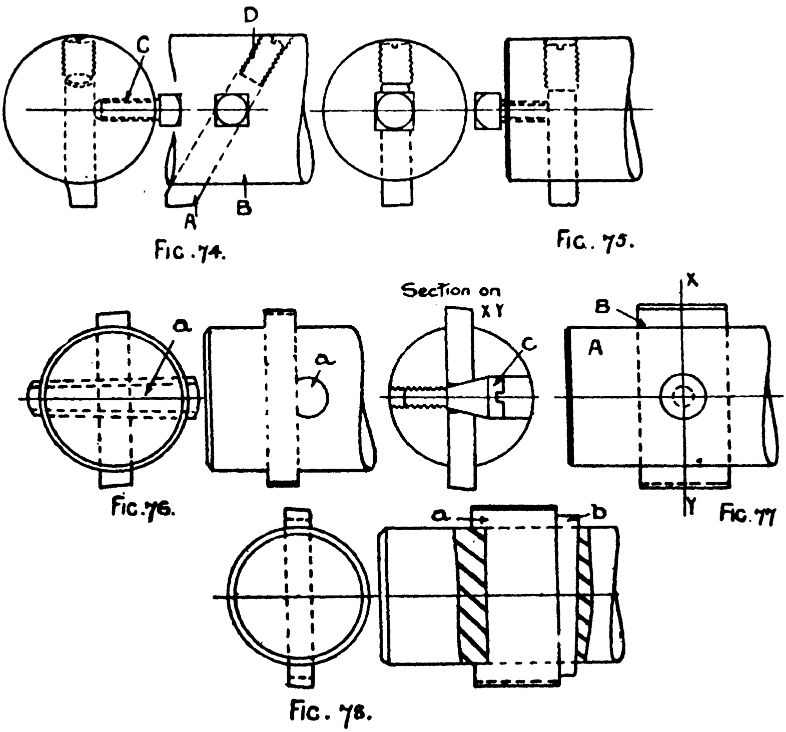
Fig. 72.—Special type of reamer.
Fig. 73.—Shell reamer on boring bar.

teeth must not be allowed to sink too deep, otherwise there will be a danger of the reamer breaking. The spindle *d* is case hardened, as also is the sleeve *c*.

Fig. 73 shows a shell reamer A fixed on a boring bar, immediately behind the roughing cutter, thus enabling a hole to be rough bored and finished at one setting. Had it been necessary to remove the component between the roughing and finishing operations it might have been found that the work would not set itself in the same position, in which case the reamer A could have been made to "float" (see Fig. 53) by opening its bore a few thousandths of an inch, and the non-alignment of the component would thus be overcome.

**Boring Tools and Holders.**—Several firms have given considerable attention to the subject of boring bars and tools, and the result has been a number of patents covering their products, nevertheless many of the old types of bars still find favour.

One of the simplest is shown at Fig. 74 where the tool A is inserted in the bar B and held by means of the set screw C.




METHODS OF FIXING BORING TOOLS.

To facilitate adjustment, and also to prevent the tool pushing back when under a heavy cut, the screw D is set behind the tool. By arranging the tool across the bar at an angle a slightly longer tool can be used. If necessary the finishing tool can be arranged close behind the rougher, in which case it should be so located that the cutting edges of the two tools are at opposite sides of the bar, thus equalizing the cutting strain. Where the hole being bored is very small and the bar is being kept as large in diameter as possible, the existence of a binding screw on the circumference is impossible, unless a form of grub screw be used, and this is not satisfactory. In some cases this can be overcome by locating the binding screw at the end of the bar as shown in Fig. 75.

Fig. 76 shows another method of holding a boring tool, the length of the latter equalling the diameter of the hole to be bored. A flat is made on the side and in the centre of the tool, and a taper peg *a* is driven in.

As a rough idea of the proportions of this type of cutter to the boring bar, it will be found that the diameter of the cutter, or the thickness if not of round section, will be found quite satisfactory if made to equal about $\frac{1}{5}$ the diameter of the boring bar.

Figs. 77 and 78 show two other methods of fixing cutters. In the former the bar *a* is accurately slotted to take the tool *b*, the latter being held in place by means of a tapered screw *c*.

This taper proves very useful when it becomes necessary to "float" the cutter, it being merely necessary to release the screw according to the amount of "float" desired. With Fig. 78 the cutter *a* has a portion milled out of the centre which enables it to be located central with the bar without any adjusting, and is held there by means of the wedge *b*.

The cutting angle and clearance for boring tools will, of course, depend upon the material and in some cases on the section or form of the component being bored. Fig. 79 shows at X and Y a roughing and finishing tool. The former, it will be noticed, has a pronounced cutting edge *a* due to the tool angle of 60°. This provides a very free-cutting action, but the feed must not be too coarse, and if properly heat-treated such a tool will have a long life.

Clearance is provided on the side *a*, the top *c*, and the end *b*. For the two former this should be about 4 degrees for cast iron and brass, increasing to 6 degrees for malleable iron and soft steel and 10 degrees for aluminium. The end clearance need only be about 2 or 3 degrees, in fact for the finishing tool some designers leave this without any clearance on its end, merely providing a few degrees on its side. This is not advisable, as considerable friction takes place, and particles of metal will sometimes seize on to the cutter and cause enlarged bores. Fig. 79 is another form of cutter for obtaining the finished size, but is not adjustable for wear.

As the accuracy of the fit of the boring bar in its guide bush decides final accuracy of the work produced, any method of maintaining this should be taken advantage of.

Fig. 80 shows one method where the bar has, milled along its length, several slots equally spaced round its circumference, into which are fitted hardened steel strips. The bar is then placed between centres in a grinding machine, and the strips circular ground to the required diameter.

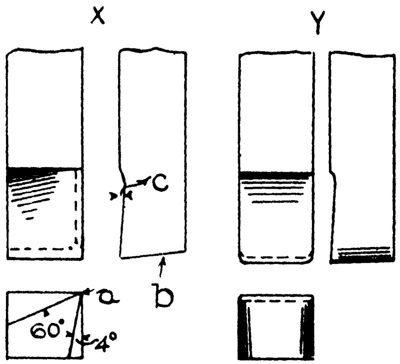



FIG. 79.

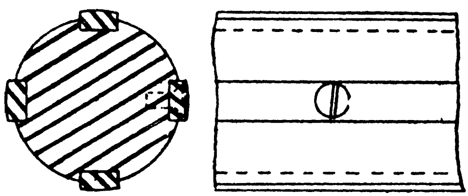


FIG. 80.

FIG. 79.—BORING CUTTERS.
FIG. 80.—BAR CONSTRUCTION.

The diameter of the slotted bar is, in this case, about $\frac{1}{8}''$ less than the final diameter required, and the strips stood out about $\frac{3}{32}''$ above this, before grinding.

**Boring Cutters of Special Form.**—It is necessary with some components to make a cutter of special irregular form, or else with several steps of different diameters which must produce a hole with these diameters concentric and at certain distances apart.

Fig. 81 shows a special flat-bladed boring cutter, perhaps familiar to the reader, used for forming the interior of certain

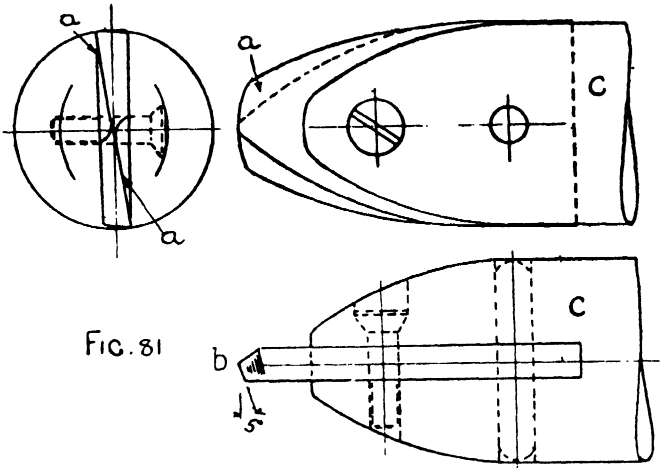



FIG. 81

SPECIAL FORM BORING CUTTER.

projectiles. The method of securing top rake is seen at *a* and this also allows the edges to lay central for the purpose

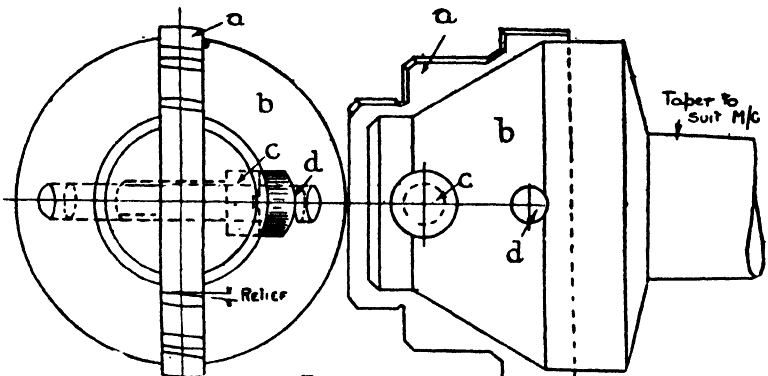



FIG. 82

STEPPED FORM BORING HEAD.

of machining a flat bottom when necessary, the front clearance at *b* being about 5 degrees.

For roughing purposes the profile of the cutter is provided with a number of nicks or chip breakers. This cutter is located centrally on the bar *c* by milling a slot to form a seating, in which it is held by means of a screw and a dowel pin as shown.

A boring head holding another special cutter is shown at Fig. 82, where the cutter *a* has three steps, and is held in a slot in the head *b* by means of the cheese-headed screw *c* and dowel pin *d*. Where it is possible, a component having a bore with several steps should be machined on the capstan lathe, using separate tools for each diameter, as the manufacture of these formed blades, which are scrap when worn undersize, is a very expensive item. The illustration shown is taken from actual practice, but cannot be described as good tool engineering for the reason mentioned.

**Flat Bits.**—Flat bits, one of which is illustrated in Fig. 83, share the work of the reamer and counterbore, their big advantage being cheapness of manufacture. During the late war, huge quantities of this type were used on fuse work, it being an easy job to turn the blanks on a good capstan lathe, set up an indexing head on the milling machine to mill the two sides; there then remained the three most important operations of giving side clearance, hardening, and finally grinding to size.

The portion *a* performs the work of an ordinary reamer and the rear part of *b* that of the counterbore. To enable the cutting edges at *c* to be so ground as to produce a square shoulder and also to facilitate any subsequent grinding, the blade is undercut as shown at *c*.

The blade portion should not be of too thin a section, and it will be found that a thickness of about $\frac{1}{8}$ D, where D equals the diameter of the cutter, or where there are two diameters as in Fig. 83, D can represent the mean of these.

The front clearance for the counterbore, also for the bottom of the reamer if it has to make the bottom of the hole square, should not exceed 4 degrees, otherwise the cutter will tend to dig into the work and probably break.

To avoid the tendency of bits and reamers generally to produce holes "bellmouthed," i.e. larger at the mouth than at the back, a slight back taper of about ·005" per foot will be an advantage. The side clearance on all cutter foot the flat-blade type should be represented by an arc as shown in Fig. 84, A, in preference to the double flat method as at B, the latter often being the cause of "chatter," particularly when new or recently sharpened.

**Counterbores and Spot-facing Cutters.**—There does not exist a great difference between these two types of cutter,

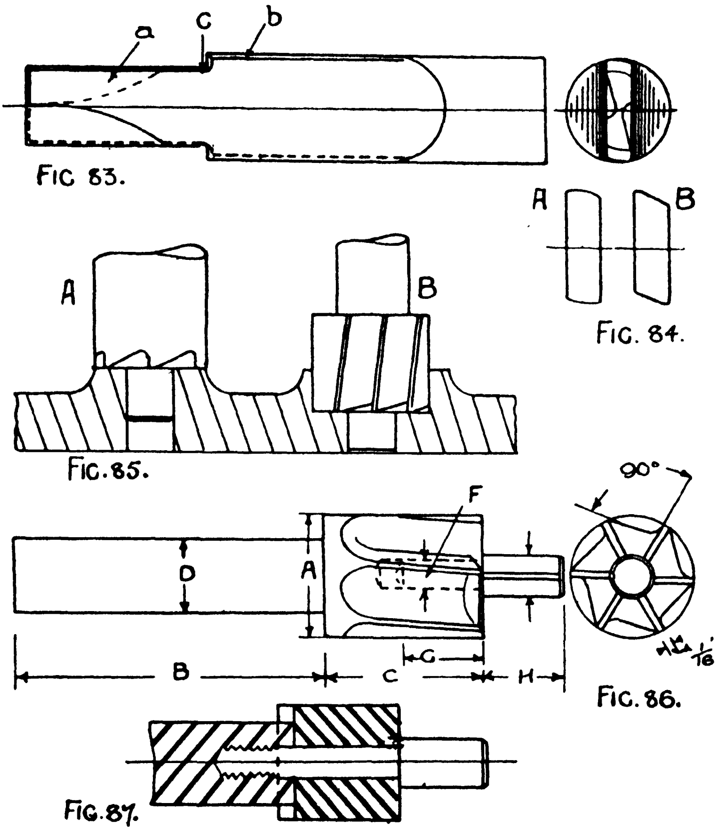



FIG. 83.—FLAT BIT.
FIG. 84.—CORRECT RELIEF OR SIDE CLEARANCE.
FIG. 85.—SPOT-FACING AND COUNTERBORING.
FIG. 86.—COUNTERBORE WITH REMOVABLE PIN.
FIG. 87.—COUNTERBORE WITH REMOVABLE CUTTER AND PIN.

but it will be well to point out, that while a counterbore can be used for spot-facing, a spot-facing cutter cannot be used for making a counterbore. A glance at Fig. 85 will show that the cutter at A, which is not provided with any side teeth, would not allow of the escape of the cuttings if taken far below the surface. Fig. 86 illustrates a counterboring cutter with removable pin allowing for the insertion of a pin of varying diameter, the cutter and shank being in one piece. The cutter is generally made of either carbon or high-speed steel. The pin can be either carbon steel hardened and tempered, or case-hardening steel.

The teeth can be cut spiral or straight, depending upon the nature of the material to be machined. With counterbores over $\frac{5}{8}''$ diameter the shank can be made separate from the cutter portion, the latter being slipped on and retained by the pilot pin which screws into the shank as shown in Fig. 87.

Table No. 5 gives fair proportions for counterbores, though, naturally, the relation between the pilot pin and the cutter

TABLE NO. 5.

COUNTERBORES.

| A. | B. | C. | D. | | F. | G. | H. | Number of Teeth. |
|---|---|---|---|---|---|---|---|---|
| In. | In. | In. | In. | | In. | In. | In. | |
| $\frac{3}{4}$ | $3\frac{1}{2}$ | 1 | $\frac{1}{2}$ | Pilot Pin to suit component. | $\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | 4 |
| 1 | $3\frac{1}{2}$ | $1\frac{1}{8}$ | $\frac{9}{16}$ | | $\frac{5}{16}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | 4 |
| $1\frac{1}{2}$ | 4 | 2 | $\frac{7}{8}$ | | $\frac{7}{16}$ | $\frac{3}{4}$ | 1 | 4–6 |
| 2 | 5 | $2\frac{1}{2}$ | 1 | | $\frac{9}{16}$ | 1 | $1\frac{1}{4}$ | 6 |

diameter will vary, and must be made to suit any particular job. The stem or shank can be made straight or to a Morse taper, or any other standard taper required.

The angle of spiral should be about 5 degrees, and this amount will also be quite satisfactory for front clearance on the teeth. To avoid a common trouble with piloted cutters, that is, the seizing of the pilot pin in the hole, the pin is provided with a small groove which retains any grease and also collects any cuttings which would cause binding. Some form of groove or slot should be introduced on all bars or pins used for steady or guiding purposes.

**Countersink Cutters.**—As these are generally used for letting screw heads below the surface and the largest size called for is about $\frac{3}{4}''$ diameter, they are usually made in one piece as in Fig. 88. The diameter of the stem is equal to the diameter of the screw head for which the tool is intended, plus about ·002″ for clearance. Four teeth only are provided, these being formed by using a milling cutter with an angle of 90 degrees.

For large work, where a chamfer or radius is wanted for any purpose, the pattern at Fig. 89 is quite useful, being pro-

FIG. 88.

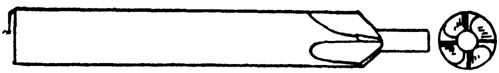


FIG 89.

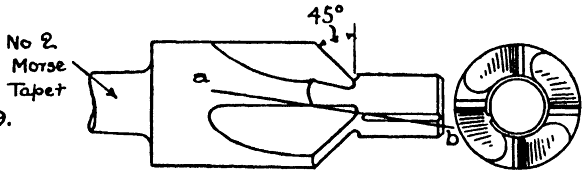



FIG. 90.

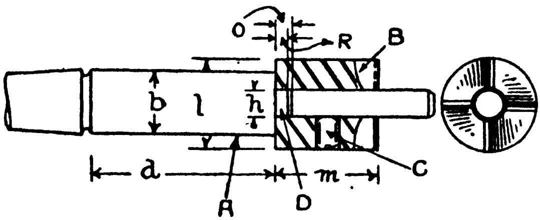



FIG. 91.

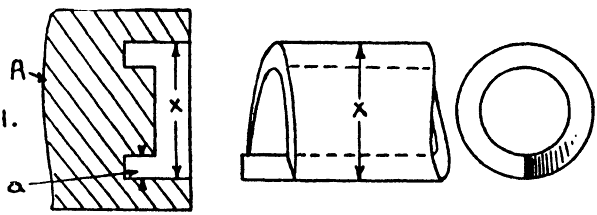



FIG. 88.—SMALL COUNTERSINK.
FIG. 89.—COUNTERSINK FOR LARGER WORK.
FIG. 90.—SPOT-FACING CUTTER.
FIG. 91.—TREPANNING OR SPIRALLY RELIEVED END-WORKING TOOL.

vided with a standard taper shank. If it is intended to use the tool on aluminium or steel rake must be given to the teeth, which can be done by cutting them at an angle of about 5 degrees as indicated by the line *a*, *b*. Note here also the groove in the pilot pin.

**Spot-facing Cutters.**—It has already been mentioned that this tool is employed for facing purposes only, therefore no side teeth are provided. Fig. 90 shows a very useful pattern, the stem and pin A being made in one piece of case-hardening steel hardened and ground, while the cutter B is of high-speed steel held on to the pin by a grub screw C and driven by the tongue D. This convenience of being able to remove the cutter for grinding purposes is much appreciated in the machine shop.

Some idea of the proportions of this tool can be gained by an examination of Table No. 6. The diameter of pin and cutter as with counterbores, will be governed by the work to be done, but a set of cutters and bars to this standard will be found to be very useful and covering a very large range of work. For exceptionally large work the pattern shown in

TABLE No. 6.

SPOT-FACING CUTTERS.

| l. | m. | o. | c. | h. | b. | a. | Taper (Morse). | Number of Teeth. |
|---|---|---|---|---|---|---|---|---|
| In. | In. | In. | | In. | In. | In. | | |
| $\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{1}{8}$ | 2 B.A. | $\frac{1}{4}$ | $\frac{5}{8}$ | $1\frac{15}{16}$ | 1 | 4 |
| $\frac{7}{8}$ | $1\frac{1}{8}$ | $\frac{5}{32}$ | 0 B.A. | $\frac{1}{4}$ | $\frac{3}{4}$ | $1\frac{15}{16}$ | 2 | 4 |
| 1 | $1\frac{1}{8}$ | $\frac{5}{32}$ | $\frac{1}{4}$ Whit. | $\frac{9}{32}$ | $\frac{7}{8}$ | $2\frac{3}{4}$ | 2 | 4 |
| $1\frac{1}{4}$ | $1\frac{1}{2}$ | $\frac{1}{4}$ | $\frac{5}{16}$ Whit. | $\frac{9}{32}$ | $\frac{7}{8}$ | 4 | 2–3 | 4 |
| $1\frac{3}{4}$ | $2\frac{1}{8}$ | $\frac{1}{4}$ | $\frac{5}{16}$ Whit. | $\frac{5}{16}$ | $1\frac{1}{8}$ | 5 | 3 | 4 |

Fig. 92 will be more economical as the circular cutter is replaced by one of the blade pattern.

This particular design of cutter is used in conjunction with the spot-facing fixture, Fig. 93 where the component locates on the hollow stud A which is perfectly square on its base B and the pilot pin of the cutter is a running fit in the bore C.

This method is very satisfactory where the hole in the component varies, making it impossible to pilot directly into the component itself.

The peg E prevents the component from swinging round when the cutting is taking place. The cutter blade, it will be noticed, is held in a similar manner to the boring cutter in Fig. 78.

**Trepanning or Spirally Relieved End-working Tools.**— The economy effected by the use of circular form tools for producing a desired profile on the circumference of a component has resulted in the introduction of a tool on similar principles for reproducing a form on the ends or faces of components in the lathe. Fig. 91 illustrates such a tool where the form can be accurately maintained after the tool has been ground.

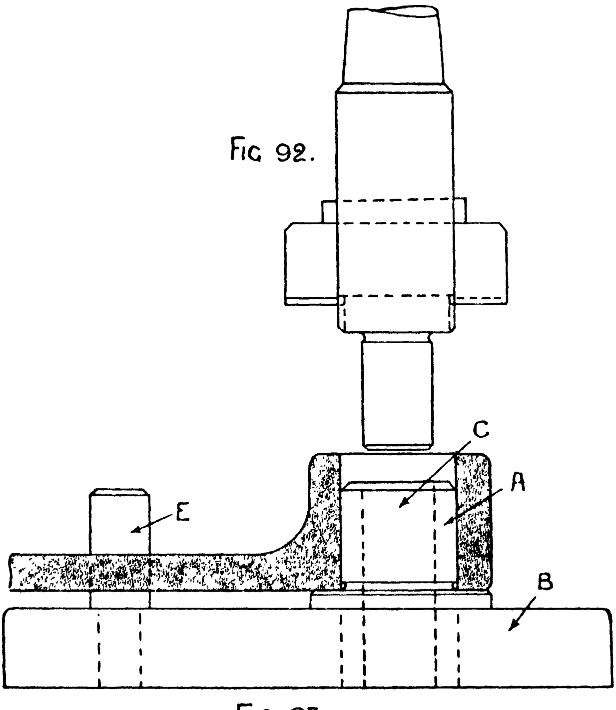



FIG. 92.—SPOT-FACING TOOL FOR LARGE WORK.
FIG. 93.—SPOT-FACING FIXTURE WITH COMPONENT IN POSITION

A section of the component is shown at A where the internal recess *a* is required to be maintained at a certain width. It is obvious that with a flat type of tool re-grinding would be very difficult, and the weak form of tool thus produced would " chatter " and probably break.

The lead of the spiral necessary to provide front clearance, assuming the circumference of the tool to be, say, 6″, would be ½″, from which it will be found that the clearance angle will be approximately 5 degrees. The diameter of the tool x should be a running fit in the component to act as a guide, and it might be said that the only objection to this type of tool is its lack of chip capacity. The cutter can be attached to a mild or other steel holder.

**Broaches.**—Broaching is an operation that is rapidly coming to the front not merely to displace some reaming operations, but on the actual production of formed work, an instance of this being the broaching of teeth on internal gears.

An illustration of a broach use on blanks for automobile gears to produce the spline in their bores is shown in Fig. 94.

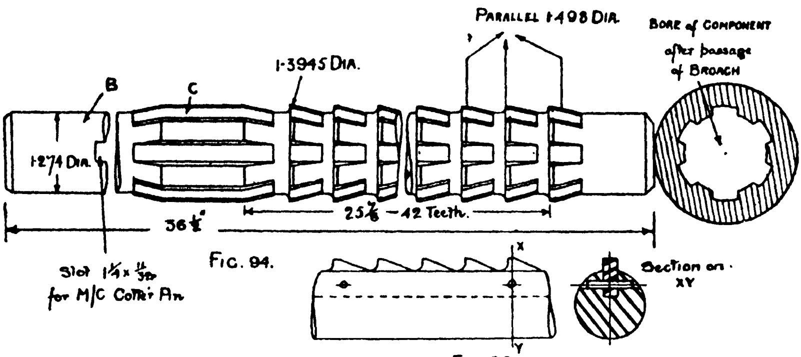



Fig. 94.—Broaches.
Fig. 95.—Keyway broaches.

As the material from which the gears were made was a very tough steel, it was found necessary to have two broaches, one to follow the other, the one shown being the second.

In designing broaches there are several points to be kept in mind, the first of which is the amount of metal to be removed, and next, the proportion per tooth. For round holes that merely require sizing about ·020″, that is ·010″ each side, will be found a correct amount for the broach to remove, and the amount per tooth can be ·001″ or ·002″.

With the broach in Fig. 94, the total amount to be removed is shown by the depth of the spline, and allowing the same amount per tooth and the necessary amount of space between the teeth for clearance, it is obvious that a broach longer than any standard broaching machine could accommodate would be necessary, hence the two broaches as already mentioned.

With this broach, seeing that only about $\frac{1}{8}$th of the circumference of the hole is in contact with the broach, an amount of ·0025″ per tooth was removed.

The question of pitch of distance between the teeth must also be dealt with, and as a starting-point it has been found by experience that not less than two teeth, or more than four, should be in contact with the work at once. It is also clear that the space between the teeth must be greater in larger holes to give the necessary clearance for the cuttings.

There were 48 teeth in the broach shown, their diameter commencing at 1·3945″, leaving the last three parallel at 1·498″ to guarantee the finished size.

The correct form and spacing for the teeth is largely a matter of experiment, for when large chip capacity is secured it generally means a weakened section of broach.

The teeth are generally given a front rake of about 4 degrees and back clearance of 3 degrees as indicated and the land width of about $\frac{1}{16}$″. The diameter at B is a slide fit in the component, the splines at C having an outside diameter of 1·392″ and being a fit in the gear blank as it leaves the first broach. When operating the broach, the lack of chip capacity due to strengthening the teeth may be compensated by having plenty of lubricant pumped on to the broach; there are, however, some broaches on the market of hollow section, allowing lubricant to be pumped through and out of holes drilled at different points in the circumference which assists cutting.

Broaches are generally made in one piece, except where excessive wear occurs, and in this case very successful results have been obtained by making this part removable by providing it with a screwed portion. Keyways are also easily broached, the cutting portion of this type of broach being made separate from the body, into which it is carefully fitted and then pinned as shown in section at Fig. 95.

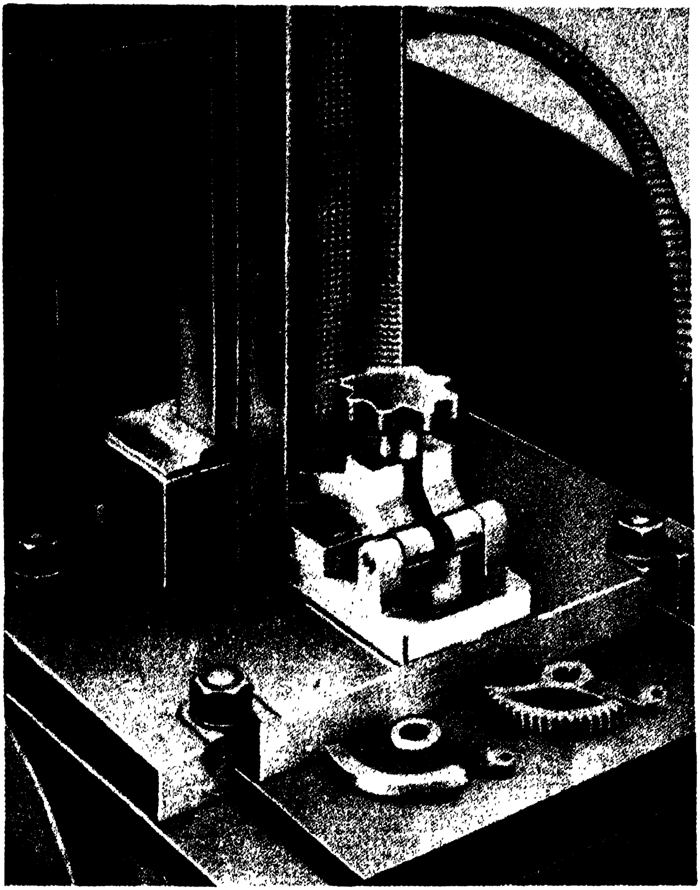


Plate VII.

**Surface Broaching.**—This comparatively recent development is here shown on an Alfred Herbert machine, one of the components being seen in the foreground.

The work is placed in the fixture, the starting lever is depressed, and the broach travels down past the work. The work is then removed, after which the broach returns to its original position at twice its cutting speed.

The simplicity of the work holder is striking.

[*Facing page 118*

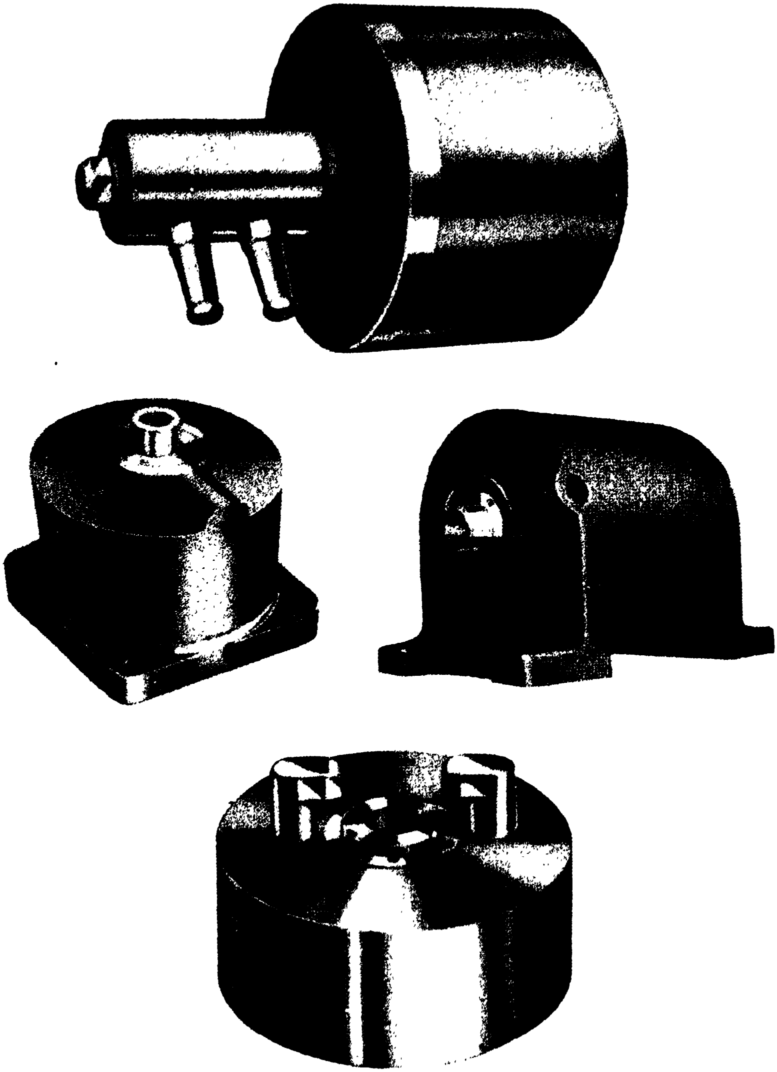


Plate VIIa.

Air-operated units can often be built into a fixture or attached to a machine. *Upper:* Rotating air cylinder for attaching to rear end of machine spindle. *Centre:* Two units ready for any adaptation. *Lower:* A chuck with two fingers air operated. This equipment is the product of F. Pratt & Co. Ltd., Halifax.

[*Facing page 119*

## CHAPTER VIII

# SCREWING EQUIPMENT

Dies—Hinged Button Dies—Spring Dies—Taps—Double Taps—Chasing Tools—Thread Milling Cutters—Nut Taps.

**Dies.**—The development of the releasing die head, holding chasers which can be removed for grinding purposes, and replaced when worn, has sounded the death-knell of ordinary round dies, commonly known as button dies.

As, however, they are at the moment still widely used, it will be well to deal briefly with them.

The chief proportions are given in Table No. 7, the out-

TABLE No. 7.

BUTTON DIES.

| Outside Diameter. | Thickness. | Thread Size. |
|---|---|---|
| In. | In. | In. |
| $\frac{5}{8}$ | $\frac{1}{4}$ | $\frac{1}{16}$ |
| — | — | $\frac{3}{32}$ |
| — | — | $\frac{1}{8}$ |
| — | — | $\frac{5}{32}$ |
| — | — | $\frac{3}{16}$ |
| — | — | $\frac{7}{32}$ |
| — | — | $\frac{1}{4}$ |
| $\frac{13}{16}$ | $\frac{1}{4}$ | $\frac{1}{8}$–$\frac{5}{16}$ |
| 1 | $\frac{5}{16}$ | $\frac{1}{4}$–$\frac{3}{8}$ |
| $1\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{3}{8}$–$\frac{1}{2}$ |
| 2 | $\frac{5}{8}$ | $\frac{1}{2}$–$\frac{3}{4}$ |
| $2\frac{1}{2}$ | $\frac{11}{16}$ | $\frac{1}{2}$–1 |
| 3 | 1 | $\frac{5}{8}$–$1\frac{3}{16}$ |

side diameter and the thickness being important because die holders and adapters are generally made to this standard.

In deciding the proportion of the teeth *b* (Fig. 96) and the size of the clearance holes *c*, a compromise must be effected between the two. As the majority of these dies are made with four teeth, a fair diameter for the clearance holes will be found to equal about $\frac{1}{6}$th of the threading size of the die. The land *a* or width of the teeth must not be excessive, otherwise considerable friction will result, which generally means pieces of the thread being twisted off in the die.

It will be noticed that the size and position of the clear-

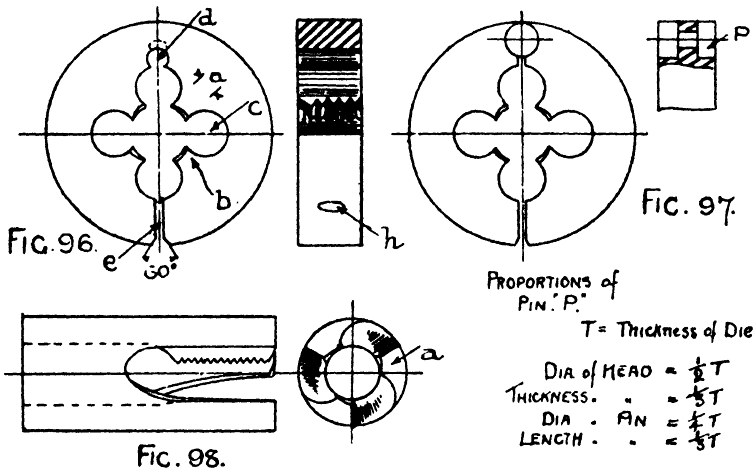



FIG. 96.—BUTTON DIE.
FIG. 97.—BUTTON DIE HINGED.
FIG. 98.—SPRING DIE.

ance holes affect the width of the teeth, and also the amount of rake, if any is wanted, on the cutting edges.

With the clearance hole proportioned as already mentioned, the centre of the latter should be such that the clearance circle cuts away about $\frac{1}{8}$th of the circumference of the centre hole.

The small hole *d* is inserted to add spring, and so facilitate the adjustment of the die. In some cases this hole is elongated as shown dotted, but in any case this hole or slot should not extend further than half-way between the clearance hole and the outside of the die.

Slot *e* is usually about $\frac{1}{16}''$ or $\frac{1}{32}''$ wide and its front is opened at an angle of about 60 degrees to enable the tapered adjusting screw in the die holder or adapter to engage therein. The three countersunk depressions *h* are arranged 120 degrees apart, one at the back and one each side of the slot, for adjusting purposes, and their diameter should be to suit the diameter of the screws in any particular holder in use, or at least $\frac{1}{3}$ of the thickness of the die.

In some cases these dies are left quite solid, the slot *e* being omitted.

**Hinged Button Dies.**—The great disadvantage of button dies lies in the fact that it is impossible to sharpen them easily, and also, unlike other cutting tools, the cutting angle, rake, etc., cannot be varied to suit the various materials used. Button dies provided with a hinge as shown at Fig. 97, however, do permit of regrinding and the provision of rake when necessary, the only objection to these dies being their extra cost of manufacture.

The diameter of the head of the hinge-pin P should be about $\frac{1}{2}$ the thickness of the die, its thickness $\frac{1}{3}$, and the pin or portion between the heads $\frac{1}{3}$, and for the diameter of the pin, about $\frac{1}{4}$ of the die thickness will be quite good.

Dies should be made of steel made for that particular purpose, any alteration in form and pitch of thread after heat treatment rendering the die useless. If the size or form of thread is in any way special, the designer is advised to mark his drawing calling for suitable identification marks to be stamped on the die before finishing.

**Spring Dies.**—This type of die, illustrated in Fig. 98, is not so popular as the button shape, and the writer does not know of any particular quality it possesses, but it appears to find favour in America rather than this country. Its proportions are indicated in Table No. 8.

The gashes that form the cutting edges, generally three in number, are made with a milling cutter having an angle of from 60 to 70 degrees. The length of the threaded portion is from $1\frac{1}{2}$ to twice the diameter of the threaded bore. The lands *a* are proportioned as for button dies, that is, their width should equal about $\frac{1}{8}$ of their threaded bore.

The finished die should be hardened and tempered so as to provide spring for the jaws, because adjustment is obtained by slipping a collar over the jaws, the latter having three grub screws by which means the jaws are set in or released.

If the die is too hard the jaws will break on adjustment, if too soft the jaws will not open out after having been once set in.

**Taps.**—The manufacture of taps for ordinary commercial purposes is quite simple work, but where the form and pitch of the thread have to be very accurate, the various dimensions of the standard thread have to be modified.

In some cases the test for a threaded bore, apart from the fit of a thread gauge, will be a cylindrical plug gauge, of a diameter about equal to the core diameter of the thread being produced, and if this enters, the hole is not considered satisfactory. When inspection is very strict on this point,

TABLE NO. 8.

SPRING DIES.

| Outside Diameter. | Length. | Size of Thread. |
| --- | --- | --- |
| In. | In. | In. |
| $\frac{1}{2}$ | $1\frac{1}{4}$ | $\frac{1}{8}$ |
| $\frac{1}{2}$ | $\frac{1}{4}$ | $\frac{1}{4}$ |
| $\frac{3}{4}$ | $1\frac{3}{4}$ | $\frac{3}{8}$ |
| 1 | 2 | $\frac{1}{2}$ |
| $1\frac{3}{16}$ | $2\frac{1}{4}$ | $\frac{5}{8}$ |
| $1\frac{3}{16}$ | $2\frac{1}{4}$ | $\frac{3}{4}$ |

the correct size can be obtained by varying the depth of the thread on the tap by a few thousandths.

Also when the form of the thread on the tap is affected by final heat treatment, thus interfering with the fit of the finished component, the effective diameter which governs the angle of the thread can be corrected to obviate this. Ordinary hand taps are rarely made, being bought cheaper from firms who specialize and produce them in huge quantities. Taps of special form of thread and diameter, however, are drawn by the jig and tool department.

As the length of the shank and its diameter is often decided by the conditions and holders available, it is not proposed to offer any proportions for this.

Factors such as the nature of the material, thickness of wall round the hole, etc., have to be considered when dealing with special taps. Standard cutters are available which are indicated by numbers. No. 1 being suitable for taps up to $\frac{1}{8}''$ diameter, and No. 8 for taps between $1\frac{11}{16}''$ and $2''$ diameter. Convex milling cutters are also satisfactory in some cases and a rough balance

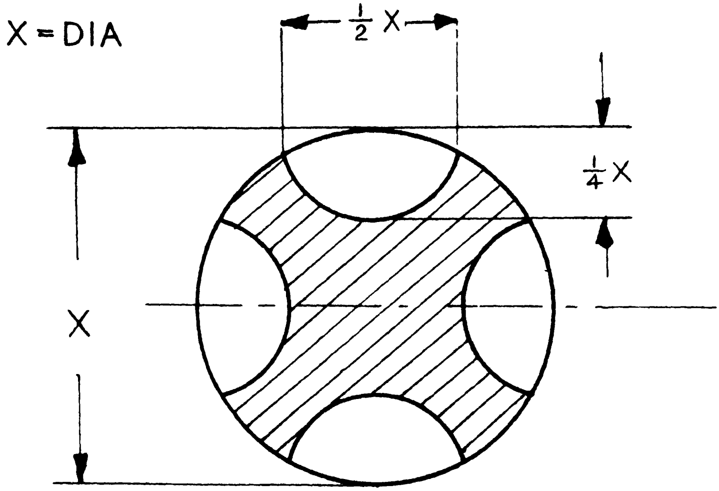



FIG. 99.
TAP FLUTE PROPORTIONS.

between the land and flute can be obtained by dropping the cutter into the tap by a distance equal to one quarter of its diameter as shown in Fig. 99. Excessive land makes tapping difficult due to friction, while too little means a reduction in tap life. Maximum chip room is essential. Recent developments in grinding practice have made it possible to grind the thread instead of cutting it, also, relief can be given, a combination which makes for free cutting. Taps for tapping nuts known as Nut taps and Tapper taps, have a long shank, *e.g.*, a ⅜" tap has a total length of 11", and its diameter is just below that of the taps core size. These are generally provided with three or four flutes,

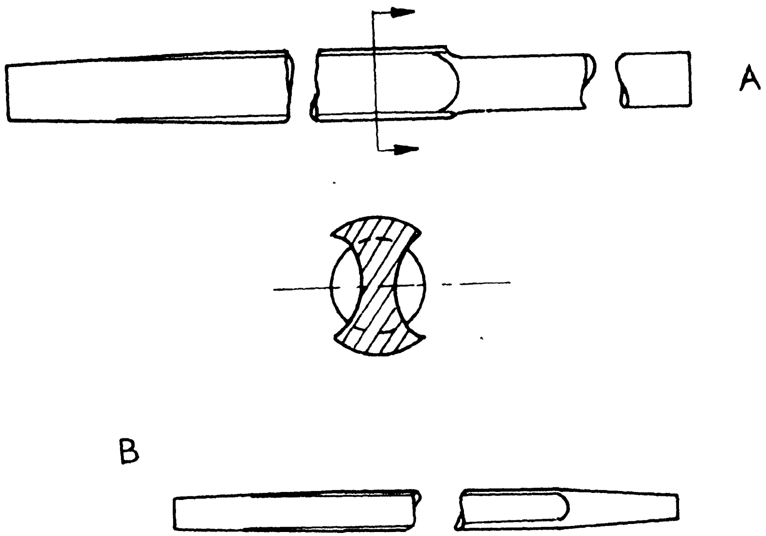



FIG. 100

FIG. 100.
TWO FLUTED TAPS.

but for long holes, especially in soft material, it may be better to have two flutes as at A, Fig. 100. The same applies to the small Straight Through taps, B, Fig. 100, which are provided with a tapered four-sided cone to suit its female counterpart in the vertical machine spindle by which it is driven through the work. An ideal tap for such work as cycle spoke nipples, etc.

**Double Taps.**—Where two concentric bores require threading, and the threads are of equal lead, this can be accomplished by means of a double tap as shown at Fig. 102. The larger tap is a sliding fit on the smaller and is held thereon by means of a screw A, the latter having a plain pin which enters a small slot, the length of which is sufficient to allow the large tap a small amount of movement, about $\frac{1}{8}''$, in the direction of the axis of the tap. This " play " is useful where the two taps are screwing up to a shoulder, guaranteeing the thread reaching up to this point. With larger size taps proportions laid down for smaller sizes are not adhered to, but where they can be followed it is much better. The lands of these large taps can be obtained by dividing the circumference into twelve parts and taking six of them as teeth, and the diameter of the shank should be made according to the size of the sliding tap, the bore of which must not be made too large, so as to run the risk of the tap cracking when going through heat treatment.

For the same reason the clearance slots of this part of the tap are made shallower, about $\frac{1}{2}$ the width of the grooves will be found to answer. In this design of tap the lengths $x$ will, of course, depend on the component.

**Chasing Tools.**—For the production of threads for ordinary commercial work, a simple single-point chaser of the pattern shown in Fig. 103 is used, where it will be noticed that the tool only allows for a radius at the bottom of the thread, and if the blank diameter of the work is left oversize, a thread with a knife edge will result.

It is usual, however, to make the blank size slightly small, so that a very small flat on the thread top replaces the radius. Where the form is to be produced more accurately, provision must be made for the top radius in the manner shown in Fig. 104. The front clearance for these tools should be as small as possible, 2 to 4 degrees being quite enough, otherwise the cutting-point is weakened.

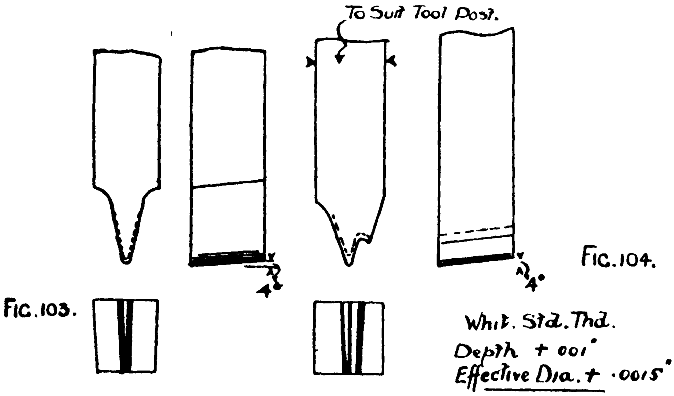
The chaser in Fig. 104, it will be noticed, is to be made ·001″ deeper than the standard size, making the core diameter ·002″ small, the effective diameter is also to be ·0015″ higher than the standard.

**Thread Milling Cutters.**—Thread milling is an operation that was greatly developed during the war, and lends itself to cheap production.

When considering the design of cutters, the points mentioned in connection with milling cutters hold good.

Fig. 105 shows a very useful type of cutter which is held on its arbor by means of a cheese-headed screw, the head of which fits the countersunk portion *a* laying flush with the end *b*, thus enabling the cutter to work close to a shoulder.

To assist in driving the cutter, a keyway of circular form



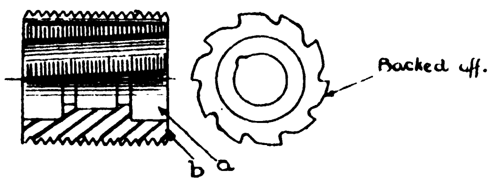




FIG. 103.—SIMPLE SINGLE-POINT CHASING TOOL.
FIG. 104.—SINGLE-POINT CHASER WITH PROVISION FOR CREST RADIUS.
FIG. 105.—THREAD MILLING CUTTER.

is cut in the bore, which fits a key of corresponding shape on the arbor. The round form is selected because the avoidance of sharp corners prevents cracking, which could easily happen in so thin a shell. It will be noticed that this pattern cutter is counterbored both ends, permitting it to be turned round when cutting threads of different hand.

The teeth for this diameter cutter are ten in number and the clearance slots are milled with a cutter having an angle of about 60 degrees, provided with a radius, and to a depth equal at least to twice the depth of the thread. The slots are so milled as to make the cutting edges radial and the top of the threads are form relieved (see Fig. 64), allowing for sharpening by grinding the cutting faces. The slots are also best milled at an angle of 10 degrees, which will greatly assist cutting and avoid "chatter."

In some types the cutter is integral with the arbor, but, in the writer's opinion, that indicated in Fig. 105 is both satisfactory and economical.

## CHAPTER IX

# GAUGES

Limits—Plug Gauges—Caliper Gauges—Scissor Gauges—Depth Gauges—Screw Thread Gauges—Profile Gauges—Combination Gauges—Variety—Materials—Pilot Gauges.

To produce repetition work quickly and to dimensions, it is necessary to obviate the necessity of taking measurements with the usual precision instruments, micrometers, verniers, etc., and more so is this essential where unskilled or semi-skilled labour is employed. Another reason for their use is to secure interchangeability at as low a cost as possible. This is accomplished by fixing limits of accuracy to whatever class of apparatus is being manufactured, which will allow of the component parts being assembled without difficulty, and at the same time allow them to be produced cheaply. The plug gauge, Fig. 106, for example, has one end made to a diameter of ·75″ and the other ·760″, the difference, or tolerance, being ·010″.

This means that the hole produced must allow the ·75 end to enter and not the ·760 end, thus the hole will be within the limits decided.

**Limits.**—It is not proposed here to discuss in detail the question of limits and the methods of fixing them, because almost every firm has a different method, and also at the moment correct limits and gauging methods generally is forming the subject of much controversy. Further, the fixing of limits is usually accomplished by the chief inspector in conjunction with the person responsible for the design of the article being produced. As, however, in the building of jigs and fixtures some system of limits is necessary to secure interchangeability and the correct fit, details of a well-known scheme known as the "Newall" are given.

Table No. 9 gives various classes of fits for diameters, ranging from ½″ to ·12″, which is a useful range. As it is generally easier to secure varying degrees of accuracy exter-

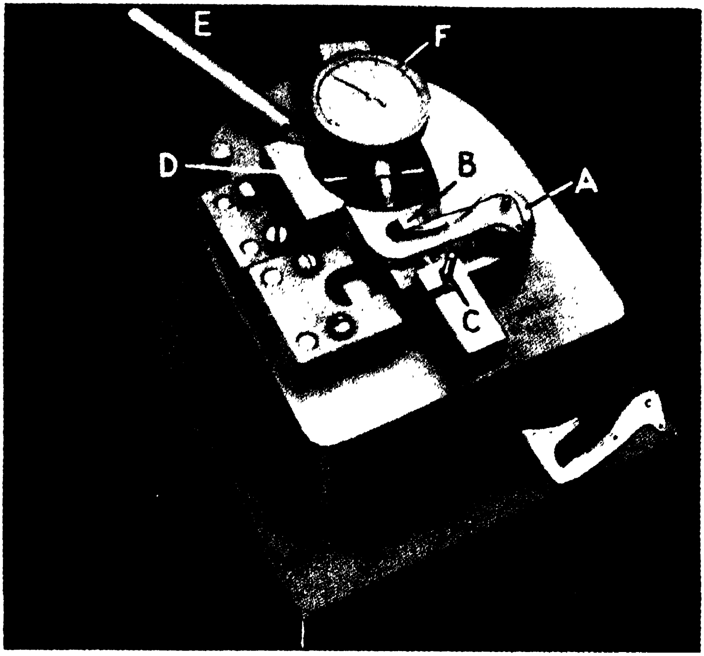


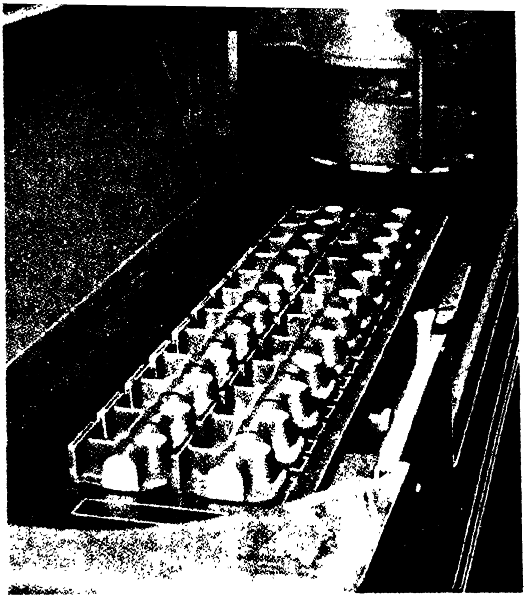

Plate VIII.

**Checking Fixtures.**—Among the immense variety of components produced for various purposes, there arise frequent occasions when a certain dimension cannot be checked by means of regular gauges; in short, the gauge instead of being a portable device has to be made bulkier and consequently becomes a fixture.

Here is a good example of such a fixture which was designed to check a calculating machine part A, one of which is also seen lying at the base.

It will be noted that the latch portion is held against a location piece B by means of a spring-loaded plunger C. Block D is radiused to the dimension required, namely 1·015″ and the dial gauge F set to it. By moving the lever E, the diamond point of the dial gauge is made to swing round in the ground radius and any deviation from the correct dimension that occurs is read on the dial.

[*Facing page 128*



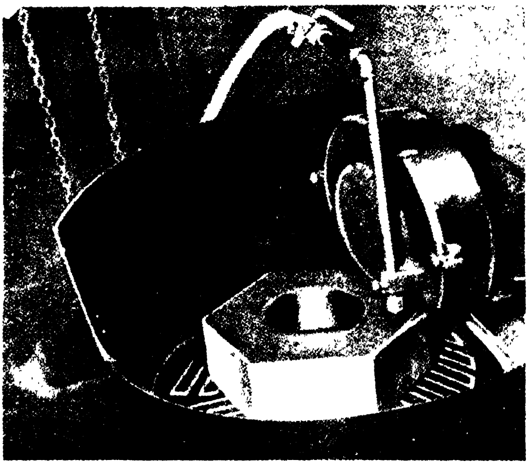


Plate VIIIa.

In smaller works a degree of responsibility for methods of production may rest upon the tool designer, so that he should make himself acquainted with the plant available. In this case no fixture is needed. *Upper:* Churchill grinder facing 24″ "Lang" sud pump castings on a magnetic chuck. *Lower:* Here we see a hexagon turret for the "Lang" 26″ surfacing and boring lathe being ground on a Churchill piston ring and surface grinder.

[*Facing page 129*

# NEWALL STANDARD LIMITS. — ALL SIZES UP TO 12". —

## TOLERANCES IN STANDARD HOLES. (2 GRADES.)

TABLE No. 9.

| CLASS. | NOMINAL DIAMETERS | UP TO 1/2" | 9/16"–1" | 1 1/16"–2" | 2 1/16"–3" | 3 1/16"–4" | 4 1/16"–5" | 5 1/16"–6" | 6 1/16"–7" | 7 1/16"–8" | 8 1/16"–9" | 9 1/16"–10" | 10 1/16"–11" | 11 1/16"–12" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | HIGH LIMIT | +·00025 | +·00050 | +·00075 | +·00100 | +·00100 | +·00100 | +·00150 | +·00150 | +·00175 | +·00175 | +·00175 | +·00200 | +·00200 |
| | LOW " | −·00025 | −·00025 | −·00025 | −·00050 | −·00050 | −·00050 | −·00050 | −·00075 | −·00075 | −·00100 | −·00100 | −·00100 | −·00100 |
| | TOLERANCE | ·00050 | ·00075 | ·00100 | ·00150 | ·00150 | ·00150 | ·00200 | ·00225 | ·00250 | ·00275 | ·00275 | ·00300 | ·00300 |
| B | | +·00050 | +·00075 | +·00100 | +·00125 | +·00150 | +·00175 | +·00200 | +·00225 | +·00225 | +·00250 | +·00250 | +·00275 | +·00275 |
| | | −·00050 | −·00050 | −·00050 | −·00075 | −·00075 | −·00075 | −·00100 | −·00100 | −·00125 | −·00125 | −·00125 | −·00125 | −·00150 |
| | | ·00100 | ·00125 | ·00150 | ·00200 | ·00225 | ·00250 | ·00300 | ·00325 | ·00350 | ·00375 | ·00375 | ·00400 | ·00425 |

## ALLOWANCES FOR VARIOUS FITS.

FORCE FITS.

| CLASS. | | UP TO 1/2" | 9/16"–1" | 1 1/16"–2" | 2 1/16"–3" | 3 1/16"–4" | 4 1/16"–5" | 5 1/16"–6" | 6 1/16"–7" | 7 1/16"–8" | 8 1/16"–9" | 9 1/16"–10" | 10 1/16"–11" | 11 1/16"–12" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F | | +·00100 | +·00200 | +·00400 | +·00600 | +·00800 | +·01000 | +·01200 | +·014 | +·016 | +·018 | +·020 | +·022 | +·024 |
| | | +·00050 | +·00150 | +·00300 | +·00450 | +·00600 | +·00800 | +·01000 | +·012 | +·014 | +·016 | +·018 | +·020 | +·022 |
| | | ·00050 | ·00050 | ·00100 | ·00150 | ·00200 | ·00200 | ·00200 | ·002 | ·002 | ·002 | ·002 | ·002 | ·002 |

DRIVING FITS.

| CLASS. | | UP TO 1/2" | 9/16"–1" | 1 1/16"–2" | 2 1/16"–3" | 3 1/16"–4" | 4 1/16"–5" | 5 1/16"–6" | 6 1/16"–7" | 7 1/16"–8" | 8 1/16"–9" | 9 1/16"–10" | 10 1/16"–11" | 11 1/16"–12" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D | | +·00050 | +·00100 | +·00150 | +·00250 | +·00300 | +·00350 | +·00400 | +·00450 | +·00500 | +·00550 | +·00600 | +·00650 | +·00700 |
| | | +·00025 | +·00075 | +·00100 | +·00150 | +·00200 | +·00250 | +·00300 | +·00300 | +·00350 | +·00400 | +·00450 | +·00450 | +·00500 |
| | | ·00025 | ·00025 | ·00050 | ·00100 | ·00100 | ·00100 | ·00100 | ·00150 | ·00150 | ·00150 | ·00150 | ·00200 | ·00200 |

PUSH FITS.

| CLASS. | | UP TO 1/2" | 9/16"–1" | 1 1/16"–2" | 2 1/16"–3" | 3 1/16"–4" | 4 1/16"–5" | 5 1/16"–6" | 6 1/16"–7" | 7 1/16"–8" | 8 1/16"–9" | 9 1/16"–10" | 10 1/16"–11" | 11 1/16"–12" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P | | −·00025 | −·00025 | −·00025 | −·0005 | −·0005 | −·0005 | −·0005 | −·00050 | −·00050 | −·00050 | −·00075 | −·00075 | −·00075 |
| | | −·00075 | −·00075 | −·00075 | −·0010 | −·0010 | −·0010 | −·0010 | −·00125 | −·00150 | −·00150 | −·00200 | −·00200 | −·00200 |
| | | ·0005 | ·0005 | ·0005 | ·0005 | ·0005 | ·0005 | ·0005 | ·00075 | ·00100 | ·00100 | ·00125 | ·00125 | ·00125 |

RUNNING FITS. (3 GRADES)

| CLASS. | | UP TO 1/2" | 9/16"–1" | 1 1/16"–2" | 2 1/16"–3" | 3 1/16"–4" | 4 1/16"–5" | 5 1/16"–6" | 6 1/16"–7" | 7 1/16"–8" | 8 1/16"–9" | 9 1/16"–10" | 10 1/16"–11" | 11 1/16"–12" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X | | −·00100 | −·00125 | −·00175 | −·00200 | −·00250 | −·00300 | −·00350 | −·00350 | −·00350 | −·00375 | −·00400 | −·00400 | −·00425 |
| | | −·00200 | −·00275 | −·00355 | −·00425 | −·00500 | −·00575 | −·00650 | −·00675 | −·00700 | −·00750 | −·00800 | −·00825 | −·00850 |
| | | ·00100 | ·00150 | ·00175 | ·00225 | ·00250 | ·00275 | ·00300 | ·00325 | ·00350 | ·00375 | ·00400 | ·00425 | ·00425 |
| Y | | −·00075 | −·00100 | −·00125 | −·00150 | −·00200 | −·00225 | −·00250 | −·00275 | −·00275 | −·00300 | −·00325 | −·00325 | −·00350 |
| | | −·00125 | −·00200 | −·00250 | −·00300 | −·00350 | −·00400 | −·00450 | −·00475 | −·00500 | −·00550 | −·00575 | −·00600 | −·00625 |
| | | ·00050 | ·00100 | ·00125 | ·00150 | ·00150 | ·00175 | ·00200 | ·00200 | ·00225 | ·00250 | ·00250 | ·00275 | ·00275 |
| Z | | −·00050 | −·00075 | −·00075 | −·00100 | −·00100 | −·00125 | −·00125 | −·00125 | −·00150 | −·00150 | −·00150 | −·00175 | −·00175 |
| | | −·00075 | −·00125 | −·00150 | −·00200 | −·00225 | −·00250 | −·00275 | −·00275 | −·00300 | −·00300 | −·00325 | −·00350 | −·00350 |
| | | ·00025 | ·00050 | ·00075 | ·00100 | ·00125 | ·00125 | ·00150 | ·00150 | ·00150 | ·00150 | ·00175 | ·00175 | ·00175 |

nally than internally, only two grades of fit, A and B, are given for holes, and the letters F, D, P, X, Y, Z indicate limits that will ensure a certain class of fit. For example, a shaft machined to F limits will require machine pressure to force it into a hole. One arranged for D limits will allow of a driving fit, while P limits give a push fit. Shafts machined to the limits at X and Y are suitable for revolving work, or running fits, and that at Z for the very accurate work called for in tool production.

This system simplifies matters considerably, for, instead of writing a dimension, say, $3\frac{1}{16}''$ + ·0010″ and − ·0005″, it is only necessary to call for $3\frac{1}{16}''$ A, and the mechanic knows at once what class of fit is required, and, more important still, any number of mechanics working to this method would produce exactly the same results.

**Plug Gauges.**—These vary somewhat in construction, but the chief points to be watched are, that they are not too bulky, and therefore expensive, and also that no elaborations are indulged in, some designers making this an opportunity to indulge in a variety of radii and diameters which are both costly and useless.

Remembering the huge variety of components produced, it would be deceptive to lay down any fixed rules for the dimensions of gauges of whatever pattern, and it is obvious that they must vary slightly according to the accessibility of the part being gauged. Table No. 10 gives proportions

TABLE NO. 10.

SOLID PLUG GAUGES.

| Z. | B. | C. | D. | E. | F. |
|---|---|---|---|---|---|
| In. | In. | In. | In. | In. | In. |
| $\frac{3}{16}$–$\frac{3}{8}$ | $1\frac{1}{4}$ | $\frac{1}{2}$ | $1\frac{1}{4}$ | $\frac{3}{16}$ | $\frac{1}{8}$ |
| $\frac{3}{8}$–$\frac{3}{4}$ | 2 | $\frac{3}{4}$ | $1\frac{1}{2}$ | $\frac{3}{8}$ | $\frac{1}{8}$ |
| $\frac{3}{4}$–1 | 2 | $\frac{3}{4}$ | $1\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{1}{8}$ |
| 1–$1\frac{1}{2}$ | $2\frac{1}{4}$ | 1 | 2 | 1 | $\frac{5}{32}$ |
| $1\frac{1}{2}$–2 | $2\frac{5}{8}$ | $1\frac{1}{8}$ | $2\frac{1}{8}$ | 1–$1\frac{1}{2}$ | $\frac{1}{4}$ |

for plugs up to $\frac{3}{4}''$ diameter, below which diameter they are usually made solid. Above this size to about $1\frac{1}{2}''$ diameter they are either lightened by having a hole drilled through, as shown at Fig. 106, the hole having a diameter of about half that of the gauge itself, or the two end-pieces are made separate and hollow, as shown at Fig. 107, thus allowing these to be replaced when worn, without scrapping the

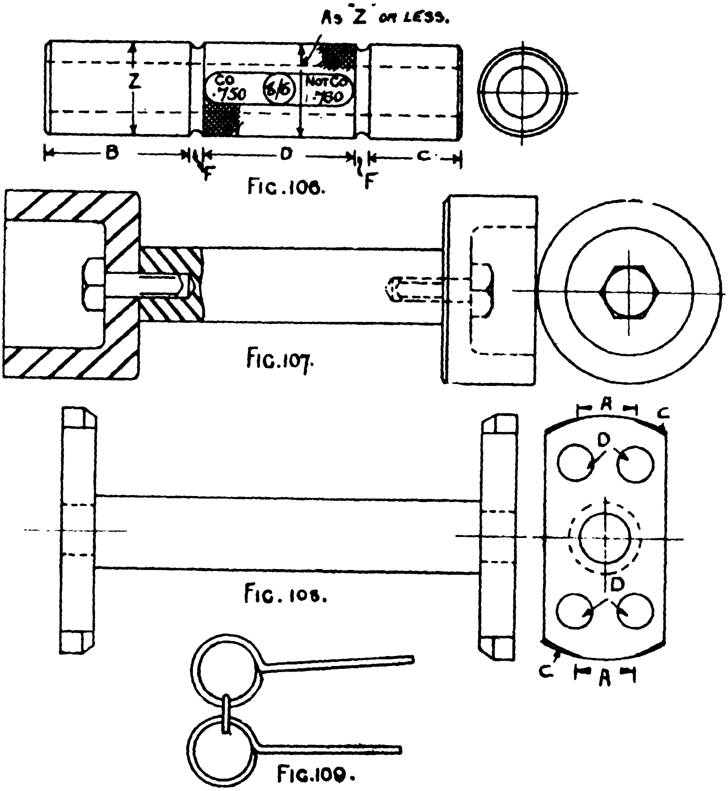



FIG. 106.—SOLID PLUG GAUGE.
FIG. 107.—SOLID PLUG GAUGE WITH RENEWABLE ENDS.
FIG. 108.—PLATE PLUG GAUGE FOR LARGE BORES.
FIG. 109.—PIN PLUG GAUGE FOR SMALL HOLES.

entire gauge. In some works, where the hole to be gauged exceeds 3″ diameter, a plate gauge of the form shown at Fig. 108 is used.

It will be realized that when the limit on a hole of large diameter is very close, it will be found very difficult with a gauge that is heavy to hold it sufficiently square to enter the hole, with the result that the work may be condemned, apart from which considerable time is wasted.

Endeavour should always be made to secure light gauges, while at the same time the possibility of distortion due to weakness must not be overlooked. The type of gauge at Fig. 108 is usually made from sheet steel $\frac{1}{4}''$ to $\frac{1}{2}''$ thick, and the diameter is removed or relieved as indicated at C, leaving a land at A, making it necessary for the inspector to test any hole in two positions to ensure that the latter is quite round.

The handle B is often made of steel tube for lightness, and if necessary the plate can be holed as at D for the same reason. Upon the holder a blank is ground, and the number of the gauge as well as the limits marked thereon.

For very fine holes, say $\frac{1}{8}''$ diameter and less, a useful and cheap form of gauge is shown at Fig. 109, consisting of two pieces of silver steel wire, one on the high and the other on the low limit, linked together, each having a steel or celluloid disc attached marked with the details.

**Caliper Gauges.**—These are often referred to as gap gauges, and again as snap gauges, but it is considered that the word caliper is more fitting, so this word will be adhered to.

This type is used for measuring external diameters and thicknesses, and as the tendency is for the jaws to be forced open, slightly, the strength of the part A, Fig. 110, must be of such a section as to withstand this. The thickness B will depend on the article being checked, if a shoulder exists, as at C, Fig. 111, then a very thin section of about $\frac{1}{4}''$ will suffice. The stem D would call for a gauge of wider section, not for strengthening purposes, but to enable the inspector to check over the length of spindle quicker. It will be best to err on the wide side with all gauges of the caliper class, thus securing a good seating, as at A, Fig. 112, in contrast to that at B, where, owing to the small area of seat, there is the risk of the operator not holding the gauge square and obtaining a false result.

To-day it is not the practice to make these gauges of sheet material, unless a very special form is wanted, as it is possible to buy steel forgings of very strong section visible at A in the photograph, Fig. 122, at a very low price, so that the designer should call for these.

**Scissor Gauges.**—The checking of diameters or recesses calls for the introduction of a special form of caliper gauge known as a scissor gauge. Fig. 113 shows one in position, where it will be noticed that the two limbs are pivoted at a certain point, not too near the measuring points, otherwise the gauge would be clumsy when held in one hand, yet so as to multiply the limit allowed in the recess on the dial B.

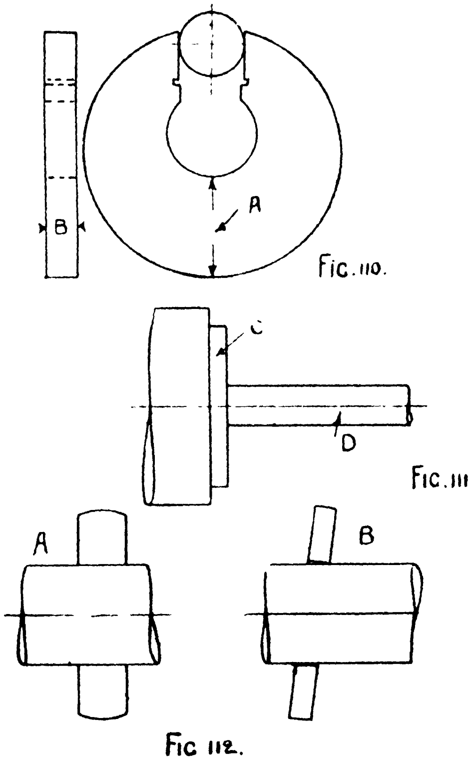


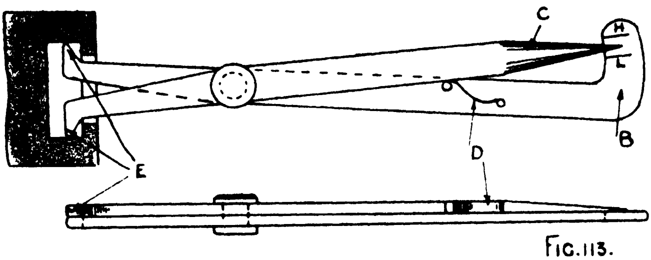

FIG. 110.—CALIPER GAUGES.
FIG. 111.—DECIDING WIDTH OF GAUGE.
FIG. 112.—ADVANTAGE OF WIDTH.

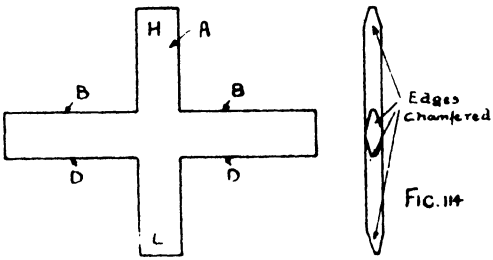
Here it is seen that the limb C has a point which must rest between the high and low limits marked on the dial when the component is correct.

A somewhat similar form of gauge is used for roughly measuring the walls of cylinders, or other pieces where a direct measurement cannot be taken. In the latter case the pivot pin is equidistant from both ends, so that the actual measurement taken on one end is shown fully on the other.

The spring D, Fig. 113, keeps the jaws E in contact with the object being checked, and also makes it possible to use the gauge in one hand.

**Depth Gauges.**—For checking the depth of holes where



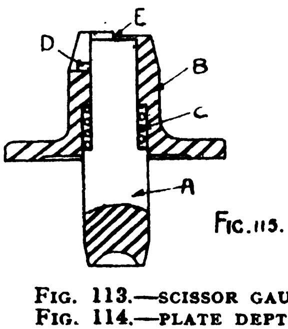




FIG. 113.—SCISSOR GAUGES.
FIG. 114.—PLATE DEPTH GAUGES.
FIG. 115.—PLUG DEPTH GAUGES.

there is a shoulder or flat bottom, the simplest form of gauge is, as shown at Fig. 114, made from sheet steel $\frac{1}{16}$ to $\frac{3}{16}$" thick. The limb A is inserted in the hole till it bottoms, when the shoulders B should swing clear of the top of the component.

When the opposite or low limb is introduced, it should just clear the bottom of the hole and rest on its shoulders D, the difference in the lengths of the limbs being equal to the tolerance allowed in the hole depth.

Another form of depth gauge is shown at Fig. 115, the gauge stem A being a slide fit in the casing B, and retained there by the spring C and the pin D. The tolerance allowed is represented by the step E at the top of the casing, so that the stem A is inserted in the hole, and the outer casing B depressed till it seats on the work, and the top of the stem should rest on the mean of the step E, when the depth of the component is correct. The edges of plate gauges should be chamfered to almost a knife so as to enable the operator to "feel" better, and also to prevent dirt lodging under and giving false results, where the edge of the gauge is hidden this is essential, and in the case of the depth gauge, Fig. 115, the bottom of the stem A should be hollowed, leaving a rim to touch the work.

**Screw Thread Gauges.**—These are among the most expensive gauges to produce, the final hardening process calling for considerable care. If, however, a suitable grade of steel is secured, this risk of spoiling is greatly reduced. Suitable proportions for ring gauges, Fig. 117, that is gauges for checking external threads, are given in Table No. 11.

TABLE No. 11.

RING SCREW GAUGES.

| Bore. | Outside Diameter. | Thickness. |
|---|---|---|
| In. | In. | In. |
| $\frac{1}{8}$ | $\frac{3}{4}$ | $\frac{3}{16}$ |
| $\frac{1}{4}$ | 1 | $\frac{9}{32}$ |
| $\frac{3}{8}$ | $1\frac{1}{4}$ | $\frac{1}{2}$ |
| $\frac{1}{2}$ | $1\frac{1}{2}$ | $\frac{9}{16}$ |
| $\frac{3}{4}$ | 2 | $\frac{3}{4}$ |
| 1 | $2\frac{1}{2}$ | $\frac{7}{8}$ |

The gauge should always be provided with a knurl to assist when the screw fits rather tight.

As the hard work of a thread is taken on its side or angle, this is the part that should be watched carefully ; the crest and the root are obviously not so important.

The finished plug and ring gauge should not screw together, or at least the fit should be rather tight, because there is a tendency for operators to work on the high side for safety, and if the two gauges fit together easily, there is a probability that the components will not assemble.

The writer has found it a great advantage to have a groove made across the threads, as at A, Fig. 116, which enables screwed components, the threads of which are clogged with

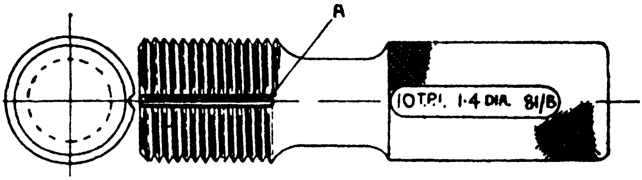



FIG. 116.

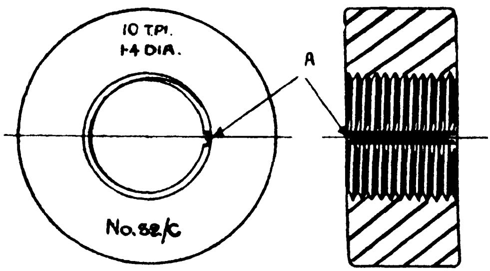



FIG. 117.

FIG. 116.—MALE SCREW GAUGES.
FIG. 117.—FEMALE SCREW GAUGES.

dirt or cuttings, to be checked without having to wash out the threads previously, the groove acting as a scraper.

The difficulty with the gauging of a large quantity of screw threads is that, while the feel of a gauge is quite satisfactory for work that can be seen as well as felt, it is impossible to tell whether the screw that has passed is not low on the effective diameter and simply fits the screw gauge by binding on the tops of the thread, or whether the screw that has been rejected is a little low on the outside diameter, yet has a good angle. In this connection it might be mentioned that there is being developed a method of checking screw threads by reflecting their forms, considerably enlarged.

on a screen against the outline of a perfect specimen, by which means the real dangerous defects are at once made apparent.

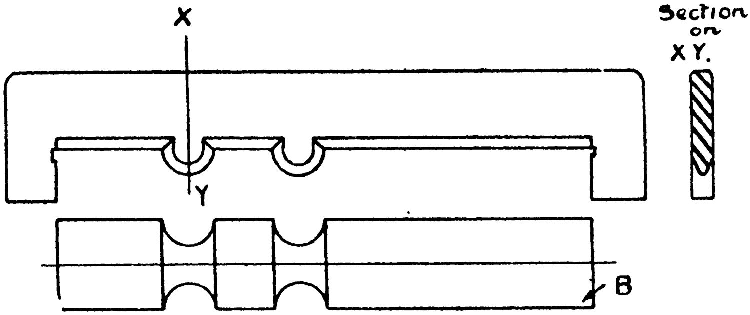



Fig. 118.

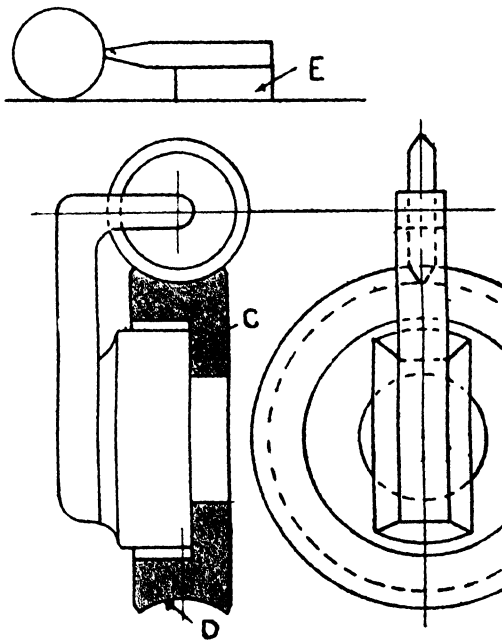



Fig. 119.

Fig. 118.—PROFILE GAUGE.
Fig. 119.—PROFILE AND POSITION GAUGE.

**Profile Gauges.**—As the name suggests, this gauge checks the shape of a component or part of a component. One such is shown at Fig. 122, C, and in outline in Fig. 118

for checking the form and position of the grooves in the component B.

An improvement on this gauge would be to mount the gauge on two small blocks so that its profiled edge is raised from off the surface plate an amount equal to that of the centre line of the component as at E, thus facilitating accurate checking. Another profile gauge, which is also a position gauge, that is, a gauge which checks the relation of one part with another, is shown at D, Fig. 122, and in principle at A, Fig. 119. The component is a worm-wheel blank,

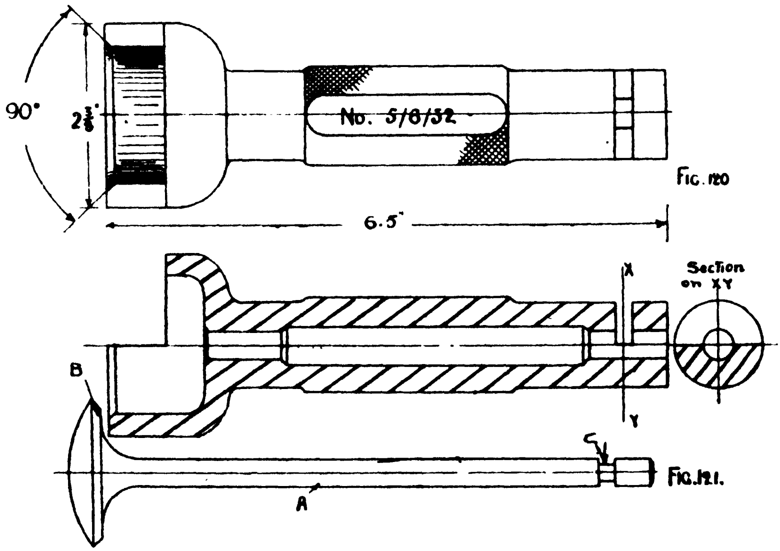



FIG. 120.—COMBINATION GAUGE.
FIG. 121.—COMPONENT AUTOMOBILE ENGINE VALVE FOR WHICH FIG. 120 WAS DESIGNED.

and the concave throat must be of correct radius, and also in correct relation to the seat of the recess C. The gauge therefore takes its seating from this recess, and the circular part checks the form of the throat D, this checking disc being provided with a knife-edge to facilitate this.

**Combination Gauges.**—It is often convenient to combine two or more of the gauges already mentioned, and to illustrate this Fig. 120 is given. The component is an automobile engine valve, shown in the photograph, Fig. 122, at E, as well as in Fig. 121. The gauge checked the diameter of the stem, the straightness of the stem, the angle of the seat B, the diameter of the seat, the concentricity of the seat with the stem, and, lastly, the position of the slot C. The gauge fails in one respect, that is, there is no check on the stem should it be oval or undersize slightly.

**Variety.**—The writer has already mentioned that the designing of production equipment provides a wide field for the ingenious, and to give a very small idea of the multi-

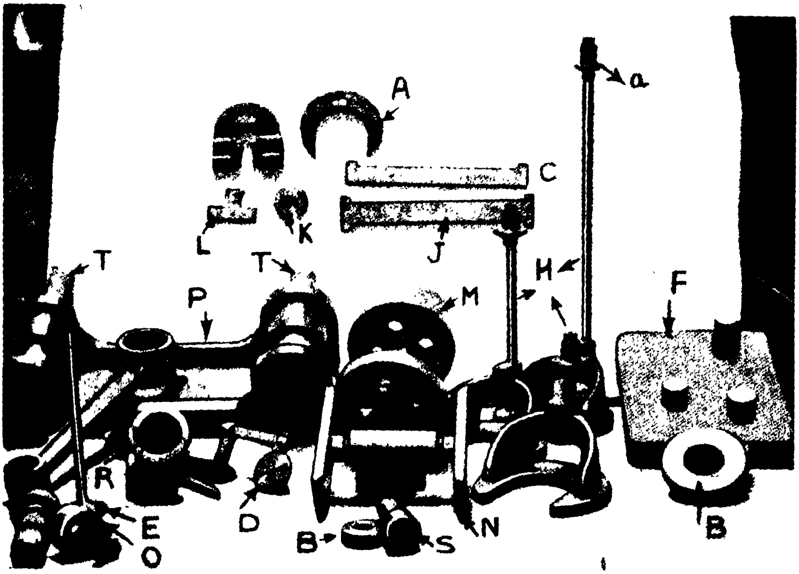



FIG. 122.—GROUP OF VARIOUS GAUGES.

tude and variety of shapes of gauges alone the illustration, Fig. 122, is given.

Some shown have already been mentioned, and the remainder will be briefly introduced. The plate bearing the three pegs at F is for testing the smooth running and correctness of centres of three-gear wheels; by turning them slowly on this, any irregularity in the size or form of the teeth being immediately noticeable.

The base of this fixture is of cast iron, with pegs of hardened steel. The three gauges at H are for checking the relation of the crank pins of a four-throw crank shaft. The thin stem is of steel tube with a hardened steel knife-edged roller at *a*, and the base is of aluminium, with a thin steel sole to avoid wear. The latter locates on the flange at the end of the crank shaft, and a gauge is provided for each crank pin or journal, thus ensuring their correct relation.

J is a plate length gauge made from $\frac{1}{4}''$ sheet steel, with the high and low limits on each side. The small caliper gauge at K is made from a piece cut from a bar of round section, and for measuring up to about $\frac{3}{16}''$ this type can be economically made. The gauge L is for checking the thickness of the rim of a gear wheel, the long upper edge of the gap resting on the gear blank, the gauge being moved down till the small lip touches or misses the other side of the rim. The high and low limits are seen to the right and left.

Immediately above this is an adjustable caliper gauge, allowing an adjustment of $\frac{1}{4}''$ to $\frac{1}{2}''$, that is, its steel measuring pegs can be moved forward or backward to check any piece of a $\frac{1}{4}''$ thickness to $\frac{1}{2}''$, after which the pegs can be locked to prevent their getting accidentally altered. The "Go" pegs are, of course, at the front of the jaws, and the "No Go" immediately behind them. The large plug gauge at M was introduced for purposes of comparison with the plate plug gauge N laying in front of it. The extreme weight and cost of the former will be at once suggested.

At O is seen a dissembled plug gauge, of which mention has already been made. P is a position gauge for the two bores of the engine connecting rod seen laying across it. The two plugs T being a sliding fit in the frame, will not enter the bores of the connecting rod when it is placed in position, should either of its holes be out of position in any way.

The end view of the combination gauge already dealt with can be seen at R. A partial view of a $1\frac{1}{4}''$ male screw gauge is also visible at S. Two ring screw gauges will be noticed at B.

**Materials.**—As gauges are generally expensive tools, the degree of accuracy determining this, the material from which they are made should be such that the possibility of wear is reduced to a minimum. Tcol or carbon steel is the best material for getting hardness with a view to avoiding wear, yet it carries with it danger, for it is possible that it may crack in the hardening, and perhaps a very expensive gauge scrapped.

This is partly overcome by using mild steel or case-hardening steels, and hardening to instructions supplied on application to the makers. In the case of plate gauges, only the parts where wear takes place need be hardened.

With thread gauges the steel should be selected that will harden at a low heat, thus reducing the tendency of the threads to warp or otherwise distort.

Where gauges are of rather bulky size the introduction of aluminium parts to secure lightness should be done with great caution, otherwise the relation of the more important parts may be thrown out by an accidental blow or strain.

**"PILOT" Plug Gauges.**—All mechanics are aware of the care that is needed to insert a plug gauge into a hole particularly when the limit is very fine. The gauge becomes wedged, the work often damaged or else loosened in the machine chuck and much time is wasted. A very simple device has been developed consisting of the machining of a vee groove round the gauge leaving a land of $\frac{1}{8}''$ from the bottom, the latter acting as a pilot, its diameter being reduced by a small amount. It has been found that with this arrangement the gauge can be entered in perfect alignment without difficulty, the lip left by the groove providing a lead. As the use of such a gauge in a *blind* hole would not be satisfactory seeing that the diameter at the bottom for a distance equal to the groove width plus the pilot length could not be checked, a modified type of gauge is used known as the *Semi* Pilot. In this case the groove does not extend completely round the gauge, but two blank portions are left, diametrically opposite. When using this type the gauge must enter across the annular ring otherwise the gauge will jamb as with an ordinary plug. It should be mentioned that this gauge is the subject of a patent and a licence is necessary before making use of it.

## CHAPTER X

# PRESS TOOLS

Simple Blanking Tools—Multiple or Gang Tools—Holding Punches—Bolsters—Strippers—Stops—" Follow " Dies—Piloted Punches—Drawing Tools—Re-Drawing—Combination Tools—Bending Tools—A Special Forming Die—Sub-Presses—Materials.

THIS branch of tool engineering, together with that relating to automatic work, are in the writer's opinion the most important and offering the brightest future. The range of

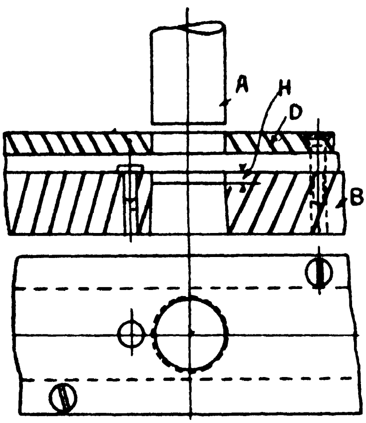


FIG. 123.

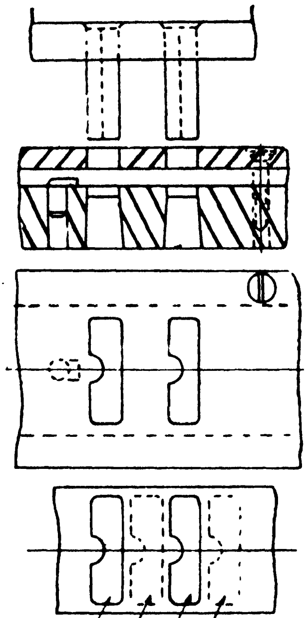


FIG. 124.

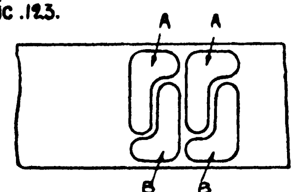


FIG. 125.

FIG. 123.—SIMPLE BLANKING TOOL.
FIG. 124.—MULTIPLE OR GANG TOOL.
FIG. 125.—ARRANGEMENT OF PUNCHES FOR IRREGULAR SHAPED BLANKS.

articles produced by means of the press is enormous, reaching from pins and pen nibs to steel coffins and automobile side frames. More recent engineering practice is against the

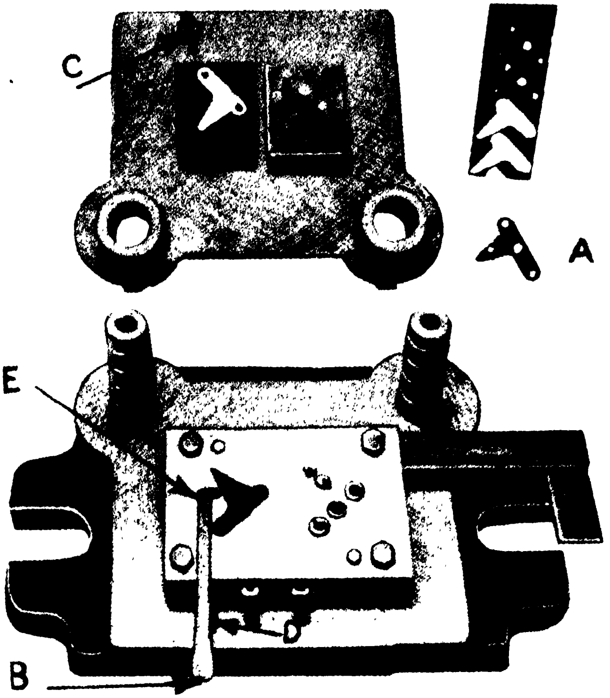



Plate IX.

**Press Tool with Guide Pillars and Side Swing Stop.**—These two features are included in the tool shown where the stamping A is to be produced. The two guide pillars prevent the punches and the die from shearing one another, especially when being set up in the press, thus the length of life of the tool is increased. Bolsters fitted with guides are now obtainable at competitive prices from firms specializing in such items. The action of the stop is as follows:—The trigger B is depressed by the adjustable bolt C on the top tool, just as the punches touch the metal. Upon the up stroke, the trigger drops down, and due to the side pull of the spring D, and the extra space provided at E, the nose of B drops into the hole just punched, the stock having been fed forward immediately the punches were clear.

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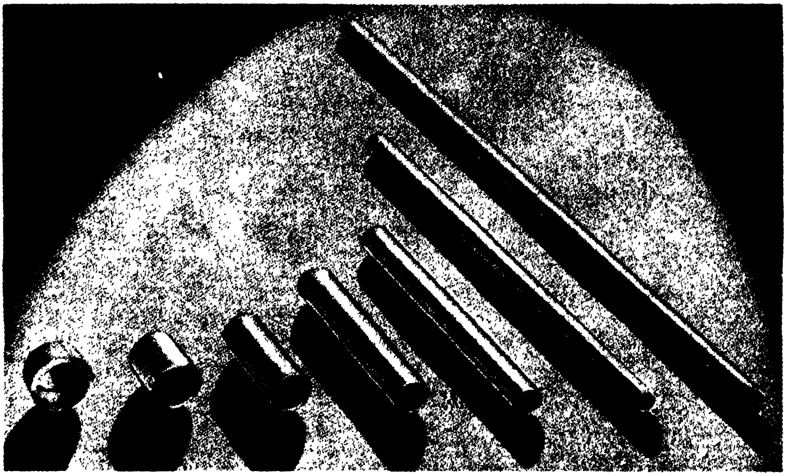

Plate IXa.

*Upper:* Successive "draws" in the fabrication of brass inflator tubes for cycle pumps, during which the metal is reduced from about 0·10″ to 0·02″ thickness.

*Lower:* This shows the influence of blank holder pressure on wrinkle formation. With increased pressure, unless the article has been well annealed, there is risk of the drawing punch bursting through the bottom of the cup. Reading from left to right the pressures are:—220, 264, 331, 375, 441, 529, 639 lbs.

[*Facing page 143*

*Courtesy of Copper Development Assn., Thames House, Millbank, S W.1.*

addition of weight to secure strength, an example of this existing in line-shaft hangers, which, until a few years ago, were made of heavy cast iron, are now pressed out of steel.

A piece of, say, $\frac{1}{32}''$ sheet steel will bend easily in two hands, but make an acute corrugation in it, then try and bend across this, and the result that can be obtained by carefully designed press-work will then be apparent. The

TABLE No. 12.

CLEARANCE BETWEEN PUNCH AND DIE ON DIAMETER.

| Thickness of Material. | Clearance for Soft Brass and Steel. | Clearance for Hard Material. |
|---|---|---|
| In. | In. | In. |
| ·0156 | ·0015 | ·0019 |
| ·025 | ·0025 | ·0031 |
| ·0375 | ·0037 | ·0046 |
| ·05 | ·005 | ·0062 |
| ·062 | ·0062 | ·0078 |
| ·093 | ·0093 | ·0117 |
| ·125 | ·0125 | ·0156 |
| ·1875 | ·0187 | ·0234 |
| ·250 | ·025 | ·0312 |
| ·312 | ·0312 | ·039 |
| ·375 | ·0375 | ·0468 |
| ·437 | ·0437 | ·0546 |
| ·5 | ·050 | ·0625 |
| ·625 | ·0625 | ·0781 |
| ·750 | ·075 | ·0937 |
| ·875 | ·0875 | ·1093 |
| 1·0 | ·10 | ·125 |

reader is advised to make a special study of this very interesting branch.

**Simple Blanking Tools.**—The simplest possible type of blanking tool is shown in Fig. 123, the blank being a round disc.

The fit of the punch A in the die B depends on the thickness of the material being punched. With heavy thick material more clearance must be allowed between the punch and die so as to assist in reducing the strain of punching. With thin metal such as sheet "tin," etc., too much clearance would cause the finished blanks to have a burr on their edges. Some idea of the correct clearance can be gathered from Table No. 12, which is followed by the famous firm of Bliss.

The mouth of the die is generally left straight for about $\frac{1}{8}''$ as indicated at H and then tapering away, the amount of this taper being about 1 or 2 degrees.

The punch should also be a good fit in the stripper plate D, preventing the tool setter from shearing the edge of punch or die when setting them in the press.

**Multiple or Gang Tools.**—In this type two or more blanking punches are grouped in one holder, and in arranging the punches care must be exercised so as not to waste any material, at the same time too close an arrangement of punches will mean thin walls between the dies. The general practice is to allow about $\frac{1}{16}''$ or an amount equal to the thickness of the material being blanked. The actual punches could not, of course, be so closely arranged, but are located as shown in Fig. 124, where with the first stroke of the press the two blanks A are punched, the material is then fed along and those at B are completed.

To avoid waste of metal with irregular shaped blanks, the strip of metal is often fed through the press blanking one side A, Fig. 125, and afterwards passed through again so that the opposite side B is punched.

**Holding Punches.**—The most common and successful method of holding punches is indicated at Fig. 126, where the punch is forced through the punch plate accurately at right angles and the back is then riveted over.

Another method, especially with bending and forming tools, is shown at Fig. 127, where they are held by means of a countersunk headed screw and dowel pins, the latter passing through the back of the punch plate into the punch. With fine punches that are liable to break, provision must be made for quickly extracting them, and this can be accomplished as in Fig. 128 where the punch is held by an ordinary set screw, or the punch can be made with a head and passed through the punch plate, being a very accurate fit, the head being sunk below the surface as in Fig. 129.

**Bolsters.**—This name is given to the cast-iron or steel bed plate upon which is fixed the die when in the press, some dies being fixed permanently thereon, others are removable. One form of bolster is given in Fig. 130, consisting of an iron casting with two lugs A for holding down purposes and a dovetail seating into which fits the die. The set screws B

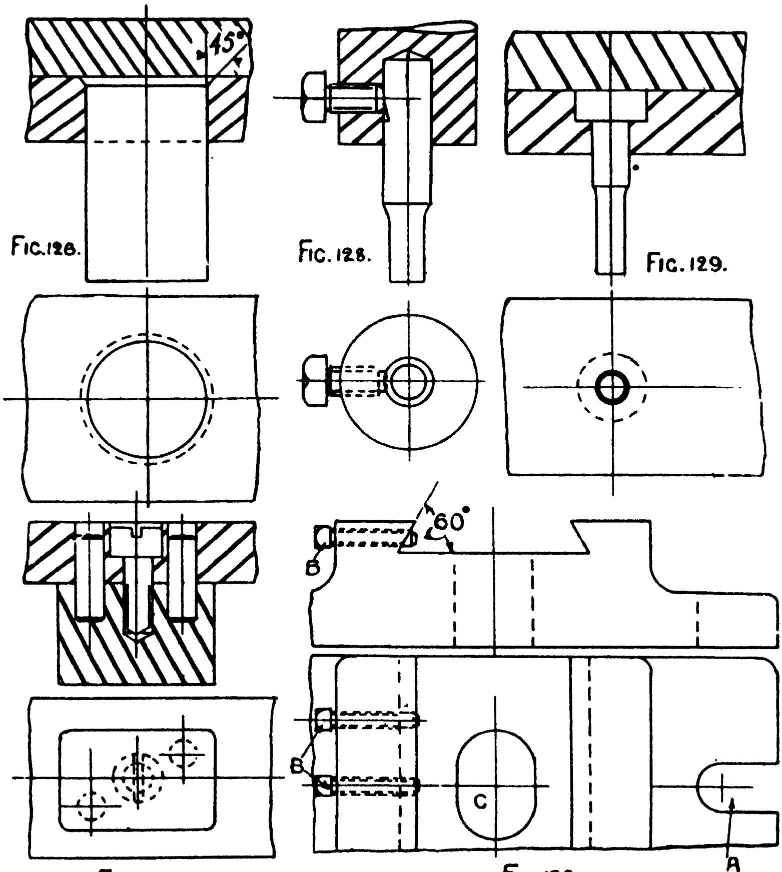


Fig. 127. Fig. 130.

FIG. 126.—HOLDING PUNCH BY RIVETING.
FIG. 127.—HOLDING PUNCH BY SCREWS AND DOWELS.
FIGS. 128 AND 129.—HELD SO AS TO FACILITATE REMOVAL.
FIG. 130.—BOLSTERS.

engage in small depressions in the side of the die holding the latter securely. The hole C should not be large enough to weaken the bolster, yet there is danger, if made too small, of a blanking operation being fixed on it and the hole not being large enough to allow of passage of the blanks as they fall, the result being a continual jambing of blanks till finally either punch or bolster breaks.

Other pattern bolsters do not have the dovetail portion but are quite flat, the die being bolted direct on to the face.

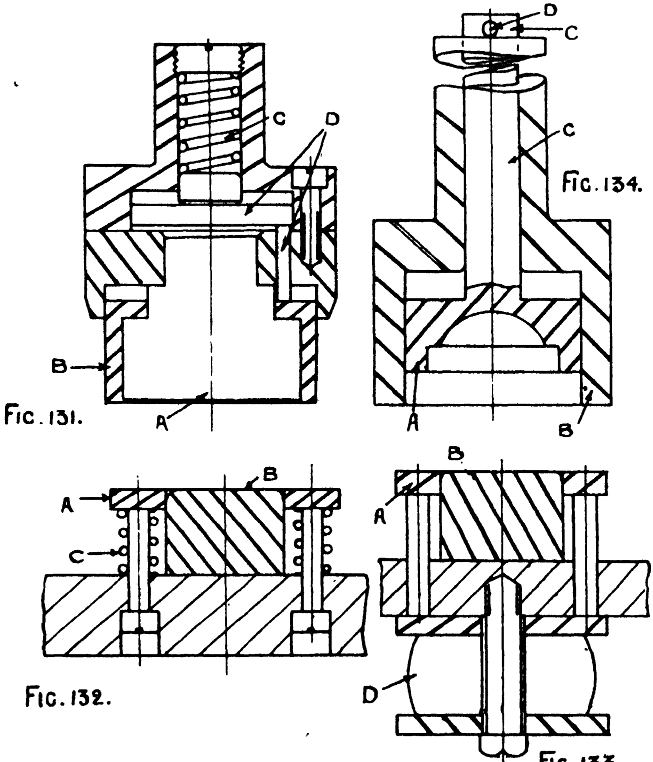


FIG. 131.—PUNCH AND STRIPPER COMBINED.
FIG. 132.—SPRING ACTUATED PRESSURE RINGS AS STRIPPER.
FIG. 133.—RUBBER BUFFER ACTUATED PRESSURE RING AS STRIPPER.
FIG. 134.—DRAWING PUNCH "KNOCKOUT" AS STRIPPER.

**Strippers.**—The punch having pierced the metal would, on its upward stroke, take the metal with it, and as it can only be removed with difficulty, some device or stripper must be included in the equipment. The most common method of stripping is shown in Fig. 123, where the plate D would remove the metal from the punches as the latter passed upwards. This form has the advantage of giving support to the punch, but makes it practically impossible to see the punch at work. A punch with stripper combined is shown in Fig. 131 where the punch A is inside the stripper sleeve B, so that on descending, the punch A passes through the material and the sleeve B is pushed up; as the punch is withdrawn, however, sleeve B, due to the action of spring C on the plate and pegs D, forces the material off the punch. In some cases the pressure ring (see Drawing Tools) also acts as a stripper, Figs. 132 and 133 are illustrations of this, where the rings A surrounding the drawing punch B strip or remove the drawn shell from punch. The ring receives its return motion from the springs C in the case of Fig. 132 or the rubber buffer D in Fig. 133.

India-rubber is preferred to steel springs in press tools, as it is more resilient, and also the life of the rubber is longer, due to the practice of building the buffers up with a number of pieces; adjustment is also secured in this manner.

In the upper tool of blanking and drawing dies, a stripper or "knockout" is located as at A, Fig. 134, where the component is prevented from sticking in the die B by its action. It is actuated by a projection in the press engaging the top C on the upward stroke. The "knockout" is retained by the pin D.

**Stops.**—These are arranged on the die to determine the relation of one blank to another. The usual method is shown at A, Fig. 135, where the bent steel peg is inserted, the metal butting against *a* when being punched. The peg is bent as shown, enabling the hole *b* to be drilled a greater distance from the die hole, thus avoiding the possibility of a crack when hardening.

One great trouble with this form of stop is that when feeding the metal along, if the latter is not kept under proper control, it may rest *on* the stop instead of against it, with the result that the punch descending on to a sloping surface as at B, Fig. 136, will be damaged.

This can be partly avoided by introducing a spring beneath the stop pin as shown at C, Fig. 137, so that it would be depressed in the event of the metal being punched thereon.

At D, Fig. 138, is seen another type of stop: the trigger *a* is suspended from the stripping plate *b*, and as the metal is fed along to the left it lifts and drops into the latest punched

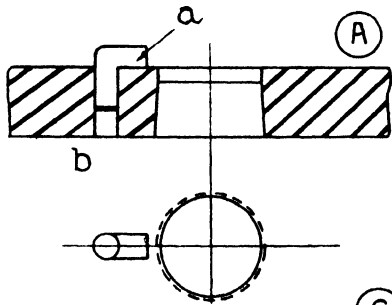


FIG. 135.

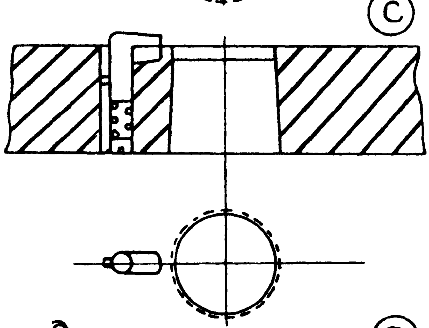


FIG. 137.

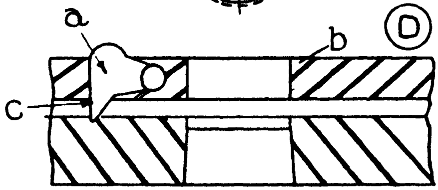


FIG. 138

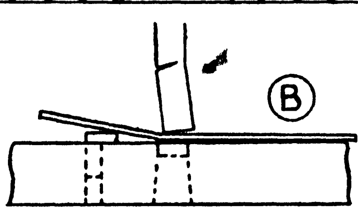


FIG. 136.

FIG. 135.—PLAIN STOP.
FIG. 136.—DANGER OF FIXED STOPS.
FIG. 137.—SPRING STOP.
FIG. 138.—TRIGGER STOP.

hole, after which, on giving the material a slight pull to the right, it is safely located against the trigger at C.

**"Follow" Dies.**—The name "follow" is employed because more than one operation—ranging from two to six—is completed with each stroke of the press, the tools for

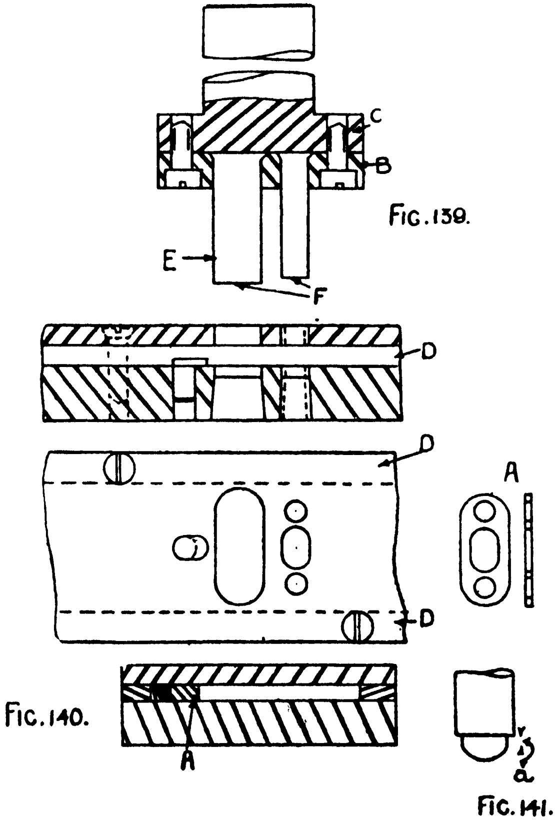


FIG. 139.—SIMPLE FOLLOW DIE.
FIG. 140.—ADJUSTABLE GUIDE.
FIG. 141.—PILOTED PUNCHES.

the operations being located or following one behind the other.

Fig. 139 is an illustration of a simple tool of this type, the component being seen at A, each stroke of the press punching the slot and two holes and blanking out the shape. The punches are seen located in the punch plate B which is screwed to the holder C, the shank of the latter fitting the ram of the press.

The strips or guides D are wide enough to allow of a free passage for the material being punched and as the width of the latter may vary a little and so either move laterally or stick between the guides, one of the latter is often provided with springs as at Fig. 140, enabling the guide A to meet any variation in width of material—the strength of the springs must be arrived at by experiment.

It will be noticed that the heavy blanking punch E is a trifle longer than the finer punches, this allows the former to enter the work first, avoiding the vibration or shock that would otherwise be thrown on the more delicate punches. The punches should not be too long, because they may buckle, but allowance must be made for grinding which is done on the faces F. The thickness of dies, naturally, will depend on the thickness and area of the piece being blanked, but it may vary between ½" and about 1".

**Piloted Punches.**—In cases where a very accurate relation must be kept between a hole and the outside edge of a stamping, it is usual to make a pilot pin on the end of the punch as in Fig. 141, so that the pilot pin enters the punched holes before the blanking punch.

The part *a* of the pilot must be parallel and a good fit in the hole.

**Drawing Tools.**—The production of cups, shells, metal boxes, etc., necessitate the use of drawing tools, the simplest form of which is known as the "push-through" type shown in Fig. 142.

It is obvious that only a shell of straight formation can be so drawn, the blank for which is located in the guide plate A and the punch B descending forces it through the die C and on the upward stroke of the punch the shell is stripped off by catching on the edge D which is left sharp for this purpose. The edge of the die E and the punch F must have a radius to assist the operation, and if the component must have a sharp corner, this must be arranged later by introducing another operation.

The method of drawing indicated in Fig. 142 can only be carried out with material of about ⅛" thick and over, because below this size the edge of the metal as it is entering the die will cockle and form a number of creases in the shell. To prevent this a pressure ring is introduced, as in A, Fig. 144, so that the blank *b* is located in its guide over the die, and when the punch descends the steel ring A holds the blank firmly under pressure of the rubber buffer C while the punch continues downwards drawing the blank from beneath the

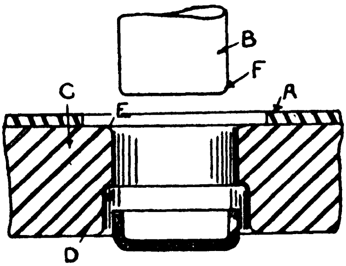


FIG. 142.

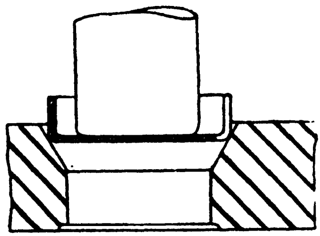

FIG. 143.

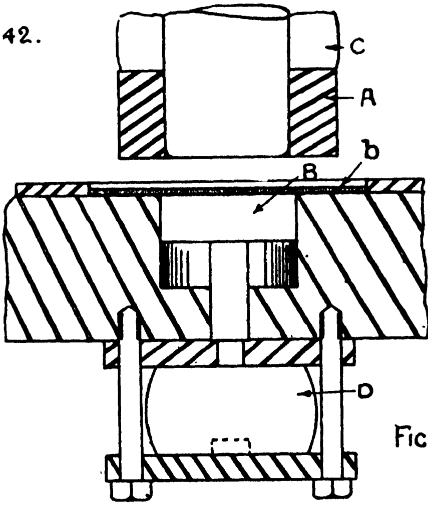


FIG. 144.

FIG. 142.—PLAIN PUSH-THROUGH DRAWING TOOL.
FIG. 143.—SIMPLE RE-DRAWING DIE.
FIG. 144.—DRAWING WITH PRESSURE RING.

pressure ring and so avoiding the formation of any creases. The ejector B operated by the buffer D removes the shell when drawn.

The buffer C must not be too strong, especially if the drawing punch has a small radius, as it will probably tear the metal instead of drawing it, yet if the pressure is too weak, the creases will re-appear. As the drawing operation stretches the metal it is obviously impossible to give the size of the original blank to begin with, especially where the shell drawn is of irregular shape, but by mensuration some idea of the size can be calculated and then it is a matter of experiment to find the exact shape of the blank.

For cylindrical shells the blank can be found roughly from the formula—

$$D = \sqrt{d^2 + 4dh}$$

which is from the practice of Messrs. E. W. Bliss, of New York, where

D = Diameter of blank,
$d$ = Diameter of shell,
$h$ = Height of shell.

**Re-drawing.**—Where the depth of a shell is such that it cannot without risk of splitting be drawn in one operation, a re-drawing operation becomes necessary, as shown at Fig. 143. The shell previously partly drawn is located on a die having a "start" of about 45 degrees and the punch forces it through the die.

The number of draws necessary for a shell cannot be decided by rule; many points enter into the question, such as—

(1) Quality of material,
(2) Depth of draw,
(3) Radius required,

so that the matter becomes somewhat experimental. An idea can be gained from the telephone receiver, Fig. 149, which required 6 draws, the original blank being $\frac{9}{32}''$ thick and about 3″ diameter, and a brass projectile case 12″ long, 3·3 diameter can be produced from a blank 6·2″ diameter and ·330″ thick in 8 draws.

**Combination Tools.**—High production makes it necessary to reduce the number of operations to the minimum, and for this reason two or more operations are carried out with one tool, as shown at Fig. 145. A is the die and B the blanking punch, C is the pressure ring supported by three studs equidistant from each other, the studs being screwed into the plate D, the rubber buffer being compressed between it and plate

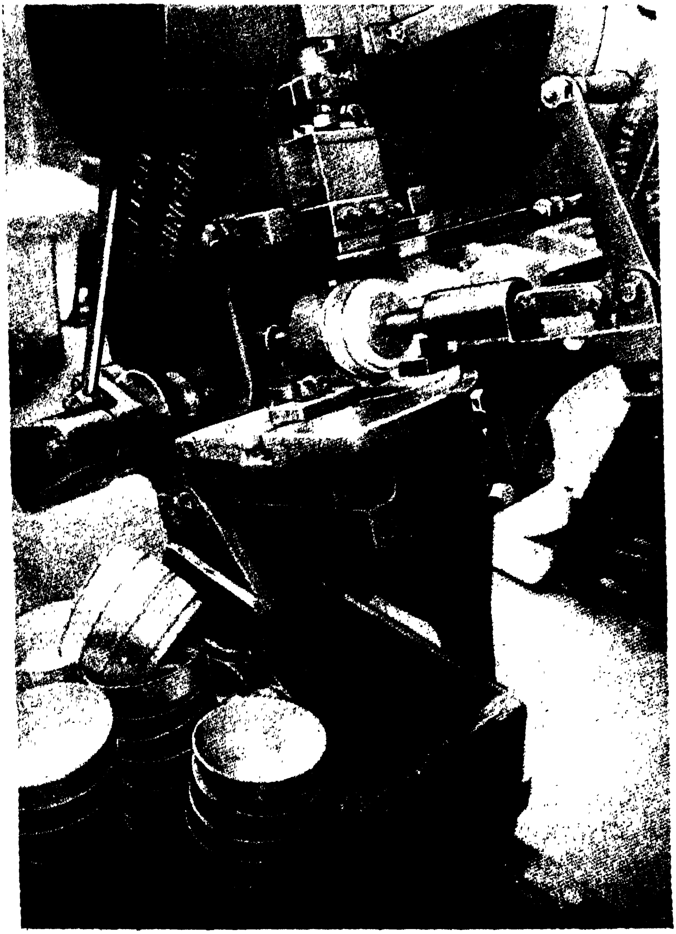

**Plate X.**

**Rotary Perforating.**—Here is an automatic press by Messrs. Taylor & Challen occupied in perforating the side of burners for oil stoves.

The lever in the foreground is spring loaded and controls the pad seen retaining the component on the die. The latter is rotated, synchronizing with the stroke of the press.

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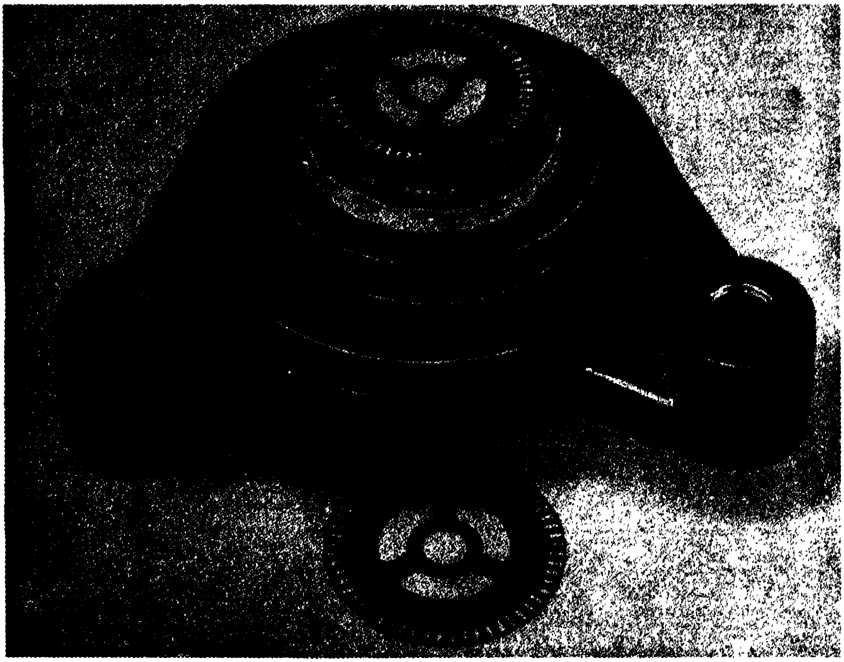


Plate Xa.

A new development, with which the designer should get acquainted, is the use of a special alloy available under the name of "Cerromatrix" and handled by Mining and Chemical Products Ltd. of Station Wharf Works, Alperton. The illustration shows a mass of punches held in position by this alloy, which is poured round the punches after initial location. Much elaborated machining and time is thus saved.

[*Facing page 153*

E. The drawing die F, which is of hardened steel, is located centrally to the die A. Pressure ring C should be a close fit between the blanking die and drawing die. The " knockout " pad H which also helps to form the shell is a push fit in the punch B and a hole is usually placed as at J to allow of the escape of air from K behind the pad. With this tool then, one stroke of the press blanks and draws the shell as shown

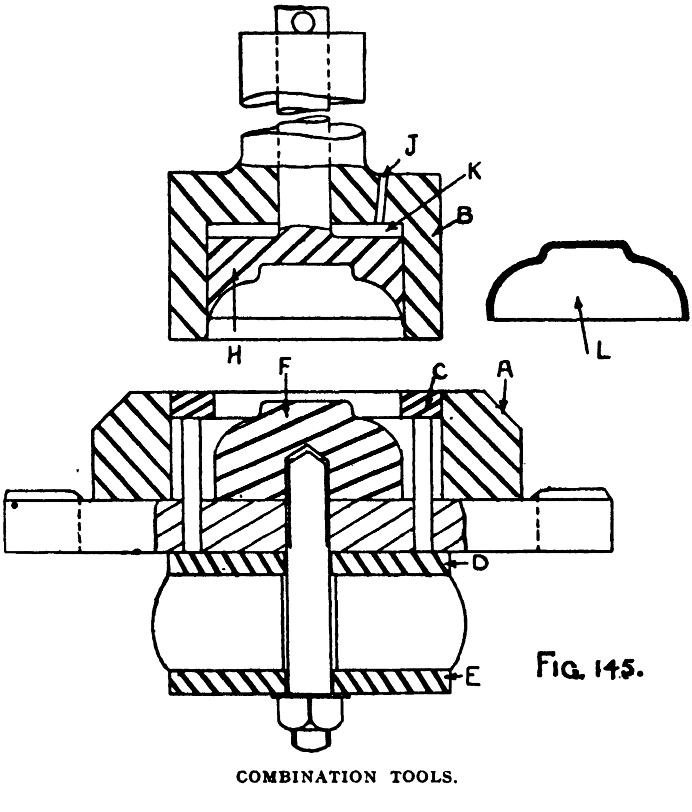



FIG. 145.

COMBINATION TOOLS.

at L. If the latter calls for embossing, the figure or letters can be arranged on the top of die F and pad H.

**Bending Tools.**—For plain right-angle bends the most simple form of tool is shown in Fig. 146, where the strip A to be bent is located in a guide plate B while punch C descends. For accurate work the possibility of the piece slipping while being bent is removed by employing a tool of the type shown in Fig. 147 where the strip of material rests on its guide and on the spring pad A, the latter descending with the punch and ensuring a perfect bend. To assist bending a radius should always be arranged at b. The gap B is equal to the width of the finished component plus ·002″, and the punch

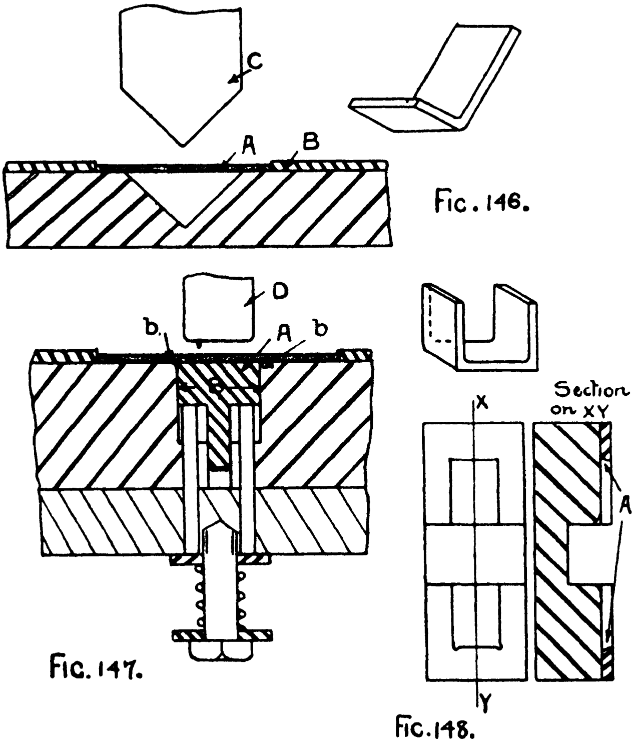



Fig. 146.—Plain bending tool.
Fig. 147.—Bending tool with spring pad.
Fig. 148.—Allowing for foreign substances in the guide plate.

D will therefore equal the same width, less twice thickness of metal and minus ·002″.

The guide plate for locating a piece to be pierced should be slightly chamfered as at A, Fig. 148, which prevents any chips of metal or other matter lodging in the corner, so that the piece to be punched does not lay flat, which may result in broken punches.

**A Special Forming Die.**—Fig. 149 shows an operation on a brass shell, the latter being the case of a telephone receiver. The shell is first drawn from the blank which leaves the thickness at A about $\frac{1}{32}''$. To get the bulged part the drawn shell is placed in a die made in two halves B and C and having the desired shape cut out, the halves being retained by an outer clamp D. A definite quantity of water is then poured into the shell and a leather disc of a diameter to lightly fit the bore placed in after. The ram of the press descends and

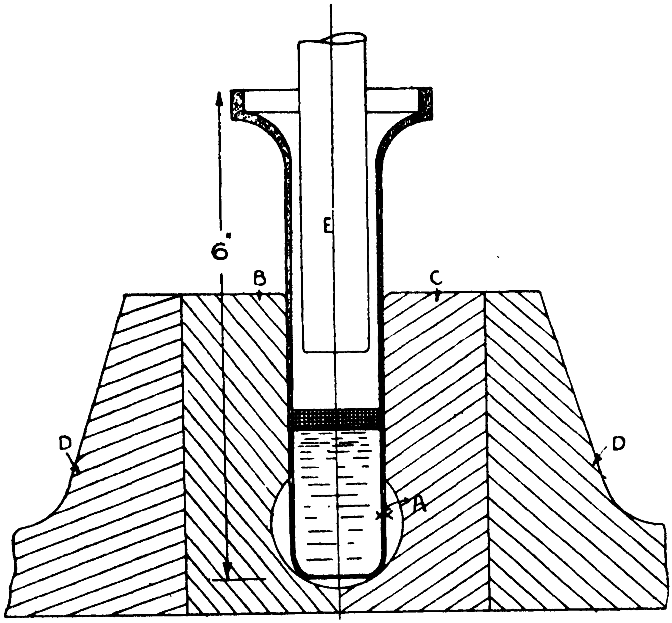



FIG 149.

SPECIAL FORMING OPERATION.

rod E, attached to it, forces the leather blank down the shell, causing the water to bulge the shell bottom and conform to the shape already cut out in the die. Water and special india-rubber pads can often be used in this manner for unusual forms.

The clamp D operates on the principle of a two-jaw chuck, the clamps being tightened or released by means of a right- and left-handed screw.

**Sub-Presses.**—The latter consists of a ram working in a sleeve operating a punch and die which are permanently assembled, so that no setting is necessary, the sub-press being placed under the press ram, and nut A, Fig. 150, connected thereto, after which the base B is clamped to the press bed and the stroke adjusted to suit the die.

This type does not pay except for very delicate and important parts such as clock gears, etc., but once made they last a considerable time, as no interference with the alignment

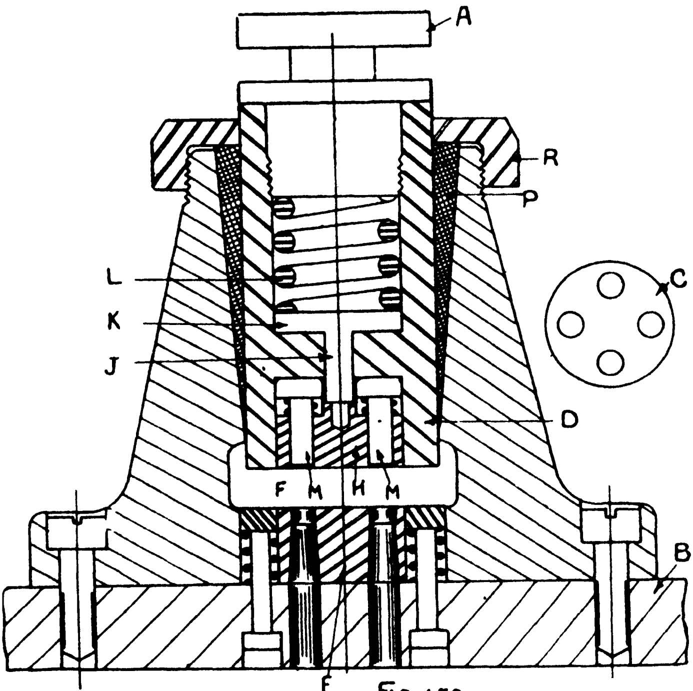



FIG. 150.

SUB-PRESSES.

of punch and die is necessary, the latter being the chief source of wear in press tools.

The one shown at Fig. 150 is for producing the brass disc C with its four holes, which must be kept very accurate. The ram, which is also the blanking punch, is seen at D and the die portion at E. The stripper ring, spring actuated, is visible at F. The upper stripper H is arranged inside the punch D, where it is connected by means of three steady rods J to the plate K which thrusts against the spring L.

The punches M for the holes are located in the upper stripper H, being a very accurate slide fit therein, and reaching almost to the bottom of the blanking punch. The metal is fed beneath the punch and die, and when the blanking punch descends, the disc is momentarily held between the upper stripper H and the die E, while the ram of the press, still descending, forces the small punches M down to complete the work. As the press ram ascends, lifting with it the punch D, stripper F forces the metal up to its original position, and as the disc is at that moment held by the upper stripper on the die face, the disc is lightly pressed back into the hole in the material from which it was previously blanked, from which it must afterwards be very carefully removed. By the method described it will be seen that a perfect stamping is continually being produced, not even the usual distortion due to the "flow" of the metal interfering, because when the holes are punched the disc is sandwiched between the upper stripper H and the die E. The punch D is held central in the outer casting by a babbit liner P which can be adjusted when necessary by the nut R.

**Materials.**—Press tools score over cutting tools because the expensive high-speed steel is not necessary. The steel used will largely depend on the material being punched, but one would be perfectly safe in using carbon steel for all punches.

For punching brass and softer materials a mild steel punch left in its soft state is often used, the dies in all cases being made of carbon steel hardened and tempered.

For piercing punches, ordinary silver steel or drill rod is quite good if not left too hard.

A common practice is to use case-hardening steel and give it the necessary heat treatment, afterwards finishing by grinding

When punching or forming ebonite, a common occurrence in the electrical trade, it will be found of great service to arrange a small water boiler near the particular press and run the hot water through pipes which can be arranged to pass through the die bolster; by this method very little work is scrapped due to cracked ebonite. In very hot weather this can be obviated by allowing the ebonite to remain in the sun an hour or so before using.

# CHAPTER XI

## BROWN & SHARP CAMS

Feeds and Speeds—Direction of Spindle Rotation—Total Revolutions per Piece—Correcting the Revolutions—Selecting Gears—List of Operations—Determining Cam Surface—Plotting the Cam—Back Slide Cam—Front Slide Cam.

WHILE the tendency in the design of machine tools is to reduce the skill required for their setting up and operation, the Brown & Sharp automatic, one of the few that require special cams designed for every new piece of work, still retains its popularity. The objection to the necessity of continually designing cams is outweighed by the fact that when so doing the designer is able to reduce the idle time to an absolute minimum, and the finished cam can then give the maximum production in the minimum time. To give an idea of the method adopted, it is proposed to design cams for a Brown & Sharp automatic No. " 00," for making a quantity of mild steel screws as shown in Fig. 151.

The cams are three in number, the lead cam, Fig. 152, which controls the movements of the end-working tools, the rear and front cross-slide cams, Fig. 153, which are responsible for the working of the cross slides, carrying the cutting off and form tools.

**Feeds and Speeds.**—The working out of the proportions of the various lobes of the cam is based on the revolutions of the spindle, therefore this is the first consideration.

For machining mild steel 70 to 80 feet per minute is quite a satisfactory speed, so that an examination of a surface speed table will give the number of revolutions for material ¼" diameter as 1,069. It must be remembered, however, that the speed changes on the machine are limited and the nearest speed to this is 1,087, so this will be decided upon as near enough.

The threading, to obtain satisfactory results, should be carried out at a lower speed; about 30 feet per minute is considered correct, and the nearest obtainable to this is

792 revolutions per minute, so that the two speeds, 1,087 and 792, will be accepted as giving good cutting results. As the rate of travel or feed of the cutting tools is an important factor in designing the cam this must also be decided upon, it being possible to proportion the cam so as to vary the speed to suit any particular tool. Considering the component Fig. 151, which is of mild steel and has no extremely fine limits, a fairly coarse feed may be selected.

To machine down to the thread diameter $\frac{3}{16}''$, only $\frac{1}{32}''$ of metal each side requires removing, so that a feed of about ·010″ per revolution will not be too coarse. The reduction of this thread diameter for the formation of the $\frac{1}{8}''$ pin also only calls for the removal of $\frac{1}{32}''$ of material, therefore the same feed can be used here. The feed of cross-slide tools must not be quite so coarse, and its selection is not quite so easy as for end-working tools, there being several points which must be watched.

The grade of material being used, the diameter, the width of the form and cutting-off tools, and the condition of the machine, must all be considered.

With the component under consideration, it will be assumed that the cut-off tool is of substantial width, the material quite ordinary and the machine bearings in good condition, then as the form tool has only to make the recess under the head and remove burrs, a feed of, say, ·002″ per revolution will not be excessive.

**Direction of Spindle Rotation.**—As the threading die must be run on to the work at the slow speed, i.e. 792 r.p.m., there is no reason why the high speed at which the spindle revolves when reversed for running off the die should not be taken advantage of.

It can be arranged therefore that the reduction of the stock diameter by the hollow mill or box tool can be done on the forward motion, and the forming and cutting off when the spindle is running backward at high speed.

**Total Revolutions per Piece.**—Having fixed upon the necessary feeds and speeds, the operations can be fixed and timed from which the total revolutions can be obtained. For the component Fig. 151 the operations will include turning down to $\frac{3}{16}''$ diameter as far as the head, which is best accomplished by means of a hollow mill, and then turning the $\frac{1}{8}''$ nose portion, using for the purpose a box tool.

The piece is threaded next, and immediately the die is withdrawn the form and cut-oft tools move forward, operating simultaneously. First, however, the turret is indexed into position, and the spindle reversed which both take place together. For this particular machine the time for this is one half-second, so that with the spindle running at 792 r.p.m., the indexing will take 6½ revolutions, to which it is usual to add two or three more, in this case to make even figures add, say, 3½, making the revolutions for indexing 10.

The turning operation comes next, and the length ·750″ divided by the feed per revolution ·01″ will give 75 revolutions, to which add ·01 for clearance, making 76 revolutions.

The turret is again indexed, taking as before 10 revolutions, and bringing into position the box tool for turning the point. The length ¼″ is divided by ·01″, giving 27 revolutions for this operation, after which the indexing of the turret again adds ten revolutions.

The threading operation comes next, and the revolutions for this are obtained by multiplying the length to be threaded by the number of threads per inch, so that ·5 × 26 = 13, to which is added 2 revolutions for clearance, making 15.

To run the die off the screw on reversal of the spindle will add a similar number. Following the die is the cross slide tools, and taking the cut-off tool as the one that moves the greater distance and therefore upon which any calculations should be based, it will be seen that the travel equals ·125″, that is, half the diameter of the component plus another ·01″ to allow for the small angle at the point of the tool, and a further ·01″ for clearance, making in all ·125 + ·01″ + ·01″ = ·145. This amount, then, divided by the feed per revolution, which for the cross slide is ·002″ = 72, which is the number of revolutions required for the working of the cross slides.

During this operation, however, the turret has indexed round to the stock stop position, that is, three indexings, and has also fed forward another length of metal, which means that to the previous numbers must be added another ½ second or 14 revolutions.

**Correcting the Number of Revolutions for the Higher Speed.**—Though two speeds are employed in making the screw, all calculations when proportioning the cam are based on the fast speed. It is necessary, therefore, to increase the number of revolutions of the slow-speed operations proportionately, which is done by using the simple formula—

$$R = \frac{H \times r}{L}$$

where R = Revolutions required,
$r$ = Existing number of revolutions,
H = High-speed revolutions,
L = Low-speed revolutions.

ORDER OF OPERATIONS.

| | R.P.M. | Corrected R.P.M. | Proportion of Cam Surface. |
|---|---|---|---|
| At 792 r.p.m.— | | | |
| Index turret and reverse spindle .. | 10 | 14 | 5 |
| Hollow mill .. | 76 | 105 | 33 |
| Index turret .. | 10 | 14 | 5 |
| Finish point (box tool) .. .. | 27 | 37 + 2 | 12 |
| Index turret .. | 10 | 14 | 5 |
| Thread on .. .. | 15 | 21 | 7 |
| At 1,087 r.p.m.— | | | |
| Run off die .. | 15 | 15 | 5 |
| Form. Index 3 times and cut off .. | 72 | 72 | 23 |
| Feed stock .. | 14 | 14 | 5 |
| | | 306 + 2 | 100 |

So that taking the operation of indexing the turret, etc., we have

$$\frac{1,087 \times 10}{792} = 14 \text{ revolutions approx.}$$

This method is followed out for all operations on the slow speed, and it will be seen by examining the order of operations that the total revolutions of all operations is **306**.

**Selecting Gears.**—Having found the number of revolutions necessary to make one piece, it is a simple matter to find the time per piece. With the spindle running at 1087 r.p.m., by proportion it will turn 18 times in one second and the 306 turns will be made in 17 seconds. With the machine for which these cams are intended, it has been arranged that the rate of motion of the cams controlling the various tools can be varied by altering a system of change gears, and to produce the piece in 17 seconds it is essential that gears having the correct number of teeth to give the required rate of motion must be selected.

The "Table for Laying Out Cams," No. 13, is similar to the one supplied with the machine, and to which reference must be made when selecting the gears.

Looking down the column headed "1,087 Revs.," it is found that the nearest "revolutions per piece" is 308, which gives on the extreme left 17 seconds per piece, and to the right of this number it will be seen that the gears necessary to give this result are a 20-toothed wheel on the driving shaft and a 34-toothed gear on the worm shaft.

It is only necessary then to adjust the original number of revolutions to meet this, which can be done by adding two to the operation, "Finish Point," making this 39 as indicated in the "Order of Operations."

**Determining Cam Surface.**—To convert the number of revolutions already calculated into a measure of cam surface, a circle equal to the diameter of the cam blank is drawn and its circumference is divided into one hundred equal parts. These hundred divisions represent then, in the case of the cam being designed, 308 revolutions of the machine spindle, so that one division equals $308 \div 100 = 3 \cdot 08$. If after dealing with each operation in this manner the total divisions exceed or are less than 100, a slight adjustment must be made to correct this. The number of divisions are indicated in the "Order of Operations."

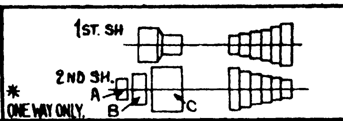
**Plotting the Cam.**—The cam blanks are provided with a central hole to fit the shaft upon which they are located when in use and also with a hole $\frac{1}{4}''$ diameter which provides a positive drive for the cam and also fixes its position on the shaft.

These two holes and the zero point of the 100 divisions are on the same radial line, and it is from this line that the

# No. 00 AUTOMATIC SCREW MACHINE.

## TABLE FOR LAYING OUT CAMS.

TABLE No. 13.




SPINDLE SPEEDS. BELT ON *A *B *C
420 792 1087
492 927 1273
576 1087 1492
675 1273 1748
792 1492 2048
927 1748 2400

| Seconds to make one piece. | Gross product - 10 hours. | Net product - 10 hours. Gross minus 10%. | Gears on driving shaft. | 1st. gear on stud. | 2nd. gear on stud. | Gear on worm shaft. | Hundredths of cam surface to feed stock. | Number of revolutions to make one piece. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spindle speeds: rev. per sec. | | | | | | | | 3.5 | 4.1 | 4.8 | 5.6 | 6.6 | 7.7 | 9.1 | 10.6 | 12.4 | 14.6 | 17.1 | 20 |
| Spindle speeds: rev. per ½ sec. | | | | | | | | 7 | 8.2 | 9.6 | 11.2 | 13.2 | 15.4 | 18.1 | 21.2 | 24.8 | 29.1 | 34.1 | 40 |
| Spindle speeds: rev. per min. | | | | | | | | 420 | 492 | 576 | 675 | 792 | 927 | 1087 | 1273 | 1492 | 1748 | 2048 | 2400 |
| 3 | 12000 | 10800 | 70 | | | 21 | 17 | 21 | 25 | 29 | 34 | 40 | 46 | 54 | 64 | 75 | 87 | 102 | 120 |
| 4 | 9000 | 8100 | 50 | | | 20 | 13 | 28 | 33 | 38 | 45 | 53 | 62 | 72 | 85 | 99 | 117 | 137 | 160 |
| 5 | 7200 | 6400 | 60 | | | 30 | 10 | 35 | 41 | 48 | 56 | 66 | 77 | 91 | 106 | 124 | 146 | 171 | 200 |
| 6 | 6000 | 5400 | 50 | | | 30 | 9 | 42 | 49 | 58 | 67 | 79 | 93 | 109 | 127 | 149 | 175 | 205 | 240 |
| 7 | 5142 | 4600 | 60 | | | 42 | 8 | 49 | 57 | 67 | 79 | 92 | 108 | 127 | 149 | 174 | 204 | 239 | 280 |
| 8 | 4500 | 4000 | 60 | | | 48 | 7 | 56 | 66 | 77 | 90 | 106 | 124 | 145 | 170 | 199 | 233 | 273 | 320 |
| 9 | 4000 | 3600 | 60 | | | 54 | 6 | 63 | 74 | 86 | 101 | 119 | 139 | 163 | 191 | 224 | 262 | 307 | 360 |
| 10 | 3600 | 3200 | 40 | | | 40 | 5 | 70 | 82 | 96 | 112 | 132 | 154 | 181 | 212 | 249 | 291 | 341 | 400 |
| 11 | 3272 | 2900 | 40 | | | 44 | 5 | 77 | 90 | 106 | 124 | 145 | 170 | 199 | 233 | 274 | 320 | 375 | 440 |
| 12 | 3000 | 2700 | 40 | | | 48 | 5 | 84 | 98 | 115 | 135 | 158 | 185 | 217 | 255 | 298 | 350 | 410 | 480 |
| 13 | 2769 | 2500 | 40 | | | 52 | 4 | 91 | 107 | 125 | 146 | 172 | 201 | 236 | 276 | 323 | 379 | 444 | 520 |
| 14 | 2571 | 2300 | 30 | | | 42 | 4 | 98 | 115 | 134 | 157 | 185 | 216 | 254 | 297 | 348 | 408 | 478 | 560 |
| 15 | 2400 | 2100 | 40 | | | 60 | 4 | 105 | 123 | 144 | 169 | 198 | 232 | 272 | 318 | 373 | 437 | 512 | 600 |
| 16 | 2250 | 2000 | 30 | | | 48 | 4 | 112 | 131 | 154 | 180 | 211 | 247 | 290 | 339 | 398 | 466 | 546 | 640 |
| 17 | 2117 | 1900 | 20 | | | 34 | 3 | 119 | 139 | 163 | 191 | 224 | 263 | 308 | 361 | 423 | 495 | 580 | 680 |
| 18 | 2000 | 1800 | 30 | | | 54 | 3 | 126 | 148 | 173 | 202 | 238 | 278 | 326 | 382 | 448 | 524 | 614 | 720 |
| 19 | 1894 | 1700 | 20 | | | 38 | 3 | 133 | 156 | 182 | 214 | 251 | 294 | 344 | 403 | 472 | 554 | 649 | 760 |
| 20 | 1800 | 1600 | 20 | | | 40 | 3 | 140 | 164 | 192 | 224 | 264 | 309 | 362 | 424 | 497 | 583 | 683 | 800 |
| 21 | 1714 | 1500 | 20 | | | 42 | 3 | 147 | 172 | 202 | 236 | 277 | 324 | 380 | 448 | 522 | 612 | 717 | 840 |
| 22 | 1636 | 1450 | 20 | | | 44 | 3 | 154 | 180 | 211 | 247 | 290 | 340 | 399 | 467 | 547 | 641 | 751 | 880 |
| 23 | 1565 | 1400 | 20 | | | 46 | 3 | 161 | 189 | 221 | 259 | 304 | 355 | 417 | 488 | 572 | 670 | 785 | 920 |
| 24 | 1500 | 1350 | 20 | | | 48 | 3 | 168 | 197 | 230 | 270 | 317 | 371 | 435 | 509 | 597 | 699 | 819 | 960 |
| 25 | 1440 | 1300 | 20 | | | 50 | 3 | 175 | 205 | 240 | 281 | 330 | 386 | 453 | 530 | 622 | 728 | 853 | 1000 |
| 26 | 1384 | 1250 | 20 | | | 52 | 3 | 182 | 213 | 250 | 292 | 343 | 402 | 471 | 552 | 647 | 757 | 887 | 1040 |
| 27 | 1333 | 1200 | 20 | | | 54 | 3 | 189 | 221 | 259 | 304 | 356 | 417 | 489 | 573 | 671 | 787 | 922 | 1080 |
| 28 | 1285 | 1150 | 20 | | | 56 | 3 | 196 | 230 | 269 | 315 | 370 | 433 | 507 | 594 | 696 | 816 | 956 | 1120 |
| 29 | 1241 | 1100 | 20 | | | 58 | 3 | 203 | 238 | 278 | 326 | 383 | 448 | 525 | 615 | 721 | 845 | 990 | 1160 |
| 30 | 1200 | 1050 | 20 | | | 60 | 3 | 210 | 246 | 288 | 337 | 396 | 463 | 543 | 636 | 746 | 874 | 1024 | 1200 |
| 32 | 1125 | 1000 | 30 | 30 | 48 | 60 | 3 | 224 | 262 | 307 | 360 | 422 | 494 | 580 | 679 | 796 | 932 | 1092 | 1280 |
| 34 | 1050 | 950 | 20 | 44 | 50 | 60 | 3 | 238 | 279 | 326 | 383 | 449 | 525 | 616 | 721 | 846 | 990 | 1161 | 1360 |
| 36 | 1000 | 900 | 30 | 30 | 54 | 60 | 3 | 252 | 295 | 346 | 405 | 475 | 556 | 652 | 764 | 895 | 1049 | 1229 | 1440 |
| 38 | 947 | 850 | 20 | 30 | 38 | 60 | 3 | 266 | 312 | 365 | 428 | 502 | 587 | 688 | 806 | 945 | 1107 | 1297 | 1520 |
| 40 | 900 | 800 | 20 | 30 | 40 | 60 | 3 | 280 | 328 | 384 | 450 | 528 | 618 | 724 | 849 | 995 | 1165 | 1365 | 1600 |
| 42 | 857 | 775 | 20 | 30 | 42 | 60 | 3 | 294 | 344 | 403 | 473 | 554 | 649 | 761 | 891 | 1045 | 1224 | 1434 | 1680 |
| 44 | 818 | 725 | 20 | 30 | 44 | 60 | 3 | 308 | 361 | 422 | 495 | 581 | -680 | 797 | 934 | 1094 | 1282 | 1502 | 1760 |
| 46 | 782 | 700 | 20 | 30 | 46 | 60 | 3 | 322 | 377 | 442 | 518 | 607 | 711 | 833 | 976 | 1144 | 1340 | 1570 | 1840 |
| 48 | 750 | 675 | 20 | 30 | 48 | 60 | 3 | 336 | 394 | 461 | 540 | 634 | 742 | 870 | 1018 | 1194 | 1398 | 1638 | 1920 |
| 50 | 720 | 650 | 20 | 30 | 50 | 60 | 3 | 350 | 410 | 480 | 563 | 660 | 773 | 906 | 1061 | 1243 | 1457 | 1707 | 2000 |
| 52 | 692 | 620 | 20 | 30 | 52 | 60 | 3 | 364 | 426 | 499 | 585 | 686 | 803 | 942 | 1103 | 1293 | 1515 | 1775 | 2080 |
| 54 | 666 | 600 | 20 | 30 | 54 | 60 | 3 | 378 | 443 | 518 | 608 | 713 | 834 | 978 | 1146 | 1343 | 1573 | 1843 | 2160 |
| 56 | 642 | 575 | 20 | 30 | 56 | 60 | 3 | 392 | 459 | 538 | 630 | 739 | 865 | 1015 | 1188 | 1393 | 1631 | 1911 | 2240 |
| 58 | 620 | 550 | 20 | 30 | 58 | 60 | 3 | 406 | 476 | 557 | 653 | 766 | 896 | 1051 | 1231 | 1442 | 1690 | 1980 | 2320 |
| 60 | 600 | 525 | 30 | 21 | 54 | 70 | 3 | 420 | 492 | 576 | 675 | 792 | 927 | 1087 | 1273 | 1492 | 1748 | 2048 | 2400 |
| 63 | 571 | 500 | 30 | 20 | 54 | 70 | 3 | 441 | 517 | 605 | 709 | 832 | 973 | 1141 | 1337 | 1567 | 1835 | 2150 | 2520 |
| 70 | 514 | 450 | 20 | 20 | 40 | 70 | 3 | 490 | 574 | 672 | 788 | 924 | 1082 | 1268 | 1485 | 1741 | 2039 | 2389 | 2800 |
| 77 | 467 | 420 | 20 | 20 | 44 | 70 | 3 | 539 | 631 | 739 | 866 | 1016 | 1190 | 1395 | 1634 | 1915 | 2243 | 2628 | 3080 |
| 84 | 428 | 385 | 20 | 20 | 48 | 70 | 3 | 588 | 689 | 806 | 945 | 1109 | 1298 | 1522 | 1782 | 2089 | 2447 | 2867 | 3360 |
| 91 | 395 | 355 | 20 | 20 | 52 | 70 | 3 | 637 | 746 | 874 | 1024 | 1201 | 1406 | 1649 | 1931 | 2263 | 2651 | 3106 | 3640 |

spacing of the cam commences. Taking the operations as already laid out, the indexing and reversing take 5 hundredths, so that a radial line can be drawn at mark 5.

Leaving this space unmarked, the space for the turning operation with the hollow mill is measured off, which takes 33 divisions, and the radial line drawn at point 38. As it is the work of this cam to take the end working tools to their work and return them, it is obvious that the question of length of the tool and holder will have an effect on the position of the highest point of the cam in relation to the outer edge of the cam blank, the latter being $4\frac{1}{2}''$ diameter to suit the machine in question.

This point is made clear in the diagram Fig. 154, where the component is represented in position in the machine, and the turret slide is indicated at the extremity of its stroke, which leaves $1\frac{5}{8}''$ between it and the machine nose.

It is assumed that standard equipment or equipment of similar proportions is being used on the machine, because the position of the highest point is found by measuring off as shown, from the point on the component where any particular tool finishes back to the turret face. If the measurement extends past the turret face, it means that the highest point of the cam for that tool will be that amount from the outer edge of the blank.

Taking the hollow mill and the turning operation, it will be seen that the length of the mill in its holder, say $1\frac{1}{2}''$, measured from under the screw head, extends about $\frac{1}{4}''$ beyond the turret face. The highest part of the cam on the lobe for turning, therefore, will be $\frac{1}{4}''$ from the outside measured on the radial line number 38. Within the space enclosed by the lines 5 and 38 commencing from a point on the line 5 equal to $\frac{1}{4} + \cdot 750$, that is, the distance from the outside edge already fixed plus the amount of rise called for by the component, a curve is drawn having a uniform rise.

One way of securing this is to divide the space between the lines 5 and 38 into an equal number of parts, also the line 5, commencing at the start of the curve to a point $\frac{1}{4}''$ from the outer edge into a similar number. Through the latter, using the cam centre as a pivot, describe arcs, and through the former radial lines are drawn cutting the arcs, and through the points of intersection, the lobe for operating the hollow mill is drawn. Fig. 152 will make this clear. Indexing the turret again occupies five divisions, another line being drawn at 43. From line 38, the turret must rotate

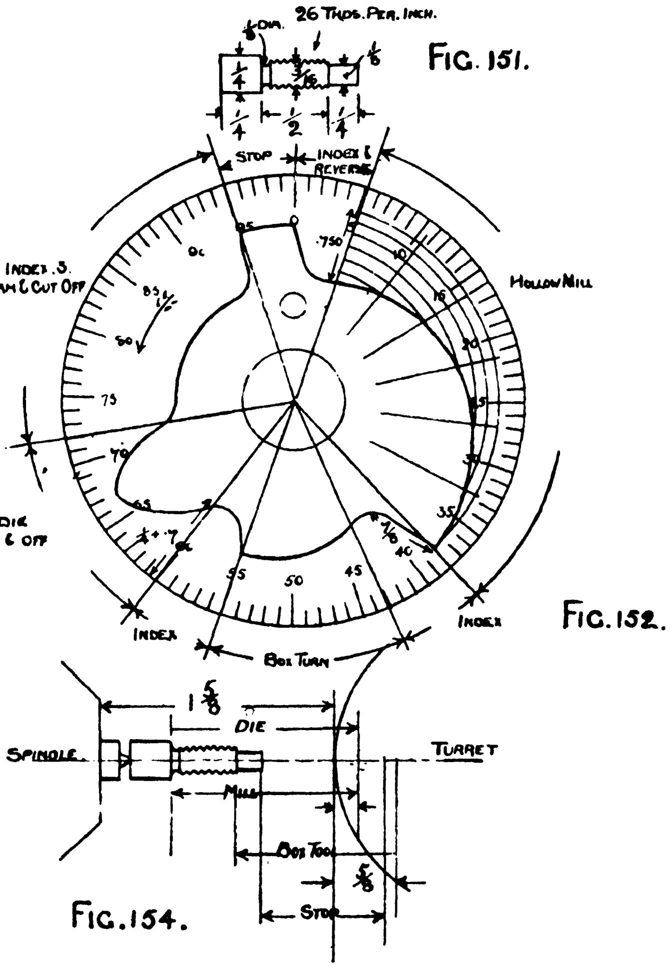



FIG. 151.—COMPONENT FOR WHICH CAMS FIGS. 153 AND 154 WERE DESIGNED
FIG. 152.—LEAD CAM.
FIG. 154.—DIAGRAM SHOWING RELATION OF TOOLS TO TURRET AND MACHINE NOSE.

and recede for the next tool, which means that the roll on the actuating lever must drop from the high point on 38 to a position ready to rise for the next tool.

The line generally drawn for this drop is made tangential to the centre hole of the cam, and at the bottom of the drop, an arc is described equal in radius to that of the roller on the cam lever, and blending with the rising curve for the next tool at its commencing point. This point at which begins the curve for operating the box tool is determined in the manner already described, the length of the tool being $1\frac{3}{8}''$, which, it will be seen on examining the diagram, passes the turret face by $\frac{5}{8}''$.

The curve for the box tool will, therefore, commence on line 43 at a point $\frac{5}{8}'' + \frac{1}{4}''$ from the outside and rise to a point $\frac{5}{8}''$ from the outside on line 55, twelve divisions intervening. Another drop is now made for indexing the turret in a manner already described, reaching from line 55 to 60.

The lobe for controlling the die comes next for consideration, and in determining the amount of its rise a different method is followed to that for ordinary cutting tools.

This is generally arrived at by dividing the number of revolutions required for threading by the number of threads per inch to be cut, and then, as it is essential in the production of good threads that the die should be neither forced on nor torn from the work, an amount between 7 to 12 per cent. is usually deducted. Also when the lobe has been drawn, the high point is removed for about $\frac{3}{32}''$, which enables the die holder to draw out of its socket and finish up close to the screw head without the positive thrust of the cam.

With a component having 26 threads per inch and having found that 21 revolutions are required to run the die on, the rise will equal $21 \div 26 - 10$ per cent., say ·7. Next, considering the room for the die holder as with previous tools, it will be found that $\frac{1}{4}''$ must be added to the ·7 as the starting-point of the lobe, rising to within $\frac{1}{4}''$ of the outside of the cam blank. The curve for feeding the die to its work fills the space between lines 60 and 67 and for removing the die from the work between 67 and 72.

For threaded work of extreme accuracy the lobe must be very accurately drawn, taking into consideration the different speeds at which the die is run on and off the work, the relative position of the cam lever, and the number of threads per inch; for ordinary work, however, the method described will give satisfactory results.

After the threading operation the turret is indexed three times, during which time the form and cut-off tools on the cross slide come into operation. For this purpose the form of the cam after the threading lobe from line 72 consists of a portion of a circle, described with the centre of the cam as centre, and a radius of $1\frac{1}{8}''$, continuing for twenty-three divisions, thus ending at line 95.

The last five spaces of the cam are occupied by the lobe for feeding forward the stock in the machine. The top of this lobe is an arc concentric with the outside of the cam, forming what is known as a "dwell," that is, being concentric, or having no "rise," the tool it controls remains stationary during its passage. The stop for fixing the amount of metal to be fed forward is actuated by this lobe, and the distance from its top to the outside of the cam blank is determined in a similar manner to that for the previous tools. The stop, therefore, extending, say, 1″ from the end of the component, passes the turret face $\frac{1}{2}''$, which is the distance the arc must be described from the outer edge.

From point o a line is drawn tangential to the centre hole and blending with the turning lobe commencing at line 5 an arc is drawn to suit the cam lever roll. After printing on the cam the revolutions and the gears necessary for the benefit of the machine setter, the cam is finished.

**The Back Slide Cam.**—Only one large lobe is necessary on this cam, and as according to the lead cam just completed the cross slide operates at division 72 and extends twenty-three spaces, this area is marked off for the back slide cam. It was also figured when arriving at the revolutions necessary, that the travel of the cut-off tool was ·145″, so that the low point of the cam on line 72 will be that amount from the outer edge as shown in Fig. 153. The remainder of the cam surface is reduced concentrically, using a radius of $1\frac{1}{4}''$. The lines 72 and 93 are tangential to the centre hole, the former, however, having a slight radius as indicated, and both blending into the remaining portion of the cam.

**Front Slide Cam.**—As the form and cut-off tools operate simultaneously, line 72 is again used as a starting-point. To fix the amount of cam area, the number of hundredths must be first found, which is accomplished in a manner already described.

The travel of the form tool will equal the difference between the radius of the screw head, Fig. 151, and the radius of the undercut portion, plus about ·01″ for clearance, equalling ·0625″ + ·01″, from which the revolutions and then the number of divisions can be figured.

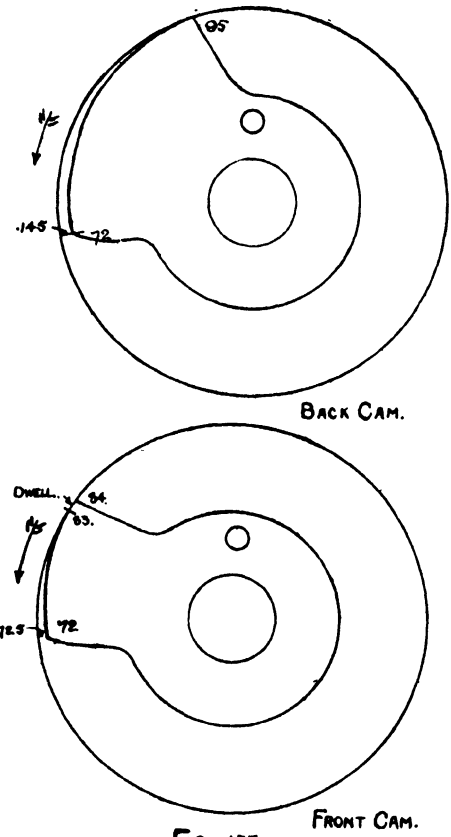



FIG. 153.

CROSS SLIDE CAMS.

The low point of the cam, therefore, will be on line 72 and ·0725 from the outside and extending to line 84.

The last division on this cam is generally left unmachined and concentric, thus providing a " dwell " for the form tool which enables it to remove burrs thrown up by the front cut-off tool.

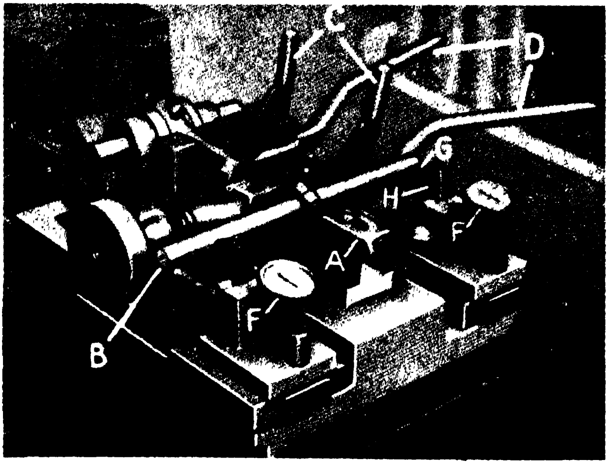



**Plate XI.**

**A Setting Fixture.**—This is a special device for ensuring that the main bore of a Daimler connecting rod is parallel with its gudgeon pin hole.

Plugs are provided for both bores, the big end plug resting in vees as shown while the small end plug B is supported by an anvil carried by an extension of slide A. The setting levers D are fitted with jaws for gripping the work, these being operated by levers C. The recording dial gauges F are mounted on the slide so that the gauging points may be brought towards the bar B as required.

As the dial gauges are brought towards the work, the points G engage the bar B first of all and indicate any twist in the con rod. As the gauges are brought still further towards the work the points H engage the bar, any difference in the reading of the dials showing that the rod is bent.

While readings are being taken the jaws are released by the levers C, and the gudgeon pin bar B is supported by the anvil on the slide A.

To set the work in cases where it is found to be necessary, the dial gauges and the slide A are withdrawn, the work is gripped in the jaws, and the levers D are operated until the gauges show that the bores are perfectly parallel.

[*Facing page 168*

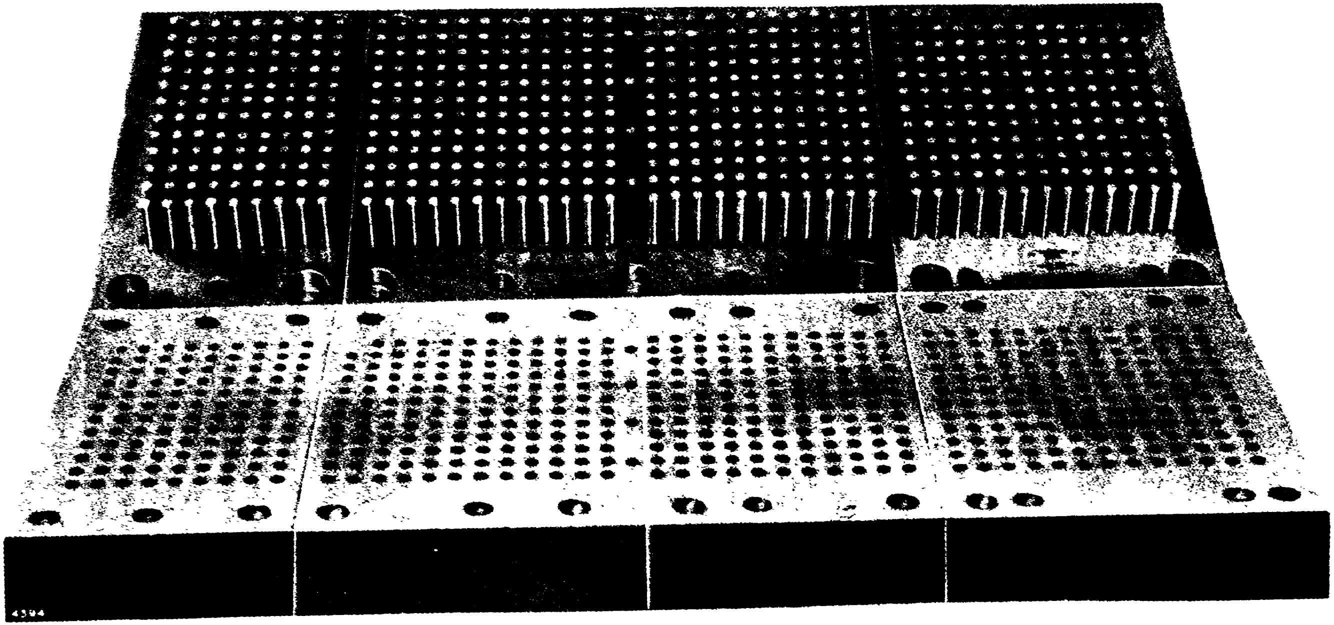



Plate XIa.

A Société Génevoise jig boring machine has bored 1100 holes to make this punch and die, and they mate together perfectly.

[*Facing page 169*

# CHAPTER XII

## SPECIAL EQUIPMENT

Truck Jig—Friction Screwdriver—Special Cut-Off and Forming Tool—Watertight Inlet Gland.

THOUGH in offices employing a large number of men it is usual to grade them, certain men always dealing with one class of work, it is a big advantage for the designer to gain as wide an experience as possible so as to be in a position to deal with all types of equipment. To give some idea of the diversity of work which comes to the tool and jig draughtsman, several examples of what would be described as special equipment are mentioned in this chapter.

**Truck Jig.**—Fig. 155 shows a multiple-drilling operation on a cylinder block, the latter not being visible because it is located inside the body A of the movable or truck jig. This method of dealing with heavy components originated in America and enables a very high rate of production to be maintained, the truck passing to different machines where the necessary operations are performed. The component in Fig. 23, as already mentioned, could be easily handled in this manner, and the only disadvantage in the method being that the lines upon which the trucks run and the absence of machine tables make the machines inconvenient for working on any other component, should work slacken enough to allow of this. A fixture of this type needs to be very strong, and as the rails are fixed direct to the bed of the machine, there should be no difficulty in machining due to the truck not being square with the spindles.

To enable the drills to find and enter the drill bushes easily, a slight lateral float is allowed on the truck.

The jig plates B are located by means of the stud and latch C, and the handles D are provided to facilitate lifting the plates when removing the finished casting.

The body A revolves on two trunnions in the bearings E and the indexing and clamping levers are seen to the right, while one hole for the indexing plunger is visible at F. The rails upon which the truck runs can be of standard section

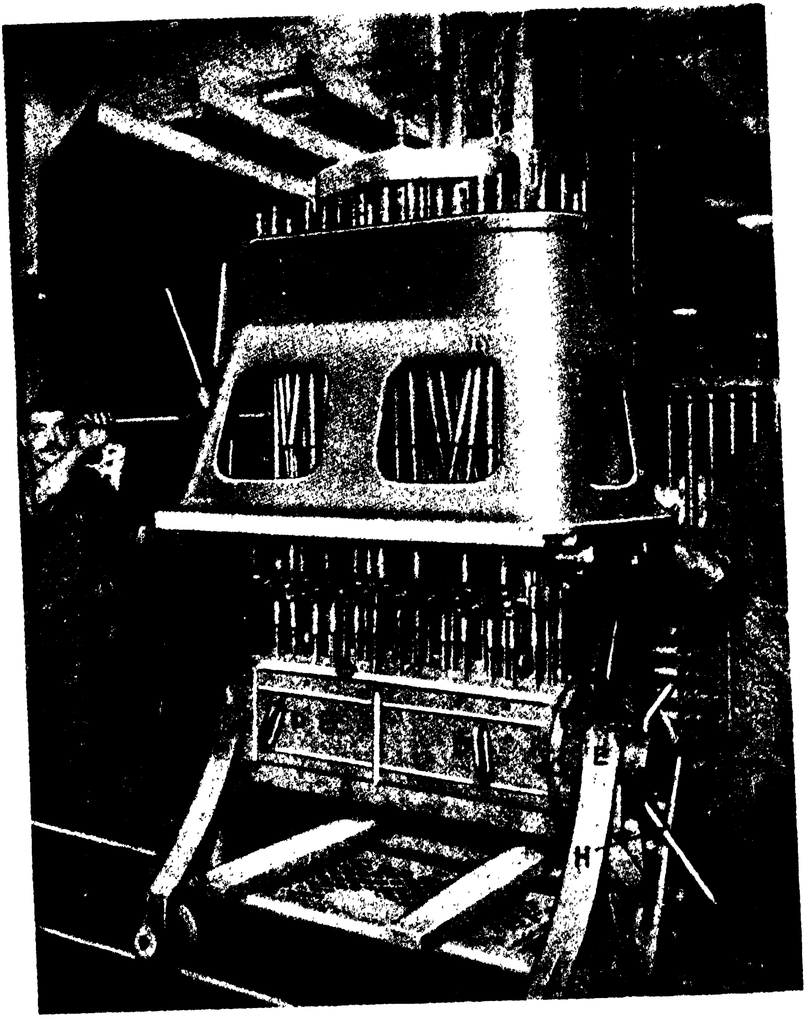
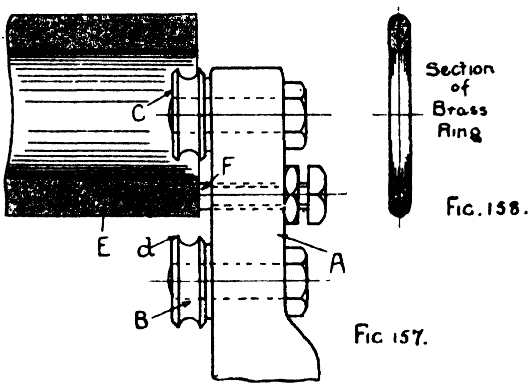



FIG. 155.—"TRUCK" JIG BENEATH A MULTIPLE SPINDLE DRILLING MACHINE.

or of solid rod as in the illustration, specially designed "chairs" being designed to hold them. The body of the truck is revolved directly by means of the handle H, but in some cases where the component is extra heavy a hand wheel with gearing is necessary.

The important point in the arrangement of the body casting is its balance, and when considering this the component itself as well as the jig plate must not be forgotten. Should the balance not be correct the jig becomes a danger to the operator, and to safeguard himself the designer should indicate on his drawing that the final balance is to be got by trial, that is, pieces of metal must be added or removed



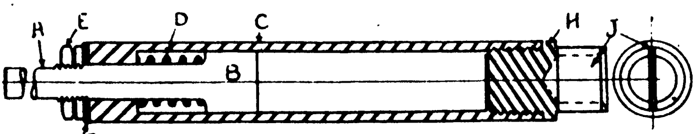




FIG. 156.—FRICTION SCREWDRIVER FOR ASSEMBLY WORK.
FIG. 157.—SPECIAL CUT-OFF AND FORMING TOOL.
FIG. 158.—COMPONENT PRODUCED BY FIG. 157.

as is found necessary when the jig is completed, it being impossible to calculate this exactly.

**Friction Screwdriver.**—In a factory producing enormous quantities of cheap electrical accessories it was found that the greater part of the time spent on the assembly of the parts was taken in screwing in screws of varying lengths. The tool office was called upon to design something simple and cheap to get over this difficulty, and the idea in Fig. 156 resulted.

This can be made from brass or steel, though the former will not stand the rough usage which is general in establishments employing unskilled labour. The shank A is held in the chuck of a drilling machine or lathe, while its other end, terminating in a boss B, is a sliding fit in the sleeve C and is retained there by means of the spring D, two lock nuts E and fibre washer F.

The nosepiece H, carrying a steel blade or screwdriver J, screws into the lower end of the sleeve C, and for special size screw heads another nosepiece must be made and kept by. The tool, gripped in the machine chuck, is brought down on to the screw head sending the screw down to its seat. When at this point the sleeve C, carrying the screwdriver, slips until raised by the operator. The tension of the spring D which controls the slip of the sleeve is adjusted by means of the two nuts E to suit tight- and loose-fitting screws.

**Special Cut-Off and Forming Tool.**—To produce the brass ring of unusual section shown at Fig. 158 a tool holder was designed and is seen in Fig. 157. The bar A is of mild steel, and upon it is arranged two circular form tools B and C, edge *d* of the former cutting off the finished ring. The brass tube E, from which the rings are made, is fed forward against the stop screw F, which is adjustable, and the tool C is moved forward forming the internal convex shape of the ring, after which B is fed in forming the outside and cutting off the finished ring.

**Watertight Inlet Gland.**—To force water into some hollow castings at a pressure of about 80 lb. to the square inch, the existing flange of the casting not being provided with any studs with which to secure a grip, proved a difficult proposition, especially as the operation had to be finished to time. The device illustrated in Fig. 159, where it is seen in position on the flange of a casting, successfully overcame this.

The two hook bolts A are a very close fit in the bush B. The latter is a watertight fit in the sleeve and nut C and D and resting on the top of the latter. To ensure the sleeve being watertight a groove *a* is turned into which is fitted some packing. The sleeve C beds down on to an india-rubber washer W, which should not be less than $\frac{3}{16}''$ thick because the surface of the casting X may be very rough.

The hose connection E passes down between the two hook bolts. To remove the gland from its present position, the nut D is screwed down lower on the sleeve C, the handles J facilitating this, which allows bush B to be pressed down together with the bolts A. The latter can then be lifted

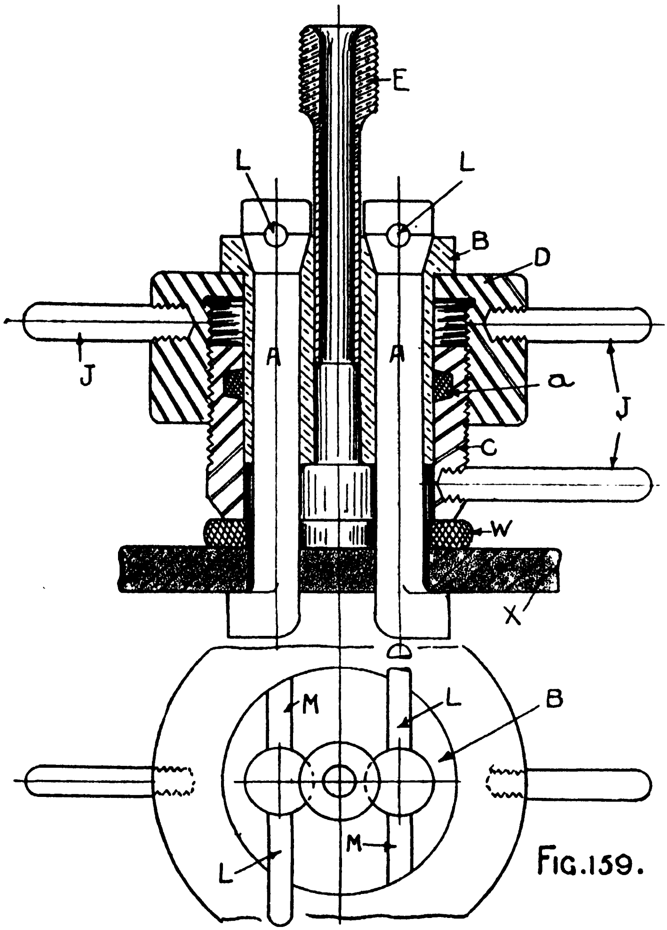



FIG. 159.

WATERTIGHT INLET GLAND.

slightly by means of the short levers L, which lay in shallow grooves made in the top of bush B and turned round so that the hook end of the bolts are in such position that the whole apparatus can be lifted off. The grooves M are so placed as to remove guesswork, when the levers lay in one end of the grooves the hook bolts are in position under the casting, and when in the opposite end of the grooves the apparatus is ready for removal. It will be seen from Fig. 159 that as nut D is raised, the flange of the casting and the rubber washer are compressed between the sleeve C and the hook bolts A.

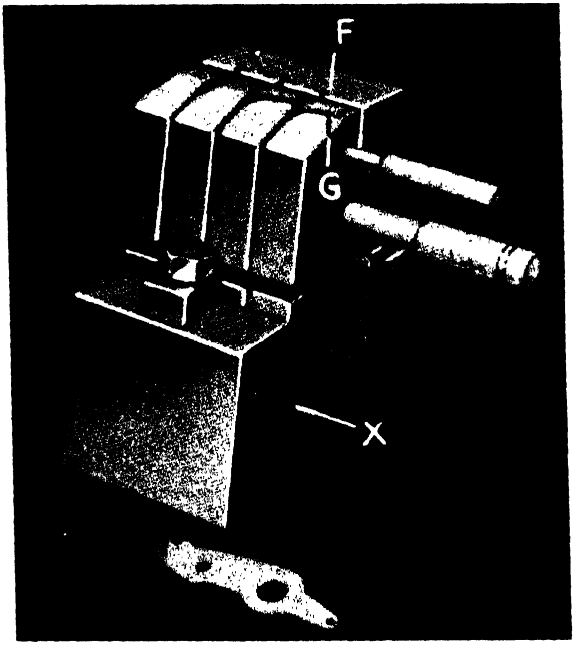



FIG. 159 A.

**Grinding Fixture.**—This is for grinding the lip of the component seen in the foreground, three levers being accommodated at once. For the first operation the angle piece is removed from base X, and clamped to the table of the grinding machine so that the surface F is ground at 90° to the main body of the lever. Notice that two plugs are provided for locating the levers from the reamed holes.

The 20° angle piece is then replaced and face G ground at 20° to face F.

## CHAPTER XIII

# JIG AND TOOL OFFICE PROCEDURE

Personnel of a Jig and Tool Office—Duties of Jig and Tool Office—Method of Working—Detailing—Checking—Tracing—Filing and Recording—Alterations—Operation Sheets.

HOWEVER skilful a draughtsman may be, it is necessary that he should, to some extent, sink his individuality and work on the lines laid down for that particular office, in fact, though it may sound rather far-fetched, procedure must be practically standardized (see Chap. XIV).

**Personnel of the Office.**—A word is necessary first on the duties of the staff, which, of course, will vary according to the size and financial strength of the firm.

It is usual to employ a chief, who is responsible for the grade of the designs produced, the general conduct of the department, and also the cost of running. He may be supported by an assistant, or rely on section leaders, to whom he will give instructions, and who generally act as a kind of foreman between himself and the rest of the staff.

The section leaders are generally put in charge of a number of draughtsmen and "detailers," who probably specialize on one or more particular branches of jig and tool design.

"Detailers," whose work consists of taking the design or "General Arrangement"—abbreviated G.A.—and making separate drawings of the parts comprising it, are generally youths or apprentices working with the draughtsmen, more or less as assistants, and in working thus any hidden talent is quickly discovered.

The tracing section, now consisting entirely of females, has generally a leader who is responsible to the head of the office. Provided that there is enough work forthcoming, this section is a great success, as the work is admirably suited to female labour.

The printing department, where the Blue Prints—abbreviated B.P.—are produced, is also worked by female labour.

The introduction of electric printing machines, electric drying irons, etc., displacing the old cumbersome frames, has made this possible.

There remains a clerk and storekeeper, though this work is often carried out by one person. The duties consist of taking care of the stocks of drawing materials, and keeping the drawing and tracing filing system in order, a simple though very important duty.

**Duties of the Jig and Tool Office.**—It must not be assumed that all offices are conducted in the same manner, but a knowledge of one system will always act as a guide, and be helpful when encountering a new one. In some cases the jig and tool office acts as a "Planning Department," that is, it "lays out" the complete method of manufacture of the product in all details, and then proceeds to design and draw the necessary tools, etc.

Alternatively the chief draughtsman may receive a set of prints of the various components, comprising the finished article, together with a list giving the sequence of the operations, also indicating the particular machines on which they are to be carried out, the work is then divided between various draughtsmen, and in due course the designs are produced. Apart from new work, the machine shops are continually calling for replacements for wornout or broken equipment, and it is for the jig and tool office to supply the print, and also give the necessary orders.

If the tool in question has not been quite a success, the matter is investigated and improvements included in the new drawing.

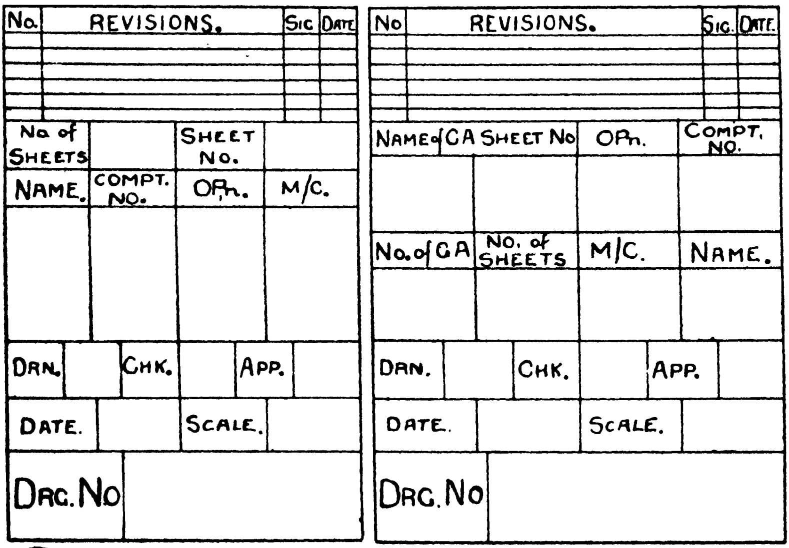
**Method of Working.**—In developing an idea for a tool, jig or fixture, the designer relies on his past experience of similar work, and will probably recall some design that proved very successful. He may, by examining the record cards already referred to, find that equipment exists on the firm for another component of somewhat similar form, and then follow its design. If he has not met anything like this particular job in the past, he must exercise his ingenuity and apply his past workshop experience to devise something suitable, and submit this for approval in various stages as he proceeds.

Whatever he attempts he must remember that, while originality is always welcome, anything in the nature of a freak design should be avoided, as firms do not relish pet ideas being carried out at their expense.

It should be understood that where accepted methods of machining have given satisfaction, adhere to them, remembering that while your own ideas might be a decided improvement, they may not always be acceptable to those immediately above you.

When the much coveted chief's position has been gained, the time will be ripe to indulge in a judicious riot of ideas.

**Detailing.**—The "General Arrangement" of the fixture having been completed, and the idea approved, the drawing




(A) (B) FIG. 160.

RECORD FRAMES FOR VARIOUS DRAWINGS.

is passed to the "Detailer," who proceeds to dissect it and make separate drawings of each part.

To do this successfully, the "Detailer" must be able to thoroughly understand a mechanical drawing, and must also see that no part escapes his attention.

The various parts of the jig or fixture on the "General Arrangement" are numbered, and the detail drawings must bear corresponding numbers for purposes of reference.

The reference frames, Fig. 160, or similar, are finally added to the drawing and filled in, the one shown at A being for the "General Arrangement," and that at B for the detail drawing. To the uninitiated this may seem superfluous, yet, while a drawing is intended to convey the ideas of the designer to the mechanic, it should also bear sufficient details of its past history to enable easy reference to be made. Various offices have their own pattern frames, there being some difference of opinion as to just what should be included in it.

The ones shown in Fig. 160, A and B, are an average type, and taking B first, the spaces require to be filled in as indicated with Reference Number, Scale, Date of Completion, also the Signature of the draughtsman, together with those of persons who approve and check it.

So as to know to which component the drawing refers the Component Number and Name is added, as also is the Operation Number (see Fig. 163), and the machine on which this is to be carried out.

To the left of this is the Number of the Sheet, and also the Total Number of Sheets, these numbers enabling anyone to know whether they are in possession of the complete set of details, and so prevent one item being overlooked.

Again, to the left is the Name and Number of the "General Arrangement" to which the detail belongs.

Above this is a column for Revisions or Alterations, as it is most important that these should be recorded, together with the date of revision.

A being for the "General Arrangement," would not need to carry so much information, and the filling in of this will be followed from what has been said concerning B. In some cases the form can be made less elaborate by including some of the references in the tool number, for example :—

2A, Component or Detail Number.

2A/4/B, Component or Detail Number, and G.A. Number.

2A/4B/10A, Detail Number, G.A. Number, and Tool Number.

On looking at the last number one can tell at once to which "G.A." the component or detail belongs, also the number of the tool used thereon, the letters indicating the particular drawer in which that size drawing is stored.

To maintain uniformity in the office the question of the different "fits" should be carefully watched, as a lot of time can be wasted, both in the office and the shops, by allowing individuals a free hand.

A system such as that indicated in Chapter IX can be used with advantage, where it is only necessary to quote the fractional size of, say, the diameter of a hole, and then add the letter denoting the class of fit, then the tool room and machine shop, working on the same system, know just what is expected.

The questions of material and heat treatment are extremely important in tool and jig work, and it has been found of great advantage for all parties to mark the drawings for this in a recognized way.

At Fig. 161 is a useful symbol, consisting of a circle in which

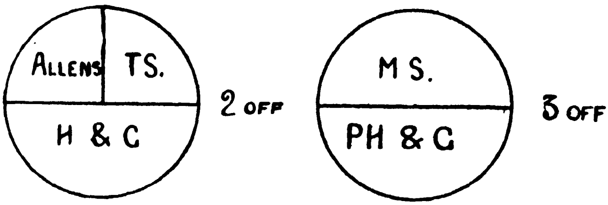



FIG. 161

SYMBOLS FOR INDICATING HEAT TREATMENT.

is marked the material, with its grade or maker, and beneath that the necessary heat treatment.

One of those given indicates :—

**Allen's Tool Steel.** Hardened and ground.

and the other—

**Mild Steel.**—Pack hardened and ground.

To these symbols can be added, if considered advisable, depths of case hardening, and also scleroscope numbers.

**Checking.**—The detailing having been completed the drawings are passed to the checker, whose duty is to examine them carefully for faults and errors of all kinds.

Though he is not engaged for the purpose of criticizing, this forms part of his work. On receiving a drawing, then, the checker should also secure a drawing of the component for which the tool or jig was designed, and, better still, it one of the actual components are available.

Armed thus, he will examine the drawing from the point of view of general construction, the design he will not interfere with, for it is assumed that it has already been approved by the chief of the department.

His line of thought will be as indicated below, though not necessarily in that order, and it will be at once obvious that the position calls for a man of experience.

1. In the case of jigs and fixtures—Can the loading and unloading be carried out quickly ?
2. Are the locating spots arranged at the most important and reliable points ?
3. Are the clamping arrangements satisfactory ?
4. Will they distort the component when in position ?
5. Will they allow the component to move when being machined ?
6. Will they take too long to manipulate ?
7. Will the operator have to think about it ?
8. Can any loose pieces, if they exist, be avoided ?
9. Is the machining thrust against the clamps ?
10. Is there plenty of "chip capacity," i.e. room for the escape of cuttings ?
11. Is there any allowance made for any variation in the shape of the component ?
12. Are all the details of the equipment to standard ?
13. In the case of a cutting tool—In proportioning its cutting edges, has the length of its life been considered ?
14. Has the correct heat treatment been called for ?
15. And generally are the various fits suitable for their duties ?
16. Have the proper methods of the office been followed ?
17. Are the various dimensions correct when totalled and compared with the overall dimension ?
18. Are there any unnecessary dimensions ?
19. Are all the details enumerated drawn ?
20. Is the material called for correct ?
21. Are the filing details correctly filled in ?

If an error is detected anywhere, it is indicated to the draughtsman, who corrects it, and when the checker is satisfied and adds his signature to the drawing to signify this, the drawing is ready for the tracing department.

**Tracing.**—Tracings which are essential, if blue prints

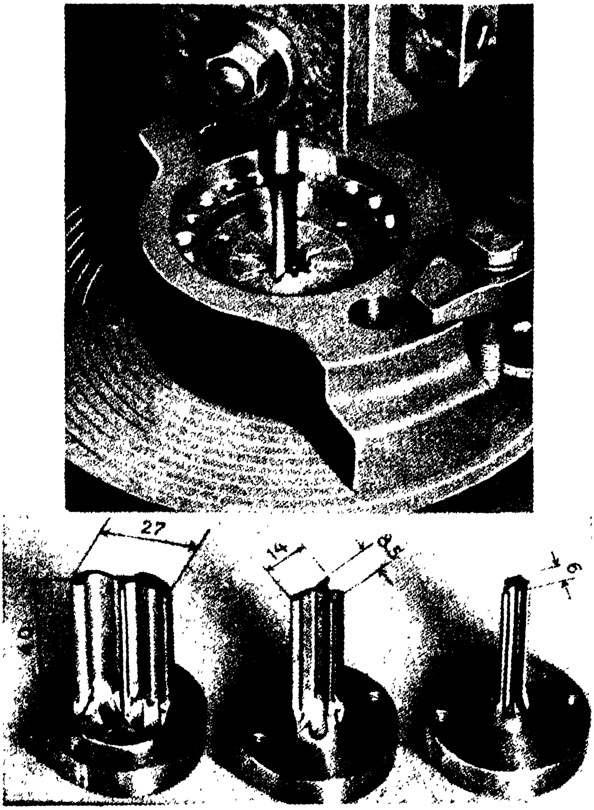



Plate XII.

**Tool Room Milling.**—Tool designing can be carried out with more confidence when the designer can rely upon the support of a well-equipped tool room. A very versatile machine, the " Deckel " Universal Miller, supplied by Messrs. Geo. Alexander, Ltd., of Birmingham, appears to be very popular in this field.

The upper picture shows it at work as a slotting machine. With a quick change-over it becomes a milling machine, responsible for such fine work as shown below. The time for each piece from left to right is 3·10, 1·70, 2·50 hours respectively, the dimensions being in millimetres.

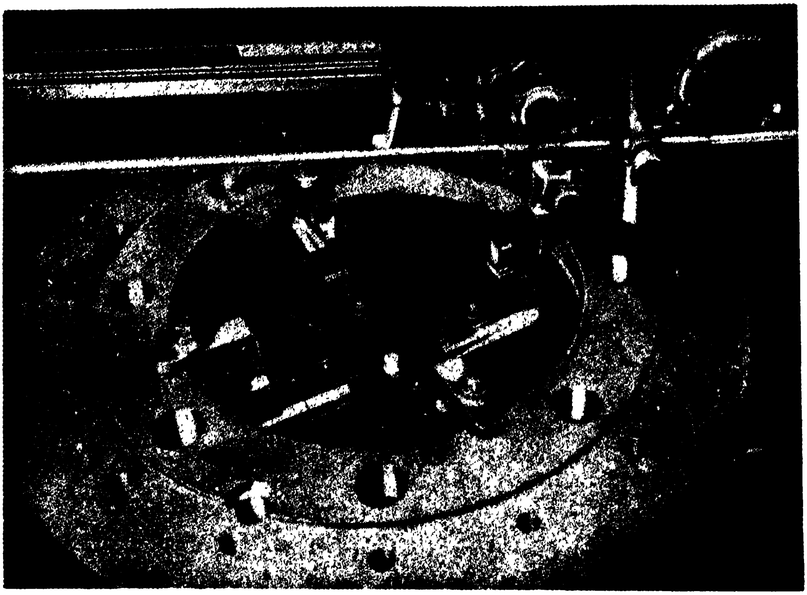


Plate XIIa.

When the jig and tool office is supported by a fully equipped tool room, intelligently designed and intricate equipment will be well made, with economic results in the production shops. Here is a No. 6 Société Génevoise jig borer at work on a jig which is 45″ diameter, with holes ranging from 0·0625″ to 2·750″ and *without limits*. These machines are the product of Société Génevoise Ltd., 5–6 Brettenham House, Wellington Street, London, W.C.2.

[*Facing page 181*

are wanted, are done on tracing cloth, though occasionally temporary rough tracings are made on paper.

This work is not at all difficult, requiring only common-sense, plus a pair of steady hands. To make a tracing the cloth is laid with the polished side to the drawing, and firmly pinned in position.

The pins should be pressed well home, so that the pinhead also helps to hold the cloth, failure to do this results in the cloth tearing slightly at the pins, thus altering the relation of the tracing to the drawing.

Next, starting at the top left-hand corner of the work, put in all the circular parts, using the ink compasses and bows for this purpose, and working always towards the right-hand lower corner, this will prevent any smearing.

This finished, the tee and set squares are employed to put in all the straight lines. This order of working has been found very satisfactory, for it is easier to make the lines blend in with the curves than vice versa.

Titles and large printed letters can be put in with the aid of stencils, of which a great variety of different sizes exist, so that after a little practice in their use no complaint should be possible on the score of neatness. Dimensions and small lettering must be inserted by hand. The tracer must not be tempted to put in lettering of her own design, but should cultivate the habit of following the drawing in strict detail, the slightest addition or omission sometimes causing serious trouble.

One of the best pens for handwork is the "Gillot" mapping pen, the flexibility of which is amazing, being capable of producing a line as fine as a hair to one so wide as to permit of it being easily measured.

If the surface of the cloth appears greasy, and the ink fails to flow, some french chalk dusted on, and then brushed off, will remedy this.

When a blot occurs it can be removed by immediately absorbing by means of blotting paper, the spot being then wiped with a damped cloth. Other than this, water, rain-spots, etc., must not be allowed to get on the tracings, neither must the latter be folded, because both the crease and the spots will appear on the print.

**Filing and Recording.**—The importance of keeping correct records cannot be overestimated, and while it is not intended to deal with the subject here in detail, a few remarks are necessary. The extent to which indexing is carried depends on the class of management existing, some firms simply require a card to indicate that a certain tool or fixture has been made, together with the date, while others may call for minute details, even to the number of the final storage bin in the tool stores.

Fig. 162 shows an index card for location, that is to say, suppose an inquiry was made in the drawing office as to what drill jigs were in existence for component Number 9/B, an examination of the files for this part would perhaps reveal the fact that there were in stock two, Nos. 9/B/4/A and

| COMPONENT | | | | | | | |
|---|---|---|---|---|---|---|---|
| OPERATION | TOOL NOS. | | | | | | |
| TURNING | | | | | | | |
| DRILLING | | | | | | | |
| MILLING | | | | | | | |
| BORING | | | | | | | |
| PLANING | | | | | | | |
| GRINDING | | | | | | | |
| | | | | | | | |
| | | | | | | | |

FIG. 162.

TOOL INDEX CARD.

9/B/2/A, and on looking in the drawer containing the " General Arrangements " size A, those of the jigs mentioned, should be there, from which, if necessary, the detail drawings could be traced.

It is fairly obvious then that waste time and muddle can be avoided by the judicious use of a filing system.

**Alterations or Revisions.**—Any alteration should be carefully recorded, and, of course, only the signatures of responsible persons are accepted for this.

The alteration is generally entered into a special book or index, and after the tracing has been corrected and the detail entered in the column under Revisions or Alterations, the blue prints that may be in circulation are immediately recalled, and replaced by new ones.

Unless this part of the work is carried out efficiently, enormous losses can be sustained by work being machined to old drawings that were supposed to have been recalled.

It is also essential that people directly concerned should be notified of the change, because the habit is easily acquired of remembering dimensions without consulting a drawing, which, though very convenient, is equally dangerous

**Operation Sheets.**—As a guide to the available equipment for the operations on a component and the order of

OPERATION SHEET.

| OP. NO. | DESCRIPTION. | JIG NO. | TOOL NO. | FIXTURE NO. | GAGE NO. | M/C NO. | REMARKS. |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
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| | | | | | | | |
| | | | | | | | |

BOSTON ENG CO. BOSTON. LINCS. 3/6/21.

FIG. 163.

OPERATION SHEET.

their use, sheets are printed giving this, and are usually fixed to the component drawings issued to the shops.

The sheets are made out according to the "lay out" of the operations, and when the tools, etc., are designed and numbered they are entered on the sheet.

The sheets are made up, traced, blue prints are taken from them, and they are then ready for issue.

It is important that the order of operations should be correct, otherwise great trouble will result when attempts are made to follow the order given, both from the point of view of "progress" and accuracy of work.

Fig. 163 is an illustration of such a sheet.

## CHAPTER XIV

# STANDARDIZATION

THE moment a single component or device is allowed to depart from the original standard, interchangeability commences to break down, and as the latter is the foundation of successful high production it must be prevented at all cost.

Most firms set up a standard of their own productions to assist manufacture and facilitate smooth working, also it enables them to supply new parts to customers without loss of time.

One can imagine the trouble caused by, say, an automobile built up with parts of varying dimensions and fits, which would necessitate the firm keeping a very accurate log book containing the shortcomings of each car, so that when a customer requires a certain part replaced the book would have to be scanned to see what there was peculiar to the part in question, whereas if a standard is maintained, the whole wheels of the business will move with increased freedom and give satisfaction to all concerned. The value of this is clearly demonstrated in the huge sales effected in this country of several types of American cars.

Standards are fixed for certain articles, which remain so throughout the world, such as screw threads, pipes, etc. For this country, however, a body of engineers, known as The British Engineering Standards Association, have fixed standards for a great variety of commodities, varying from tyres and wheel rims to filament lamps and fittings, and from rails and girders to broken stone and chippings. If, then, it is considered advisable to fix a standard for such items as broken stones, surely the tool designer must find it necessary to fix or work to existing standards in the office, and so facilitate not only the passage of designs through the department, but the final manufacture and upkeep of the commodity itself.

The man who introduced the ratchet stop for micrometers standardized thumb pressure, because previously it was possible for any number of people to set the instrument to read differently.

Drill bushes, clamps, brackets, press bolsters and drawings themselves are, or can be, standardized with advantage, and the beginner is advised to give this his close attention. Fig. 164 shows a drill bush, and Table No. 14 gives a statement of its standard sizes, and it should be the duty of every draughtsman to work to that laid down in his particular office when called upon to design equipment containing bushes, and the far-seeing chief will see that this is done.

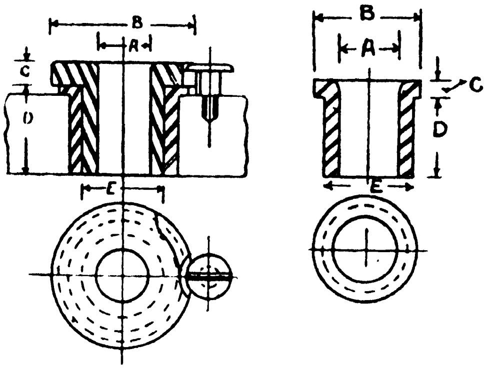



FIG. 165. FIG. 164.

FIG. 164.—DRILL BUSH.
FIG. 165.—REAMER SLIP BUSH.

A reamer slip bush is also illustrated in Fig. 165, and Table No. 15 gives its general proportions.

The same holds good for the various fits necessary, and with an office containing a number of designers it is obvious what would happen if each one called for what he considered to be the correct allowance (see Chapter IX).

The walls of some jig and tool offices are hung with charts in large type, of the most important standardized parts, and there are also in existence several handbooks which give numerous other tables, so that it would appear more easy for the draughtsman to do right than wrong.

TABLE NO. 14.

DRILL BUSHES.

| A. | B. | C. | D. | E. |
|---|---|---|---|---|
| In. | In. | In. | In. | In. |
| 1/16 | 3/8 | 3/32 | 3/8 | 1/4 |
| 3/32 | 13/32 | — | — | 9/32 |
| 1/8 | 7/16 | — | — | 5/16 |
| 5/32 | 1/2 | — | 7/16 | 3/8 |
| 3/16 | 17/32 | — | 7/16 | 13/32 |
| 1/4 | 19/32 | 1/8 | 1/2 | 15/32 |
| 5/16 | 11/16 | — | 9/16 | 1/2 |
| 3/8 | 3/4 | — | 5/8 | 5/8 |
| 7/16 | 13/16 | — | 5/8 | 11/16 |
| 1/2 | 29/32 | — | 11/16 | 25/32 |
| 5/8 | 1 1/16 | 5/32 | 3/4 | 15/16 |
| 3/4 | 1 7/32 | — | 13/16 | 1 3/32 |
| 7/8 | 1 13/32 | 3/16 | 1 | 1 9/32 |
| 1 | 1 1/2 | 3/16 | 1 | 1 7/16 |

TABLE NO. 15.

REAMER BUSHES.

| A. | B. | C. | D. | E. |
|---|---|---|---|---|
| In. | In. | In. | In. | In. |
| 3/16 | 19/32 | 1/4 | 7/16 | 13/32 |
| 1/4 | 11/16 | — | 1/2 | 15/32 |
| 5/16 | 3/4 | — | 9/16 | 1/2 |
| 3/8 | 1 | — | 5/8 | 5/8 |
| 7/16 | 1 | 5/16 | 5/8 | 11/16 |
| 1/2 | 1 1/16 | — | 11/16 | 25/32 |
| 5/8 | 1 1/8 | — | 3/4 | 15/16 |
| 3/4 | 1 1/8 | — | 13/16 | 1 3/32 |
| 7/8 | 1 1/4 | 3/8 | 1 | 1 9/32 |
| 1 | 1 1/4 | 3/8 | 1 | 1 7/16 |

TABLE NO. 16

WEIGHTS per Sq. Ft. (lbs.)

| GAUGE S.W.G. | SIZE Fraction | Decimal | Alumi-nium | Brass | Copper | Mild Steel |
|---|---|---|---|---|---|---|
| 1 | | 0·300 | 4·23 | 13·00 | 13·90 | 12·20 |
| 2 | | 0·276 | 3·89 | 11·90 | 12·80 | 11·30 |
| 3 | | 0·252 | 3·55 | 10·90 | 11·70 | 10·30 |
| | $\frac{1}{4}$" | 0·250 | 3·52 | 10·80 | 11·60 | 10·20 |
| 4 | | 0·232 | 3·27 | 10·00 | 10·70 | 9·46 |
| 5 | | 0·212 | 2·99 | 9·16 | 9·80 | 8·65 |
| 6 | | 0·192 | 2·71 | 8·29 | 8·88 | 7·83 |
| | $\frac{3}{16}$" | 0·187 | 2·64 | 8·08 | 8·65 | 7·63 |
| 7 | | 0·176 | 2·48 | 7·60 | 8·14 | 7·18 |
| 8 | | 0·160 | 2·26 | 6·91 | 7·40 | 6·53 |
| 9 | | 0·144 | 2·03 | 6·22 | 6·66 | 5·87 |
| 10 | | 0·128 | 1·80 | 5·53 | 5·92 | 5·22 |
| | $\frac{1}{8}$" | 0·125 | 1·76 | 5·40 | 5·78 | 5·10 |
| 11 | | 0·116 | 1·64 | 5·01 | 5·37 | 4·73 |
| 12 | | 0·104 | 1·47 | 4·49 | 4·81 | 4·24 |
| 13 | | 0·092 | 1·30 | 3·97 | 4·26 | 3·75 |
| 14 | | 0·080 | 1·13 | 3·46 | 3·70 | 3·26 |
| 15 | | 0·072 | 1·02 | 3·11 | 3·33 | 2·94 |
| 16 | | 0·064 | 0·902 | 2·76 | 2·96 | 2·61 |
| | $\frac{1}{16}$" | 0·062 | 0·874 | 2·68 | 2·87 | 2·53 |
| 17 | | 0·056 | 0·790 | 2·42 | 2·59 | 2·28 |
| 18 | | 0·048 | 0·677 | 2·07 | 2·22 | 1·96 |
| 19 | | 0·040 | 0·564 | 1·73 | 1·85 | 1·63 |
| 20 | | 0·036 | 0·508 | 1·55 | 1·67 | 1·47 |
| 21 | | 0·032 | 0·451 | 1·38 | 1·48 | 1·31 |
| 22 | | 0·028 | 0·395 | 1·21 | 1·30 | 1·14 |
| 23 | | 0·024 | 0·338 | 1·04 | 1·11 | 0·979 |
| 24 | | 0·022 | 0·310 | 0·950 | 1·02 | 0·897 |
| 25 | | 0·020 | 0·282 | 0·864 | 0·925 | 0·816 |
| 26 | | 0·018 | 0·254 | 0·777 | 0·833 | 0·734 |
| 27 | | 0·016 | 0·231 | 0·708 | 0·759 | 0·669 |
| 28 | | 0·0148 | 0·209 | 0·639 | 0·685 | 0·604 |
| 29 | | 0·0136 | 0·192 | 0·587 | 0·629 | 0·555 |
| 30 | | 0·0124 | 0·175 | 0·536 | 0·574 | 0·506 |
| 31 | | 0·0116 | 0·164 | 0·501 | 0·537 | 0·473 |
| 32 | | 0·0108 | 0·152 | 0·466 | 0·500 | 0·440 |
| 33 | | 0·0105 | 0·148 | 0·453 | 0·486 | 0·428 |
| 34 | | 0·0092 | 0·130 | 0·397 | 0·426 | 0·375 |
| 35 | | 0·0084 | 0·118 | 0·363 | 0·389 | 0·343 |
| 36 | | 0·0076 | 0·107 | 0·328 | 0·352 | 0·310 |
| 37 | | 0·0068 | 0·959 | 0·294 | 0·315 | 0·277 |

TABLE NO. 16 (cont.)

WEIGHTS per Sq. Ft. (lbs.)

| GAUGE S.W.G. | SIZE Fraction | Decimal | Aluminium | Brass | Copper | Mild Steel |
|---|---|---|---|---|---|---|
| 38 | | 0·0060 | 0·0846 | 0·259 | 0·278 | 0·245 |
| 39 | | 0·0052 | 0·0733 | 0·225 | 0·241 | 0·212 |
| 40 | | 0·0048 | 0·0677 | 0·207 | 0·222 | 0·196 |
| 41 | | 0·0044 | 0·0620 | 0·190 | 0·204 | 0·179 |
| 42 | | 0·0040 | 0·0564 | 0·173 | 0·185 | 0·163 |
| 43 | | 0·0036 | 0·0508 | 0·155 | 0·167 | 0·147 |
| 44 | | 0·0032 | 0·0451 | 0·138 | 0·148 | 0·131 |
| 45 | | 0·0028 | 0·0395 | 0·121 | 0·130 | 0·114 |
| 46 | | 0·0024 | 0·0338 | 0·104 | 0·111 | 0·0979 |
| 47 | | 0·0020 | 0·0282 | 0·0864 | 0·0925 | 0·0816 |
| 48 | | 0·0016 | 0·0226 | 0·0691 | 0·0740 | 0·0653 |
| 49 | | 0·0012 | 0·0169 | 0·0518 | 0·0555 | 0·0488 |
| 50 | | 0·0010 | 0·0141 | 0·0432 | 0·0463 | 0·0408 |

### TABLE NO. 16A

SHEET MATERIAL—SIZES

| Material | Width | Tolerance | Thickness | Tolerance |
|---|---|---|---|---|
| ALUMINIUM | | | | |
| Std. Sheet .. | 3′ × 3′ | | Under ·010″ | ± ·0005″ |
| Max. width and length .. | 4′ × 50′ | | ·010″ to ·024″ | ± ·0015″ |
| | 6′ × 18′ | | ·024″ ,, ·040″ | ± ·0025″ |
| | 7′ 6″ × 15′ | | ·040″ ,, ·080″ | ± ·0035″ |
| Coiled Strip | $\frac{3}{16}$″ to 6′ | | | |
| FOIL | Up to 24″ | | ·00024″ ,, ·006″ | |
| | | | ·006 mm. ,, ·150 mm. | |
| BRASS | | | | |
| Std. Sheet .. | 4′ × 4′ otherwise width related to thickness, *e.g.*, | | | |
| | Up to 24″ | | ·010″ | |
| | ,, ,, 12″ | | ·004″ | |
| | ,, ,, 3″ | | ·0015″ | |
| | Not exceeding 6″ | ± ·025″ | | |
| | 6″ to 12″ | ± ·032″ | | |
| | Over 12″ | ± ·062″ | | |
| STEEL | Width related to thickness, *e.g.*, | | | |
| | Up to 6″ wide | ± ·005″ | less than ·064″ | |
| | ,, ,, ,, ,, | ± ·0075″ | ·0064″ to ·187″ | |
| | Over 6″ to 14″ | ± ·0075″ | less than ·064″ | |
| | ,, ,, ,, ,, | ± ·012″ | ·064 to ·187″ | |
| | Up to 8″ wide | | Up to ·0124″ | ± ·0005″ |
| | ,, ,, 10″ ,, | | Over ·0124″ to ·028″ | ± ·001″ |
| | ,, ,, 12″ ,, | | ,, ·028″ ,, ·048″ | ± ·0015″ |
| | ,, ,, 14″ ,, | | ,, ·048″ ,, ·128″ | ± ·002″ |
| | ,, ,, 10″ ,, | | ,, ·128″ ,, ·250″ | ± ·003″ |
| | ,, ,, 8″ ,, | | ,, ·250″ ,, ·50″ | ± ·005″ |
| STAYBRITE | | | Gauge Nos. | |
| | | ± ·030″ | 10 and 11 | ± ·004″ |
| | | ± ·030″ | 12 and 13 | ± ·003″ |
| | | ± ·025″ | 14 and 15 | ± ·0025″ |
| | | ± ·025″ | 16, 17 and 18 | ± ·002″ |
| | | ± ·025″ | 19 | ± ·0015″ |
| | | ± ·020″ | 20 and 21 | ± ·0015″ |
| | | ± ·020″ | 22 and 23 | ± ·00125″ |
| | | ± ·020″ | 24 | ± ·0010″ |
| | | ± ·015″ | 25, 26, 27, 28 | ± ·0010″ |
| | | ± ·015″ | 29 and 30 | ± ·00075″ |
| | | ± ·012″ | 31 and 32 | ± ·00075″ |
| | | ± ·012″ | 33 | ± ·0005″ |
| | | ± ·010″ | 34 to 40 | ± ·0005″ |

## Table No. 16b

### TENSILE STRENGTHS (Tons/Sq. In.)

| | |
|---|---|
| **Aluminium** | |
| Annealed | 5–6½ |
| Half hard | 7–8½ |
| Hard | 9 |
| **Al-Silicon** | |
| Annealed | 9–10 |
| Half hard | 10–12 |
| Hard | 12–14 |
| **Al-Manganese** | |
| Annealed | 6–7 |
| Half hard | 9–11 |
| Hard | 14–17 |
| **Al-Magnesium** | |
| Annealed | 12½ |
| Hard | 19½ |
| **Aluminium Bronze** | |
| Soft | 26 |
| Hard | 44 |
| **Brass** W 63%Cu W 37% Zn | |
| Annealed | 23 |
| Hard | 37 |
| **Brass** W 70% Cu W 30% Zn | |
| Soft | 22 |
| Hard | 36 |
| **Brass** (Yellow) | 26 |
| **Copper** | |
| Annealed | 15 |
| Hard | 25 |
| **Duralumin** | 24 |
| **Ph. Bronze** | |
| Annealed | 25 |
| Hard | 44 |
| **Nickel Silver** | |
| Annealed | 25 |
| Hard | 43 |
| **Cupro-Nickel** | |
| Annealed | 22 |
| Hard | 32 |
| **Mild Steel Strip** (Cold rolled) | |
| Soft | 25–32 |
| Medium | 28–34 |
| Hard | 37½ |
| C.R.C.A. | 23 |
| Deep drawing | 20–25 |
| **Medium Carbon** (25–50%) | 40 |
| **High Carbon** (50–90%) | 60 |
| **Steel Strip** (Hardened and tempered) | 76–82 |
| "**Staybrite**" (Deep drawing) | 30–40 |

## CHAPTER XV

# MAGNETIC AND PNEUMATIC GRIPPING

Permeability—Pole Location to secure Maximum Grip—Plate Work—Awkward Shapes—Pneumatic Chucks—Application of Compressed Air.

ONE of the tool designer's greatest difficulties is the efficient clamping or fixing of a component into its jig or on to the machine table. At times there is little or no provision on the component itself for the location of a clamp plate, with the result that awkward and expensive operations are necessary.

When this difficulty is not present, the piece is often of so thin a section that distortion due to clamping is unavoidable. Added to this is the ever-present necessity that, whatever method of gripping be adopted, it must be cheap, that is, cheap in the matter of handling time.

The loading, unloading, and clamping of components has necessitated the introduction of "Time Studies," but this becomes practically unnecessary where this loading, clamping, etc., only forms a small portion of the time per piece.

Apart from considerations of time, the magnetic chuck removes the necessity for all spanners, levers, and handles, thus rendering the operation of the equipment as near foolproof as possible. The effect of clamping a thin plate at each end in the usual manner will produce a variety of movements in that plate all tending to destroy future accuracy.

Large castings are not generally handled economically on the magnetic chuck, the latter being of somewhat limited size. In the domain of small work, however, its success is most marked, particularly when the area to be machined is close to the chuck face.

Areas at a height from the chuck face present difficulties due to the excessive leverage, which tends to turn the component over.

Magnetic chucks have been designed that will exert a downward pull of 200 lb. to the square inch, but even this will not prevent a lateral movement according to the form of cutting tool being used or the method of presenting the tool to the work. The too sudden movement of the machine table bearing the component against the cutter or the thrust of a planing machine tool is fatal.

Provide a means of preventing this and the magnetism will do what no other clamping methods can, that is, exert pressure equally over the whole foundation of the component.

Fortunately this skidding action can be prevented by the simple expedient of arranging suitable guide plates or pegs; it is then possible to take exceptionally heavy cuts without fear.

Naturally components of iron and steel are specially favoured for machining on these chucks; nevertheless articles made from non-magnetic materials can be handled provided that iron or steel clamp plates be introduced.

As this would be little better than employing ordinary clamps, it is not generally attempted.

**Permeability.**—When arranging for the use of magnetic chucks, it is well to remember that the greater the mass of iron in contact with the chuck face the stronger will be the pull. A magnetic field is generally strengthened by the presence of iron; in other words, a greater number of lines of magnetic force will pass through a unit area of iron than would pass through the same area of air; also, the softer the iron the more permeable it will be to the lines of force.

It is worth while to recall a simple experiment which illustrates this admirably. Two magnets are taken having one face concave, so that on placing them with opposite poles together a cylindrical hole is formed as in Fig. 166. In this position the lines of force, if plotted, will be found to stream straight across from pole to pole. Now, on introducing into the hole an iron tube *a*, these lines of force will distort and crowd through the iron tube as indicated, showing their preference for iron. Some idea of the principles of the magnetic chuck may be obtained from Fig. 166 B, where the face of the chuck upon which any work is located is represented at H. Arranged about this face is a number of pole pieces *b*, which are insulated magnetically by liners of white metal. The magnetism produced in these poles at will is caused by allowing a current of electricity to flow round the coils C, which are located about the poles. Thus when the work E is laid upon the face H, the lines of force pass from pole to pole through it and, as we have already mentioned, the greater the mass of iron the more powerful will be the pull.

**Pole Location to ensure Maximum Grip.**—From the foregoing it will be gathered that the best gripping results are obtained when the work is of such shape that it will cover the maximum area of pole surface.

An ideal arrangement, of course, would be where the poles could be arranged in any desired formation. There are, however, on the market chucks having various arrangements which can be adapted to various needs.

The design at C, Fig. 166, is one often found on the chucks of rectangular shape employed on milling machines, etc., and is best suited for the class of work generally attempted on these machines.

The circular chuck at D is generally employed for small repetition work on vertical grinding machines, the chuck rotating slowly beneath the grinding wheel.

A most efficient form of chuck, that is, one offering the maximum area of pole surface, consists of two main parts, a circular base and a covering cap.

The cap has radial arms cast, and from these branch off concentric projections. The base portion is also cast in such a manner that projections are left, which fit the spaces between the projections in the cap, except for a thin section of babbit.

A very popular circular chuck for repetition work is that made by the Blanchard Company, of Mass., U.S.A.

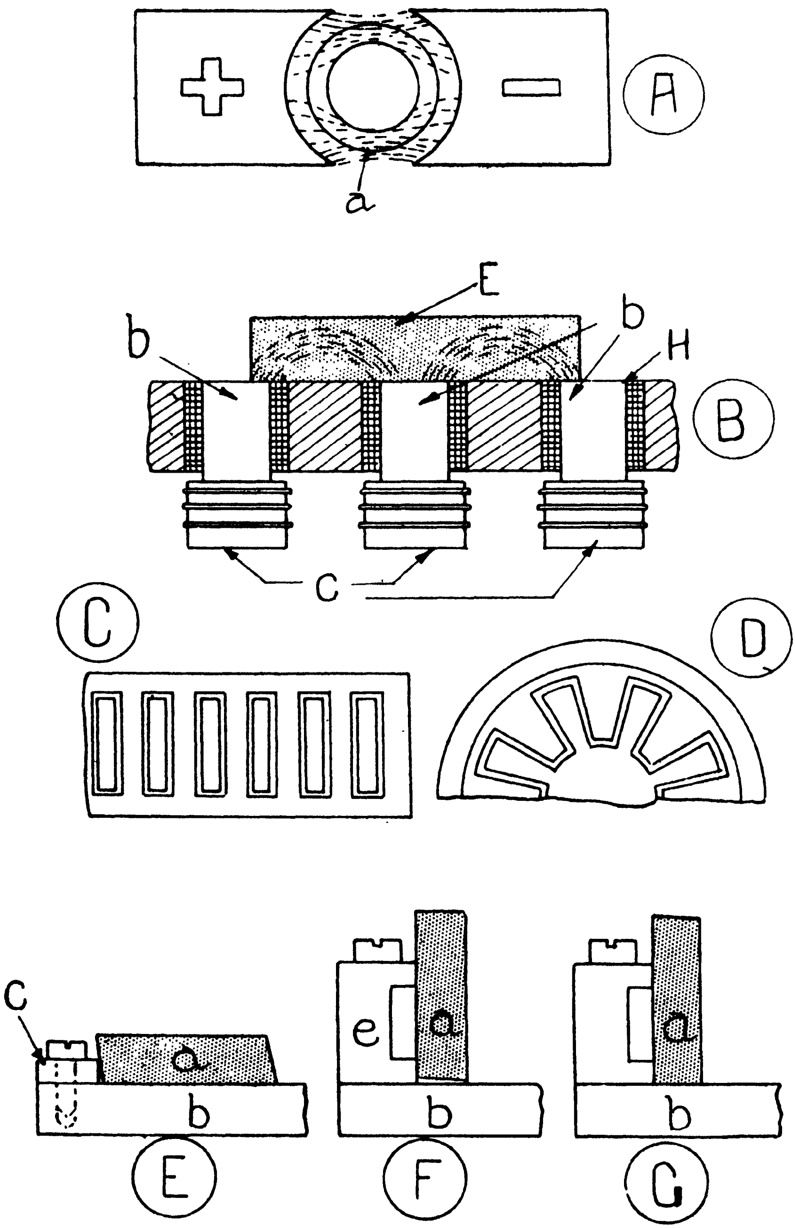
This is made from one solid piece 26″ diameter, and has its magnetizing coils located in such a manner as to distribute their effects as widely as possible.

Further, in this particular case, seeing that the machine upon which it is used is generally run "wet," that is, with a very copious supply of cutting lubricant, the coils are prevented from getting damped.

**Plate Work.**—Reference has been made to the usefulness of the magnetic chuck in connection with the machining of delicate pieces, notably thin plate work.

In this field the magnetic chuck is not devoid of trouble. The fact that all metal is in a varying degree held in tension by its outer "skin" is well known by most mechanics, and the removal of this "skin" sets up a movement in the material itself.

Again, unless a full supply of coolant be used, warping will




A.—PERMEABILITY OF IRON.
B.—PRINCIPLE OF MAGNETIC CHUCK.
C.—POLE DISTRIBUTION.
D.—LOCATING WORK TO ENSURE SQUARENESS.

FIG. 166.

commence, due to heat generated by the heat of the wheel. Another trouble, more costly to correct, is that a component may be slightly warped before being placed upon the chuck, so that upon switching on the current the plate is gripped perfectly flat, the magnetism overcoming the torsion of the plate, so that, while the plate will be ground or otherwise machined flat, on removal from the chuck and the influence of the magnetism the piece will resume its warped formation. In such cases the cheapest method is to have the plates checked in the first instance and any warping corrected.

**Awkward Shapes.**—In grinding short lengths of material of say rectangular section, which have one or more sides out of square, the method shown in Fig. 166, E, F, and G is considered good. Taking E first, the piece is laid upon the chuck face *b*, while its exposed face is ground flat, the stop strip c acting as a means of location and a stop to prevent any skidding. One edge is next dealt with in the manner indicated at F. Here the stop strip is removed and replaced by stop *e*. By locating the side of the strip previously ground against this, the strip will be held quite vertical, and the edge can be finished.

Using the same stop and arranging the work in a similar manner, the other edge can be finished as at G.

The final operation, the grinding of the last face, is accomplished with the aid of the stop as at E.

In cases where the edges of components require finishing, it is usual to give them support by sandwiching them between parallel strips as at A, Fig. 167.

A very effective method of handling rings which require grinding on their faces is indicated at B.

The dial plate *a* is fitted in such a manner as to be capable of revolving closely over, yet without touching, the small rotary magnetic chuck *b*.

Below this dial is another disc which remains stationary, and with its upper face on a level with that of the magnetic chuck. In the upper and rotary dial plate holes are cut of such diameter as to accommodate the rings to be ground, allowing about $\frac{1}{8}''$ of play.

In the bottom plate an escape hole is cut at *c*. The method of operation then is as follows: The operator inserts a ring in the hole *d*, and with the current switched off turns the disc round in the direction of the arrow, so that a finished ring falls through the escape at *c*, while a raw ring is presented to the grinding wheel at *b*. Of course, it is best to arrange a receptacle at *c*, to catch finished components as they drop.

The plasticity, if this term may be used in connection with magnetic lines of force, proves very convenient at times, and C, Fig. 167, is a good illustration of this. The components *a*, which require to be ground on their faces, are held in a number of radial grooves cut in a circular fixture, the latter being held on to the chuck by its magnetism.

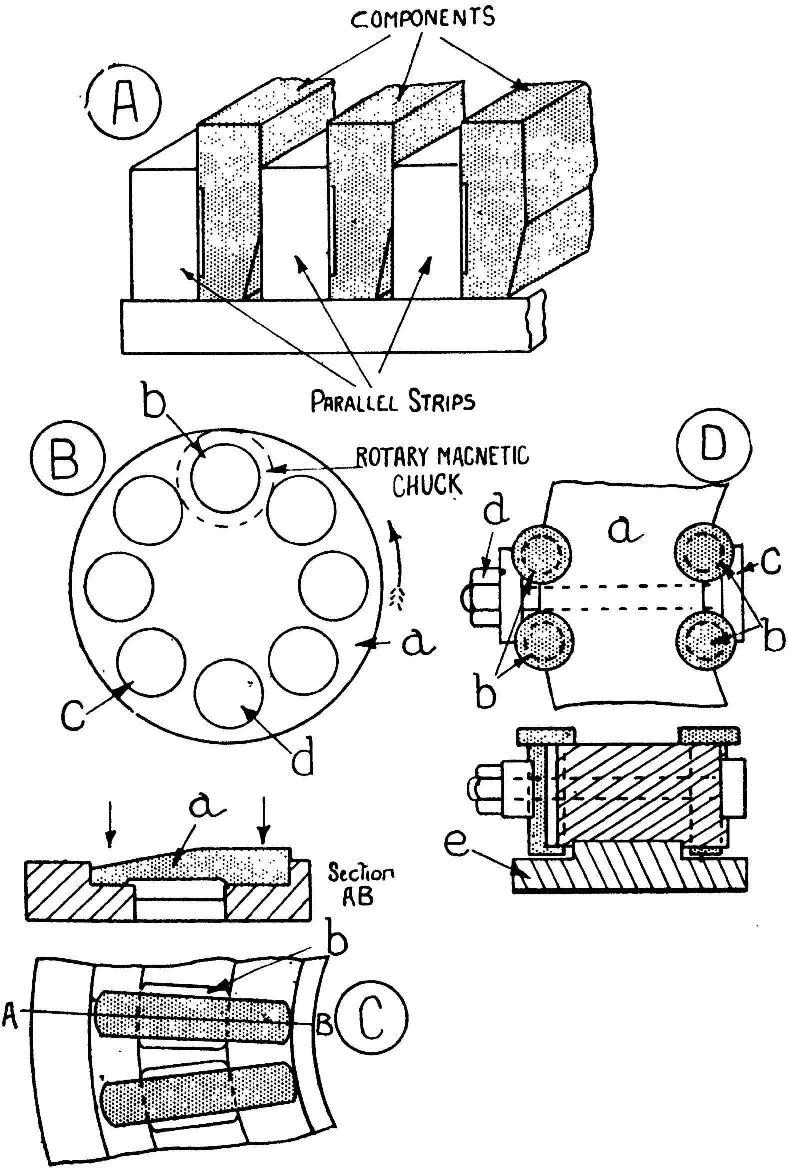
Now, to ensure that the components will be held down quite flat and to avoid any suggestion of tilting, due to an unequal magnetic pull, the work-holding fixture has holes cut below the centre of each component, as seen at *b*. Remembering previous remarks concerning the permeability of iron, the lines of magnetic force will be diverted to each end of the component, and this is what is required to hold the piece successfully.

From the latter case it will be seen that, keeping in mind the question of permeability, jigs and fixtures can be designed to hold the most difficult pieces so that they can be machined accurately and without risk of their being swept off the machine.

The grinding of the ends of slender pieces, such as valve tappets and rods generally, is accomplished by providing a circular fixture round which is drilled a number of holes close together to receive the pieces, relying on the magnetism of the chuck to grip both work and fixture. Where both ends of a stem call for grinding, a ring-shaped fixture of a section shown at D, Fig. 167, will be found to give satisfaction.

The components *b* are shown located in the ring casting *a*, being held in this case by the draw bolt *c*, which is locked by the nut *d*. By holding the piece in this manner it is possible to switch off the current and remove the fixture from the machine without the components dropping off. With this type of fixture it is customary to have them in duplicate, one being in operation while the other is being loaded close at hand. Where such a fixture is likely to prove exceptionally bulky, it can be designed so as to consist of a number of pieces or segments, provision being made for their correct location on the magnetic chuck, and in relation to each other.

Pieces of ring section, such as bevel gears, etc., which




A.—LOCATING AWKWARD PIECES.
B.—HANDLING RING COMPONENTS.
C.—"PLASTICITY" OF LINES OF FORCE.
D.—GRINDING ROD ENDS.

FIG. 167.

require grinding on the face yet have not sufficient area of base to provide stability, can be dropped on to pegs arranged vertically in a circular plate. Such pegs should be of brass or bronze, diverting, as before, the lines of force through the component.

**Pneumatic Chucks.**—Compressed air as a production engineering ally, has received very brusque treatment at the hands of manufacturers in this country. In competition with electricity, or, to be precise, electro-magnetism, it has come second, and in a measure this can be understood. Most or all firms are now equipped with electricity for lighting if not for power purposes, and are therefore half-way towards the goal of magnetic gripping. The maintenance costs in connection with magnetic chucks are low as compared with air compressors and the necessary connections. Finally, a compressed air installation is rather expensive and cumbersome.

**Application of Compressed Air.**—The only difference between an ordinary fixture and one intended for use in connection with compressed air is that the usual clamps or other gripping medium are omitted and replaced by toggles or wedges operated by an air cylinder.

An idea of the construction of one such is given in Fig. 168. The illustration shows a fixture for holding the component A for a milling operation. The hook clamps B are made to grip or release the work.

Air is admitted through the cocks C, which forces forward the plungers D. To the other end of the plungers are fixed the wedges E, so that when the pistons move forward due to the air pressure the wedges also are advanced. Thus the hooks B are drawn down and grip the work. To assist the hook clamps and the wedges to regain their open position, springs are introduced at J and K.

The admission of air into both pistons is controlled by one valve, so that a single movement of the lever either opens or closes the clamps.

The type of component to be gripped will decide whether the clamps can be operated by one or more pistons.

Here the extreme elasticity of compressed air for operating in this manner is demonstrated. If the clamping surface is uneven, it is obvious that with clamps operated with one piston they will, while having the same movement, not all grip equally, whereas with each clamp controlled by its own piston, full pressure will be expended at each clamp.

Single piston equipment is admirable for operating draw-back or push-out collets (see pp. 71 and 72) where the components to be held are of even profile, so that the jaws of the gripping mechanism are enabled to bed equally.

The economy effected by the employment of pneumatic devices is immediately obvious, seeing that, provided the air pressure is sufficient, any number of clamps can be controlled by the simple movement of a lever.

A compressed air installation has advantages not possessed by a battery of magnetic chucks. First, materials of all kinds

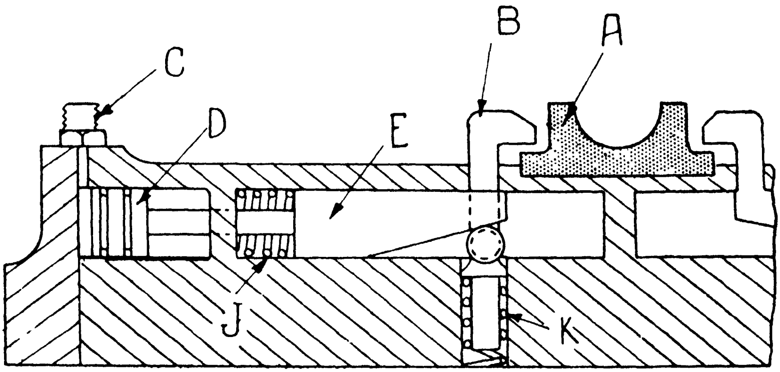



FIG. 168.—AIR CYLINDER AND CLAMP ARRANGED IN A FIXTURE.

can be gripped with the same facility, whereas with the magnetic chuck materials of a non-magnetic nature call for some form of special clamp, thus detracting from the advantages of the magnetic grip. Secondly, and of great importance, the removal of cuttings (see p. 180, item 10) can be expedited by arranging for a nozzle delivering compressed air at the right spot, thus saving the operator the work of washing or brushing them away.

Unfortunately, with magnetic chucks, dirt and cuttings have a tendency to cling about the chucks and the finished components.

However, it is the writer's opinion that neither the pneumatic nor magnetic forces have been exploited to the fullest extent in engineering production, and where mass production conditions obtain, their absence is even more surprising.

# TWIST DRILL GAUGE SIZES

| No Drill | Dec. Size | No Drill | Dec Size | No Drill | Dec Size |
|---|---|---|---|---|---|
| 1 | ·2280 | 31 | ·1200 | 61 | ·0390 |
| 2 | ·2210 | 32 | ·1160 | 62 | ·0380 |
| 3 | ·2130 | 33 | ·1130 | 63 | ·0370 |
| 4 | ·2090 | 34 | ·1110 | 64 | ·0360 |
| 5 | ·2055 | 35 | ·1100 | 65 | ·0350 |
| 6 | ·2040 | 36 | ·1065 | 66 | ·0330 |
| 7 | ·2010 | 37 | ·1040 | 67 | ·0320 |
| 8 | ·1990 | 38 | ·1015 | 68 | ·0310 |
| 9 | ·1960 | 39 | ·0995 | 69 | ·0292 |
| 10 | ·1935 | 40 | ·0980 | 70 | ·0280 |
| 11 | ·1910 | 41 | ·0960 | 71 | ·0260 |
| 12 | ·1890 | 42 | ·0935 | 72 | ·0250 |
| 13 | ·1850 | 43 | ·0890 | 73 | ·0240 |
| 14 | ·1820 | 44 | ·0860 | 74 | ·0225 |
| 15 | ·1800 | 45 | ·0820 | 75 | ·0210 |
| 16 | ·1770 | 46 | ·0810 | 76 | ·0200 |
| 17 | ·1730 | 47 | ·0785 | 77 | ·0180 |
| 18 | ·1695 | 48 | ·0760 | 78 | ·0160 |
| 19 | ·1660 | 49 | ·0730 | 79 | ·0145 |
| 20 | ·1610 | 50 | ·0700 | 80 | ·0135 |
| 21 | ·1590 | 51 | ·0670 | | |
| 22 | ·1570 | 52 | ·0635 | | |
| 23 | ·1540 | 53 | ·0595 | | |
| 24 | ·1520 | 54 | ·0550 | | |
| 25 | ·1495 | 55 | ·0520 | | |
| 26 | ·1470 | 56 | ·0465 | | |
| 27 | ·1440 | 57 | ·0430 | | |
| 28 | 1405 | 58 | ·0420 | | |
| 29 | ·1360 | 59 | ·0410 | | |
| 30 | 1285 | 60 | ·0400 | | |

## LETTER SIZES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A | ·234 | H | ·266 | O | ·316 | V | ·377 |
| B | ·238 | I | ·272 | P | ·323 | W | ·386 |
| C | ·242 | J | ·277 | Q | ·332 | X | ·397 |
| D | ·246 | K | ·281 | R | ·339 | Y | ·404 |
| E | ·250 | L | ·290 | S | ·348 | Z | ·413 |
| F | ·257 | M | ·295 | T | ·358 | | |
| G | ·261 | N | ·302 | U | ·368 | | |

# TABLE OF CONE ANGLES

| CONE OF | EQUIV, IN DEGREES | CONE OF | EQUIV, IN DEGREES | CONE OF | EQUIV, IN DEGREES |
|---|---|---|---|---|---|
| 1 IN 2 | 28 1/12 | 1 IN 6 | 9 1/2 | 1 IN 14 | 4 1/12 |
| 1 " 2 1/4 | 25 | 1 " 6 1/2 | 8 4/5 | 1 " 14 1/2 | 4 |
| 1 " 2 1/2 | 22 2/3 | 1 " 7 | 8 1/5 | 1 " 15 | 3 3/4 |
| 1 " 2 3/4 | 20 1/2 | 1 " 7 1/2 | 7 2/3 | 1 " 16 | 3 3/5 |
| 1 " 3 | 19 | 1 " 8 | 7 1/16 | 1 " 17 | 3 2/5 |
| 1 " 3 1/4 | 17 1/2 | 1 " 8 1/2 | 6 3/4 | 1 " 18 | 3 1/6 |
| 1 " 3 1/2 | 16 1/4 | 1 " 9 | 6 1/3 | 1 " 19 | 3 |
| 1 " 3 3/4 | 15 1/6 | 1 " 9 1/2 | 6 | 1 " 20 | 2 5/6 |
| 1 " 4 | 14 1/4 | 1 " 10 | 5 2/3 | 1 " 25 | 2 1/4 |
| 1 " 4 1/4 | 13 2/5 | 1 " 10 1/2 | 5 1/2 | 1 " 30 | 2 |
| 1 " 4 1/2 | 12 2/3 | 1 " 11 | 5 1/5 | 1 " 35 | 1 3/5 |
| 1 " 4 3/4 | 12 | 1 " 11 1/2 | 5 | 1 " 40 | 1 2/5 |
| 1 " 5 | 11 2/5 | 1 " 12 | 4 3/4 | | |
| 1 " 5 1/4 | 10 5/16 | 1 " 12 1/2 | 4 3/5 | | |
| 1 " 5 1/2 | 10 1/3 | 1 " 13 | 4 1/2 | | |
| 1 " 5 3/4 | 10 | 1 " 13 1/2 | 4 1/4 | | |

# TAPERS PER FOOT AND CORRESPONING ANGLES

| TAPER PER FT | INCLUDED ANGLE | | ANGLE WITH C/L | | TAPER PER.FT | INCLUDED ANGLE | | ANGLE WITH C/L | |
|---|---|---|---|---|---|---|---|---|---|
| INS. | DEG. | MIN. | DEC. | MIN. | INS. | DEC | MIN. | DEG. | MIN. |
| 1/8 | 0 | 36 | 0 | 18 | 2 1/2 | 11 | 54 | 5 | 57 |
| 1/4 | 1 | 12 | 0 | 36 | 3 | 14 | 16 | 7 | 08 |
| 5/16 | 1 | 30 | 0 | 45 | 3 1/2 | 16 | 36 | 8 | 18 |
| 3/8 | 1 | 47 | 0 | 53 | 4 | 18 | 54 | 9 | 27 |
| 7/16 | 2 | 05 | 1 | 02 | 4 1/2 | 21 | 14 | 10 | 37 |
| 1/2 | 2 | 23 | 1 | 11 | 5 | 23 | 32 | 11 | 46 |
| 3/4 | 3 | 35 | 1 | 47 | 6 | 28 | 4 | 14 | 2 |
| 15/16 | 4 | 28 | 2 | 14 | 7 | 32 | 31 | 16 | 16 |
| 1 | 4 | 45 | 2 | 23 | 8 | 36 | 52 | 18 | 26 |
| 1 1/2 | 7 | 08 | 3 | 34 | 9 | 41 | 7 | 20 | 33 |
| 1 3/4 | 8 | 20 | 4 | 10 | 10 | 45 | 14 | 22 | 37 |
| 2 | 9 | 32 | 4 | 46 | 11 | 49 | 15 | 24 | 37 |

## Table No. 19.

### ALLOWANCE FOR SHRINK FITS (IN M/M)

| DIA | ALLOWANCE | DIA | ALLOWANCE | DIA | ALLOWANCE | DIA | ALLOWANCE |
|---|---|---|---|---|---|---|---|
| 20 | ·021 | 36 | ·037 | 52 | ·054 | 68 | ·071 |
| 21 | ·022 | 37 | ·038 | 53 | ·055 | 69 | ·072 |
| 22 | ·023 | 38 | ·039 | 54 | ·056 | 70 | ·073 |
| 23 | ·024 | 39 | ·040 | 55 | ·057 | 71 | ·074 |
| 24 | ·025 | 40 | ·041 | 56 | ·058 | 72 | ·075 |
| 25 | ·026 | 41 | ·043 | 57 | ·059 | 73 | ·076 |
| 26 | ·027 | 42 | ·044 | 58 | ·060 | 74 | ·077 |
| 27 | ·028 | 43 | ·045 | 59 | ·061 | 75 | ·078 |
| 28 | ·029 | 44 | ·046 | 60 | ·063 | 76 | ·079 |
| 29 | ·030 | 45 | ·047 | 61 | ·064 | 77 | ·080 |
| 30 | ·031 | 46 | ·048 | 62 | ·065 | 78 | ·081 |
| 31 | ·032 | 47 | ·049 | 63 | ·066 | 79 | ·082 |
| 32 | ·033 | 48 | ·050 | 64 | ·067 | 80 | ·083 |
| 33 | ·034 | 49 | ·051 | 65 | ·068 | 81 | ·084 |
| 34 | ·035 | 50 | ·052 | 66 | ·069 | 82 | ·085 |
| 35 | ·036 | 51 | ·053 | 67 | ·070 | 83 | ·086 |

# TABLE OF CUTTING SPEEDS

| FT PER MIN. | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DIA. | REVOLUTIONS PER MINUTE | | | | | | | | | | |
| 1/16 | 917· | 1223· | 1528· | 1834· | 2140· | 2445· | 2751· | 3057· | 3668· | 4280· | 4891· |
| 1/8 | 459· | 611· | 764· | 917· | 1070· | 1222· | 1375· | 1528· | 1834· | 2139· | 2445· |
| 3/16 | 306· | 408· | 509· | 611· | 713· | 815· | 917· | 1019· | 1222· | 1426· | 1630· |
| 1/4 | 229· | 306· | 382· | 458· | 535· | 611· | 688· | 764· | 917· | 1070· | 1222· |
| 5/16 | 183· | 245· | 306· | 367· | 428· | 489· | 550· | 611· | 733· | 856· | 978· |
| 3/8 | 153· | 204· | 255· | 306· | 357· | 408· | 458· | 509· | 611· | 713· | 815· |
| 7/16 | 131· | 175· | 218· | 262· | 306· | 349· | 393· | 437· | 524· | 611· | 699· |
| 1/2 | 115· | 153· | 191· | 229· | 268· | 306· | 344· | 382· | 459· | 535· | 611· |
| 5/8 | 91·8 | 123· | 153· | 184· | 214· | 245· | 276· | 306· | 367· | 428· | 489· |
| 3/4 | 76·3 | 102· | 127· | 153· | 178· | 203· | 229· | 254· | 306· | 357· | 408· |
| 7/8 | 65·5 | 87·3 | 109· | 131· | 153· | 173· | 196· | 219· | 262· | 306· | 349· |
| 1 | 57·3 | 76·4 | 95·5 | 115· | 134· | 153· | 172· | 191· | 229· | 267· | 306· |
| 1 1/8 | 51·0 | 68·0 | 85·0 | 102· | 119· | 136· | 153· | 170· | 204· | 238· | 272· |
| 1 1/4 | 45·8 | 61·2 | 76·3 | 91·8 | 107· | 123· | 137· | 153· | 183· | 214· | 245 |
| 1 3/8 | 41·7 | 55·6 | 69·5 | 83·3 | 97·2 | 111· | 125· | 139· | 167· | 195· | 222· |
| 1 1/2 | 38·2 | 50·8 | 63·7 | 76·3 | 89·2 | 102· | 115· | 127· | 153· | 178· | 204 |
| 1 5/8 | 35·0 | 47·0 | 58·8 | 70·5 | 82·2 | 93·9 | 106· | 117· | 141· | 165· | 188· |
| 1 3/4 | 32·7 | 43·6 | 54·5 | 65·5 | 76·4 | 87·3 | 98·2 | 109· | 131· | 153· | 175· |
| 1 7/8 | 30·6 | 40·7 | 50·9 | 61·1 | 71·3 | 81·5 | 91·9 | 102· | 122· | 143· | 163· |
| 2 | 28·7 | 38·2 | 47·8 | 57·3 | 66·9 | 76·4 | 86·0 | 95·5 | 115· | 134· | 153· |
| 2 1/4 | 25·4 | 34·0 | 42·4 | 51·0 | 59·4 | 68·0 | 76·2 | 85·0 | 102· | 119· | 136· |
| 2 1/2 | 22·9 | 30·6 | 38·2 | 45·8 | 53·5 | 61·2 | 68·8 | 76·3 | 91·7 | 107· | 122· |
| 2 3/4 | 20·8 | 27·8 | 34·7 | 41·7 | 48·6 | 55·6 | 62·5 | 69·5 | 83·4 | 97·2 | 111· |
| 3 | 19·1 | 25·5 | 31·8 | 38·2 | 44·6 | 51·0 | 57·3 | 63·7 | 76·4 | 89·1 | 102· |

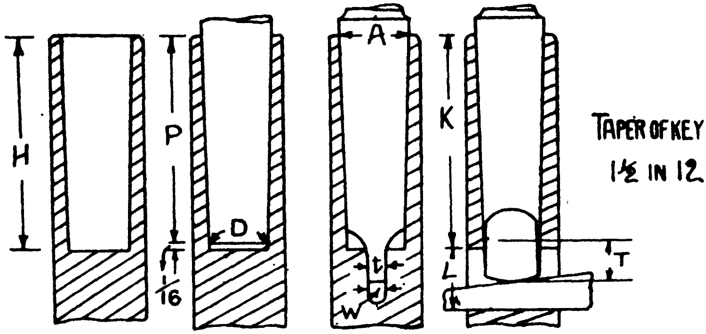
## PRESSURE (APPROX) FOR PUNCHING — STEEL. HIGH CARBON STEEL & BRASS PLATE

FORMULA: LENGTH × THICKNESS × SHEARING STRENGTH

| | | |
|---|---|---|
| SHEARING STRENGTH OF H.C. STEEL | | 75000 LBS |
| " " | " | 50000 " |
| " " | BRASS PLATE | 35000 " |

| No. OF GAUGE USA STD. | FOR 1 INCH HOLES. | | |
|---|---|---|---|
| | STEEL | H.C. STEEL | BRASS |
| 24 | 3:927 | 5 890 | 2.749 |
| 20 | 5.890 | 8.835 | 4.123 |
| 18 | 7.854 | 11.781 | 5.498 |
| 16 | 9:817 | 14.726 | 6.872 |
| 13 | 14.765 | 22.148 | 10.335 |
| 11 | 19.635 | 29.452 | 13.744 |
| 3/16 | 29.452 | 44.178 | 20.616 |
| 1/4 | 39.270 | 58.905 | 27.489 |
| 5/16 | 49.087 | 73.631 | 34.361 |
| 3/8 | 58.905 | 88.357 | 41.233 |
| 7/16 | 68.722 | 103.080 | 48.104 |
| 1/2 | 78.540 | 117.810 | 54.978 |
| 5/8 | 98.175 | 147.262 | 68.722 |
| 3/4 | 117.810 | 176.715 | 82.467 |
| 7/8 | 137.445 | 206.167 | 96.211 |
| 1 | 157.080 | 235.620 | 109.956 |

## B & S AND MORSE STD TAPERS




| No. | Plug Dia Small End B&S | Plug Dia Small End MOR | Plug Depth B&S | Plug Depth MOR | Depth of Hole B&S | Depth of Hole MOR | Keyway from End of Spindle B&S | Keyway from End of Spindle MOR | Length of Keyway B&S | Length of Keyway MOR | Width of Keyway B&S | Width of Keyway MOR | Length of Arbor Tongue B&S | Length of Arbor Tongue MOR | Thickness of Arbor Tongue B&S | Thickness of Arbor Tongue MOR | Taper per Foot B&S | Taper per Foot MOR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | | P | | H | | K | | L | | W | | T | | t | | | |
| 1 | ·20 | ·369 | 15/16 | 2 1/8 | 1 1/16 | 2 3/16 | 15/16 | 2 1/16 | 3/8 | 3/4 | ·135 | ·213 | 3/16 | 5/16 | 1/8 | 13/64 | ·500 | ·600 |
| 2 | ·25 | ·572 | 1 3/16 | 2 9/16 | 1 5/16 | 2 5/8 | 1 11/64 | 2 1/2 | 1/2 | 7/8 | ·166 | ·265 | 1/4 | 3/8 | 5/32 | 1/4 | " | ·602 |
| 3 | ·312 | ·778 | 2 | 3 3/16 | 2 1/8 | 3 1/4 | 1 31/32 | 3 1/16 | 5/8 | 1 1/16 | ·197 | ·330 | 5/16 | 9/16 | 3/16 | 5/16 | " | ·602 |
| 4 | ·35 | 1·02 | 1 1/4 | 4 1/16 | 1 3/8 | 4 1/8 | 1 13/64 | 3 7/8 | 11/16 | 1 1/4 | ·228 | ·490 | 11/32 | 5/8 | 7/32 | 15/32 | " | ·623 |
| 5 | ·45 | 1·475 | 1 3/4 | 5 3/16 | 1 7/8 | 5 1/4 | 1 11/16 | 4 15/16 | 3/4 | 1 1/2 | ·260 | ·650 | 3/8 | 3/4 | 1/4 | 5/8 | " | ·630 |
| 6 | ·50 | 2·116 | 2 3/8 | 7 1/4 | 2 1/2 | 7 3/8 | 2 29/64 | 7 | 7/8 | 1 3/4 | ·291 | ·780 | 7/16 | 1 | 9/32 | 3/4 | " | ·626 |
| 7 | ·60 | | 3 | | 3 1/8 | | 2 29/32 | | 15/16 | | ·322 | | 15/32 | | 5/16 | | " | |
| 8 | ·75 | | 3 9/16 | | 3 11/16 | | 3 29/64 | | 1 | | ·353 | | 1/2 | | 11/32 | | " | |
| 9 | ·90 | | 4 | | 4 1/8 | | 3 7/8 | | 1 1/8 | | ·385 | | 9/16 | | 3/8 | | " | |
| 10 | 1·045 | | 5 | | 5 1/8 | | 4 27/32 | | 1 5/16 | | ·447 | | 21/32 | | 7/16 | | ·5161 | |
| 11 | 1·25 | | 6 3/4 | | 6 7/8 | | 6 19/32 | | 1 5/16 | | ·447 | | 21/32 | | 7/16 | | ·500 | |
| 12 | 1·50 | | 7 1/8 | | 7 1/4 | | 6 15/16 | | 1 1/2 | | ·510 | | 3/4 | | 1/2 | | " | |
| 13 | 1·75 | | 7 3/4 | | 7 7/8 | | 7 9/16 | | 1 1/2 | | ·510 | | 3/4 | | 1/2 | | " | |
| 14 | 2 | | 8 1/4 | | 8 3/8 | | 8 1/32 | | 1 11/16 | | ·572 | | 27/32 | | 9/16 | | " | |
| 15 | 2·25 | | 8 3/4 | | 8 7/8 | | 8 17/32 | | 1 11/16 | | ·572 | | 27/32 | | 9/16 | | " | |
| 16 | 2·50 | | 9 1/4 | | 9 3/8 | | 9 | | 1 7/8 | | ·635 | | 15/16 | | 5/8 | | " | |

# CHAPTER XVI

# MATERIALS

Cast Iron—Mild Steel—Cast Steel—Silver Steel—Steel-faced Iron—Tool Steel—Brass and Copper—Aluminium—Duralumin—Stainless Steel—Strip Steel—Miscellaneous Materials.

THE relation between materials and mass production equipment is very close. A specially shaped cutter for use on high tensile steel would need a more robust cross section than if the material were mild steel. Cutting angles and clearances vary, cavities and outlets for swarf have to be considered in relation to the metal to be machined. The short powder and chips of cast iron need different treatment to the long curling shavings of mild steel or aluminium. Clearances between punch and die must also be kept in mind.

In addition there are the various and growing varieties of high-speed steels with which the manufacturer seeks to reduce production costs.

**Cast Iron.**—The choice of materials for components is not the business of the tool designer, although as already mentioned, when a particular piece, due either to material or shape, proves troublesome, representation in the proper quarter will generally bring relief.

Whether or not cast iron should be used for a certain jig or fixture, however, is very much the affair of the tool designer. When this material is chosen care should be taken to see that without being unnecessarily elaborate, the casting design is sound, that is, while it should fulfil the function for which it was designed, it should also (1) Not be unwieldy; (2) Not have violent changes of cross section; (3) Not have unnecessary webs and braces; (4) Not be liable to distort at clamping places. It should, however, be convenient to handle and be made of machinable cast iron. It is always well to insist upon the last point when ordering.

**Mild Steel.**—This is sometimes called low carbon steel, its content of carbon being about 0·2 %. A wide range of sections

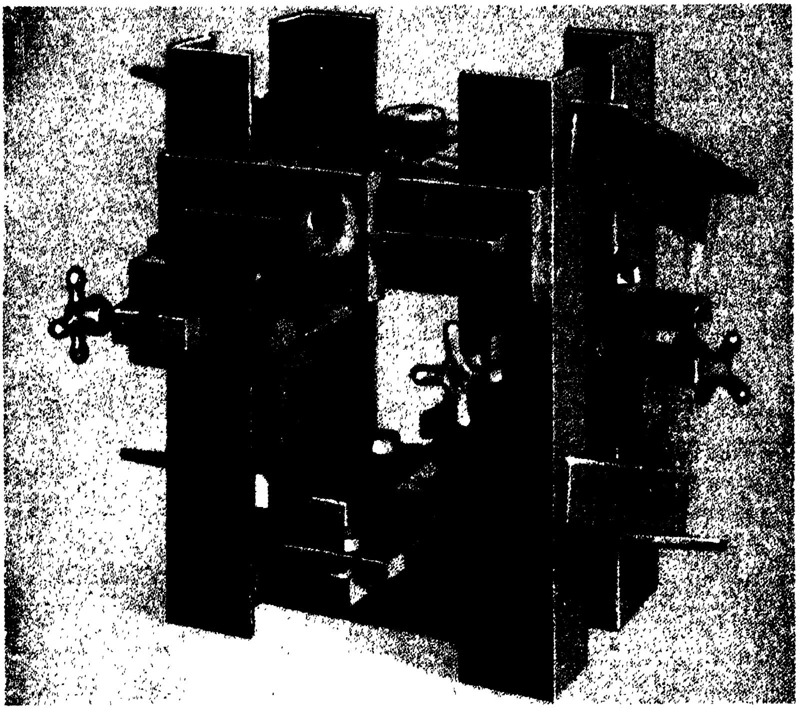


Plate XIII.

**Welded Jig Construction.**—This is being carried out in some fields where angle iron and strip material are welded together to form the body. Obviously the finished jig cannot have so neat an appearance as the normally produced article, and it is argued by many that a badly finished tool is apt to be treated with less care than a well finished one, with resultant expense due to loss of accuracy and maintenance charges.

Where facilities exist for the cutting and shaping of plates by means of the torch, substantial economies must be effected.

The finish or final appearance of equipment varies, some firms insisting upon a high standard, i.e. ground faces, blue or mottled fittings, etc., while others are quite satisfied though the original shaper marks and saw cuts remain.

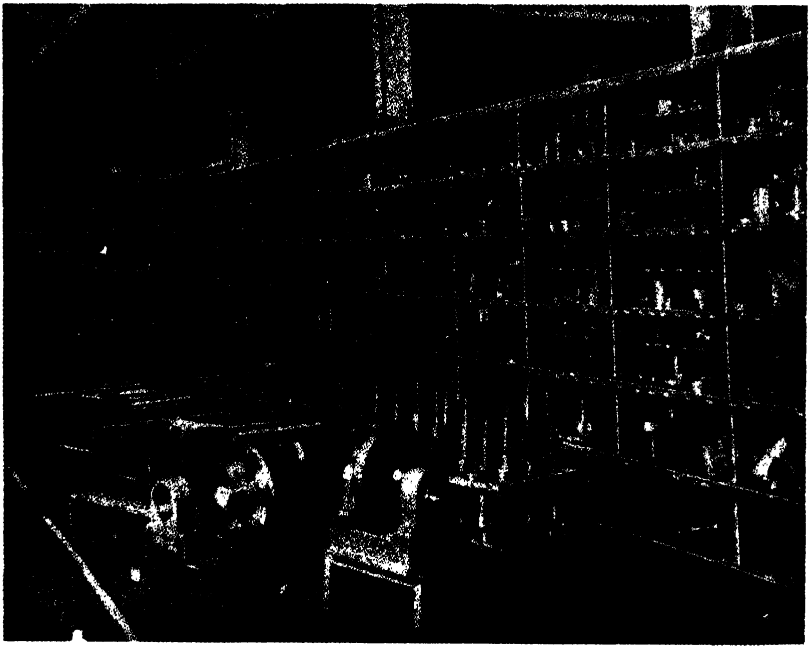


Plate XIIIa.

This is the jig and tool store of the Wickman automatic department, a section of the works of Messrs. John Lang & Sons Ltd., Glasgow. Here are stored and *indexed* over 900 items.

[*Facing page 207*

*Courtesy Associated British M/c. Tool Makers Ltd.*

is available and its condition is such that with cheap or emergency fixtures it can be used without any surfacing.

Round sections can now be obtained with a ground finish to very fine limits, and can certainly be used straight from stock. In some cases, too, costs have been reduced by using mild steel bar or angle iron to form the main frame of a fixture, the parts being lightly pinned together and then welded. Tool room time needed for machining and fitting or perhaps the cost of a casting, are thus saved. An example of this is seen in the illustration facing page 206.

**Cast Steel.**—This is not now extensively used in the tool room. Years ago it was the steel from which all tools and cutters were made. Hardening in water or oil it is very unreliable, warping and cracking freely. Turning tools and die chasers made of cast steel have, however, given better results than high-speed tools when machining copper.

**Silver Steel.**—This is often called drill rod or Stubbs steel. There are two systems of sizes, Stubbs and Morse, the latter corresponding to Morse drills ranging from No. 1 to 60. Stubbs sizes run very close to these and thus between the two a very useful range is available. The steel is water or oil hardening and, like cast steel, risk of cracking can be reduced by annealing after working, before the hardening operation. It is extremely useful for pins and dowels.

**Steel-faced Iron.**—This material was introduced many years ago before heat treatment had been given serious thought. It consists of mild steel having a facing of approximately half its thickness of carbon steel, the latter being capable of responding to water hardening. Having a backing of mild steel the tendency of the other side to warp or crack when quenched is greatly, though not altogether, reduced.

**Tool Steel.**—The everpressing demand for increased production has resulted in a competition between metallurgists and designers. The former produce a steel the cutting capabilities of which are only limited by the strength and rigidity of the machine. The designers then redesign headstock, saddle, etc., and so throw the onus back on to the metallurgist. Thus to-day there are in existence an almost bewildering variety of steels for different purposes. Chromium, vanadium, cobalt, tungsten, nickel, and molybdenum are added to alloy steels destined for a specific purpose. With such a variety no tool designer would be expected to be acquainted with them all.

Fortunately, in the larger offices at least, the responsibility for making a choice does not rest with the individual, he merely having to quote the particular brand officially adopted.

In view of the highly important matter of steel selection, a firm cannot do better than to seek the advice of the manufacturer on both material and treatment, and then to rigorously follow it.

**Brass and Copper.**—From among the foregoing materials the designing department make a selection, and the particular material called for will appear on the drawing. Certain materials, however, are in extensive use in the production shops, and having direct connection with tool design should be given some thought. Among these brass and copper take a prominent place.

The hardness of these may affect tool design especially where sharp bends or deep drawing operations are needed. They can be purchased with a specified degree of hardness, e.g. 70/30 grade is very ductile and suitable for drawing work, 100/120 is suitable for shallow pressings of large area, 180/200 is hard and springy and can only be bent across the direction of rolling. The metals are generally available sheets, roll, or strip, the sheets generally measuring 4′ by 2′.

The width of strip material varies with the thickness. Down to ·004″ thick, it is available up to 12″ wide, less than that the width is 6″. Tolerances on the width of strip is important. For material not exceeding 6″ wide, it is plus or minus ·025″, for material 6″ to 12″, plus or minus ·032″. Over 12″ wide, plus or minus ·0625″.

For normal widths coils of ·050″ thickness average 40′ to 70′ in length.

**Aluminium.**—Press tools for use with aluminium should be highly finished on the wearing part as it tends to cling, also clearance between punch and die may be a little greater than the figures in Table 12. The tensile strength varies with the temper but with annealed aluminium it is 5–6 tons per sq. inch. Half-hard, 7–8 tons per sq. inch; and hard, 9 tons.

The material is available in sheets or coils, but only gauges of No. 16 or less are coiled. Sheets down to 20 gauge are, 6′ × 3′, 8′ × 3′, 8′ × 4′, and 12′ × 4′. For gauges between 20 and 26, 6′ × 3′, and 8′ × 3′.

The hard material should be capable of being bent round a radius equal to the sheet thickness without cracking. For half-hard the radius is one-half the thickness, and for soft, it should be capable of being bent flat on itself without cracking. A variety of intermediate tempers is also available.

**Duralumin.**—This useful alloy, much used in aircraft work, is weight for weight three times as strong as mild steel. It has a tensile strength of 17 tons when soft, 26 tons when hardened. It is available in sheets, tubes, rods, and bars. In operation it will be found to have the peculiar toughness ot stainless steel. If presswork involves considerable deformation, annealing is advised.

**Stainless Steel.**—Various makes of stainless steel are on the market and the various grades are alloyed for some specific purpose. Generally the tensile strength for the softer grades lies between 35–60 tons per sq. inch. If hardened, however, the figure approaches 120 tons. In the lathe it machines at about tool steel speeds and on the press it can be compared to carbon steel. As with duralumin, intermediate annealing may be necessary when drawing in the press.

**Strip Steel.**—Bright steel strip with a tensile strength of 22 tons for presswork is generally purchased to suit the component to be blanked, selecting where possible the nearest strip width. The strips are sheared to the following limits.

For a thickness up to ·125″ and up to 10″ wide, plus or minus ·015″. Some works, having the necessary guillotine, shear sheets as required, the black material known as CRCA being generally treated in this manner.

**Miscellaneous Materials.**—Sheet phosphor bronze and stalloy iron will need closer fitting punches to avoid excessive burring. Sheet bakelite up to $\frac{1}{16}$″ can be sheared on the guillotine and at all times calls for very keen tools.

**Rubber.**—Principally due to intensive aircraft production a quicker method of producing the sheet alumimium and alloy coverings, cowlings, etc., became necessary, thus the use of indiarubber has been successfully developed. Advantage is taken of two properties: cohesion, or the tendency of its particles to remain united; and resilence, or its ability to resume its original form. The rubber blankets, which vary from 3″ to 10″ in thickness, are located in a metal shroud to form the die. The forming punches are either made of hard wood or are cast from one of the light alloys. Rubber can also be used for small expanded shell work as in Fig. 149.

# INDEX

# INDEX